Module 3

Radio Amateur Basic Course

References

- Canadian Amateur Radio Basic Qualification Study Guide (2009) Chapters 5 and 6
- RIC-7

Outline

- Review
- Waves, Wavelength, Frequency and Bands
- RF Propagation
- Conclusion
- Questions
- Demonstrations

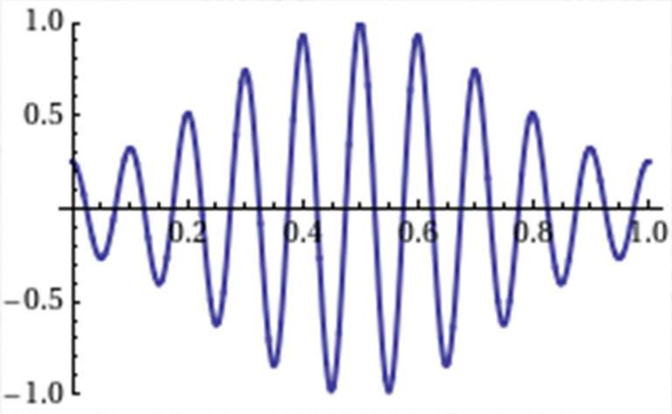
Waves, Wavelength, frequency and Bands

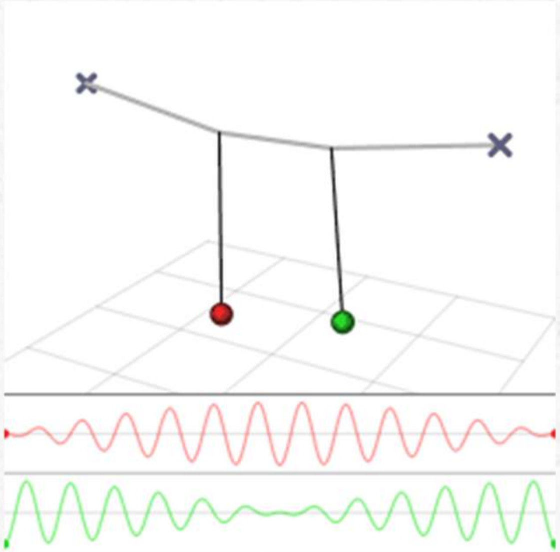
Chapter 5

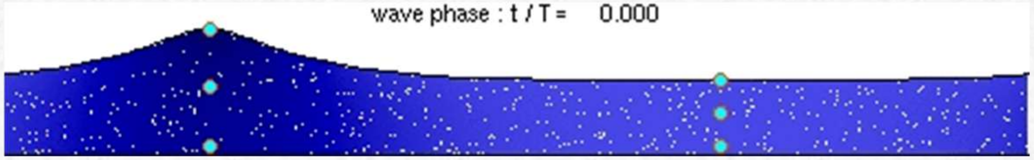
What is a Wave?

- In physics a wave is a disturbance or oscillation that travels through spacetime, accompanied by a transfer of energy. Wave motion transfers energy from one point to another, often with no permanent displacement of the particles of the medium—that is, with little or no associated mass transport. They consist, instead, of oscillations or vibrations around almost fixed locations. Waves are described by a wave equation which sets out how the disturbance proceeds over time. The mathematical form of this equation varies depending on the type of wave.

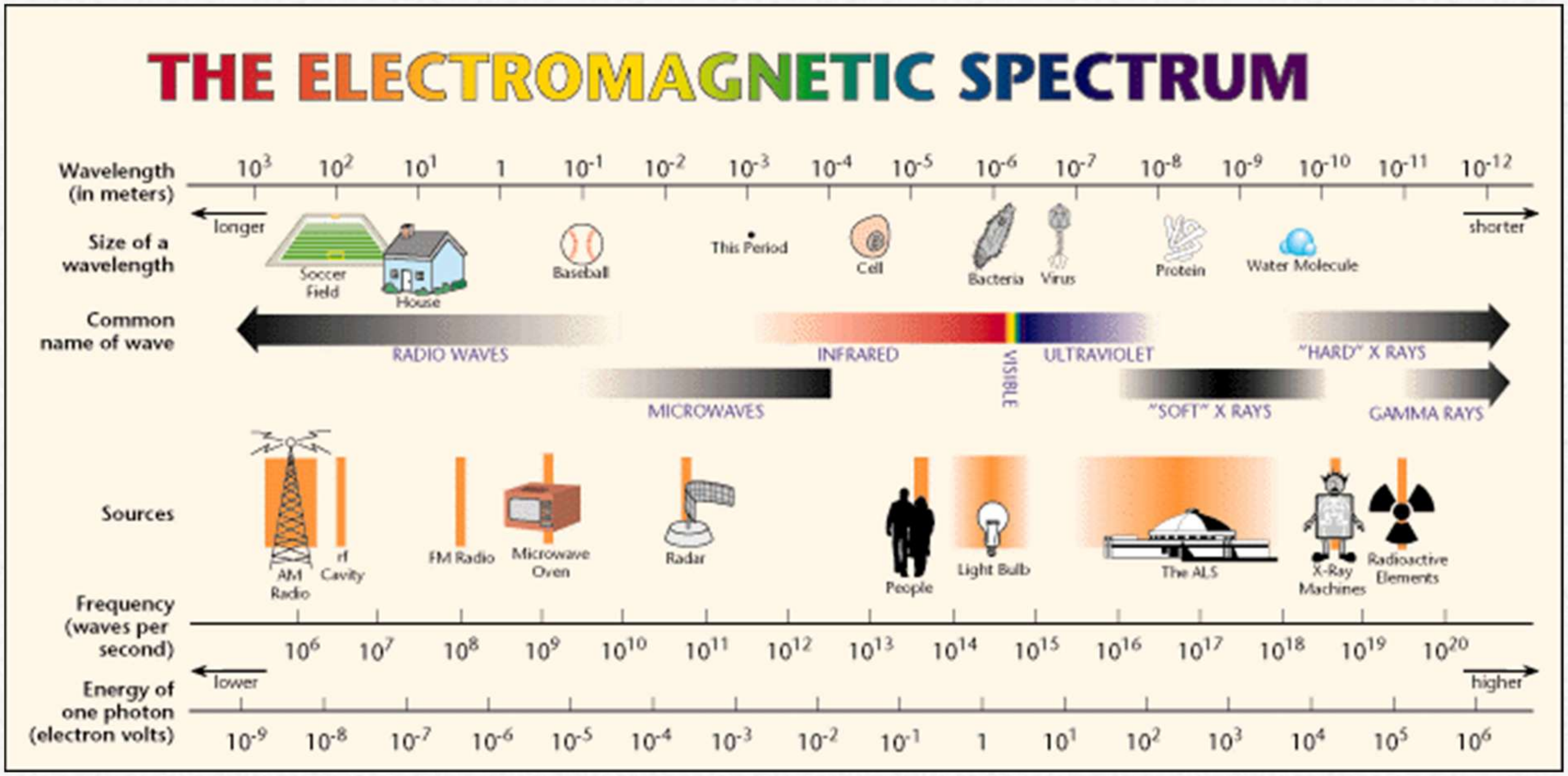
Waves







Light



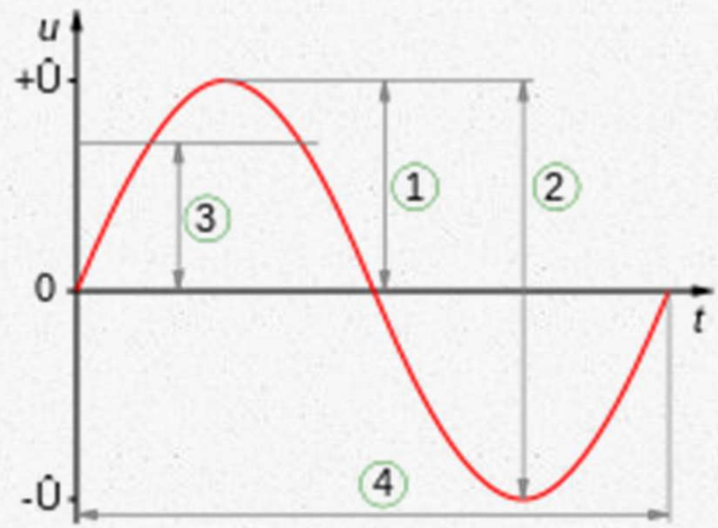
THE ELECTROMAGNETIC SPECTRUM
Wavelength (in meters)
10^3 10^2 10^1 1 10^-1 10^-2 10^-3 10^-4 10^-5 10^-6 10^-7 10^-8 10^-9 10^-10 10^-11 10^-12
longer
shorter
Size of a wavelength
Soccer Field
House
Baseball
This Period
Cell
Bacteria
Virus
Protein
Water Molecule
Common name of wave
RADIO WAVES
INFRARED
VISIBLE
ULTRAVIOLET
"HARD" X RAYS
MICROWAVES
"SOFT" X RAYS
GAMMA RAYS
Sources
AM Radio
rf Cavity
FM Radio
Microwave Oven
Radar
People
Light Bulb
The ALS
X-Ray Machines
Radioactive Elements
Frequency (waves per second)
10^6 10^7 10^8 10^9 10^10 10^11 10^12 10^13 10^14 10^15 10^16 10^17 10^18 10^19 10^20
lower
higher
Energy of one photon (electron volts)
10^-9 10^-8 10^-7 10^-6 10^-5 10^-4 10^-3 10^-2 10^-1 1 10^1 10^2 10^3 10^4 10^5 10^6

Light

- Complementarity
  - particles and waves
- Radio waves are light
- $c = f\lambda$
- speed of light (c) is a constant in the universe at about 2.99 x 10^8 m/s
- f is frequency (Hz)
- λ or lambda is wavelength (m)
- not f and λ are inversely related

Properties of a Wave

- Peak Amplitude (1)
- Peak to Peak Amplitude (2)
- RMS Amplitude (3)
- Wave Period (4)



Amplitude

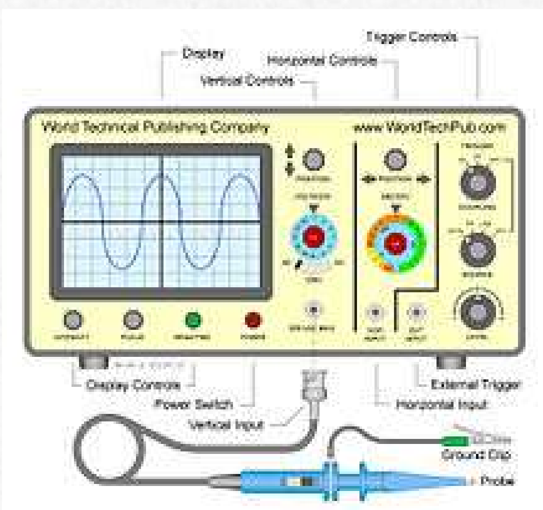
- measurement of intensity of the wave
- could be a voltage, current, field intensity, power etc. depending on way the wave is being described
- we have seen peak amplitude before (PEP)
- we have seen RMS amplitude before (peak/sqrt(2))

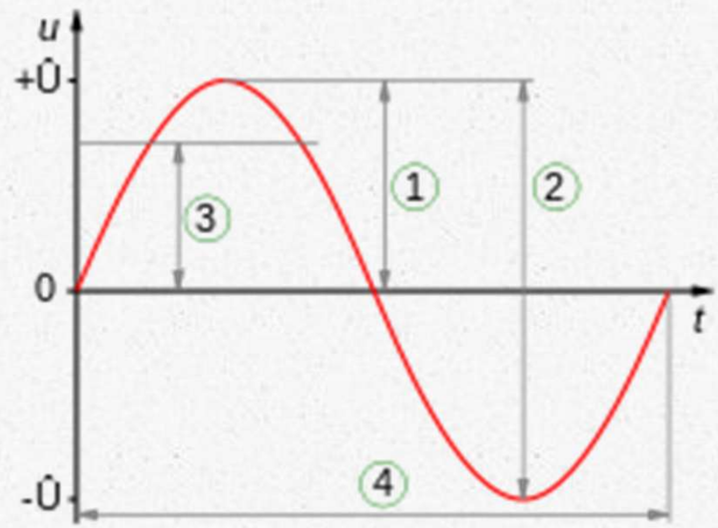
Frequency

- number of crests or troughs that pass a given point in a fixed amount of time
- rate of completion of a cycle
- expressed in Hz (s^{-1})
- e.g. 100 cycles in 5 seconds, what is frequency?
  - $f = \frac{100}{5s} = 20Hz$ [20 cycles per second]
  - T=$\frac{1}{f} = \frac{1}{20}s = 0.05s$ [Period – 1 cycle in 0.05s]

Wavelength

- distance travelled during one cycle of a wave is called its wavelength (4)
- metres
- oscilloscope





Electromagnetic Waves (EM Waves)

- travel at the speed of light (c)
- $c = f\lambda$
- c=2.99x10^8 m/s
- $f = \frac{c}{\lambda} = \frac{300\ Mm/s}{\lambda} \Longrightarrow \frac{300\ Mm/s}{80\ m} = 3.75\ MHz$
- $\lambda = \frac{c}{f} = \frac{300\ Mm/s}{f} \Longrightarrow \frac{300\ Mm/s}{146.5\ MHz} = 2.05\ m$
- Note use of metric prefixes (base ten)
- Note how units also cancel out (parity check)

Conversions

- MHz to kHz is 10^6 to 10^3 so the factor is 10^3
- kHz to MHz is 10^3 to 10^6 so the factor is 10^{-3}
- e.g. 1050 kHz is how many MHz?
  - 1050 kHz = 1050×10^3 Hz
  - 1050×10^3 Hz = $y \times 10^6$ Hz
  - 1050×10^3 Hz = $1050 \times 10^3 \times 10^{-6} \times 10^6$ Hz
  - 1050×10^3 Hz = $1050 \times 10^3 \times 10^{-6}$ MHz
  - 1050×10^3 Hz = 1050×10^{-3} MHz
  - 1050×10^3 Hz = 1.050 MHz

Frequency Allocations

- Radiocommunication Act (Canada)
  - "radiocommunication" or "radio" means any transmission, emission or reception of signs, signals, writing, images, sounds or intelligence of any nature by means of electromagnetic waves of frequencies lower than 3 000 GHz propagated in space without artificial guide;
  - EM frequencies >0 Hz but < 3 000 GHz [far infrared]
  - Signs etc. via visible light are 400-790 THz
  - Tera- prefix is 10^{12} and giga- is 10^{9} so 3,000 GHz is $3x10^{12}$. An IR, visible light, UV, X-ray etc. signal does not fall under the Act.
    - Optical communications
    - mm wave technology (body scanners)

Frequency Allocations

Name	Frequency Span/Wavelength Span
VLF*	3 kHz to 30 kHz (λ>10 km wavelength)
LF	30 kHz to 300 kHz ($10\text{ km} > \lambda > 1\ km$)
MF	300 kHz to 3000 kHz ($1\text{ km} > \lambda > 100\ m$)
HF	3 MHz to 30 MHz ($100\text{ m} > \lambda > 10\ m$)
VHF	30 MHz to 300 MHz ($10\text{ m} > \lambda > 1\ m$)
UHF	0.3 GHz to 3 GHz ($100\text{cm} > \lambda > 10cm$)
SHF	3 GHz to 30 GHz ($10\text{cm} > \lambda > 1cm$)
EHF	30 GHz to 300 GHz ($1\text{cm} > \lambda > 0.1cm$)

*Amateur radio service is allocated bands in all but VLF

Bands

- Band is a group of clearly defined frequencies that lie between clearly defined limits.
- Recall for Basic Qualification
  - can use frequencies above 30 MHz
  - to use frequencies below require
    - basic + 5 WPM
    - basic with Honours Pass (mark>80%)
    - basic + advanced
- Primary use v. secondary use of band
- Value of the Bands –
  - importance of following the rules and regulations

Modes

- Refers to type of transmission employed
  - FM – Frequency modulation
  - More later on modulation
- Note in some countries some modes are restricted to sub-bands (i.e. USA)
- Need to check with those countries
- Also some bands are trimmed (e.g. UK on 2 m; or USA on 40 m)

Band Plans

- Radio Amateurs of Canada (RSGB, ARRL etc.) adopt national band plans so that certain types of activity occur in certain portions of a band.
- e.g. CW at the lower end of 7 MHz but SSB at higher end and PSK at 7.083 MHz.
- Not legally binding but gentlemen's convention
- Repeater Councils
- See pages 5-11 to 5-24.
- Note in some cases band plans are coordinated internationally

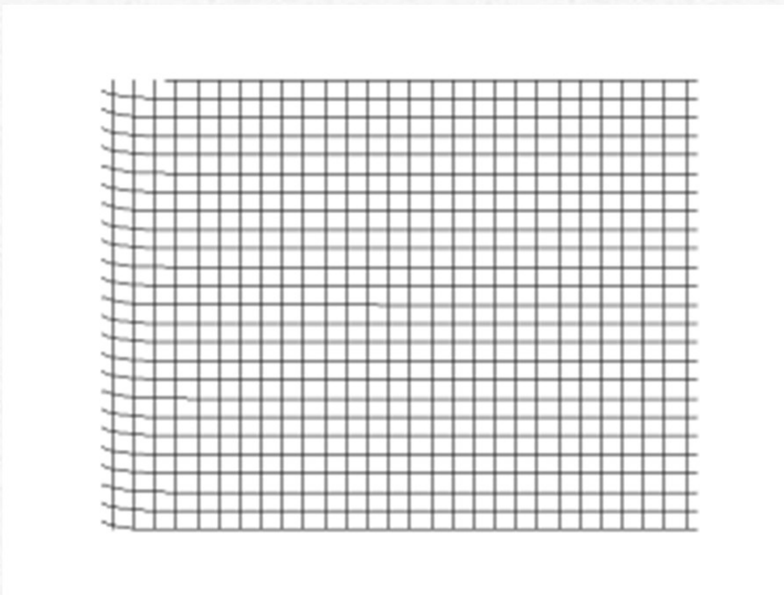
Propagation

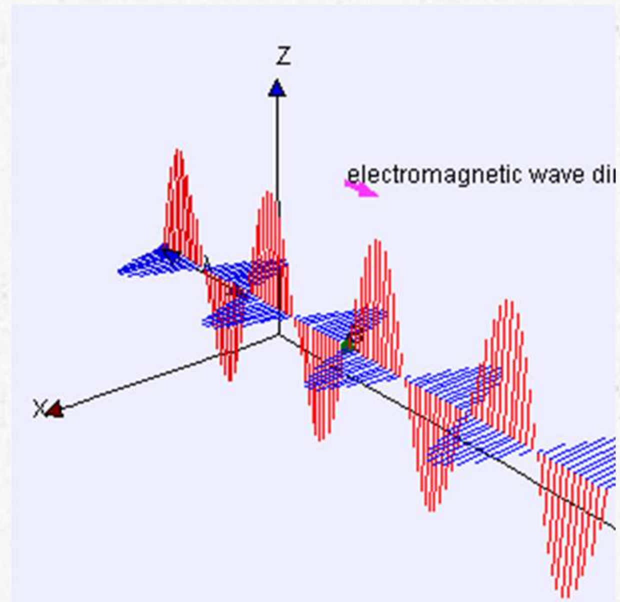
Chapter 6

Transverse Waves

- Transverse waves
  - are those in which the vibration is from side to side – that is at right angles to the direction in which they travel, the direction propagation
  - A guitar string vibrates with transverse motion
  - EM waves are always transverse

Transverse Wave

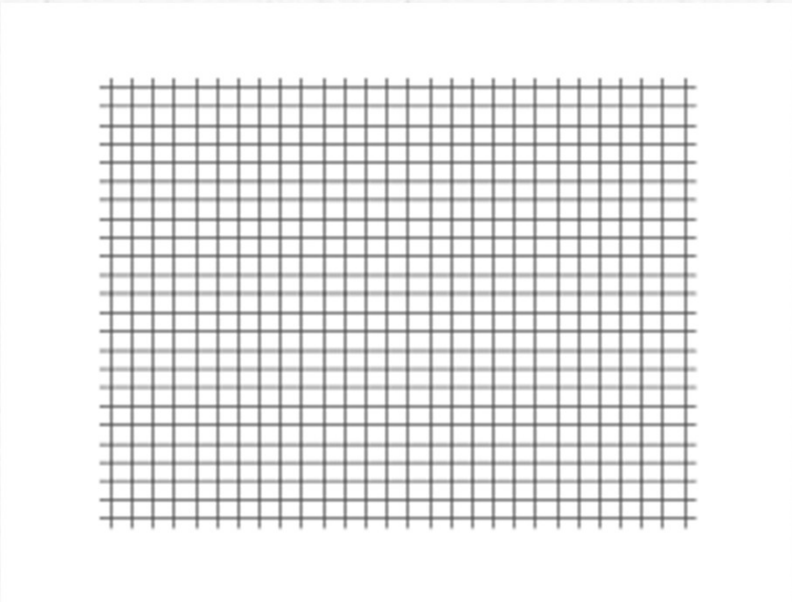




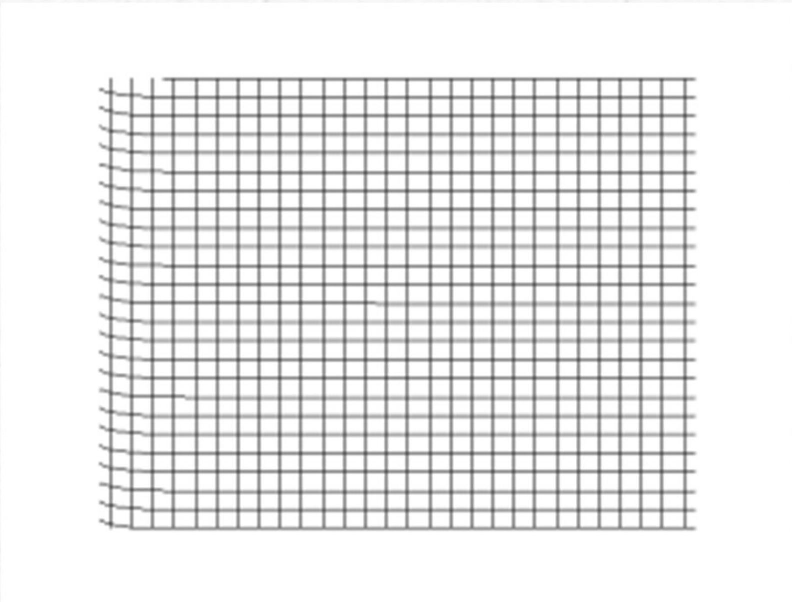
Longitudinal Waves

- Longitudinal waves
  - waves in which the vibration is parallel to the direction of propagation
  - sound waves are longitudinal

Longitudinal Waves

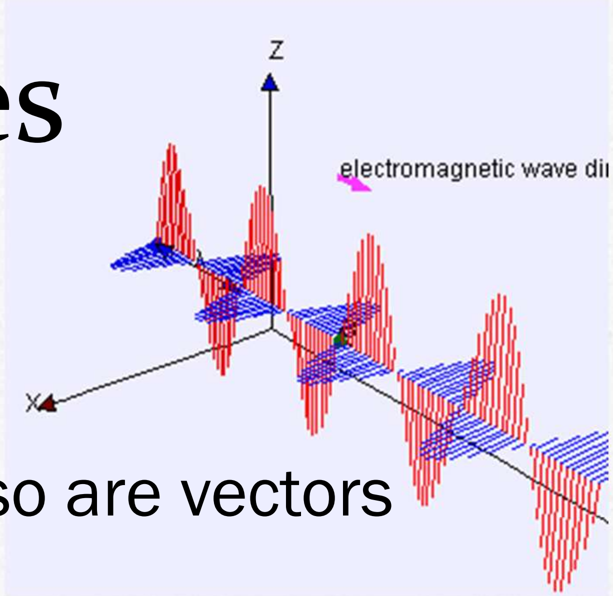


Longitudinal



Transverse

EM Waves



- magnetic field (H)
- electrical field (E)
- both H and E have direction so are vectors
- E and M are orthogonal
- If E is in vertical plane it is vertically polarized – vertical antenna is used
- If E is in horizontal plane it is horizontally polarized – horizontal antenna is used
- If no H or no E it is not an EM wave

Classification of (EM)Waves

- Space Waves
  - space wave follows two distinct paths from the transmitting antenna to the receiving antenna—one through the air directly to the receiving antenna, the other reflected from the ground to the receiving antenna.
  - The primary path of the space wave is directly from the transmitting antenna to the receiving antenna.
  - So, the receiving antenna must be located within the radio horizon of the transmitting antenna. Because space waves are refracted slightly, even when propagated through the troposphere, the radio horizon is actually about one-third farther than the line-of-sight or natural horizon.

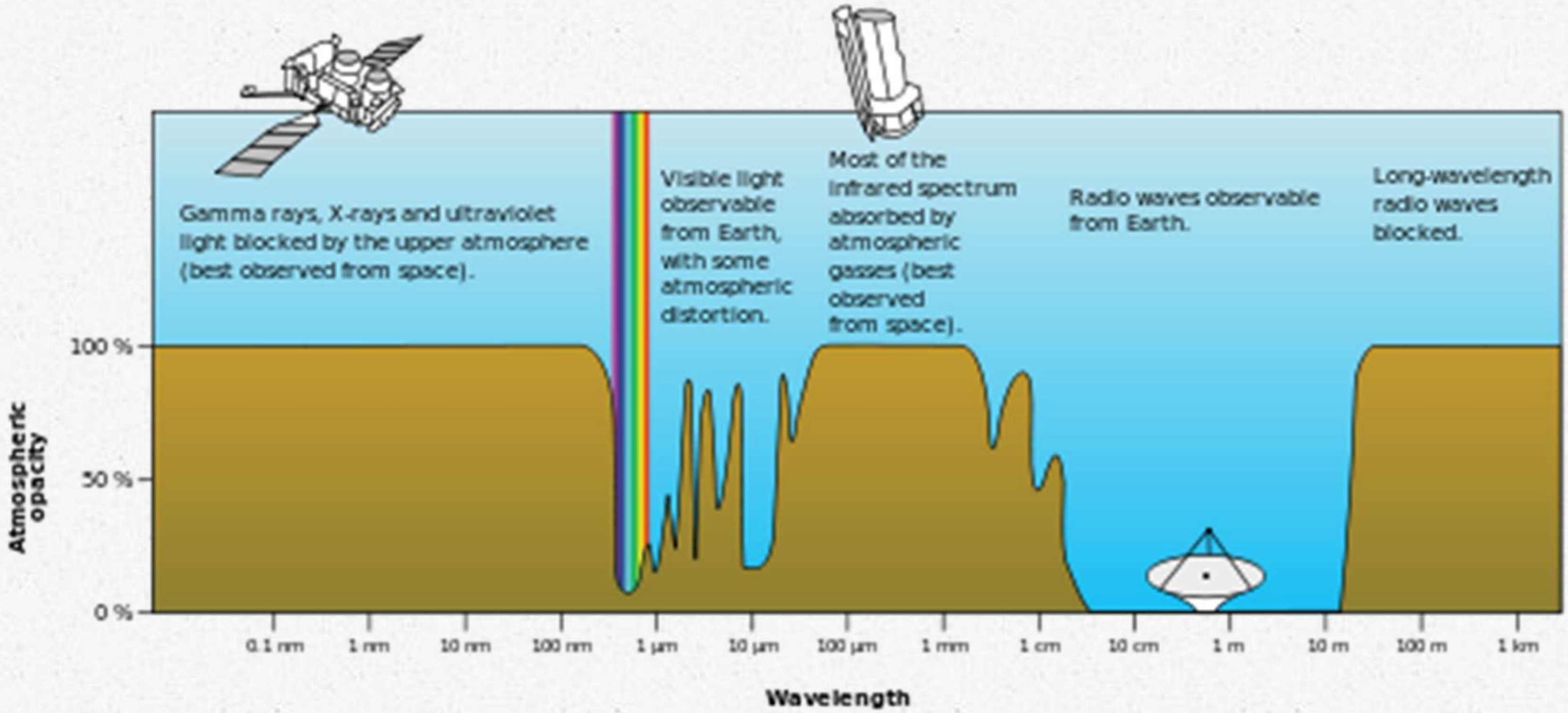
Space Waves

- **Ground Wave** may follow straight line from antenna or may curve to follow Earth's surface depending on frequency
- **Direct Wave** or **Tropospheric Wave** – propagated entirely with Earth's troposphere 10-20 km up – VHF and UHF use direct waves exclusively
- **Surface Wave** – aka **ground wave** – propagated along surface of Earth – lower frequencies of HF use these during daylight hours – vertically polarized
- **Sky Wave** is a wave that propagates toward the ionosphere – aka **ionospheric waves**

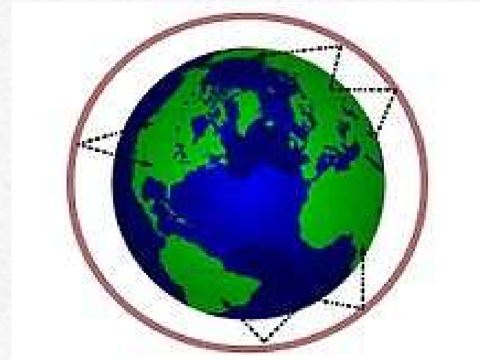
Waves

Band		Frequency	Wavelength	Propagation via
ELF	Extremely Low Frequency	3–300 Hz	1000-100,000 km	
VLF	Very Low Frequency	3–30 kHz	100–10 km	Guided between the earth and the ionosphere.
LF	Low Frequency	30–300 kHz	10–1 km	Guided between the earth and the D layer of the ionosphere.
				Surface waves.
MF	Medium Frequency	300–3000 kHz	1000–100 m	Surface waves. E, F layer ionospheric refraction at night, when D layer absorption weakens.
HF	High Frequency (Short Wave)	3–30 MHz	100–10 m	E layer ionospheric refraction. F1, F2 layer ionospheric refraction. Infrequent E ionospheric (Es) refraction. Uncommonly F2 layer ionospheric refraction during high sunspot activity up to 50 MHz and rarely to 80 MHz. Generally direct wave. Sometimes tropospheric ducting.
VHF	Very High Frequency	30–300 MHz	10–1 m	
UHF	Ultra High Frequency	300–3000 MHz	100–10 cm	Direct wave. Sometimes tropospheric ducting.
SHF	Super High Frequency	3–30 GHz	10–1 cm	Direct wave.
EHF	Extremely High Frequency	30–300 GHz	10–1 mm	Direct wave limited by absorption

Atmospheric Transmittance

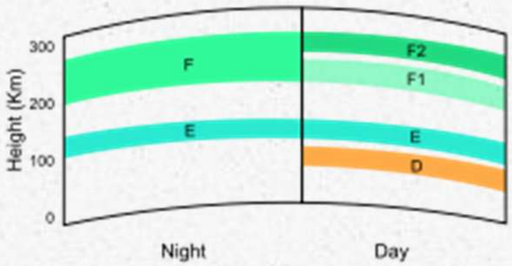


Waves

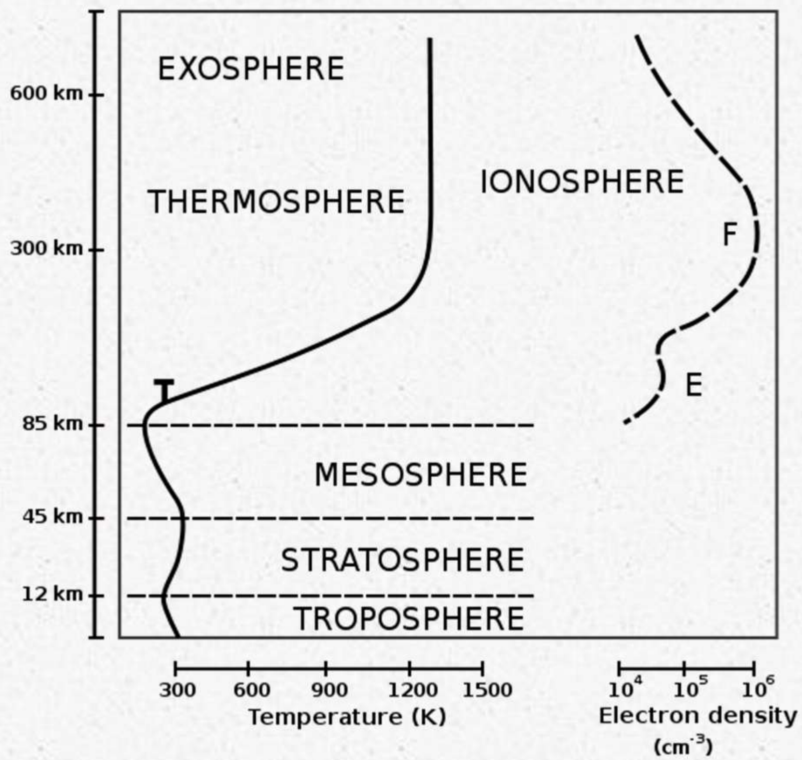


- Radio Waves
  - Space Wave
    - Reflected
    - Sky
  - Ground Wave
    - Direct
    - Surface

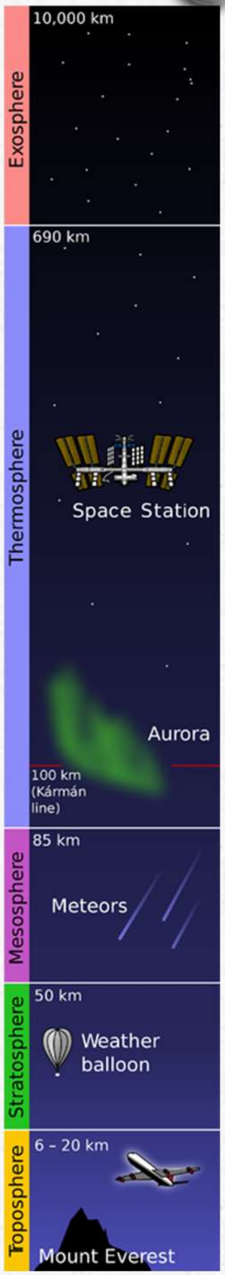
Atmosphere



300
200
100
0
Height (Km)
F
E
F2
F1
E
D
Night
Day



600 km
300 km
85 km
45 km
12 km
EXOSPHERE
THERMOSPHERE
IONOSPHERE
F
E
MESOSPHERE
STRATOSPHERE
TROPOSPHERE
300 600 900 1200 1500
Temperature (K)
10^4 10^5 10^6
Electron density
(cm^{-3})



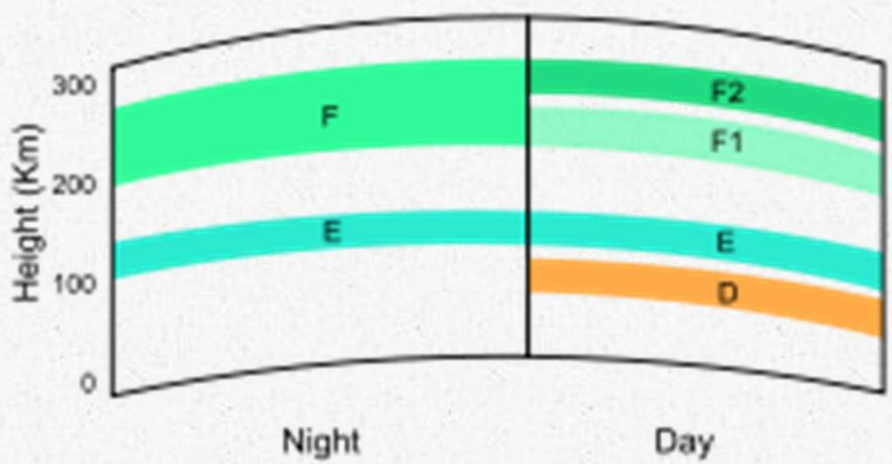
Exosphere
10,000 km
Thermosphere
690 km
Space Station
Aurora
100 km
(Kármán
line)
Mesosphere
85 km
Meteors
Stratosphere
50 km
Weather
balloon
Troposphere
6 - 20 km
Mount Everest

Ionosophere

- UV light from the sun strikes molecules and ionizes them – ionizing radiation - daylight
- Deionization or recombination occurs in the hours of darkness
- Time of year also has an effect – seasons
- 4 distinct layers of the ionosphere

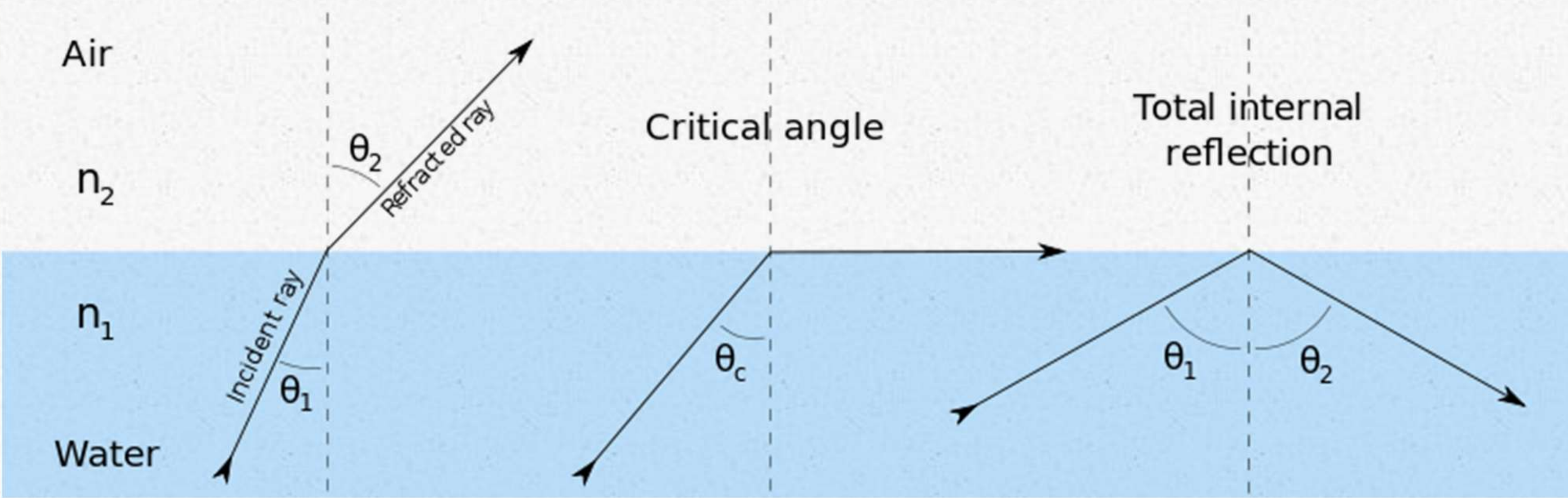
Ionosphere

- D, E, F1 and F2
- D is closest to Earth 70-90 km – absorbs RF
- E (Kennelly-Heaviside Layer) 100-120 km
- F (Appleton Layer) single during night and when not ionized but two layers otherwise



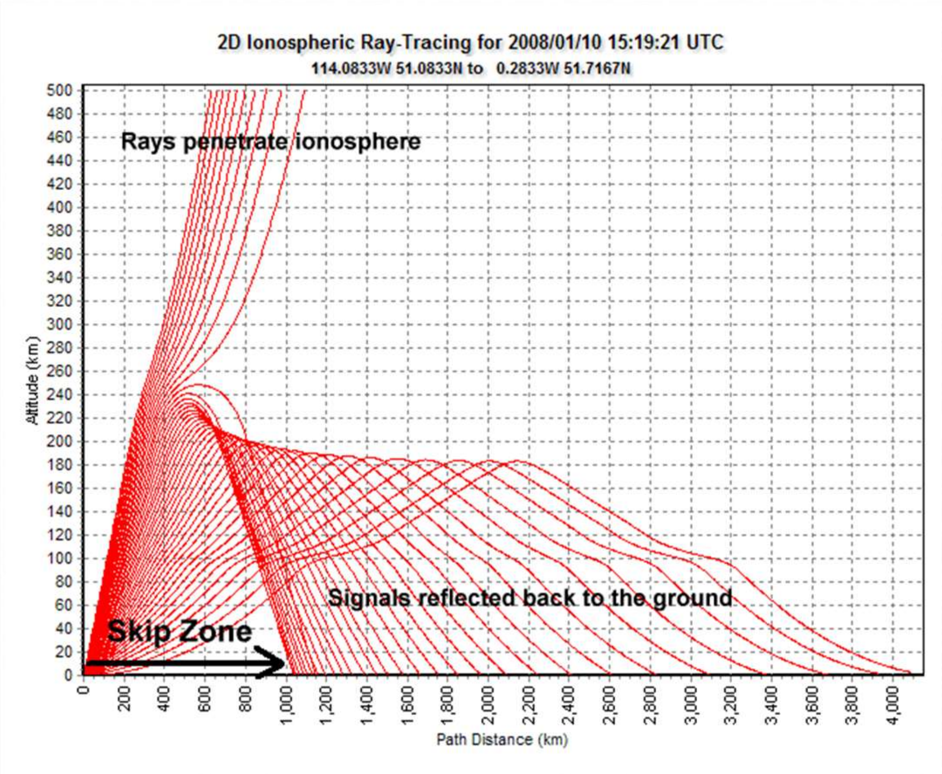
Reflection and Refraction

- Radio waves are light
- Layers of the ionosphere have different densities and may reflect, absorb or refract radio waves



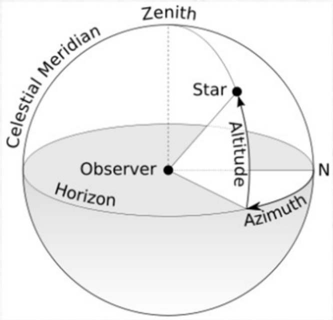
Propagation

- Skip zone – no signal heard – distance between the furthest point reached by the ground wave and nearest point at which the refracted sky waves first come back to earth
- Zone of Silence
- Multihop Propagation



Skip Distance

- Skip distance is inversely related to angle of radiation
- Lower the radiation angle to the horizon, greater the skip distance
- F2 skip is about 4500 km
- E layer skip is 2200 km
- NVIS – 100 km



Effects

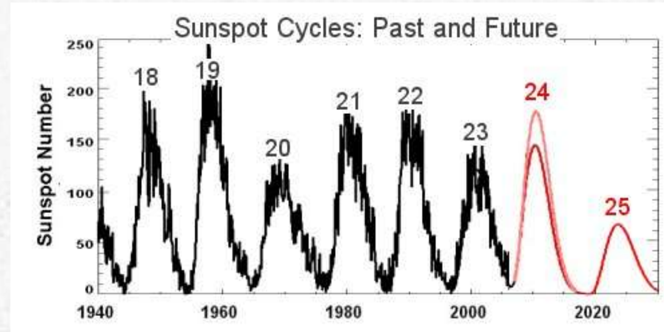
- sudden changes in refracting angles causes fading
- radio mirror is not smooth – diffused – return of waves can be varied – Faraday Rotation

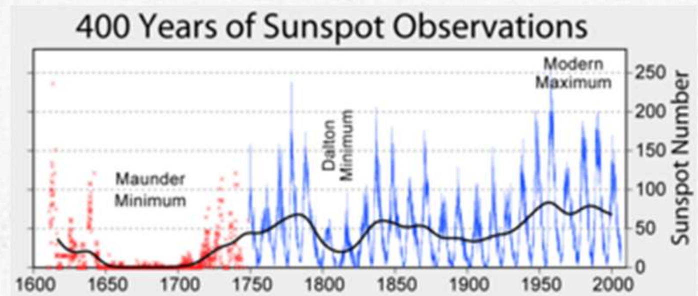
Attenuation of Radio Waves and Signal Strength

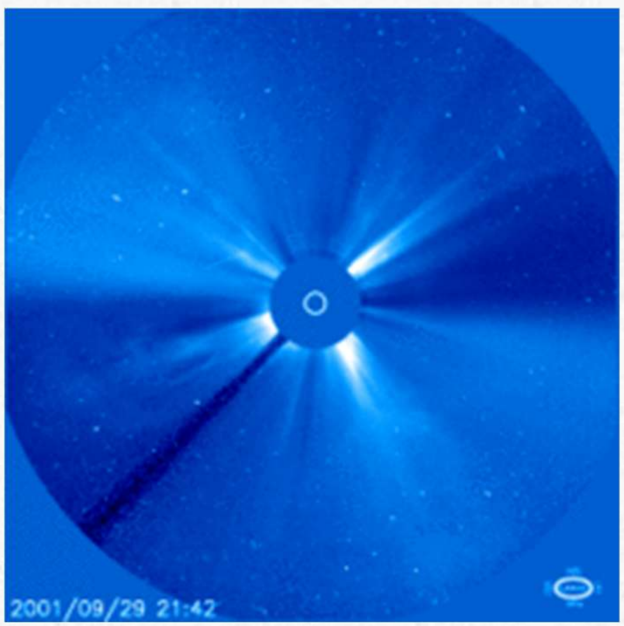
- Inverse square law
- direct waves and skywaves affected by absorption and travelling by different paths
- waves in phase and out of phase
- multipath fading
- absorption with each skip
- selective fading
- S-meter relative indication of signal strength
- Scatter propagation (VHF) – forward, backscatter and side scatter

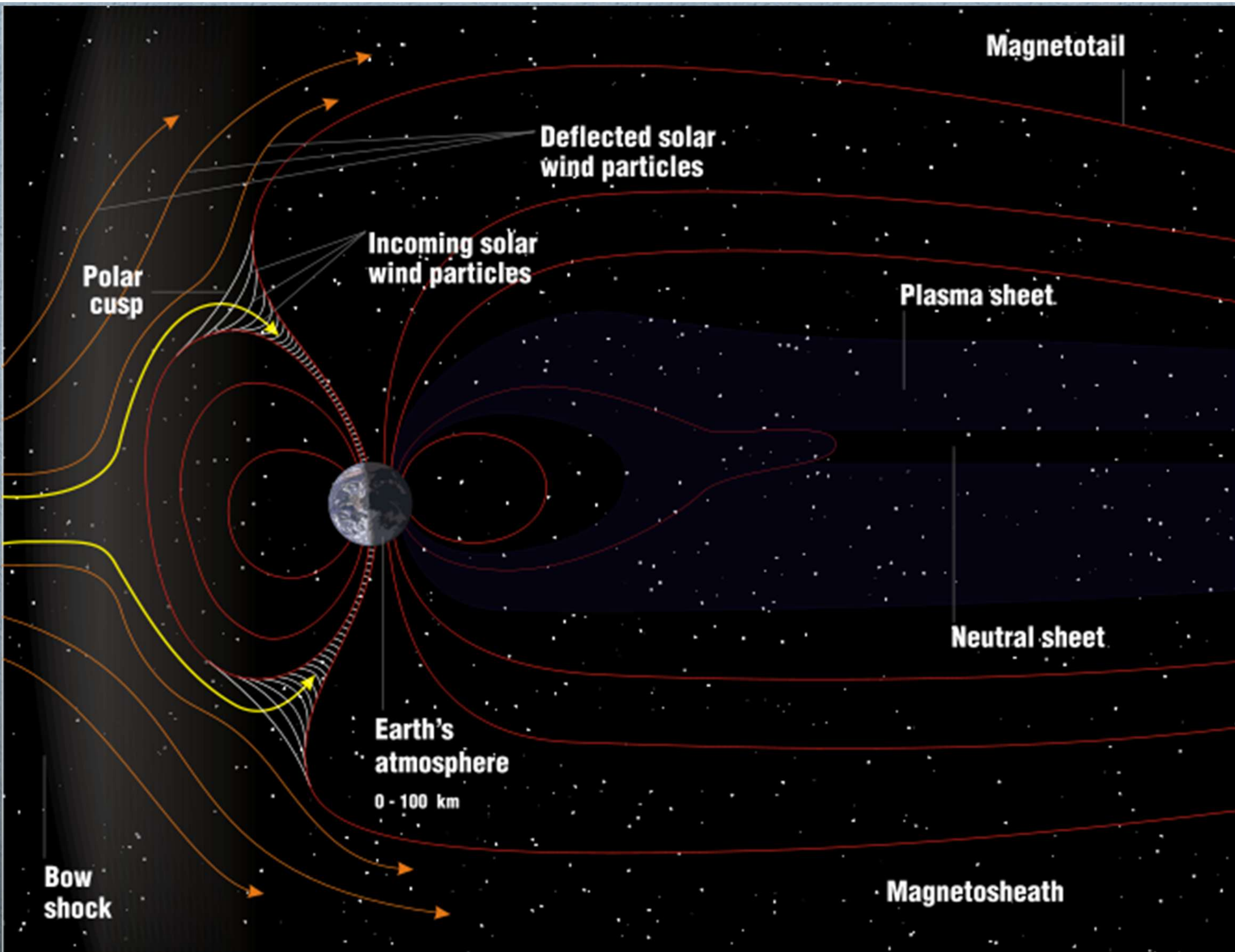
Solar Cylce and Activity

- 22 year cycles of sunspots
- ionization of atmosphere affected
- solar and geophysical storms
- sunspots
- coronal mass ejections
- sudden ionosopheric disturbance (SID)
- solar storms, space weather


Sunspot Cycles: Past and Future
Sunspot Number
250
200
150
100
50
0
18
19
20
21
22
23
24
25
1940
1960
1980
2000
2020


400 Years of Sunspot Observations
Maunder Minimum
Dalton Minimum
Modern Maximum
Sunspot Number
250
200
150
100
50
0
1600
1650
1700
1750
1800
1850
1900
1950
2000


2001/09/29 21:42

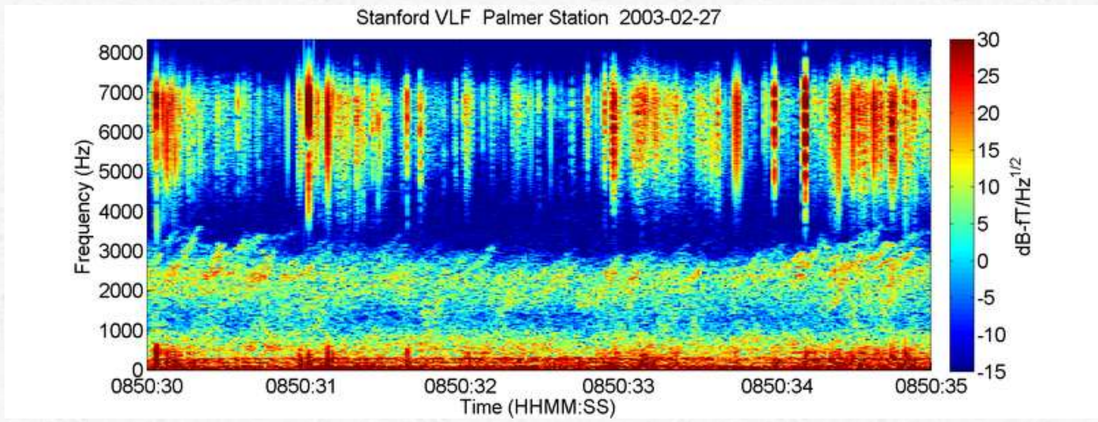

Magnetotail
Deflected solar wind particles
Incoming solar wind particles
Polar cusp
Plasma sheet
Neutral sheet
Earth's atmosphere
0 - 100 km
Bow shock
Magnetosheath

WWV

- WWV Colorado
- WWVH Hawaii
- Solar Flux Index
  - Daily activity of sun measured at 2800 MHz
  - Scale of 0-400.
  - A Index and K Index
  - 2.5, 5, 10, 15 and 20 MHz (Minute 45)

Atmospherics

- Lightning and related discharges
- Ducting
- Refraction and reflection
- Dawn Chorus
- VLF noises



Propagation Prediction

- propagation forecasts
- critical frequency/penetrating frequency
  - highest frequency that a radio wave directed vertically will refract back to earth from ionized layer frequencies greater than the CF will be transmitted into space – skip zone
- maximum usable frequency (MUF)
  - highest frequency that a radio wave directed vertically will reflect back to earth from ionized layer (recall critical angle)
- solar flux – energy emitted from sun
- geomagnetic index – stations >45ºN most sensitive

Prediction

- Optimum Working Frequency (OWF)
  - slightly lower than the MUF
  - if using frequencies close to MUF, any change may result in abrupt loss of signal
  - E layer, for distances of 2000 km MUF is about 5 times Critical Frequency
  - F layer, for distances of 4000 km MUF is about 3 times Critical Frequency
- Remember the atmosphere is ever changing

MF and HF Band Propagation

- 160 m (1.8-2.0 MHz) – during day 100 km as D layer absorbs – evening it improves and range is several 1000 km
- 80 m (3.5-4.0 MHz) – day 400 km and night thousands of km; susceptible to transformers BPL etc. CHU 3.330 MHz
- 40 m (7.0-7.3 MHz) – day 800 km; night thousands; CHU 7.850 MHz (book is wrong)

MF and HF Propagation

- 30 m (10.1-10.15 MHz) – narrow band modes; day 1500 km; night worldwide; VE8RT QSO with Antarctica from YK
- 20 m (14.0-14.35 MHz) – favourite; peak sunspots, always open; day and night; WWV and CHU 14.670 MHz
- 17 m (18.068-18.168 MHz) – DX day and night
- 15 m (21.0-21.45 MHz) – DX day and night- Sporadic E activity – quieter in terms of manmade noise
- 12 m (28.0-29.7 MHz) – DX day and night; Sporadic E
- 10 m (28.0-29.7 MHz) – DX - highest HF band at threshold of VHF; "fascinating and perplexing"; solar activity at a high one can work world wide on a few watts; Sporadic E; beacons and repeaters (CB just below 10 m at 26.965 MHz)

VHF and UHF Propagation

- Recall all classes of amateur licence allow use of HAM bands with f>30 MHz
- Directwave, amateur satellites and moonbounce
- Generally not affected by ionosphere and pass through (though not always)
- 6 m is the exception
- VHF line of sight communications
- tropospheric refraction – 4/3

VHF and UHF Effects

- Sporadic E – iononized clouds in E layer
- Meteor Scatter – iononized trails – rapid CW – 6 metres – FM broadcast radio
- Auroral Effects – scatter – enhance and degrade – very noticeable here
- Tropospheric Ducting – meteorological conditions – VHF and UHF – thousands of miles?
- Hilly Terrain – reflections, absorption and diffraction effects
- Flat Terrain – nodes and nulls – trial and error
- Built up Areas –
- Mobile – mobile flutter

VHF and UHF Propagation

- 6 m (50.0 MHz to 54.0 MHz) – like 10 m; has HF and VHF properties; 800 km; enhanced effects 1500 km; Sporadic E; double hop up to 3000 km; aurora sensitive;
- 2 m (144-148 MHz) – most popular band; FM repeater activity; some CW and SSB; rare ionospheric openings; Sporadic E; satellites; EME; SSB 300-500 km
- 1.35 m (219-220 MHz and 222-225 MHz) – highly neglected; portion eroded from HAM service by commercial interests; little equipment around; highest primary HAM band; middle chunk for disaster relief
- 70 cm (430-450 MHz) – FM repeaters, satellites, ATV, EME, CW and SSB DX – tropo in particular
- >70 cm are open generally at experimental level – amateurs are secondary users

Conclusion

- Review
- Waves, Wavelength, Frequency and Bands
- RF Propagation
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- Questions
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Questions