EGM703 – Advanced Active and Passive Remote Sensing

Week 3, Part 1: Principles of Microwave Remote Sensing

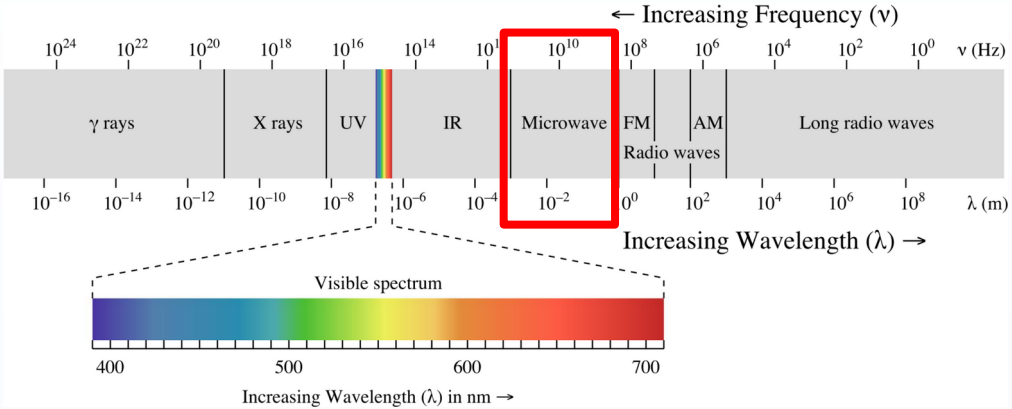
Week 3 Outline

1. Principles of Microwave Remote Sensing
2. Atmospheric and Surface Interaction
3. Principles of Radar Remote Sensing
4. Synthetic Aperture Radar (SAR)

   S1: Complex Numbers

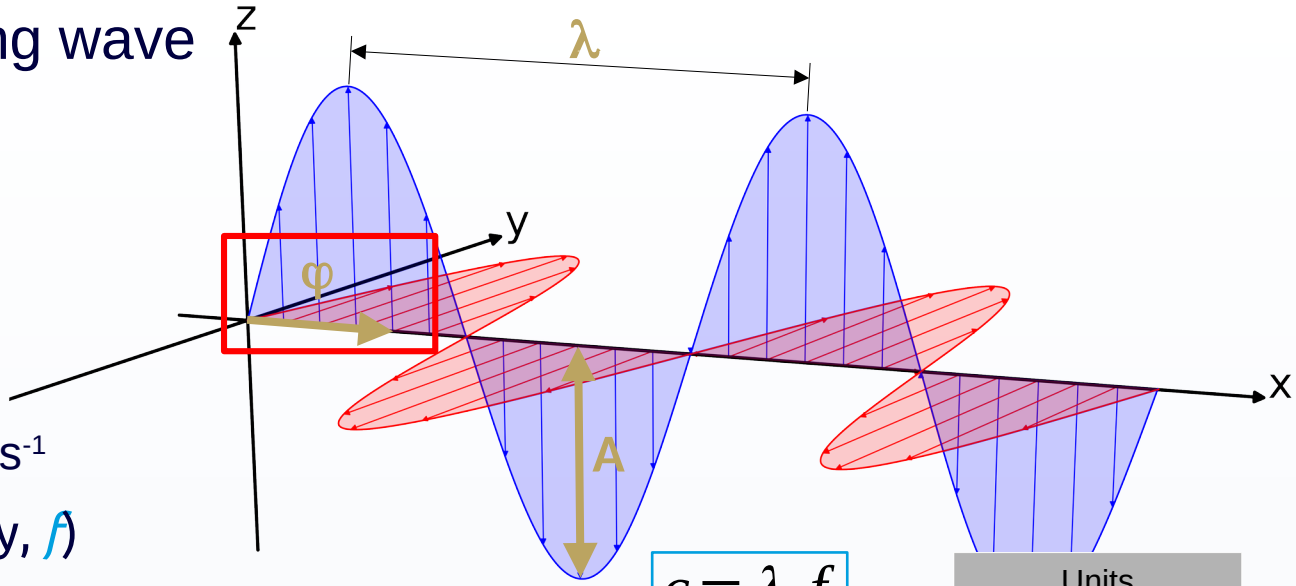
The microwave spectrum

- Up until now, we've mostly focused on visible and infrared wavelengths
- Microwave remote sensing:
  - λ: 1 mm – 1 m
  - *f*: 300 GHz – 300 MHz
- Similar to visible, infrared, often divided into smaller bands/regions



Recap: The Wave Model

- EMR is a self-propagating wave
  - Electric (E) component
  - Magnetic (B) component
- Waves have properties:
  - Speed (often *c*)
    - For light, $c_0 \approx 3 \times 10^8$ m s^{-1}
  - Wavelength, λ (frequency, *f*)
  - Phase, φ
  - Amplitude, A

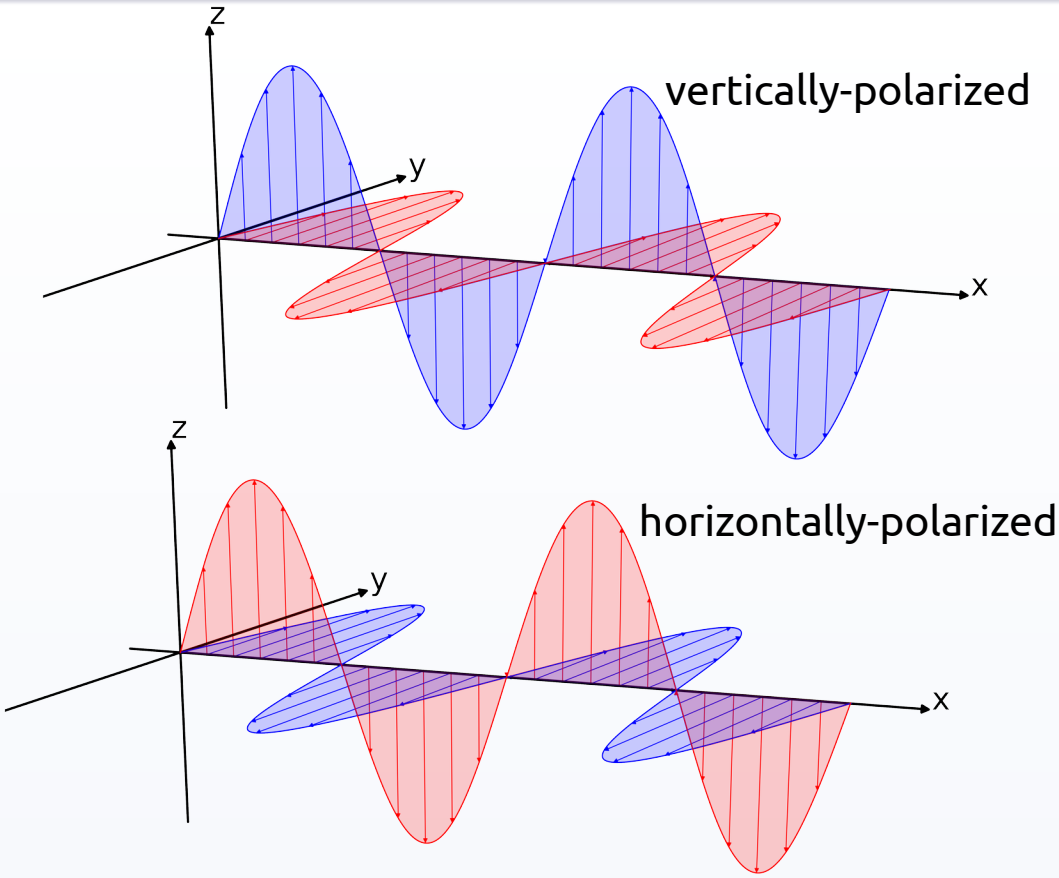


$$c = \lambda \cdot f$$

Units	
c	m s^{-1}
λ	m
f	s^{-1} (Hz)
φ	rad

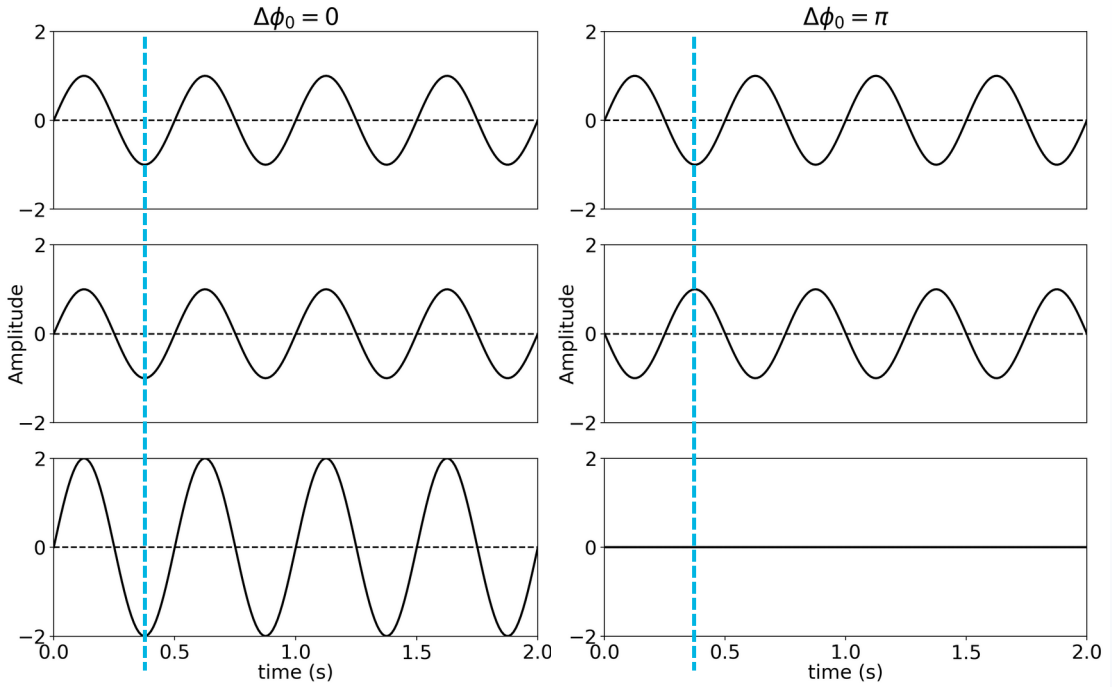
Polarization

- Light is a transverse wave
  - Oscillation perpendicular to direction of travel
- Polarization: the orientation of the wave
  - Normally defined using E (electric component)
  - Used frequently in microwave/radar remote sensing
- Can use as a filter (ex.: polarized sunglasses)



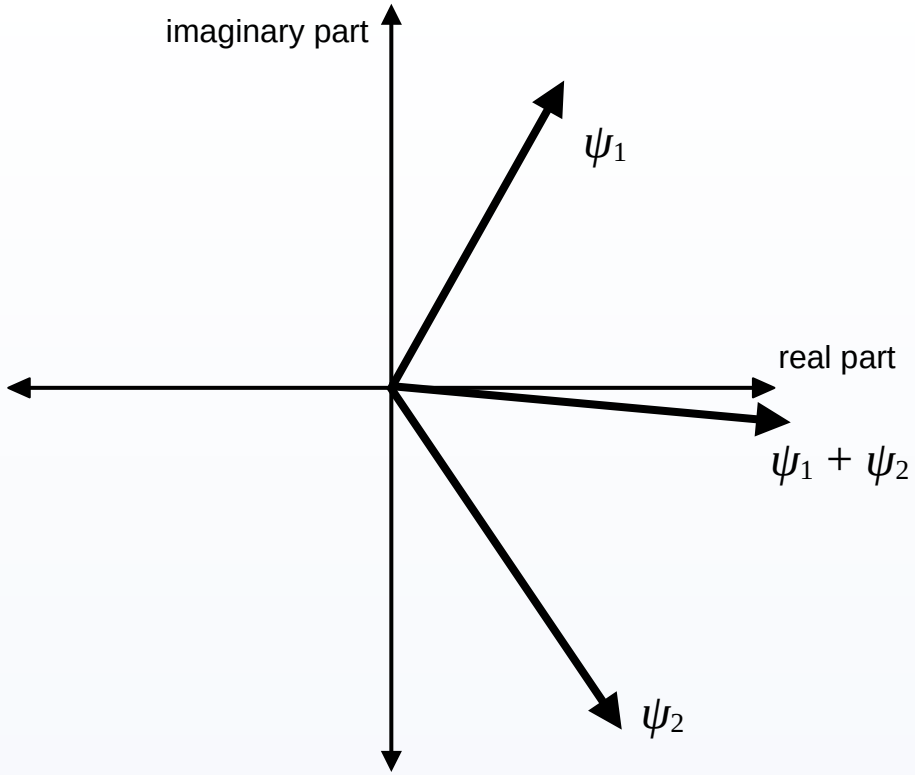
Superposition of waves

- We can combine waves (superposition/interference)
  - e.g.: $\psi = \psi_1 + \psi_2$
- Given that A, f, φ_0, are often different, result is not obvious
- In general:
  - If phase shift isn't an odd multiple of π: constructive interference (example: phase shift of 0)
  - If phase shift is an odd multiple of π: destructive interference (example: phase shift of π)



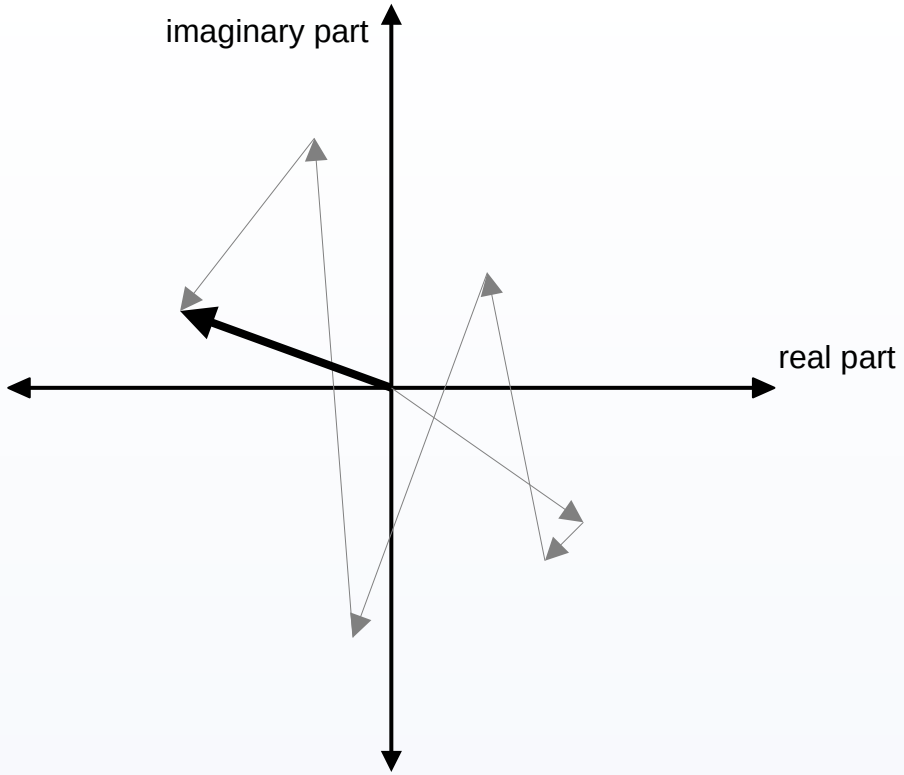
Superposition

- Electromagnetic waves can be expressed as complex numbers
  - Recall: complex numbers/signals are vectors (see Week 3 Supplement!)
- So, combination of waves becomes vector addition



Coherence

- If phase differences are constant over time: coherent
  - Angular frequencies are the same
  - We can treat them as stationary vectors
- Coherence is like a measure of predictability
  - High coherence → phase difference is constant → can predict by adding vectors
  - Low coherence → changing phase difference → less predictable (time-dependent)
- Can measure coherence using, e.g., cross-correlation
  - Normally over a small window around a pixel



Summary

- Electromagnetic radiation is a self-propagating wave*
- Waves can combine (interfere)
- We like it when the phase difference between waves is constant over time (coherent)

Additional resources

- Lillesand, Kiefer & Chipman – Chapter 6.6
- Understanding Maxwell, his equations and magnetic theory [PhysicsHigh]
- Polarization of light, linear and circular [Khan Academy]
- GEOS657: Microwave Remote Sensing [F. Meyer, UAF]
- Schumann, 2020 [Frontiers in Rem. Sens.]