Handout # 2

EE355 / GP 355

Imaging Radar and Applications

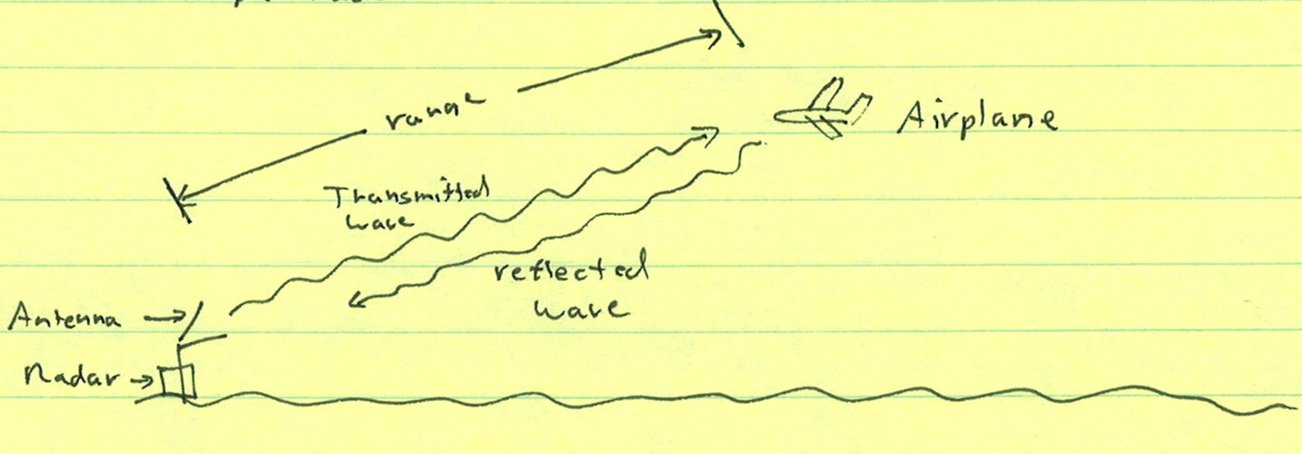
For an overview of imaging radar and remote sensing, read chapter 1 in the textbook.

What is a radar?

Radar, an acronym for "radio detection and ranging", is an instrument whose fundamental measurement is the distance from a sensing antenna to an object, hence the term ranging in the definition. While initially developed to allow military reconnaissance of aircraft in flight, radar has evolved to include any microwave active sensing system.

In this class we will be mostly concerned with imaging radars, those that are able to distinguish objects at such fine detail that they can produce "images" of terrain or the sky. We will often interchange the terms imaging radar and synthetic aperture radar or SAR, the latter being a common technique to achieve fine resolution in the along-track, or azimuth, direction.

A simple radar:



Suppose the radar transmits a pulse at time 0, which propagates a distance r (for <u>range</u>) to the airplane, and, upon reflection, back to the radar. The total distance traveled is thus 2r. Since the speed of light is c, the time τ required for the round-trip "echo" is

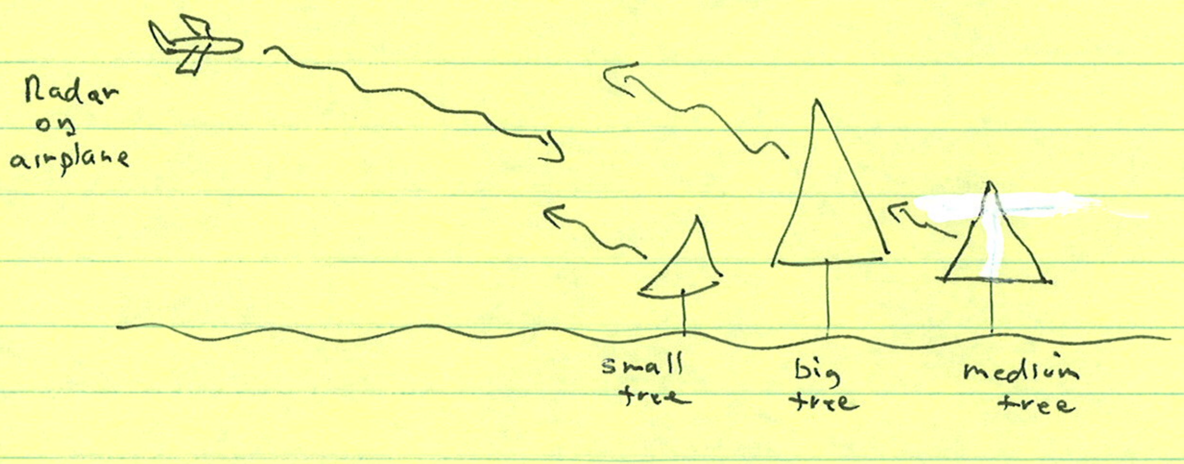
$$\tau = \frac{2r}{c}$$

Conversely, if we measure a time τ for an echo to be received, we can compute the distance to the object as

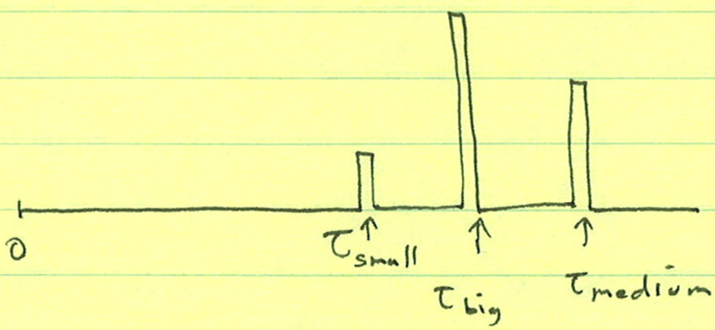
$$\boxed{r = \frac{c\tau}{2}}$$

← you probably want to memorize this.

Next, consider the geometry obtained by transposing the radar and scatterer, and put several scatterers on the ground:



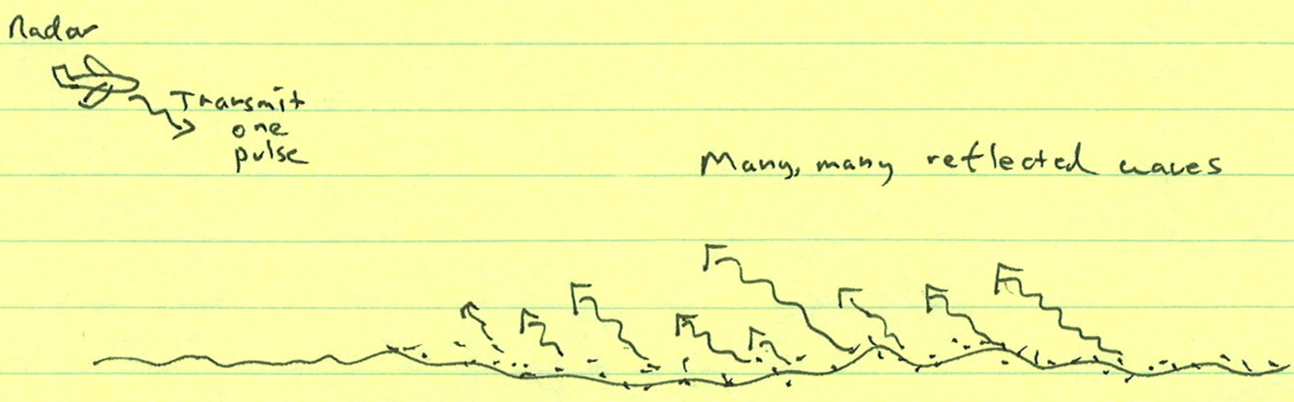
The radar illuminates all three trees, hence echoes are received from all three. Since the trees are at different distances, though, the echoes are received at different times. We can plot the echo power vs. time:



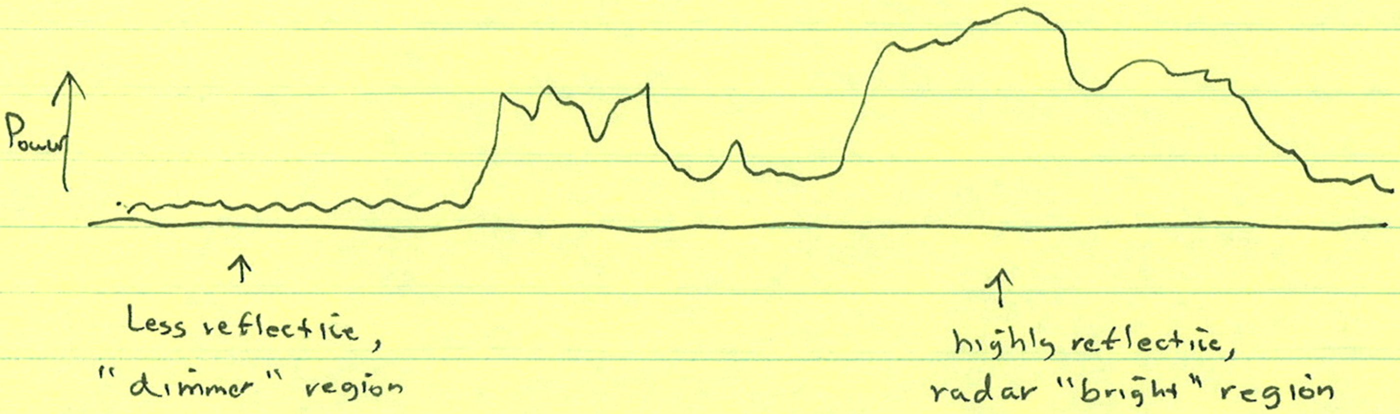
Note also that each tree reflects an echo whose intensity is related to its size. Given this composite echo signal we can determine not only the range to each tree, but can estimate it's size if we have a good model for how echo intensity relates to tree size and shape.

Now, consider the limiting case when we have many small, closely spaced scatterers of various size, shape, and hence reflectivity on the surface. Here we receive a continuous distribution of echo power.

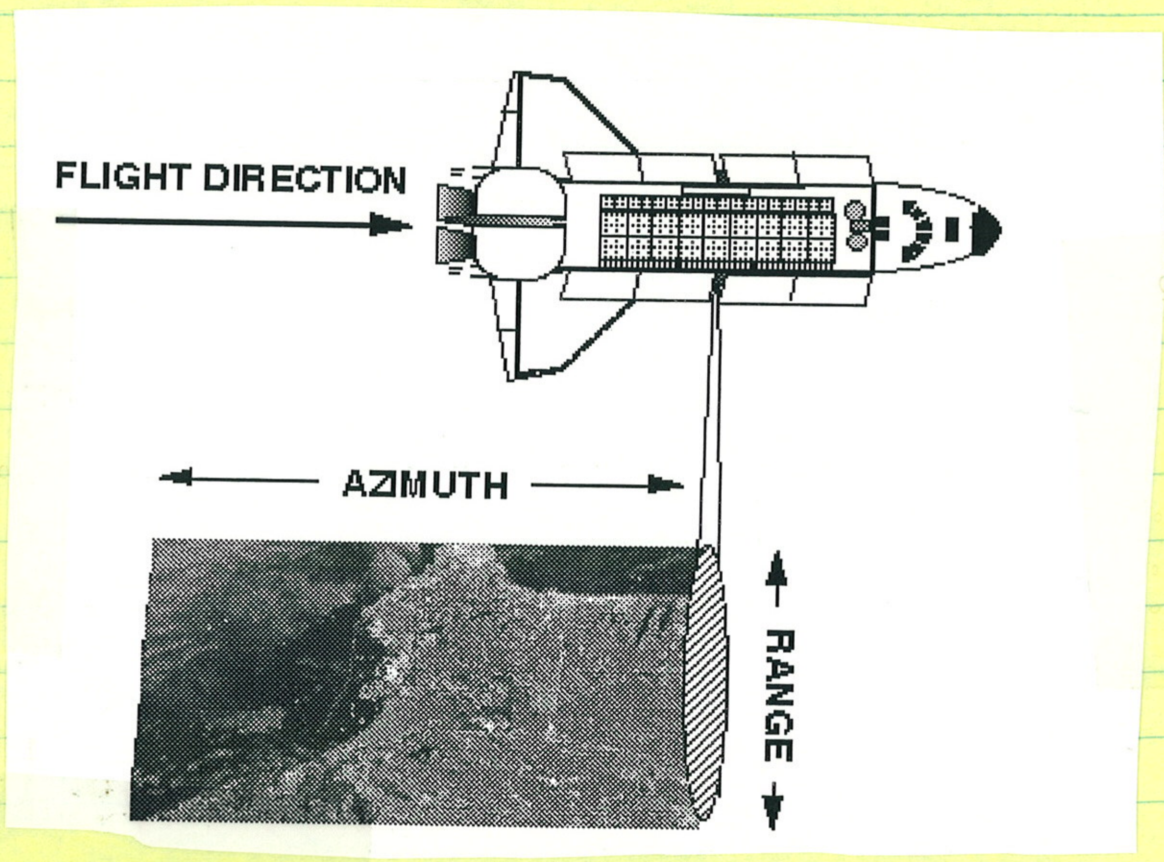
Physical scattering problem:



Resulting echo intensity vs. time:



Finally, imagine a series of lines from a series of pulses acquired as the radar travels along on its platform:

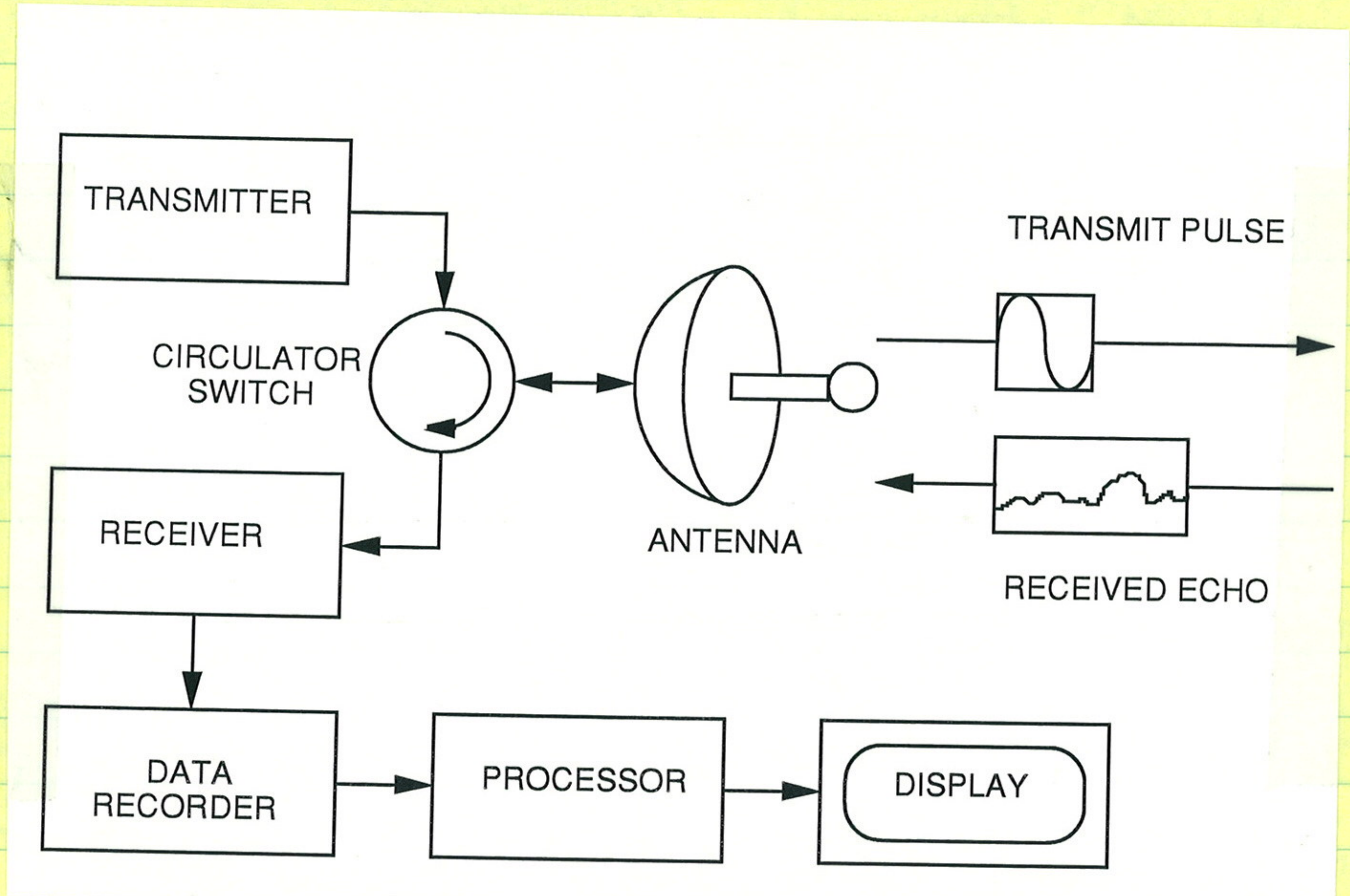


The succession of lines builds up an image of the surface, where brightness in the image corresponds to higher radar reflectivity. Note also the identification of the terms range and azimuth for across-track and along-track directions, respectively.

How we generate such pictures at very fine resolution in both directions (and sometimes a third, in the vertical direction), is the focus (sic) of this class.

Radar Block Diagram

The basic radar instrument can be depicted as:



The function of each of these blocks should be self-evident.

Radar in remote sensing

Radar is used in remote sensing for several reasons:

1) It penetrates both the atmosphere and clouds easily
2) It gives sensitivity to objects cm to m in size
3) Its geometric resolution is independent of wavelength and little dependent on sensor geometry
4) It measures distances precisely, permitting 3-D high-resolution reconstructions

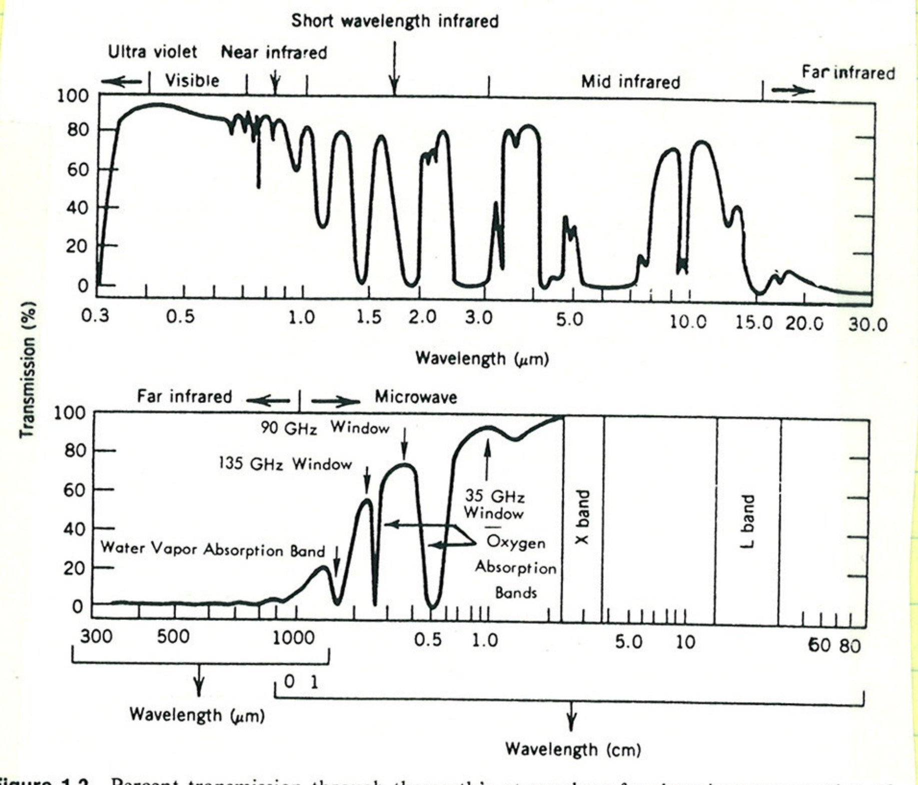


Figure 1.2 Percent transmission through the earth's atmosphere for the microwave portion of the electromagnetic spectrum.

The radio portion of the spectrum is itself divided into a number of sub-bands:

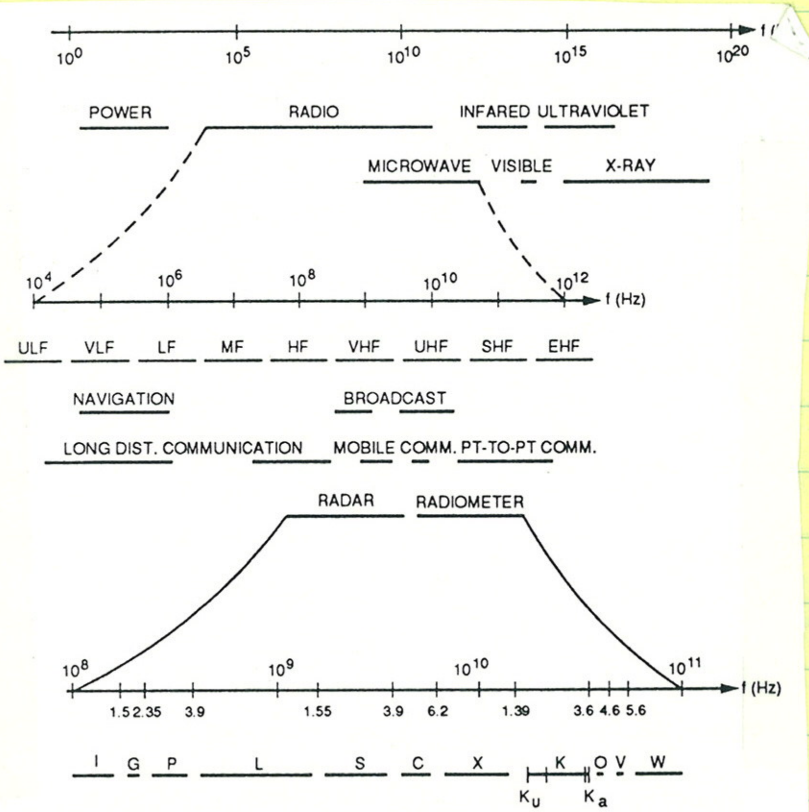


Figure 1.4 Definition of various regions of the electromagnetic spectrum.

Since waves interact most strongly with scattering objects with sizes on the order of their wavelengths, multiple wavelength radars can probe several aspects of a surface at once. This is particulary useful for surface roughness measurement or vegetation canopy characterization.

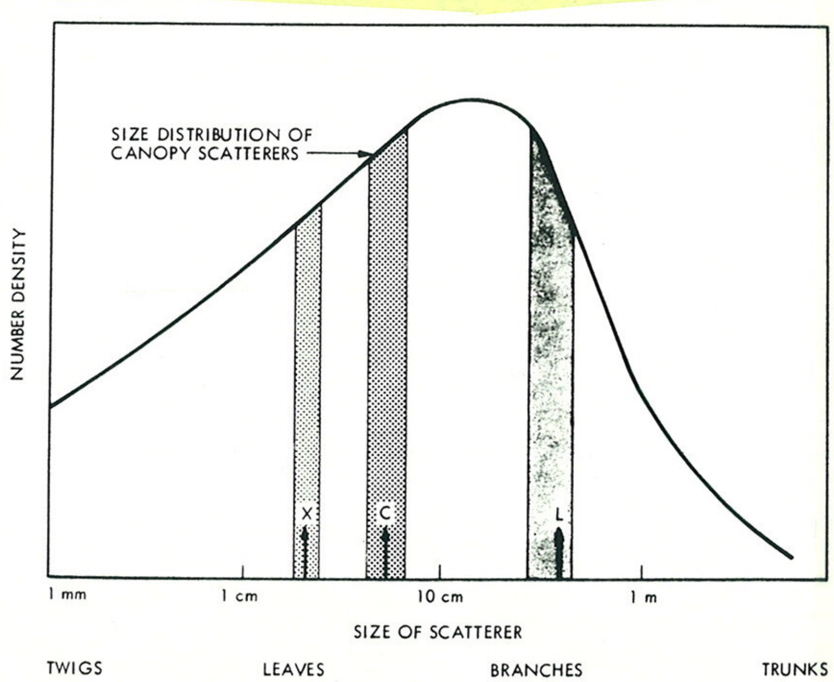
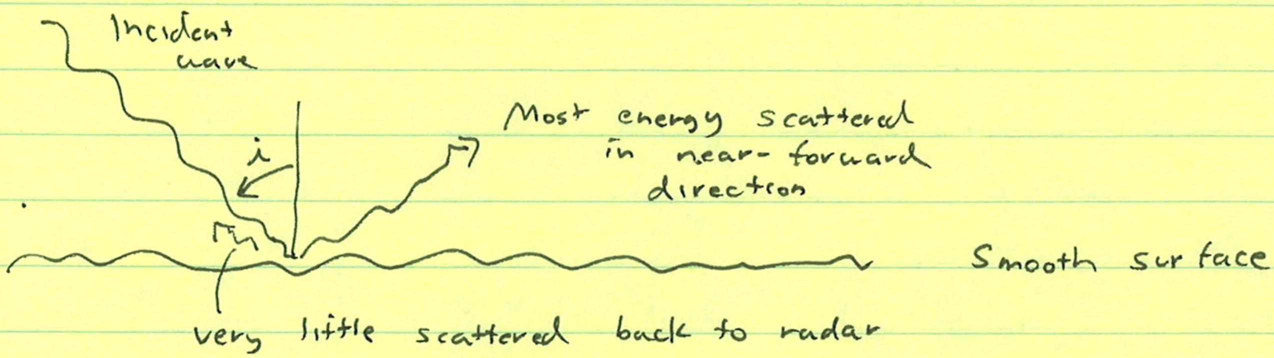
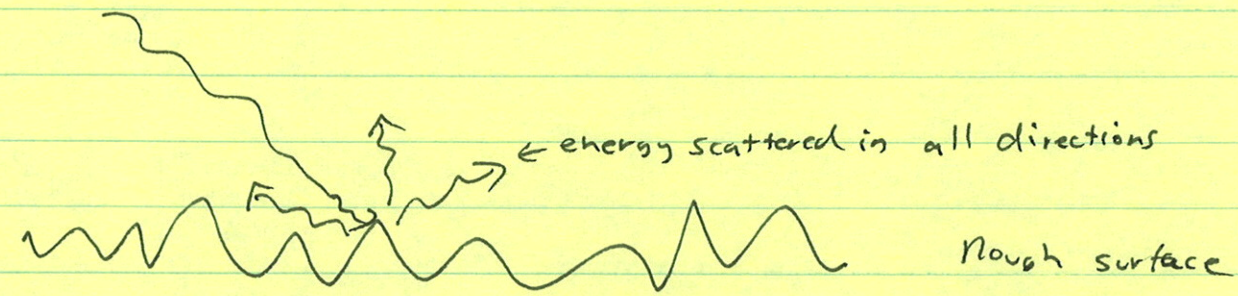


Figure 1.28 Model response of forest canopy to various wavelengths based on number and distribution of scatterers (Carver et al., 1987).

The brightness also depends greatly on the angle of incidence i and the surface roughness. Rough surfaces diffuse energy more isotropically than smooth surfaces, and most surfaces are brightest at near-normal incidence.





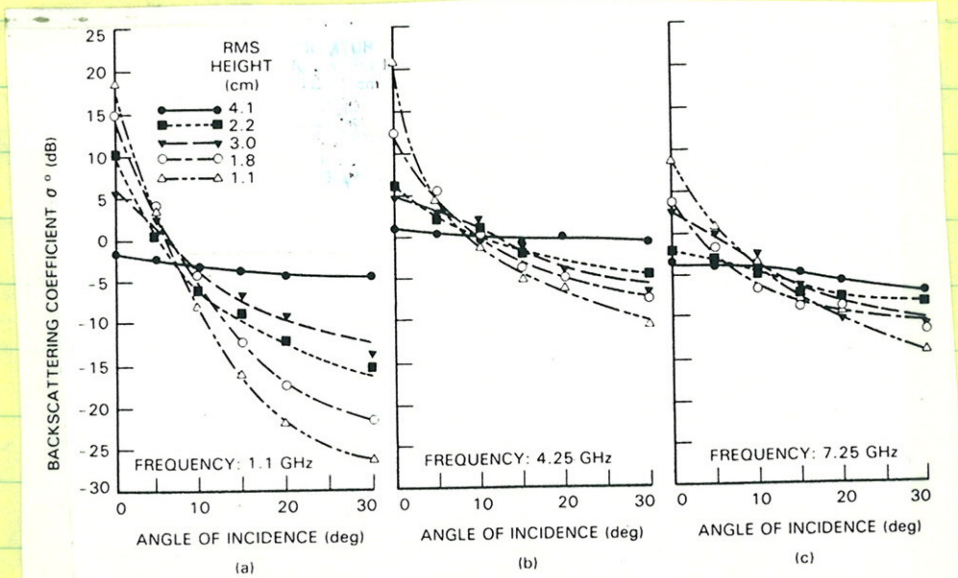


Figure 1.3 Normalized backscatter coefficient as a function of surface roughness for three radar frequencies (Ulaby et al., 1986).

Finally, the brightness depends on composition through the dielectric constant of the scattering medium. We'll deal with all of these effects in greater detail when we discuss applications of radar in the second half of the class.

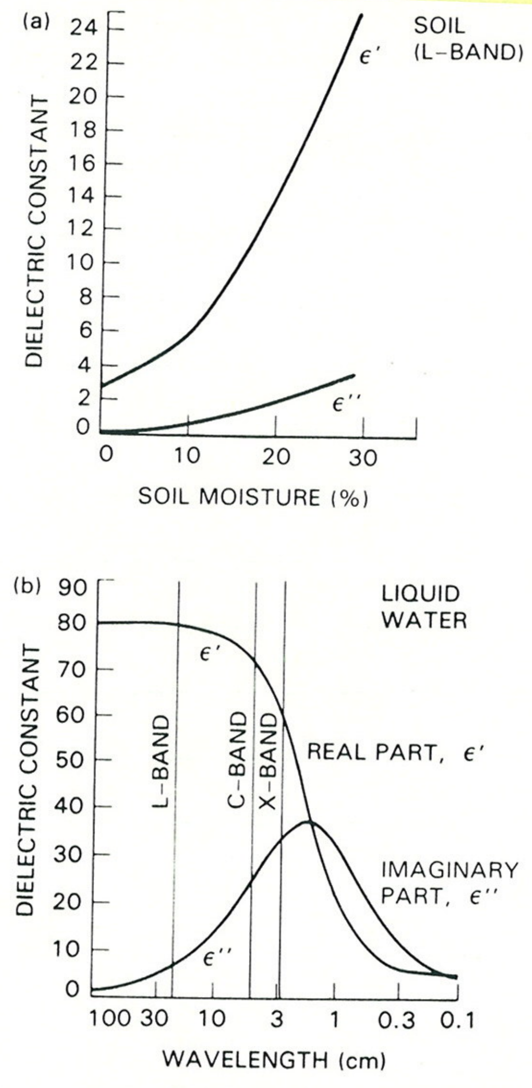


Figure 1.34 Dependence of complex dielectric constant on: (a) Soil moisture at L-band; and (b) Radar wavelength (Ulaby et al., 1982).