Journal of Sound and Vibration 374 (2016) 77–91

Contents lists available at ScienceDirect

Journal of Sound and Vibration

journal homepage: www.elsevier.com/locate/jsvi

Directional monitoring terminal for aircraft noise

M. Genescà [a,b,*]

[a] Acoustics Research Center, Department of Electronics and Telecommunications, Norwegian University of Science and Technology, NO-7491 Trondheim, Norway

[b] Laboratory of Acoustics/Noise Control, Empa - Swiss Federal Laboratories for Materials Science and Technology, 8600 Dübendorf, Switzerland

ARTICLE INFO

Article history:
Received 7 October 2015
Received in revised form
14 March 2016
Accepted 4 April 2016
Handling Editor: P. Joseph
Available online 19 April 2016

Keywords:
Aircraft noise monitoring
Microphone array

ABSTRACT

This paper presents a concept of an aircraft noise monitoring terminal (NMT) that reduces background noise and the influence of ground reflection, in comparison with a single microphone. Also, it automatically identifies aircraft sound events based on the direction of arrival of the sound rather than on the sound pressure level (or radar data). And moreover, it provides an indicator of the quality of the sound pressure level measurement, i.e. if it is possibly disturbed by extraneous sources. The performance of this NMT is experimentally tested under real conditions in a measurement site close to Zurich airport. The results show that the NMT unambiguously identifies the noise events generated by the target aircraft, correctly detects those aircraft noise events that may be disturbed by the presence of other sources, and offers a substantial reduction in background and ground reflected sound.

1. Introduction

Airport noise monitoring systems and prediction models are the two main tools for airport noise assessment and management. Prediction models are necessary to forecast the airport's acoustic footprint in future or hypothetical situations involving, for example, increases in flight volume or the modification of flight paths. Noise monitoring systems are mainly used to inform the public about the current airport noise situation and also to validate the output of the prediction models and reinforce its credibility in the eyes of the public. The noise monitoring systems include a network of noise measurement terminals (NMTs) distributed within the acoustic area of influence of the airport. These NMTs are typically equipped with an omnidirectional microphone that continuously monitors the noise levels at the site. Since this data is used for public information, the placement of these terminals is chosen so that the measured noise levels are representative of the acoustic influence of the airport on the population. Therefore they are located in urban, or at least inhabited, areas where other sound sources such as traffic or industrial noise may be present. This NMTs placement has two main disadvantages:

First, the continuous sound pressure level recording contains noise events that may not be generated by aircraft. Therefore strategies to identify the aircraft noise events need to be put in place. The ISO standard 20906:2009(E) [1] describes the event identification process. It starts with a detection stage in which the parts of the recording that exceed a given threshold by a specified amount, for a duration which lies within specified limits, are detected. Next, it follows a

* Correspondence address: Acoustics Research Center, Department of Electronics and Telecommunications, Norwegian University of Science and Technology, NO-7491 Trondheim, Norway.
E-mail address: meritxell.genesca@ntnu.no

http://dx.doi.org/10.1016/j.jsv.2016.04.004
0022-460X/

classification stage in which acoustical properties, that may help to separate non-aircraft sound events from aircraft events, of the detected events are analyzed. It finishes with an identification stage in which non-acoustical information such as radar or flight plan data is used to finally confirm whether an event is generated by an aircraft. The fact that the detection is based on a sound pressure level threshold causes a number of aircraft noise events to be missed in locations where the level of background noise is comparable to the aircraft noise level [2]. Moreover, the event identification error rate grows considerably in airports that do not have a radar data connected to the noise monitoring system because the final identification stage cannot be implemented. To overcome this first disadvantage, several algorithms to automatically classify noise events caused by aircraft have been developed [3–5].

The second disadvantage of the NMTs placement is that noise events caused by other sources may occur simultaneously to the aircraft noise events. In such a case the sound pressure level of the aircraft may be overestimated. As a consequence, NMTs cannot be used solely as a tool to penalize an airline when a particular flight exceeds the legal noise limits.

Moreover, interference effects due to ground reflections are undesirable in aircraft noise monitoring applications because they depend on the height of the receiver and introduce uncertainty in the measurement [6]. To reduce these effects the ISO standard 20906:2009(E) [1] describes an ideal measurement site; but such sites are not always available.

To overcome these disadvantages, the existing literature [7–10] provides examples of advanced NMTs that are integrated by a linear microphone array and that use beamforming to reduce the contribution of ground-borne sources and aircraft ground reflections on the continuous sound pressure level recording. Such terminals typically consist of a linear array of 12–15 microphones with a length of around 3 m and provide a reduction of the ground-borne noise level between 5 dB and 10 dB.

The NMT concept presented in this paper is also aimed at overcoming these disadvantages and consists of an array of nine microphones distributed in a 3D geometry with a diameter of approximately 1 m. This NMT provides an estimate of the direction of arrival (DOA) of the aircraft sound and a measurement of the aircraft sound pressure level (frequency spectrum and overall level) with a reduced contribution of the background noise and ground reflections compared to an omnidirectional microphone measurement. As in the case of the noise monitoring terminal NA-37 developed by RION [11], the sound DOA estimates are used for automatic aircraft event identification purposes so that non-acoustical information such as radar or flight plan information is not required. Thus it can be used in small airports without radar and by external (to the airport) entities or administrations. In addition, the DOA estimates provided by the NMT presented here are robust against ground reflections and, to an extent, to the presence of ground-borne noise sources. This feature is used to determine the quality of the measurement, i.e. if sources other than the target aircraft may have influenced the measurement.

Furthermore, such a NMT can be used to obtain reliable aircraft spectral sound power data of individual flights. This data is required by the new generation of prediction models to be able to calculate the acoustic impact of individual flights [12,13]. This would allow the design of noise abatement operational procedures affecting not only flight paths but also the aircraft flight configuration (e.g. slats, flaps, landing gear and power settings). Initiatives to use NMTs integrated by single omnidirectional microphones as a basis to calculate aircraft spectral sound power data are reported in the literature [14]. However, they require the placement of NMTs in low background noise locations using them purely as a source of data for prediction models and removing their utility as a source of public information. The NMT presented here can be used in measurement campaigns dedicated to the collection of sound power spectral data such as those described in the literature [13,15] or as a permanent installation as part of the noise monitoring system of an airport. If at least two of these NMTs are used, the position of the aircraft could be estimated by triangulation. Once the aircraft position and the associated sound pressure levels at a set of NMTs are available, the aircraft sound power spectral data could be calculated by back propagating to the source.

The remainder of this manuscript is structured as follows: In Section 2 the different modules of the NMT are described; Section 3 presents a case study used here to show the features of such a NMT; In Section 4 the results provided by the NMT

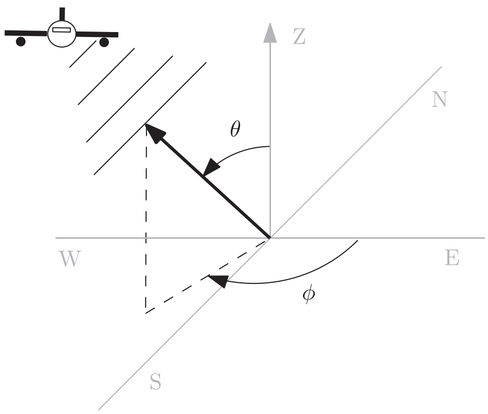

Fig. 1. Convention used to define the vertical θ and horizontal ϕ angle of arrival of the aircraft noise. The origin of coordinates represents the position of the array.