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Quantitative Evaluation of Adaptive Satellite Power Control using Japanese Rain Radar Data

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1. Introduction

In order to realize future large-capacity, high-speed and highly advanced multimedia satellite communication and broadcasting systems, utilization of Ka-, Q-, V- and even W-bands radio wave is indispensable. In such radio link, performance degradation due to rain-induced attenuation and noise increase, gaseous attenuation, rain- or ice-induced depolarization and interference from other systems is expected. Above all, rain attenuation is the most significant factor for link performance. This is the reason that attenuation mitigation becomes very important. To cope with such large attenuation events, powerful attenuation mitigation technologies should be developed. Attenuation mitigation methods are roughly classified into the following three categories as shown in Table 1;

- **Static methods** such as margin increase in transmitter and receiver system. These are not suitable in the system in which large attenuation is expected.
- **Adaptive methods** such as adaptive EIRP allocation toward the area suffered from large attenuation. They are effective in large attenuation case within a limit of total resource capability such as satellite total power.
- **Diversity methods** such as site- and time-diversity. They prepare several redundant links which have low attenuation correlation and adopt the best performance link selectively.

In this paper, we assume adaptive satellite power control method by which satellite transmitting power for relevant area is increased using multi-beams or modified beam pattern as shown in Fig.1. The effect of this method is evaluated by using rain-radar data obtained in Japan. Especially, link performance within a beam is evaluated.

2. Data Used and Analysis

2.1 Data Used

In this analysis we use rain-radar measurement data(Radar-AMeDAS) produced by Japanese Meteorological Office and distributed by Japan Meteorological Business Support Center. The data covers all over Japan and rainfall rate is stored in each about 1km mesh point. In Fig.2, sample of measured data is displayed on Japanese map. There are two kinds of data set as follows;
- **1-hour data** : Data are stored every 30 minutes and data indicates rainfall rate during past 1 hour
- **5-minutes data**(Now-cast data) : Data are stored every 5minutes and data indicates rainfall rate during past 5 minutes

We mainly use above 1-hour data for derivation of long-term statistics over from 2005 to 2010. The 5-minutes data are used for event analysis rather than statistical analysis.

2.2 Adaptive Power Control Schemes and Analysis

We assumed the following adaptive power control scheme:
- **Beam size**: 50,100 and 200km beam sizes (Although real beam shape may be circle, evaluation is done using square shape as shown in Fig.3.)
- **Analysed area**: Kanto area as shown in Fig.3

As feedback scheme for adaptive control, the following two methods are assumed:
- **Average Method**: Attenuation averaged within the beam should be compensated.
- **Monitor Method**: Real attenuation at monitor station located within the beam should be compensated. Concept of the monitor method is shown in Fig.4.

3. Place and Time Distributions

Of course, rain-induced attenuation directly affects link performance. However it is easy to transform from rainfall rate to attenuation at arbitrary frequencies by using ITU recommendations or many proposed literature such as reference [1], then we mainly treat rainfall rate data in this paper. As preliminary analysis, we derived cumulative place distributions of rainfall rate in Kanto and Okinawa areas using radar data as shown in Fig.5. Place distribution means data distribution among rainfall rates at mesh points in Kanto and Okinawa area. Similar to time distribution, reasonable local dependence can be observed from Fig.5. We also compare distributions obtained by ground-based rain gauge and radar data in Kanto area. Fig.6 shows places where ground based rain gauges are located. Rain gauge data are obtained every 10 min. Cumulative distributions in Fig.7 show this comparison. These distributions are place distribution from radar data and time distribution from rain gauge data. In deriving these distributions, rainfall rate data with 0 mm/h are excluded. These curves are quite similar in the rainfall rate region less than 20 mm/h. This result means that place distribution and time one is similar if rainfall events in which rainfall rate is not 0 mm/h.

4. Beam Size dependence of Link Availability

It is useful to know place availability within the boosted beam when the power to the beam is adaptively boosted according to the attenuation in the beam. Figs. 8 and 9 show unavailability within the boosted beam with size of 100 and 200 km as a function of month in a year, respectively. In this analysis, power control scheme is Average method mentioned in section 2.2. This means that average attenuation within the beam is compensated by boosting the satellite power to the beam. Unavailability shown in Figs. 8 and 9 means place percentage where the attenuation exceeds average attenuation in the beam. It is noticed that unavailability tends to increase in winter season and depends on beam size. Unavailability tends to be larger in beam size of 100 km than that of 200km. Fig.10 shows cumulative place distributions of rainfall rate in the beam as a parameter of beam size. It is noticed that smaller the beam size is, larger the cumulative place percentage is. This feature of place distribution of rainfall rates may cause beam size dependence of unavailability statistics shown in figs.8 and 9. Further detailed statistical analysis is needed for derivation of optimal beam size for adaptive satellite power control scheme.

5. Conclusion

By using radar data produced Japanese Meteorological Office over Japan with 1 km mesh points, we analysed effect of adaptive satellite power control method. As attenuation feedback schemes, we assume two kinds of attenuation values, those are average attenuation in the beam and attenuation at monitor station within the beam. As regards former scheme, beam size dependence and seasonal variation of link unavailability are observed. Further detailed analysis is needed to discuss optimal beam size for adaptive satellite power control method.

Acknowledgement

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Reference

[1] S. Nakazawa, et al., "A method to transform rainfall rate to rain attenuation and its application to 21GHz band satellite broadcasting", Proc. ISAP2007, no.4D1-3, Niigata Japan, Aug. 2007.

Table 1 Classification of attenuation counter-measure

	Principle and Feature	Examples
Static	-Margin addition -Hierarchical channel -Waste of Resource	-EIRP, G/T increase -Hierarchical coding & modulation
Adaptive (Dynamic)	-Adaptive distribution of link Resources -Good for point-to-point	-Power control -Bandwidth control -Coding rate control
Diversity	-Prepare channels with low attenuation correlation -Good for large attenuation	-Site or/and Time diversity -Frequency diversity -Orbit diversity

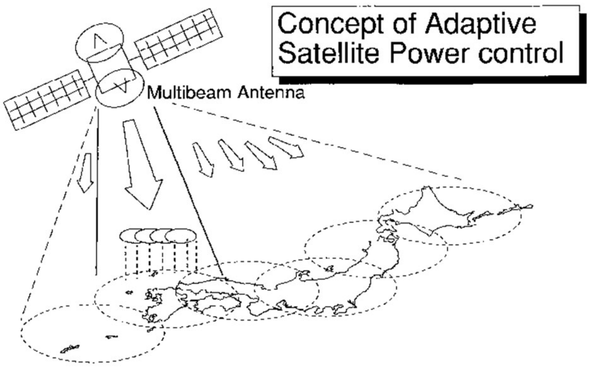

Fig.1 Concept of adaptive satellite power control method

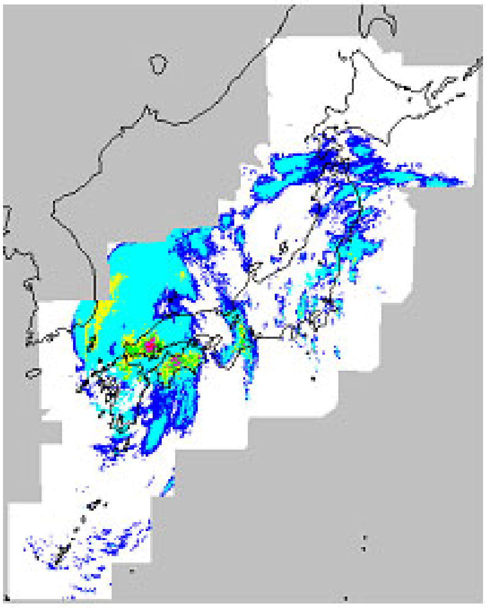

Fig.2 Sample of rainfall rate map derived from radar

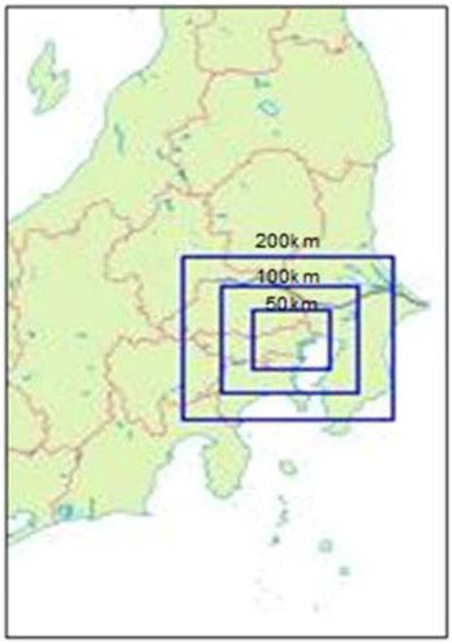

Fig.3 Assumed power control beam sizes

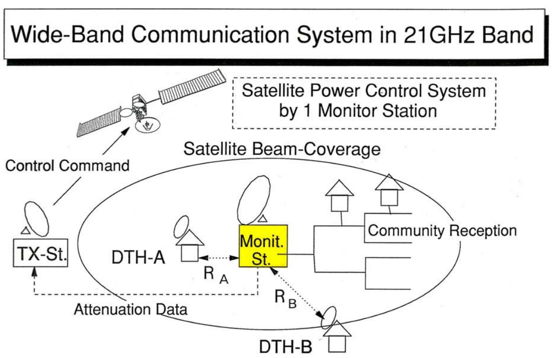

Fig.4 Concept of Monitor Method

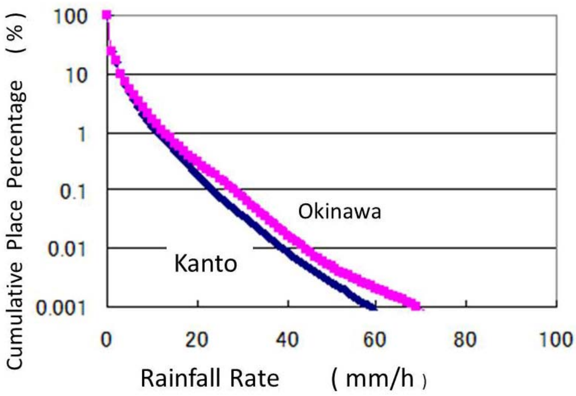

Fig.5 Cumulative place distributions

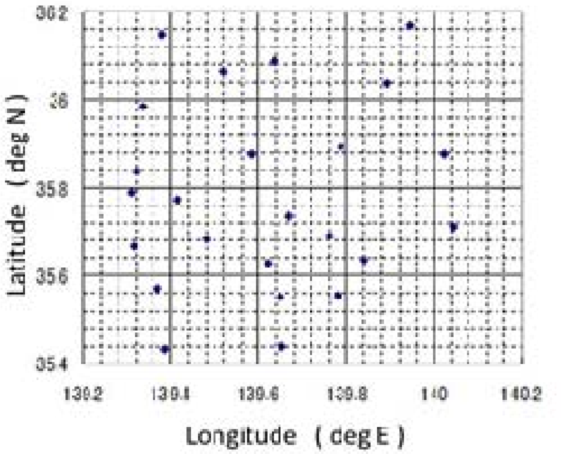

Fig.6 Places of ground-based rain gauges in Kanto area

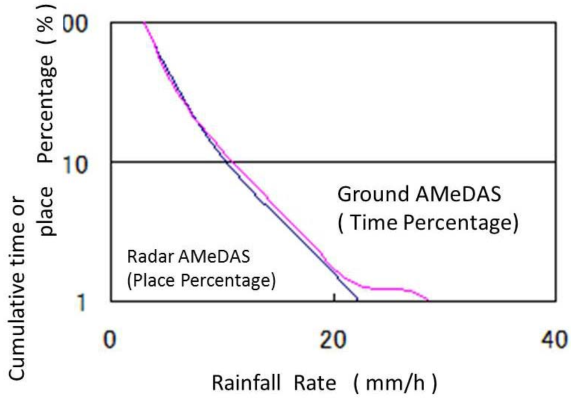

Fig.7 Comparison of place distribution and time one

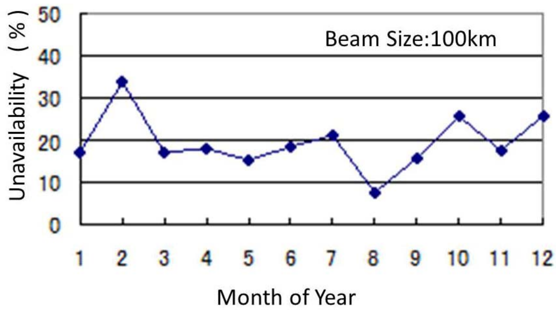

Fig.8 Unavailability in case of beam size of 100 km (Average Method)

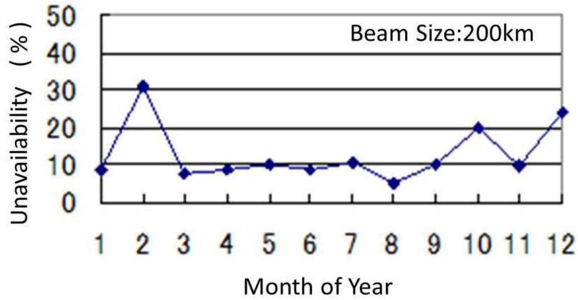

Fig.9 Unavailability in case of beam size of 200 km (Average Method)

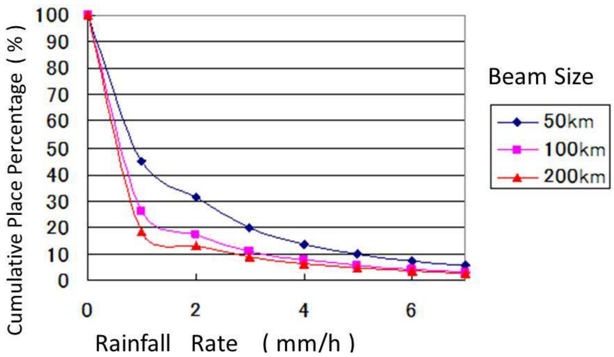

Fig.10 Cumulative place distributions of rainfall rates