Study of lateral attenuation under meteorological conditions for airport noise modeling

Naoaki SHINOHARA[1,2]; Kazuyuki HANAKA[3]; Ichiro YAMADA[4]

[1,3] Narita International Airport Promotion Foundation

[2,4] Aviation Environment Research Center, Airport Environment Improvement Foundation

ABSTRACT

This paper describes the result of examination on the validity of equations for lateral attenuation of over-ground sound propagation during aircraft flyover under various meteorological conditions, using long-term unattended noise monitoring at Narita Airport. The well-known SAE/AIR 1751 equation was said to bring a little overestimation. Thus, we examined the validity of the equation by following the procedure to construct AIR 1751. As a result, we found that lateral attenuation changes dramatically dependent on meteorological conditions and that lateral attenuation using AIR 1751 corresponds to upwind conditions. Based on these, we proposed a modified equation (1751M) applicable under various meteorological conditions, and decided to use it in the case of wind calm and temperature gradient neutral conditions for long term average noise prediction. Since first using it, a lot of new types of aircraft have been introduced, and comparing noise predictions with measurements suggests that 1751M gives a bit of underestimation. Aside from these, another new equation (SAE/AIR 5662) gives a bit higher value of lateral attenuation. Thus, we made this study to check the validity of lateral attenuation equations, following the same procedure we used when constructing 1751M. This paper describes the result as well as discusses further issues related to lateral attenuation in airport noise modeling.

Keywords: Airport noise, Modeling, Lateral attenuation, Meteorological conditions
I-INCE Classification of Subjects Numbers: 24.6, 52.2, 76.1.3

1. INTRODUCTION

It is necessary to take account of lateral attenuation (LA) for airport noise modeling. Lateral attenuation is defined as the difference in level between the sound observed at a location directly under the flight path and that at another location to the side of the aircraft at the time of closest approach. It is a combination of attenuation due to ground effects, attenuation due to refraction-scattering effects and engine installation effects.

The well-known SAE/AIR 1751 (1) equation was introduced in the 1980's, but since the 90's, it has been said to bring a little overestimation. Thus, we examined the validity of the SAE/AIR 1751 equation in evaluating lateral attenuation using the results of noise monitoring stations which were installed along the runway of Narita Airport. At each inter-noise congress 2003 to 2006 (2, 3, 4), we suggested that lateral attenuation is strongly affected by meteorological conditions, especially vector wind. Further, we proposed using a modified equation (1751M) allowing for various conditions of vector wind and temperature gradient, which can suppress as much as possible the deviation of predicted and measured. However, in the past decade, new types of aircraft and engines have been introduced which have brought change to noise exposure around airports. In addition, the values of lateral attenuation using the 1751M have also resulted in a little underestimation. On the other hand, the SAE issued a new method for predicting lateral attenuation as AIR 5662 (5) in 2006 which is a reformulation of AIR 1751 and gives a bit higher value of lateral attenuation than that of 1751M in the case of aircraft with engines mounted under the wing. ICAO DOC9911 'Recommended method for computing noise contours around airports' (6) has adopted AIR 5662.

In Japan, the national noise guideline "Environmental Quality Standard for Aircraft Noise" was

[1] shino@napf.or.jp, [2] n-shinohara@aeif.or.jp , [3] hanaka@napf.or.jp , [4] i-yamada@aeif.or.jp
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revised in 2013 to use L_{den} as the noise index, in place of WECPNL, for evaluation of cumulative noise exposure around airports. It was also revised to take into account noise contributions of aircraft ground activities such as taxiing, APU operation and engine run-up tests, if necessary. Such ground noise and noise during take-off roll or thrust reversal after landing is strongly affected by meteorological conditions. So, 1751M is still useful because it can calculate under various meteorological conditions (vector wind and temperature gradient) in comparison to AIR 5662 which cannot consider meteorological conditions. Thus, we made this study to check the validity of lateral attenuation equations, following the same procedure we used when constructing 1751M.

This paper describes examination results of over-ground attenuation for current types of aircraft under various meteorological conditions using data of long-term unattended noise monitoring at Narita Airport. The procedure is the same as that used when previously reviewing the 1751M. Furthermore, this paper considers additional issues related to the examining of lateral attenuation in airport noise modeling.

2. Review of equations for lateral attenuation in aircraft noise models

2.1 SAE/AIR 1751

The well-known equation for evaluation of lateral attenuation in the aircraft noise segment modeling is SAE/AIR 1751, which was proposed in 1981. It aimed at evaluating effects of various sound propagation phenomena including ground reflection, refraction, and airplane shielding. The lateral attenuation was defined as $\Lambda(\beta,\ell)$, in Eq.(1), in the form of a product of two components; one is a component $\mathrm{G}(\ell)$ for the Ground-to-Ground (GTG) sound propagation in Eq.(2), and the other is $\Lambda(\beta)$ for the Air-to-Ground (ATG) situation in Eq.(3).

$$\Lambda(\beta,\ell) = [G(\ell)\cdot\Lambda(\beta)]/13.86 \quad (1)$$

$$G(\ell) = 15.09\left[1 - e^{-0.00274\ell}\right] \qquad for\ 0 < \ell < 914m \quad (2)$$

$$= 13.86 \quad for\ \ell \geq 914m$$

$$\Lambda(\beta) = 3.96 - 0.066\beta + 9.9e^{-0.13\beta} \qquad for\ 0° < \beta < 60° \quad (3)$$

$$= 0 \quad \text{for } \beta \geq 60°$$

Engine installation effects include interactions between the engine mount positions, airplane wings, and fuselage. But, separation of the shielding effect from the fuselage due to engine mounting position was not considered when formulating the AIR 1751.

Several studies undertaken after the 1990's revealed that today's aircraft noise models have a tendency to underestimate noise levels around airports. The major contributor to this miscalculation is believed to be the SAE/AIR 1751 on lateral attenuation having a little overestimation.

2.2 1751 Modified (1751M)

It is said that the AIR 1751 has a remarkable difference between calculations and measurements when the aircraft rolls on the runway and when it changes to climbing. So, we started our study in the early 2000's to examine the validity of the SAE/AIR 1751.

First, we examined the validity of the GTG component of the SAE equation, using frequency spectra of recent aircraft, by following the process in which the SAE equation was formulated. It turned out that the GTG component changes dependent on meteorological conditions and that the difference of aircraft types between the 1970's and the 2000's only affects it a little.

Then, we examined it using the results of long-term unattended ground noise monitoring installed around Narita Airport with weather conditions (temperature, wind direction and wind speed) observed at two remote weather monitoring stations, at heights of 40m and 2m respectively. The result shows that the magnitude of LA/GTG changes considerably dependent on meteorological conditions as shown in Figure 1, i.e., vector wind (VW) and temperature gradient (TG).

We also examined what weather conditions were representative of the long-term average evaluation. As a result, if we obtain average sound levels and LA/GTG values for weather conditions of 'calm' (VW) and 'neutral' (TG), the results become very close to the long-term average estimations calculated from all observations throughout the year. The value of long-term average LA/GTG at long distances (>914m) was about 9dB. It is lower than the value of 13.86dB in the original SAE equation, which is close to the result of our examination at upwind condition. From this, it seemed that the original AIR 1751 equation has overestimated the LA / GTG.

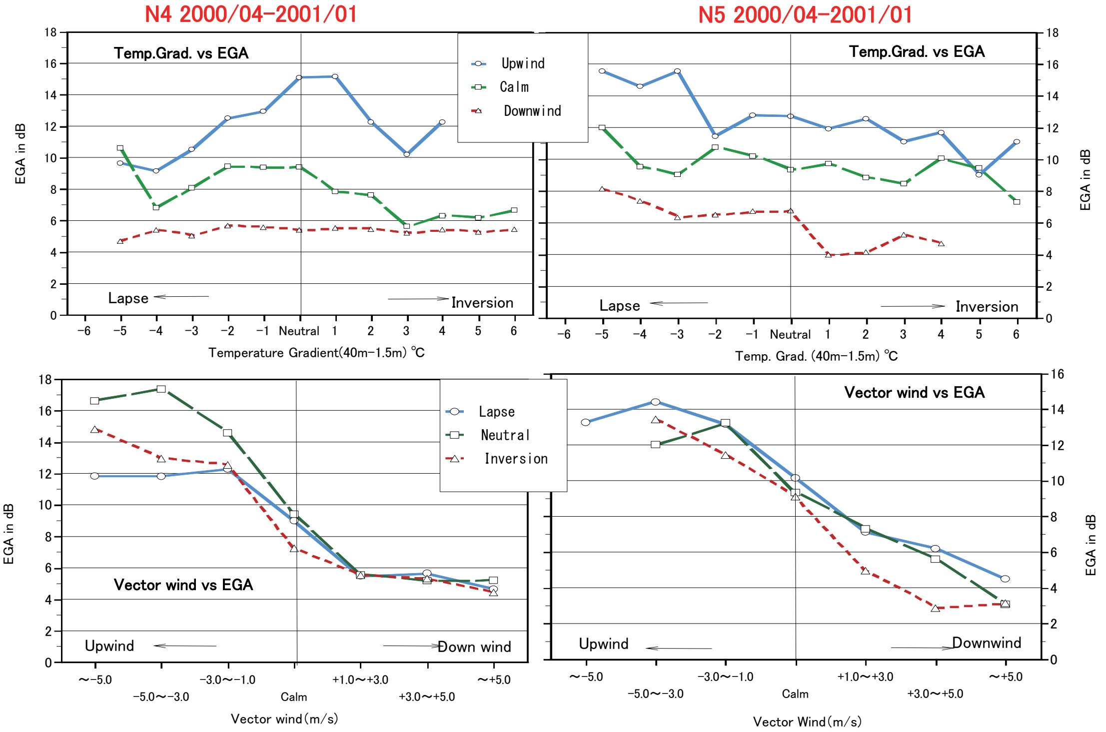

Figure 1 - Relationship between EGA=Lateral Attenuation (B747-400) and meteorological conditions at N4 (left) and N5 (right); temperature gradient (upper) and vector wind (lower) in our former study. N4 located 700m and N5 located 1560m respectively from the A-runway of Narita.

We also examined the validity of the SAE/AIR 1751 equation, evaluating lateral attenuation for Air-to-Ground conditions (LA/ATG). The relationship of LA/ATG values with meteorological conditions was investigated using long-term noise observations by unattended noise monitoring around Narita Airport. The result shows that LA/ATG rapidly decreases above an elevation angle of about 12°, and that LA/ATG becomes higher as vector wind moves from 'downwind' to 'upwind'. This tendency is consistent with the result of LA/GTG. It turned out that the ATG component of the SAE/AIR 1751 equation should be revised so as to be consistent with measurements.

Provided that LA/ATG coincides with LA/GTG at an elevation angle of $\beta = 0°$ and that LA/ATG is negligible at elevation angles higher than 12°, we proposed three revised LA/ATG equations for 'upwind', 'calm' and 'downwind' VW conditions respectively.

$$\Delta L_{\mathrm{LA,\ meteo}} = G(d) \cdot \Lambda(\beta) \tag{4}$$

$$G(d) = C_1 \cdot \left(1 - e^{-0.00274 \cdot d}\right) \quad d \le 914m$$
$$= C_2 \quad d \ge 914\ m \tag{5}$$

$$\Lambda(\beta) = -0.925 + 0.044\beta + 1.925 e^{-0.13\beta} \quad \beta \le 12°$$
$$= 0 \quad \beta \ge 12° \tag{6}$$

In Eq. (5), the coefficient C_1 was determined as 15.09/9.80/5.44 (upwind/ calm or representative of long-term average/ downwind), while the coefficient C_2 as 13.86/9.0/5.0 (upwind/ calm or representative of long-term average/ downwind), respectively for three typical vector wind conditions. However, it is, not possible to consider the influence of temperature gradient with Eq. (5). Note that we named it "1751 Modified" (1751M) as the reviewed version of AIR 1751 which is the equation under conditions of representative for a long-term average.

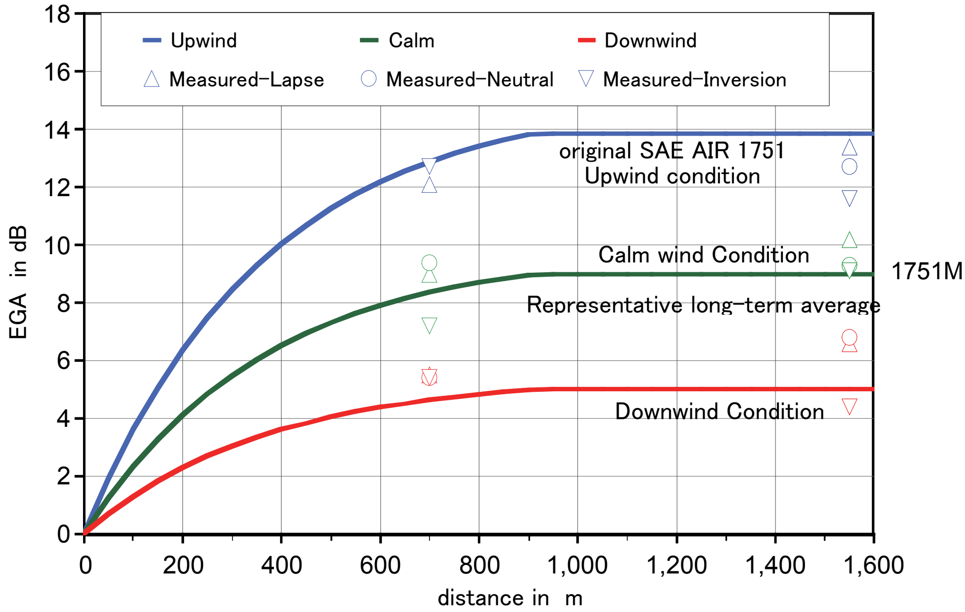

Figure 2 - The empirical relationship of LA/GTG with meteorological conditions, which was derived through the reconsideration of SAE/AIR 1751 (1751 Modified).

We also proposed a unified LA equation, which is expected to add in a segment model type noise prediction considering the effects of ground and meteorological conditions, for use under various vector wind and temperature gradient conditions. The equation is empirically modified to the following Equations (7) and (8) so as to fit the experimental relationship of LA/GTG with VW and TG. The first term in Eq. (8) considers the influence of vector wind (m/s) and the second term is that of temperature gradient (°C/m) using a sigmoid function.

$$\begin{aligned} G(d) &= G_0(V_w, T_g)\cdot\left(1-e^{-0.00274d}\right) \quad d \le 914m \\ &= G(914) \quad d \ge 914\,m \end{aligned} \tag{7}$$

$$G_0(V_w, T_g) = 5\cdot\left[1+\frac{2}{1+e^{0.6\cdot V_w}}\right] + 2\cdot\frac{1-e^{T_g}}{1+e^{T_g}}\cdot\frac{1}{1+e^{V_m}} \tag{8}$$

2.3 SAE/AIR 5662

At around the same time that when we started to examine the validity of AIR 1751, as described in chapter 2.2, the SAE A-21 Committee on Aircraft Noise initiated an evaluation of the need to revise the 'lateral attenuation' prediction method contained in SAE/AIR 1751. It was widely accepted that the equations for the prediction of lateral attenuation in AIR 1751 perform well only for older generation airplanes that have fuselage-mounted low-bypass-ration turbofan engines. These airplanes, however, no longer dominate the noise resulting from current airplane operations.

In 2006, SAE/AIR 5662 “Method for Predicting Lateral Attenuation of Airplane Noise” was published to supersede SAE/AIR 1751. The method applies to turbofan-powered transport category airplanes with engines mounted at the rear of the fuselage or under the wings, and to propeller-driven transport-category airplanes.

The lateral attenuation adjustment given in AIR 5662 takes into account the combination of the product of the Ground-to-Ground component (GTG) and the Air-to-Ground component (ATG), as well as the engine installation effect component. The formula of GTG and ATG components follow the previous AIR 1751 style which expresses LA in Eq.(9) as the product of GTG and ATG values in Eq.(11) & Eq.(12), in spite of changing constants in the equations. Engine installation effect was not taken into account in AIR 1751, but the new AIR 5662 does consider it by calculating differently for each type of aircraft engine mounting location (fuselage or wing or propeller-driven) and depression angle φ. Eq.(10) is engine-installation effect for airplanes with wing-mounted jets.

$$LA_{ADJ} = -\left[E_{ENG}(\varphi) - \frac{G(l_{seg})\cdot\Lambda(\beta)}{10.86}\right] \quad (9)$$

$$E_{ENG,wing}(\varphi) = \begin{cases} 10\cdot\log_{10}\left(\frac{[0.0039\cdot\cos^2(\varphi)+\sin^2(\varphi)]^{\,0.062}}{[0.8786\cdot\sin^2(2\cdot\varphi)+\cos^2(2\cdot\varphi)]}\right) & for\ 0° \le \varphi \le 180° \\ -1.49 & for\ 0° > \varphi > -180° \end{cases} \quad (10)$$

$$\mathrm{G}(l_{seg}) = \begin{cases} 11.83\left[1 - e^{-0.00274 l_{seg}}\right] & for\ 0\ \le l_{seg} \le 914m(3000ft) \\ 10.86 & for\ l_{seg} > 914m(3000ft) \end{cases} \quad (11)$$

$$\Delta(\beta) = \begin{cases} 10.86 & for\ \beta \le 0° \\ 1.137 - 0.0229\cdot\beta + 9.72\cdot e^{-0.142\cdot\beta} & for\ 0° < \beta \le 50° \\ 0.0 & for\ 50° < \beta \le 90° \end{cases} \quad (12)$$

According to this equation, Lateral Attenuation is given by GTG components at an elevation angle of 0 °, becomes a value of 10.86dB in long distance. (It does not include the value of the engine installation effect component). It is a little bit lower than its value when using the previous AIR 1751 and it is higher than its value when using 1751M.

Note that AIR 5662 only assumes the conditions of propagation over ground surfaces that are considered to be "acoustically soft" such as lawn or field grass. The "acoustically hard" surfaces such as frozen or compacted soil, ice, or water and the surfaces with significant undulating terrain are not applicable.

ICAO DOC9911"Recommended method for computing noise contours around airports" and European Civil Aviation Conference (ECAC) Doc 29 (3rd Edition) "Report on Standard Method of Computing Noise Contours around Civil Airports" (7) have adopted the new SAE/AIR 5662. Also, INM Version 7.0 (8) is compliant with ECAC Doc 29 which includes the new method for predicting lateral attenuation following the AIR 5662.

3. Issues of lateral attenuation adjustment in airport noise modeling in Japan

The value of lateral attenuation calculated using the 1751M resulted in a little underestimation. So, we have recognized that the 1751M equation needs to be reaffirmed. When the 1751M was first proposed in the early 2000's, the most commonly operated type of aircraft in Japan was the B747-400, which was therefore the main target of our studies. Nowadays, most B747's have been phased out, whereas new twin-engine aircraft such as the A320, B777 and B787 which all have high bypass ratio engines, have rapidly increased in operation movements. These low-noise aircraft bring change in source noise characteristics, and therefore there is concern about the applicability of the 1751M equation to the lateral attenuation of the sound from aircraft with low-noise and high bypass ratio engines.

Furthermore, the form of the 1751M equation was determined to fit the correction of lateral attenuation in the evaluation of maximum sound pressure level (L_{ASmax}), but now consideration must be given to how suitable it is in the evaluation of sound exposure level (L_{AE}).

In our previous studies, although the impact of the engine installation effect seems to have been suggested, it could not be clearly confirmed. Thus, it is necessary to confirm it again under the current operating conditions of commonly used middle and small sized twin engine aircraft.

Additionally, it is also necessary to consider how to deal with lateral attenuation in the case of complex ground surface conditions such as densely residential area and highly uneven ground, which are not included in the targets of applications by the method of AIR 5662.

In Japan, ground noise such as the sound of aircraft taxiing, APU operation and engine run-up tests is usually required to be taken into account in airport noise prediction. Consequently, lateral attenuation of the sound due to aircraft ground activities is needed to be considered as follows;

- How should lateral attenuation of the sound from aircraft running on the taxiway be considered? The sound source characteristics (directivity and frequency spectrum) would differ from those of aircraft taking-off and landing.
- The sound from APU operation on the apron usually continues very long and stationary and its sound source characteristics are also different from taking-off and landing.

4. Re-examination of LA/GTG using results of long-term monitoring at Narita

As mentioned above, the SAE/AIR 1751 equation brings overestimation in lateral attenuation. Conversely, lateral attenuation calculated using the 1751M result in a little underestimation. On the other, the AIR 5662, which is a reformulation of the AIR 1751, gives a bit higher value of lateral attenuation than that of the 1751M in the case of aircraft with engines mounted under the wings. At first glance, it seems to suggest that it would be better to use the AIR 5662 (See Fig. 3). However, it cannot take into account effects of meteorological conditions on lateral attenuation. Therefore, if the 1751M equation can be modified to fit recent aircraft, it will be still useful to apply to noise prediction under various meteorological conditions.

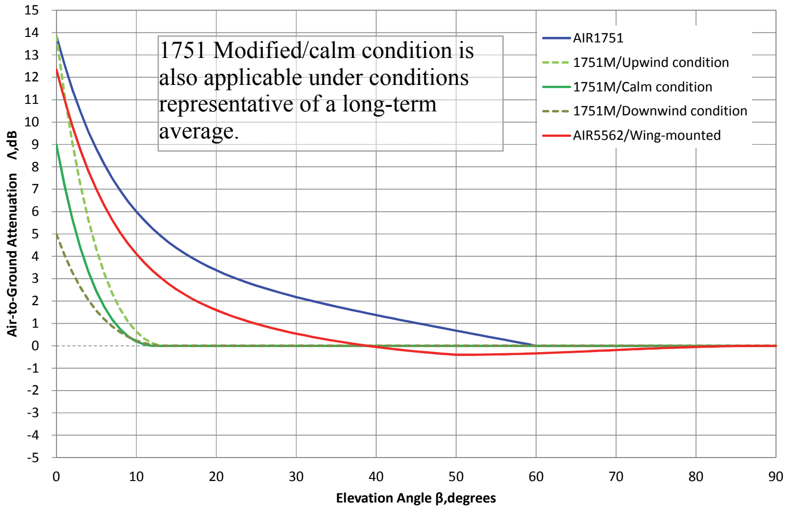

Figure 3 - Comparison of Air-to-Ground (ATG) component of lateral attenuation for long distance (>914m) among the three equations: AIR 1751, 1751M and AIR 5662 for wing-mounted engines.

In carrying out our comprehensive re-examination of the lateral attenuation in noise prediction modeling, the first step was that we revealed the lateral attenuation for Ground-to-Ground (GTG) sound propagation from current types of aircraft, using observations of long-term noise monitoring around Narita Airport, following the same procedure we used when constructing the 1751M.

4.1 Validation procedure for lateral LA /GTG calculation

The calculation procedure for lateral attenuation using observations from the long-term unattended monitoring system is shown as follows: (Incidentally, this procedure is the same as we used when constructing 1751M).

(a) Obtain noise measurements in L_{ASmax} from unattended monitoring stations for take-off,
(b) Obtain sound source spectra (1/3-octave band spectra relative to distance 1m) for individual categories of aircraft model and engine, using two separate one-week noise measurements under the take-off flight path,
(c) Calculate noise level estimations at the monitoring stations, by applying adjustments for spherical spreading and atmospheric absorption to the A-weighted sound source spectra obtained in the step (b), and
(d) Calculate the lateral attenuation as the difference between the noise measurements in (a) and noise level estimations in (c) at each of the monitoring stations.

Afterwards, we investigated the relationship of lateral attenuation with meteorological conditions. Figure 4 shows an illustrated map indicating the point relationship of the unattended noise and meteorological monitoring stations and the short term measurement point for source noise investigation.

Using unattended noise observations at the stations N4 and N5 (710m and 1560m respectively, from Runway-A), we evaluated both temperature gradient (TG) as a temperature difference between heights of 40m & 2m, and vector wind (VW) as a wind velocity directed from the runway to the observer stations at a height of 40m. Noise data used were limited to those of take-off roll and were classified into categories according to aircraft type, in order to avoid the effects of dispersion in sound source strength as well as to guarantee Ground-to-Ground (GTG) sound propagation. Here, we analyzed noise and meteorological observations during two years i.e., fiscal year (FY) 2012 and 2013. Note that the previous studies when constructing the 1751M used the data from FY2000.

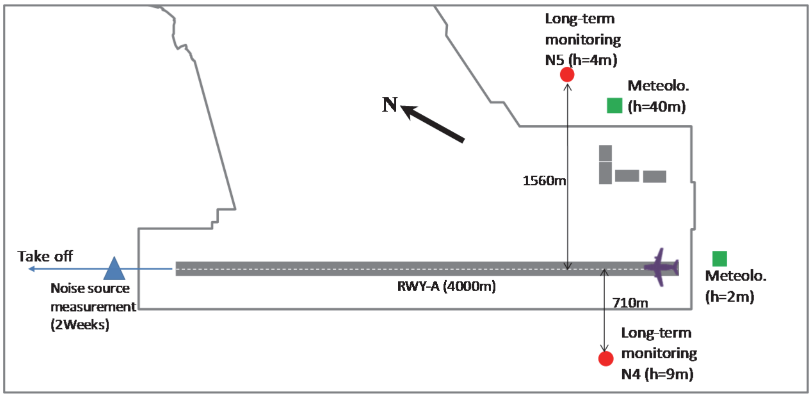

Figure 4 - Illustrated map indicating the point relationship of the unattended noise and meteorological monitoring stations and the short-term measurement point for source noise investigation.

4.2 Results of LA/GTG with meteorological conditions and compared with former results

Figure 5 shows results of re-examination of LA/GTG related to VW and TG for B747-400 at N4, in comparison with those when constructed the 1751M using FY2000 data. The total of noise data investigated in FY2000 was approx. 7500, whereas it was approx. 8400 for FY2012-2013, which is sufficient to ensure the reliability, although B747-400 operations have decreased over the past decade.

Note that in the figures solid lines indicate the results of current re-examination using FY2012-2013 data, while dotted lines show the previous results using FY2000 data. Note also that in the left figure LA/GTG was calculated as arithmetic average of data included in each VW class of '2m/s wide' for individual TG categories of lapse (< -0.5°C), neutral (-0.5 ～+0.5°C) and inversion (> +0.5°C), while in the right figure LA/GTG was calculated as arithmetic average of data included in each TG class of '1 degree wide' for individual VW categories of downwind (< -1m/s), calm (-1 ～ +1m/s) and upwind (> +1m/s).

Looking at the left figure for VW, we can see a clear tendency that LA/GTG is higher upwind than it is downwind. Although there seems to be a slight level difference in the calm and downwind sections, i.e., LA of FY2012-2013 is a little higher than FY2000, the overall tendency has not changed from the previous investigation results. On the other hand, in the right figure for TG, LA/GTG seems to be higher as TG changes from inversion to lapse in both upwind and calm VW categories of this investigation. Also, the downwind VW category is mostly low and stable in spite of changing TG. There is a difference from the results of FY2000 which has an ambiguous trend that LA/GTG is at a maximum when TG is neutral.

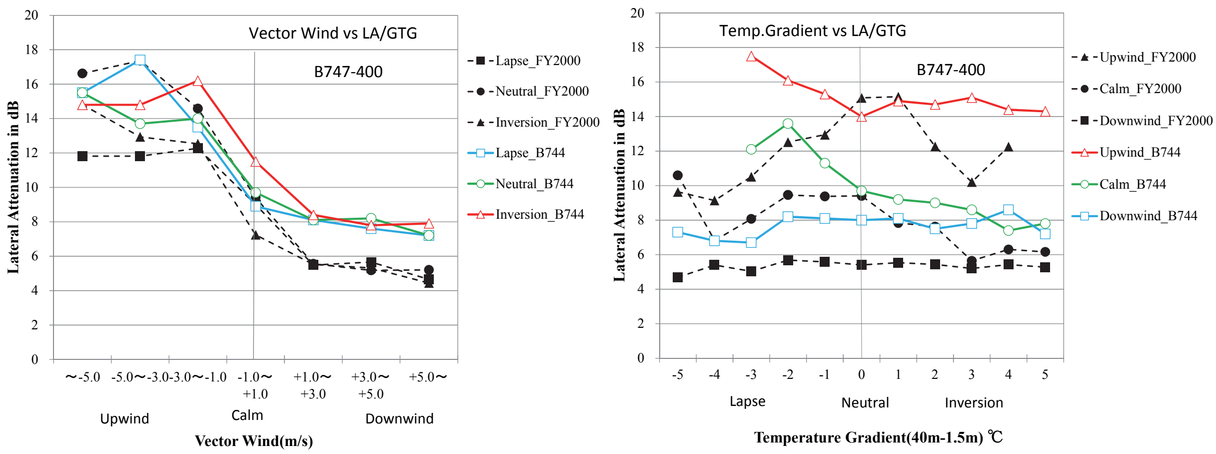

Figure 5 - Relationship between LA/GTG (B747-400) and meteorological conditions at N4 (710m); vector wind (left) and temperature gradient (right) compared with previous results.

4.3 Comparison of LA/GTG among types of aircraft

Figure 6 shows a comparison of 'LA/GTG relationship with vector wind' among various aircraft types observed at point N4 in FY2012-2013, together with that of FY2000 data for B747-400's. Note that LA/GTG was calculated as arithmetic average of data included in each VW class of '2m/s wide', but these are not classified into the TG category.

Looking at the figure, we can see a clear tendency that LA/GTG is higher upwind than downwind for all aircraft types. Above all, LA/GTG of B747-400's (B744) is clearly larger than other aircraft types. Furthermore, it is higher than the results of the same model in the previous FY2000 investigation. The results of B747-8's (B748) or B777-300ER's (B77W) appear to be similar to the results of B747-400's in FY2000. Roughly speaking, LA/GTG results of twin engine low noise aircraft are smaller.

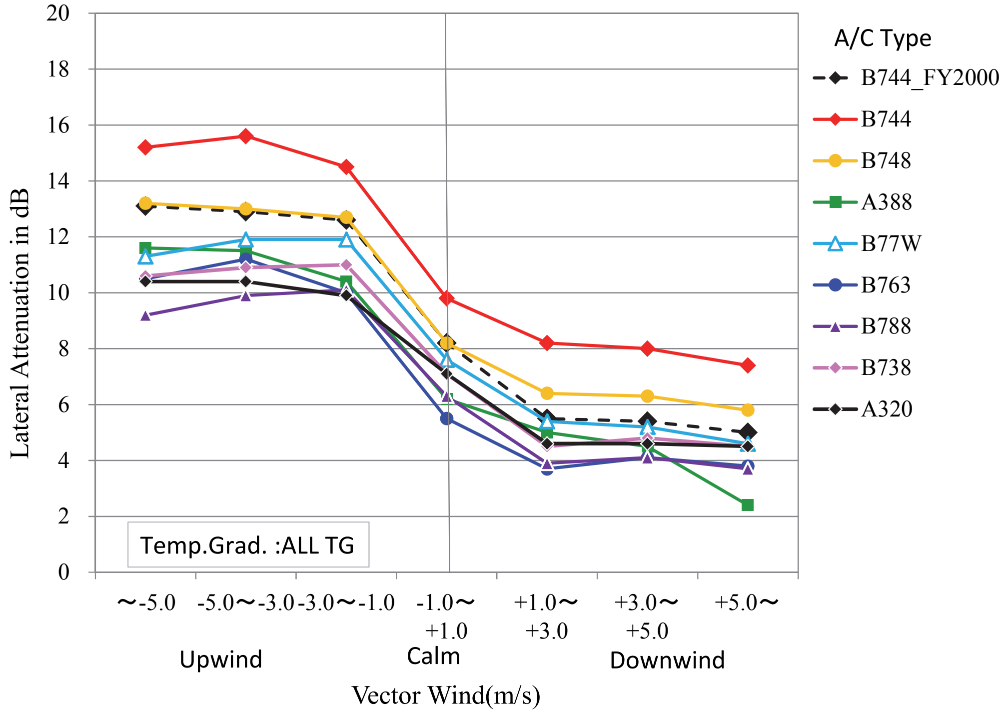

Figure 6 - Relationship between LA/GTG FY2012-2013 and VW at N4 (710m) among various aircraft types, together with that of B747-400's FY2000 data.

4.4 Comparison with various methods of predicting LA/GTG and measurements

Figure 7 shows a comparison of LA/GTG calculations obtained using the three equations, i.e., the original SAE/AIR1751, AIR5662 without adjustment for the engine installation effect and 1751M for individual VW and TG conditions, together with the FY2012-2013 measurements, which were averaged irrespective of aircraft type.

From the figure, we can see that the measurements in downwind (favorable) condition are consistent with the 1751M calculation, but the measurements in calm or upwind conditions are lower than calculations at both measurement stations. We had anticipated that the 1751M calculation would have slightly underestimated the LA/GTG measurements. Although from the results of this investigation, the LA/GTG measurements are lower unexpectedly. We could consider factors affecting LA/GTG using measurement data to become smaller than as expected, as follows:

- Monitoring station N4 has a microphone at a height of 9m which might result in a smaller ground attenuation value compared to having a microphone at a height of 1.5m.
- In the case of unattended noise monitoring, low noise level data might be not acquired because of insufficient level difference from the background noise level. Besides, the monitoring system has to set a threshold level in order to avoid contamination with other noise sources. This lack of measurement at low noise levels may affect the reliability of the results for LA/GTG in upwind conditions.
- Some new houses have been built in the vicinity of the N5 monitoring station since the last examination in FY 2000.

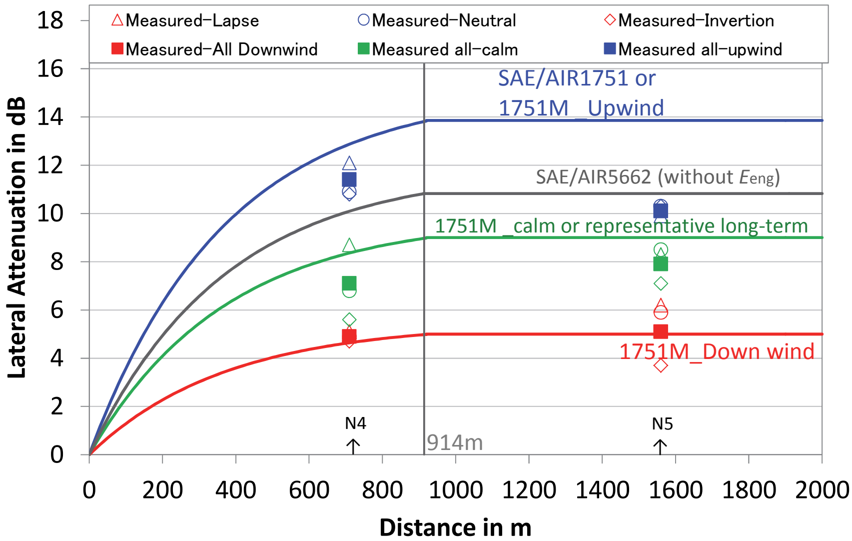

Figure 7 - Comparison of calculated LA/GTG using various equations and the results of measurement in this study.

5. Further investigation

We recognize the necessity for further consideration of the following factors through the results of this investigation using long-term noise monitoring at Narita airport.

- The results of noise measurement at various distances is necessary because there are currently only two different distances in long-term unattended monitoring which therefore cannot give a very detailed insight.
- The microphone height was different as 9m above the ground at the N4 stations, although the noise predicting model assumes the receiver position at a height of 1.5m. Its influence needs to be examined, because the results of LA/GTG of this investigation were lower than what we had expected. One contributor to this underestimation can be the difference in microphone height.
- In this investigation, the value of LA was evaluated using maximum sound pressure level (L_{ASmax}). It is necessary to consider how suitable it is in the case of evaluation using sound exposure level (L_{AE}).
- In addition, it is necessary to consider where aircraft position is when L_{ASmax} is observed. It might not be directly in front of the measurement point. It will be also necessary to consider how LA/GTG changes if we use noise data radiated from the aircraft rolling just in front.
- Needless to say, confirmation of the air-to-ground (ATG) equation, taking into account the influence of weather conditions, is also necessary. The engine installation effect is also needed to be examined.

Therefore, we planned a multi-point and short-term measurement for the detailed investigation to solve the above issues. The measurement was carried out continuously for 7 days in each season at Narita airport, also including the unattended noise monitoring point N4 which was used this study. Up to now, we carried out the short-term measurement three times in summer, autumn and winter. During the three separate measurements, aircraft noise was observed at different lateral distances from 190 m to 1460 m with 8 points along a perpendicular line to the runway. We plan to carry out one (or more) detailed short-term measurements from now on. Although the analyses of measured data have just started, parts of these results are introduced in another paper (9) being presented in this congress.

6. CONCLUSIONS

This paper described a result of discussion on the validity of equations for lateral attenuation of over-ground sound propagation in airport noise prediction modeling. First, it briefly reviewed evaluation equations for lateral attenuation: the SAE/AIR 1751, the 1751M (modified equation based on the AIR 1751 applicable under various meteorological conditions) and SAE/AIR 5662.

The method of the SAE/AIR 1751 brings a little overestimation in lateral attenuation, whereas the prediction results using the 1751M results in a little underestimation. The AIR 5662 which is a reformulation of the AIR 1751 gives a bit higher value of lateral attenuation than that of 1751M. It may be better to use the AIR 5662 if considering international comparability, but it cannot consider meteorological conditions. We believe the 1751M is still useful because it can calculate under various meteorological conditions.

Therefore, we decided to perform a comprehensive re-consideration of the lateral attenuation in the noise prediction model. The first step is that we revealed lateral attenuation of Ground-to-Ground (GTG) propagation, using results of a long-term monitoring system installed around Narita Airport, following the same procedure we used when constructing the 1751M.

From the results of examination of relationship between LA/GTG with Vector Wind (VW) for B747-400's, the overall tendency has not changed from the previous investigation when constructing 1751M, although it seems to be higher compared to the previous results. As for the current aircraft models, the results of B747-8's and B777-300ER's are similar to the previous result of B747-400's which was the basis for the determination of the 1751M. Roughly speaking, the rest of the current aircraft models' (twin engine low noise such as the B737, B787 or the A320), LA/GTG results are smaller than the previous ones. We had anticipated that the 1751M would make the LA/GTG value show a little underestimation, but the results of measured LA/GTG are even lower, contrary to what we had expected.

Through the results of this investigation, we now recognize the necessity for further consideration of the various affecting factors.

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