inter•noise 83

ACOUSTIC RECOGNITION OF AIRCRAFT TYPES IN FLIGHT

I.Yamada, A.Yokota, S.Shimizu, M.Yamashita (1) and T.Okamoto (2)

(1) Kobayasi Institute of Physical Research, 3-20-41 Kokubunji, Tokyo, Japan.
(2) Defence Facilities Environment Improvement Association, 3-41-8 Shiba, Minato-ku, Tokyo, Japan.

INTRODUCTION

In an aircraft noise monitoring system around an airport, an additional information on aircraft types is required from the airport authority. In order to develop an acoustic recognition method using the aircraft noise itself, measurements of fly-over noise of various types of aircraft have been made beneath the flight path near the airport. Discriminatory analysis based on 1/3 octave band spectra showed a fairly good possibility of the recognition of aircraft types in flight acoustically.

RECOGNITION PROCEDURE

The recognition of aircraft types belong to the discriminatory analysis. Before discussing how the reference patterns of aircraft types can be obtained, we give a brief explanation of the recognition procedure used in our study. When an unknown aircraft fly-over noise is observed, its sample pattern of characteristics, $X=(x_1,x_2,..,x_N)$ is computed and then compared to the respective reference patterns of the aircraft types, $P_i=(p_1^i,p_2^i,..,p_N^i)$, $i=1,2,..,M$, where x_n and p_n^i represent n-th characteristic parameters for a sample and the i-th reference patterns. A series of candidate distance scores $D_1(X,P_i)$, $i=1,2,..,M$ between the sample and reference patterns are computed according to the following definition of the weighted distance;

$$D_1(X,P_i) = \Sigma\ |X-P_i|^2 = \Sigma(x_n-p_n^i)^2\cdot W_n^i \qquad (1)$$

where W_n^i is a weight for n-th parameter of i-th aircraft type. This aircraft noise sample is distinguished to belong to an aircraft type whose distance score is the smallest one and below a pre-determined threshold value D_0. Otherwise, the noise sample is judged to be in the other group of aircraft types, and then in the second stage it is examined whether it belongs to jet aircraft or propeller-driven aircraft. The distance scores $D_2(Y,Q_j)$, $j=J,P$ are calculated with another sample and reference patterns Y and Q_j.
In our study, the weight W_n^i is defined as a reciprocal of the estimated variance on n-th parameter of i-th aircraft type. If the variance on some param-

eter of certain aircraft type is very large ,the weight value becomes too small to affect the distance. Furthermore, if the aircraft type of a sample is determined by only a few parts of parameters, the others can be suppressed to be so small values as not to affect the distance computation.

FIELD MEASUREMENTS OF AIRCRAFT NOISE

We made field measurements of aircraft noise in order to select characteristic parameters, to create reference patterns of aircraft types and also to make an experimental evaluation of the recognition procedure. Aircraft types and their flight patterns are different according to the mission of an airport. Here we treated two types of airports. One is a military airbase (case A) and another is an airport that is commonly used to civil and military aircraft operations (case B) .
In the following, we discuss the case A to explain the recognition procedure. Although a variety of aircraft types can be seen at the airbase case A, we tried to recognize the aircraft type from fly-over noise according to the classification shown in the row of Table 2. The classification was determined in the order of the frequency of operations. The distance from microphones to the closer runway end was about 500~1000 metres. Microphones were set up 1.2m above the ground beneath the flight path of the aircraft.
There are a lot of TOUCH & GO (T/G) operations of C-130 and T-39 repeatedly in addition to the normal TAKE-OFFs and LANDINGs. These T/G operations are executed for the training of pilots. Therefore, the height of aircraft varied from several tens to hundreds metres above microphones.

PROCEDURE TO SELECT PARAMETERS AND TO CREATE REFERENCE PATTERNS

The differences of acoustic characteristics among various aircraft types and flight patterns were investigated from field measurements through a 1/3 octave band real time analyzer. Center frequencies of 1/3 octave bands were 25Hz~20kHz. Time constant of signal averager was SLOW and the sampling rate was 0.1s. Time patterns of 1/3 octave band spectra were piled up for each aircraft type and each 1/3 octave band so that maximum positions of A-weighted sound pressure levels (we call it "dBA-peak" in the following) were gathered to a pre-determined position. As can be seen from an example in Fig.1, the relationships between peak positions of 1/3 octave bands relative to dBA-peak are very stable. Therefore, we decided to utilize these peak-holded 1/3 octave band spectra relative to dBA-peak as characteristics from which we select parameters to discriminate the aircraft type of observed fly-over noise. In Fig. 2 and 3 average peak-holded 1/3 octave band spectra relative to dBA-peak and those standard deviations are plotted for all aircraft types which are classified in Table 2. From the comparison between average characteristics, we selected only ten characteristic parameters in Table 1. Parameters 1~9 are used in the first stage of the recognition procedure, but the tenth parameter is used to discriminate whether the examined aircraft is a propeller-driven aircraft or not. In general, noise spectra of a jet aircraft spread over a wide frequency range and have smooth spectral shapes, while a propeller-driven aircraft has a lot of peaks and dips in the spectra. To detect this difference we compute the tenth parameter by the equation,

$$(\Delta L)^2 = \Sigma \left|L_{j+1}-L_j\right|^2 \text{ ,where } L_j \text{ is j-th 1/3 octave band level.} \quad (2)$$

We applied the recognition procedure, based on the 10 characteristic parameters in Table 1, to all field measurements of case A. The resulted recognition accuracy, shown as a confusion matrix in Table 2, suggests a fairly good possibility to recognize aircraft types acoustically.

Another field measurements were made to evaluate the ability of the recognition procedure near an airport where not only military aircraft but also civil airliners were commonly operated. Measurements were, however, made for only TAKE-OFF patterns. The procedure was the same as used in case A, but characteristic parameters and reference patterns were a little different. The results show that the procedure is equally effective as in the case A (Table 3).

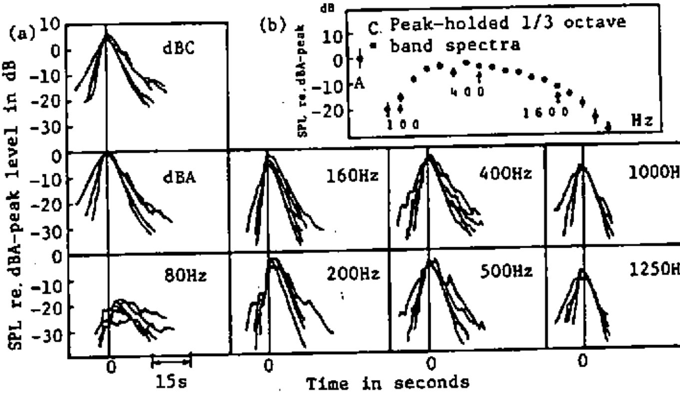

Fig.1. (a) An example of superpositions of time patterns of 1/3 octave band spectra so that maximum positions of A-weighted sound pressure levels coincide together. (b) Average peak-holded 1/3 octave band spectra and those confidence intervals ($\pm\sigma$).

Table 1. Characteristic parameters used in the recognition procedure for the example of case A.

1	25 Hz 1/3 octave band level re. dBA-peak
2	difference of 50 and 63 Hz 1/3 octave band levels
3	80 Hz 1/3 octave band level re. dBA-peak
4	100 Hz 1/3 octave band level re. dBA-peak
5	125 Hz 1/3 octave band level re. dBA-peak
6	160 Hz 1/3 octave band level re. dBA-peak
7	200 Hz 1/3 octave band level re. dBA-peak
8	315 Hz 1/3 octave band level re. dBA-peak
9	2500 Hz 1/3 octave band level re. dBA-peak
10	squared sum of first order differences between 100~200 Hz 1/3 octave band levels

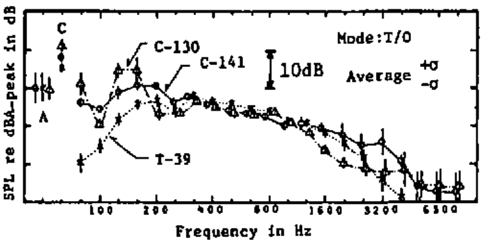

Fig.2. An example of average peak-holded 1/3 octave band spectra relative to dBA-peak ; case A, T/O patterns.

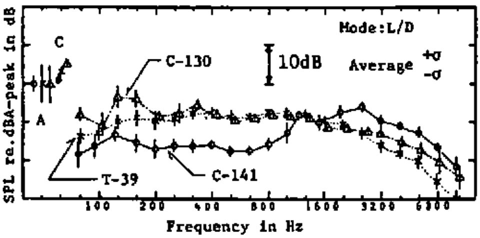

Fig.3. An example of average peak-holded 1/3 octave band spectra relative to dBA-peak ; case A, L/D patterns.

Table 2. Confusion matrix of case A;

C141:4 engine turbofan,
C130:4 engine turboprop,
T39 :2 engine turbojet.

IN \ OUT		C141		C130		T39		Heli	Others	
		T/O	L/D	T/O	L/D	T/O	L/D		Jet	Prop
C141	T/O	10							2	
	L/D		15						1	
C130	T/O			45						
	L/D			1	25		1			1
T39	T/O					55	1		6	1
	L/D				2	2	41		3	
Helicopter								33	3	1
Others	Jet		2		1	5	4		21	1
	Prop			3					1	17

Table 3. Confusion matrix of case B.

IN \ OUT	B747 (JAL)	B747 (ANA)	L1011	DC10	B727	DC8	DC9	YS11	F104	F4	T33	Others (Jet)	Others (Prop)
B747 J	19		2										
B747 A		17	2										
L1011			8										
DC10				3									
B727					16								
DC8						7							
DC9							16				1		
YS11								14					1
F104									12	8			
F4										23			
T33							1				14		
A300			2	1									
MU2													2
C1							2				2		
F1										2			
Others P													1