Rain Attenuation Prediction using Combined Raindrop Size Distribution for the Fixed Services of HAPS System

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Abstract: The frequencies for HAPS used in fixed wireless access are allocated in the millimeter wave bands. The systems using these frequencies can have a serious impact on the radio communication qualities due to rain. In this paper, we compare the specific rain attenuation using CM(combined) raindrop size distribution with those using different sevral raindrop size distributions for the frequency bands 28/48GHz. The rain attenuations using CM raindrop size distribution for the path between the earth and HAPS platform according to the elevation angle are described.

1. Introduction

HAPS (High Altitude Platform Station) is defined in RR No.1.66A as "A station located on object an altitude of 20 to 50 km and specified, nominal, fixed point relative to the Earth", which has recently been interested in applying many areas such as telecommunication, traffic monitoring and environmental remote sensing, etc. The new infrastructure defined as HAPS (High Altitude Platform Station) is being developed in many countries to provide fixed wireless communication services to users, such as USA, Europe, Japan, China, etc[1].

The service coverage of HAPS system is depend on the the elevation angle between HAPS flatform and the earth. HAPS system should be operated in line-of-sight link in order to provide a fixed wireless service.

ITU-R has assigned the frequencies around 48 GHz and 28 GHz as the provision for the use of HAPS in fixed wireless services. Systems using these frequencies can have a serious impact on the radio communication qualities due to rain. Therefore, to maintain the reliability of the radio link between HAPS platform and the earth, it is necessary to estimate more accurately the attenuation due to rain in rain condition considered regional climate.

In this paper, we describes general equation for the rain attenuation in Section 2. The specific attenuation values due to rain in frequency bands assigned to provide the fixed wireless service by HAPS are calculated. The specific rain attenuation using CM raindrop size distribution[2] proposed by ETRI and those using sevral different raindrop size distributions are compared. Rain attenuations using both CM(Combined) distribution and effective path length in rain conditions according to the elevation angle are described.

2. Rain Attenuation Model

Rain attenuation is simply described by the following expression.

$$A = \gamma \bullet L_{eff} = aR^b \bullet L_{eff} \ \text{(dB)} \qquad (1)$$

where, γ (dB/km) is specific rain attenuation and L_{eff} (km) is an effective path length of rain. The specific rain attenuation is derived as aR^b [3] by power-law, coefficients a and b are dependent on drop shape of falling rain , drop number, and polarization and frequency, etc.

Specific rain attenuation, which is the attenuation of an electromagnetic wave traveling through the rain in a unit distance, can be expressed by

$$\gamma = 4.343\times10^3 \int_0^{D_m} Q(D)N(D)dD \ \text{(dB/km)} \qquad (2)$$

where, $Q(D)$ is the extinction cross section in m^2 and $N(D)dD$ a density of raindrop distributed in dameter between D and $D+dD$.

Raindrop size distribution: A number of raindrop size distributions have been proposed in various region of the world. Especially, Laws and Parsons (LP) distribution [4], Marshall-Palmer (MP) distribution [5] and Japanese (JM) distribution [6] are used widely. In our previous study, the modified raindrop size distribution (CM; Combined distribution) as the exponential function has been proposed [2].

- CM(Combined) distribution: This distribution that was combined several existing raindrop size distribution models was proposed by ETRI. This raindrop size distribution is given as the exponential function

$$N(D) = N_0 e^{-\Lambda D} \text{ (mm}^{-1}\text{m}^{-3}\text{)}, \quad (3)$$

$$N_0 = 4.86R / \left[\Lambda^{-4} - (\Lambda + 0.582)^{-4}\right] \text{ (mm}^{-1}\text{m}^{-3}\text{)},$$

$$\Lambda = 6.6R^{-0.33} \text{ (mm}^{-1}\text{)}.$$

Raindrop size distribution is a function of rain-rate, and rain-rate is a function of size distribution and terminal velocity of falling rainfall. Therefore, rain-rate has to be checked consystency and the equation is given by

$$R = 6\pi \times 10^{-4} \int_0^{D_m} v(D) D^3 N(D) dD \text{ (mm/h)} \quad (4)$$

where, $v(D)$ is terminal velocity in m/s and D (mm) is a diameter with equivalent raindrop volume.

The effective path length in rain [7] is expressed as

$$L_{eff} = L_s \bullet \frac{1}{1 + L_h / L_o} = \frac{L_s}{1 + L_h / (35R^{-0.015})} \text{ (km)} \quad (5)$$

where L_s, L_h, and L_o is slant path length, horizontal path length, and characteristic length, respectively and the unit of the lengths is km.

Path diagram between the earth and HAPS platform is shown in Figure 1. As it is shown Figure 1, length of slant path L_s is dependent on the elevation angle.

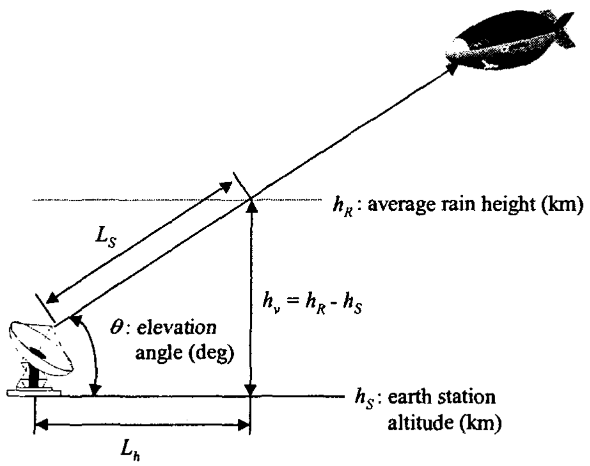


Figure 1. Path diagram between the earth and HAPS flatform in rain condition.

In order to estimate the rain attenuation more accurately, it is necessary to consider two significant parametes both specific rain attenuation and the effective path length in rain condition. In previously noted equation (2), specific rain attenuation depends on drop size distribution of falling rain. Both raindrop size distribution and effective path length are a function of a rain-rate. Rain-rate distribution is dependant on a reginal climatic characteristics. Thus, we need to appropriately choose between the raindrop size distribution and effective path length for falling rain as parameter considered the reginal climatic characteristics.

Rain-rate consists of a number of raindrop with different size of falling rain. Even though rain-rate are the same, raindrop size distribution is different as regional rain conditions. Therefore, in this paper, we assume that the reginal rain conditons is reflected in raindrop size distribution rather than the effective path length..

3. Calculation of Rain Attenuations

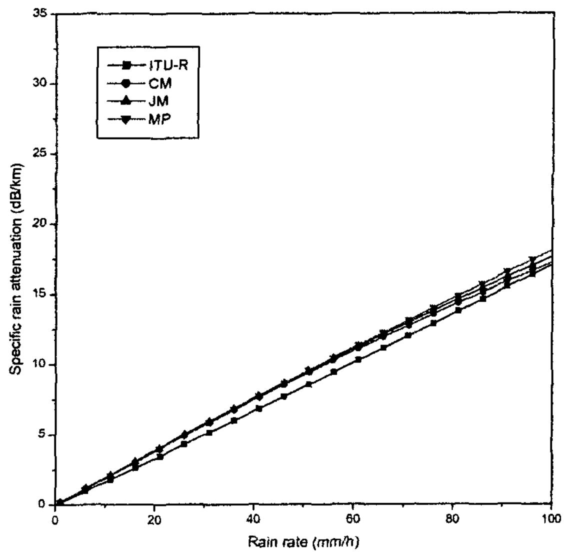
3.1 Specific rain attenuation

In this section, we cocalculate the specific rain attenuation using CM raindrop size distribution and those using sevral different raindrop size distributions at 28/48GHz, and the calculated results are compared

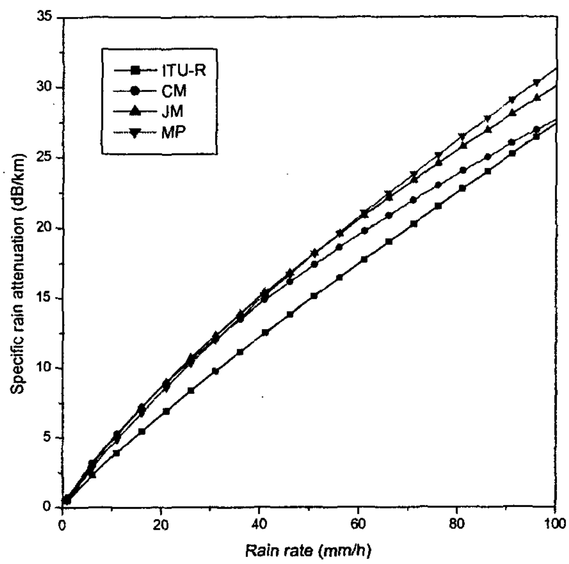
The specific rain attenuation based on CM raindrop size distribution, those using several raindrop size distributions such as MP, JM, and the results by ITU-R model using LP distribution at the frequency bands 28/48GHz are shown in Figure 2. At 28GHz, the specific attenuation using CM raindrop distribution is simillar to those using JM and MP raindrop size distributions. At 48GHz, The specific rain attenuation using CM raindrop size distribution are simillair to those from MP and JM raindrop size distributions about until rain-rate 50 mm/h, and the specific attenuation at rain-rate over 50 mm/h is lower than those from the other raindrop size distributions such as MP, JM.

ITU-R model using LP distribution underestimates the specific attenuations compared to other raindrop size distributions at the frequency bands 28/48GHz. The higher the frequency, the estimation values of the spcific rain attenuation using between ITU-R model and other raindrop size distributions.

The rain condition of Korea is specified as K-zone by ITU-R. The rain-rate for time percentage 0.01% in K-zone is 42mm/h, at that rain-rate, the differences between the specific attenuations for 28GHz from the ITU-R model and the other raindrop size distributions are about 2.3~2.9dB. At 48 GHz, the differences between the specific attenuations from the ITU-R model and the other raindrop size distributions are lager than those at 28GHz rain path according to the elevation angle is lower, and attenuation due to rain increases.

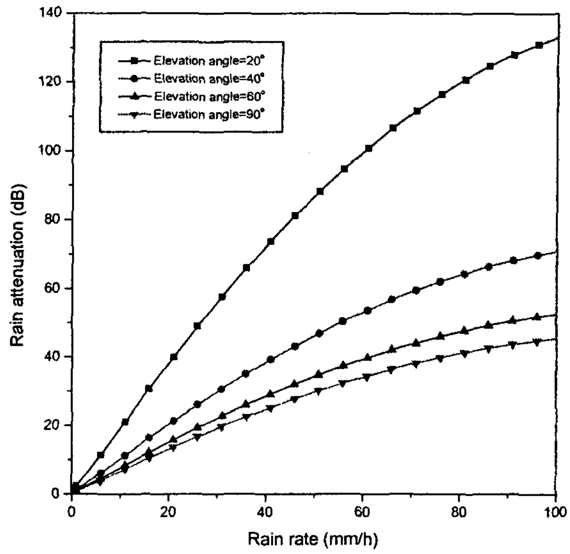


(a) 28GHz

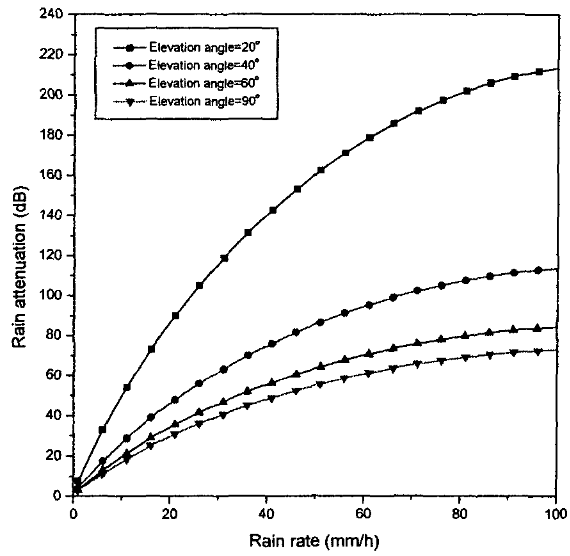


(b) 48GHz

Figure 2. Specific rain attenuation



(a) 28GHz



(b) 48GHz

Figure 3. Rain attenuation using CM distribution as to the elevation angle

3.2 Rain attenuation between HAPS flatform and the earth

This section describes the rain attenuation value according to the elevation angle using CM raindrop size distribution and effective path length in equation (5).

Rain attenuation values for the elevation angle at the frequency bands 28/48GHz are shown in Figure 3. The lower the elevation angle is, the more rain attenuation value increases. Because the radiowave travels through longer rain path according to the elevation angle is lower, and attenuation due to rain increases.

The rain attenuation valus according to the elevation angle as the time percentage of rain-rate distribution for 28GHz and 48GHz are summatrized in Table 1 and Table 2, respectively.

At 28GHz, time percentage of rain-rate 0.1%, rain attenuation value at the elevation angle 20° is 15 dB larger than that value at the elevation angle 90°. At 48GHz, time percentage of rain-rate 0.1%, rain attenuation value at the elevation angle 20° is about 38 dB larger than that value at the elevation angle 90°.

Table 1. Rain attenuation for the elevation angle at 28GHz

Time percentage (%)	Rain rate (mm/h)	The elevation angle			
		20°	40°	60°	90°
1	1	3.2	1.7	1.3	1.1
0.3	4.2	8.0	4.3	3.2	2.8
0.1	12	23.0	12.3	9.1	7.9
0.03	23	43.6	23.2	17.2	14.9
0.01	42	75.2	40.0	29.7	25.7

Table 2. Rain attenuation for the elevation angle at 48GHz

Time percentage (%)	Rain rate (mm/h)	The elevation angle			
		20°	40°	60°	90°
1	1	7.9	4.2	3.1	2.7
0.3	4.2	24.1	12.8	9.5	8.2
0.1	12	58.1	30.9	22.9	19.9
0.03	23	96.0	51.1	37.9	32.8
0.01	42	144.8	77.0	57.2	49.5

4. Conclusion

We compared the specific rain attenuation value for CM raindrop size distribution with those from several different raindrop size distributions at the frequency bands 28/48GHz. Also, the rain attenuation values using CM distribution for the elevation angle at 28/48GHz are described.

As the result, the specific rain attnuation value using CM raidrop size dsitribution is similliar to those estimated from other raindrop size distributions proposed in temperate climate such as MP and JM distributions. ITU-R model underestimates specific rain attenuation compared to those of other distributions at 28/48GHz.

The rain attenuation values at low elevation angle is lger than those values at higher elevation angle. Because the path between the earth and HAPS flatform at low elevation angle is longer than that at high elevation angle

Therefore, To estimate the rain attenuation more accurately, the study of raindrop size distribution and effective path length considered in regional climate condition should be carried out continuously.

References

[1] T. C. Tozer, and D. Grace, "High-altitude platforms for wireless communications," *IEEE Electronics & Communication Engineering Journal*, June. 2001.

[2] Sam-mo Cho, Yang-Su Kim, Jeong-Ki Pack, Sung-Soo Lee, Hyuk-Je Kim, "Estimation of Rain Attenuation for Millimeter-wave Propagation in Domestic Environments", *The Journal of the Korean Institute of Communication Sciences (Korean)*, vol. 23, no.7, pp.1755-1763, july, 1999.

[3] R. L. Olson, D. V. Rogers, and D.B.Hodge, "The aR^b relation in the calculation of rain attenuation," *IEEE Trans. on Antennas and Propagation*, Vol. AP-26, No.2, pp. 318 ~ 329, Mar. 1978.

[4] J. O. Laws and D. A. Parsons, "The Relation of Raindrop-Size to Intensity", *Tras. American Geophy. Union*, vol. 24, pp. 452-460, 1943.

[5] J.S. Marshall & W. McK. Palmer, "The distribution of raindrops with size", *Journal of Meteorology*, vol. 5, no. 6, pp. 955-1019, 1974.

[6] T. Ihara, Y. Furuhama, and T. Manabe, "Inference of Raindrop Size Distribution from Rain Attenuation Statistics at 12, 35, and 82 GHz", *IECE Trans.*, vol. E67, 70.4, pp. 211-217, 1984.

[7] ITU-R, "Propagation data and prediction methods required for the design of earth-space telecommunication systems", *Rec. P618-5*, 1997.