ANCORA: ANOTEC-COMOTI ROTORCRAFT ACOUSTICS INITIATIVE FOR PRELIMINARY ACOUSTIC FLIGHT TESTS FOR THE TUNING OF SIMPLIFIED ROTORCRAFT NOISE MODELS

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Abstract

One of the objectives of Clean Sky GRC5 is to implement a tool for the minimisation of noise impact on the ground, capable of being executed on-board “on-the-fly”, providing flight directives to the Flight Management System of the helicopter. The semi-empirical model to be used for this purpose requires information to be derived from experimental data. For this purpose noise measurements have to be made simultaneously on the exterior of the helicopter (i.e. close to the noise source) and on the ground. The main objective of the ANCORA project was to develop the measurement systems and methodologies required to derive the transfer functions between on-board and ground-based microphones and validate them with flight tests.
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1. INTRODUCTION

Since many years research has been performed on reducing main rotor noise of helicopters. In recent years active solutions have been studied, which require an error signal to be minimised.
This signal usually is taken by means of one or more microphones on the exterior of the helicopter (e.g. on the skid). In these applications only the relative noise levels at some frequencies are of importance for the controller of the active system, allowing for quite relaxed requirements with respect to the microphone type and its location.
To determine the transfer function between on-board and ground noise, a correct measurement of the absolute noise levels on-board over a wide frequency range is required. This implies a much more strict selection of the type of microphone to be used and its location on the helicopter exterior. The microphone should be placed outside areas where important influence of rotor flow or forward speed are encountered.
During many years ground noise of helicopters was measured with only 3 microphones, according to noise certification standards (ICAO Annex 16, Volume 1).
Due to the increased interest in noise reduction on the ground, requiring more information, several solutions have been developed to measure the noise at more locations. In the past helicopters have been flown through “L”- or “U”-shaped microphone arrays, by use of cranes or towers (Nasa-Wallops, EMPA, NLR). This type of installations is expensive and not very practical. In addition it is only applicable to steady-state conditions, since it measures the noise in a single plane, perpendicular to the flight path.
In recent years another solution has been developed (e.g. Friendcopter), in which the helicopter is flown over a horizontal (2-D) grid of microphones of significant size (typically 600x1000m). This allows for the measurement of manoeuvre flights, which are gaining interest when developing lownoise flight procedures. In order to be able to monitor the functioning of the measurement stations, wireless communication is required with the central control station. Specific noise measuring units have been developed for this purpose. Disadvantages of the systems applied until now are the high unit cost and mounting time, requiring a significant amount of persons.
Data analysis of helicopter exterior noise measurements usually are restricted to processing procedures similar to those used in noise certification, where noise recorded on the ground is corrected to certain reference conditions. More recently, with the introduction of additional microphones during the measurements, the use of hemispheres has extended. This requires a different processing, but still only based on ground noise measurements.
The ANCORA project developed both ground and on-board noise measurement systems. An initial flight test campaign was performed with a small turboprop aircraft to test and validate the measurement systems and data analysis procedures. After this, the same systems were applied in a flight test campaign with an AW139 helicopter.
The paper presents the development of the measurement systems and its application in the flight test campaigns.

2. DEVELOPMENT AND VALIDATION OF THE NOISE MEASUREMENT SYSTEMS

2.1. Validation of the on-board microphones

The on-board microphones in the frame of the ANCORA project consist of two surface microphones (GRAS 40PS and 40LA) on the exterior fuselage and a free field microphone (GRAS 40AE) connected with a nose cone on a boom.

Due to the fact that the available surface microphones were of different type, a compatibility test was performed first. For this a test in a subsonic wind tunnel was performed, at approximately 97 knots speed with both surface microphones installed on a lateral wall (Figure1).

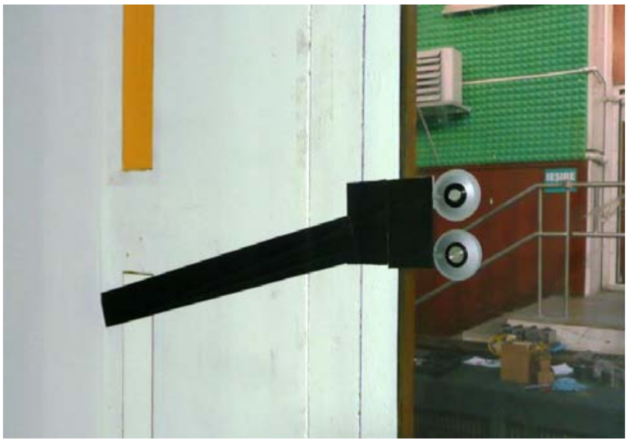

Figure 1: Surface microphone inside the wind tunnel

The difference between overall sound pressure levels was in the order of 1 dB, which was considered acceptable for the purpose of the ANCORA test.

A second test campaign was conducted, consisting of highway automobile tests. During these tests, the surface microphones were mounted in two different locations in order to measure the aerodynamic noise under different flow conditions (Figure 2).

Based on earlier wind tunnel experience it was known that use of a nose cone is sensitive to the angle of attack of the incoming flow. Therefore the boom microphone was mounted on a device that allowed for a change of the angle of attack. Two different nose cone designs were tested (parabolic and ogive). Using both nose-cones for the boom microphone at 0 and 10 degree, the aerodynamic noise was very similar in the frequency domain, whereas from 20 degree onwards the parabolic design started to show significantly more flow induced noise (Figure 3).

Figure 2: Microphone positions during highway tests

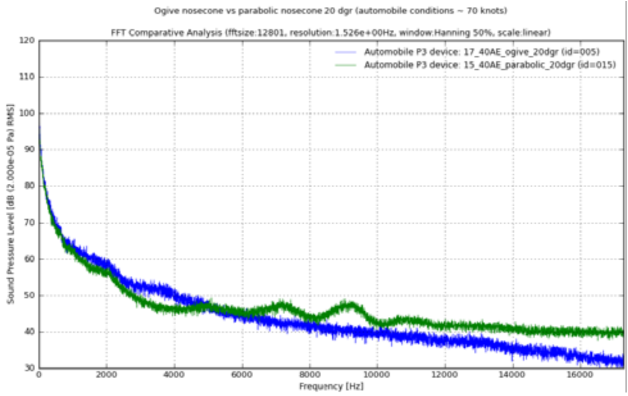

Figure 3: Nose Cones comparison at 20 degree

The results of the wind tunnel and automobile tests were compared with noise spectra obtained during a pre-test with the AW139 (see 3.1), which showed that the induced flow noise of the microphones was well below the noise levels on the helicopter fuselage. Based on the results of these tests it was concluded that the microphones selected were adequate for the purpose of the ANCORA project

2.2. Design and validation of the ground-based noise system

For the final noise measurements on the ground a total of 31 microphones was envisaged, in order to provide a comprehensive dataset for a variety of flight procedures.

The noise measurement system (NMS) designed for ANCORA consisted of 31 units based on the Svantek Sound Level Meter SV979 (Figure 4). These were integrated in a noise station, equipped with a gps for time synchronisation and a battery which provides autonomy of at least 8 hours under normal operating conditions. Each unit is located in the vicinity (< 10 m) of the microphone position, thus avoiding long cables. The NMS system is controlled wirelessly from the Central Ground Station (CGS), through a Zigbee network. This network is also used to send 1/3 octave spectra to CGS in real-time for quick-look purposes. In addition the 1/3 octave spectra and wav files are stored locally on each unit an internal micro SD card for final analysis after the tests.

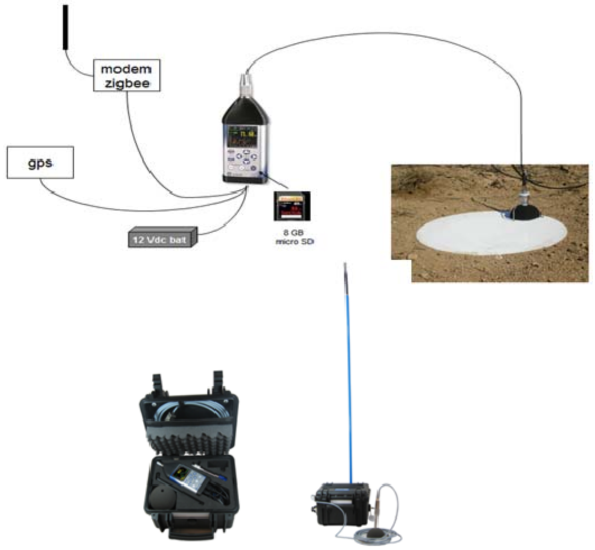

Figure 4: Ground-based noise station

2.3. Validation of the entire measurement system

As a risk reduction exercise a full flight test campaign was performed with a small turboprop aircraft (Evektor EV-97 Eurostar) at Trebujena Airfield (LETJ), located in the province of Cádiz, southern Spain. The main objective of these flight tests and the subsequent data analysis was to validate the measurement systems and the data analysis software developed as part of ANCORA, under representative conditions.

Due to limitations of the test aircraft it was not possible to perform controlled manoeuvres as planned for the original AW139 tests. Therefore there was no need for a 2D microphone array layout, as envisaged originally. All noise units were located in a linear array alongside the runway. Therefore most of the flight tests were performed perpendicular to the runway (Figure 5).

The measurement system designed for collecting flight tests data was based on the CEDRA system developed by Anotec for aircraft noise certification (Figure 6), composed of the following sub-systems:

- Noise measurement system (NMS);
- Ground based meteo system (GMS);
- On-board flight track system (including pilot guidance) (FTS);
- On-board aircraft/engine data system (ADS);
- On-board meteo data system (AMS);
- On-board Noise measurement system (ANMS);

During the tests these systems were controlled from the Central Ground Station (CGS).

Figure 5: Noise measurement locations Trebujena

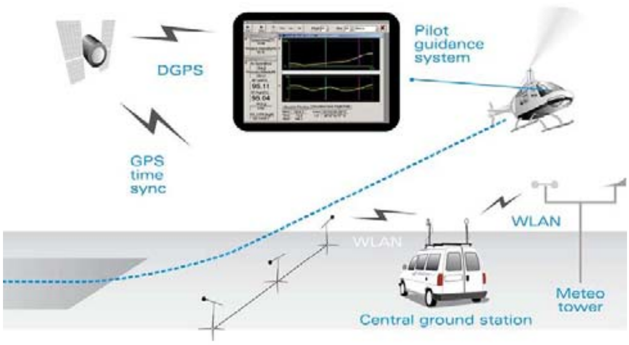

Figure 6: Overview of the CEDRA system

In order to capture the asymmetry effect caused by the rotation of the propeller, both surface microphones were located symmetrically on either side of the fuselage. Several positions were tested so as to select the optimum location of these microphones (P40 and P41, Figure 7).

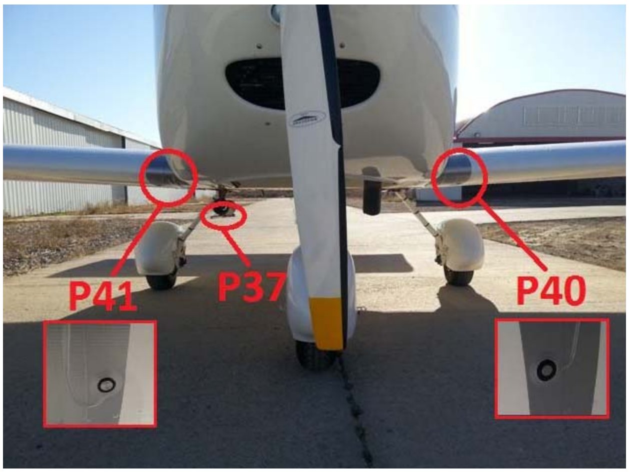

Figure 7: Final configuration for on-board microphones during Trebujena tests

Due to safety reasons no dedicated boom could be mounted on the aircraft. Therefore the boom microphone had to be located on a ventury tube under the fuselage, in the wake of the propeller (Figure 8).

Figure 8: Boom microphone during Trebujena tests

The signal of the on-board microphones was recorded with a Svantek SV958 4-channel analyser.

Directly after each run the noise received in real-time from the NMS units was processed in order to obtain SEL and EPNL values for each NMS unit to detect if all units are working correctly and/or are exposed to unexpected background noise. Together with the quick-look data from the other systems the validity of the measurement run could be evaluated immediately. In this manner the flight time could be reduced to a minimum.

After the flight the on-board noise data was analysed. In the spectra the propeller harmonics can be identified. A clear difference is found between left and right surface microphones, due to the rotation of the propeller (Figure 9).

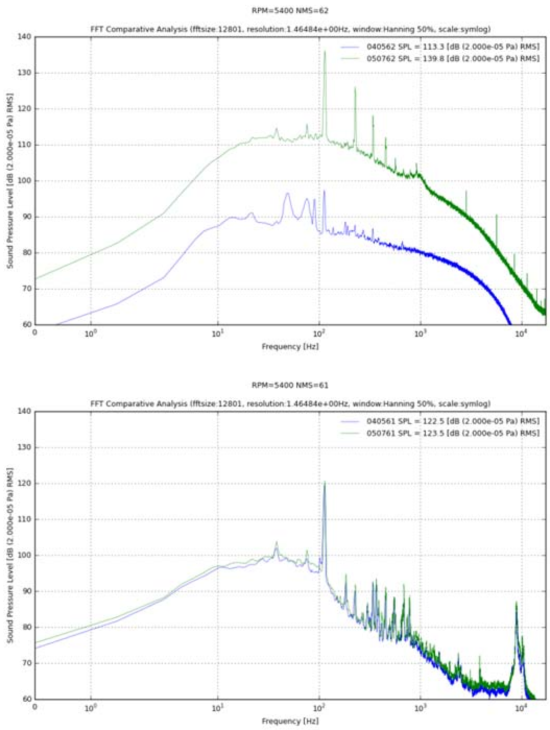

Figure 9: Example of spectra from on-board microphones

After this, the Transfer Functions between on-board and ground-based microphones could then be determined (Figure 10).

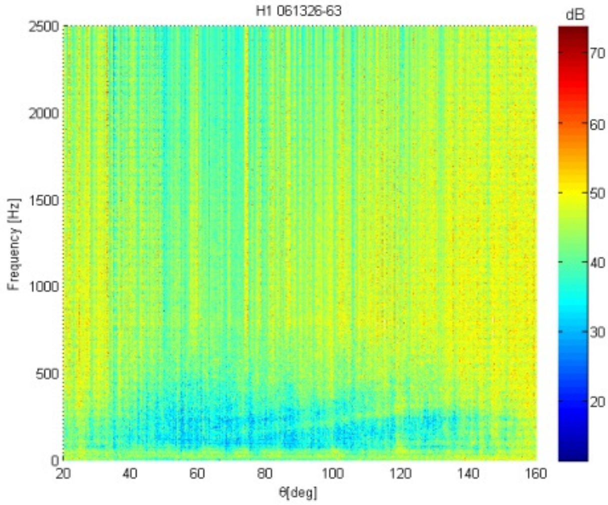

Figure 10: Example of the Transfer Function between a surface and a ground microphone

Based on the results of the flight tests in Trebujena it was concluded that:

- The use of surface microphones and boom microphone is feasible
- Appropriate locations for microphones can be found by semi-empirical approach
- The developed ground-based noise system is robust, reliable and easily deployable
- It is feasible to derive Transfer Functions between noise measured on-board and on the ground

3. APPLICATION OF THE MEASUREMENT SYSTEMS FOR A HELICOPTER (AW139)

3.1. On-board pre-tests

Well in advance of the full flight test campaign some pre-tests were performed, with the to determine the best position for both surface microphones and validating their use for the project purpose. To this end a variety of flight procedures was tested, at different airspeeds in order to simulate the same conditions as those encountered during the main test campaign. Based on CFD calculations the most promising locations were defined and subsequently tested. These measurements revealed that the best positions for the surface microphones were P3 (40PS) and P4 (40LA) (Figure 11).

Figure 11: Final Positions of surface microphones

3.2. Full flight test with AW139

In October 2014 a full flight test campaign was performed at Cameri air base (LIMN), located to the South-West of Milan-Malpensa airport, with the objective to obtain a comprehensive dataset for the AW139 helicopter.

The measurement system validated in Trebujena was deployed again, this time enhanced with an additional on-board functionality that provided a signal at the start and stop triggers which was recorded by the AgustaWestland system (at 1kHz sample rate) and in parallel by Channel 4 of the SV958 of the ANMS system. In this manner a synchronisation between all systems was achieved accurate to 1 msec.

Figure 12 shows the mounting of the boom microphone in front of the helicopter.

Figure 12: Boom microphone on AW139 helicopter

For these measurements 31 microphones were deployed on the airport over a 1350x550m area (Figure 13).

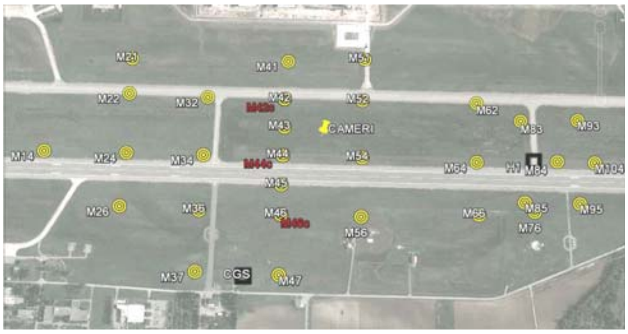

Figure 13: Measurement locations NMS System

This array was especially designed for the purpose of these tests, providing maximum information for both steady-state flights, manoeuvres and hover.
Microphones located at the ICAO Annex 16 Ch.8 noise certification positions were placed on a tripod with the microphone grid 1.2m above local ground. The microphones were placed such that nominally grazing incidence is obtained for the envisaged flight altitudes. The other 28 microphones were located inverted above a ground plate, in compliance with ICAO Annex 16 Ch10 specifications. The latter mounting avoids the ground reflection interference effects in the frequency range of interest known to exist in the former.

A test matrix was defined to cover a wide range of flight procedures.

Also here the Anotec Central Ground Station was deployed to remotely control the whole measurement system and monitor test progress (Figure 14).

Figure 14: Central Ground Station with meteo mast and remote control panel.

Immediately after each test run an initial noise footprint was generated in order to check the data quality of all noise stations (Figure 15).

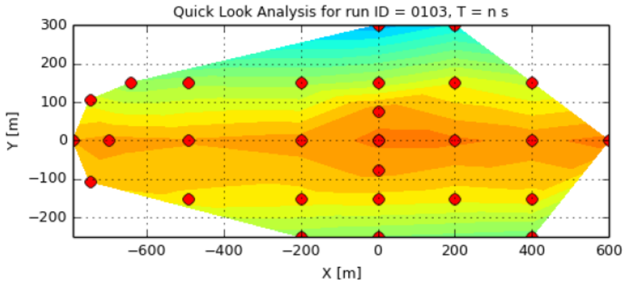

Figure 15: Example of a quick-look noise footprint

After each flight the on-board noise data was analysed. The tones of the various sources (main rotor, tail rotor and engine) can clearly be distinguished (Figure 16).

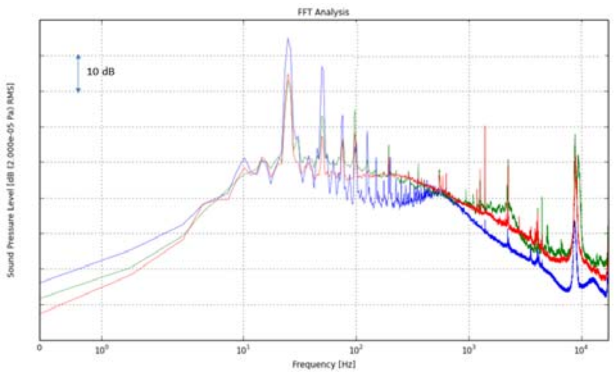

Figure 16: Example of the on-board noise spectra

A comprehensive dataset was obtained during this test campaign, which is now being analysed to derive the Transfer Functions between on-board and ground-based microphones.

4. CONCLUSIONS

The main objective of the ANCORA project was to develop the measurement systems and methodologies required to derive the transfer functions between on-board and ground-based microphones and validate them with flight tests.

ANCORA demonstrated the feasibility of the application of surface and boom microphones on a small turboprop aircraft and on the helicopter fuselage.

ANCORA delivered a robust and reliable mobile noise measurement system, easily scalable and optimised for minimum deployment time and cost. During the test campaigns a large number of flight procedures were flown over a grid consisting of 31 microphones.

ANCORA developed an advanced method for the determination of the transfer functions between on-board and ground microphones.

Thanks to ANCORA, a robust measurement solution is now available at a relatively low cost. This will allow for an increased use in future flight tests, contributing to a better understanding of the noise characteristics of helicopters and enabling the design of low-noise flight procedures.

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