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CUMULATIVE TIME PERCENTAGES OF RAINFALL RATE AND RAIN ATTENUATION OBSERVED ON THE SATELLITE LINKS AT EQUATORIAL ATMOSPHERIC RADAR

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1. Introduction

Recently the demand for satellite communications keeps on increasing. Especially this tendency is remarkable in newly developing areas such as South-East Asia, but this region is one of the heaviest rain regions in the world. Radio wave with frequency above 10GHz such as Ku band (14/12 GHz) which will be used even in this region tends to be attenuated by rain more significantly than C band (6/4 GHz), so we need to know characteristics of the rain attenuation at Ku band in more detail in the equatorial region.

This study presents the first year results of rainfall rate and rain attenuation by measuring received signal levels of the satellite links which connect Equatorial Atmospheric Radar (EAR, Indonesia) and Radio Science Center for Space and Atmosphere of Kyoto University (RASC, Uji). Worst month and yearly average statistics for cumulative time percentages of rainfall rate and rain attenuation are compared with the ITU-R recommendations [1].

2. Observation Systems

The satellite links that connect EAR and RASC uses Super Bird C. The data transmission rate is 128kbps. At EAR, the up-link transmission carrier frequency is 14.1498GHz and the down-link receive carrier frequency is 12.3992GHz. At RASC, the up-link transmission carrier frequency is 14.1292GHz and the down-link receive carrier frequency is 12.4198GHz. At both stations, the up-link radio waves use the vertical linear polarization, while the down-link radio waves use the horizontal linear polarization. Equatorial Atmospheric Radar (EAR) is built by Radio Atmospheric Center for Space and Atmosphere, Kyoto University in 2001, which had also constructed MU Radar at Shigaraki, Shiga, Japan in 1985. EAR is the only high-power VHF Doppler radar that can measure atmospheric turbulent echoes and velocities of the upper atmosphere in South-East Asia.

Figure 1 shows a block diagram of the data acquisition systems. The data acquisition PCs equipped with A/D converter boards are set up at both EAR and RASC stations. The PCs measure Automatic Gain Control (AGC) voltage of the In Door Unit (IDU) of the VSATs every second. The measured data is stored in their internal hard disk drives. The PCs are connected to the Internet through the satellite links, so we can control them and execute file transfer from Osaka Electro-Communication University (OECU, Osaka). An Optical Rain Gauge (ORG) is also installed at EAR and we can transfer 1-mim rainfall rate data from Indonesia to Japan via the satellite links. At the RASC station, we installed a rain gauge with 0.1 mm tipping buckets last November and started measurements of 1 mm rainfall rates. Before the last November, we substitute 1 min rainfall rates obtained at OECU, which is about 18 km away from RASC.

The observation systems directly measure the AGC voltage, so we have to convert the voltage into received signal levels to discuss rain attenuation of the signal. We did this

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conversion using several samples of representative output voltage, which are calibrated by a wide range of signal levels indicated on the front panel of the IDU in dBm.

3. Estimation of Up and Down Link Attenuation

The satellite Super Bird C receives an SCPC signal from one earth station, linearly amplifies it by a constant factor without saturation of the transponder, and transmits it to the other station. Note that in this case the gain of the satellite transponder is constant regardless of up-link signal strength. So, we can detect up-link attenuation of one station from down-link signal strength of the other station [2]. Although a dynamic range of the attenuation measurements depends on a clear sky level, we can usually estimate rain attenuation down to about 15 dB, which is a little smaller than in satellite beacon or broadcasting channel measurements.

Figure 2 shows an example of the observational methods when it is raining at EAR in Indonesia. In this case, down-link attenuation is directly measured by the down-link signal strength received at EAR. At the same time, up-link attenuation at EAR is estimated from the down-link signal strength received by its opposite terminal at RASC in Japan. When rain is falling at RASC, on the other hand, down- and up-link attenuation is measured at RASC and EAR, respectively Thus, the rain attenuation of the up and down links can be observed by simultaneously measuring signal levels received at both stations in Japan and Indonesia.

4. Observation results

Figure 3 shows an example of rain attenuation which was measured at EAR on September 9, 2003. The solid and dashed lines indicate the up- and down-link attenuation, respectively. The bar chart at the bottom of the figure is the rainfall rates of ORG which were concentrated around 15:00 Indonesia time. According to this heavy rain, the up- and down-link attenuation reaches about 5 and 4 dB, respectively. The up link suffers by about 20% larger attenuation than the down link due to its higher frequency.

Next, yearly statistics are shown for the rainfall rate observed at EAR in 2003. Figure 4 depicts the yearly average and worst month time percentages of the observed rainfall rate, together with those obtained from the ITU-R recommendations for the corresponding P zone. It is found that the yearly cumulative time percentages of the rainfall rate at EAR in West Sumatra area are comparatively smaller than the ITU-R recommendations for the P zone, while their worst month statistics are quite similar to the values obtained from the ITU-R recommendations.

Finally, the Figure 5 shows time percentages of (a) the up-link attenuation and (b) down-link attenuation observed at EAR for yearly average and worst month statistics, as well as those of the ITU-R recommendations. Although there is a fairly large discrepancy between their yearly averages and the recommendations as was the case in the rainfall rate, their worst month statistics agree well up to about 5-6 dB attenuation. Above this level with time percentages of less than 0.2% or so, however, even the worst month statistics indicate much smaller time percentages than the recommendations.

5. Conclusion

The observation systems and methods to simultaneously measure the up- and down-link rain attenuation of Ku-band satellite communications are, for the first time, established in the equatorial region, making use of the SCPC signals of Super Bird C and continuously monitoring the signal levels received by their terminals at EAR in Indonesia and RASC, Kyoto University in Japan. The up-link attenuation is, in general, found to be by about 10-20% larger than the down-link attenuation.

The worst month statistics of cumulative time percentages for the rainfall rate at EAR are, as a whole, in good agreement with the ITU-R recommendations for P zone. The yearly average of the time percentages is, however, by one order smaller than the recommendations, especially in heavy rain of more than 100 mm/h. This is partly due to the fact that EAR is located on a high land at the height of about 1000 m above the sea level. Also, the cumulative time percentages for the attenuation of both up and down links are by one or two orders smaller than the ITU-R recommendations above the levels of 5-6 dB attenuation. This tendency may be related to a fairly localized structure of convective precipitating clouds in the equatorial region. In future, these rain attenuation statistics at EAR should be compared with those at RASC in Japan. Also, the comparison with precipitating cloud structures measured by EAR and many other instruments at the radar site is highly desired.

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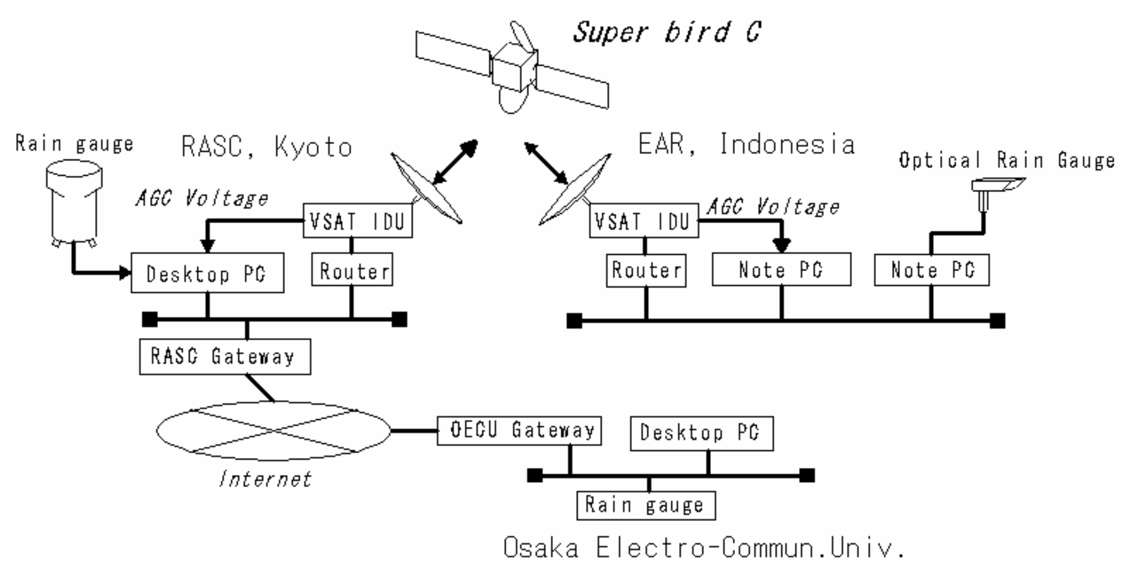

Fig.1 Observation Systems.

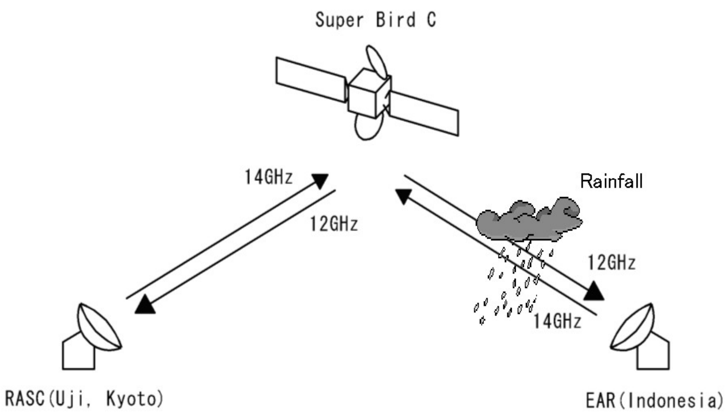

Fig.2. Measurement methods of up-and down-link attenuation.

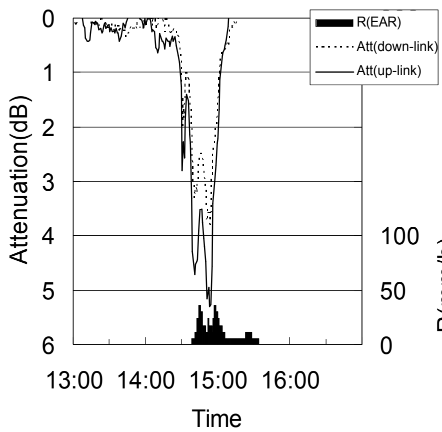

Fig.3 Example of rainfall rate and attenuation observed at EAR

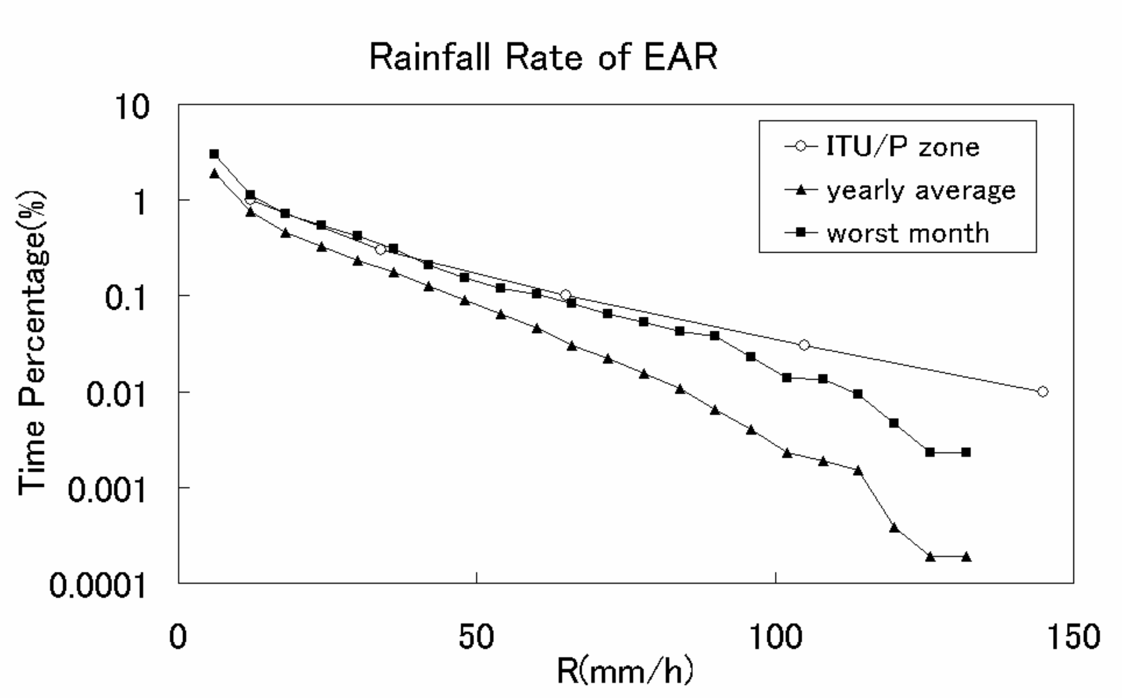

Fig.4 Cumulative time percentages of the rainfall rate measured at EAR in 2003 together with ITR-R recommendations at P zone.

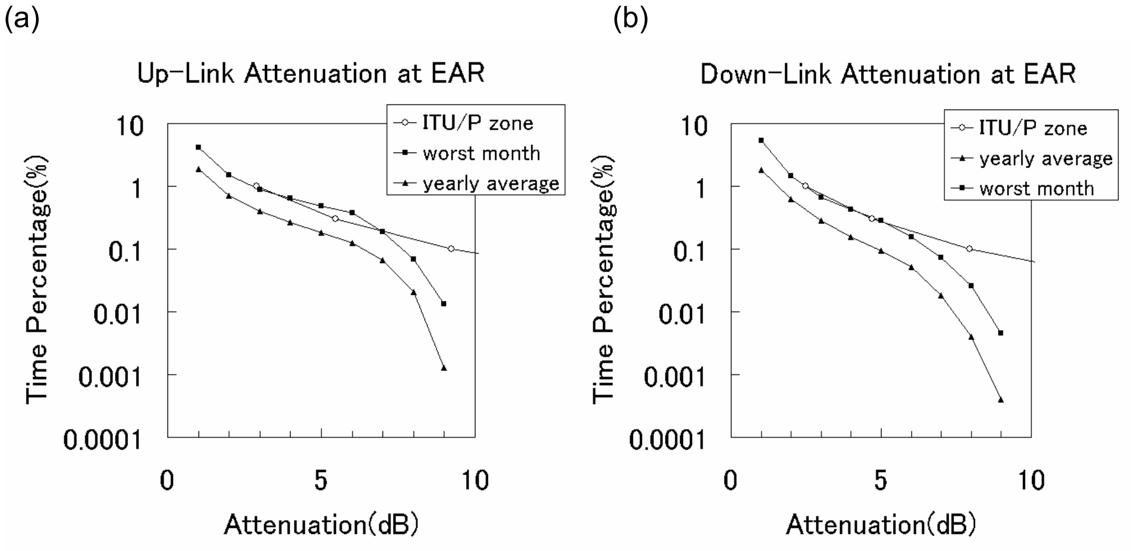

Fig.5 Cumulative time percentages of (a) the up-link attenuation and (b) down-link attenuation rate measured at EAR in 2003 together with ITR-R recommendations at P zone