COMPARISON OF PREDICTED RAIN ATTENUATION BY ITU-R-METHODS WITH MEASURED DATA

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1. Introduction

We have been studying on the system design for satellite digital broadcasting system in the 21-GHz band [1]. The required rain attenuation margin can be determined from the required service availability of satellite broadcasting. It is interesting to compare the required service availability in the 21-GHz band with the service availability in the 12-GHz band. Hence , the relationship between the rain attenuations of 12-GHz and 21-GHz bands is very important as well as the prediction of the 21GHz band rain attenuation itself.

The International Telecommunication Union Radio Communication (ITU-R) recommends a method to predict rain attenuation in its recommendation of P.618.

In Section 2 of this paper, predicted rain attenuation in the 12-GHz and the 21-GHz bands for Tokyo and Osaka (two big cities in Japan) and measured results of rain attenuation in the 12-GHz band for both areas are presented. In Section 3, comparison of predicted rain attenuation by the ITU-R methods with measured data in the 12-GHz band is conducted. It is shown that the prediction result using the old version of Rec.P.618(Rec.P.618-5) better fits the measured rain attenuation data for Tokyo and Osaka. It is also shown that the latest prediction method (Rec.P.618-8) has inconsistency in the prediction results of rain attenuation between the 12-GHz and the 21-GHz bands.

2. Rain Attenuation Prediction Method and Measurement

2.1 Rain Attenuation Prediction Method by the ITU-R

The Rec.ITU-R P.618 describes a prediction method of rain attenuation for earth-space telecommunication systems in its section 2.2.1.1. The latest version is Rec.P.618-8[2], which has been in force since 2003. The rain attenuation prediction for the 12-GHz band by Rec.P.618-8 is considerably different from that by the old version of Rec.P.618-5 [3] as shown later.

In this paper, the time percentage of the rain attenuation from 0.01 % to 1.0 % in Tokyo and Osaka were evaluated in the 12-GHz and 21-GHz bands. Parameters for the prediction are shown in Table 1. $R_{0.01}$ is a 1-minute rain rate at time percentage of 0.01 % measured in each location. The $R_{0.01}$ of 70.9 mm/h for Tokyo was derived from 3-year measurement(2000-2002) and 47.5 mm/h for Osaka was derived from 8-year measurement(1988-1995)[4].

The prediction results of rain attenuation by using Rec P.618-8 and Rec.P.618-5 are shown in Figure 1.

Table 1 Conditions for prediction of rain attenuation by Rec. P.618

Predicting Site	Tokyo(Setagaya)	Osaka(Neyagawa)
Location	E 139.64° N 35.62°	E 135.63° N 34.67°
Antenna Elevation Angle	38.0°	41.4°
R0.01	70.9 mm/h	47.5 mm/h

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2.2 Measured Rain attenuation

Table 2 shows the conditions of measured data in Tokyo and Osaka. The condition of measured rain attenuation data in Osaka was referred to [4],[5]. The measured results are shown in Figure 1.

Table 2 Conditions of measured rain attenuation data

Measureing Site	Tokyo(Setagaya)	Osaka(Neyagawa)
Location	E 139.64° N 35.62°	E 135.63° N 34.67°
Antenna Elevation Angle	38.0°	41.4°
Reception Antenna Diameter	0.65 m	1.2 m
Recetpion Dynamic Range	20 dB	25 dB
Sampling Rate	1 sec	1 minute
Observation Period	Apr.2000 - Dec.2003 (About 3 Years)	Jan.1988 - Dec.1995 (8 Years)

3. Comparison among Prediction Results and Measured Rain Attenuation Results

3.1 Comparison between Prediction Results by Rec.P.618-5 and Rec.P.618-8

Comparisons are based on the predicted time percentage difference $d\,(A)$ defined as

$$d(A) = \frac{T_{P.618-5}(A) - T(A)_{P.618-8}}{T(A)_{P.618-5}} \times 100 \qquad (1)$$

where $T_{P.618\text{-}5\,(8)}$ is the predicted time percentage for the same rain attenuation derived by Rec. P.618-5 and Rec.P.618-8 and A represents the rain attenuation. The root-mean-square (r.m.s.) time percentage difference is used as the metric to judge the overall fit of the predictions by both recommendations and is given by

$$d_{r.m.s} = \sqrt{\langle d(A)^2 \rangle} \qquad (2)$$

where < > denotes averaging.

Figure 2 shows $d_{r.m.s.}$ of predicted time percentage of rain attenuation. $d_{r.m.s}$ of the 12-GHz band are 52.7 % for Tokyo, 36.7 % for Osaka and $d_{r.m.s}$ of the 21-GHz band are 18.3 % for Tokyo and 7.8 % for Osaka. From this figure, $d_{r.m.s}$ of the 12-GHz band is found to be much lager than that of the 21-GHz band. Especially in the 12-GHz band, the prediction results of rain attenuation time percentage by Rec. P.618-8 considerably lower than that by Rec. P.618-5.

3.2 Comparison between Prediction Results and Measured Data for Rain Attenuation

From Figure 1, it can be found that the measured data are close to the prediction result by Rec. P.618-5. Comparisons are based on the percentage prediction error $e_{(i)}$ defined as

$$e(i) = \frac{A_p(i) - A_m(i)}{A_m(i)} \times 100 \qquad (3)$$

where A_P is the predicted rain attenuation and A_m is the measured rain attenuation (both in decibels) and i represents the time percentage at which the prediction error is estimated. The root-mean-square (r.m.s.) error is given by

$$e_{r.m.s} = \sqrt{\langle e(i)^2 \rangle} \qquad (4)$$

where < > denotes averaging.

Figure 3 shows $e_{r.m.s.}$ of rain attenuation in the 12-GHz band for Tokyo and Osaka. From this figure, it is found that $e_{r.m.s.}$ by Rec. P.618-5 are 11.3 % for Tokyo and 11.2 % for Osaka. However, $e_{r.m.s.}$ by Rec. P.618-8 are about more than twice as that by Rec. P.618-5 i.e., 35.9 % for Tokyo and 26.0 % for Osaka. These results show that Rec. P.618-5 gives better prediction results compared with Rec. P.618-8 .

3.3 Comparison of Predicted Rain Attenuation between the 12-GHz and 21-GHz bands

Another method to predict rain attenuation is described in Section 2.2.1.2 of Rec.P.618. This method scales rain attenuation of reference by using a function of frequency to retrieve the rain attenuation at another frequency of interest. Figure 4 shows the predicted relationships between rain attenuation in the 12-GHz and the 21-GHz bands for Tokyo and Osaka by using the two methods of Section 2.2.1.1 and 2.2.1.2 of Rec. P.618. From this figure, it is found that (1) the rain attenuation in the 21-GHz band predicted by the method of Section 2.2.1.1 in Rec.P.618-8 considerably differs from the prediction result by the method of its Section 2.2.1.2 and (2) the predicted results obtained by the both two methods in Rec.P.618-5 agree well . This means that Rec.P.618-8 has inconsistencies in its prediction of rain attenuation. It is considered that the reason for this inconsistency is due to the underestimation of rain attenuation in the 12-GHz band predicted by Rec. P.618-8.

4. Conclusion

In this paper, the comparison of prediction results of rain attenuation for Tokyo and Osaka in the 12-GHz and the 21-GHz bands by Rec.P.618 was conducted. It has been found that the prediction results of rain attenuation in the 12-GHz band have considerable difference between the two versions of recommendations of Rec.P.618. By comparing the prediction results in the 12-GHz band with measured data in Tokyo and Osaka, it has been shown that prediction results by old version of Rec. P.618-5 fits well to measured rain attenuation data.

The relationship of rain attenuation between the 12-GHz band and the 21-GHz band was compared. The comparison result has shown that the latest version of Rec. P. 618-8 has inconsistency in the prediction results of rain attenuation due to its underestimation of time percentage of rain attenuation in the 12-GHz band. Further study is needed to resolve this inconsistency.

5. Reference

[1] F.Minematsu et al,"Estimation of Transmitting Power to Compensate for Rain Attenuation for A Broadcasting Satellite System in the 21-GHz band," 53rd International Astronautics Congress, October 2002

[2] Recommendation ITU-R P.618-8, 2003

[3] Recommendation ITU-R P.618-5, 2001

[4] Y.Maekawa et al, "A Study on Rain Attenuation Statistics on Ku-band and Ka-band Satellite-to-Ground Paths," Technical Report of IEICE, A.P96-16, pp.8-9, May 1996

[5] Y.Maekawa et al, " Rain Attenuation Characteristics on Ku-band and Ka-band Satellite-to-Ground Paths related to Cross-polarized phase" Technical Report of IEICE,A.P93-26,SAT93-9,pp20, May 1993

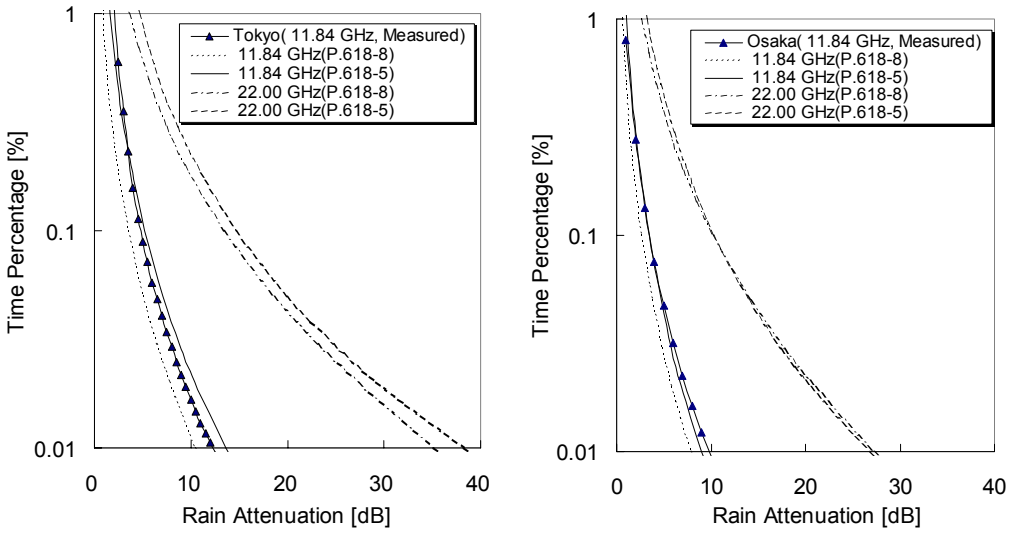

Figure 1 Predicted and measured rain attenuation for Tokyo and Osaka

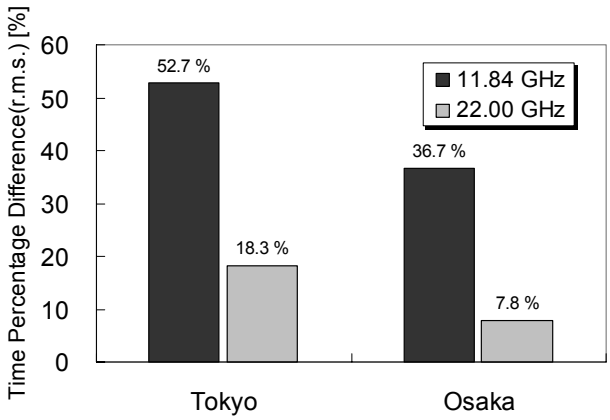

Figure 2 Time percentage difference

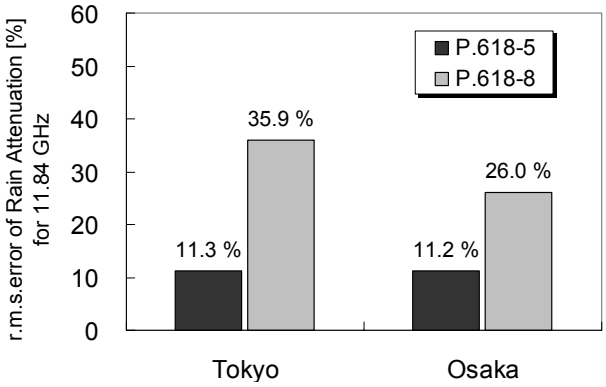

Figure 3 r.m.s. error of rain attenuation

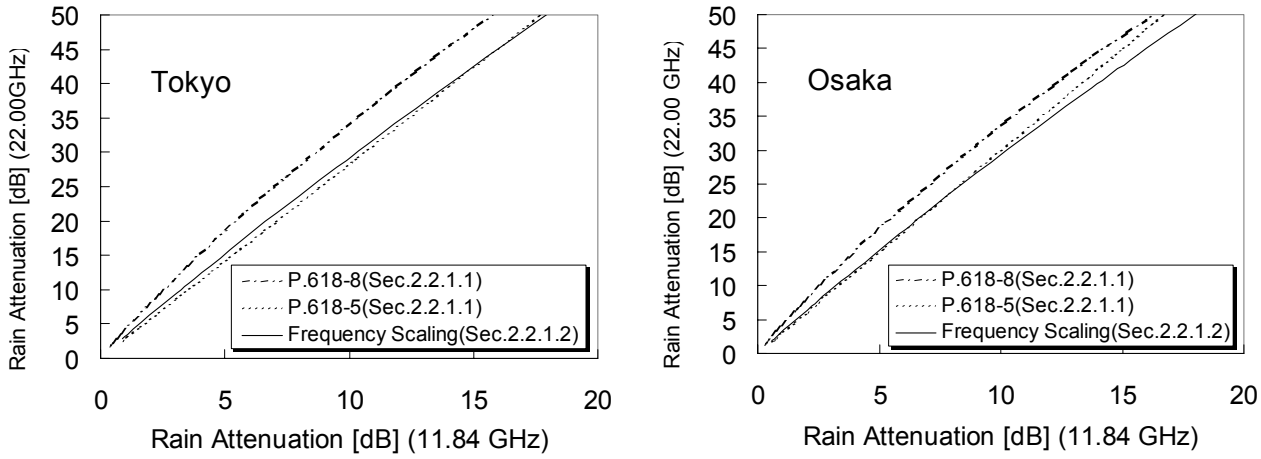

Figure 4 Relationship between predicted rain attenuations in the 12-GHz and the 21-GHz bands