Conversion of Rain Rate Cumulative Distributions by Multiple Regression Model

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다중회기모형에 의한 강우강도 누적분포의 변환

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ABSTRACT

At frequencies above 10 GHz, rain is a dominant propagation phenomenon on satellite link attenuation. The prediction of rain attenuation is based on the point rainfall rate for 0.01 % of an average year with one minute integration time. Most of available rain data have been measured with 60 minutes integration time, and many researchers have been studying on converting the rainfall rate data from various integration times to one minute integration time. This paper proposes a new Multiple Regression model for the conversion, and the proposed schemes show better performance than the existing schemes.

Key Words : Rainfall rate, CF-PL, LG, Multiple Regression.

요 약

10 GHz 이상의 주파수에서는 강우가 위성링크감쇠의 유력한 전달현상이다. 강우감쇠를 예측하기 위해서는 평균년의 0.01%를 초과하는 1분단위로 누적된 강우율이 필요하다. 대부분의 강우데이터는 60분 누적시간으로 측정되었기 때문에, 강우데이터를 다수의 누적시간으로부터 1분 누적시간으로 변환하는 연구가 많이 수행되었다. 이 논문은 새로운 변환 모델인 다중회기모형을 제안하며, 제안 방안은 기존 방안보다 우수한 성능을 보여 주었다.

I. Introduction

Rain attenuation is one of the most important parameters for the satellite link design, and it can be estimated using rainfall rates exceeded 0.01% with 1 minute integration time [1]. The availability of the 1-minute rainfall rate data is limited, and there have been many studies about converting rainfall rate from various integration times to one minute [2,3].

The Power Law method (PL) belongs to the current ITU-R method [1], and proposes a set of coefficients for the conversion of rainfall statistics for selected integration times in the five to 30 minutes interval [3]. The Conversion Factor modeled with Power Law (CF-PL) uses a conversion factor defined as the ratio between equiprobable rain rates, and it is modeled as a function of the probability of exceeding the given rates, and approximated by means of a power law with power and exponential components [3]. The Lavergnat and Golé semi-empirical method (LG) involves the scaling of a conversion factor by a single, site-dependent parameter applicable regardless of the considered integration times [4].

The mentioned models suggest global coefficients, and they are not effective for a specific region and their r.m.s errors are not small enough. To alleviate the problems from the existing models, this paper proposes a Multiple Regression method (MR) to convert rainfall rate cumulative distributions from various integration times to one minute with measured database in Seoul, Korea. The comparison among MR, CF-PL and LG methods is investigated under the same conditions, and it is found that the MR model gives the best-fit compliance with the measured data.

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Ⅱ. CF-PL and LG Models

1. CF-PL Method

The power-law model is parameterized by means of a linear regression to the logarithm of the equiprobable rain rates. The CF-PL method uses a conversion factor, and it is modeled as a function of the probability of exceeding the given rain rates, and approximated by means of a power law with power and exponential components.

The conversion factor (CF) depends on probability , and it is defined as

$$CF(P) = a(T)P^{b(T)} = \frac{R_1(P)}{R_T(P)} \quad (1)$$

where T is an integration time (min.), P is a probability, $R_1(P)$ and $R_T(P)$ are rain rate values, exceeded with the same probability P and measured with T integration times, and $a(T)$ and $b(T)$ are integration time dependent coefficients.

2. LG Model

The LG model belongs to the physical-stochastic category, and it is usually mathematically complex and specific to the field of meteorology for weather-forecasting activities. The model involves the scaling of a conversion factor by a single site-dependent parameter, α. The parameter is found in order to give the best conversion performance over all integration times. This is as opposed to the previous case, where a fit was performed separately for each integration time. The LG method is defined by

$$CF = \frac{1}{T} \text{ and } R_1(P) = \frac{R_T(P)}{CF^{\alpha}} \quad (2)$$

where α being an empirical conversion parameter, and $R_1(P)$ and $R_T(P)$ are rain rate values exceeded with the same probability P and measured with T (min.) integration time.

Ⅲ. MR Model

This paper proposes a new scheme called Multiple Regression (MR) method for the conversion based on rainfall rate data measured in Seoul, Korea. It attempts to model the relationship between two or more independent variables. Because the interesting probabilities P are very small, it is necessary to investigate the model at P and $\log P$ values. The MR model is defined as

$$R_1(P) = a_1 + a_2 R_T(P) + a_3 \log P + a_4 R_T(P) \log P \quad (3)$$

where coefficients, a_1, a_2, a_3, a_4 are estimated by using multiple regression.

Ⅳ. Simulation Results and Discussion

We exploited the rainfall rates data measured with 1 minute and 60 minutes integration times separately in Seoul, Korea from 2000 to 2012.

Table 1 shows the 1 minute and 60 minutes measured rainfall rates exceeded at 0.01 % with respect to averaging years. For example, the measured data in 2012 for 3 averaging years are based on 2010, 2011 and 2012 data.

Table 1. Rainfall rate data measured in Seoul.

year	1 year		3 years		5 years		7 years	
	R_{60}	R_1	R_{60}	R_1	R_{60}	R_1	R_{60}	R_1
2000	43.8	60						
2001	93.9	120						
2002	53.1	90	54.9	120				
2003	65.8	90	61.0	120				
2004	39.0	90	53.1	120	53.4	120		
2005	49.3	90	50.9	120	53.4	120		
2006	42.8	90	44.0	120	48.6	120	52.0	120
2007	28.5	90	44.0	120	46.5	120	52.0	120
2008	34.5	90	39.9	120	40.1	120	46.5	120
2009	39.7	90	33.4	120	40.1	120	42.2	120
2010	71.5	90	62.9	120	44.1	120	44.7	120
2011	58.5	90	62.9	120	54.3	120	48.7	120
2012	70.6	90	67.0	120	59.4	120	48.6	120

Tables 2 shows the empirical parameters for CF-PL and LG models obtained by regression using the measured data, and Table 3 shows the parameters for MR model.

Table 2. Coefficients for CF-PL and LG models.

Averaging years	CF-PL		LG
	a	b	α
1 year	0.99	-0.05	0.109
3 years	1	-0.05	0.194
5 years	1	-0.05	0.230
7 years	1	-0.05	0.230

Table 3. Coefficients for MR model.

Averaging years	MR model			
	a_1	a_2	a_3	a_4
1 year	2	-2.3	-4.9	0.9
3 years	2	-2.6	-4.9	-1.1
5 years	2	1.6	-4.9	-0.1
7 years	0	-3.9	-4.9	-1.5

The relative error (%) for each probability and integration times is calculated using

$$\varepsilon(P,T) = 100\frac{R_e(P,T)_1 - R_m(P)_1}{R_m(P)_1} \quad (\%) \tag{4}$$

where $R_m(P)_1$ is the measured rain rate with 1-minute integration time and $R_e(P,T)_1$ is the rain rate estimated with 1-minute integration time using T minute integration time.

The performance of each conversion model is evaluated by the RMS values of $\varepsilon(P,T)$. Table 4 shows RMS of exceeded at 0.01% for CF-PL, LG and MR models, and it is observed that the ML model shows the smallest RMS errors.

Table 4. Comparison among CF-PL, LG, MR at 0.01% probability.

Averaging years	CF-PL	LG	MR
1 year	26.45	56.27	18.74
3 years	34.50	121.33	16.00
5 years	36.97	141.38	10.61
7 years	37.67	149.66	5.91

V. Conclusion

This paper proposes a multiple regression model for conversion of rainfall rate cumulative distribution exceeded 0.01 % from 60 minutes to one minute using recent 13 year's rainfall rate data measured in Seoul, Korea. It is observed that the proposed multiple regression model shows better results than LG model and CF-PL models.

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