Chapter 5

Prob 5.1 Vertical column of Atmosphere $1 m^2$ in area is 1.034×10^4 kg in mass

$$M_{air} = A \int_0^\infty \rho_{air}(z)\, dz \qquad \text{where } A \text{ is } 1\ m^2$$

a) $\rho_{air}(z) = 1.225\, e^{-z/H_1}$ kg m^{-3} Eq. (5.2)

where $H_1 = 9.5$ km

$$M_{air} = 1.225 \int_0^\infty e^{-z/H_1}\, dz$$

$$= 1.225 \cdot H_1 \left[1 - 0\right] = 1.225 \cdot 9.5 \times 10^3$$

$$M_{air} = 1.164 \times 10^4 \text{ kg}$$

$$\text{percent error} = \left| \frac{1.034 - 1.164}{1.034} \times 100 \right| = 12.6\%$$

b) $\rho_{air}(z) = 1.225\, e^{-z/H_2}\left[1 + 0.3 \sin(z/H_2)\right]$ kg m^{-3}

Eq (5.3)

where $H_2 = 7.3$ km

$$M_{air} = 1.225 \left[\int_0^\infty e^{-z/H_2}\, dz + 0.3 \int_0^\infty e^{-z/H_2} \sin(z/H_2)\, dz \right]$$

$$= 1.225\, H_2 + 1.225 \times 0.3 \left[\frac{1/H_2}{1/H_2^2 + 1/H_2^2} \right]$$

$$= H_2 \cdot 1.225 \cdot (1 + 0.15) = 1.028 \times 10^4 \text{ kg}$$

percent error $= 0.6\%$

Prob. 6.1 (cont.)

$$F = 5.0119 + \frac{1.4125-1}{100} + \frac{1.4125(6.3096-1)}{100} + \frac{1.4125(3.9811-1)}{100 \times 3.9811}$$

$$F = 5.1016 = 7.08 \text{ dB}$$

AGAIN SINCE ALL COMPONENTS ARE AT THE SAME $T_{phys} = 290 K$

$$T_{eff} = (F-1)T_p = 1189.5 K$$

$\therefore$ by moving the RF AMPLIFIER CLOSER TO THE ANTENNA, A REDUCTION OF NEARLY 600K in EFFECTIVE SYSTEM TEMP. WAS ACHEIVED.

Prob. 6.2 System from Prob. 6.1(a) is connected to an antenna with a radiation efficiency, η_l, of 0.9 observing a scene with $T_A = 100$ K. Physical antenna temperature is 290 K

$$T_{sys} = \eta_l T_A + (1-\eta_l)T_p + \underbrace{(L-1)T_p + LT_{REC}}_{\text{Teff from Prob. 6.1 (a) found to be 1787.8 K}} \quad , \text{Eq.}(6.33)$$

Prob. 5.2 $\rho_v(z) = \rho_o e^{-z/H_4}$ g m^{-3} Eq. (5.7)

water-vapor density profile

$$M_v = \int_0^\infty \rho_v(z)\,dz = \rho_o H_4 \qquad \text{Eq (5.8)}$$

a) Mass contained within one scale height

$$M_{v_1} = \int_0^{H_4} \rho_v(z)\,dz = \rho_o\left[1 - e^{-1}\right] H_4$$

$$M_{v_1}/M_v = \frac{1-e^{-1}}{1} = 0.632 \text{ or } 63.2\%$$

is contained in one scale height

b) Mass contained within two scale heights

$$M_{v_2} = \int_0^{2H_4} \rho_v(z)\,dz = \rho_o H\left[1 - e^{-2}\right]$$

$$M_{v2}/M_v = 1 - e^{-2} = 0.865 \text{ or } 86.5\%$$

is contained in the first two scale heights

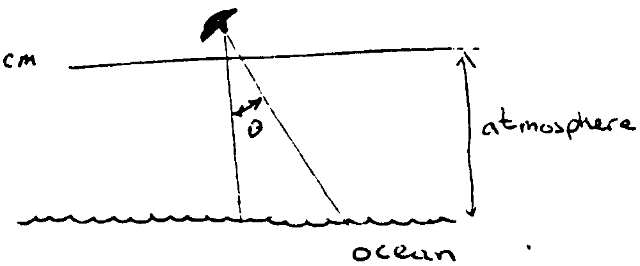
Prob. 5.10 $f = 35$ GHz, $\lambda_0 = 0.8571$ cm

$0^\circ \le \theta \le 70^\circ$

polarization: H

$T_{ocean} = 300$ K

$\epsilon_{ocean}(35 \text{ GHz}) = 20 - j30$



atmosphere: a) lossless

b) 2-km-thick cloud, $m_v = 1 \text{ g m}^{-3}$, $K_s = 0$

$T_{cloud} = 273$ K

c) 2-km-thick cloud with rain falling at 10 mm hr^{-1}, $T_{rain} = 280$ K

$$T_{AP}(\theta; H) = T_{AP}(\theta; 0)\, e^{-\tau(0,H)\sec\theta} + T_{up}(\theta; H)$$

$$T_{up}(\theta; H) = \sec\theta \int_0^H K_a(z')\, T(z')\, e^{-\tau(z';H)\sec\theta}\, dz'$$

$$\tau(z', H) = \int_{z'}^{H} K_e(z)\, dz$$

$$T_{AP}(\theta; 0) = T_B(\theta) + T_{sc}(\theta) \qquad \text{Eq. (4.103)}$$

where

$$T_{sc}(\theta) = \Gamma(\theta)\, T_{DN}(\theta)$$

$$T_B(\theta) = e(\theta)\, T_0$$

where

$$e(\theta) = 1 - \Gamma(\theta)$$

Prob. 5.10 (cont.) due to the uniformity of $T(z)$ and $K_a(z)$

$$T_{DN}(\theta) = T_{up}(\theta)$$

$$T_{AP}(\theta; H) = \left[T_0\, e(\theta) + T_{DN}(\theta)\,\Gamma(\theta)\right] e^{-2K_{ec}\sec\theta} + T_{up}(\theta)$$

In case (c) $K_{er} = K_1 R_r^b$, dB km^{-1} Eq (5.119)

where for 35 GHz, $K_1 = 0.225$, $b = 1.05$

$R_r = 10$ mm hr^{-1} $\rightarrow$ $K_{er} = 2.525$ dB km^{-1}

or $K_{er} = 0.5813$ Np km^{-1}

$K_{er} \gg K_{ec}$ $\rightarrow$ ignore cloud effects

As in case (b), $T_{DN}(\theta) = T_{up}(\theta)$

$$T_{AP}(\theta) = \left[T_0\, e(\theta) + T_{DN}(\theta)\,\Gamma(\theta)\right] e^{-2K_{er}\sec\theta} + T_{up}(\theta)$$

where $T_{up}(\theta) = T_r\left[1 - e^{-2K_{er}\sec\theta}\right]$

See the program listing, output, and plot which follows which use the above results.

Prob. 5.10 (cont.)

$$\Gamma_h(\theta) = \left| \frac{\cos\theta - \sqrt{\epsilon - \sin^2\theta}}{\cos\theta + \sqrt{\epsilon - \sin^2\theta}} \right|^2 \qquad \text{from Eq. (4.132a)}$$

$$T_{DN}(\theta) = \sec\theta \int_0^\infty K_a(z')\, T(z')\, e^{-\tau(0,z')\sec\theta}\, dz'$$

In case (a) $K_e = 0$, $T_{AP}(\theta) = e(\theta)\, T_o$

In case (b) $K_{ec} = K_1 m_v$, where

$K_1 = 0.434 \frac{6\pi}{\lambda_o} \mathrm{Im}\{-K\}$ dB km^{-1} g^{-1} m^3 Eq. (5.105)

with λ_o in cm , or

$K_1 = \frac{6\pi}{\lambda_o} \mathrm{Im}\{-K\} \times 10^{-1}$ Np km^{-1} g^{-1} m^3

and $K = \frac{n^2-1}{n^2+2}$, $n^2 = \epsilon$

$K = 0.9523 - j0.06503$

$K_1 = 0.1430$ Np km^{-1} g^{-1} m^3

$m_v = 1$ g m^{-3}

$\rightarrow K_{ec} = 0.1430$ Np km^{-1} $(K_{ac} = K_{ec})$

$$\tau(0,2) = \int_0^2 K_{ec}\, dz = K_{ec}(2-0)$$

$$\rightarrow \tau = 2K_{ec}$$

$$T_{up}(\theta) = \sec\theta\, K_{ec} T_c \int_0^H e^{-\tau(z)}\, dz$$

$$= \sec\theta\, K_{ec}\, T_c \int_0^2 e^{-K_{ec}(2-z)\sec\theta}\, dz$$

$$= T_c\left[1 - e^{-2K_{ec}\sec\theta}\right]$$