SPCE_5400 - Homework #1

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Submission date: 2025.09.28

Problem 1: for a LEO satellite emitting a signal at 2.5GHz at 1,000 km altitude, directly overhead of the ground station, what is the free space loss [Ls] in dB. See equation 1.13 in textbook, then convert to dB units.

$$\text{eq. 1.13}: L_s = \left(\frac{4\pi}{\lambda}\right)^2 = s\left(\frac{4\pi d f}{c}\right)^2$$

λ = wave length = c/f
d = distance = 1000 km
f = frequency = 2.5 GHz
c = speed of light = 2.998×10^8 m/s

$$dB = 10 \log_{10}(\text{ratio})$$

$$dB = 10\log_{10}\left(\frac{4\pi d f}{c}\right)^2 \quad \text{log rule: } \log(a^b) = b\log(a)$$

$$\therefore\ dB = 20\log_{10}\left(\frac{4\pi d f}{c}\right)$$

$$= 20\log_{10} \frac{4\pi(1{,}000{,}000\,m)(2.5\times 10^9\,Hz)}{2.9979\times 10^8\,m/s}$$

$$\boxed{\text{Free space loss } (L_s) = 160.407\ dB}$$

Problem 2: Section 2.1 of the text describes an empirical model to estimate rain attenuation using equation 2.3 and table 2.1 constants aligning to frequency in GHz and polarization (vertical or horizontal). Based on that method estimate the specific rain attenuation (units dB/km) for a signal at 2.5 GHz and vertical polarization during rain fall of R = 30 mm/h.

eq 2.1: $\gamma = aR^b$

- γ = rain specific attenuation
- a & b = constants based on f, polarization & average rain temp.
- $f = 2.5\,\text{GHz} = 2.5 \times 10^9\,\text{Hz}$
- $R = 30\,\text{mm/h}$
- polarization = vertical

table 2.1 shows a & b @ various f @ an avg temp of 20°C.

$\therefore a_v = 0.0001464$ & $b_v = 1.0085$

$$\gamma = .0001464(30)^{1.0085} = .0045208\ \text{dB/km}$$

$$\boxed{\gamma = 0.0045208\ \text{dB/km}}$$

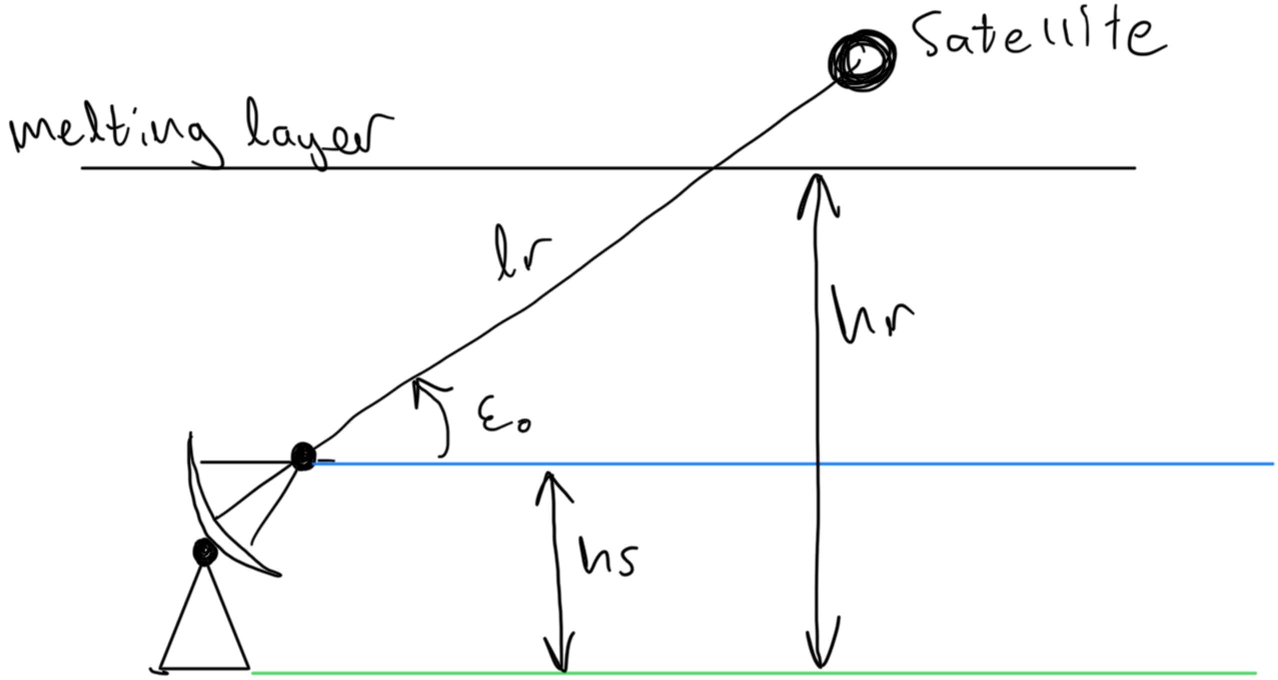
Problem 3: Using the same frequency of 2.5 GHz and vertical polarization, Find total rain attenuation (Ar) in units dB @ 15 deg of elevation. Assume location is Madrid.

- 1st I will try eq. 2.7 since $\varepsilon_o > 5°$. If $\varepsilon_o < 5°$ then eq. 2.8 $\gamma a R^b s l_r \rightarrow s$ = reduction factor.

$A_R = \gamma l_r$, where l_r = rain path length

$\gamma = aR^b$

$l_r = \frac{\Delta h}{\sin \varepsilon_o}$, $\Delta h = h_r - h_s$



- $\gamma = .0045208$ dB/km
- h_s (madrid) = 588 m
- h_r (madrid) = 3.695 km
- $\Delta h = 3.695 - .588 = 3.107$ km
- $l_r = \frac{3.107 \text{ km}}{\sin 15} = 12.0045$ km

$$A_R = .0045208\,dB/\cancel{km}\,(12.0045\,\cancel{km})$$

$$\Rightarrow \boxed{A_R = 0.05427\,dB}$$

Problem 4: Develop a software tool [spreadsheet, MATLAB, Python, etc] following the flowchart in figure 2.4 “Rain Attenuation Modeling”, with user inputs, functionally similar to that in figure 2.5. Show graph of results for various locations in table 2.5.

Development was done in a python Jupyter notebook for Problem 4. The file will be submitted along with this document. The file will also be stored at the following GitHub repository: https://github.com/majikthise911/spce_5400/blob/main/RainAttenuation/rain_attenuation_notebook.ipynb

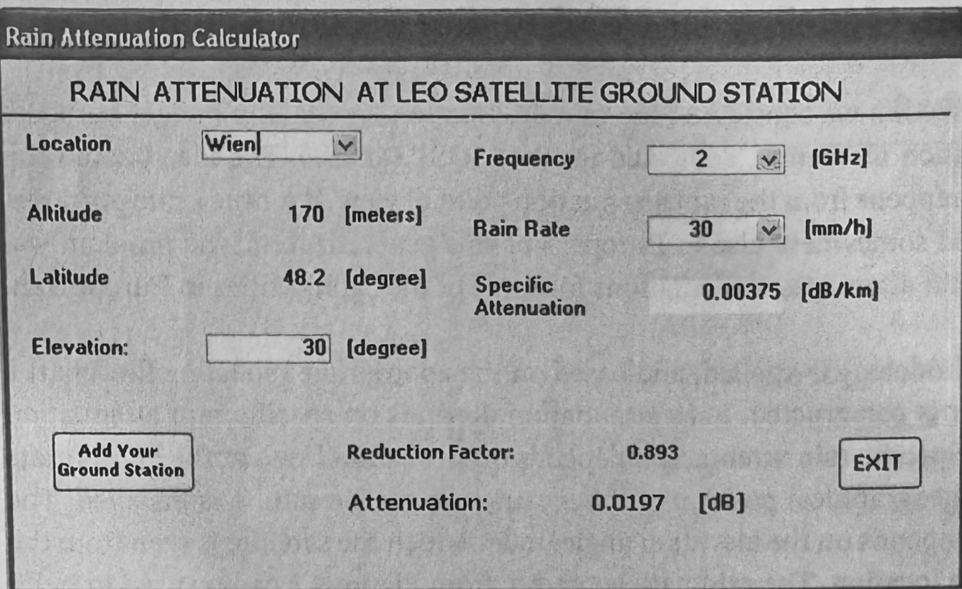
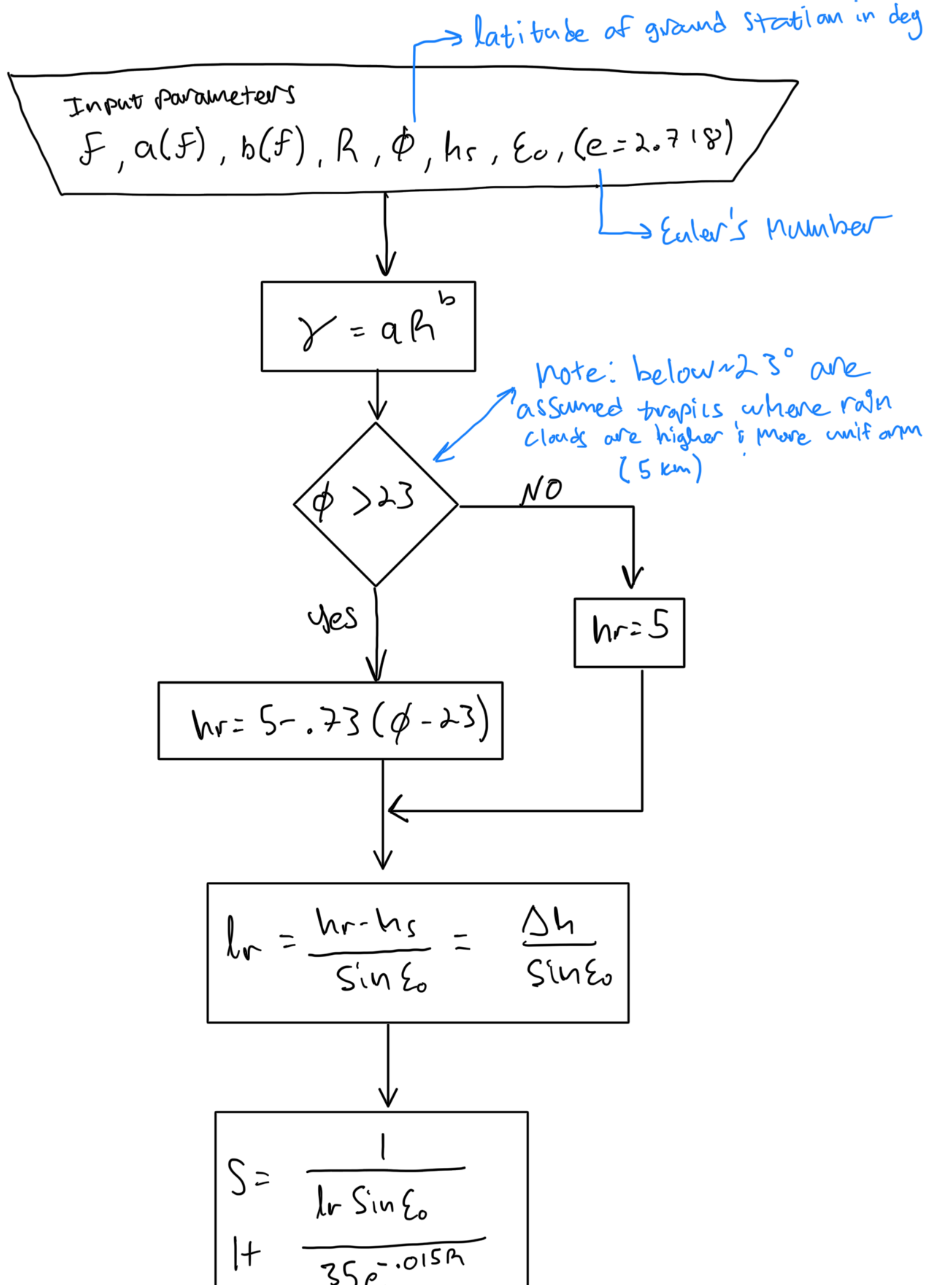


Figure 2.5 Rain attenuation calculator.

Table 2.5 Altitude and latitude of some European cities.

Location	Altitude (h_S) [m]	Latitude ϕ [°]	h_r [km]	$\Delta h = h_r - h_S$ [km]
Madrid	588	40.4	3.0.695	3.107
Tirana	104	41.3	3.625	3.521
Rome	14	41.9	3.582	3.568
Pristina	652	42.6	3.525	2.873
Zagreb	130	45.8	3.290	3.160
Vienna	193	48.2	3.113	2.920
Paris	34	48.8	3.060	3.026
Brussels	76	50.8	2.915	2.839
London	14	51.5	2.862	2.848
Berlin	34	52.5	2.786	2.752

Figure 2.4 Rain attenuation modeling flow chart.



$$A_R = \gamma S l_r$$

$$A_R$$