Prediction of Regional Rain Attenuation Using Hourly Rain-Rate Data

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ABSTRACT

Rain attenuation can have a serious impact on the availability of radio communication services operating in the frequencies above 10 GHz. For higher frequencies, more rain impairments occur on the communication links. In order to predict reliable rain attenuation for a given location, an appropriate distribution of rainfall rate for the site is required. The international limitations of rain rate distribution in predicting rain attenuation are in long-term (typically more than consecutive 10 years) measurement with 1-minute integration time.

Since it is impossible to collect long-term measured 1-minute rainfall data on a regional basis of Korea, ETRI developed an efficient conversion process for predicting one-minute rainfall rate distribution from that for different integration time data. Using the conversion method and regional hourly data of rainfalls, it is possible to predict useful rain attenuation characteristics at several locations in Korea.

This paper introduces an efficient conversion method for time probability of one-minute rainfall rate from that for integration time great than one-minute. Based on 10-year rain-rate measurements for 1-hour integration collected at 6 major cities in Korea, distributions of regional rain attenuation on Ka-band satellite links are estimated by ETRI rain attenuation model, and link margins for those locations are discussed in this paper.

1. INTRODUCTIONS

In order to satisfy increasing satellite communications by Koreasat, the Ka-band frequencies will be introduced in the existing Ku-band satellite system. At the frequencies above 10 GHz, however, the attenuation values due to rain has a serious problem in the design of the communication systems. To determine the likely levels of signal impairments for a given available time percentage of year, system designers make use of predictive models, the most widely applied being those of the ITU-R[1], although other models[2][3] [4] including ETRI developed are competitive in predicting rain fading. Those models suggest prediction methods of rain attenuation as a function of rain rate for a given annual time probability. Thus, they are used to estimate system availability in considering rain impairments.

The rain rate distribution has international limitation[1][5] to derive, which are on the measurement period of long-term (typically more than consecutive 10 years) and the integration time of 1-minute. However, it is almost impossible to collect long-term measurement data with 1-minute integration time in Korean locations. Most of the keeping rainfall data were measured with 20-minute or higher integration time.

Considering such a situation in Korea, ETRI conducted to develop an efficient conversion algorithm of 1-minute rain rate statistics from various integration time data.

2. RAIN-RATE DISTRIBUTIONS

Rain-rate distribution is most important factor in estimating rain attenuation on terrestrial or satellite links. According to the ITU-R recommendation[1], long-term measurements with 1-minute or less integration time are required to use a rain attenuation method.

In order to resolve the limitation problems, ETRI developed an efficient conversion method of 1-min rain-rate statistics from various integration time data[6]. The converting process would be started by collecting long-term measurements with an arbitrary integration time higher than 1 minute.

[Step 1] Observed Hourly Distributions

The Korean Meteorological Agency has been collecting a lot of measurements of rainfall with an hour integration time from AWS (Automatic Weather System) on various locations in Korea. Using the KMA records of rainfall, ETRI conducted to access 10-years (1990 to 1999) hourly measurements of 6 major cities in Korea, and analyse the regional distributions. Figure 1 shows the observed rain-rate distributions of annual average data.

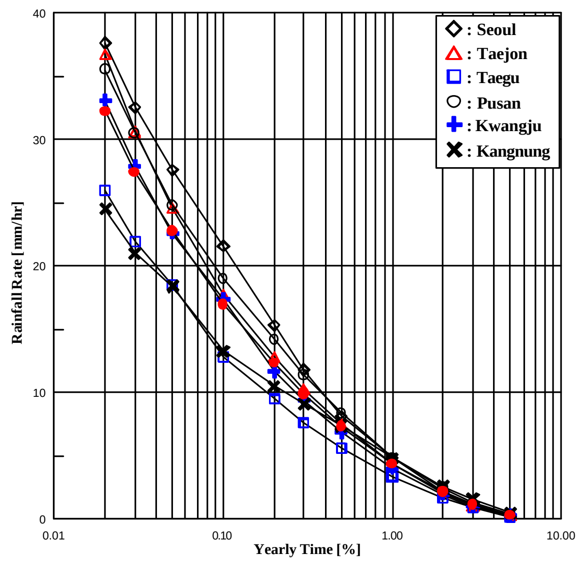


Fig. 1. Observed Distributions of Hourly Rain-Rate

[Step 2] Approximated Hourly Distributions

Observed rain-rate distribution usually would be approximated by a specific distribution function[7]. Adoption of most appropriate distribution coefficients for each location introduced the well-defined distributions as shown in Figure 2.

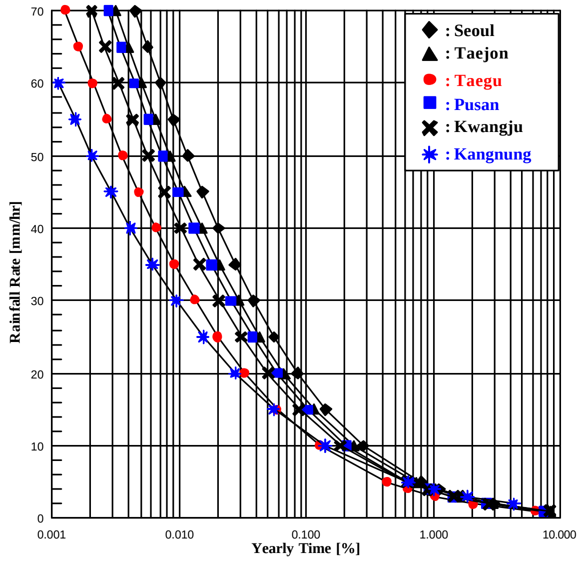


Fig. 2. Approximated Hourly Distributions

[Step 3] Converted to 1-min Distributions

Based on the ETRI conversion method of rainfall statistics[6], the conversion coefficients of 1-minute distribution from hourly data were leaded 1.217 of slope and –0.186 of interception in logarithmic scale case.

Thus, the equivalent 1-min rain rate distributions of regional hourly data would be obtained by the leading coefficients as shown in Figure 3. These distributions can be considered as efficient regional rain rate characteristics for 1-minute integration time.

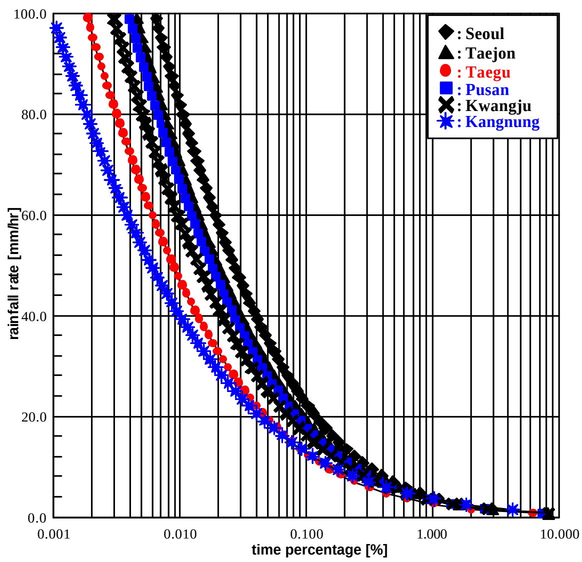


Fig. 3. Converted 1-Minute Distributions

3. RAIN ATTENUATION MODEL

The most difficult parameter in an attenuation model (see eq.(1)) is the spatial distribution of rain. Radar measurements indicate that most precipitation is characterized by varying horizontal and vertical structures[8]. For this reason, correction factors for horizontal as well as vertical rain paths are required in modeling path length of rain attenuation on a satellite link

Considering the above phenomenon, ETRI developed a prediction model of rain attenuation, which is appropriate to Korean rain condition.

Proposed ETRI model includes the following two factors ;

i) horizontal correction factor :

$$F_H = 0.158 + 0.837 \times e^{-R/130.14} \quad (1)$$

ii) vertical correction factor :

$$F_V = 4.175 \times R^{-0.409} \quad (2)$$

With the above factors, an empirical prediction model for the effective path length on the earth-satellite link as shown in Figure 4, could be obtained by ;

$$L_{eff} = L_S \times F_S \quad (3)$$

where, F_S indicates the correction factor for the slant path, which is calculated from following equation:

$$F_S = \sqrt{(F_H \cdot \cos q)^2 + (F_V \cdot \sin q)^2} \quad (4)$$

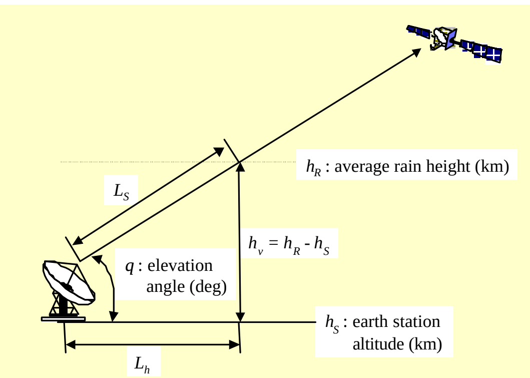


Figure 4. Path Diagram of Earth-Satellite Radio Link

And finally, rain attenuation value(A_p, dB) for a given time percentage which is crosely related to rain rate can be estimated as ;

$$A_p = aR^b \times L_{eff} \quad (5)$$

where, the coefficients *a* and *b* were given in ITU-R recommendation[9].

4. PREDICTIONS

Using the regional rain-rate distributions for Korean major cities, as shown in Figure 3, predictions of regional rain attenuation for uplink and downlink Ka-band frequencies were carried out.

In accordance with the estimation procedure of rain attenuation, described on section 3, regional distribution of rain attenuation would be obtained as shown in Table 1 and Figure 5.

Table 1. Estimated Attenuation in Yearly Time[dB]

(1-a) for 20 GHz System

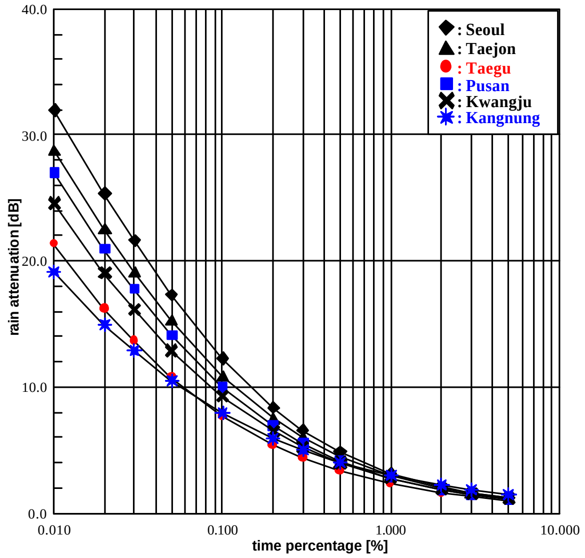
City Name	1.0 %	0.1 %	0.01 %
SEOUL	3.2	12.3	32.0
TAEJON	3.0	10.9	28.8
TAEGU	2.3	7.7	21.3
PUSAN	2.8	10.0	27.0
KWANGJU	2.8	9.2	24.6
KANGNUNG	3.0	7.9	19.1

(1-b) for 30 GHz System

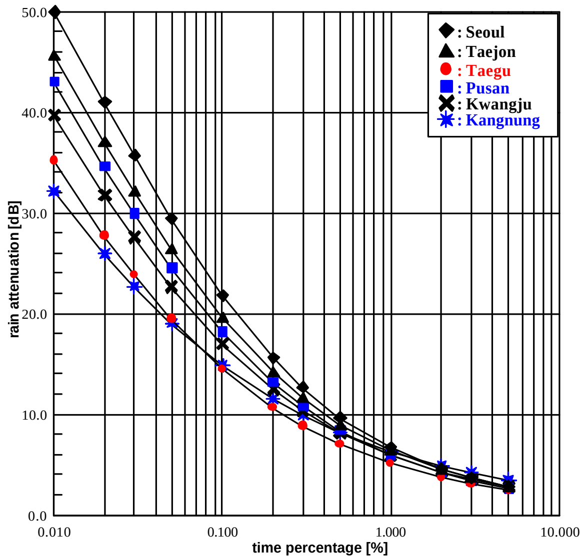
City Name	1.0 %	0.1 %	0.01 %
SEOUL	6.7	21.8	50.0
TAEJON	6.4	19.6	45.7
TAEGU	5.1	14.5	35.2
PUSAN	6.0	18.2	43.0
KWANGJU	5.9	17.0	39.7
KANGNUNG	6.3	14.9	32.1

Based on this analysis, most value of attenuation will be occurred on SEOUL to satellite link, and least one taken place on a KANGNUNG – satellite path, for 0.01 % of yearly time percentage.

And a normal power control with 15 dB power margin introduces 99.95 % ~ 99.98 % of available time on downlinks, 99.8 % ~ 99.9 % on uplinks. Therefore, Ka-band satellite systems which consructed at high attenuated locations such as SEOUL, TAEJON, PUSAN, etc. requires other compensation technologies to serve the safe communication service for 99.99 % available time.



(Fig. 5a) for 20 GHz System



(Fig. 5b) for 30 GHz System

Fig. 5. Regional Characteristics of Rain Attenuation

5. CONCLUSIONS

In this paper, prediction of rain attenuation value from hourly rain rate data.

In order to overcome the international limitations of rain rate distribution, an effective conversion method, ETRI developed, of 1-minute rain rate statistics from other integration time data was used in obtaining regional 1-minute rain rate distributions. And in estimating rain attenuation on Korean regional links, recently developed model of rain effective path length, which includes a horizontal and vertical adjustment factors, was used.

Since the estimated values of rain attenuation showed different characteristics for interesting location, link margin should be considered differently for each region in the design of satellite system.

Based on this analysis, typical Ka-band satellite systems in Korean territory usually can have about 99.75 % of link availability with 15 dB margins. In case of heavy rain location, the link availability is possible to be getting worse, thus an extra compensation method such as diversity is needed to have better link availability.

6. REFERENCES

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