Rain attenuation prediction model by using the 1-hour rain rate without 1-minute rain rate conversion

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Summary
I present the results of the measurements of rain-induced attenuation in the 12.25GHz band during certain rain events, which occurred in the rainy wet season of the year 2001 at Yong-in, Korea (temperate climate). The total experimentally measured attenuation over the link path was measured experimentally has been compared with that obtained using the ITU-R methods. I also propose a prediction model which can predict the rain attenuation in microwave communication systems more conveniently and efficiently, by using the 1-h rain rate data without 1-m rain rate data conversion.
Key words:
Rain attenuation, ITU-R, Prediction model.

1. Introduction

Attenuation or radio frequency signal by clouds, snow and in particular, rains have to be considers at frequency above 10GHz. Among this factors rain become an important limiting factor when operating at tropical region. Therefore, rain rate data and rain attenuation prediction models are being required for establishing any microwave communication systems.

Many rain attenuation prediction models have been developed including the ITU-R methods [3][4], in order to permit the design of effect microwave communication systems. I have been measuring a satellite system in the 12.25GHz band [5]. Then to provide analysis, the experimental data was compared with that obtained using typical rain attenuation models, such as the ITU-R model [3,4], the SAM model [6] and the Global model [7].

It is recommended in the ITU-R methods, that the rainfall be measured at intervals of one minute, in order to determine the rain rate [4]. However, in many countries, it is practically impossible to obtain 1-min rain rate data over period of several years. Moreover, it is inconvenient to convert the available data into a 1-min rain rate and to apply this to a rain attenuation prediction model.

For this reason, in this paper I propose a 1-h rain rate-based attenuation prediction model, in order to provide a more convenient and efficient method of predicting rain attenuation.

Manuscript received March 25, 2006.
Manuscript revised March 30 , 2006.

2. Measured beacon signal and rain rate

In this study, I selected Koreasat-3, which uses the Ku-band frequency, and analyzed the beacon signal level data according to the rain rate from June to August in 2001 [5].

To measure the rain rate, I used the rain measurement system, 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 Figs. 1 and 2.

As shown in Fig. 1, the accumulated rain rate data is first collected in a data collector and is then saved in a computer. The rain rate data may be saved in either 10-min or 10-sec intervals. Since 10-min interval data was not sufficiently accurate for use with the satellite beacon signal level, the 10-sec interval data collection was used.
The experimental system saves the received beacon signal level at intervals of 1-min, as shown in Fig. 2.

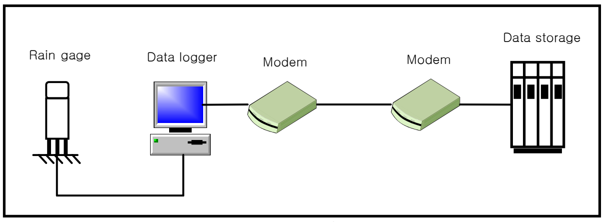

Fig. 1 Experimental system used for measuring the rain rate

Table 1: Rain gauge

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

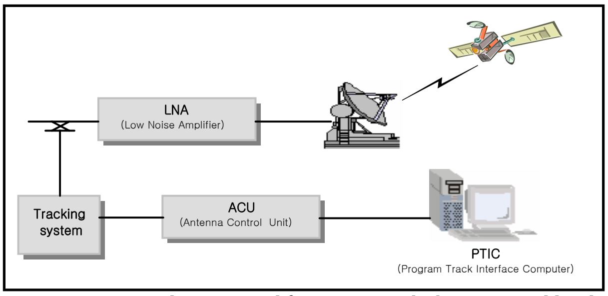

Fig. 2 Experimental system used for measuring the beacon signal level

Table 2: LNA specifications

Parameter	Characteristic
Model	LKA-12070-1-2
Band width	11.7 GHz ~ 12.75 GHz
Gain	> 50dB (Minimum)

Table 3: Experimental specifications

System location	Latitude(Yong-in)	37° 43’
	Longitude(Koreasat-3)	116°
	Elevation angle	45° 20’
	Sea level	0.142km
Climatic zone	ITU-R model	K-zone
Polarization	Transmitter	Dual Linear
	Receiver	Dual Linear
Beacon frequency	12.25GHz (Down Link)	

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

Table 4: Antenna specifications

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

The amount of attenuation due to rain over the path was estimated by measuring the excess attenuation compared to the 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]

$$A = \alpha L \quad \text{[dB]} \qquad (1)$$

where α is the specific attenuation of the rain volume, expressed in decibels per kilometer. The specific attenuation can be calculated using the raindrop size distribution. The relation between the specific attenuation α and rain rate R, is given by Olsen et al. [10] as

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

The values of coefficient a and b depend upon the frequency, rain temperature and drop size distribution. In the present work, the coefficients a, b and L were chosen for the ITU-R model at a frequency of 12.25GHz, by comparing the measured values of the rain attenuation over the link path.

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.

Table 5: 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

3. Proposed of prediction model

It is recommended in the ITU-R model to measure the rainfall at 1-min intervals, in order to determine or anticipate the rain rate[4]. However, in many countries including Korea, it is very difficult to obtain 1-min rain rate data for a period of several years. Furthermore, the 1-h rain rate data needs to be converted, in order to be able to apply it to the rain attenuation prediction model. Thus, in this paper, I propose to use A_{PH} as determined by Expression (3) on the basis of the ITU-R model, and which can predict rain attenuation more conveniently and efficiently, by using the 1-h rain rate without conversion. Then, K_H is used as a compensatory factor, in order to approximate the surveyed results. Also, to convert the 1-min rain rate data into the 1-h rain rate data, Yang-Su Kim et al.'s model [11], which is a modified from of the Moupfouma-Martin model [12] which takes into consideration the Korean rain environment, was used.

$$A_{PH} = A_{ITU-R\ \text{model}} - K_H \quad [\text{dB}] \qquad (3)$$

where $A_{ITU-R\,\text{model}}$ is rain attenuation prediction value obtained from the ITU-R model, and K_H is a compensatory factor.

To determine the compensatory factor, K_H, the 1-min rain rate data at the time of the survey was converted into the 1-h rain rate data and then the rain attenuation was predicted using the ITU-R model. The prediction results are shown in Fig. 3.

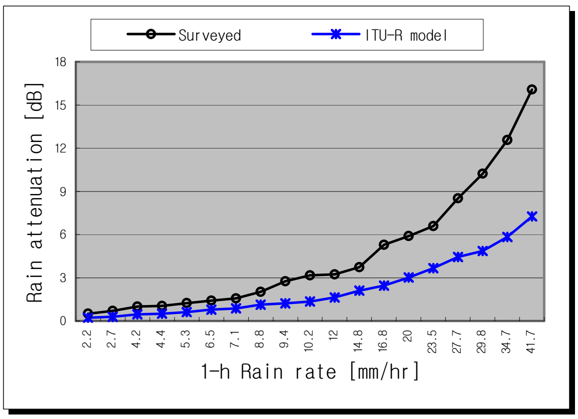

Fig. 3 Comparison of surveyed attenuation values and 1-h rain rate-based attenuation prediction values

Based on the result shown in Fig. 3, it can be seen that the error between the surveyed attenuation value and the ITU-R model prediction value using the 1-h rain rate converted from the 1-min rain rate ranged from a minimum of -0.2864dB to a maximum -8.8035dB. Also, the absolute mean error was 2.3595dB and the absolute error standard deviation was 2.3706, suggesting that there was a big error in the predicted value.

Fig. 4 shows the result of the regression analysis of the error between the surveyed attenuation value and the rain attenuation prediction value of the 1-h rain rate-based ITU-R model in order to determine the value of K_H.

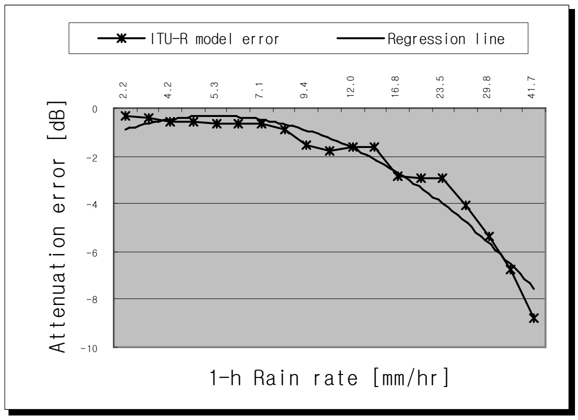

Fig. 4 Regression analysis result of the error of the 1-h rain rate-based ITU-R model prediction value

Equation (4), which represents a regression distribution curve was modeled mathematically, was decided as a compensation factor K_H.

$$K_H = -0.25666 - (0.060952 \times R_H) - (0.0034327 \times R_H{}^2) \quad [\text{dB}] \qquad (4)$$

where R_H is the 1-h rain rate [㎜/hr].

In order to predict the rain attenuation in Korea more conveniently and efficiently by means of the compensatory factor K_H, so determined, this paper proposes a rain attenuation prediction model, A_{PH}, as described in Expression (5).

$$A_{PH} = A_{ITU-R\ \text{model}} - \{-0.25666 - (0.060952 \times R_H) - (0.0034327 \times R_H{}^2)\} \quad [\text{dB}] \qquad (5)$$

Fig. 5 shows the simulation result for the rain attenuation prediction model [Expression (5)] on the basis of the specifications given in Table 3.

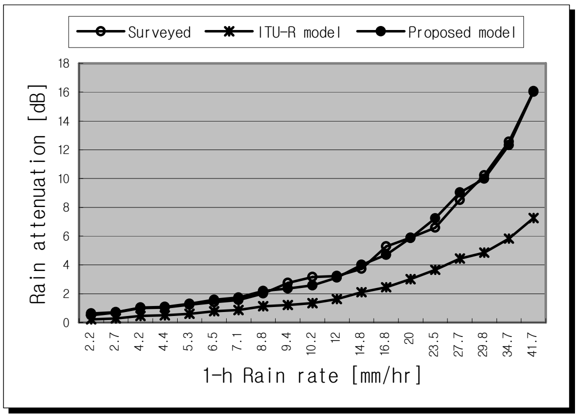

Fig. 5. Simulation result for the proposed rain attenuation prediction model (A_{PH})

Based on the result shown in Fig. 5, the error in the prediction value based on the surveyed attenuation value ranged from a minimum of -0.2864dB to a maximum of -8.8035dB for the ITU-R model, whereas that for the proposed rain attenuation prediction model ranged from a minimum of +0.0193dB to a maximum of +0.6486dB, thus demonstrating a considerable decrease in the case of the proposed rain attenuation prediction model. In addition, the absolute mean error decreased from 2.3595dB to 0.2362dB and the absolute error standard deviation decreased from 2.3706 to 0.2118. These results demonstrate reasonableness of the compensatory factory, K_H .

4. Summary and conclusion

It is recommended in the ITU-R model that a 1-min interval be used to measure rainfall, in order to determine or anticipate the rain rate. However, in practice, it is very difficult to maintain 1-min rain rate data over a period of several years. Furthermore, the 1-h rain rate data needs to be converted into 1-min rain rate data, in order to apply this information to the existing rain attenuation prediction models. In order to overcome thus inconvenience, in this paper, I propose a novel prediction model, which can be used to predict rain attenuation more conveniently and efficiently for in microwave communication systems, using the 1-h rain rate data without 1-min rain rate data conversion.

From the comparison of the proposed prediction model with the ITU-R model, based on the measured rain attenuation values, it was found that the proposed model was able to reduce the values of the absolute mean error and the absolute error standard deviation (by 2.1233dB and 2.1588, respectively).

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