EFFECT OF METEOROLOGICAL CONDITIONS ON THE EXCESS GROUND ATTENUATION FOR THE AIRCRAFT NOISE PREDICTION

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ABSTRACT

This paper talks about a method of evaluating excess ground attenuation (EGA) revised in consideration of effects of meteorological conditions. It is necessary to take the EGA into account in the prediction of airport noise, but the well known SAE/AIR 1751 equation is said to bring a little overestimation. We examined the validity of the AIR 1751 equation by following up the process in which it was formulated. It turned out that the form of equation changes dependent on meteorological conditions. We, therefore, investigated what conditions are appropriate for evaluating the long-term average noise exposure, using noise observations by an unattended noise monitoring system. The result suggests, it is reasonable to use an EGA equation, derived for weather conditions ‘calm’ and ‘neutral’, as representative as far as concerned with noise prediction near the side of runway.

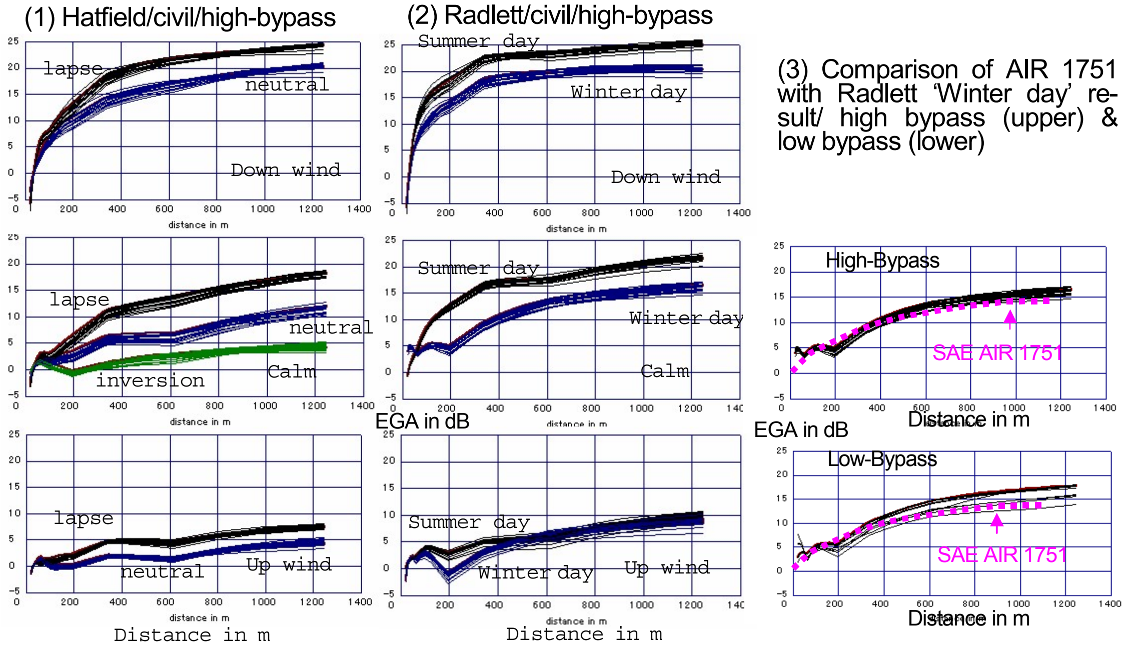
1. INTRODUCTION

It is necessary to take account of excess ground attenuation in the prediction of airport noise, but the well known SAE/AIR 1751 equation [1] is said to bring a little overestimation due to changes in source noise characteristics, etc. In Japan, we have been using an empirically modified equation which calculates EGA adjustment a little as low compared to the original. Besides, the AIR 1751 equation is not applicable to acoustically hard surfaces. The FAA is now in preparation for developing a new EGA-calculating equation based on a theoretical noise propagation model [2]. The conventional AIR 1751 equation is, however, still of worth because it is easy to handle. We decided to examine the validity of the equation by following up the process in which the equation form was determined, being based on frequency spectra of recent aircraft equipped with high-bypass engines and result of field experiments by Parkin et al. [3, 4]. As is expected, the result shows a considerable change in magnitude according to meteorological conditions. Then, we examined the validity of the result using long-term noise observations obtained by an unattended noise monitoring system, and investigated what conditions are representative for evaluating the long-term average noise exposure.

2. EXAMINATION OF THE VALIDITY OF THE AIR 1751 EQUATION

The AIR 1751 equation for the EGA adjustment is expressed as a product of a ground-to-ground component (GTG) with an air-to-ground component (ATG), but when the aircraft is on the ground, it has the GTG term only. Here, first, we examined the validity of the GTG component, because the difference between noise prediction and measurement is remarkable when the aircraft rolls on the runway and it turns to climb.

According to Ref. 1, the EGA/GTG at a site was evaluated as the difference in A-weighted sound pressure levels, which were calculated from one-third octave-band sound-source spectra, between with and without adjustment of band attenuations due to sound propagation over ground. The sound sources at that time were mainly old types of aircraft equipped with old low-bypass engines, although now almost all aircraft are equipped with high-bypass engines. It means there are changes in source spectra. On the other, the band attenuation data used were derived by Parkin et al. from field measurements obtained at Radlett airfield [3] in ‘winter day’ condition, which was expected in Ref. 1 to bring a conservative result of attenuation. But, temperature gradient in daytime is in general ‘lapse’, which may result in rather large attenuation compared to other conditions. Note that Ref. 1 does not clearly refer to wind conditions, but it was guessed as calm, although the field measurements in Ref. 3 were reduced to three categories of wind conditions (calm, down wind/15 ft/s and up wind/-15 ft/s). We calculated EGA for source spectra (of take-off & landing noise) of many representative aircraft flying in Japan including military aircraft; (civil/ high-bypass) B747-400, B777, etc., (civil/ low-bypass) B727, B737, etc., (military) A6, F15, F18, etc. and (propeller) C130, YS11, etc. Each of these spectra was an average of five or more observations at the maximum A-weighted sound level beneath the flight path, for individual aircraft types after adjustment for spherical spreading and air absorption. As for band attenuation values, we used data at both Radlett and Hatfield, which we read from average one-third band spectra at seven points 35 – 1,100 m from the sound source from figures in Ref. 3 and 4. Figure 1 shows some results of calculation. It shows; 1) Radlett/ winter/calm result was almost the same but a little high compared to average attenuation at takeoff shown in Ref. 3 or to the AIR 1751 equation, 2) there is no clear difference among results of high and low bypass civil aircraft and military aircraft, 3) Hatfield/ lapse results lie between summer and winter results at Radlett, and finally 4) the EGA magnitude greatly changes dependent on vector wind as well as temperature gradient.


(1) Hatfield/civil/high-bypass

(2) Radlett/civil/high-bypass

(3) Comparison of AIR 1751 with Radlett ‘Winter day’ result/ high bypass (upper) & low bypass (lower)

Figure 1. Re-constructed EGA/GTG curves for aircraft with high bypass engines using band attenuation data at (1) Hatfield and (2) Radlett, and comparison of Radlett result with AIR 1751.

3. EXAMINATION OF THE EFFECTS OF METEOROLOGICAL CONDITIONS ON EGA

The above result suggests that the AIR 1751 equation is still valid as far as the ‘winter/calm’ condition suits to evaluate the long-term average noise exposure, while it also shows that meteorological conditions strongly affect the EGA magnitude. Then, we investigated the relationship between meteorological conditions and long-term average noise exposure or EGA, using noise observations obtained by an unattended noise monitoring system at Narita Airport [5].

Narita Airport Authority has an unattended ground noise monitoring system, which started its regular operation since April, 2000, to monitor airport noise arising from different airport ground activities such as engine run-up tests throughout the year [6]. The system consists of a central station and eight remote monitoring stations, N_1–N_8, as shown in Figure 2, and weather conditions (temperature, wind direction and wind speed) are observed at three remote stations N_3, N_5 and N_7, respectively at heights of 40m, 1.5m and 20m from the ground. Here, we analyzed noise and meteorological observations during a long period, i.e., ten months, from April 2000 to January 2001.

Frequency Distribution of Meteorological Conditions

First, we investigated predominant weather conditions by calculating frequency distribution of the meteorological observations at Narita Airport. The data was first reduced to temperature gradient (TG) and vector wind (VW). Then it was averaged every ten minutes, and finally it was classified into TG and VW classes respectively for every one-hour time zone. TG was evaluated as the temperature difference between heights of 1.5m and 40 m (neutral/ ±0.5°C, lapse/ less than -0.5°C, inversion/ greater than +0.5°C), while VW was calculated as a velocity component perpendicularly directed from the runway to the west side (i.e., to the station N_4), using the wind velocity and direction data at the height of 40m (calm/ inside of ±1.0 m/s, downwind/ higher than +1.0 m/s, upwind/ lower than-1.0 m/s). The class widths were 1°C and 2 m/s.

The result is shown in Fig.3 (left: TG, right: VW). In the figure, frequencies in each class are expressed discretely using marks showing percent rates in round numbers of several tens percents. From the left figure, the result of TG shows a remarkable daily rhythm, in which it becomes lapse in the daytime and inversion in the nighttime. Looking at the total percent rate of frequencies for all day, shown in the second bottom line, the frequency of the neutral condition is the most prevailing (33%). The shape of distribution is a little deflected to the inversion; the accumulated frequency is 49% for the inversion and 18% for the lapse. On the other hand, we see no clear daily rhythm in the frequency distributions of VW. Although the distribution is a little widened in the afternoon time, a round half of the total frequency rate of VW remains to be calm (49%), while downwind is 33% and upwind 18%. It is easily understood if we consider that the runway is in general constructed so that the aircraft flies facing to wind. We also obtained a frequency distribution of aircraft operation numbers classified according to weather conditions. The result was almost the same as the above stated frequency distributions of TG and VW themselves. That is, the most prevailing weather conditions were ‘wind/calm’ and ‘temperature gradient/neutral’ [5].

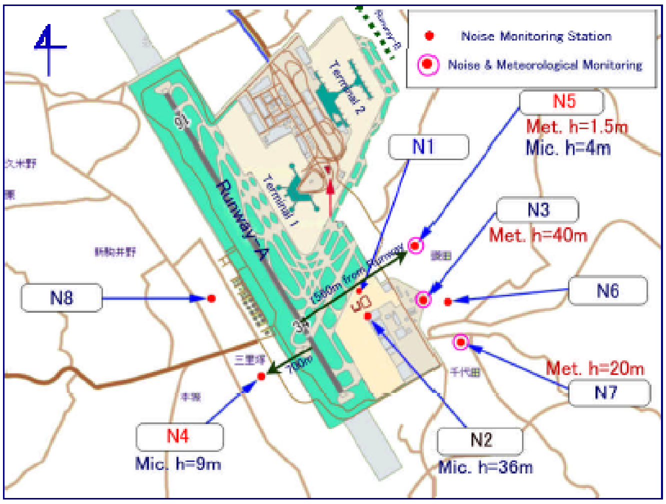


Figure 2. The site location of stations of an unattended ground noise monitoring system at Narita. In the figure ‘Mic.h’ & ‘Met.h’ mean the height (from the ground) of noise & meteorological measurement at each station.

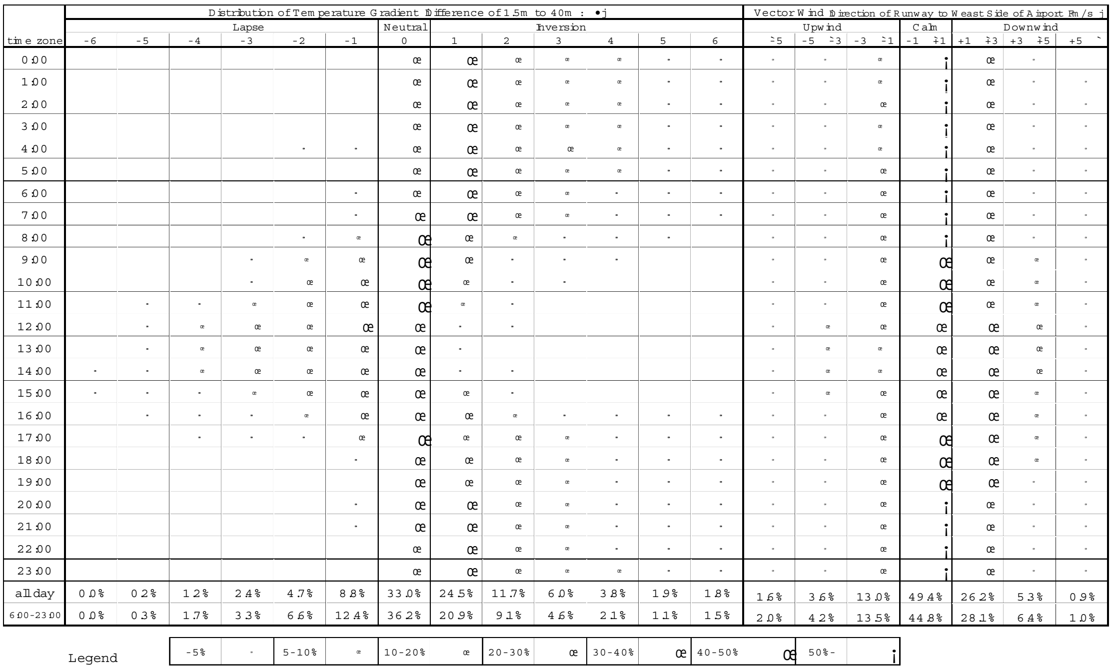


Figure 3. Frequency-rate distributions of meteorological conditions at Narita Airport (April/ 2000-January/2001); (Left) temperature gradient, and (right) vector wind.

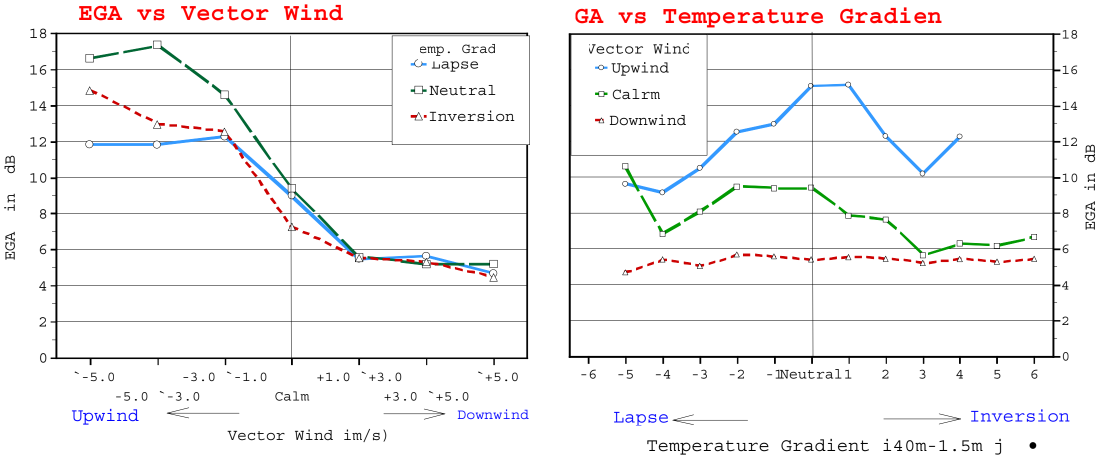


Figure 4. Relationship between EGA (B747-400) and meteorological conditions at N_4; (left) vector wind and (right) temperature gradient.

Relationship of Meteorological Conditions with EGA

Using unattended noise observations at the stations N_4 (700m) and N_5 (1560m), we investigated the relationship of TG and VW with EGA values estimated from measurements of maximum A-weighted sound pressure levels, which were observed during aircraft take-off roll. The noise data were classified into classes according to aircraft types and trip lengths, in order to avoid effects of dispersion in sound source strength as well as to guarantee 'ground to ground' sound propagation. Figure 4 shows a result at N_4 for only B747-400. Looking at the left figure, we clearly see a tendency that EGA is higher at upwind than at downwind, irrespective of TG. In the right, EGA is unexpectedly large for neutral/upwind, but it is constantly low irrespective of TG in case of downwind. Note that in the left figure EGA values were calculated by taking arithmetic averages of all data respectively for lapse (< -1°C), neutral (-1 - +1°C) and inversion (> +1°C) conditions at each VW, while in the right EGA values were obtained as arithmetic averages of data independently for downwind (< -1m/s), calm (-1 - +1m/s) and upwind (> +1m/s) at each TG. The result at N_5 was almost similar to that at N_4, except that EGA for lapse was a little large compared to that for inversion, irrespective of VW.

Figure 5 shows a comparison of long-term average of measured EGA values with the re-constructed EGA/GTG curves for high bypass aircraft at Hatfield in Fig.1. Roughly speaking, the measured EGA seems to follow the re-constructed neutral curve for each VW condition and it is a little low compared to the AIR 1751 equation.

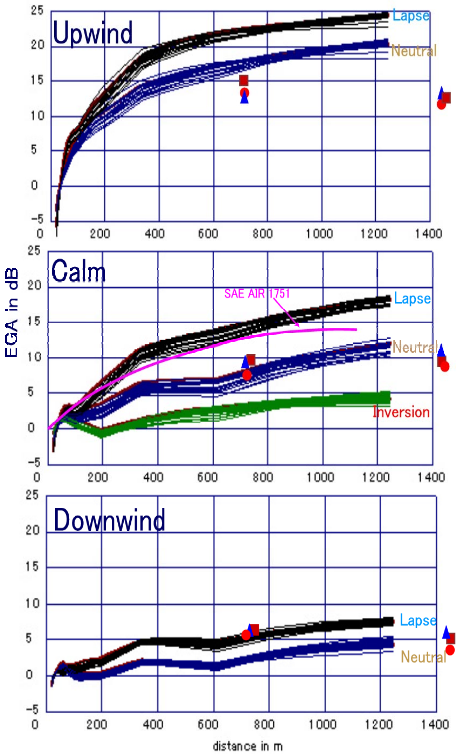


Figure 5. Comparison of measured EGA values with the re-constructed EGA/GTG curves for high bypass aircraft at N_4 and N_5 at Hatfield.

Representative Conditions for the Long-term Average

As shown in Fig.3, the typical weather conditions at Narita Airport were almost VW/calm and TG/neutral. Here, we examined whether some meteorological conditions can be representative for evaluating long-term average maximum A-weighted sound pressure level and EGA. The result shows that if we calculate average sound level and EGA for VW/calm and TG/neutral conditions, the result becomes very close to the long-term average values calculated from the entire data for all weather conditions. Figure 6 shows a result for EGA, in which we can see that the difference of EGA between long-term average and individual weather conditions become very small when VW/calm and TG/neutral. The AIR 1751 equation was derived using Radlett winter day data, in other words, it was derived under the assumption of 'calm & lapse'. But, although it is a limited result at Narita, it suggests that we had better assume 'calm and neutral' conditions for evaluating long-term average sound levels. Then, we derived a roughly approximated modified EGA/GTG equation (Eq.1), which is similar to the original AIR 1751 equation as follows;

$$G_m(d) = 9.8 \cdot \left(1 - e^{-0.00274 \cdot d}\right) \tag{1}$$

Figure 7 shows a comparison of A-weighted sound pressure levels between measurements and calculations (1) with EGA by the original AIR 1751 equation, (2) with EGA by the above modified equation and (3).without EGA., in addition to adjustment for spherical spreading and air absorption. In

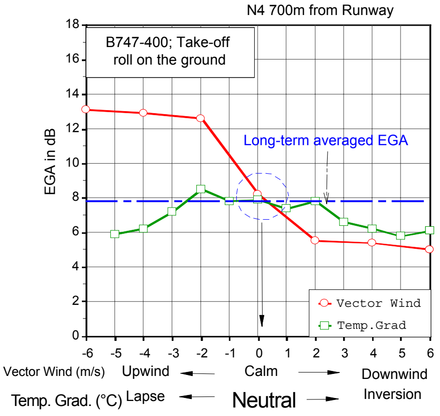


Figure 6 Comparison of EGA values between long-term average and individual weather conditions..

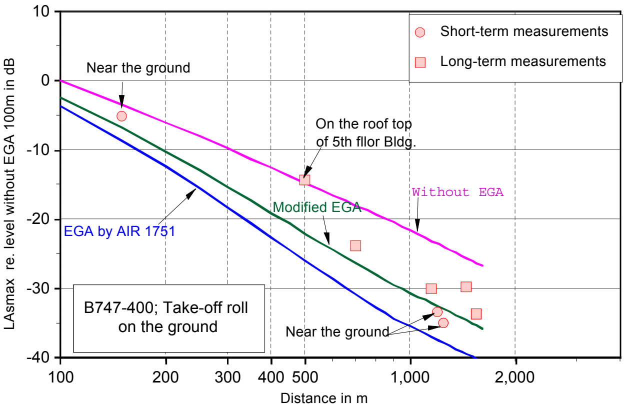


Figure 7 Comparison of L_{ASmax} by long-term and short-term measurements with predictions using (1) EGA by AIR 1751, (2) modified EGA and (3) without EGA.

the figure, the modified EGA equation seems to fit measurements better than the AIR equation.

4. LATERAL ATTENUATION FOR AIR-TO-GROUND CASES

Based on the modified EGA/GTG equation Eq.1, we examined the form of the ATG component. We evaluated it as the ratio of measured EGA at ATG conditions calculated from measurements to the value GTG by Eq.1, as follows;

$$\alpha_m(\beta)=\Delta_m(d,\beta)/G_m(d) \qquad (2)$$

Noise measurements were made at the side of flight courses at Narita airport and another airbase. The result, shown in Fig.8, suggests that the value of ATG component estimated from measurements seems to become rapidly high at elevation angles lower than around 10°, as well as a little low at angles higher than 10°, compared to AIR 1751. Finally, Figures 9 and 10 show comparisons of our result with calculation by the newly proposed EPD model for the FAA's integrated noise model [7].

5. CONCLUSION

The validity of the AIR 1751 equation evaluating EGA was examined. The result suggests that there is a need to revise it in consideration of effects of meteorological conditions. It seems to be reasonable to use an EGA equation, derived for weather conditions 'calm' and 'neutral', as representative as far as concerned with noise prediction near the side of runway. We also investigated the validity of the ATG component, resulting in a suggestion of high attenuation at elevation angles lower than around 10°, as well as a little low at higher than 10°, compared to AIR 1751.

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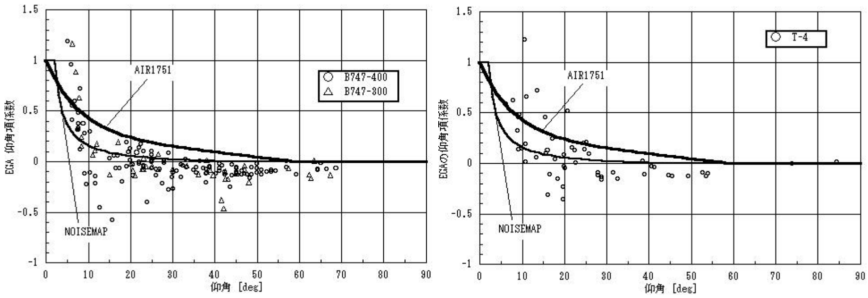

Figure 8. Comparison of ATG components among AIR 1751, NOISEMAP and estimations from measurement; (left) B747 at Narita and (right) T4 at Hamamatsu Airbase.

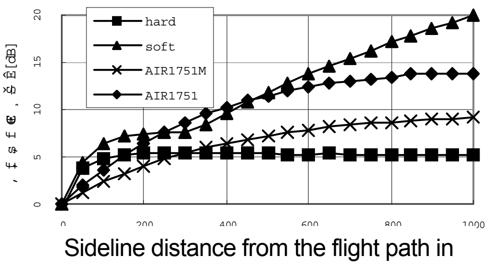

Figure 9. Comparison of EGA/GTG curves among EPD model (hard/soft), AIR 1751 and our modified equation (AIR 1751M).

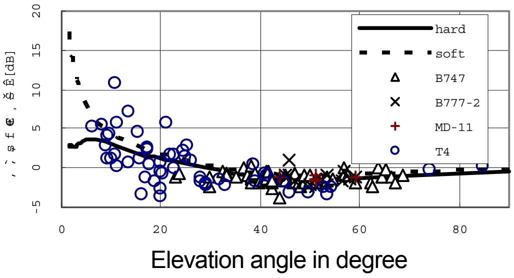

Figure 10. Comparison of measured EGA/ATG components at Narita with prediction by EPD model (hard/soft).