Measurement of Rain Induced Attenuation using the Beacon Signal of Koreasat-3

Dong-You Choi[1] · Chang-Gyun Park[2]

Abstract

This paper presents here the results of the measurements of rain-induced attenuation in the vertically polarized signal propagating at 12.2525 GHz during some rain events, which occurred in the rainy wet season of the year 2001 at Yong-in, Korea(temperate climate). The attenuation measured experimentally was compared with that obtained using the International Telecommunication Union Radio Communication Sector(ITU-R) model, the SAM model and the Global model. In this paper, measured results are in good agreement with the ITU-R prediction.

Key words : Rain Attenuation, Itu-R Model, Sam Model, Global Model, Koreasat-3.

Ⅰ. Introduction

Rain attenuation degrades the performance of the microwave communication system and restricts the use of microwave frequencies for line of sight and space-to-earth communication link. Although fog, clouds and dust particles effect the propagation of signals significantly but rain is the major factor that adversely effects the propagation of signals at frequencies above 10 GHz[1],[2]. The knowledge of rain attenuation statistics for the frequency of operation at a particular location is very useful for the planning and engineering of a reliable satellite communication systems[3].

Thus this paper selected Koreasat-3, which uses the Ku-band(14 GHz/12 GHz) frequency, and analyzed the beacon signal level data according to the rain rate from June to August in 2001. Then to provide analysis, the experimental data was compared with that obtained using typical rain attenuation models, such as the ITU-R model[4],[5], the SAM model[6] and the Global model[7], which have previously been used in satellite communication systems.

Ⅱ. Experimental Systems

To measure the rain rate, a rain measurement system was used, which was installed when the Yong-in Satellite Control Office was established. To measure the beacon signal level which is always received at a certain level from a satellite, the controlling equipment of Koreasat-3 was used. Block diagrams for the two measurement systems are shown Fig. 1 and Fig. 2.

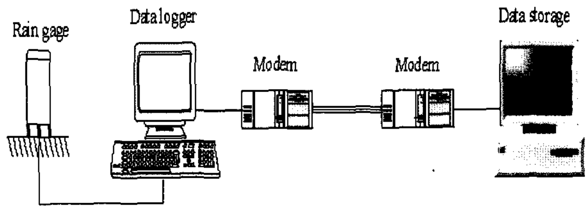

Fig. 1. Experimental system for measuring the rain rate.

As shown in Fig. 1, the accumulated rain rate data is first collected in a data collector and then is saved in a computer. The rain rate data may be saved in

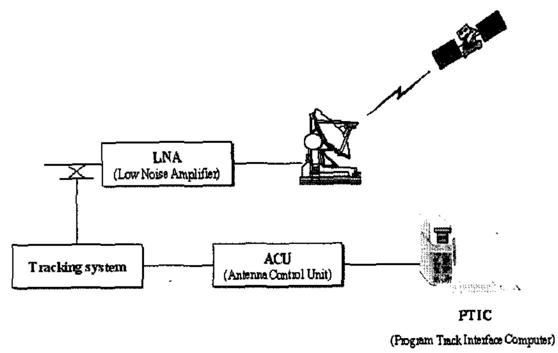

Fig. 2. Experimental system for measuring the beacon signal level.

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Table 1. Rain gauge.

Type	Tipping bucket
Size	Diameter 200 mm
Resolution	0.5 mm
Accuracy	Less than 5 %(in rain rate 10 mm/hr)
Environment temperature	−40 ℃ ~ +50 ℃

Table 2. Experimental specifications.

System location	Latitude(Yong-in)	37° 43'
	Longitude(Koreasat-3)	116°
	Elevation angle	45° 20'
	Sea level	0.142 km
Climatic zone	ITU-R model	K-zone
	Global model	D_2-zone
Polarization	Transmitter	Dual linear
	Receiver	Dual linear
Beacon frequency	12.2525 GHz(Down link)	

either 10 minute or 10 sec intervals. Since the 10 minute interval data collection was not sufficiently accurate for use with the satellite beacon signal level in accuracy, the 10 sec interval data collection was used.

The beacon signal, which is received at a certain level from a satellite, saves the received signal level at intervals of 1 minute, as shown in Fig. 2.

The beacon signal receiving antenna used 7.2 m cassegrain antenna designed specifically for Koreasat-3. In order to compensate for the changes in power level caused by the perturbation of the satellite transmission, which is located in a geostationary orbit, a tracking system using the steptrack tracking method was used.

Attenuation due to rain over the path was estimated by measuring the excess attenuation over clear weather attenuation values at various rain rates recorded using a tipping bucket rain gauge, which usually provides a good approximation to the instantaneous rain rates. The attenuation of radio wave propagation in a volume of rain of extent L(effective path length[km]) in the direction of wave propagation can be expressed as [8], [9]

$$A = \alpha L \quad [\text{dB}] \tag{1}$$

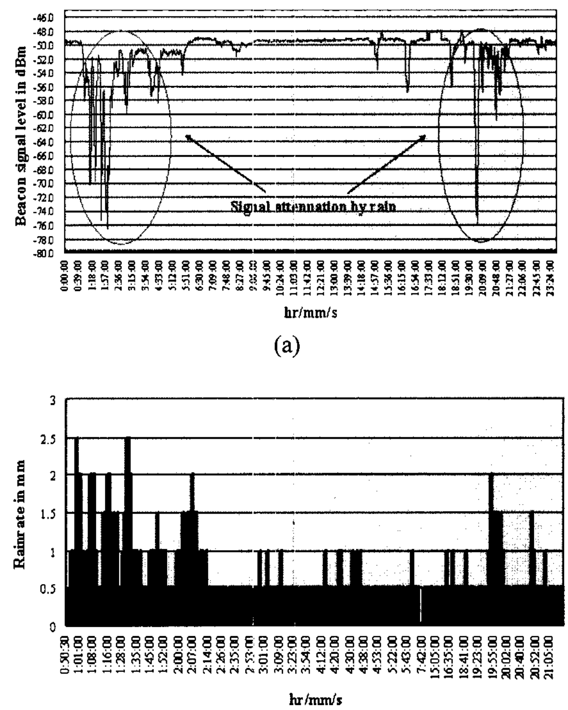
where α is the specific attenuation of the rain volume, expressed in decibels per kilometer. Specific attenuation can be calculated using raindrop size distribution. The relation of specific attenuation α and rain rate R,

Table 3. Antenna specifications.

Parameter	Characteristic
Diameter	7.2 m
Transmit band	14.0~14.8 GHz
Receive band	11.7~12.75 GHz
G/T at 20° EL	33.5 B/K@11.7 GHz
Polarization Transmit Receive	 Dual linear polarized Dual linear polarized
Transmit gain	>58.4 dBi@14.25 GHz
Receive gain	>56.2 dBi@11.7 GHz
VSWR Transmit Receive	 1.25:1 Maximum 1.25:1 Maximum
Cross poll isolation	>35 dB over 1 dB BW
Sidelobes First sidelobe Envelope 1~20°	 < −14 dB 5 log(Degree) dBi for 1<(Degree)<20 35 dBi for 20<(Degree)<26.3

is given by Olsen et al. [10] as

$$\alpha = aR^b \quad [\text{dB/km}] \tag{2}$$



(b)

Fig. 3. (a) Excess attenuation over the path on July 30, 2001.
(b) Rainfall rate over the path on July 30, 2001.

The values of the coefficient a and b depend upon frequency, rain temperature and drop size distribution.

III. Experimental Results

3-1 Received Beacon Signal Level and Rain Rate

Data corresponding to the signal levels and rain rates during the propagation and communication times were collected and analyzed during the period from June to August, 2001. The rain-induced attenuation and rainfall rate over the path have been plotted as a function of time on the same time scale, in Fig. 3(a) and (b) respectively, for one such rain event, which occurred on July 30, 2001. Fig. 3 shows that the rain-induced attenuation varies as rain rate varies. The maximum attenuation occurs when the rainfall rate is maximum.

Rain attenuation is obtained by subtracting a reference level from the measurement of the received beacon signal level. The reference level is obtained by averaging the beacon signal level data obtained during a period in which there is no rain. The relation between the rain attenuation and the rain rate is shown in Table 4. The 1st to 8th set of statistical data represent the mean values of the data collected on rainy days at intervals of 3~4 days after excluding the minimum and maximum values. The total statistical data was obtained by summing all of the mean data values during each measurement period. Fig. 4 shows the rain attenuation according to rain rate, which was both measured and calculated using the rain attenuation prediction model.

3-2 Discussion

It can be seen in Fig. 4 above, that the experimentally measured attenuation at 12.2525 GHz is in agreement with that calculated using the ITU-R model, the SAM model, and the Global model for the measured rain rates.

The results shown in Fig. 4 show that, the ITU-R model was in good agreement with the measured attenuation up to a rain rate of about 20 mm/hr, however above this value there is a difference in the attenuation value of above 0.34~2.2 dB(average 0.91 dB) up to the measured rain rate of 90 mm/hr. Therefore, when the rain rate exceeds 20 mm/hr, the

Table 4. Mean values of measured attenuation data.

Rain rate (mm/hr)	Measured attenuation [dB]								
	1st	2nd	3rd	4th	5th	6th	7th	8th	mean
2.6	-	-	0.5	-	-	-	-	-	0.50
3.3	0.7	-	-	-	-	-	-	-	0.70
5.6	-	-	0.8	1.2	-	-	-	-	1.00
6.0	-	1.05	-	-	-	-	-	-	1.05
7.5	1.5	1.1	1.1	-	-	-	-	-	1.23
9.5	-	-	-	1.4	-	-	-	-	1.40
10.6	-	-	-	-	1.55	-	-	-	1.55
13.8	2.0	-	-	1.7	-	2.4	2.0	-	2.02
15.0	2.85	3.7	-	2.1	-	2.8	2.32	-	2.75
16.4	3.95	-	-	-	-	3.1	2.46	-	3.17
20.0	-	-	-	3.4	-	3.05	-	-	3.23
25.7	3.55	-	-	-	3.7	4.5	3.15	3.71	3.72
30.0	4.63	6.1	5.9	-	4.1	5.2	4.9	6.19	5.29
37.0	5.35	6.09	-	-	-	-	-	6.26	5.90
45.0	-	-	5.8	-	-	6.18	6.7	7.7	6.59
55.0	-	-	-	-	8.09	-	-	8.95	8.52
60.0	10.35	-	9.20	-	-	-	-	11.12	10.22
72.0	-	-	12.74	-	-	-	12.38	-	12.56
90.0	-	-	-	-	-	-	15.65	16.48	16.07

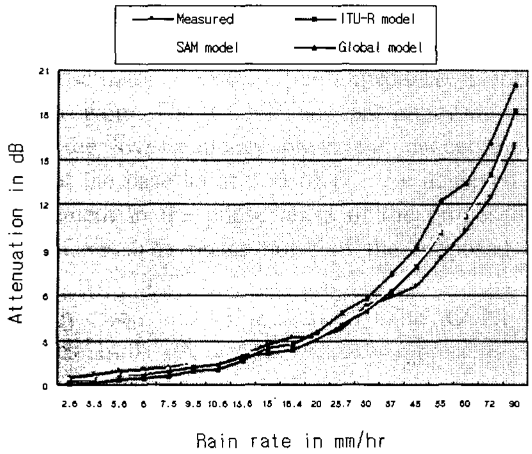


Fig. 4. Comparison of calculated attenuation and measured attenuation.

ITU-R model was in excellent agreement with the measured attenuation. As shown in Fig. 4, the SAM model was in excellent agreement with the measured attenuation up to about 20 mm/hr, however above this value there is a difference in the attenuation value of above 0.17~1.63 dB(average 1.01 dB) up to the measured rain rate of 90 mm/hr. The Global model shown in Fig. 4 underestimates the attenuation up to a rain rate of about 20 mm/hr and, above that rate, it overestimates the attenuation as compared with our experimental results.

Ⅳ. Conclusions

The rain-induced attenuation at 12.2525 GHz was measured experimentally. It was found that the experimental results were in good agreement with those obtained using the ITU-R model. At low rain rate, the experimental results were also in close agreement with the SAM model. However, the Global model either underestimates or overestimates the experimentally measured attenuation at the same rain rate. From the above observations, it can be concluded that the rain-induced attenuation at 12.2525 GHz can be satisfactorily predicted using the ITU-R model for this latitude. However, the rain-induced attenuation statistics cannot be predicted satisfactorily using the SAM model or the Global model for the present location.

Considering that this measurement was conducted for a short period of time(June~August in 2001), further studies need to be done using long-term rain attenuation measurement data for several frequencies, as well as rain attenuation data recorded throughout the country, in order to develop a specific model which is ideally adapted to this environment.

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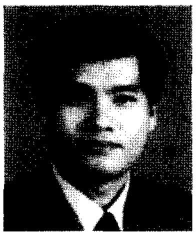

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