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Characteristics of aircraft sound propagation from high altitude

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ABSTRACT

This paper introduces analysis result of aircraft sound propagation characteristics from high altitude to the ground. Many aircraft fly high altitude route (higher than 3 km / 10,000 ft) over the west side of Tokyo, because there are some flight routes which climbing to en-route after taking off from Haneda airport. Aircraft sound propagating from high altitude is low noise level but aircraft noise from such high altitude may be heard at a quiet environment such as night time. The high altitude flight noise was not generally subject to aircraft noise measurement carried out around airport, so there were few cases of measurement. In order to grasp aircraft sound propagation characteristic from high altitude, noise measurement from aircraft flying high altitude (5 km to 9.5 km) was carried out. In addition, momentary flight position and altitude of aircraft were collected by ADS-B (Automatic Dependent Surveillance - Broadcast) synchronized with the noise measurement. Time histories of A-weighted and 1/3 octave band sound pressure level of high altitude aircraft sound were analyzed in accordance with aircraft position.

Keywords: Aircraft noise, Propagation, High altitude
I-INCE Classification of Subject Number: 24

1. INTRODUCTION

Many aircraft fly high altitude route (higher than 3 km / 10,000 ft) over the west side of Tokyo, because there are some flight routes which climbing to en-route after taking off from Haneda airport. Aircraft sound propagating from high altitude is low noise level but aircraft noise from such high altitude may be heard at a quiet environment such as night time. The high altitude flight noise was not generally subject to aircraft noise measurement carried out around airport, so there were few cases of measurement.

In order to grasp aircraft sound propagation characteristic from high altitude, noise measurement from aircraft flying high altitude (5 km to 9.5 km) was carried out. In addition, momentary flight position and altitude of aircraft were collected by ADS-B (Automatic Dependent Surveillance - Broadcast) synchronized with the noise measurement. Time histories of A-weighted and 1/3 octave band sound pressure level of high altitude aircraft sound were analyzed in accordance with aircraft position.

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2. FIELD MEASUREMENT FROM AIRCRAFT FLYING HIGH ALTITUDE

The field measurement was carried out at Kokubunji city in west of Tokyo for 24 hours continuously for three weeks from June to July in 2018. Continuous recording of A-weighted sound pressure level ($L_{A,S}$) and 1/3 octave band level every 0.1 s was performed using sound level meter (RION NL-62). Additionally, sound recording was performed for noise above a certain level for identification of noise events by listening. In general, aircraft noise events are extracted for objects 10 dB or more greater than background noise. However, aircraft noise events not more than 10 dB from background noise were also analyzed.

Also, momentary flight position and altitude of aircraft were collected by ADS-B receiver (Kinetic Avionics SBS-3) synchronized with the noise measurement. The ADS-B receiver could obtain information such as the flight position, altitude and call sign. Note that some aircraft did not be installed ADS-B, in which case flight position and altitude information could not be obtained.

3. AIRCRAFT SOUND PROPAGATED FROM HIGH ALTITUDE

3.1 Observed Aircraft Sound Event

The aircraft sound events confirmed by recording and listening and the ADS-B data were compared, and the aircraft flyover sound was extracted. Table 1 shows aircraft sound event of the three major aircraft types (B737-800 / B738, B777-200 / B772 and B777-300 / B773). The altitude data obtained by ADS-B is the barometric altimeter before the correction by the ground pressure, the correction by the ground pressure was performed. The meteorological data at "Fuchu AMeDAS" where located 1.5 km south from microphone are also shown.

Table 1 Observed aircraft sound event

Flight direction	Position	Type	Date	Time	L_{ASmax} [dB]	Corrected altitude [m]	Temp. [℃]	Wind speed [m/s]	Wind direction	Remarks
E to W	Overhead	B738	2018/6/28	10:21:39	54.4	6391	26.6	2.6	SSE	
	Overhead	B738	2018/6/28	13:14:06	53.2	5509	30.1	5.0	SSW	
	Overhead	B738	2018/6/28	19:02:09	52.8	5732	27.4	4.0	S	
	Overhead	B738	2018/7/2	06:39:55	52.6	5493	27.3	1.5	S	
	2.0 km S	B738	2018/7/2	14:50:57	52.9	5151	32.9	4.4	S	
	Overhead	B738	2018/7/2	17:50:55	52.8	5232	29.9	3.4	SSE	
	Overhead	B738	2018/7/2	18:12:36	52.5	5202	29.9	3.4	SSE	
	Overhead	B772	2018/6/28	08:43:01	53.8	5842	26.8	3.4	SSE	
	3.2 km S	B772	2018/6/28	11:43:54	54.7	5812	31.0	4.9	SSW	
	4.8 km S	B772	2018/6/28	11:59:57	53.8	5021	31.0	4.9	SSW	
	Overhead	B772	2018/6/30	08:50:29	52.2	5585	30.7	4.6	S	
	Overhead	B773	2018/7/1	20:28:00	54.0	5586	26.4	4.2	S	
	Overhead	B773	2018/7/2	20:09:36	52.9	5782	27.9	2.2	SE	
S to N	3.8 km W	B773	2018/6/12	01:30:41	54.2	8770	18.7	0.4	ESE	
	9.4 km E	B773	2018/6/20	01:29:48	53.5	9408	21.2	2.5	SSE	Rain

Background noise often interfered with the detection of aircraft sound events because $L_{A,Smax}$ of aircraft was as low as 55 dB or less. The environment around the microphone was relatively quiet, but the voices of birds, ambulance sirens traveling on a 130 m distance road, etc. interfered with the detection. The aircraft sound event of major aircraft types that could be detected was 7 data for B738, 4 data for B772, and 4 data for B773 in 3 weeks.

There were 13 aircraft noise events going from Haneda airport to west Japan. 10 aircraft flew just above the microphone and 3 aircraft flew 2 km to 4.8 km south side. The corrected altitude were 5000 m (16400 ft) to 6400 m (21000 ft), and it was all climbing to the cruise altitude after takeoff. $L_{A,Smax}$ is in the range of 52.2 dB to 54.7 dB.

In addition, there were 2 aircraft sound event that flew from Haneda airport to the north at midnight. These aircraft were cargo planes that fly on a midnight-only flight course, and were climbing towards the cruise altitude. They flew a distance of 3.8 km west and 9.4 km east. The corrected altitude were 8800 m (29000 ft) and 9400 m (30800 ft). $L_{A,Smax}$ are 54.2 dB and 53.5 dB.

3.2 Time histories of A-weighted Sound Pressure Level

Figure 1 shows an example of time histories of A-weighted sound pressure level ($L_{A,S}$) during ± 60 s before and after the observation of the aircraft sound event. Figure 1 (1) to (3) are $L_{A,S}$ time histories of events flying westward just above microphone, (4) is an event flying westward on 4.8 km south side, and (5) is an event flying northward on 3.7 km west side. The background noise was in the range of 43 dB to 47 dB, and the difference between $L_{A,Smax}$ was approximately 6 dB to 10 dB. The aircraft sound continued for approximately 60 s for all events.

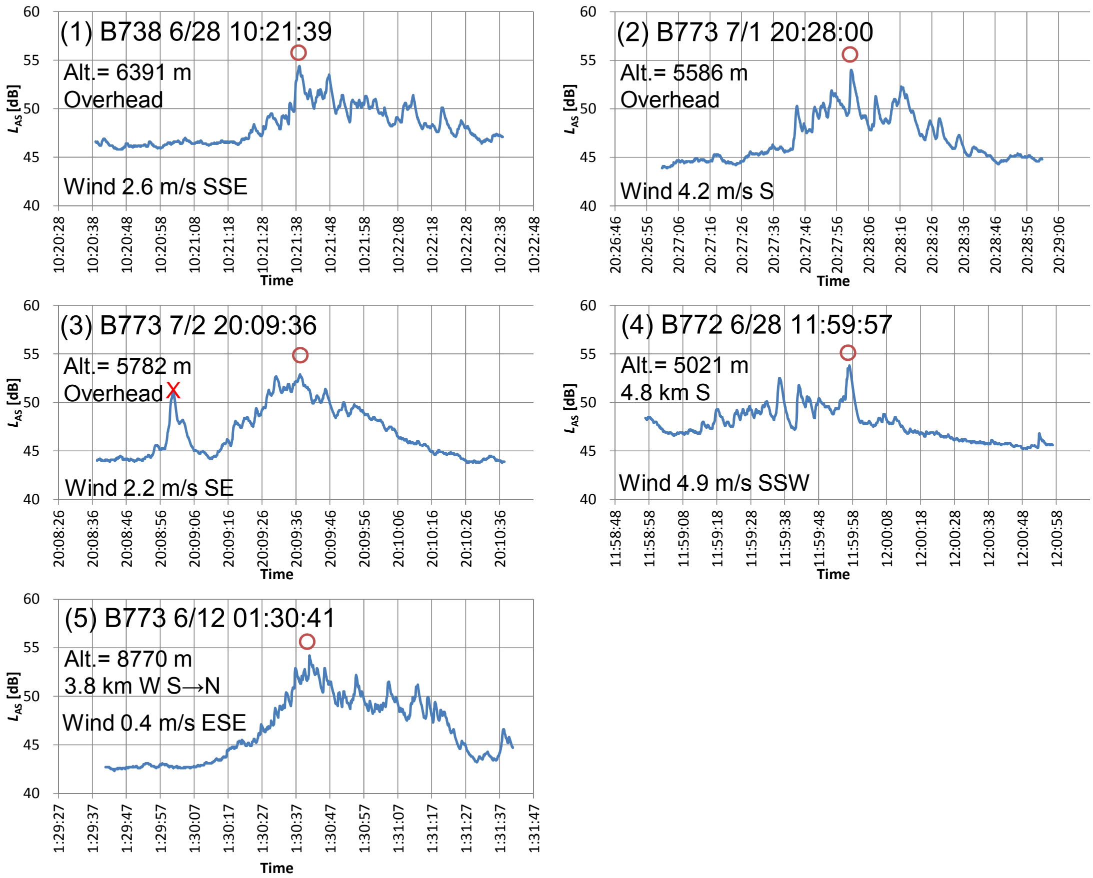


Figure 1 Time histories of A-weighted Sound Pressure Level

As shown in Figure 1 (1) to (3), the $L_{A,S}$ time history of the event flying just above the microphone shows a unimodal tendency and a slight fluctuation of levels. However, focusing on the maximum position, it can be seen that (1) and (2) are maximum before the center of the single peak due to the influence of small level fluctuations. In (3), small level fluctuations were not seen so much. This is an example of the least fluctuation among the 15 data measured this time.

Figure 1 (4) shows $L_{A,S}$ time history for westward flight of altitude 5 km at 4.8 km on the south side, and the elevation angle is approximately 45 degrees at the closest approach. The level fluctuates significantly near the peak and in the second half of the level trend. For this reason, the maximum value was observed after passing. In the data of the route on the south side, there were cases where level fluctuation was large like this case.

Figure 1 (5) shows $L_{A,S}$ time history for northward flight at an altitude of 8.8 km on 3.8 km west side, and the elevation angle is approximately 67 degrees at the closest approach. The time history of $L_{A,S}$ accompanying the passage showed a clean unimodality, because the background noise level was low at midnight. In this case, the level did not fall after the maximum level observation.

3.3 Frequency Characteristics when $L_{A,Smax}$ Observed

Figure 2 shows the 1/3 octave band frequency characteristics when $L_{A,Smax}$ observed. These five sound events (1) - (5) are the same as shown in Figure 1. The main frequency components is approximately 100 Hz to 400 Hz. At 500 Hz and higher, the level decreased as the frequency increased. In the frequency band of 500 Hz or higher, it may be considered that the influence of air absorption when propagating long distances from the high altitude sky is considered.

In the flight just above the microphone shown in Figure 2 (1)-(3), B738 (1) has a peak at 315 Hz and B773 (2)-(3) has a peak at 125 Hz, showing differences depending on the model. In the westward flight on south side of B772 shown in Figure2 (4) has a peaks at 160 Hz, and the northward flight on west side of B773 in (5) has a peaks at 250 Hz and 315 Hz.

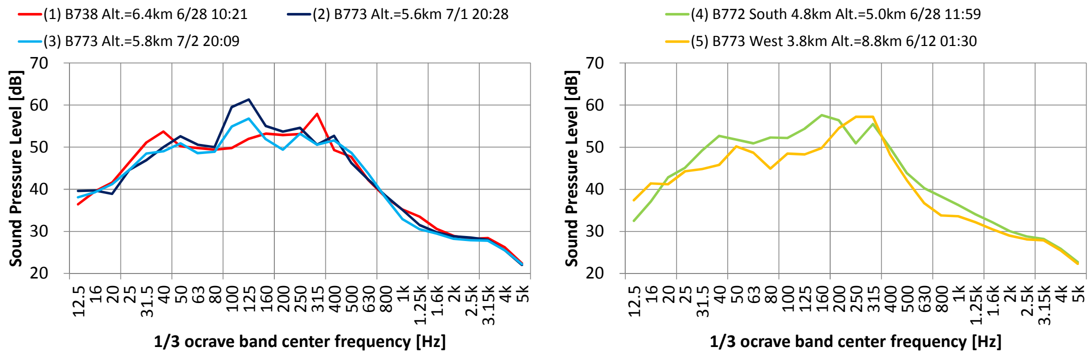


Figure 2 Frequency characteristics when $L_{A,Smax}$ observed ;
(1)-(3): East to west at overhead, (4): East to west at south side,
(5): South to north at west side

3.4 Time Histories of Octave Band Sound Pressure Level

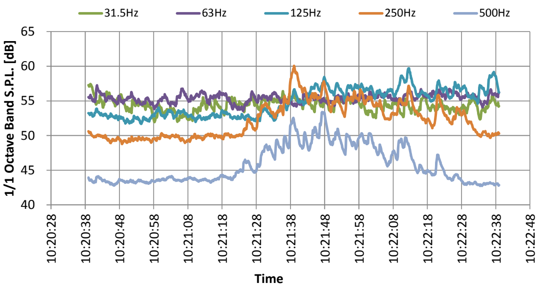
$L_{A,Smax}$ is not always observed near the closest approach due to the large level fluctuations. Therefore, in order to observe the state of level fluctuation by frequency, the measured 1/3 octave band level was synthesized, and the 1/1 octave band level was calculated. Figure 4 shows time histories of 31.5 Hz to 500 Hz octave band level for 5 aircraft same as shown in Figure 1.

In the flight of B738 just above the microphone shown in Figure 4 (1), the levels of 250 Hz and 500 Hz change as the aircraft passes. And the short-term fluctuation is generally synchronized in both frequency bands. At 125 Hz, the level before approaching is large and unclear, but the level increases by about 5 dB along with passing. However, there is no decline in levels after passing.

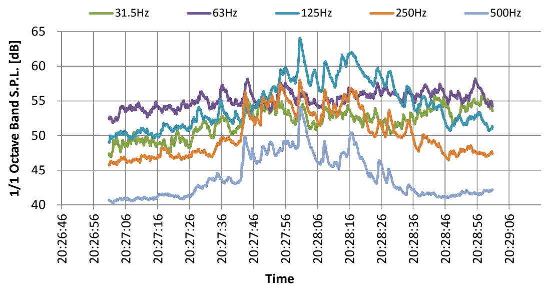
In the flight of B772 just above the microphone shown in Figure 4 (2) - (3), level of 125 Hz, 250 Hz and 500 Hz changes as the aircraft passes. The level of 125 Hz was about 5 dB larger than B738 in (1). Focusing on the short-term fluctuation, in (2), the three bands fluctuate in synchronization, but (3) does not seem to be synchronized.

In the westward flight of B772 on south side shown in Figure 4 (4), the level changes with the passage of the aircraft in the three bands of 125 Hz, 250 Hz and 500 Hz, but it can be seen that the fluctuation in a short time is large. In this data, the level fluctuation in a short time did not differ by frequency, and the three bands fluctuated synchronously.

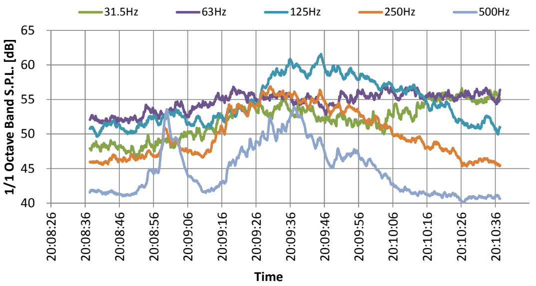
In the northward flight of B773 on west side shown in Figure 4 (5), the level of 250 Hz changes with the passage of the aircraft, but 125 Hz and 500 Hz are delayed by about 20 seconds.



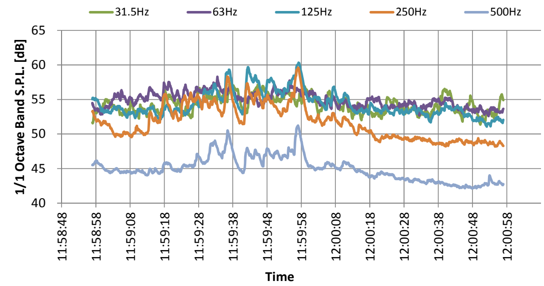
(1) B738 6/28 10:21 East to west at overhead



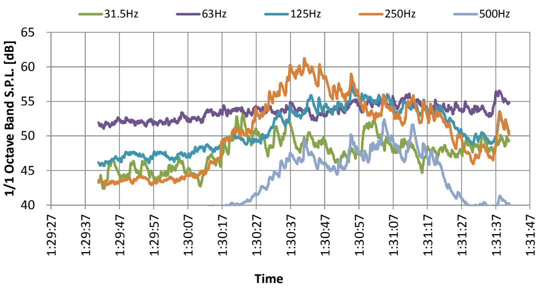
(2) B773 7/1 20:28 East to west at overhead



(3) B773 7/2 20:09 East to west at overhead



(4) B772 6/28 11:59 East to west at south side



(5) B773 6/12 01:30 South to north at west side

Figure 3 Time histories of octave band sound pressure level

4. CONCLUDING REMARKS

In order to grasp aircraft sound propagation characteristic from high altitude, noise measurement from aircraft flying high altitude (5 km to 9.5 km) was carried out. In addition, momentary flight position and altitude of aircraft were collected by ADS-B synchronized with the noise measurement. The field measurement was carried out for 24 hours continuously for three weeks.

The $L_{A,S}$ time history of aircraft sound propagated from high altitude was a unimodal tendency, but slight level fluctuations were often seen. The maximum level ($L_{A,Smax}$) was affected by the slight level fluctuations. In addition, the situation of level fluctuation might differ depending on the frequency.

With respect to propagation from several hundred meters in altitude, the meteorological effect is not large compared to propagation along the ground [1], but propagation from several kilo meters or more may also be affected by meteorological effect. In addition, it is considered that the influence of air absorption can not be ignored.

In the future, we would like to increase the measured data further and examine the effects of meteorological effect and air absorption.

5. REFERENCES

[1] Hirokazu ISHII, *et al.*, *"Numerical study on lateral attenuation of aircraft noise by using the meteorological effect database developed in JAXA's DREAMS project - Part 1. Air-to-ground propagation -"*, Proceedings of Inter-noise 2017, p.3337-3345, Hong Kong (2017).