The University of New Mexico

School of Engineering

Electrical and Computer Engineering Department

ECE 535 Satellite Communications

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Module # 5: 4.3, 4.7, 4.8, 4.10, 4.11, 4.12, 4.13, 4.14, 4.15

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4.3 Calculate the approximate value of atmospheric attenuation for a satellite transmission at 14GHz, for which the angle of elevation of the earth-station antenna is 15°.

To approximate, we can assume an average rain rate of 8 mm/h is exceeded for a typical 0.001 percent of the year.

Thus: $EL = 15°; f = 14GHz;\ a_h = 0.0369;\ b_h = 1.154;\ R_{0.001} = 8mm/h$

$$L_S = \frac{1}{sinEL} \xrightarrow{yields} \frac{1}{\sin(15)} = 3.86km$$

$$L_G = L_S cosEL \xrightarrow{yields} 3.86 * \cos(15) = 3.73km$$

$$r_{0.001} = \frac{1}{10 + L_G} \xrightarrow{yields} \frac{1}{10 + 3.73} = 0.729$$

$$A_h = a_h R_{0.001}^{b_h} \xrightarrow{yields} 0.0369 * 8^{1.154} * 0.729 \approx 0.29dB$$

4.7 Compare the specific attenuations for vertical and horizontal polarization at a frequency of 4 GHz and a point rain rate of 8mm/h which is exceeded for 0.01 percent of the year.

$f = 4GHz$

$R_{0.01} = 8mm/h$

<u>At 4 GHz…</u>

TABLE 4.2 Specific Attenuation Coefficients

Frequency, GHz	a_h	a_v	b_h	b_v
1	0.0000387	0.0000352	0.912	0.88
2	0.000154	0.000138	0.963	0.923
4	0.00065	0.000591	1.121	1.075

Horizontal Polarization

$A_h = a_h R_{0.01}^{b_h} \xrightarrow{yields} A_h = (0.00065)(8^{1.21}) = 0.0067dB$

Vertical Polarization

$A_v = a_v R_{0.01}^{b_h} \xrightarrow{yields} A_h = (0.000591)(8^{1.075}) = 0.0055dB$

4.10 For a satellite transmission path, the angle of elevation of the earth station antenna is 35°, and the earth station is situated at mean sea level. The signal is vertically polarized at a frequency of 18 GHz. The rain height is 1 km, and a rain rate of 10 mm/h is exceeded for 0.001 percent of the year. Calculate the rain attenuation under these conditions.

$$EL = 35°; f = 18GHz; h_r = 1km;\ R_{0.001} = \frac{10mm}{h};\ a_v = 0.0691;\ b_v = 1.065$$

$$h_0 = 0km\ (mean\ sea\ level)$$

$$L_S = \frac{h_r - h_o}{\sin(EL)} \xrightarrow{yields} \frac{1km - 0km}{\sin(35°)} = 1.74km$$

$$L_G = L_S \cos(EL) \xrightarrow{yields} (1.74km)\cos(35°) = 1.43km$$

$$r_{0.001} = \frac{10}{10 + L_G} \xrightarrow{yields} \frac{10}{10 + 1.42km} = 0.898$$

$$A_v = a_v R_{0.01}^{b_h} L_S r_{0.001} \xrightarrow{yields} 0.0691 * 10^{1.065} * 1.74 * 0.898 = 1.25dB$$

4.11 Repeat Prob. 4.10 when the rain rate of 10 mm/h is exceeded (a) 0.01 percent and (b) 0.1 percent of the year.

(a) At 0.01 percent:

$$EL = 35°; f = 18GHz; h_r = 1km;\ R_{0.001} = \frac{10mm}{h};\ a_v = 0.0691;\ b_v = 1.065$$

$$h_0 = 0km\ (mean\ sea\ level)$$

$$L_S = \frac{h_r - h_o}{\sin(EL)} \xrightarrow{yields} \frac{1km - 0km}{\sin(35°)} = 1.74km$$

$$L_G = L_S \cos(EL) \xrightarrow{yields} (1.74km)\cos(35°) = 1.43km$$

$$r_{0.001} = \frac{90}{90 + 4L_G} \xrightarrow{yields} \frac{90}{90 + 4(1.43km)} = 0.940$$

$$A_v = a_v R_{0.01}^{b_h} L_S r_{0.01} \xrightarrow{yields} 0.0691 * 10^{1.065} * 1.74 * 0.940 = 1.32dB$$

(b) At 0.1 percent:

$$r_{0.001} = \frac{180}{180 + L_G} \xrightarrow{yields} \frac{180}{180 + (1.43km)} = 0.992$$

$$A_v = a_v R_{0.1}^{b_h} L_S r_{0.1} \xrightarrow{yields} 0.0691 * 10^{1.065} * 1.74 * 0.992 = 1.39dB$$

4.12 Given that for a satellite transmission EL = 22°, $R_{0.01}$=15 mm/h, h_0 = 600 m, h_r = 1500 m, and horizontal polarization is used, calculate the rain attenuation for a signal frequency of 14GHz.

$EL = 22°;\ R_{0.01} = 15mm/h; h_0 = 600m;\ h_r = 1500m; f = 14GHz;\ a_h = 0.0367;\ b_h = 1.128$

$$L_S = \frac{h_r - h_o}{\sin{(EL)}} \xrightarrow{yields} \frac{1.5km - 0.6km}{\sin{(22°)}} = 2.4km$$

$$L_G = L_S \cos(EL) \xrightarrow{yields} (2.4km)\cos(22°) = 2.2km$$

$$r_{0.001} = \frac{90}{90 + 4L_G} \xrightarrow{yields} \frac{90}{90 + 4(2.2km)} = 0.910$$

$$A_v = a_v R_{0.01}^{b_h} L_S r_{0.01} \xrightarrow{yields} 0.0367 * 10^{1.128} * 2.4 * 0.910 = 1.70dB$$

4.13 Determine the specific attenuation for a circularly polarized satellite signal at a frequency of 4GHz, where a point rain rate of 8mm/h is exceeded for 0.01 percent of the year.

$f = 4GHz, a_h = 0.00065;\ b_h = 1.121;\ a_v = 0.000591;\ b_v = 1.075; R_{0.01} = 8mm/h$

$$a_c = \frac{a_h + a_v}{2} \xrightarrow{yields} \frac{0.00065 + 0.000591}{2} = 0.0006205$$

$$b_c = \frac{a_h b_h + a_v b_v}{2a_c} \xrightarrow{yields} \frac{(0.00065 * 1.121)(0.000591 * 1.075)}{2(0.000621)} = 1.103$$

$$A_c = a_c R_{0.01}^{b_c} L_S r_{0.01} \xrightarrow{yields} (0.000621)(8^{1.103}) = 0.006dB$$

4.14 A circularly polarized wave at a frequency of 12GHz is transmitted from a satellite. The point of rain rate for the region is $R_{0.01}$=13mm/h. Calculate the specific attenuation.

$f = 12GHz; a_h = 0.0188;\ b_h = 1.217;\ a_v = 0.0168;\ b_v = 1.2;\ R_{0.01} = 13mm/h$

$$a_c = \frac{a_h + a_v}{2} \xrightarrow{yields} \frac{0.0188 + 0.0168}{2} = 0.0178$$

$$b_c = \frac{a_h b_h + a_v b_v}{2a_c} \xrightarrow{yields} \frac{(0.0188 * 1.217)(0.0168 * 1.2)}{2(0.0178)} = 1.210$$

$$A_c = a_c R_{0.01}^{b_c} \xrightarrow{yields} (0.0178)(13^{1.210}) = 0.397dB$$

4.15 Given that for Prob. 4.13 the earth station is situated at altitude 500m and the rain height is 2km, calculate the rain attenuation. The angle of elevation of the path is 35°.

$EL = 35°;\ h_r = 2km;\ h_0 = 0.5km; f = 4GHz;\ a_h = 0.00065;\ b_h = 1.121;\ a_v = 0.000591$

$b_h = 1.075;\ R_{0.01} = 8mm/h$

$$a_c = \frac{a_h + a_v}{2} \xrightarrow{yields} \frac{0.00065 + 0.000591}{2} = 0.00062$$

$$b_c = \frac{a_h b_h + \ a_v b_v}{2a_c} \xrightarrow{yields} \frac{(0.00065 * 1.121)(0.000591 * 1.075)}{2(0.00062)} = 1.103$$

$$L_S = \frac{h_r - h_o}{\sin(EL)} \xrightarrow{yields} \frac{2km - 0.5km}{\sin(35°)} = 2.63km$$

$$L_G = \ L_S \cos(EL) \xrightarrow{yields} (2.63km)\cos(35°) = \ 2.15km$$

$$r_{0.001} = \frac{90}{90 + 4L_G} \xrightarrow{yields} \frac{90}{90 + 4(2.15km)} = 0.913$$

$$A_c = \ a_c R_{0.01}^{b_c} L_S r_{0.01} \xrightarrow{yields} 0.00062 * \ 8^{1.103} * 2.63km * 0.913 = 0.015dB$$