Chapter 6 (Atmospheric Effects) - Exercise Solutions

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1. (a)

$$d \approx \sqrt{2krh_t}.$$

For $h_t = 5m$,

$$d \approx \sqrt{2(1.37)(6370)(0.005)} = 9.34km$$

and for $h_t = 10m$,

$$d \approx \sqrt{2(1.37)(6370)(0.01)} = 13.21km.$$

(b) Max possible link is thus $9.34 + 13.21 = 22.55$ km.

(c) It appears we have to select a frequency. Say, 10 GHz. Then we read the attenuation coefficients off the graph.

$$\gamma_a = \gamma_o + \gamma_w \approx 0.008 + 0.009 \text{ dB km}^{-1} = 0.0017 \text{ dB km}^{-1}.$$

Thus,

$$A = (0.0017 \text{ dB km}^{-1})(22.55 \text{ km}) = 0.038 \text{ dB}.$$

(d) We first must approximate P, T and e. Let P = 1100mb, T = 298 K and e = 4, where the latter was found by looking online. It is a function of T only. Now,

$$N_s = \frac{77.6}{T}(P + \frac{4810e}{T}) = 303\text{N units}$$

and

$$\frac{dN}{dh} = -\frac{N_s}{7}e^{-\frac{h}{7}} = -\frac{303}{7}e^{-\frac{1}{7}} \approx -37.25\text{N units km}^{-1}$$

where we have used $h = 1$ km, since $h < 1$ km - as mentioned in the text. Next,

$$\frac{dn}{dh} = \frac{dN}{dh} \times 10^{-6} = -0.00003752.$$

We then find k via

$$k = \frac{1}{1 + r\frac{dn}{dh}} = \frac{1}{1 + 6370(-0.00003752)} = 1.314.$$

Finally, we can calculate the new distances to the horizon as

$$d_{5m} = \sqrt{2krh_t} = \sqrt{2(1.314)6370(0.005)} = 9.149 \text{ km}$$

and

$$d_{10m} = \sqrt{2krh_t} = \sqrt{2(1.314)6370(0.01)} = 12.938 \text{ km}.$$

We note that these distances are slightly less than in part (a), since the link will experience more attenuation due to water vapour. For the maximum possible LOS link distance, we just add $9.149 + 12.938 = 22.087$ km. Finally, to calculate the attenuation A, we must look up γ_a from the graph (curve A):

$$A = \gamma_a d = (0.02 \text{ dB km}^{-1})(22.087 \text{ km}) = 0.4417 \text{ dB}.$$

2. We first read the refractivity gradient dN_1 from Fig. 6.3, in this case $= -400$. Thus

$$K = 10^{-4.2-0.0029(-400)} \approx 9.12 \times 10^{-4}.$$

Next, recognising that since there is no angle involved (i.e. $|\epsilon_p| = 0$), then the probability as a % is

$$p(\%) = Kd^3 1^{-1.2} 10^{0.033f-0.001h_L-\frac{A}{10}} = 0.714\%$$

where we used $A = 10$ dB, $d = 10$, $f = 28$ and $h_L = 30$.

3. We repeat the above but for the Californian coast, where the refractivity gradient $\rightarrow -700$. K becomes $10^{-2.17} = 0.054$ and then

$$p(\%) = 0.054.10^3 1^{-1.2} 10^{0.924-0.03-1} = 42.27\%.$$

Note that this is a huge difference from the previous question. For Ireland, we read a refractivity gradient of -200, and thus

$$p(\%) = 10^{-3.62} 10^3 1^{-1.2} 10^{6.924-0.03-1} = 0.188\%.$$

4. For Florida, we read from the graph a refractivity gradient of -200, set $p(\%) = 98$, and then solve for A.

$$98 = 10^{-4.2-0.0029(-200)} 8^3 1^{-1.2} 10^{0.033(38)-0.001(10)-\frac{A}{10}}$$

and after some arithmetic, we find

$$45.494 = 10^{-\frac{A}{10}}$$

and thus

$$\log_{10} 45.494 = \frac{A}{10}.$$

Finally, we calculate that $A = -16.58$ dB. Interpreting this, it means that our fade margin must be very small in order to ensure that we have 98% multipath availability.

5. We must find the worst case cloud attenuation, similar to example 6.4 in the text. The first calculations we need are

$$f_p = 20.09 - 142(\frac{300}{T} - 1) + 294(\frac{300}{T} - 1)^2 = 8.92 \text{ GHz}$$

for $T = 273$ K, and

$$f_S = 590 - 1500(\frac{300}{T} - 1) = 441.65 \text{ GHz}.$$

We also calculate $\epsilon_0 = 87.81$, in addition to all the values given on page 126. Thus $\epsilon^{''}(f) = 32.84$, $\epsilon^{'}(f) = 21.71$, and $\eta = 0.722$. Thus

$$K_l = \frac{0.819(18)}{32.84(1 + 0.722^2)} = 0.295 \text{ m}^2 \text{ kg}^{-1}.$$

Given that $L = 1.6$ kg m^{-2} for worst case scenario attenuation, as per text, then

$$A = \frac{LK_l}{\sin\theta} = \frac{1.6(0.295)}{\sin 30} = 0.944 \text{ dB}.$$

6. Basically, we are being asked for two things here: atmospheric attenuation, and cloud/fog/water attenuation. For the former, we read off the specific attenuation value from Fig. 6.4 as $\gamma \approx 0.0075$ dB km^{-1}, and thus

$$A_{atmosphere} = \gamma d = 0.0075 \times 0.8 = 0.006 \text{ dB}.$$

For the latter, we first note that cloud attenuation is not really a factor below 10 GHz, as stated in the text. Similarly for less that 5° elevation. We can account for dense fog though, although unlikely being Florida. For dense fog, $M = 0.5$ g m^{-3} (given) and the specific attenuation value is

$$\gamma_{fog} = K_l M$$

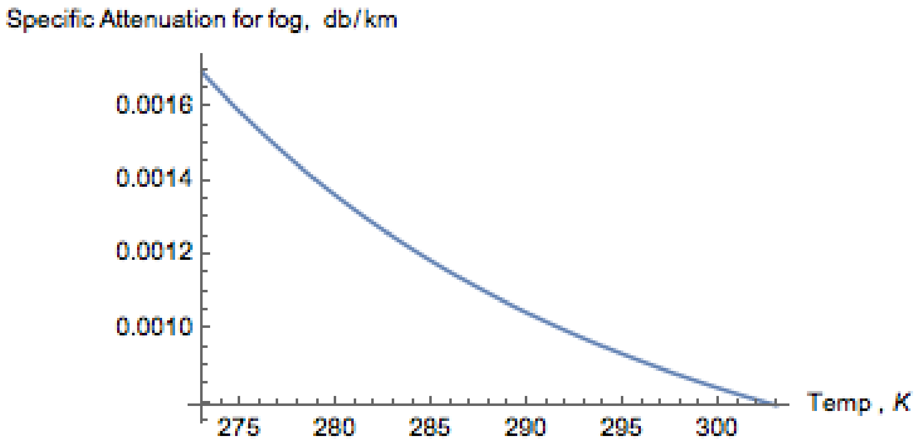
so we need K_l. This is calculated as before as 0.00175 dB km^{-1} g^{-1} m^3. Thus,

$$\gamma_{fog} = K_l M = 0.0017 \text{ dB km}^{-1}$$

and finally

$$A_{fog} = \gamma_{fog} d = 0.0017(0.8) = 0.00135 dB.$$

Further, we can plot the specific attenuation value against temperature (K) and see that as T increases, the value decreases as



Other types of applicable attenuation can be calculated, and even include path loss. These are straight forward at this stage.