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Study on over-ground lateral attenuation for prediction model of military aircraft noise

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ABSTRACT

For noise prediction of aircraft moving on the runway and flying-over, the over-ground lateral attenuation is corrected to the A-weighted sound level (noise level) calculated from the NPD database and propagation distance at the point on the side of the moving path. Existing equations indicated by SAE/AIR 1751 and 5662 are used for aircraft noise prediction. And the modified SAE/AIR 1751 ("1751M") has also been proposed a calculation method to predict lateral attenuation under various meteorological conditions. On the other hand, the Noisemap's method is also applied to noise prediction of military aircraft.

Regarding civil aviation aircraft, the correction method of lateral attenuation is verified for currently operated aircraft, because the occurrence situation of noise is changing as the aircraft model is updated. For military aircraft (especially jet fighter aircraft) in Japan, although there was little change in model, we thought that it was necessary to verify the lateral attenuation of military aircraft noise because aircraft are in operation for a long time. Therefore, we conducted a field measurement for several days and confirmed the characteristic of over-ground sound propagation for military aircraft.

As a result of comparing the over ground lateral attenuation calculated by the difference between the noise level measured on the side of the runway in the upwind conditions and the predicted noise level without lateral attenuation, it was confirmed that the results were good agreement with lateral attenuation calculated under upwind condition proposed in 1751M.

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1. INTRODUCTION

For noise prediction of aircraft moving on the runway and flying-over, the over-ground lateral attenuation is corrected to the A-weighted sound level calculated from the NPD database and propagation distance at the point on the side of the moving path. SAE/AIR 1751 [1] and 5662 [2] are used for aircraft noise prediction. And the modified SAE/AIR 1751 ("1751M”) [3] has also been proposed a calculation method to predict lateral attenuation under various meteorological conditions. On the other hand, the Noisemap's method [4] is also applied to noise prediction for military aircraft.

Regarding civil aviation aircraft, the correction method of lateral attenuation is verified for currently operated aircraft, because the occurrence situation of noise is changing as the model is updated. For military aircraft (especially jet fighter aircraft) in Japan, although there was little change in model, we thought that it was necessary to confirm the lateral attenuation of military aircraft noise due to the influence such as the secular change caused by long-term operation of aircrafts. This paper shows a comparison of lateral attenuation of over-ground sound propagation during aircraft take-off ground roll for military aircrafts obtained measurement with that calculated existing methods.

2. OUTLINE OF FIELD MEASUREMENT

Measurement to comfirm lateral attenuation in the ground-to-ground propagation (LA/GTG) was carried out regidential area which located the runway side of an airbase in Japan. The sound source to be measured was the take-off ground roll sound. As shown in Figure 1, five measurement points were arranged approximately in a straight line in a direction perpendicular to the runway. The distance from center of the runway to each points was 320 m (Pt 1) to 1 km (Pt 5). And the terrain from the runway to the measurement points was almost flat with little undulation. Therefore, it was enough to see the aircraft moving on the runway from each measurement point.

The measurement point (Pt S) to obtain a frequency characteristicsof the source sound data to predict a noise level without lateral attenuation was placed just under the take-off path which is about 1 km away from the end of the runway. The measurement result of maximum noise level ($L_{\mathrm{A,Smax}}$) at points Pt 1 to Pt 5 was compared with the $L_{\mathrm{A,Smax}}$ predicted from the frequency characteristics of flight noise obtained at Pt S. In the measurement of collection of sound source data, the distance from the flying aircraft to Pt S was also measured by the procedure of triangulation.

A sound level meter (NL-52 (RION)) and a data recorder (DA-20 (RION)) were used in the measurement. The microphone was installed at a height of 1.5 m. The vector wind speed was approximately 4 m/s toward to the runway from measurement point. And it was upwind as sound propagation.

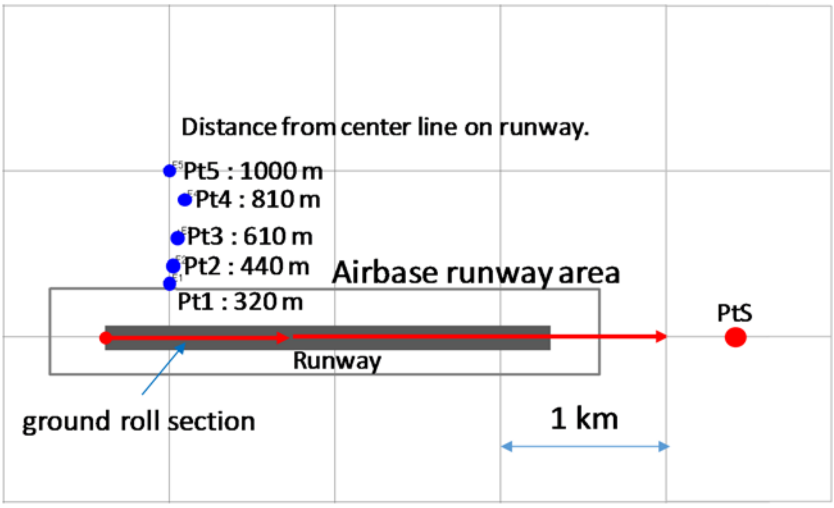

Figure 1. Schematic drawing of measurement point arrangement on the side of take-off ground roll path.

3. THE LATERAL PROPAGATION CHARACTERISTICS OF AIRCRAFT TAKE-OFF GROUND ROLL NOISE

The measurement results of the time history of the A-weighted sound level (noise level) of take-off ground roll sound on the side of runway are shown in figure 2 and figure 3. The horizontal axis represents the time and the vertical axis represents the noise level. In the figure, when the time on horizontal axis reaches 6 seconds, the aircraft has raised the engine power and been starting take-off ground roll. And at about 20 seconds, the aircraft has passed through a position that is closest to the measurement points on the runway. The maximum noise level at each measurement point has occurred after the aircraft has passed closest position on the runway. It is seems to be due to the directivity of the aircraft. As shown in figure 3, in the case of take-off using the afterburner, the time until the noise level reaches the maximum after passing closest position on the runway from the measurement points tended to be longer than the case of take-off without afterburner shown in figure 2.

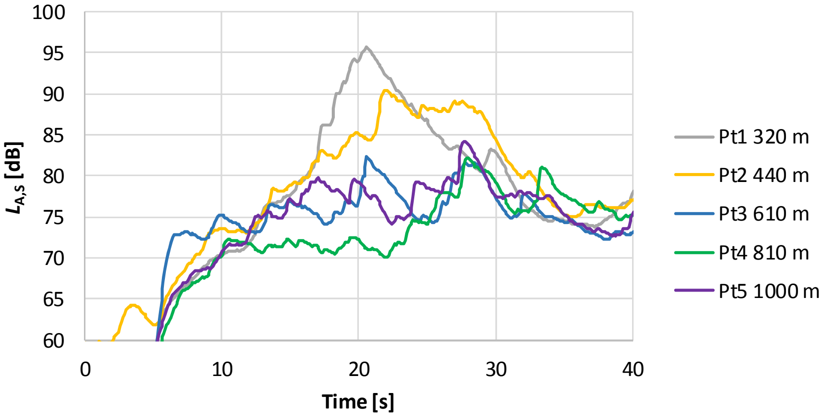

Figure 2. Time history of noise level in case of take-off without afterburner at each measurement point standardized at time of 20 seconds when aircraft was passed closest position on the runway.

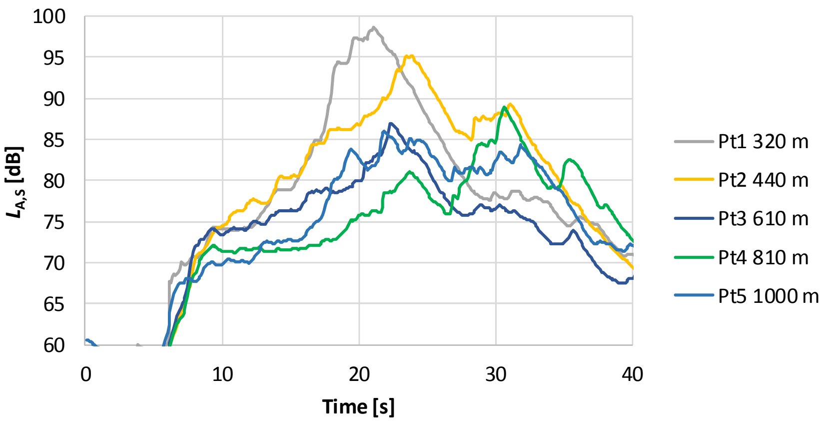

Figure 3. Time history of noise level in case of take-off using afterburner at each measurement point standardized at time of 20 seconds when aircraft was passed closest position on the runway.

Figure 4 shows the relationship between the measurement results of the $L_{\mathrm{A,Smax}}$ and the distance from the measurement points to the runway. The horizontal axis represents the distance between the points and the runway, and the vertical represents the $L_{\mathrm{A,Smax}}$. And each plots and lines are shown the aircraft model, take-off power that is using afterburner (TOAB) or not (TO).

For any aircraft model and take-off power, the attenuation in the relationship between the $L_{\mathrm{A,Smax}}$ and the propagation distance from runway to Pt 4 and Pt 5 is smaller than the attenuation trend in Pt 1 to Pt 3. In addition, the $L_{\mathrm{A,Smax}}$ at Pt 5 is larger than that at Pt 4. Figure 5 shows an example of frequency characteristics to confirm the trend when the $L_{\mathrm{A,Smax}}$ occarred. For Pt 1 to Pt 3, as the propagation distance becomes longer, the sound pressure level become smaller with similar frequency characteristics pattern. On the other hand, the sound pressure level at Pt 4 and Pt 5 are high in the frequency band around 400 Hz. The $L_{\mathrm{A,Smax}}$ occurred after the aircraft passes over the runway just beside the measurement point. Therefore, the position of the aircraft was confirmed based on the delay time to reach the maximum noise level after passing sideways of the measurement points. As a result, it was found that the maximum noise level occurred at measuring Pt 4 and Pt 5 is the part after the aircraft lift-off from the runway. Therefore, the change of the attenuation tendency is thought to be due to the change of the ground surface influence in the propagation process. In the study of LA/GTG, it is necessary to compare data in a state that does not become air-ground propagation (ATG). Therefore, in the study of LA/GTG with the maximum noise level, the measurement results of Pt 4 and Pt 5 were excluded from the comparison data and used as reference values.

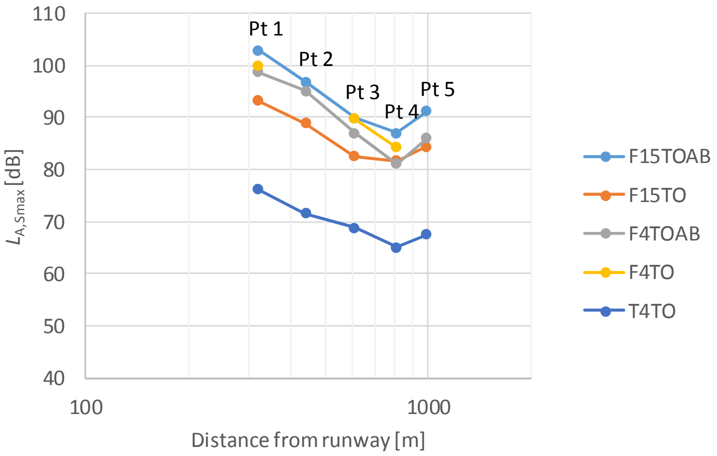

Figure 4. Relationship of $L_{A,Smax}$ *with propagation distance.*

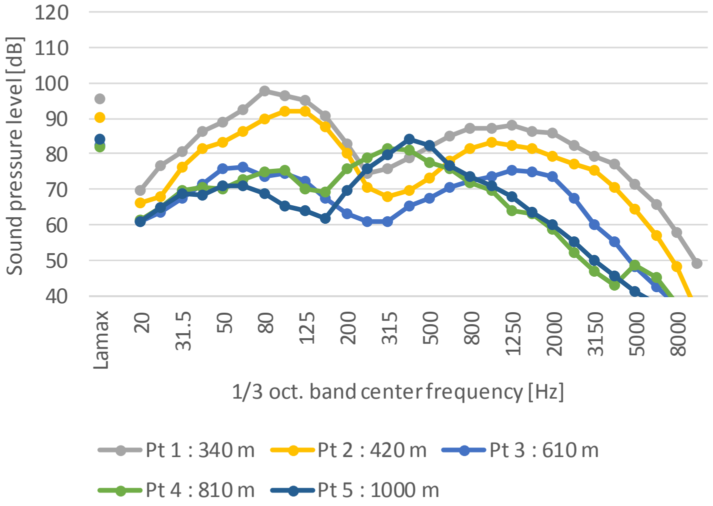

Figure 5. Frequency characteristics at $L_{A,Smax}$ *measurement*

Military aircraft such as fighter aircraft have strong directivity diagonally behind the aircraft, compared to civil aviation aircraft. We thought that it is different from the correction value of lateral attenuation based on the relationship between the distance of approach from a moving pass and a $L_{A,Smax}$ which has been examined so far. Therefore, we comformed the relationship between the noise level at the time of passing through the proximity position on runway and the distance from center of runway to measurement points. As shown in figure 6, the noise level at Pt 1 to Pt 4 attenuat continuously according to the propagation distance compared with figure 4. On the other hand, the noise level at Pt 5 is larger than Pt 4 with a short propagation distance. As shown in figure 2 and 3 showing the time histry of the noise level at Pt 5, the level is not only rising after the passage through beside of the measurement point by the influence of the directivity, but also rising at the time of passing at closest position on runway. As shown in figure 7, the frequency characteristics of the aircraft noise at the time of passing at the closest position on the runway to the measurement point are similar pattern in Pt 1 to Pt 4. In addintion, the sound pressure level are reduced according to the propagation distance. For Pt 5, the sound pressure level increase in the band around 1 kHz compared with other points. From the result, the LA/GTG due to the noise level at the time of passing the closest position to the measurement point was examined based on the results of Pt 1 to Pt4. And the results of Pt 5 was excluded from the comparison data and used as reference values.

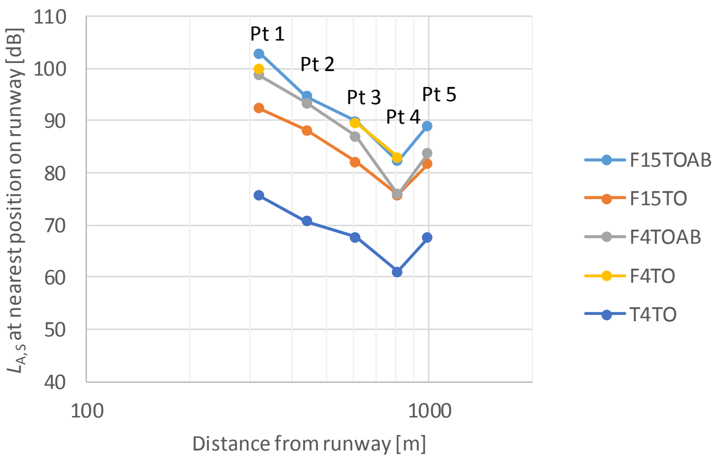

Figure 6. Relationship of noise level at the time of passing the closest position to the measurement point with propagation distance.

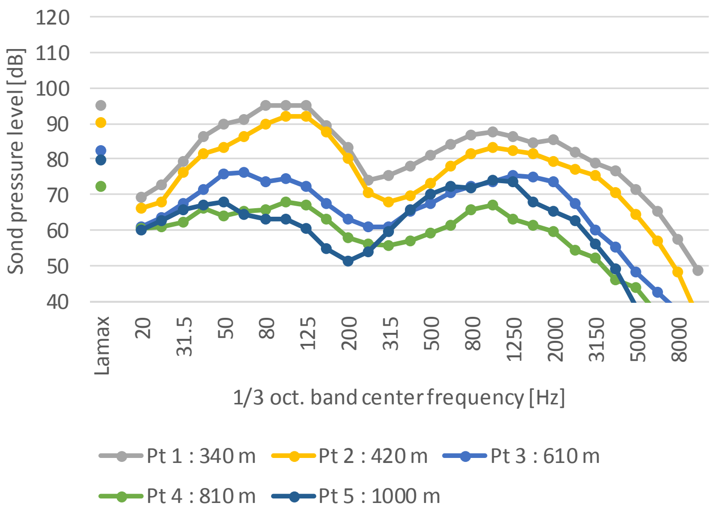

Figure 7. Frequency characteristics at noise level at the time of passing the closest position
to the measurement point.

4. OVER GROUND LATERAL ATTENUATION OF MILITARY AIRCRAFT

The LA/GTG was calculated from the measurement result of take-off ground roll sound obtained in Chapter 3 and the predicted noise level without the lateral attenuation which calculated from a frequency characteristics of take-off sound measured under a flight path at Pt S. The noise level without LA/GTG corresponding to the distance from the runway to the measurement points was predicted by correcting the attenuation by geometrical spreading, and the absorption of sound by atmosphere by ISO 9613-1 to the frequency characteristics. Only take-off noise without using afterburner was compared, since it was impossible to obtain the frequency characteristics of the take-off noise that was used afterburner. The results of LA/GTG are shown in figure 9 and figure 10 compared with SAE AIR 1751, 5662 and Noisemap. SAE AIR 1751 shown in these figures is same to the upwind condition of 1751M. In addition, the results of LA/GTG of civil aviation aircraft around four airports conducted by Kawase et al [6]. are also compared. The airports are Narita airport with unduration on the propagation path, Sendai airport and Kagoshima airport with a nearly flat path, and Osaka airport surrounded by the urban area.

Figure 8 shows the LA/GTG calculated based on the prediction and measurement result of $L_{\mathrm{A,Smax}}$. In the results of Pt 1 to Pt3 to be compared, the LA / GTG of F-4 measured under upwind conditions is larger than SAE AIR 5662 for wing-mounted engine aircraft and Noisemap. Whereras it showes good agreement with the upwind condition of SEA AIR 1751M considered vector wind speed. This result is equivalent to the result of Sendai airport with a nearly flat propagation path. However, the LA/GTG of F-15 is 2 to 3 dB larger than SAE AIR 1751M. This is closer to the measurement result of Kagoshima airport than Sendai airport. The difference in measurement results at these airports is thought to be influenced by the presence or absence of crops and their height. Tall crops were planted in the field of the propagation route in the measurement at Kagoshima airport. However, the trends of changes in LA/GTG according to the propagation distance are generally in agreement, and difference from 1751M is also almost constant. The difference might be due to the difference in operation status by the day for measuring the sound source for prediction and the day for measuring lateral attenuation. As a result of Pt 5, the lateral attenuation is small as a whole because the noise level was increased.

Figure 9 shows the LA/GTG calculated based on the prediction result of $L_{\mathrm{A,Smax}}$ and measurement result of noise level at the time that aircraft was passing the closest position on the runway from the measurement point. The LA/GTG of F-4 is close to the tend of the upwind condition of SAE AIR 1751M (same as AIR 1751) at Pt 1 to Pt 3 as with figure 9. However, the result of Pt 4 is about 2dB larger than AIR 1751M. The reason that the LA/GTG at Pt 4 was large was probably due to the fact that there is a slight mound between the runway and the measurement point. The LA/GTG of F-15, as a whole, is 2 to 3 dB larger than F-4 overall but the trend of the change is similar.

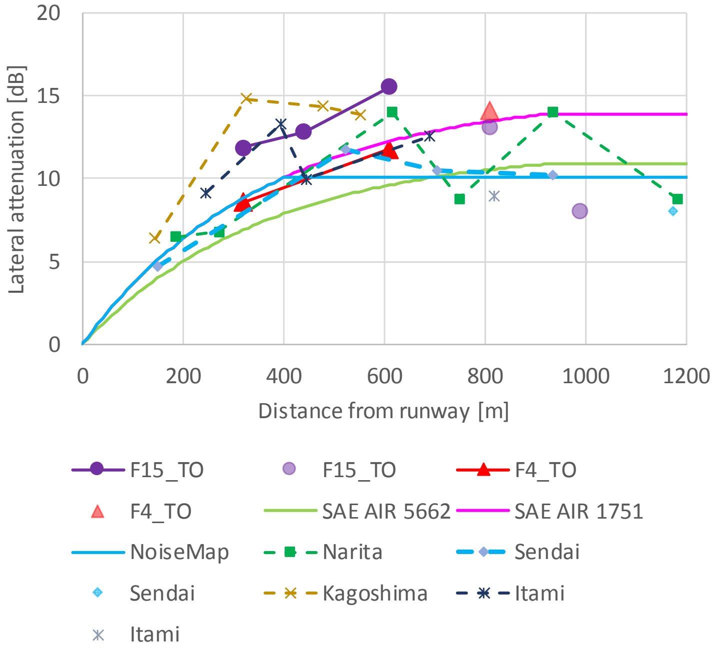

Figure 8. Comparison of LA/GTG by $L_{A,Smax}$ with existing formulas for LA/GTG and result at civil airport.

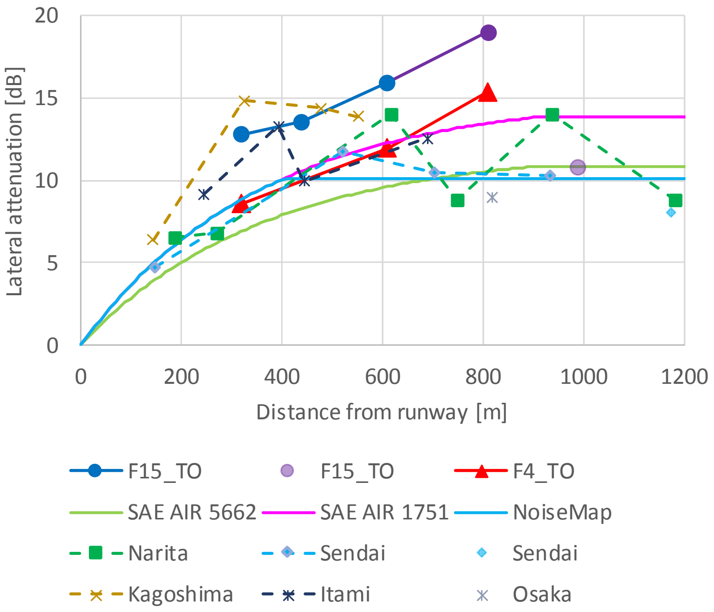

Figure 9. Comparison of LA/GTG by noise level at the time that aircraft was passing closest position on the runway with existing formulas for LA/GTG and result at civil airport.

5. CONCLUSIONS

In order to confirm the lateral attenuation due to the ground-to-ground propagation on the side of the flight path in the prediction of the aircraft noise of the jet fighter aircraft, take-off ground roll noise was measured.

As a measurement result of the relationship between the maximum noise level of the take-off ground roll noise and the close distance from the runway to the measurement points, the noise level at three measurement points close to the runway was decreased smoothly with the propagation distance. However, the maximum noise level relative to the propagation distance at the measurement point far from the runway was clearly increased. As a result to comfirm the attenuation tendency by the noise level at the time when an aircraft was passing the closest position on runway , it was found that only the farthest measurement points had a large noise level and the attenuation tendency was different. It seems to be because the jet fighter aircraft has strong directivity diagonally backwards, and the noise with low attenuation after floating from the runway was measured.

As a result of comparing the over ground lateral attenuation calculated by the difference between the noise level measured on the side of the runway in the upwind conditions and the predicted noise level without lateral attenuation, it was confirmed that the results were good agreement with lateral attenuation calculated under upwind condition proposed in 1751M, although there was an errors due to the sound source data.

In the future, we will examine the change of the lateral attenuation with different vector wind speed of the jet fighter aircraft.

6. REFERENCES

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