A Study of Rain Attenuation with Measured Data in Japan for 21GHz-band Satellite Broadcasting

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Abstract

21GHz-band satellite broadcasting is expected to provide advanced services such as UHDTV and 3DTV. However, a major challenge is the large RF signal attenuation due to rainfall. In this work, the rainfall rates across Japan and the rain attenuation in the 21-GHz band are investigated based on measured data.

Keywords : 21GHz-band satellite broadcasting rain attenuation AMeDAS

1. Introduction

The band 21.4 − 22.0 GHz is allocated as the downlink of satellite broadcasting in ITU-R Regions 1 (Europe, Africa) and 3 (Asia, Pacific). The 21GHz-band satellite broadcasting is expected to provide advanced services such as Ultra High Definition Television (UHDTV) and 3DTV, etc. NHK STRL is developing a UHDTV, Super Hi-Vision, which has 33 megapixels (7,680 × 4,320 pixels) and 22.2 multichannel sound to give an extremely realistic presentation whereby viewers may feel as though they are actually at the site shown on the screen [1].

A major challenge of the 21GHz-band satellite broadcasting is its large RF signal attenuation due to rainfall. Accurate estimation of rain attenuation will be essential to design a satellite system in the 21-GHz band for providing broadcasting services with sufficient service availability.

In this work, the rainfall rate across Japan were investigated based on measured rainfall data in the Automated Meteorological Data Acquisition System (AMeDAS). Rain attenuation in 12-GHz band measured from 2005 to 2009 in Setagaya, Tokyo was compared to the prediction from the rainfall rate. Comparison of estimated rain attenuation in 21-GHz band between a long-term frequency scaling and prediction from the rainfall rate was also performed.

2. Rainfall rate across Japan

AMeDAS consists of more than 1,000 observation stations in a network developed by the Japan Meteorological Agency is measuring rainfall data with the integration time of 10 minutes. Though rainfall data with an integration time of 1 minute are required for predicting rain attenuation, measured rainfall data can be converted to those with the integration time of 1 minute adequately by applying the conversion method provided in Annex 3 of Recommendation ITU-R P.837-5 [2][3].

On the other hand, a rainfall rate model is presented in Annex 1 of Recommendation ITU-R P.837-5. The rainfall rate at a given point all over the world is calculated from interpolation based on 51,200 points with 1.125° intervals (160 points in latitude × 320 points in longitude).

The rainfall rate $R_{0.01}$ mm/hour from the measured rainfall data from 2005 to 2009 in AMeDAS were compared to that from the model in the Recommendation. Table 1 shows the comparison in some cities and Figure 1 shows the difference of $R_{0.01}$ in 800 observation stations having more than 99% valid rainfall data. This comparison indicates that the values of $R_{0.01}$ from the measured rainfall data were higher than those from the model at the same location for many locations. For example, $R_{0.01}$ in Setagaya, Tokyo was 74.8 mm/hour from the measured rainfall data while that is 48.5 mm/hour from the model.

3. 12GHz-band rain attenuation in Setagaya, Tokyo

NHK STRL is measuring rainfall and rain attenuation in 12-GHz band occurred from a satellite in 110 degree to a receiver in Setagaya, Tokyo independently. Figure 2 shows the comparison of rain attenuation in 11.843 GHz measured from 2005 to 2009 and predicted from rainfall rate by applying calculation methods provided in Recommendation ITU-R P.618-5 and 10 [4][5].

$R_{0.01}$ from 2005 to 2009 obtained by NHK STRL was 69.0 mm/hour and similar to that of 74.5 mm/hour in AMeDAS. The prediction provided in the old version of Recommendation ITU-R P.618-5 was also evaluated because the calculation method for adjustment factors in the slant-path length was different from that provided in the latest version of Recommendation ITU-R P.618-10. The parameters required for the calculation methods provided in Recommendation ITU-R P.618-5 and 10 were derived from the latest relevant ITU-R Recommendations.

Rain attenuation predicted from Recommendation ITU-R P.618-5 was higher than that predicted from Recommendation ITU-R P.618-10 and was in a direction away from that in measured data. However, as for the time percentages of more than 0.035% which are interested in for a service availability of satellite broadcasting, rain attenuation predicted from Recommendation ITU-R P.618-10 was even higher than that in measured data. For example, rain attenuation for 0.1% predicted from Recommendation ITU-R P.618-10 was 3 to 4 dB while that in measured data was 2 to 3 dB.

4. 21-GHz band rain attenuation in Setagaya, Tokyo

The 21GHz-band satellite broadcasting is expected to provide advanced services. In particular, NHK STRL believes that 21GHz-band satellite broadcasting is appropriate for delivering Super Hi-Vision since it has a capability for a large transmission capacity. To design an adequate satellite system for the 21GHz-band satellite broadcasting, it is desirable to estimate accurate rain attenuation in the 21-GHz band.

In addition to the prediction from the rainfall rate, rain attenuation in the 21-GHz band can be derived from that in the 12-GHz band by applying a long-term frequency scaling provided in Recommendation ITU-R P.618-10. The Recommendation mentions that the frequency scaling from measured data is preferred rather than the prediction from the rainfall rate. The frequency scaling method is expressed in equations (1). Here, A_1 and A_2 are the equiprobable values of the excess rain attenuation at frequencies f_1 and f_2 (GHz), respectively.

$$A_2 = A_1 (\varphi_2 / \varphi_1)^{1-1.12\times10^{-3} (\varphi_2/\varphi_1)^{0.5} (\varphi_1 A_1)^{0.55}} \qquad \text{where: } \varphi(f) = \frac{f^2}{1+10^{-4} f^2} \qquad (1)$$

Figure 3 shows the rain attenuation in 21.7 GHz estimated by the frequency scaling from rain attenuation measured in 11.843 GHz and by the prediction from the rainfall rate provided in Recommendation ITU-R P.618-10. The orbital position of the 21GHz-band satellite is 110 degree corresponding to that of the 12GHz-band satellite.

Rain attenuation predicted from the rainfall rate was considerably higher than that estimated by the frequency scaling. For example, when considering a time percentage of 0.1%, rain attenuation of about 13 dB was predicted from the rainfall rate while that of about 8 dB was estimated by the frequency scaling. It means that the requirement of 21GHz-band satellite e.i.r.p. consists of an antenna gain and RF power will be more than three times higher considering rain attenuation predicted from the rainfall rate than considering that estimated by the frequency scaling.

5. Conclusion

The rainfall rate across Japan were investigated based on measured rainfall data from 2005 to 2009 in AMeDAS. The values of $R_{0.01}$ from the measured rainfall data were higher than those from the rainfall model presented in Annex 1 of Recommendation ITU-R P.837-5 at the same location for many locations.

Rain attenuation in 12-GHz band measured from 2005 to 2009 in Setagaya, Tokyo was compared to that predicted from the rainfall rate. Rain attenuation predicted from Recommendation ITU-R P.618-10 came close to that in measured data compared to that predicted from Recommendation ITU-R P.618-5, however, it even higher than that in measured data as for the time percentages of more than 0.035% which are interested in for a service availability of satellite broadcasting. Rain attenuation in Setagaya, Tokyo in the 21-GHz band was also estimated by the frequency scaling from rain attenuation measured in the 12-GHz band and by the prediction from the rainfall rate provided in Recommendation ITU-R P.618-10. Rain attenuation predicted from the rainfall rate was considerably higher than that estimated by the frequency scaling.

It is efficient to predict rain attenuation from the rainfall rate because the rainfall rate measured across Japan can be available. However, this study results show a possibility that the prediction from the rainfall rate provided in Recommendation ITU-R P.618-10 may overestimate rain attenuation, especially in the 21-GHz band. For a future work, long-term measurement of rain attenuation in other cities in these frequency bands will be needed to evaluate and improve the prediction from the rainfall rate.

Table 1: Comparison between the rainfall rate $R_{0.01}$ mm/hour in some cities from the measured rainfall data from 2005 to 2009 in AMeDAS and from the rainfall rate model

City	Setagaya	Osaka	Fukuoka	Naha
Location	Lat.: 35.627 Long.:139.62	Lat.: 34.682 Long.:135.52	Lat.: 33.582 Long.:130.38	Lat.: 26.207 Long.:127.69
$R_{0.01}$ mm/hour in measured data	74.8	53.6	83.4	100.8
$R_{0.01}$ mm/hour in rainfall rate model	48.5	53.9	59.6	76.7
Delta	+54%	0%	+40%	+31%

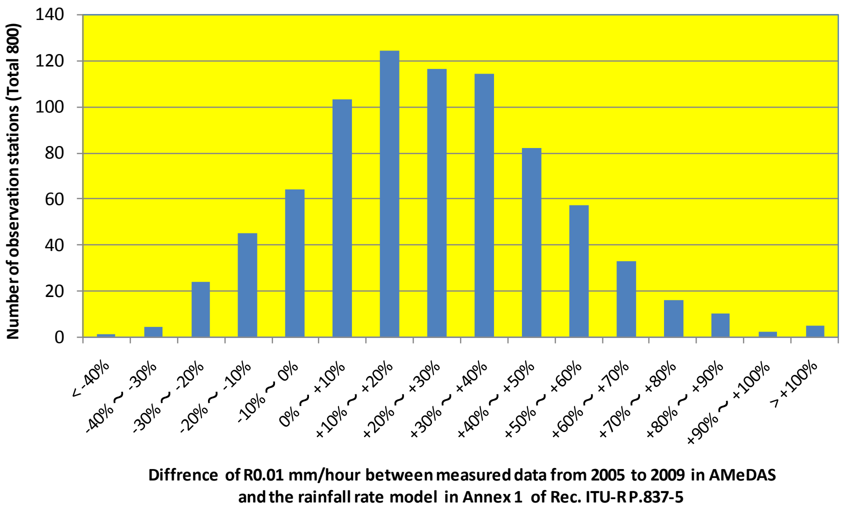

Figure 1: Difference of $R_{0.01}$ mm/hour between measured data from 2005 to 2009 and the model

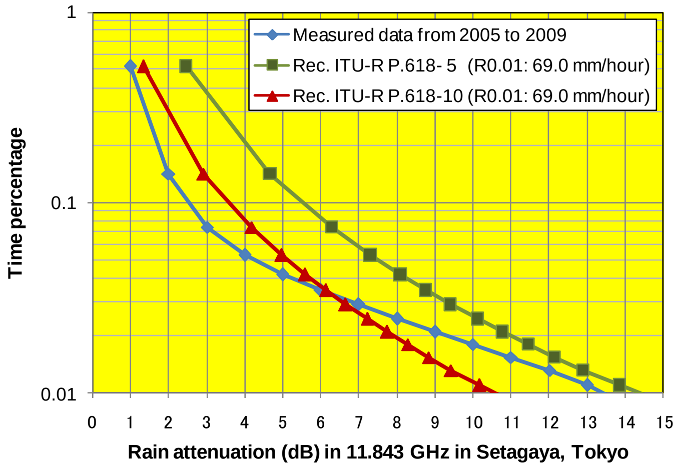

Figure 2: Comparison of rain attenuation in 11.843 GHz in Setagaya, Tokyo between measured data and prediction from rainfall rate in Rec. ITU-R P.618-10 and 5

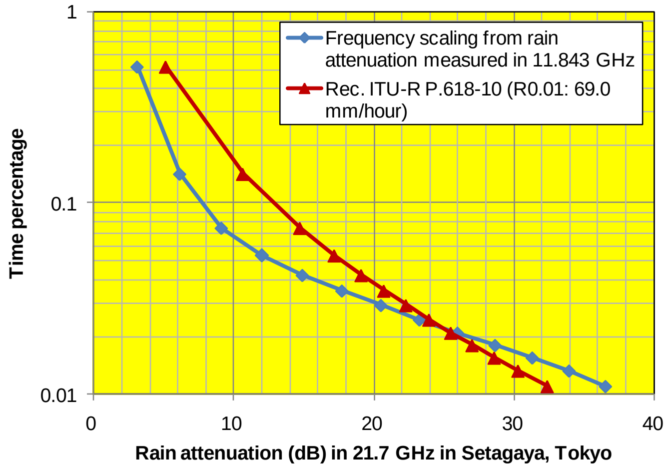

Figure 3: Rain attenuation in 21.7 GHz n Setagaya, Tokyo estimated by the frequency scaling from rain attenuation measured in 11.843 GHz and by the prediction from the rainfall rate

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