EXPERIMENTAL RESEARCH ON THE EFFECTS OF AIRPLANES ON VSAT SATELLITE COMMUNICATION SYSTEMS OF KYUSHU UNIVERSITY

Kiyotaka FUJISAKI, Yasuaki IWATA, Hitoshi YOSHIDA
Kenichi ISHIDA and Mitsuo TATEIBA
Department of Computer Science and Communication Engineering
Graduate School of Information Science and Electrical Engineering
Kyushu University
6-10-1 Hakozaki, Higashi-ku, Fukuoka 812-8581, Japan
E-mail: fujisaki@csce.kyushu-u.ac.jp

1 Introduction

Satellite communication is playing an important role in new communication infrastructures supporting various application demands. Recently, satellite communication technology have produced the very small aperture terminals (VSAT) and VSAT satellite communication networks. To establish the networks using VSAT, it is important to accumulate certain knowledge concerned with transmission characteristics via satellite communication channel through experimental researches.

VSAT satellite communications have some disadvantages. One of them is signal attenuation due to rainfall. Many experiments and analyses have been done for clarifying characteristics of rain attenuation at many points in the world. Another disadvantage is bit error due to airplanes flying across the channel between satellite and earth station. However, no sufficient qualitative or quantitative analysis has been presented for the effects as far as we know[1].

We have been performing communication experiments in Ku-band using JCSAT-1B communications satellite owned by Japan Satellite Systems Inc. and our VSAT system since January 1993. Under these experiments[2]-[4], we guessed intuitively that the bit error was caused by landing airplanes when considering the passing speed and angle of airplanes flying across the channel between JCSAT-1B and VSAT system at low altitude of about 300[m]. However I could not determine which of up- and down-link was damaged by airplanes.

In this paper, by using the VSAT system that extended in four stations in Kyushu University we present precisely effects caused by airplanes on the bit error; as a result, above intuitive guess is renewed and the incidence of bit error is discriminated between up- and down-link.

2 Experiment Systems

Figure 1 shows the position of measuring earth stations and Fukuoka Airport. Kyushu University is located at the distance of 4[km] far from Fukuoka Airport, and the VSAT antenna beams of Kyushu University and the glide path of airplanes faces in the almost same direction. In this experiment, the modulation mode is quadrature phase shift keying (QPSK) and the transmission bit rate is 64k[bps]. Figure 2 shows the incidence number of bit errors at each time for 24 hours. The term of observation was 6 months from July to December, 1999. During the term we chose only the days when the amount of rainfall was less than 1[mm] a day. Under the condition, the bit error is observed 752 times for this period. The use of Fukuoka Airport is strictly limited during the time from 7:00 to 22:00 because of the sound prevention. Therefore we may conclude that the bit error occurs at the takeoff or landing of airplanes.

3 Airplane Effects

400 airplanes land and takeoff at Fukuoka Airport every day and some of them fly across our VSAT antenna beams. We monitor airplanes which appear in the front of the antenna using a video camera located behind the station S1 in Fig.1. A picture of airplane flying across the monitor screen is shown in Fig.3 when the bit error is observed.

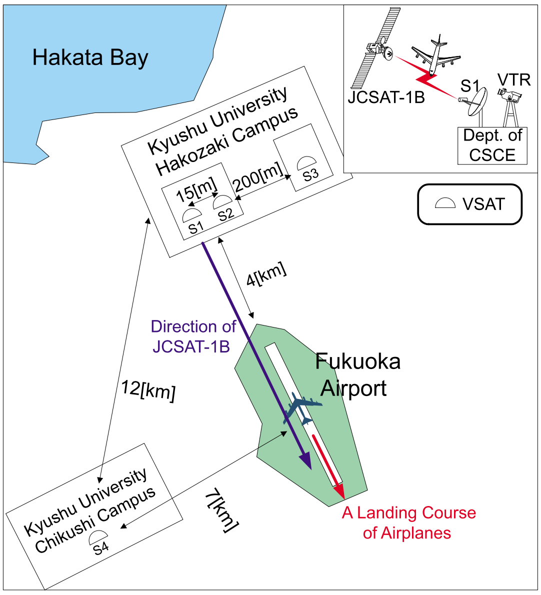

Figure 1: The position of earth stations and Fukuoka Airport.

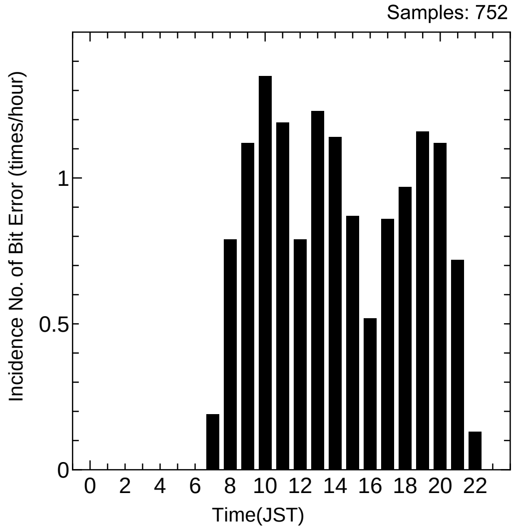

Figure 2: The incidence number of bit error per hour.

Table 1 shows the experimental results of this observation. All the time when bit errors were recorded, airplanes appeared on the monitor as seen from Fig.3. In other words, all the bit errors observed with our experiment system is caused by airplanes in this case. The direction of landing and takeoff changes according to the wind direction. If airplanes approach from or go to the side of Hakata bay, stations S1, S2, and S3 are influenced by airplanes. On the other hand, If the opposite side of Hakata bay becomes the ingress direction, airplanes go around the west side of Fukuoka city and fly over the station S4. This means that there is some possibility of observing the bit error at the station S4.

We observed the bit error due to airplanes across the antenna beams of stations S1, S2 and S3. Table 1 shows that the bit error due to airplanes occurs at the takeoff rather than the landing, although the number of airplanes catched by the video camera is roughly equal for both cases of landing and takeoff. The video camera using this experiment can record all of takeoff and landing airplanes over Hakozaki Campus where stations S1, S2 and S3 are located. As shown in Table 2, about 6% of airplanes produced the bit error. In case of landing, the altitude of airplanes becomes 200[m] to 300[m] and the distance from antenna become 300[m] to 500[m]. On the other hand, in case of takeoff, the altitude become 600[m] to 1000[m] and the distance is about 900[m] over. The longer the distance from the antenna to the airplane, the larger Fresnel zones covered with the antenna beam width. These facts lead to that the incidence number of bit errors becomes larger at the takeoff than the landing in this case.

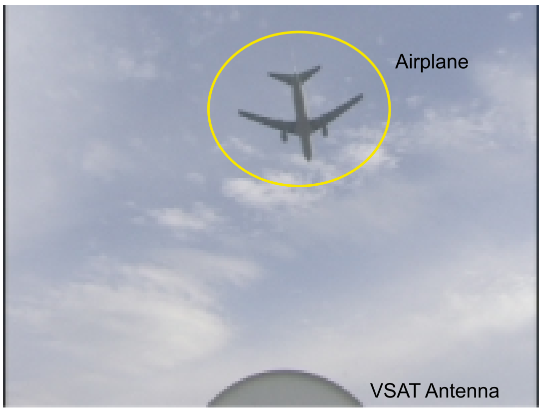

Figure 3: A flight situation of airplane, when the bit error is recorded.

Figures 4-7 show the histogram of the signal attenuation around the time of bit error at each station, by setting the beginning time of measuring bit error at zero. The maximum of signal attenuation is about 20[dB] and the signal attenuation almost occurs within two seconds.

The detection of bit error is limited within one second because of our system performance at present, although the bit error may occur outside the time. The signal attenuation tends to continue at least during the term when bit errors are detected. Because airplanes cause almost the signal attenuation, the bit error is mainly produced by the blocking of the communication link with airplanes. However, as it is seen from Figs.4 and 6, there is the case that the signal attenuation is small. In this case, we may guess that there exists the interference between a direct signal and the scattered one from an airplane.

In this experiment, a signal transmitted from station S1 or S2 was simultaneously received at all stations. Tables 3 and 4 show the observation rate of bit errors due to airplanes in up- and down-link. These tables indicate that most of the bit errors occur at station S2 independent of the link. The reason may be that the antenna beam of station S2 overlaps considerably with the runway direction of Fukuoka Airport. Moreover, we may guess from these tables that the bit errors observed in down-link at station S1, shown in Table 3 and at station S2, shown in Table 4, respectively, are due to the interference between a direct signal and the scattered one from an airplane, although most of the bit errors occur by the blocking of the communication link with airplanes as mentioned above.

4 Conclusion

We have observed bit error and signal attenuation due to airplanes by using four VSAT systems of Kyushu University, during the period from July to December, 1999. The observation shows the effects of the landing and takeoff airplanes on the VSAT communication link of Kyushu University. The observation also suggests the seriousness of airplane effects on satellite communications when airplanes fly over a town at a low altitude such as 800[m] and cross an antenna beam. Moreover, to make more clear the effects, we need extending our observation system so as to be able to measure the bit error every time.

Acknowledgement This work was supported by the Research for the Future Program (JSPS-RFTF 96P00603) from the Japan Society for the Promotion of Science.

References

[1] Z. Honggang, T. Yoshino, S. Ito, H. Ando, and R. Sato, “The prediction of attenuation due to aircrafts fly across the broadcasting-satellite link”, Record of 1997 Joint Conference of Electrical and Electronics Engineers in Kyushu, p.323, 1997.

[2] T. Kudou, K. Yoshida, K. Fujisaki and M. Tateiba, “On effects of rainfall and airplanes on a VSAT satellite communication system”, Proc. of Int. Symp. on Electromagnetic Compatibility, pp.374-377, 1994.

[3] M. Sakamoto, K. Fujisaki, Y. Ohsako and M. Tateiba, “Experimental research on the effects of rainfall and airplanes on a VSAT satellite communication system”, Proc. of Int. Symp. on Antennas and Propagation, vol.2, pp.569-572, 1996.

[4] F. Takahata et. al., “Satellite communications experiments by universities”, Journal of the IEICE, vol.80, no.5, pp.435-456, 1997.

Table 1: The number of airplanes observed on monitor screen and the incidence number of bit errors caused by airplane.

Month	No. of days when the experiment was done	Total recording time	No. of airplanes across the monitor screen			Incidence No. of bit errors		
			Takeoff	Landing	Total	Takeoff	Landing	Total
Sept.	2 days	6 hrs. 18 min.	49	24	73	5	2	7
Oct.	6 days	26 hrs. 4 min.	219	87	306	15	8	23
Nov.	7 days	25 hrs. 21 min.	94	239	333	7	12	19
Dec.	6 days	21 hrs. 54 min.	138	121	259	8	2	10
Jan.	1 days	3 hrs. 26 min.	26	11	37	1	0	1
Total	22 days	83 hrs. 13 min.	526	492	1018	36	24	60

Table 2: The ratio of the incidence number of bit errors to the number of airplanes appeared on the monitor screen, based on the data in Tale 1.

Month	Takeoff	Landing	Average
Sep.	10.2 %	8.3 %	9.6 %
Oct.	6.8 %	9.2 %	7.5 %
Nov.	7.4 %	5.0 %	5.7 %
Dec.	5.8 %	1.7 %	3.9 %
Jan.	3.8 %	0 %	2.7 %
Average	6.8 %	4.9 %	5.9 %

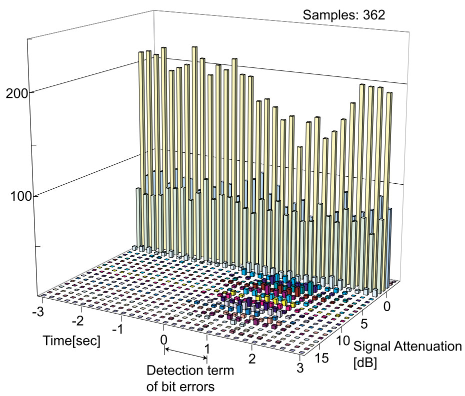

Figure 4: The histogram of the signal attenuation due to air planes, observed at station S1.

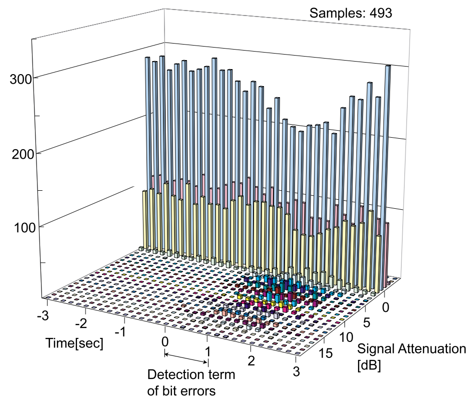

Figure 5: As Fig.4, but the observation station is S2.

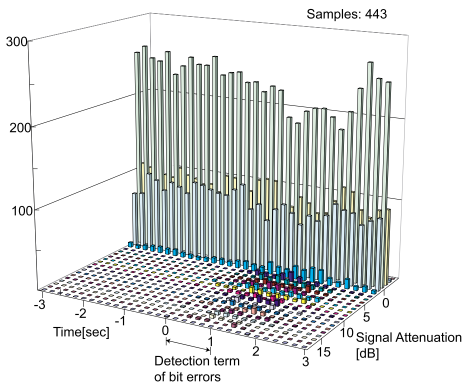

Figure 6: As Fig.4, but the observation station is S3.

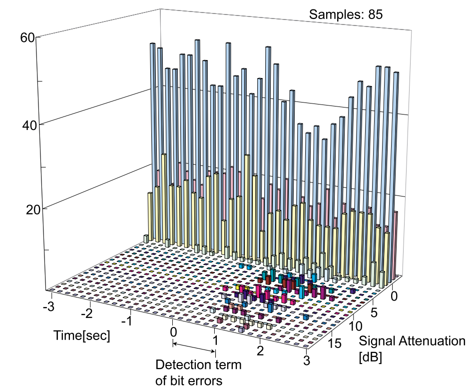

Figure 7: As Fig.4, but the observation station is S4.

Table 3: The incidence number and observation rate of bit errors caused by airplanes when the signal is transmitted from station S1.

Station	Up-link	Down-link	Total
S1	56 (25 %)	5 (2 %)	61 (27 %)
S2		115 (52 %)	115 (52 %)
S3		41 (18 %)	41 (18 %)
S4		7 (3 %)	7 (3 %)

Table 4: As Table 3, but the signal is transmitted from station S2.

Station	Up-link	Down-link	Total
S1		63 (13 %)	63 (13 %)
S2	345 (69 %)	14 (3 %)	359 (72 %)
S3		58 (11 %)	58 (11 %)
S4		19 (4 %)	19 (4 %)