

INTRODUCTION TO MICROWAVE REMOTE SENSING

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Why Microwaves ... ?

- **More difficult than with optical imaging because the technology is more complicated and the image data recorded is more varied.**
- **There are many concepts and techniques to be assimilated in this context.**
- **What interests us in radar imaging as a remote sensing modality ?**
 - **The wavelength of the radiation used compared to that of visible and infrared radiation employed in optical remote sensing.**

Why Microwaves ... ?

- **Optical imaging technologies operate at wavelengths of the order of $1\text{ }\mu\text{m}$ (i.e a millionth of a meter)**
- **Radar imaging is based on microwaves that have wavelengths of the order of 10 cm (approx 100,000 times optical wavelength order)**
- **Due to such a disparity in wavelength the features on the Earths surface appear differently at microwave than they would optically**
- **Optical and Microwave data types are complimentary and hence together used in application**

Why Microwaves ... ?

- Another major difference between optical and microwave is the wave penetration capability
 - While there can be some penetration through media such as water and thin leaves at optical wavelengths, the longer wavelengths of radar can often penetrate vegetation canopies and even soils
- The imagery recorded optically usually represents the surface elements of the landscape whereas the radar image data is more **complex** because it often contains volumetric and sub-surface information as well
- With the long wavelengths used for radar imaging, the surfaces appear much smoother than at visible and IR wavelengths

Why Microwaves ... ?

- **With radar we have control over the properties of the incident energy which allows a wide variety of data types to be recorded and enables innovative applications**
 - **Topographic mapping, Landscape change detection, 3D modeling of volume**

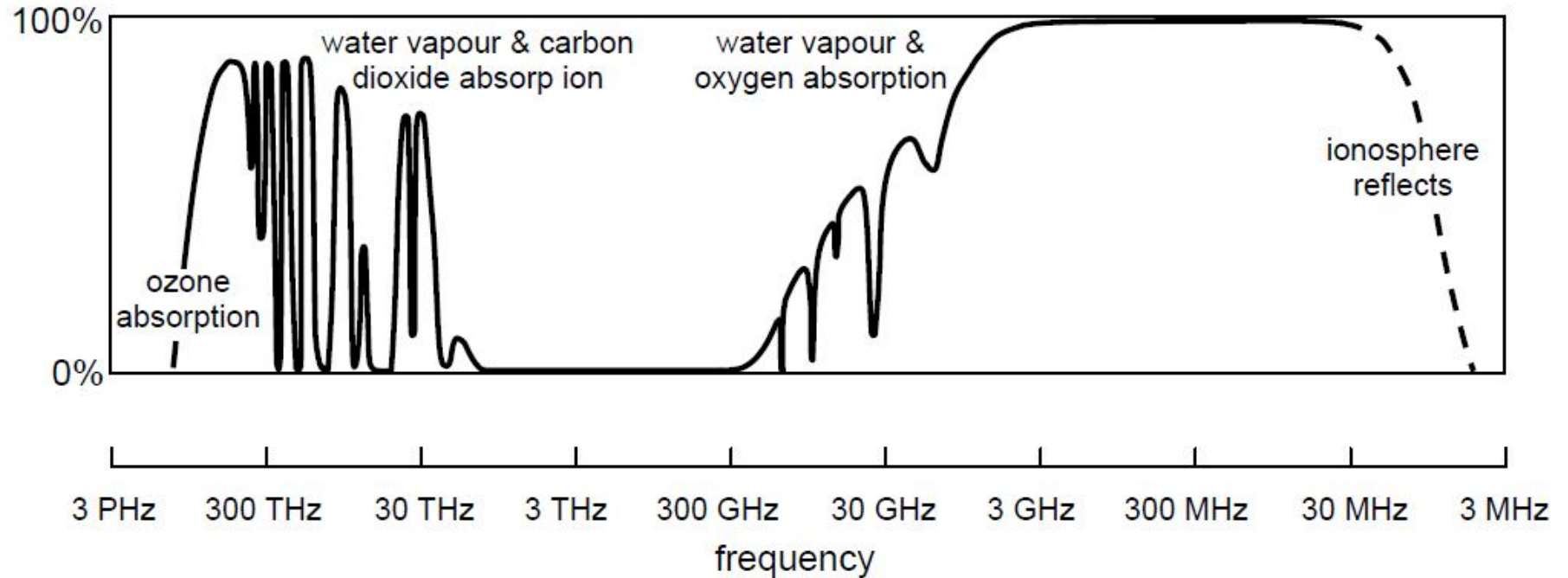
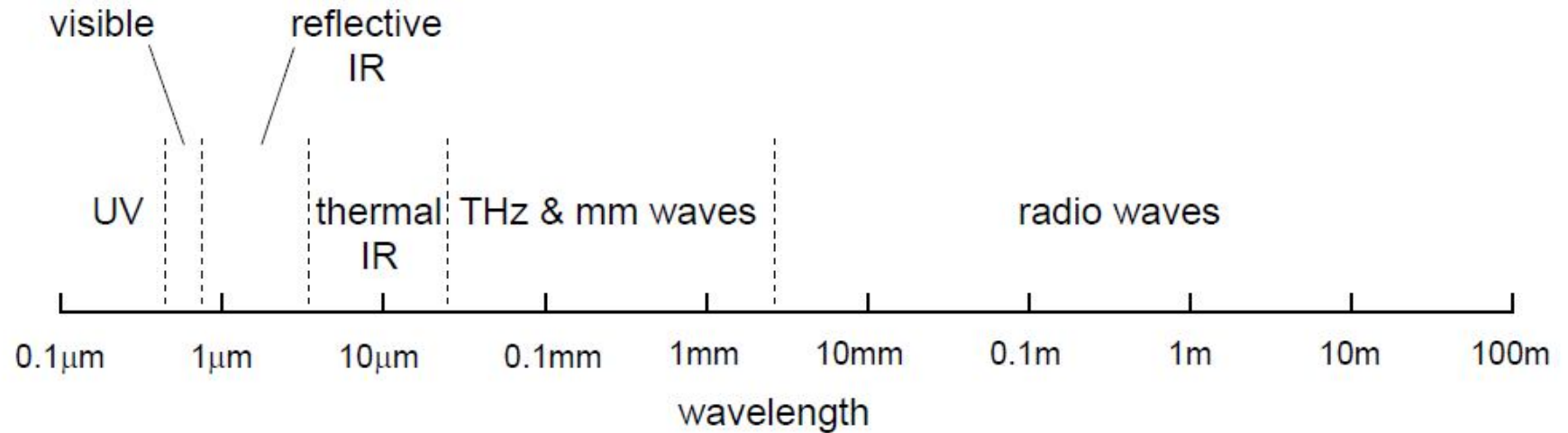
Imaging With Microwaves

- To form an image with any technology the first consideration is to know the energy source to view the landscape
- In case of optical data the energy source is visible and IR sunlight or Thermal energy from the Earth itself
- Although there is a limited amount of Microwave energy available from the Earth and Sun, it is so small that we generally need to provide our own source of incident radiation → ***Active Microwave Remote Sensing***

Imaging With Microwaves

- There could be two remote sensing platforms –
 - One carrying the energy source
 - The other (can be several) receiving scattered energy
- Most radar remote sensing systems have used the same platform (for transmitting and receiving) and are called *Monostatic*
- When two platforms (for transmitting and receiving) are used the radar system is called *Bistatic*

Imaging With Microwaves



Imaging With Microwaves

- Microwave energy is *just one form* of Electromagnetic (EM) radiation
- The continuous EM spectrum also includes the visible and IR energy that is the basis of *Optical Remote Sensing*
- The most significant difference in characterizing remote sensing image properties is wavelength
- In general we could use any wavelength for imaging the Earth's surface, the only real limit being the levels of energy available at the surface

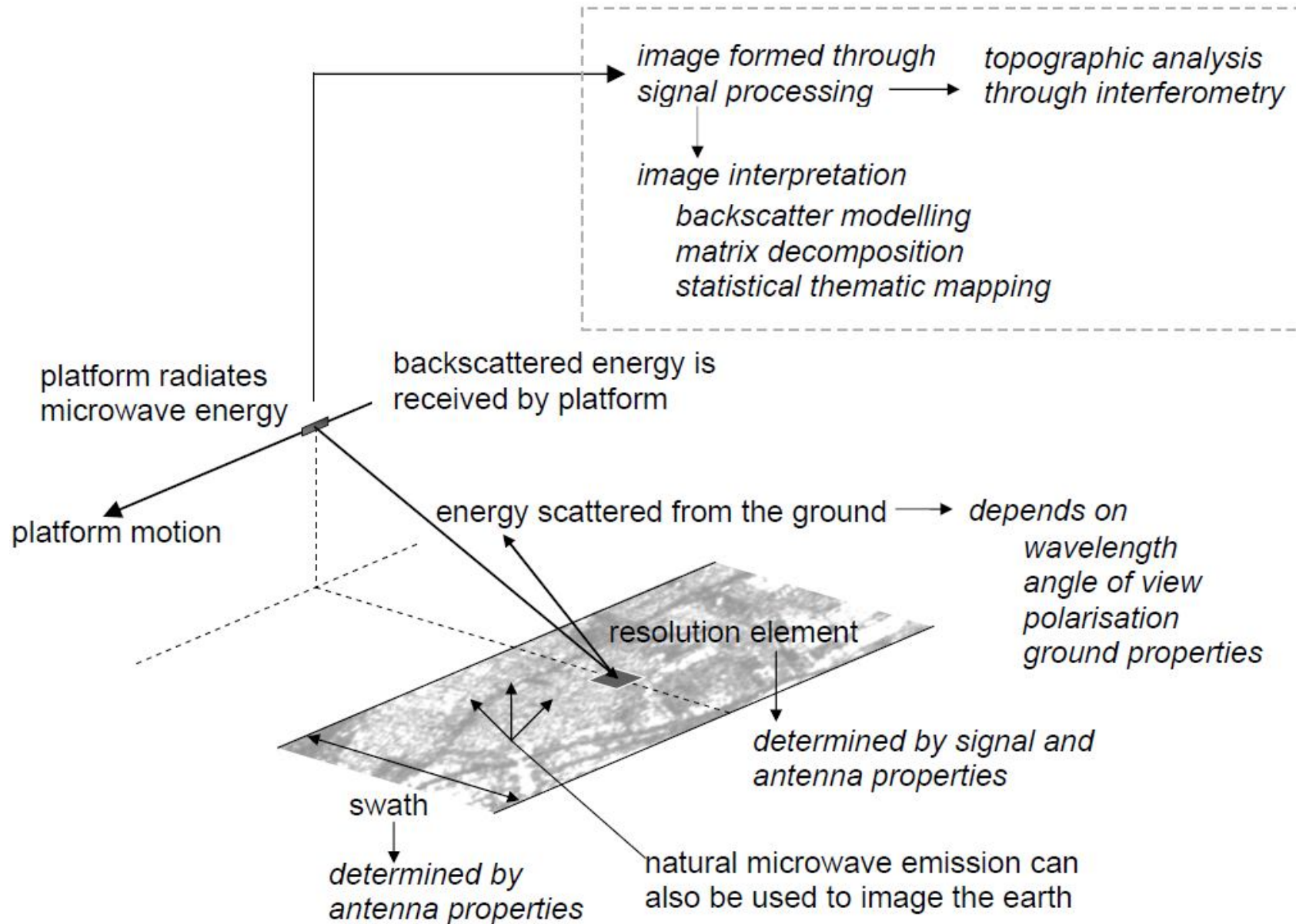
Imaging With Microwaves

- **Are there any fundamental limitations in using any particular wavelength range for remote sensing purposes ?**
 - **The Earth's atmosphere is not transparent at all wavelengths (Significant atmospheric absorption in suns ultraviolet (UV) and far IR)**
- **The characteristics of the atmospheric absorption are quite complex because of its molecular composition**
 - **The figure showing atmospheric transmittance as a function of wavelengths ranges from UV → Radio waves**

Imaging With Microwaves

- Regions in which there is little absorption are referred to as *Atmospheric Windows*
 - Visible and Near IR ($\sim 0.3 - 1.3 \mu\text{m}$)
 - Middle IR ($\sim 1.5 - 1.8 \mu\text{m}$; $\sim 2.0 - 2.6 \mu\text{m}$; $\sim 3.0 - 3.6 \mu\text{m}$; $\sim 4.2 - 5.0 \mu\text{m}$)
 - Thermal IR ($\sim 7.0 - 15.0 \mu\text{m}$)
- For wavelengths beyond 3 cm the atmosphere is regarded as transparent

Components of an Imaging Radar System



Components of an Imaging Radar System

- **The ability of the radar system to resolve the field of interest into resolution cells, or pixels**
- **Different principles are used to create resolution in the direction parallel to the motion of the platform (along track or azimuth), and orthogonal to it (across track or range)**
- **The landscape is irradiated using pulses of energy**
 - **The time taken from transmission to the landscape and back to the radar determines the how far away that part of the landscape is**
 - **Innovative signal processing techniques are used to high spatial resolution possible in this dimension**

Components of an Imaging Radar System

- The ***Synthetic Aperture*** Concept :
 - In the along track direction the motion of the platform relative to the landscape gives a Doppler change in the frequency of radiation used for illuminating the landscape
 - The signal processing methods are used to achieve very high spatial resolution in the azimuth direction by keeping track of the Doppler shift as the platform passes through the regions of interest

Components of an Imaging Radar System

- **We can use the radar data meaningfully by understanding the distortion (geometrical/signal noise) introduced into the recorded imagery**
- **The incident radiation scattered from the landscape should be understood since the backscatter energy contains about the properties of the part of the earth surface being imaged**
- **We need to understand the scattering properties of Earth surface materials and also be able to model them which is an important step in radar image interpretation**

Components of an Imaging Radar System

- The Earth's surface will respond differently for different **polarizations** and wavelength of the incident energy and also for the different angle of incidence
 - The polarization characteristic of the EM wave adds a new complexity to the radar imagery
- A distinct feature of radar images is that they have an overlying **speckled** appearance as a result of interference of the energy reflected from the many elemental scatterers that occur within a resolution cell (pixel)
- **Interferometric** techniques can be developed because of the pure (or coherent) nature of the energy used in Microwave imaging