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EXPERIMENTAL RESEARCH ON FLIGHT ROUTE AND ITS EFFECT ON SATELLITE COMMUNICATIONS AT KYUSHU UNIVERSITY

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1 Introduction

Nowadays, satellite communications are widely used and are expected to provide various services using new systems such as very small aperture terminals (VSAT) and VSAT networks. Satellite communications also are trending toward the high data-rate in response to the spread of optical fiber networks[1]. In the high data-rate links, we should take account of minor damages for better quality of services. One of these damages is the short time blocking of the communication link, which is mostly caused by flying engines. This type of damages becomes a serious problem in the design of an efficient data transfer system[2]-[6].

We have been performing communication experiments in Ku-band using our VSAT systems and JCSAT-1B communication satellite owned by Japan Satellite Systems Inc. since January, 1993. Under some experiments [3][5][6], we have shown that the bit error or signal attenuation occurred in a clear sky was caused by the landing and takeoff airplanes passing on the VSAT communication link in Kyushu University; the takeoff airplanes more affect the link than landing ones. The airplane effects depend on the antenna location and the flight route. However, there are no enough data on the flight route in all seasons, and then it is needed to make precisely clear a relation between the route and bit errors through a year.

In this paper, we first investigate the flight route for four seasons. Next we discuss above relation. This research is an extended work of our previous ones [5][6] and an important step for designing satellite communication systems in the region located near the airport to be affected by airplanes.

2 Experiment Systems

Figure 1 shows the location of experimental stations and Fukuoka Airport. The Hakozaki campus of Kyushu University is about 4 km away from Fukuoka Airport. The direction of VSAT antenna beam is almost the same as that of flying airplanes. In this experiment, the station S1 is used for signal transmission to the JCSAT-1B satellite and all stations S1, S2, S3 and S4 receive the return signal. The modulation mode is quadrature phase shift keying (QPSK) and the transmission bit rate is 64 kbps with forward error correction of coding rate = 1/2.

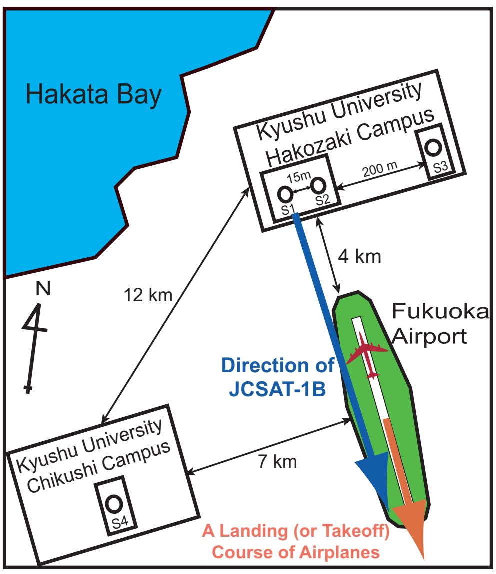

Figure 1: The location of earth stations and Fukuoka Airport.

About 400 airplanes land and takeoff at Fukuoka Airport every day and some of them fly across our VSAT antenna beams. In order

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Figure 2: An observation of airplanes at Hakozaki Campus of Kyushu University.

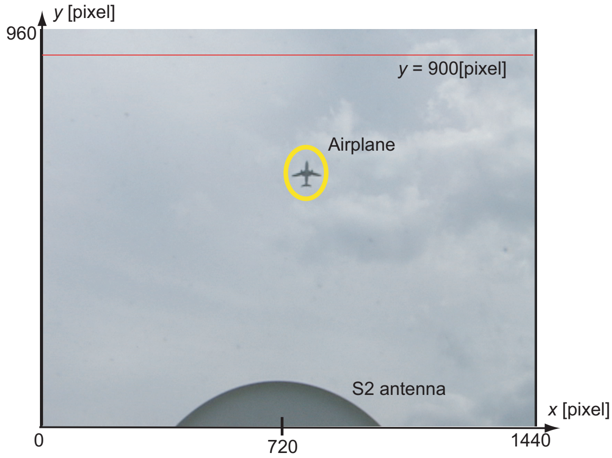

Figure 3: The observation area

to investigate the flight route and its effect, we observe airplanes appearing within the angle about 50 times as large as the VSAT antenna beam width, using a video camera located 5 m behind the earth station S2, as shown in Figure 2. The observation of airplanes has been proceed in daytime without rainy days from July, 1999 to January, 2004, and we have measured bit errors from July, 1999 to March, 2003.

3 Airplane Effects on Satellite Link and the Flying Route

Japan has four seasons and basic characteristics of meteorological elements, such as wind direction, depend on the seasons; hence we, at first, make clear a relation between the seasons and the flight routes. In this paper, the seasons: spring, summer, fall and winter, are defined as March to May, June to August, September to November and December to February, respectively. An example of obtained pictures is shown in Fig. 3. The pictures are formed into 1,440 by 960 pixels. When the bit errors occur in a clear sky, the airplanes are almost observed at about $y = 900$. Therefore we read the x coordinate in pixel at which the flight route and $y = 900$ cross each other, and make the route distribution at $y = 900$.

In the observation term, the 1,460 takeoff and 1,344 landing airplanes are captured and classified by the seasons as shown in Table 1. The route distributions for each season are shown in Fig. 4 where the route of takeoff airplanes spreads more widely than landing ones. This is why the landing airplanes are steered for the runway of Fukuoka Airport and the others are not. In the summer, the route distribution has an almost symmetry shape, but the shape of distribution change to asymmetry as winter comes. This result comes from the following facts. The wind over Fukuoka, the prevailing westerlies, usually blows from the west to the east, get hard in winter and tends to be calm in summer.

Table 2 shows both numbers of all the captured airplanes and the observed bit errors. The number of bit errors is also illustrated in Fig. 4. The bit errors around $x = 360$ occur at only station S3, while around $x = 720$, the bit errors are measured at S1 and S2. The observation shows that takeoff airplanes have ill effects more than landing airplanes do. This may be explained as follows. Airplanes have a certain scattering cross-section normalized to the VSAT antenna beam area around $y = 900$, and the number of times that airplanes cross the beam area is larger for the takeoff than for the landing. From the Fig. 4, it seems that the routes producing bit errors are not closely related on the seasons, because antenna beams of stations S1, S2, and S3 overlap considerably with the runway direction of Fukuoka Airport. The flight altitude of takeoff airplanes around $y = 900$ corresponds to 1000$\sim$1200 m[6]; hence, the width of one pixel is estimated to be 0.52∼0.93 m. For landing airplanes, the width of one pixel becomes 0.17∼0.29 m because the altitude is 200∼300 m[6]. Then the horizontal width having the effects on the communications is 62.4∼111.0 m for takeoff airplanes and 20.4∼34.8 m for landing ones. The result means that the airplanes passing a limited area affect the communication at Hakozaki Campus; therefore it will be possible to overcome the damage by a site diversity technique. In general, the shorter the distance between antennas, the lower the costs of designing systems. It is a future work to estimate the minimum distance between antennas. The further direction of this study is to design satellite communication networks not affected by airplanes.

4 Conclusion

We have observed the occurrence of bit errors due to airplanes using three VSAT systems of Kyushu University and have monitored the flight routes for four seasons. The observation has shown that the flight route of landing airplanes takes almost the same one all the year around, but in case of takeoff airplanes, it depends on the wind direction. The observation also has indicated that satellite communications are affected by airplanes which pass a limited area. Therefore the analysis of the flight route, which caused bit errors, makes possible the design of reliable satellite communications by a suitable technique of site diversity.

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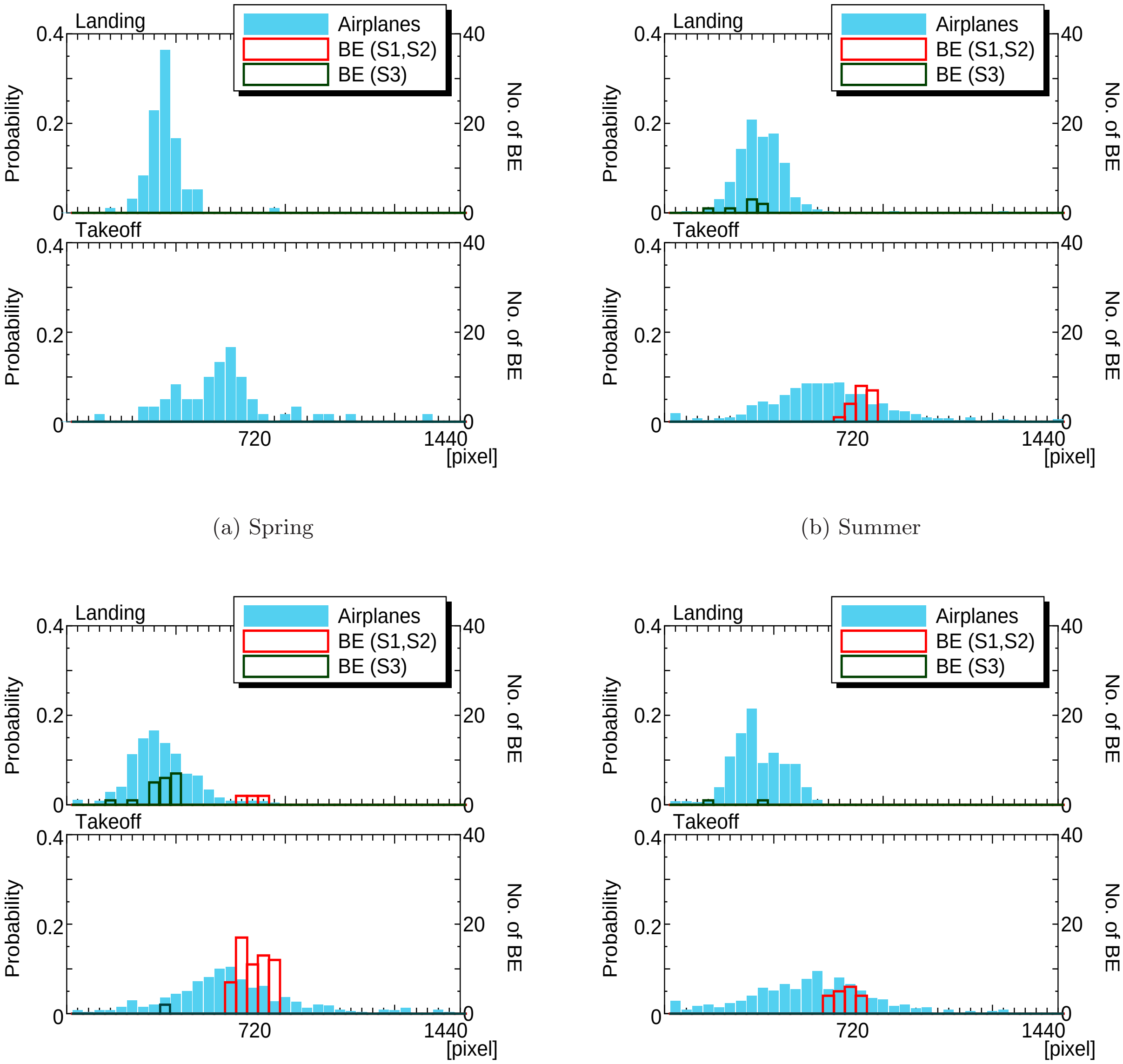
Table 1: The number of airplanes observed on monitor screen in all the observation terms.

Season	No. of airplanes that used in the flying route analysis			Total recording time
	Takeoff	Landing	Total	
Spring	60	96	156	13 hrs. 39 min.
Summer	515	259	774	70 hrs. 32 min.
Fall	537	625	1162	127 hrs. 29 min.
Winter	348	364	712	75 hrs. 47 min.
Total	1460	1344	2804	187 hrs. 27 min.



(a) Spring

(b) Summer

(c) Fall

(d) Winter

Figure 4: The distribution of the route of flying airplanes and the incidence number of bit errors (BE) due to airplanes along the horizontal axis, where we have no data on the bit error in the spring.

Table 2: The number of airplanes and The incidence number of bit errors caused by airplanes (From July, 1999 to March, 2003).

Season	Incidence No. of BE			No. of airplanes across the monitor screen			Total recording time
	Takeoff	Landing	Total	Takeoff	Landing	Total	
Spring	No Data						
Summer	20	7	27	444	177	621	52 hrs. 20 min.
Fall	62	26	88	396	481	877	91 hrs. 5 min.
Winter	19	2	21	268	311	579	62 hrs. 8 min.
Total	101	35	136	1108	969	2077	205 hrs. 33 min.