

## Nature of Electromagnetic Radiation

## Electromagnetic radiation (EMR)

- Velocity:  $3 \times 10^8 \text{ m s}^{-1}$ 
  - Energy comes from the source, directly through free space, or indirectly by reflection & reradiation to the remote sensor
- Useful force field for remote sensing
- Changes in amount & properties of EMR become a valuable source of data for interpreting important properties of features
- Understanding fundamental properties - foundation

## Wave properties

- Many remote sensing techniques use wave motion for detecting & identifying distant objects
  - Seismographs – seismic waves in earth's crust
  - Microphones, human hearing – use sound waves in air
  - Sonar – use sound waves in water
  - Electromagnetic sensors – use EM waves

## Maxwell's formulation

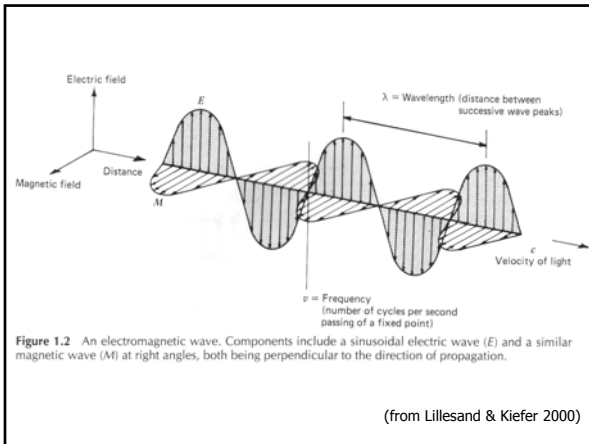
- *EMR is a dynamic form of energy made manifest only by its interaction with matter.*
- James Clerk Maxwell, British physicist
  - Mathematical formulation – explained experimental results, logical basis for predicting the possible existence of dynamic form of electric & magnetic phenomena (EMR in form of wave motion)
  - No limitations on possible frequencies, wavelengths or amplitudes

## Force field

- Maxwell's formulation & our modern theory – based on concept of force field
  - Example: compass needle held near magnetized piece of iron
  - Nonmaterial cause of force – force field
  - Similar cause of force on electric charges

## Concept of EMR

- Mathematically smooth wave motion exists in magnetic & electric force fields
- Maxwell formulated a set of differential equations expressing interrelationship of electric & magnetic fields
  - Time rate of change of electric field, a magnetic field appears automatically in that same region as a conjugal partner
  - Similarly, a time rate of change of magnetic field, an electric field appears



- ## Concept of EMR
- Dynamic fields occur together as inseparable partners
    - Neither purely electric or purely magnetic radiated waves will occur separately
    - When EM waves are intercepted by matter – result depends upon both the magnetic and electric properties of the matter

- ## Radiant flux density
- Flux – time-rate with which radiation passes a spatial position
    - Radiant flux density of radiated waves is proportional to the squares of wave amplitudes
  - Waves propagate through empty space at a fixed velocity,  $c$ ,  $\sim 3 \times 10^8 \text{ m s}^{-1}$

- ## Velocity of propagation
- When waves propagate through material, velocity of propagation depends upon material properties & the frequency of the wave
  - Velocity of propagation,  $v$ , the wavelength,  $\lambda$ , and wave frequency,  $\nu$ , is:  $v = \lambda \nu$

- ## Velocity of propagation
- Frequency does not change when waves penetrate matter, therefore, the wavelength must change as the velocity of propagation changes
    - Visible light propagates through glass with a velocity,  $v$  approximately  $c/1.5$ 
      - Wavelength of the wave in the glass is shorter than in free space by a factor of 1.5
      - Factor called index of refraction -  $n$

- ## Principle of superposition of wave motion
- Wave motion produced in a region where 2 separate waves cross each other has an amplitude that is the sum of the amplitudes of the 2 separate waves
  - For waves in force fields, the amplitude is a sum of forces
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## Principle of superposition of wave motion

- Foundation for analysis of very complicated wave motions by superposition of many simple and more easily understood waves (sinusoidal or simple harmonic waves)
- Jean Baptiste Fourier, French mathematician, showed any complicated wave form could be constructed by superposition of an infinite number of these sinusoidal waves as components, if the sinusoidal waves had the proper amplitudes, frequencies, and phases (starting times)



## Principle of superposition of wave motion

- Particular wave impinges upon a material – amplitude of wave changes in time in some complicated fashion
- Get a graph showing how amplitude changes in time
- Fourier's analysis can be used to determine from the graph the required amplitudes, frequencies & phases of sinusoids that would exactly match the graph of the amplitude



## Principle of superposition of wave motion

- Complicated wave forms are actually composed of superposed sinusoids
- These sinusoids are called the *spectral components* of the wave
- Material properties that specify the response of the material to sinusoidal component waves at every frequency (or wavelength) are called *spectral properties*



## Principle of superposition of wave motion

- Purpose of spectrographic apparatus is to measure the amount of radiant flux carried by each of the sinusoidal components of any wave form
- In remote sensing, mathematical analysis of wave forms is rarely performed by numerical calculations from graphs – make indirect measurements with spectrographic devices



## Diffraction

- If EM waves impinge upon a finite material obstacle through which the wave cannot penetrate, part of the wave passes by the side of the obstacle
- Passing part of wave enters the region beyond the obstacle, some flux near the side of the obstacle changes direction & propagates into the shadow region behind the obstacle
- This change of direction of some of the flux due to propagation of a wave past an opaque edge is called *diffraction*



## Diffraction

- Similar to water surface wave approaching the end of a breakwater
- EM waves diffract around the edge of obstacles
- Direction & amount of EM flux forms the communications link between objects of interest and the sensor
- Quantity, quality & direction of flux arriving at sensor contains the evidence of the presence of distant objects



## Diffraction

- Diffraction of EM flux must always occur wherever a wave is cut or sliced-off by a sensor aperture
- Diffraction effects will always form one of the fundamental limiting factors in the measurement of flux direction & quality