YEAR-TO-YEAR VARIATIONS IN ATTENUATION RATIO OF Ka-BAND TO Ku-BAND SATELLITE SIGNALS

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1. Introduction

As a demand for channel capacity of satellite communications increases, higher frequencies such as Ku (14/12 GHz) and Ka (30/20 GHz) bands have become to be used more frequently. In these frequency bands, however, meteorological phenomena such as rain and snow largely affect the radiowave propagation on earth-space paths, because attenuation and depolarization are induced by these precipitating hydrometeors. The effects of the raindrop and ice particles are, in general, the more enhanced, the higher is the frequency band.

In this study, rain attenuation characteristics of Ku- and Ka-band satellite signals are compared, and correlation with the phase of Ka-band cross-polar component is presented, using the long-term data base for both signals we observed in our university for eight years[1]. The Ka-band satellite signal has been obtained from the CS-3 beacon signal (19.45 GHz, RHCP, EL=49.5°). On the other hand, the Ku-band satellite signal has been obtained from Broadcasting Satellite (BS), and the level of carrier radiowave for a specific channel (11.84 GHz, RHCP, EL=41.4°) has been measured by a BS tuner and a C/N checker. Also, cross-polar phase of the Ka-band signal (19.45 GHz) is evaluated by the output of phase-amplitude demodulator of the CS-3 beacon signal.

The attenuation ratio of Ka-band to Ku-band is investigated for each year by the difference between observed attenuation characteristics at both frequency bands. A significant change in attenuation ratio from year to year is then pointed out. This ratio is compared with the distribution of the cross-polar phase in relation to the effects of different types of rain dropsize distributions (DSD)[2]. Also, year-to-year variations of the ratio are discussed in light of yearly characteristics of DSD at each season.

2. Observational Method

The Ku-band (12 GHz) radiowave transmitted from the BS is received by a off-set parabola antenna with 1.2 m diameter. The received radiowave is converted into an IF signal in 1.0-1.3 GHz band by a down converter (D/C) installed in the primary antenna feed. The antenna gain is 41.4 dB and the gain of D/C is about 50 dB with the noise figure of 3.2 dB. The IF signal is divided into a C/N checker and a BS tuner. DC outputs of the C/N checker and the BS tuner are amplified by 50 and 10 times, respectively, and sampled by A/D converters. The resulting 12-bit digital data are then processed by a personal computer at 1 sec interval. As for DC output of the BS tuner, the AGC voltage of FM detection circuits in the second IF stage is utilized, and this output voltage is calibrated by that of the C/N checker that indicates the received radiowave electric field strength.

The attenuation and the cross-polar phase of the Ka-band (20 GHz) radiowave are measured by the beacon receiver and the phase-amplitude demodulator of the CS-3 beacon signal, respectively. These are recorded by the personal computer as well as the

Ku-band BS signal. Detailed observational techniques for the CS-3 beacon signal are described elsewhere[3]. Also, weather information such as 1-min rainfall rate and outdoor temperature is recorded every 10-min by the same computer.

3. Observational Results

First, time percentage of the attenuation statistics obtained for the Ku-band (12 GHz) BS signal and the Ka-band (20 GHz) CS signal is presented for the eight years from 1988 to 1995. The time percentage in which the attenuation exceeds 10 dB are approximately 0.01% (about 1 h per year) and 0.07% (about 6 h per year) for Ku- and Ka-band, respectively. These are equivalent to unavailable time percentage of satellite communications links due to rain in the case of rain margin of 10 dB. Note that outages of the Ku-band satellite TV broadcasting with a few or a few tens minutes will occur several times due to severe rain especially in summertime. Such long-term measurements of both Ku- and Ka-band satellite signals were also conducted at Kashima, Ibaraki by Communication Research Laboratory, indicating similar, but slightly smaller time percentages of the attenuation for both frequency bands[4]. In view of the attenuation statistics in each year, these time percentages show a fairly large variation from year to year. For example, the one-year time percentages for the same 10 dB attenuation range from 0.001 to 0.020% at the Ku-band and from 0.025 to 0.110% at the Ka-band, respectively. These variations of the yearly attenuation statistics are closely related to the total rain volume and the average rainfall rate in each year.

Next, difference of the attenuation characteristics between Ku-band and Ka-band satellite signals is discussed. To do this, the rain attenuation at Ka-band is compared with that at Ku-band using their equiprobability values. The results are shown in Fig.1 for the observational period of 1988-1991 (a) and the period of 1992-1995 (b), respectively. These data points are taken from their cumulative distributions indicating the same probability as each rainfall rate, such as 2, 4, 6,...mm/h. Thin curves in Fig.1 mean the theoretical values based on typical three types of raindrop size distributions (DSD) such as Joss-drizzle (Jt), Marshall-Palmer (MP), and Joss-thunderstorm (Jt)[5]. Also, a dashed line denotes the prediction values based on the ITU-R methods[6]. The path lengths required to calculate the theoretical values are inferred from average ground temperature and the elevation angle of each satellite. The equipropability relationships show large year-to-year variations, and the attenuation ratios estimated by the gradients of these plots in Fig.1 indicate a specific tendency for each year at least up to 22-23 dB in terms of Ka-band attenuation. The tendency for distinct yearly attenuation ratios, however, is not affected by the rainfall rate so much as the attenuation itself.

As compared with the theoretical curves, these ratios rather seem to be affected by the type of DSD that is predominant in each year. To see the nature of the attenuation ratio in more detail, Fig.2 shows the representative value of the ratio for each year from 1988 to 1995. This ratio is calculated for equiprobability value of the Ka-band (CS) attenuation to the Ku-band (BS) attenuation with the time percentage of about 0.02%. The equiprobable attenuation for this time percentage is around 5-10 dB and 12-25 dB at Ku- and Ka-band, respectively. Note that their ratio is not so much changed around this time percentage for each year. Arrows on the right hand side of the figure indicate theoretical values of the ratio for each DSD[5], when the Ku-band attenuation is 7.5 dB.

On the other hand, Fig.3 shows yearly average values of the cross-polar phase of the Ka-band CS-3 beacon signal, which is also considered to be sensitive to the type of DSD rather than rainfall intensity. The cross-polar phases measured at 1 min interval are here averaged during a year, only if each 1-min attenuation measured at the same time exceeds 10 dB in order to exclude ice effects. Arrows on the right similarly indicate theoretical values of the cross-polar phase for each type of DSD[7] in case of rainfall rate of 15 mm/h, which approximately corresponds to average rainfall rate for the same attenuation condition. It should be noted that a clear correlation is found between both year-to-year variations of the attenuation ratio in Fig.2 and the cross-polar phase in Fig.3. Thus, the effects of DSD on both observed values are commonly suggested in each year's statistics.

According to our previous study on monthly distribution of DSD based on the measurements of cross-polar phase in each rainfall event, Jd (Joss-drizzle) type is primarily found in the Baiu season from June to July[2]. Then, we show the time percentage of Ka-band attenuation (>10 dB) that occurred in (and before) the Baiu season (January-July) against the total one year. The results are shown in Fig.4 for each year. We can also see a fairly good correlation between the year-to-year variation of this attenuation time percentage and that of the attenuation ratio (Fig.2) or the cross-polar phase (Fig.3). In 1991, 1992 and 1995, for example, it is found that more than two thirds of severe attenuation (>10 dB) occurred in and before the Baiu season, giving rise to enhancement of the effects of Jd-type DSD on the yearly statistics of both attenuation ratio and cross-polar phase in each year. In 1988, 1990 and 1994, on the other hand, only about one third of severe attenuation occurred in the same season, and the effects of Jt (Joss-thunderstorm) type DSD are rather predominant in both yearly statistics.

Finally, the equiprobability relationships are estimated in (and before) the Baiu season and after the Baiu season. The latter season after Baiu includes summertime shower, typhoon and shuu (akisame) season which primarily occur in August and September. The results are shown in Fig.5, together with the equiprobability relationship during the total years. Fig.5 indicates the predominance of the effects of Jd-type in the Baiu season. This tendency is applicable in the attenuation range of 10-23 dB in terms of Ka-band attenuation, beyond which the effects of Jt-type DSD rather become predominant even in the Baiu season.

4. Conclusion

The attenuation statistics of Ku-band and Ka-band satellite signals are compared, and their yearly equiprobability values are found to show a fairly large year-to-year variation. This variation is closely related to the yearly average of the Ka-band cross-polar phase observations, suggesting the same effects of the specific DSD (Jd or Jt), which is biased from the standard type (MP). As for the seasonal characteristics, the Baiu season is primarily shown to give rise to the Jd-type DSD, and this time percentage of the attenuation occurrence in the Baiu season seems to largely affect the yearly statistics of the attenuation ratio and the cross-polar phase distributions.

References

[1] Y.Karasawa and Y.Maekawa, Proc.IEEE, vol.85, no.6, pp.821-842, 1997.
[2] Y.Maekawa, N.S.Chang, and A.Miyazaki, IEICE Trans.Commun., vol.E76-B, no.12, pp.1564-1570, 1993.
[3] Y.Maekawa, N.S.Chang, and A.Miyazaki, Radio Sci., vol.28, no.3, pp.249-259, 1993.
[4] H.Fukuchi, T.Kozu, K.Nakamura, J.Awaka, H.Inomata, and Y.Otsu, IEEE Trans. Antennas Propagat., vol.AP-31, pp.603-613, 1983.
[5] T.Iida, "Satellite Communications(Japanese)", pp.236-238, Ohmusha, 1997.
[6] Recommendation ITU-R 618-2, ITU, Geneva, 1992
[7] H.Fukuchi, J.Awaka, and T.Oguchi, IEEE Trans.Antennas Propagat., vol.AP-33, pp.997-1002, 1985.

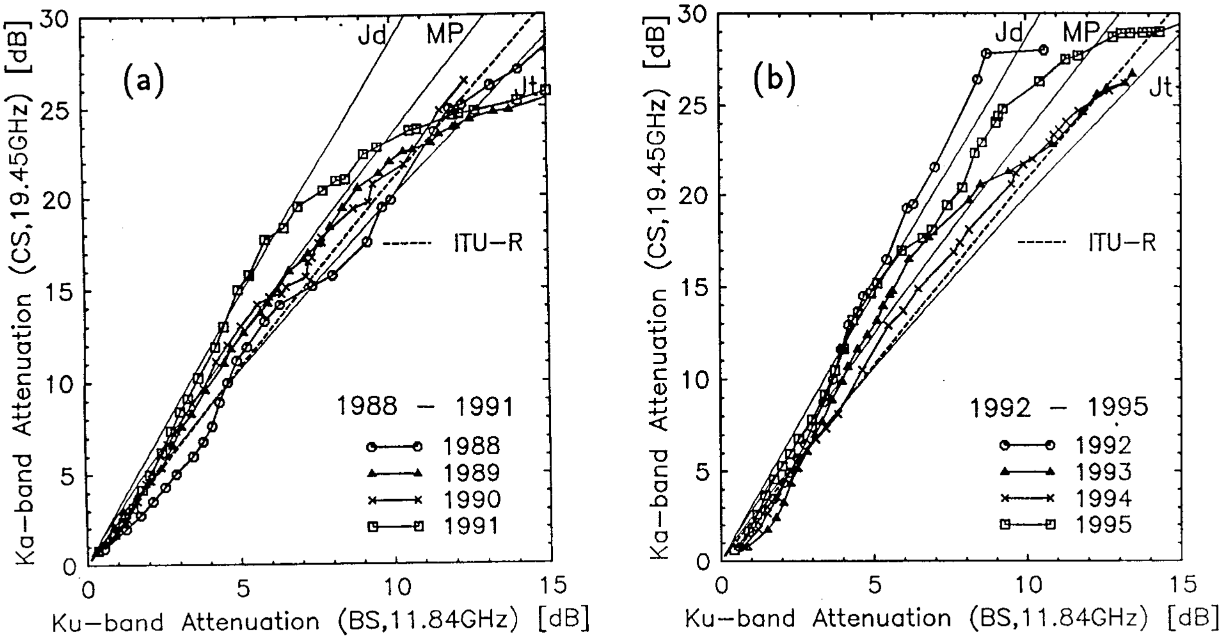

Fig.1. Comparison of rain attenuation at Ku-band and Ka-band using their equiprobability values. (a) Results in 1988-1991. (b) Results in 1992-1995.

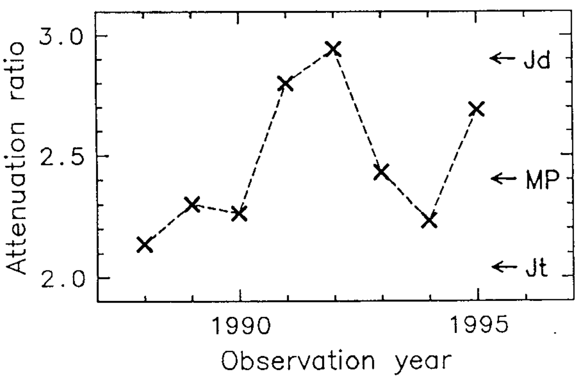

Fig.2. Attenuation ratio of Ka-band to Ku-band with time percentage of about 0.02%.

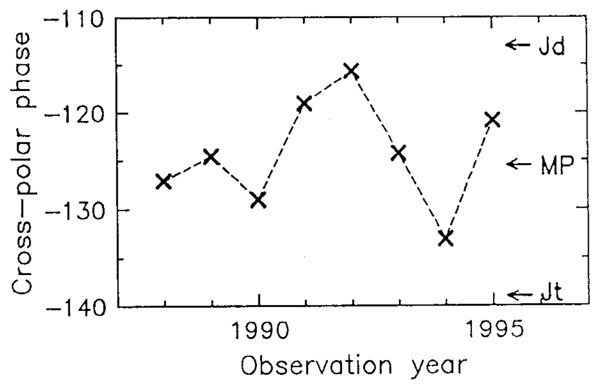

Fig.3. Yearly average of Ka-band cross-polar phase with attenuation of more than 10dB.

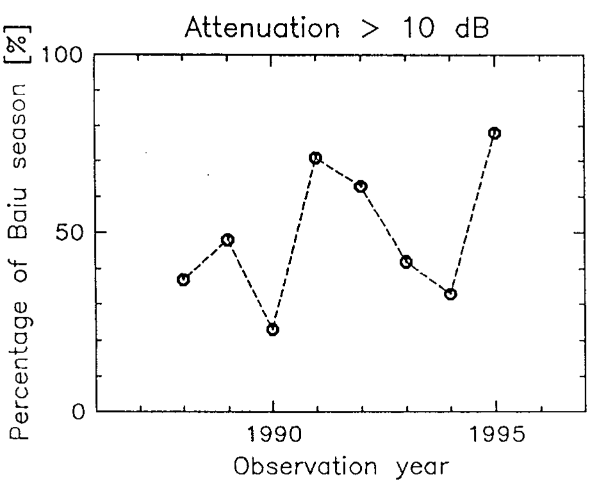

Fig.4. Time percentage of Ka-band attenuation (>10 dB) during the Baiu season against total one year.

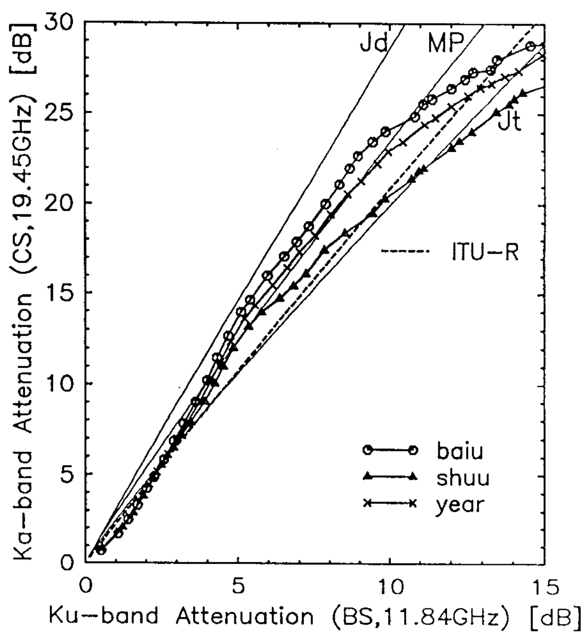

Fig.5. Equiprobability values between Ku- and Ka-band for total observational period.