**The University of New Mexico**

**School of Engineering**

**Electrical and Computer Engineering Department**

**ECE 535 Satellite Communications**

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Module # 4: Problems 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 14 GHz, for which the angle of elevation of the earth-station antenna is 15°.

* [AA] = [AA] \_ 90 cosecEl
* [AA] \_ 90 ~ 0.1 (from figure 4.2)
* [AA] = 0.1\*cosec(15)
* 0.3864 dB

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

* At 4 GHz
  + a\_h = 0.00065
  + a\_v = 0.000591
  + b\_h = 1.121
  + b\_v = 1.075
* alpha = a(R\_p)^b
* alpha\_h = 0.00065 \* 8^1.121
* alpha\_h = 0.0067 dB
* alpha\_v = 0.000591\*8^1.075
* alpha\_v = 0.0055 dB / km

4.8: Repeat Prob. 4.7 for a frequency of 12 GHz.

* At 12 GHz
  + a\_h = 0.0188
  + a\_v = 0.0168
  + b\_h = 1.217
  + b\_v = 1.2
* alpha = a(R\_p)^b
* alpha\_h = 0.0188\* 8^1.217
* alpha\_h = 0.2362 dB
* alpha\_v =0.0168 \*8^1.2
* alpha\_v = 0.2307 dB / km

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, h\_0 = 0, h\_r = 1, R = 10
* L\_s = (h\_r-h\_0) / sind(El)
* L\_s = (1-0) / sind(35)
* L\_s = 1.7434
* L\_g = L\_s\*cosd(El)
* L\_g = 1.7434\*cosd(35)
* L\_g = 1.4281
* r\_01 = 90/(90+4\*L\_g)
* r\_01 = 90/(90+4\*1.4281
* r\_01 = 0.9403
* at 18 GHz (using 20 Hz values)
  + a\_h = 0.0751
  + a\_v = 0.0691
  + b\_h = 1.099
  + b\_v = 1.065
* A = a\*R\*L\_s\*r\_01
* A\_h = 1.2312 dB
* A\_v = 1.1328 dB

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.

* El = 35, h\_0 = 0, h\_r = 1, R = 10
* L\_s = (h\_r - h\_0) / sind(El)
* L\_s = (1 - 0) / sind(35)
* L\_s = 1.7434
* L\_g = L\_s \* cosd(El)
* L\_g = 1.7434 \* cosd(35)
* L\_g = 1.4281
* r\_001 = 90 / (90 + 4 \* L\_g)
* r\_001 = 90 / (90 + 4 \* 1.4281)
* r\_001 = 0.9403
* a\_h = 0.0751, a\_v = 0.0691, b\_h = 1.099, b\_v = 1.065
* A = a \* R^b \* L\_s \* r\_001
* A\_h = 1.5464
* A\_v = 1.3157 dB

4.12: Given that for a satellite transmission El = 22°, R0.01 = 15 mm/h, h0 = 600 m, h\_r = 1500 m, and horizontal polarization is used, calculate the rain attenuation for a signal frequency of 14 GHz.

* El = 22, h\_0 = 0.6, h\_r = 1.5, R = 15
* L\_s = (h\_r - h\_0) / sind(El)
* L\_s = (1.5 - 0.6) / sind(22)
* L\_s = 0.9 / 0.3746
* L\_s = 2.4022
* L\_g = L\_s \* cosd(El)
* L\_g = 2.4022 \* cosd(22)
* L\_g = 2.2281
* r\_001 = 90 / (90 + 4 \* L\_g)
* r\_001 = 90 / (90 + 4 \* 2.2281)
* r\_001 = 90 / 98.9124
* r\_001 = 0.9100
* a\_h = 0.0367, b\_h = 1.154
* A = a\_h \* R^b\_h \* L\_s \* r\_001
* A = 0.0367 \* 15^1.154 \* 2.4022 \* 0.9100
* A = 1.826 dB

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

* At 4 GHz
* a\_h = 0.00065
* a\_v = 0.000591
* b\_h = 1.121
* b\_v = 1.075
* a\_c = (a\_h + a\_v) / 2
* b\_c = (a\_h \* b\_h + a\_v \* b\_v) / (2 \* a\_c)
* alpha\_c = a\_c \* 8^b\_c
* alpha\_c = 0.0006205 \* 8^1.098
* alpha\_c = 0.0078 dB / km

4.14: A circularly polarized wave at a frequency of 12 GHz is transmitted from a satellite. The point rain rate for the region is R0.01 = 13 mm/h. Calculate the specific attenuation.

* At 12 GHz
* a\_h = 0.0188
* a\_v = 0.0168
* b\_h = 1.217
* b\_v = 1.200
* a\_c = (a\_h + a\_v) / 2
* b\_c = (a\_h \* b\_h + a\_v \* b\_v) / (2 \* a\_c)
* alpha\_c = a\_c \* 10^b\_c
* alpha\_c = 0.0178 \* 10^1.209
* alpha\_c = 0.288 dB/km

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

* El = 22, h\_0 = 0.6, h\_r = 1.5, R = 15
* L\_s = (h\_r - h\_0) / sind(El)
* L\_s = (1.5 - 0.6) / sind(22)
* L\_s = 0.9 / 0.3746
* L\_s = 2.4022
* L\_g = L\_s \* cosd(El)
* L\_g = 2.4022 \* cosd(22)
* L\_g = 2.2281
* r\_001 = 90 / (90 + 4 \* L\_g)
* r\_001 = 90 / (90 + 4 \* 2.2281)
* r\_001 = 90 / 98.9124
* r\_001 = 0.9100
* a\_h = 0.0367, b\_h = 1.154
* A = a\_h \* R^b\_h \* L\_s \* r\_001
* A = 0.0367 \* 15^1.154 \* 2.4022 \* 0.9100
* A = 0.018614 dB

As a signal travels from a satellite down to an Earth station, it goes through several layers of the atmosphere. Each layer has its own features that can affect how the signal moves.

The troposphere is the lowest layer, reaching up to about 8 to 15 kilometers depending on the location. This is where weather happens, like clouds and rain. Since it holds most of the moisture in the air, this layer is the main cause of rain-related signal loss, known as rain attenuation. Rain rate is measured in millimeters per hour and is often based on how often that rate is passed during a year.

Above the troposphere are the stratosphere and mesosphere. These layers don’t affect signals as much because they have less moisture. Higher up is the thermosphere, which includes the ionosphere. The ionosphere contains charged particles and free electrons, which can affect signals in different ways. These include fading (scintillation), delays, and changes in signal direction or polarization. These effects get smaller as the signal frequency goes up.

Gases like water vapor and oxygen also cause signal loss across the atmosphere. This is called atmospheric absorption and it depends on frequency. The biggest absorption happens near 22.3 GHz and 60 GHz. Scintillation, which is small changes in the air’s density, can also make the signal fade or shift, both in the atmosphere and the ionosphere.