1. Model a bare soil as a homogeneous halfspace with a uniform temperature of 300 K.

(a) Plot the horizontally polarized and vertically polarized brightness temperature of the soil at 1.4 GHz as a function of incidence angle for a dry soil ($\theta_v = 0.10$ m$^3$ m$^{-3}$), a moist soil ($\theta_v = 0.25$ m$^3$ m$^{-3}$), and a wet soil ($\theta_v = 0.40$ m$^3$ m$^{-3}$). Use the function `ersoilr8.m` to compute soil relative permittivity and the function `trb.m` to compute soil reflectivity. Vary incidence angle from 0$^\circ$ to 90$^\circ$.

(b) How does the brightness temperature vary with soil water content?

(c) Over what range of incidence angles (approximately) is the horizontally polarized brightness temperature most sensitive to soil water content?

(d) Over what range of incidence angles (approximately) should the vertically polarized brightness temperature not be used to measure soil water content?

(e) How does the Brewster angle change with soil water content?

(f) Describe a procedure for determining the physical temperature of a soil with a 1.4 GHz radiometer.

2. Model a bare soil as a homogeneous halfspace with a uniform temperature of 300 K.

(a) Assume the soil surface is smooth (quasi–specular). Find the sensitivity of the 1.4 GHz horizontally polarized brightness temperature to soil water content at an incidence angle of 30$^\circ$ over the range of realistic soil water content (0.00 m$^3$ m$^{-3}$ to 0.40 m$^3$ m$^{-3}$). Use the `polyfit` function in matlab with $n = 1$ (linear fit). Report the sensitivity in units of K per 0.01 m$^3$ m$^{-3}$.

(b) Assume the soil surface is slightly rough ($h = 0.3$). Find the sensitivity of the 1.4 GHz horizontally polarized brightness temperature to soil water content at an incidence angle of 30$^\circ$. Report the sensitivity in units of K per 0.01 m$^3$ m$^{-3}$.

(c) Assume the soil surface is rough ($h = 0.6$). Find the sensitivity of the 1.4 GHz horizontally polarized brightness temperature to soil water content at an incidence angle of 30$^\circ$. Report the sensitivity in units of K per 0.01 m$^3$ m$^{-3}$.

(d) What happens to the absolute value of the sensitivity of the 1.4 GHz horizontally polarized brightness temperature to soil water content as the soil surface becomes rough?
3. Model the 1.4 GHz brightness temperature of a grass canopy. Use $\omega = 0$ and $b = 0.15$. Assume that the soil surface beneath the canopy is quasi-specular, the soil can be approximated as a uniform halfspace of physical temperature 300 K, its moisture content is 0.30 m$^3$ m$^{-3}$, and that the temperature of the canopy is also 300 K.

(a) Plot the horizontally polarized and vertically polarized brightness temperature as a function of incidence angle from 0$^\circ$ to 60$^\circ$ for three different vegetation water column densities: 1 kg m$^{-2}$; 2 kg m$^{-2}$; and 4 kg m$^{-2}$.

i. How does the horizontally-polarized brightness temperature change with incidence angle for a low vegetation water column density compared to higher vegetation water column densities?

ii. Does the same thing happen for the vertically polarized brightness temperature? Why or why not?

(b) Find the sensitivity of horizontally polarized brightness temperature to soil water content at an incidence angle of 30$^\circ$ when the soil (quasi-specular surface) is covered by a vegetation canopy with water column density of 1 kg m$^{-2}$. Compare this to the sensitivity of horizontally polarized brightness temperature of a bare soil (Problem 2a).

(c) Find the sensitivity of horizontally polarized brightness temperature to soil water content at an incidence angle of 30$^\circ$ when the soil (quasi-specular surface) is covered by a vegetation canopy of water column density 3 kg m$^{-2}$. What happens to the absolute value of the sensitivity to soil water content as the water column density of the vegetation canopy gets larger?

(d) Find the sensitivities of horizontally polarized brightness temperature to soil water content at an incidence angle of 30$^\circ$ when the soil (quasi-specular surface) is covered by vegetation canopies of water column densities 1 kg m$^{-2}$ and 3 kg m$^{-2}$ at a frequency of 10 GHz. Use $b = 0.35$. What happens to the absolute value of the sensitivity to soil water content in the presence of vegetation at higher frequencies?


(a) How can both the water vapor content and liquid water content of the atmosphere be measured with microwave radiometry?

(b) The brightness temperature of the atmosphere depends in general on both the temperature and moisture content of the atmosphere. How can the temperature of the atmosphere be measured separately from the moisture content?

(c) According to Figure 2.11, what frequency would be best for measuring sea surface temperature (SST)?

(d) According to Figure 2.11, what frequency would be best for measuring vegetation biomass?

(e) In Table 2.1, what two geophysical measurements are the most susceptible to radio frequency interference (RFI)?

(f) What is the only proposed future mission in Table 2.2 that will likely experience minimal RFI?

(g) Besides cost, what is another advantage of using ground-based radiometry instead of radiosondes to observe the atmosphere?

(h) Is strong RFI more problematic than low-level RFI? Discuss.