Radio Wave Propagation

Presented by:

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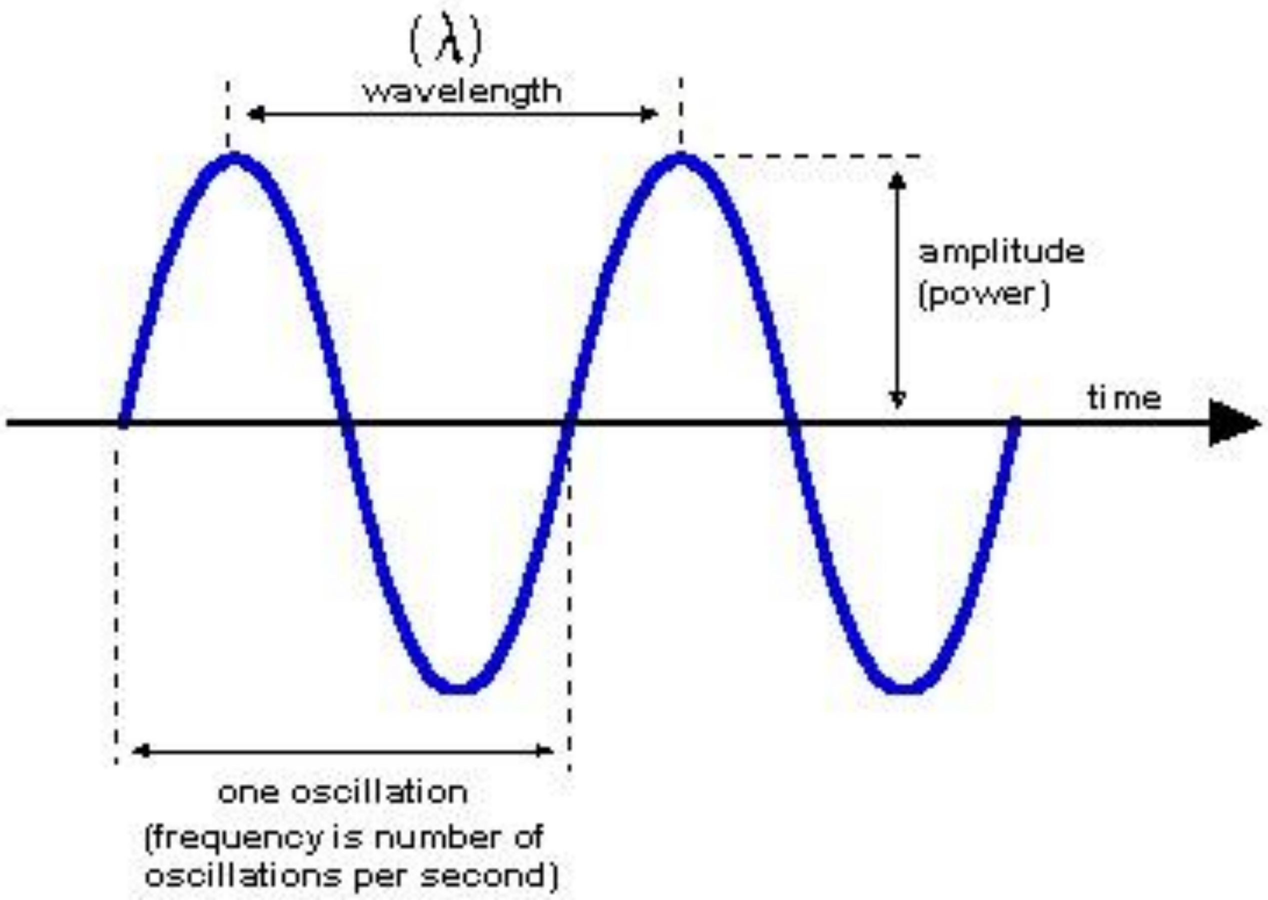
Quick recap ..

- **Wavelength** is the distance over which a wave's shape repeats; denoted by Greek alphabet 'λ' ; measured in meters
- **Frequency** is the number of occurrences of a repeating event for a given time period; denoted by '*f*'; measured in Hertz (Hz)
- **Frequency** and **wavelength** are inversely proportional to each other; Higher frequencies have smaller wavelengths; Lower frequencies have higher wavelengths
- Wavelength (λ) = Speed of light (c = 3x103 m/s) / Frequency (*f*)

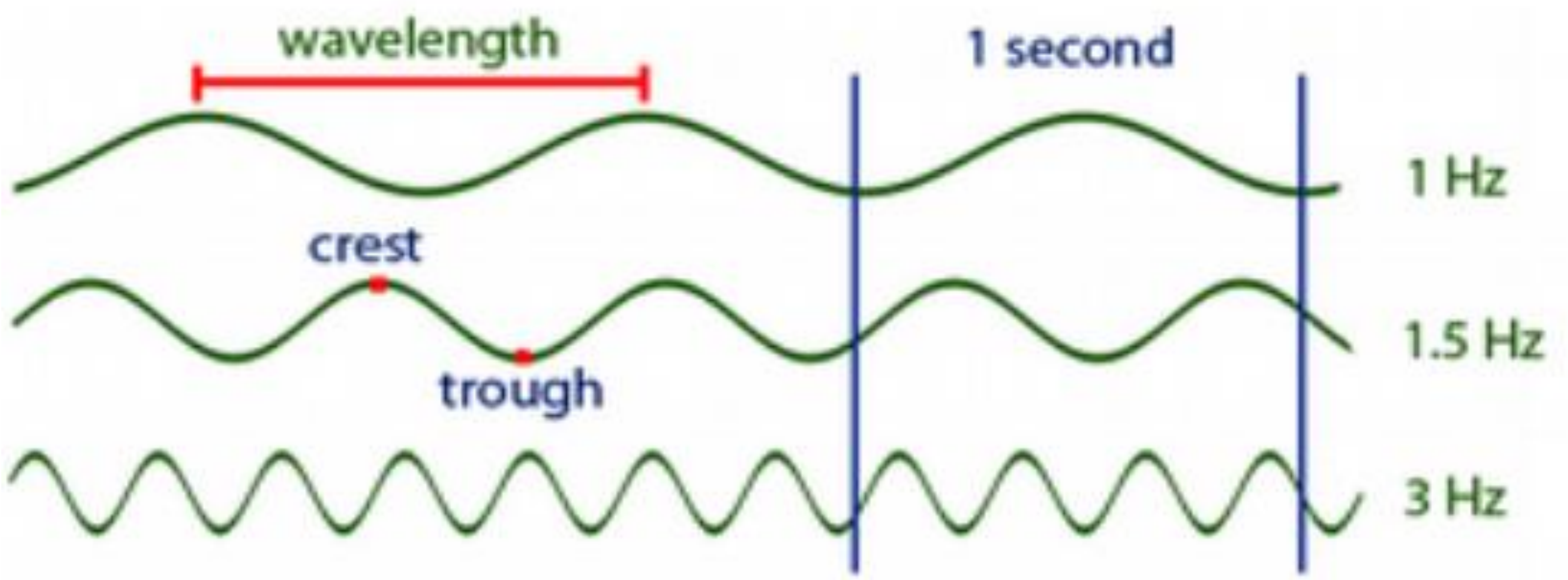
Ex: λ of a signal of frequency 100 MHz is, $c/100\ \text{MHz} = 3\text{x}10^8/100\text{x}\ 10^6 = 3\ Meters$

Quick recap ...



(λ)
wavelength
amplitude
(power)
time
one oscillation
(frequency is number of
oscillations per second)

Quick recap



Electromagnetic Spectrum

- There are waves of energy moving all around us in the form of TV and audio transmissions, gamma radiation from space, and heat in the atmosphere; We refer to them all electromagnetic radiation
- The waves of energy are called electromagnetic (EM) because they have oscillating electric and magnetic fields
- Scientists classify them by their frequency or wavelength, going from high to low frequency (short to long wavelength). For a wave with a high frequency, it has a lot of energy, so it could be a gamma ray or x-ray. If it has low frequency, it has less energy and could be a TV or radio wave.
- Electromagnetic spectrum is the entire distribution of electromagnetic radiation according to frequency or wavelength

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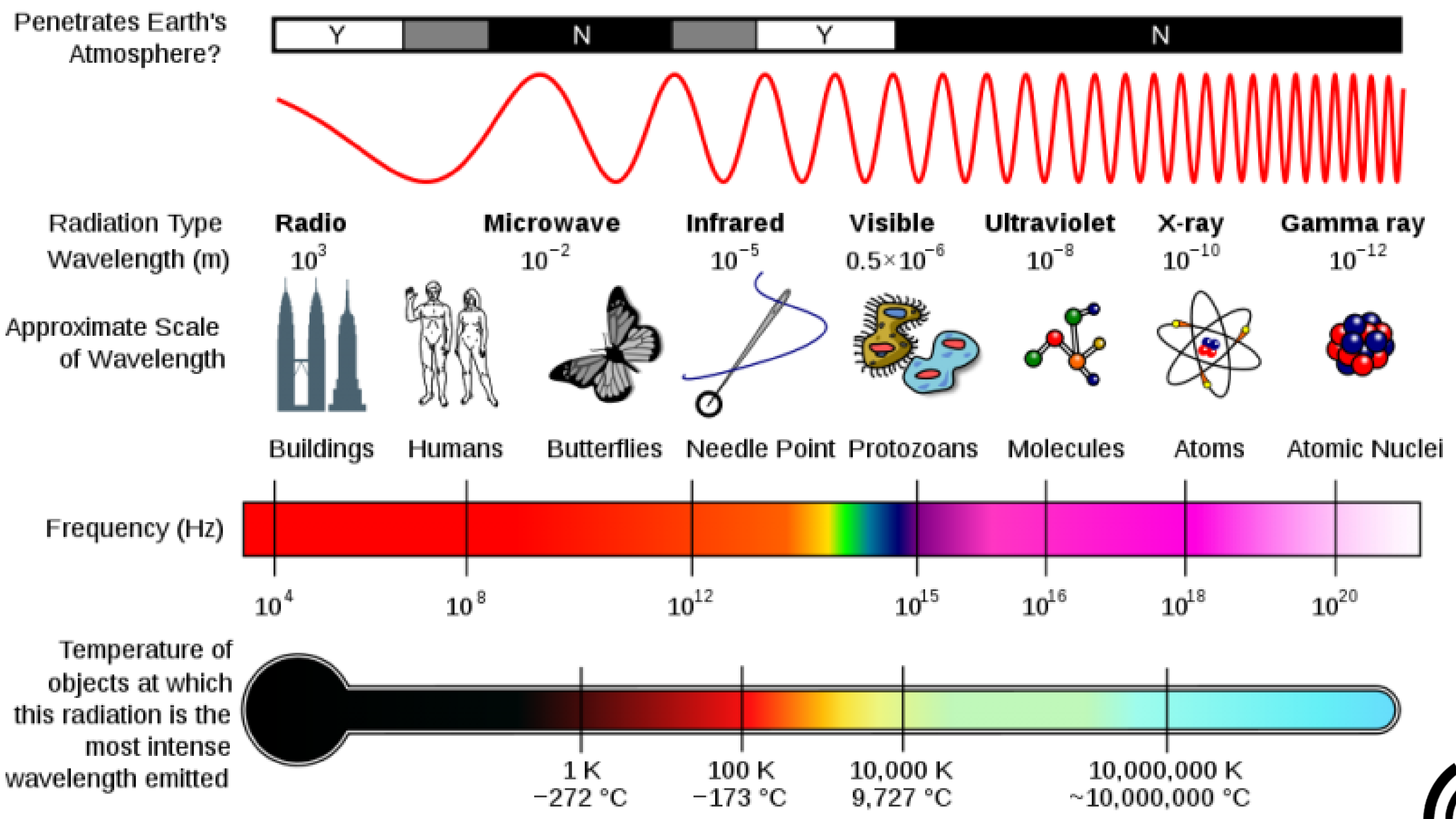


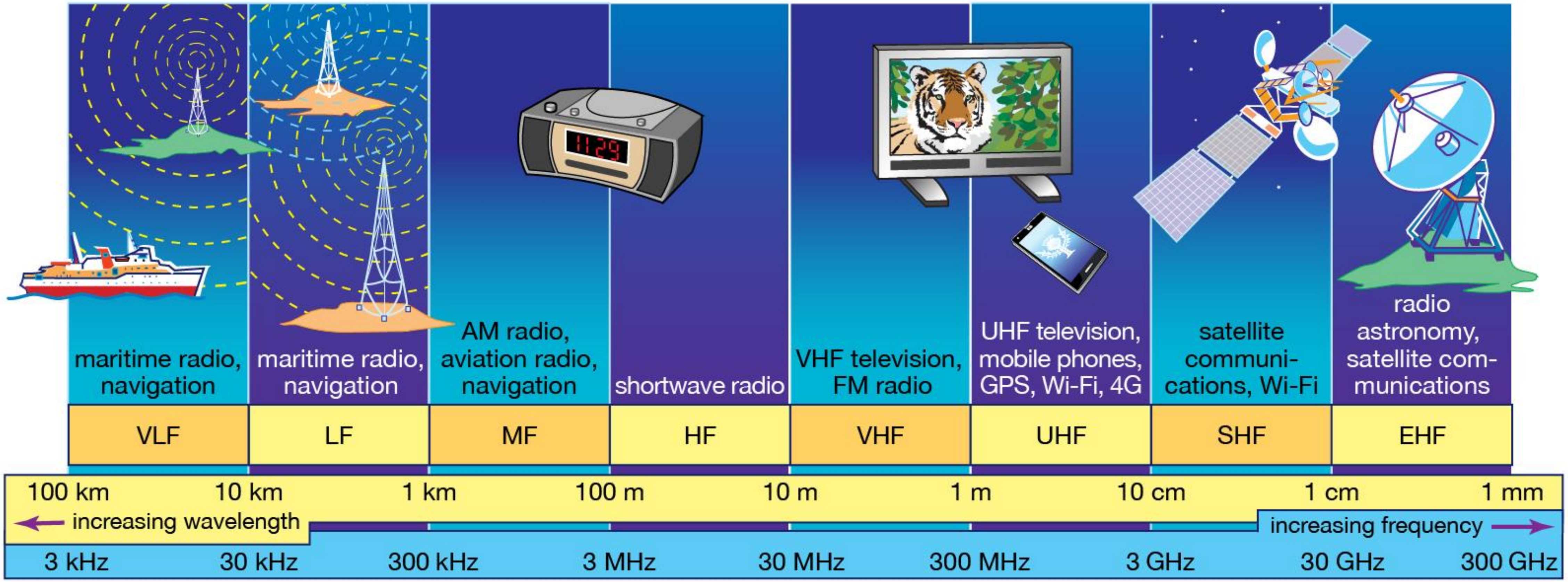
Penetrates Earth's Atmosphere?
Y
N
Y
N
Radiation Type
Wavelength (m)
Radio
10^3
Microwave
10^{-2}
Infrared
10^{-5}
Visible
0.5×10^{-6}
Ultraviolet
10^{-8}
X-ray
10^{-10}
Gamma ray
10^{-12}
Approximate Scale of Wavelength
Buildings
Humans
Butterflies
Needle Point
Protozoans
Molecules
Atoms
Atomic Nuclei
Frequency (Hz)
10^4
10^8
10^{12}
10^{15}
10^{16}
10^{18}
10^{20}
Temperature of objects at which this radiation is the most intense wavelength emitted
1 K −272 °C
100 K −173 °C
10,000 K 9,727 °C
10,000,000 K ~10,000,000 °C

Wave bands

- Before transmitting radio waves, differences in behavior of waves at different frequencies must be considered ; Long waves follow the earth’s curvature, short waves can be reflected off the ionosphere and ultra short waves can penetrate the ionosphere into space
- According to characteristics of their outspread, radio waves can be classified into 4 ranges or “bands” – Long, Mid, Short, and Ultra-short waves

Wave bands

Range	Frequency	Wavelength
Longwave (**L**ow **F**req – **V**ery**LF**)	30 - 300 KHz	10 –1Kms
Midwave (**M**edium **F**)	300 - 3000 KHz	1000 – 100 Meters
Shortwave (**H**igh **F**)	3 - 30 MHz (**H**igh **F**)	100 – 10 Meters
Ultra-shortwave : Meter range(**VeryHF**)	30 - 300 MHz	10 – 1 Meters
: Decimeter range (**U**ltra**HF**)	300 - 3000 MHz	100 – 10 Centimeter
:Centimeter range (**S**uper**HF**)	3 - 30 GHz	10 – 1 Centimeter
: Millimeter range (**E**xtremely**HF**)	30 – 300 GHz	10 – 1 Millimeter


maritime radio, navigation
maritime radio, navigation
AM radio, aviation radio, navigation
shortwave radio
VHF television, FM radio
UHF television, mobile phones, GPS, Wi-Fi, 4G
satellite communi-cations, Wi-Fi
radio astronomy, satellite com-munications
VLF
LF
MF
HF
VHF
UHF
SHF
EHF
100 km
10 km
1 km
100 m
10 m
1 m
10 cm
1 cm
1 mm
increasing wavelength
increasing frequency
3 kHz
30 kHz
300 kHz
3 MHz
30 MHz
300 MHz
3 GHz
30 GHz
300 GHz

Bands of interest …

- In amateur radio, we focus mostly on three sets of wavelengths – the shortwaves , meter and decametric waves; we can also refer to thee bands by their frequency – High Frequency (HF) for shortwaves, Very High and Ultra High Frequencies for metric and decametric waves
- High Frequency (HF) (3 - 30 MHz) employs the use of shortwaves, which can be bent and reflected across the ionosphere, to enable worldwide communication – from 500 – 1000's of kms – Shipping, Aircraft communication, worldwide radio broadcasts
- Very High Frequency (VHF) (30 -300 MHz) waves behave more like a bullet – line of sight - not bending much, and allows for medium range communication; range is limited to 50 – 100's of kms – Police, aircraft, marine communications, satellite communications
- Ultra High Frequency (UHF) (300 – 3000 MHz) waves are like VHF waves, but with very limited range, it can bounce off buildings and reflect – Police, satellite , cellphones

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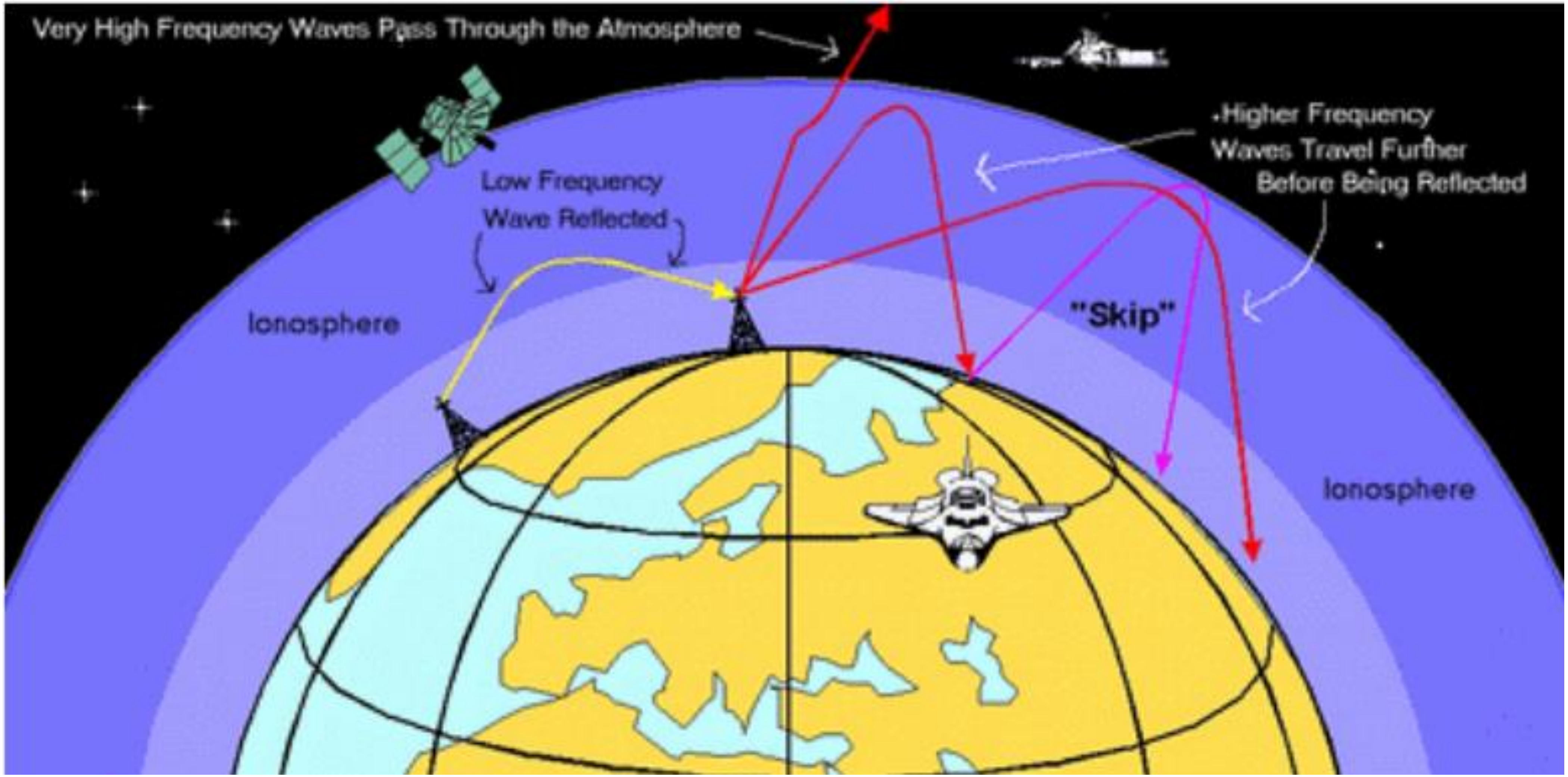
Types of propagation

- Radio waves can travel through various means; the behaviour of radio waves as it travels through the various parts of the atmosphere is what we refer to as propagation
- When a radio wave travels close to the surface or on the surface of the earth, it is called Ground Wave propagation – very short ranges, signal loss is given by various factors such as ground type, terrain, antenna height , etc. LF-VLF-MF are mostly ground wave propagated
- Sky wave propagation occurs when a radio wave is bounced off the ionosphere; it allows for worldwide communications. HF communication uses Sky Wave propagation for world wide communication
- Direct or Line Of Sight propagation is when the receiver and the transmitter can “see” each other; the radio waves may slightly bend but they are mostly act like a beam of light . VHF and above are mostly line of sight propagated

The Ionosphere

- The Ionosphere is the ionized region of the earth’s atmosphere that enables worldwide radio communications
- Radiation from celestial sources, mainly the sun, interacts with the different atoms at different heights, affecting their charges by removing or adding electrons to them – ionizing them
- As the radio waves interact with these ionized layers , they are either, reflected, refracted, or absorbed; the frequency of the wave determines the interaction with the ionosphere – lower frequencies are mostly absorbed, and higher frequencies are reflected or refracted


Very High Frequency Waves Pass Through the Atmosphere
Higher Frequency Waves Travel Further Before Being Reflected
Low Frequency Wave Reflected
Ionosphere
"Skip"
Ionosphere

Ionosphere and Radio wave Propagation

- As a radio wave travels through the ionosphere, they can get reflected, refracted or diffracted based on the frequency and ionization levels; this causes the radio wave to change directions and to reach places that would otherwise be impossible to reach, were the wave travelling in a straight and direct path
- These “skips” by a radio wave allows for transmissions to be heard in even the most remote corners of the world!
- Due to the ionization levels being directly dependent on the sun, the day and night cycle affects radio propagation and, ultimately, where the signal is heard

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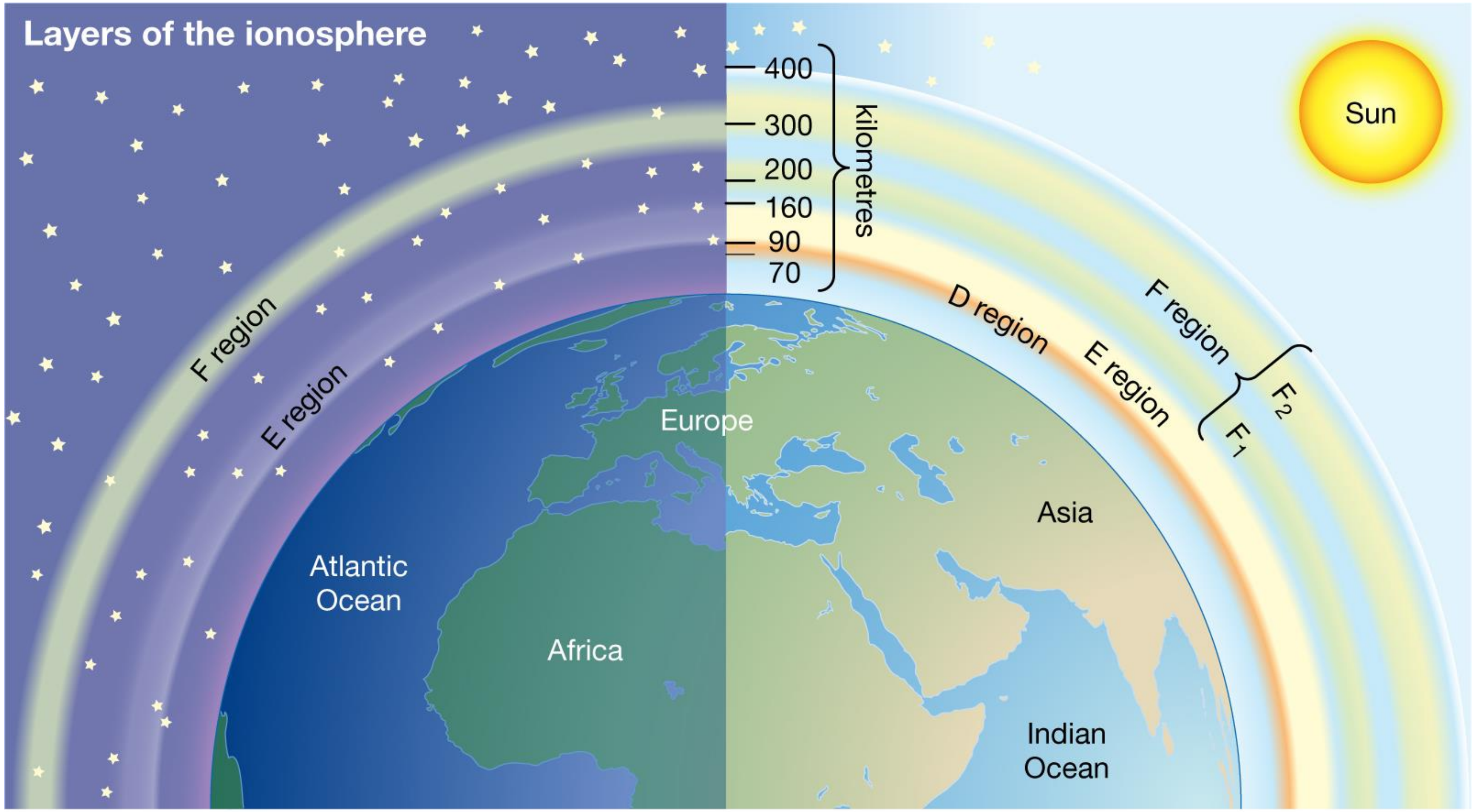
Layers of the Ionosphere

- There are different “layers” in the ionosphere categorized on there levels of ionization – each layer interacts with only radio waves of certain frequencies
- D Layer is the lowermost region of the ionosphere ; 60 – 80 Kms; ionization is highest during the day
- E Layer exists about 100 - 150 Kms from the surface; ionization level is high during day
- F Layer exists from about 150 – 500 Kms; it splits into 2 layers during the day and recombines at night


Layers of the ionosphere
400
300
200
160
90
70
kilometres
Sun
F region
E region
D region
E region
F region
F2
F1
Europe
Asia
Atlantic Ocean
Africa
Indian Ocean

D Layer

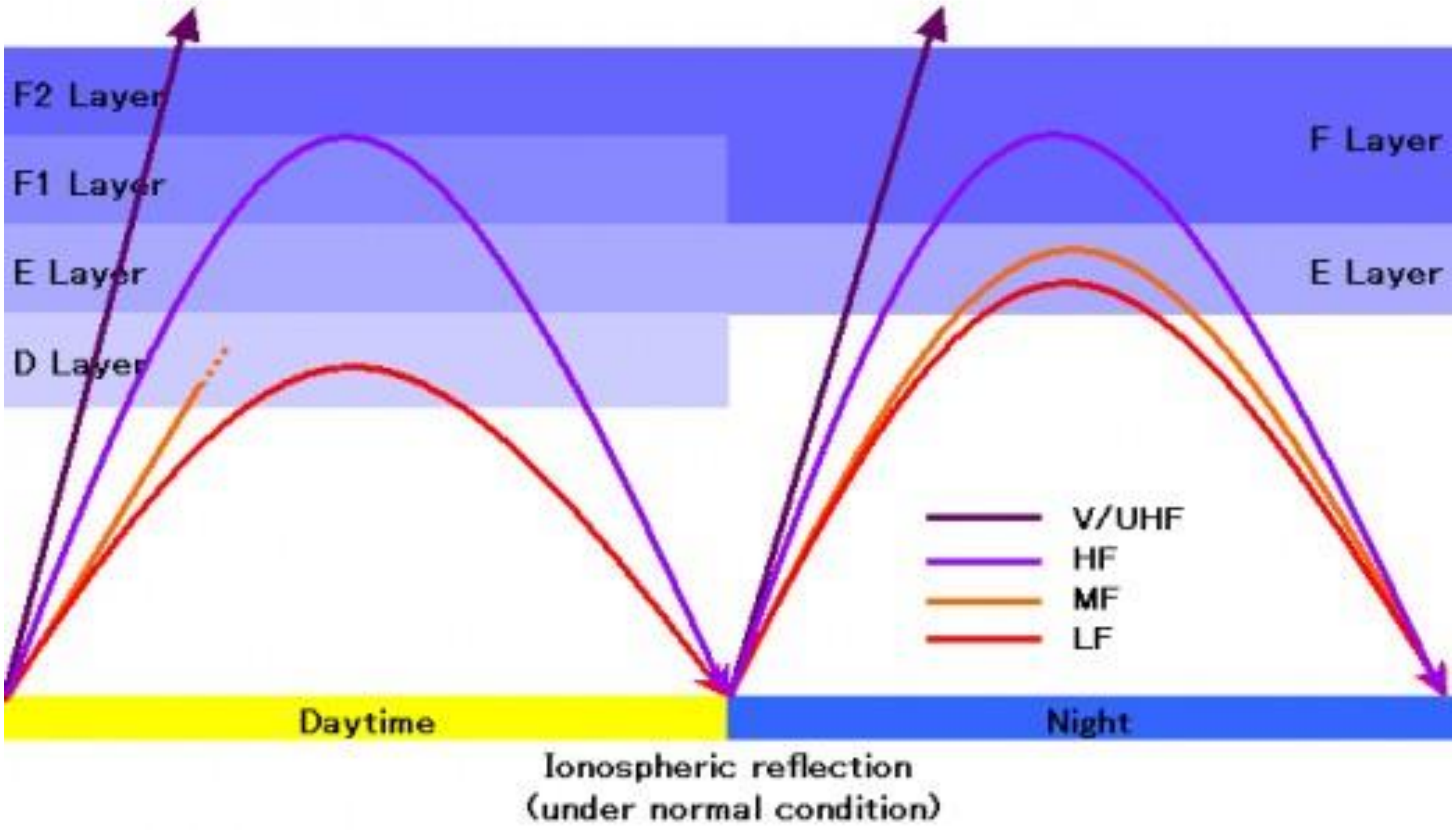
- D layer is the lowest layer of the ionosphere; 60 – 80 Kms High
- It is ionized during the day ; has little effect on HF during night
- It reflects LF, VLF and absorbs MF and HF
- Ionization by alpha particle radiation and Xrays

E layer

- Layer above the D layer; 100 - 150 Kms above the surface of the earth
- It is ionized during the day and loses ionization by night
- It reflects MF and HF signals, but can also absorb lower HF frequencies
- Ionisation is due to X ray and UV radiation from the sun
- Sometimes, a small cloud of ionization exists during both day and night and provide long distance skips – this is known as the "Sporadic" E layer due to its unpredictability

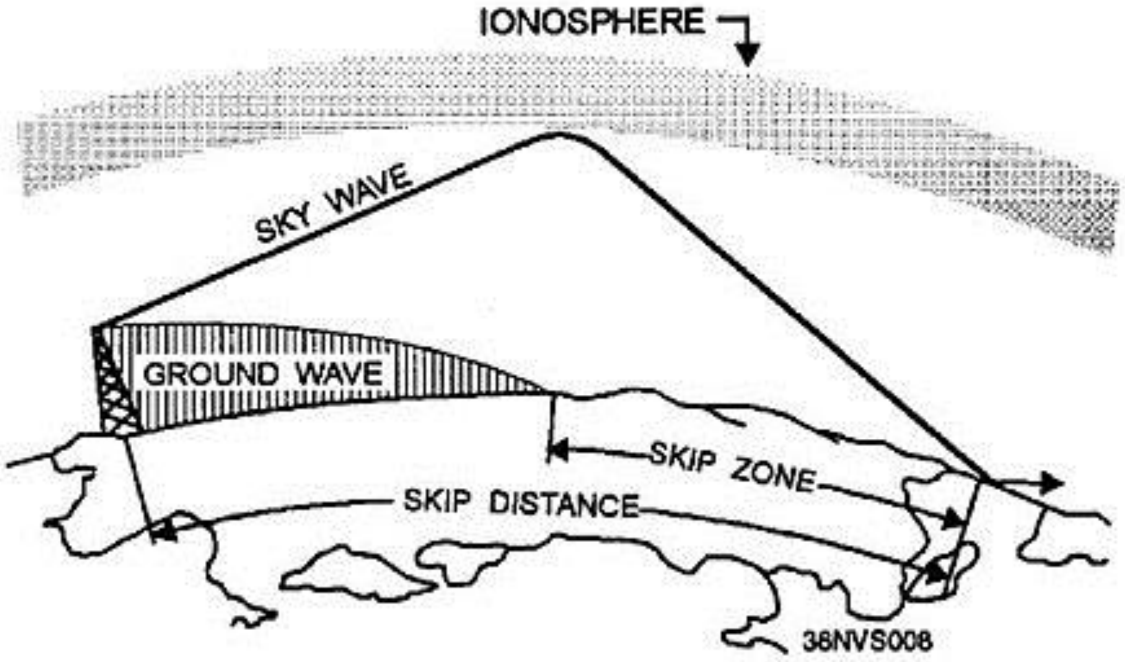
F layer

- The top-most layer of the ionosphere; 150 Kms – 500 Kms above the earth
- It is the most important layer for HF propagation as it reflects most signals back to earth
- Split into two layers during the day ; F_1 and F_2 layers
- Ionization occurs due to high UV radiation
- The layer loses ionization by night, but the process is very slow


F2 Layer
F1 Layer
E Layer
D Layer
F Layer
E Layer
V/UHF
HF
MF
LF
Daytime
Night
Ionospheric reflection
(under normal condition)

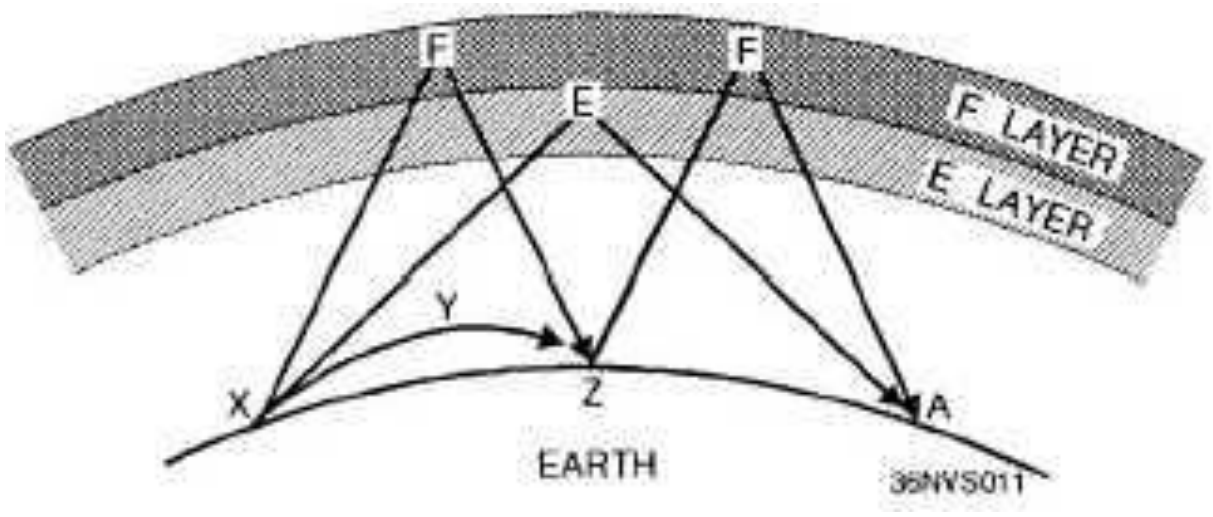
Skip Zone

- The Skip Zone is a zone of silence between the point where the ground wave becomes too weak for reception and the point where the sky wave is first returned to Earth
- The size of the skip zone depends on the extent of the ground wave coverage and the skip distance
- When the ground wave coverage is great enough or the skip distance is short enough that no zone of silence occurs, there is no skip zone



Fading

- The problem in receiving radio signals with variations in signal strength, is known as Fading
- Fading can be due to various reasons – Ionospheric absorption, change in polarization of the wave, multipath propagation etc.



Thank you!

Please post your questions and doubts in the chat box!