Physical Principles of Remote Sensing

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"Developing Interdisciplinary Postgraduate Programmes and Strengthening Research Networks in Geoinformation Technologies in Armenia and Kyrgyzstan"

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What is Remote Sensing?

Remote Sensing is an art and science of obtaining information about an object or feature without physically coming in contact with that object or feature (Lillesand and Kiefer, 1987)

RS is an art, science, and technology of obtaining reliable information about physical object and the environment, through the process of recording, measuring and interpreting imagery and digital representations of energy patterns derived from noncontact sensor system (Colwell, 1977)

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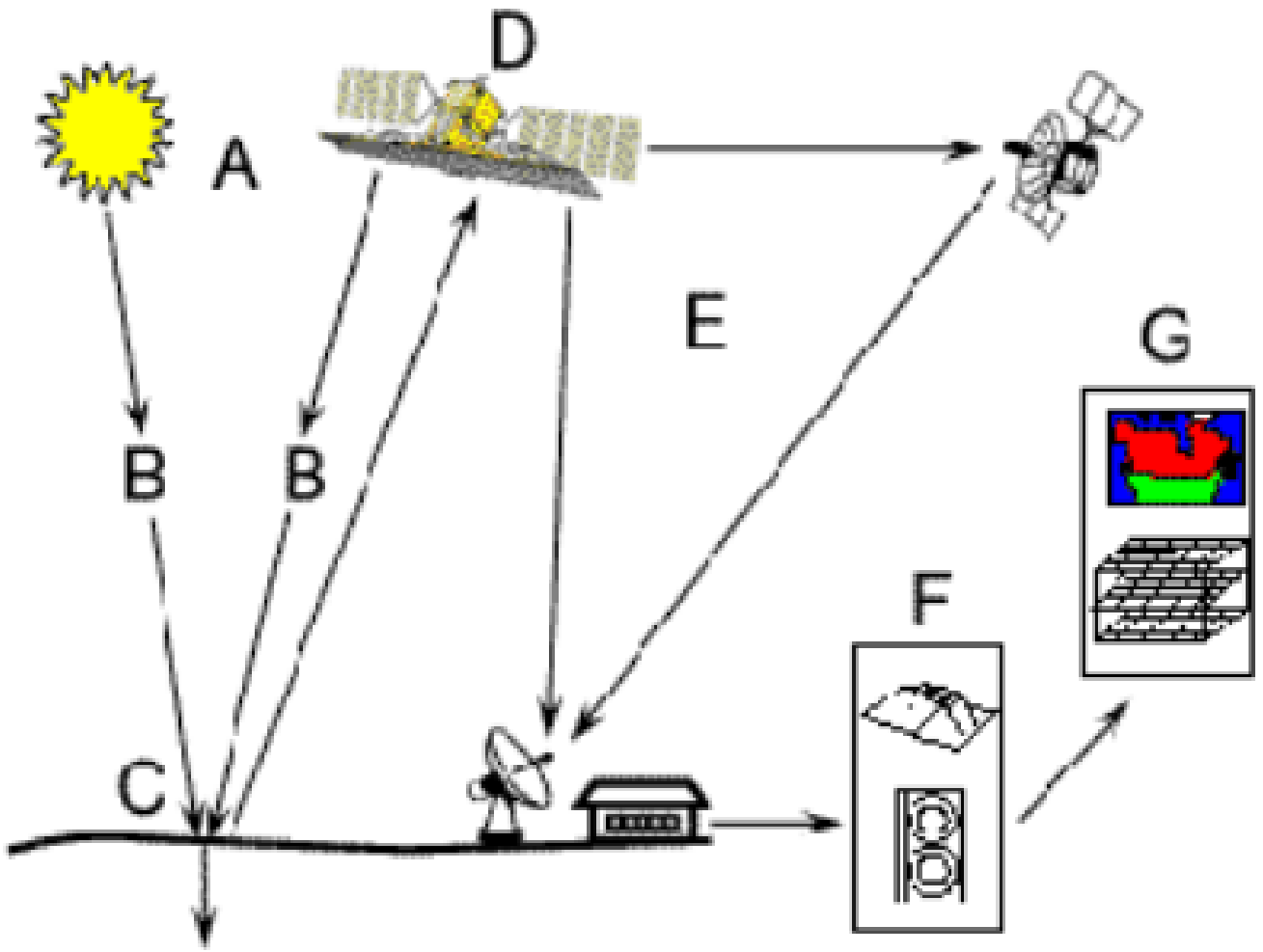
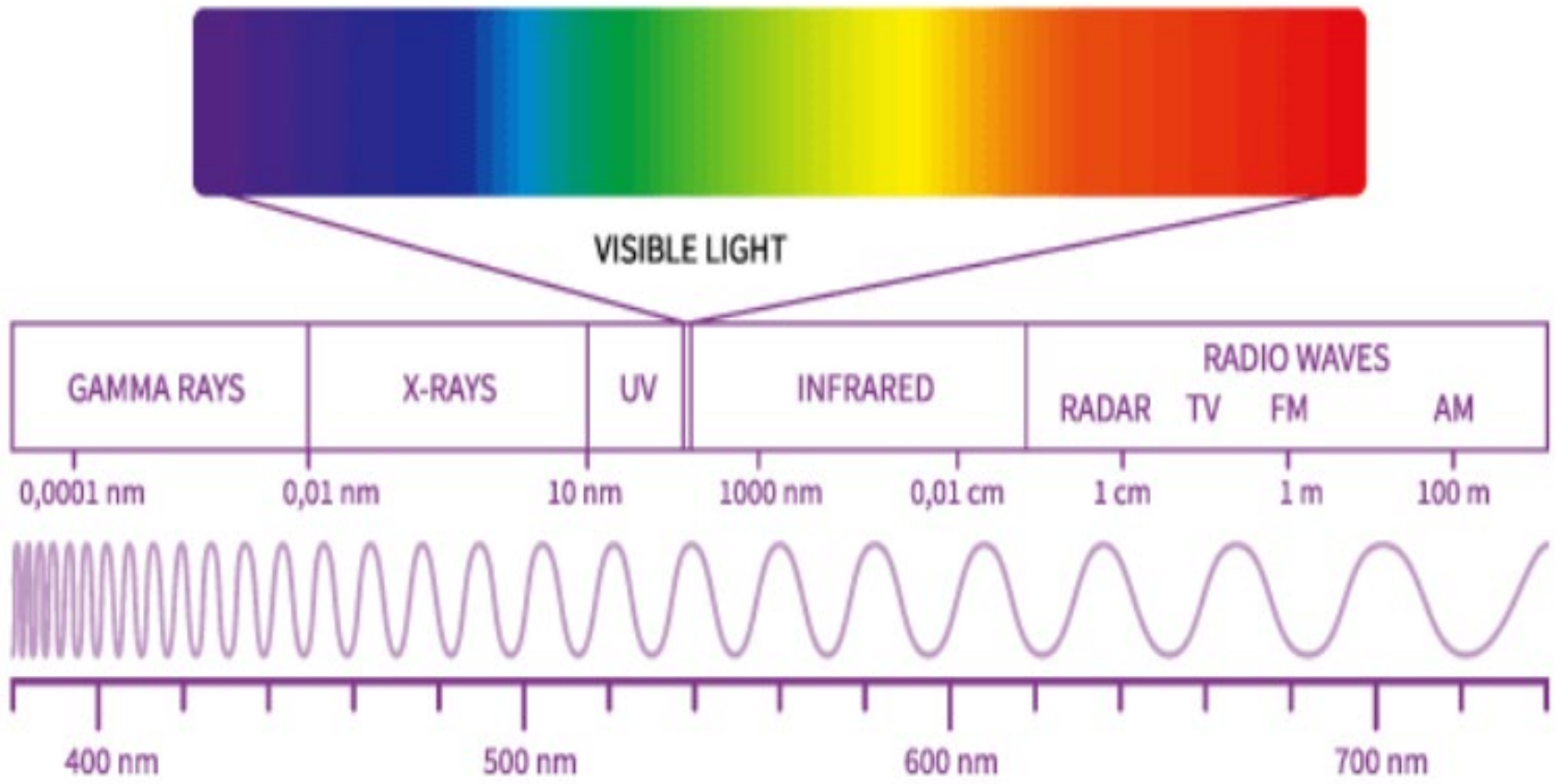


Components of Remote Sensing

Electromagnetic Waves in the Electromagnetic Spectrum

Type of Radiation	Frequency Range (Hz)	Wavelength Range
Gamma-rays	$10^{20} - 10^{24}$	$< 10^{-12}$ m
X-rays	$10^{17} - 10^{20}$	1 nm – 1 pm
Ultraviolet	$10^{15} - 10^{17}$	400 nm – 1 nm
Visible	$4 \times 10^{14} - 7.5 \times 10^{14}$	750 nm – 400 nm
Near-infrared	$1 \times 10^{14} - 4 \times 10^{14}$	2.5 μm – 750 nm
Infrared	$10^{13} - 10^{14}$	25 μm – 2.5 μm
Microwaves	$3 \times 10^{11} - 10^{13}$	1 mm – 25 μm
Radio waves	$< 3 \times 10^{11}$	> 1 mm

The electromagnetic spectrum



Formulas for the Electromagnetic Radiation

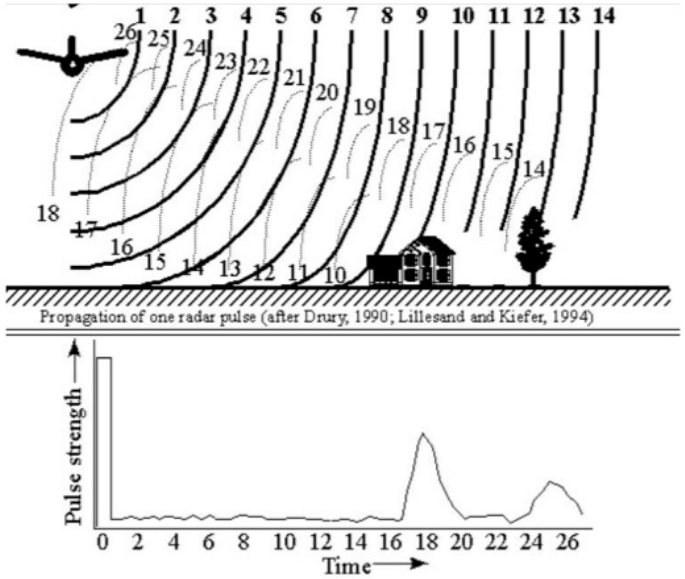
$$f = \frac{c}{\lambda}, \quad \text{or} \quad f = \frac{E}{h}, \quad \text{or} \quad E = \frac{hc}{\lambda},$$

Where,

- c = 299792458 m/s is the speed of light in a vacuum
- h = $6.62607015 \times 10^{-34}$ J·s is Planck's constant.

Active Remote Sensing

Source: Instrument pulse,
Needs power to operate



Passive Remote Sensing

Sources: surface emission,
cosmic background,
rain emission

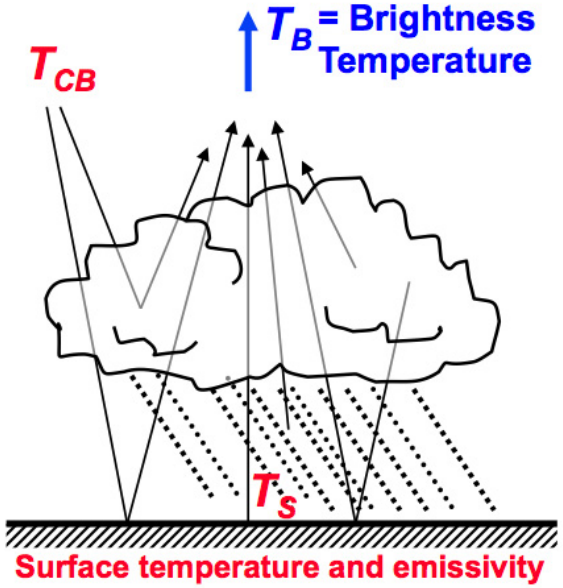


Illustration of examples with passive and active methods in remote sensing

Underwater exploration, bathymetry

Instrument / platform	Propagation (wavelength range)	Interaction	Signatures
Optical camera / ship, diver	Clear water, shallow depth ($\lambda \cong 0.4\text{-}1\ \mu m$)	Scattering of sunlight	Reflectance spectra, contours.
Sonar / ship, submarine	Deep penetration of sound waves	Backscattering of sound waves from bottom surface, from animals, ships, etc.	Depends on object Usually easy to locate depth to ocean-bottom

Speed of sound (m/s) in pure water and in sea water at P=0.1 MPa (sea surface) and at 100 MPa (10 km depth)

Temperature (C)	Pure water (surface, 10 km)	Sea water S=3.5% (surface, 10 km)
0	1402, 1578	1449, 1623
10	1447, 1618	1490, 1659
20	1483, 1650	1522, 1687
30	1511, 1677	1546, 1710

Detection of snow cover (regional, global)

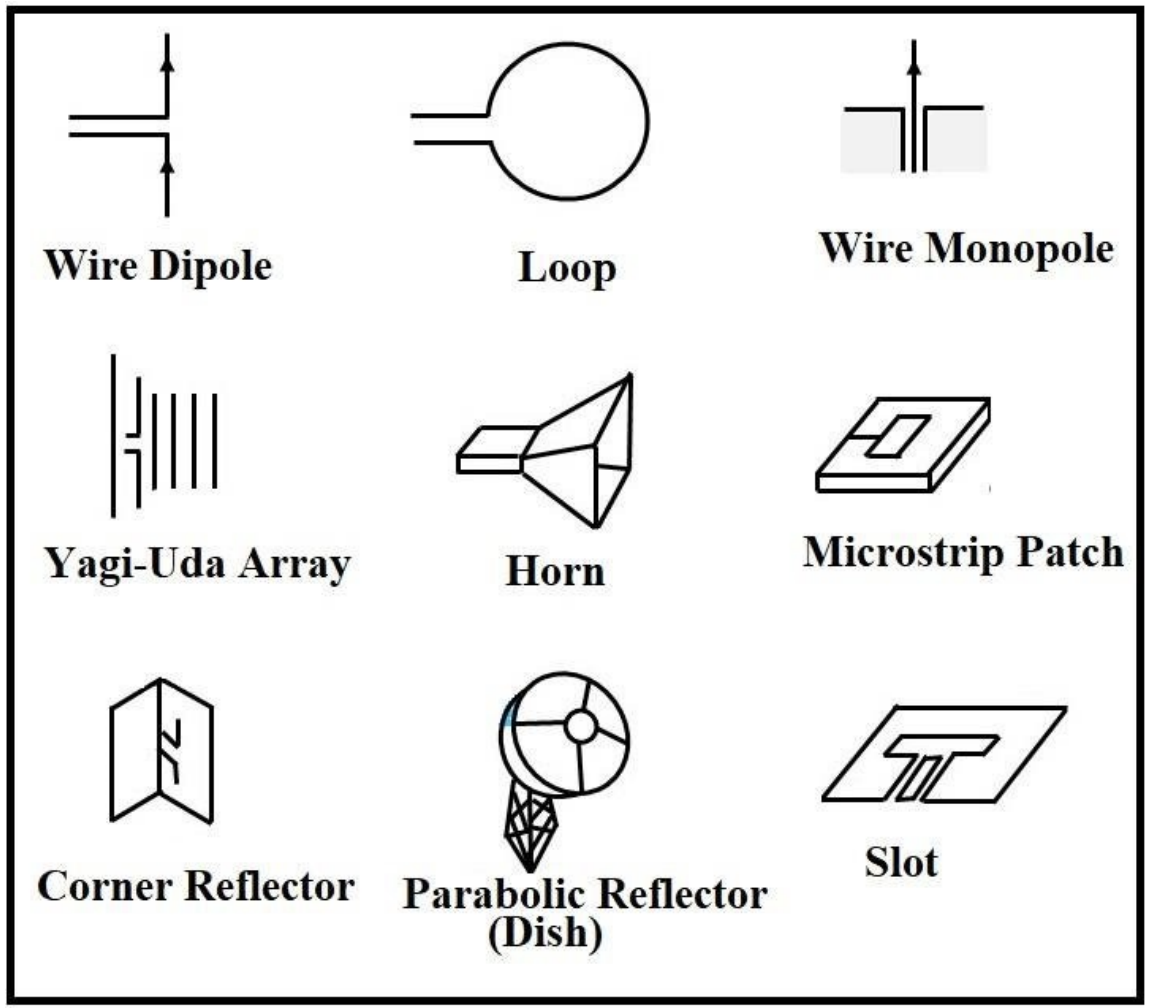
Instrument / platform	Propagation (wavelength range)	Interaction	Signatures
Optical camera / tower, aircraft, satellite	Through clear air, ($\lambda \cong$ 0.4-1 μm)	Scattering of sunlight	High reflectance, especially for fresh snow.
Thermal IR imager / satellite	Clear air ($\lambda \cong$ 8-14 μm)	Emission of thermal radiation	$T \leq 273.15$ K
Microwave radiometer / satellite	Clear air, clouds ($\lambda \cong$ 3 mm – 10 cm)	Scattering of sky radiation and emission of thermal radiation	Dry snow with characteristic reflectance, wet snow with high emissivity
Microwave radar / satellite	Clear air, clouds, precipitation ($\lambda \cong$ 3 cm – 10 cm)	Backscattering of microwave radiation	Low backscatter, especially for wet snow
Gamma-ray detector (scintillation counter) / low-flying aircraft	Short range < 300 m in air ($\lambda < 10^{-10}$ m)	Natural γ radiation of minerals (e.g. ^{40}K, ^{238}U, ^{208}Tl) in the top 10 cm of the soil	Attenuation by snow

Measurement of atmospheric water vapour H_2O

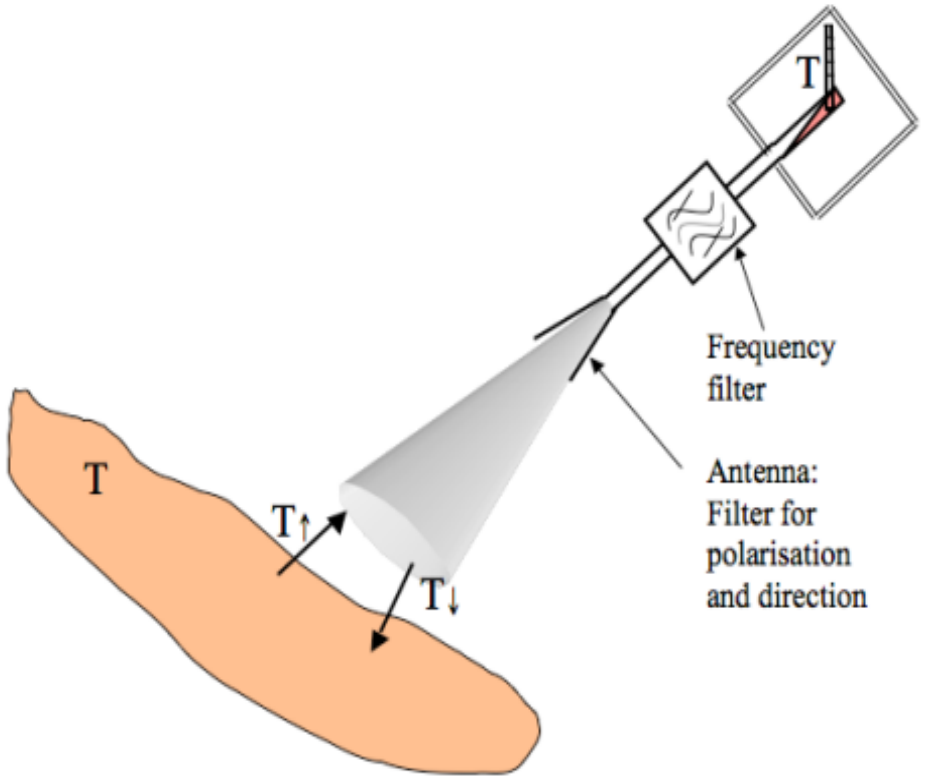
Instrument / platform	Propagation (speed)	Interaction	Signatures
GPS system with network of fixed receivers / surface and satellites	All weather (very close to speed of light in vacuum)	Delay of signal speed by water vapour and dry air	Unique for total column of H_2O if surface air pressure is known
Microwave radiometer / surface	Air, smoke, clouds	Emission line of H_2O frequency $f \cong 22$ GHz ($\lambda \cong 14$ mm)	Distinction from cloud emission by 2nd frequency
Microwave radiometer / satellite	Air, smoke, clouds	Emission line of H_2O frequency $f \cong 22$ GHz ($\lambda \cong 14$ mm)	Distinction from surface and clouds by additional channels (frequency, polarisation)
Sun photometer / surface	Clear air with sunlight	Absorption band of H_2O ($\lambda \cong 940$ nm)	Distinction from aerosols by additional channels
MERIS / satellite (ENVISAT)	Clear air with sunlight	Absorption band of H_2O ($\lambda \cong 940$ nm)	Distinction from surface and aerosols by additional channels

Detection and localization of lightning

Instrument	Propagation (speed)	Interaction	Signatures
Human observer	Viewing lightning (speed of light), Hearing thunder (sound speed)	Light flash and sound burst emitted by lightning	Characteristic flash in view direction, delay of thunder proportional to distance
Electromagnetic lightning detector network	All-weather capability (ground-wave close to speed of light)	Radio burst (sferic) emitted by lightning	Propagation distance from time-of-arrival measured at several stations.



Antennas types



Basic idea of a radiometer to measure the radiation

Thanks!

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