PROCEEDINGS OF ISAP '92, SAPPORO, JAPAN

RAIN ATTENUATION COMPENSATION BY ONBOARD RESOURCE SHARING BASED ON DYNAMIC RAIN INFORMATION FROM AMeDAS

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1. INTRODUCTION

In frequencies higher than 10GHz, rain attenuation is a serious problem. In order to overcome this problem, a technique known as Onboard Resource Sharing (ORS) has been proposed [1]-[3]. The ORS maintains communication quality of earth-satellite links by allocating the margin of resources on a satellite , such as radiated power or time slots in a TDMA system, dynamically toward rain areas. For example, as illustrated in Fig.1, when rain concentrates on one spot area (A6), we can expect that heavy degradation in the communication quality of earth-satellite links occurs in A6. Suppose that a satellite illuminates each area by 6-spot beams (A1-A6). If the margin of power for rain attenuation in areas (A1-A5), there is no degradation, is allocated to the A6, availability in the A6 must be improved.

In this paper, by simulation using both a satellite beacon signal level data and dynamic rain information obtained by the Automated Meteorological Data Acquisition System (AMeDAS) in service areas, we show that a method of ORS control of power radiated from a satellite to rain areas by dynamic rain information has the apparent effect of rain attenuation compensation.

2. DYNAMIC RAIN INFORMATION FROM AMeDAS

In order to share limited onboard resources efficiently, a system using ORS needs some dynamic information to estimate rain attenuation or to know rain areas. Such dynamic information includes the satellite signal level or rain rate. A satellite signal level is usually the best information because it shows rain attenuation by itself. However, users will need large investment for equipment to monitor and to manage the satellite signal level. On the other hand, rain rate is an indirect indication of rain attenuation, and rain attenuation estimated from it seems rough. However, if the rain information is managed well by a meteorological agency and can be easily used by general users, the possibility of using rain information as dynamic information for the ORS should be investigated. Fortunately, in Japan, we can easily use one-hour rain rate[mm/h] data as the dynamic information. The rain rate data are obtained by AMeDAS, which is operated by Japan Meteorological Agency. The data are taken every hour at more than 1300 observatories which are set at intervals about 17 km in Japan. Hence we used the one-hour rain rate data obtained by AMeDAS as dynamic rain information for ORS. Since the method of ORS using dynamic rain information doesn't require any direct information on each earth station, it is particularly suitable for receive-only systems such as broadcasting, paging and navigation.

3. METHODS OF SIMULATION

The simulation is done as follows:

Step1: We divide the whole Japanese area except the south-west islands into N service areas, assuming that the satellite is operated by N multispot beams.

In this paper, the case of N=6 as shown in Fig.1 is discussed. In this simulation, we treat each area as not overlapped by any multispot beams.

Step2: Using dynamic rain information obtained by AMeDAS, we calculate the mean one-hour rain rate in the i-th area ($\overline{R}_i$). The subscript i is from 1 to 6 in Fig.1. Rain observatories each area in Fig.1 are about 180.

Step3: The dynamic allocation rate of power to compensate for rain attenuation in the i-th area(α_i) is defined by

$$\alpha_i = \overline{R}_i / \sum_{i=1}^{N} \overline{R}_i \quad [\mathrm{dB}] \qquad (1).$$

The difference of α_i indicates nonuniformity of rainfalls in the whole service area.

Step4: The power levied from each service area to compensate for rain attenuation (P_c) is defined by

$$P_c = N\,(P_m - P_{mk}) \quad [\mathrm{W}] \qquad (2),$$

where P_m [w] is the power assigned to the margin of rain attenuation, (M[dB]) each area operated by a fixed e.i.r.p. and P_{mk} [w] is the part of P_m to be left to each area for a minimum margin of rain attenuation .

Step5: The P_c is dynamically allocated to each area in proportion to α_i. As a result, the controlled margin of rain attenuation in the i-th area (M_i [dB]) is given by

$$\begin{aligned} M_i &= 10 \log \left\{ \left(P_c\, \alpha_i + P_{mk}\right) / P_f \right\} \\ &= 10 \log \left\{ \left(10^{M/10} - 10^{M_k/10}\right) N\, \alpha_i + 10^{M_k/10} \right\} \quad [\mathrm{dB}] \qquad (3), \end{aligned}$$

where $M_k = 10 \log (P_{mk}/P_f)$ [dB], $M = 10 \log (P_m/P_f)$ [dB] and P_f is power radiated from a satellite in a clear sky.

Step6: We calculate rain attenuation (A[dB]) of which the elevation angle(E_l) is 40 degrees and the frequency(f) is 23 GHz by using a satellite beacon signal level data. The data are corrected using techniques of frequency and elevation scaling from original data(E_l=30 degrees and f=11 GHz). Next we determine M_i of the r-th area in which the signal level is received ($M_{i=r}$[dB]). Since the satellite beacon signal level data were received in Tokyo, the r is 3 in the case of Fig.1. We suppose that a margin of rain attenuation in the system giving the data is M[dB] limited by a fixed e.i.r.p.

Step7: We calculate equivalent rain attenuation (A_c[dB]) as follows:

$$A_c = A - \Delta M \quad [\mathrm{dB}] \qquad (4),$$

where

$$\Delta M = M_{i=r} - M \quad [\mathrm{dB}] \qquad (5).$$

A change in margin of rain attenuation (ΔM[dB]) is equal to a change in power radiated from a satellite. If ΔM is positive, A_c will be smaller than A and the effect of rain attenuation compensation will be promoted. On the other hand, If ΔM is negative, the effect will be decrease because A_c will be larger than A.

In this simulation, we used a linear interpolation for original α_i in (1) and calculated M_i by (3) with α_i interpolated for every second because there is the difference of sampling time between the rain attenuation data taken every second and original α_i calculated every hour in (1).

Step8: We compare a cumulative time distribution of A[dB] with that of A_c[dB] and evaluated the effect of rain attenuation compensation by ORS.

4. RESULTS OF SIMULATION

Since we set M=10 dB, we concentrate on unavailable time where equivalent rain attenuation exceeds the threshold level of 10 dB. Figure 2 shows unavailable time (hours; [hr]) plotted by crosses for N=6, M=10dB and for M_k ranging from 3 to 10 dB for one month including heavy rain events (Sep., 1990). A broken line shows unavailable time under conditions without compensation at about 10.2 hours. The maximum effect of compensation for rain attenuation, i.e. the minimum unavailable time, was about 5.1 hours at M_k=5 dB.

Circles plotted in Fig.2 show unavailable time for N=6, M=10dB and for M_k ranging from 4 to 10 dB for long periods (about 212 days between Mar.29 and Dec.12,1990, excluding a period between July 16 and Aug.25,1990 because of lack of the satellite beacon signal level data.). A dash-dotted line shows unavailable time under conditions without compensation at about 28.5 hours. The minimum of unavailable time was about 12.7 hours at M_k=6 dB.

The effect of rain attenuation compensation is to decrease unavailable time by about half. Furthermore, even if M_k giving minimum unavailable time changes within ±1 dB, the maximum effect is stable. As shown in Step 4 and 5 of section 3, when P_{mk} i.e. M_k becomes small, P_c becomes large under condition that N is a fixed value. On the other hand, when M_k becomes large, P_c becomes small. Hence, there is the most adequate value for M_k to give maximum effect of rain attenuation compensation. But the value may depend on the nonuniformity of rain, which is shown by α_i (dynamic allocation rate).

Since conditions of rain change every moment, the time interval of dynamic rain information should be as short as possible with the view of accurate control. In this simulation, even when we used one hour as the time interval for the rain rate, we confirmed that ORS based on dynamic rain information has the apparent effect of rain attenuation compensation.

In the linear interpolation for α_i mentioned in Step 7 of section 3, we used a future one-hour rain rate so as to match the time of the rain data with that of the satellite beacon signal level data. Therefore, in order to operate the ORS system, we should use a very short range forecast which is called a "nowcast" in meteorology. The nowcast gives us a forecast of the one-hour rain rate every hour until three hours from now. Furthermore, radar echo calibrated by the rain data obtained by AMeDAS will also be good information for ORS.

5. CONCLUSIONS

We showed that a method of ORS controlled satellite radiation power to rain areas based on dynamic rain information has the apparent effect of rain attenuation compensation . In Japan, considering that it is easy to obtain the one-hour rain rate data obtained by AMeDAS, which has stable operation, the realization of an ORS system using the data as dynamic rain information is expected.

In countries operating a system to get dynamic rain information like AMeDAS, the method of ORS shown in this paper could be applied successfully.

ACKNOWLEDGEMENT The authors would like to express their appreciation to Dr. K. Ono and Dr. Y. Takahashi of KDD R&D Laboratories for their encouragement in carrying out this study.

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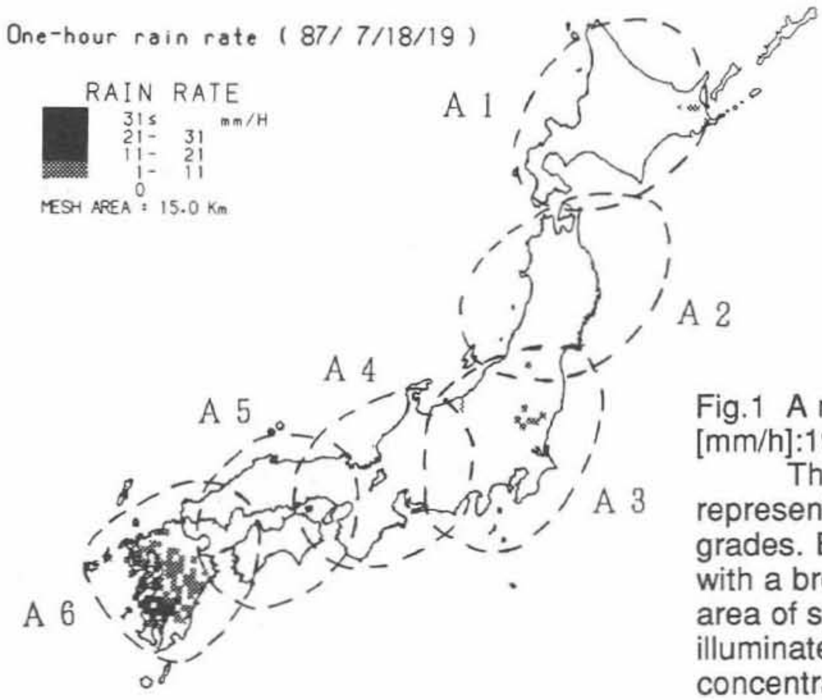

Fig.1 A map of one-hour rain rate [mm/h]:19h, July 18, 1987 JST
The shading scales represent one-hour rain rate in 5 grades. Each area surrounded with a broken line represents the area of spot beams (A1-A6) illuminated by a satellite. Rain concentrated on A6 in this case.

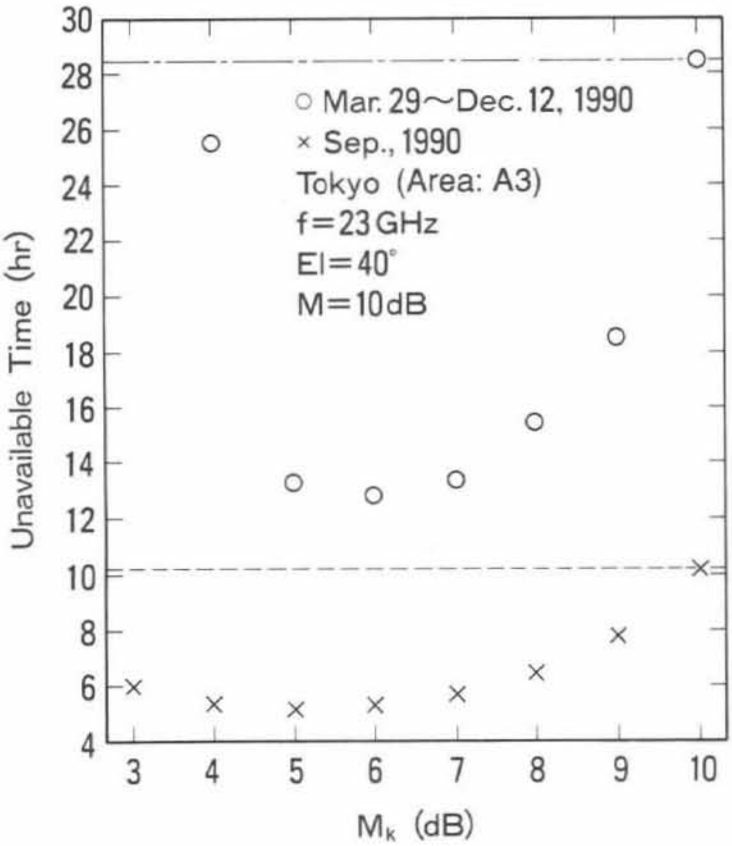

Fig.2 Unavailable time[hr] vs. M_K[dB]

The crosses represent unavailable time with compensation for one month including heavy rain events(Sep., 1990). The circles represent unavailable time with compensation for long periods (about 212 days between Mar.29 and Dec.12, 1990). Unavailable time without compensation is represented by a broken line in the case of the crosses and by a dash-dotted line in the case of the circles.