AGRON / E E / MTEOR 518: Microwave Remote Sensing

Dr. Brian K. Hornbuckle, Associate Professor
Departments of Agronomy, ECpE, and GeAT
bkh@iastate.edu
What is remote sensing?
Remote sensing: the acquisition of information about an object or surface (target) without being in physical contact with it.

Remote sensing acquires information by detecting and measuring changes that the target imposes on the surrounding field, be it an electromagnetic, acoustic, or potential (gravity, magnetic) field.

Microwave remote sensing: microwave radiation emitted or scattered by the target is used to infer the target properties.
What are microwaves?
the electromagnetic spectrum

wavelength, m

1 pm 1 nm 1 um 1 mm 1 m 1 km 1 Mm

10^-12 10^-9 10^-6 10^-3 1 10^3 10^6

1 Hz 1 PHz 1 THz 1 GHz 1 MHz 1 kHz 1 Hz

10^18 10^15 10^12 10^9 10^6 10^3 1
Microwaves have wavelengths from mm to m and frequencies from 100's MHz to 100's GHz.

Wavelength – frequency relationship:

\[ c = \lambda \times f \]

\[ c = \text{speed of light in a vacuum} = 3 \times 10^8 \, \text{m s}^{-1} \]

\[ \lambda = \text{wavelength, } [\lambda] = \text{m} \]

\[ f = \text{frequency, } [f] = \text{Hz} = \text{s}^{-1} \]
Why microwaves?
How does a microwave oven heat food?
How does a microwave oven heat food?

By shaking up at the same time all the water molecules in the food.

The agitation of the water molecules is heating. In an ordinary oven, only the molecules on the surface of the food are agitated; these then go on to shake up the others. In the microwave oven, all the water molecules are agitated at the same time.
The electrical properties of most natural materials do not vary greatly at infrared (IR) wavelengths (which is good for some remote sensing applications!).

Visible remote sensing depends on illumination by the sun, so it can not be used at night.

At microwave wavelengths

**liquid water has distinctive electrical properties.**

Water vapor and some other gases also have electrical properties that have unique characteristics in the microwave region.
Microwaves can penetrate through clouds, and to some extent, precipitation.

Microwaves penetrate (originate) into (from) the target so that the properties within the target can be inferred.

For example, microwaves can reveal the inner physical structure and water content.
Water has unique electrical properties at microwave frequencies.

Plot of soil dielectric constant versus soil volumetric water content.
Water has unique electrical properties at microwave frequencies.

Plot of absorption of radiation by water vapor versus the frequency of the radiation.

Figure 8-6. Absorption spectrum of water vapor at two pressures: 1 bar and 0.1 bar, at temperature 273°K and for a water vapor density of 1 g/m³ (Chahine et al., 1983).
passive microwave remote sensing?
(also called “radiometry”)

active microwave remote sensing?
(also called “radar”)

Active or radar remote sensing:
an electromagnetic wave is launched at the target and the radiation scattered by the target is analyzed in order to obtain information about the target (what it is and where it is).

RADAR = radio detection and ranging.

Passive remote sensing:
the radiation naturally emitted by the target is used to obtain information about the target.

target = what you are looking at, what you want to observe

Radiation is characterized by its magnitude (power), phase, polarization, and frequency content.
Different microwave frequencies (or wavelengths) reveal different aspects (or properties) of the target.
Why use microwave remote sensing?
the water (hydrologic) cycle

The terrestrial water balance does not include Antarctica.
meteorology?

agronomy?

electrical engineering?
Example microwave remote sensing satellite:

Soil Moisture and Ocean Salinity (SMOS)

European Space Agency

Launched November 1, 2009.
Low Earth Orbit (LEO) altitude of 758 km and inclination of 98.44°, Sun-synchronous, quasi-circular, dusk-dawn, 23-day repeat cycle, 3-day sub-cycle allows SMOS to view every meter of Earth's surface at least once every 2 to 3 days.
a “swath” of SMOS observations (Google “Iowa SMOS data”)
The basic physics...

This is an example of what you will learn in 518.
Why are you taking this course?

What do you want to learn in this course?

What can I do to help you succeed?
You should take 518 if you would like to...

learn about electromagnetics, a fundamental science.

obtain an appreciation for the uncertainties associated with remotely-sensed measurements.

see practical applications of theory.

improve your ability to solve quantitative problems.

improve/develop a conceptual understanding of calculus.

become aware of how remote sensing can be used to learn more about the earth system.
518 is NOT about this...
What geophysical process produced this remote sensing signal?
You should NOT take 518 if you...

are only interested in making maps / downloading data.

are not familiar with vector calculus (e.g., MATH 265).

do not have a good background in physical science.

have never written a computer program that includes IF statements, FOR loops, etc.

cannot devote a significant amount of time to the class.

are not willing to actively participate in class meetings.

cannot complete assignments on time.
During a typical class I will...

- write on the board.
- ask questions frequently (individually, to all students).
- hand out additional material.

During a typical class you should...

- take notes (suggest on loose-leaf paper).
- write on hand-outs, keep in binder with notes.
- be ready to think and communicate.

After class reconcile your notes with my notes on the web.
Assignment: read the syllabus; Problem Set 1.

MATLAB introduction: ...

First half of course: weekly homework assigned on Tuesdays and due at the beginning of class the following Tuesday.

Second half of course: longer homework “case studies” due approximately every-other week.

Case studies: remote sensing of atmospheric temperature and water vapor; precipitation; sea surface salinity; soil and vegetation water content.

Semester project: lab using a microwave radiometer.
Makeup class...

Midterm exam...