Volume XXII, 42 – No.1, 2020, DOI: 10.35116/aa.2020.0002

# ACOUSTIC CAMERA SCANNING AS A DETECTION OF NOISE SOURCES ON SMALL AIRCRAFT

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**Abstract.** This article is focused on the dynamic detection of sound/noise sources outside aircraft that can be detected as exposition. Over the last few years methods were developed for detecting noise sources in area of algorithm uses in detection methods, new procedures and devices. Nowadays, there are very important methods for quick and easy detection of a sound defect on the surface of an aircraft fuselage, components and accessories. All parts that are on the fuselage generated specific noise to the free field.

**Keywords:** Acoustic camera; noise; detection; ultra-light; sound pressure level

## 1. INTRODUCTION

The "acoustic camera" is a measuring tool which became part of the acoustics field a few years ago. This technology analyses the actual sound scene, which consists of a superposition of different sound sources, into a visual sound map. The basic principle relies on accurate calculation of specific runtime delays of acoustic sound emissions radiating from several sources to the individual microphones of an array [1]. An acoustic map of the local sound pressure distribution at a given distance will be calculated using the acoustic data of all simultaneously recorded microphone channels. The sound pressure level is displayed by colour coding, similar to popular thermal imaging. An automatic overlay of optical image and acoustic map gives rapid answers about the dominating sound source locations [2].

Outside noise generated by departing and approaching aircraft may be detected as standard or alternative / new by introducing novel aircraft technologies into aircraft design and flight procedures as detectors, accelerometers and noise level meters. Nowadays, noise assessment and noise communication are accomplished using conventional noise indicators that consider neither the perception of sound, nor its health effects but can provide noise exposition on aircraft parts.

To overcome these limitations, this article presents a new process approach that supports the movement for perception-influenced aircraft design in order to reduce negative environmental impacts and adverse health effects, as well as other technical defects on aeroplanes (propeller and exhaust) caused by increased air traffic noise. By means of scanning (acoustical visualisation), possible future changes can be evaluated by considering the human perception of sound. In this study, in virtual acoustic environment flyovers by small aircraft types (UL – Sport-Star produced by Evektor) and flight procedures are detection data of exposition given by propeller and exhaust. The aim of test procedures was to find the noise source for the propeller or exhaust. The procedure using the acoustic camera experiment revealed significant sound annoyance reductions generated by sources in low-frequency ranges in small aircraft [6].

## 2. AIRCRAFT, INSTRUEMENTS AND DEVICES

The research aim was to use two main devices for sound/noise detection in the free field for flyover by aircraft. As a sound source small aircraft type UL– Sport-Star was selected with a 3-blade propeller and an exhaust on the left side of fuselage.

**Figure 1** UL aircraft Sport-Star (OK-DNA)

### 2.1. Acoustic camera and software

Acoustic camera: sound source localisation is made very easy with acoustic cameras. Acoustic cameras are using Beamforming-methods for localisation outside or inside sources. The results are presented as a coloured acoustic picture or acoustic movie and are easy for everyone to interpret. With this powerful acoustic tool, it is possible to do acoustic optimisation not just for sound design and NVH (noise, vibration and hardness) but also for failure diagnosis e.g. gear or leakage detection on engines. Furthermore, the acoustic camera is an important tool for noise reduction e.g. machine covers.

The picture below shows the acoustic XS Bionic camera produced by CAE Systems with these parameters:

- 40 mini microphones
- Acoustic range 30 – 120 dB
- Frequency range 20 – 20 000 Hz
- Function: Beamforming, Evob, Clean SC
- Online and Offline analysis (detection up to 100 acoustic pictures per second on the touchscreen)
- Localisation of noise sources in handle regime


**Figure 2** The Acoustic XS Bionic Camera (CAE Systems)

Software: The Noise Inspector is a unique modular system which makes it an optimal solution. It is possible to expand the acoustic camera with an additional microphone array to open up new application fields. For very fast troubleshooting an upgrade with intensity array or an acoustic compass (3D acoustic intensity probe) offers you a high-performance acoustic camera for every application. Therefore, it was designed as a system which can only be setup by one person in around a minute. Immediately after setting-up the hardware, the first acoustic pictures are only a click away. The array can be selected according to the needs and types of noise to be analysed. Additionally, it is possible to expand the acoustic camera with an additional array to open up new application fields.

Next, Figure 3 and 4, show the flight tests location in the east of the Czech Republic. The small airport defined these parameters:

- Airport Štípa (LKSP, Radio 122.800/805)
- VPD 09/27 (400 x 16m, concrete)
- VPD altitude-location 336m
- Temperature = (-2 - 2) °C; on the altitude of the airport, Wing = (3 - 6) m/s


**Figure 3** Flight tests location

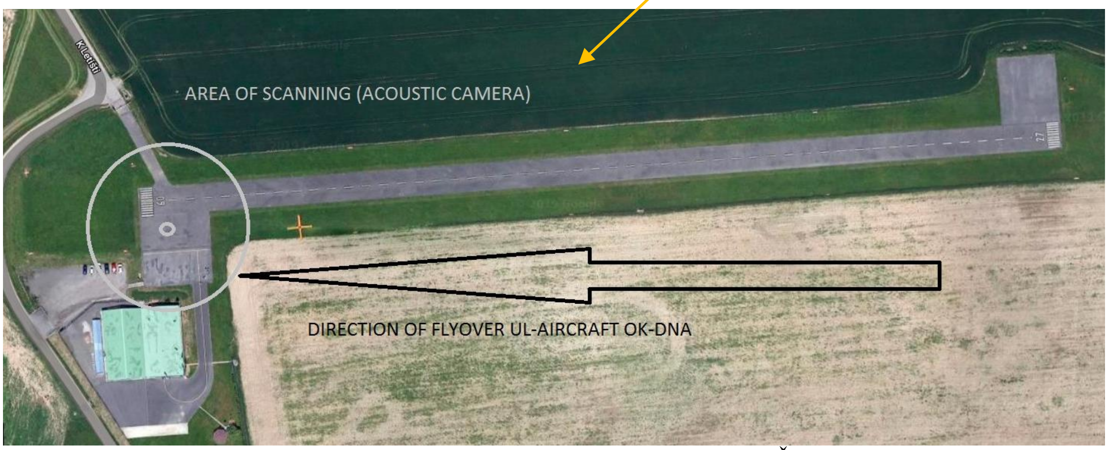


**Figure 4** Small airport scheme for UL aircraft (Štípa)

## 3. TESTS AND PROCEDURES

During flight more parameters were measured for analysis. The most important test procedure values were:

- Sound pressure level (local and global)
- Noise field frequency analysis
- Noise field spectral density
- Online detection in real time and offline models for obtained data correlation

### 3.1. Theory and methods

Acoustic beamforming is a signal processing technique based on far-field microphone array measurements. While an array produces a spatial sampling of a sound field, a beamforming algorithm performs a spatial filtering operation that makes it possible to map the distribution of the sources at a certain distance from the array and therefore, locate the strongest sources. Indeed, beamforming algorithms enhance the signal-capturing capabilities of the array in a particular direction, giving rise to a steered signal, i.e. a beamformer, that is stronger when the steering direction is closer to the source's propagating direction.
The first documented beamforming solution dates back to the 1940s and relates to the development of a radio antenna for military applications, i.e. a ''direction finder used in submarine detection". For almost 20 years beamforming was applied to radio signals and in steerable source antennas. In the 1970s it was also applied in seismic arrays and finally in acoustics. After Billingsley's work, in 1977 Fisher et Al. came up with a similar concept and called it the ''polar correlation" method. A comparison of the two approaches was then performed by Billingsley. Over the following years, different algorithms and approaches have been developed, whereby the level of complexity has also increased, benefitting from the improvement in data acquisition and computer computation performances. Most of these algorithms will be presented in the following sections of this paper; nevertheless, it might be here beneficial to provide some basic concepts of beamforming by presenting the so-called Delay-and-Sum (D&S) approach in the time domain [2, 6].

### 3.2. Test conditions

DEVICES

- Acoustic Camera (AC, XS Bionic, CAE)
- Sound analysis = 1/3 octave band
- Ring AC = oriented up
- Results = online and offline analysis (methods Delay and Sum, EVOB and CLEAN SC)

AIRCRAFT and AIRPORT

- Type = ULL (OK-DNA), 3-blade propeller, Rotax 912 Engine (100hp)
- Overflight speed = 120 km/h
- Altitude over VPD = 10m
- Overflights number = 10
- VPD surface = concrete (with big reflection, surface around airport is area with clay and low snow)

CRITICAL PART

The sound generated by aircraft propagates to the listener using a multitude of paths (e.g. diffraction in the atmosphere, reflections on the ground and on buildings). Ground reflection is a major influencing factor. As proposed by Rizzi et al. [3], ground reflections can be incorporated into the simulation using an additional delay unit and filter. The already auralised (monaural) free-field signal for the listener is delayed according to length increase of the reflection path. An additional reflection filter Hw(f) is generated from absorption coefficients *α(f)* of the ground material. This delayed and filtered signal is then added to the original signal to produce the effect of ground reflections. The acoustic impedance of the ground is assumed constant and selected from the model by Delany and

Bazley. Assuming free-field conditions and a locally reacting surface, this impedance is converted into reflection factors which are also implemented using 1/3 octave filter banks [4, 5].

### 3.2. Results

The following figures show some overflight and analyse with modelling process Noise inspector software. On the figures are images of aircraft in flight (and given condition) and dynamic range of online/offline regime of the calculated process. Number of flights over the measurement point was 10. and the calculating process in the software's offline regime was for 3 methods (EVOB, Delay and sum, CLEAN SC).

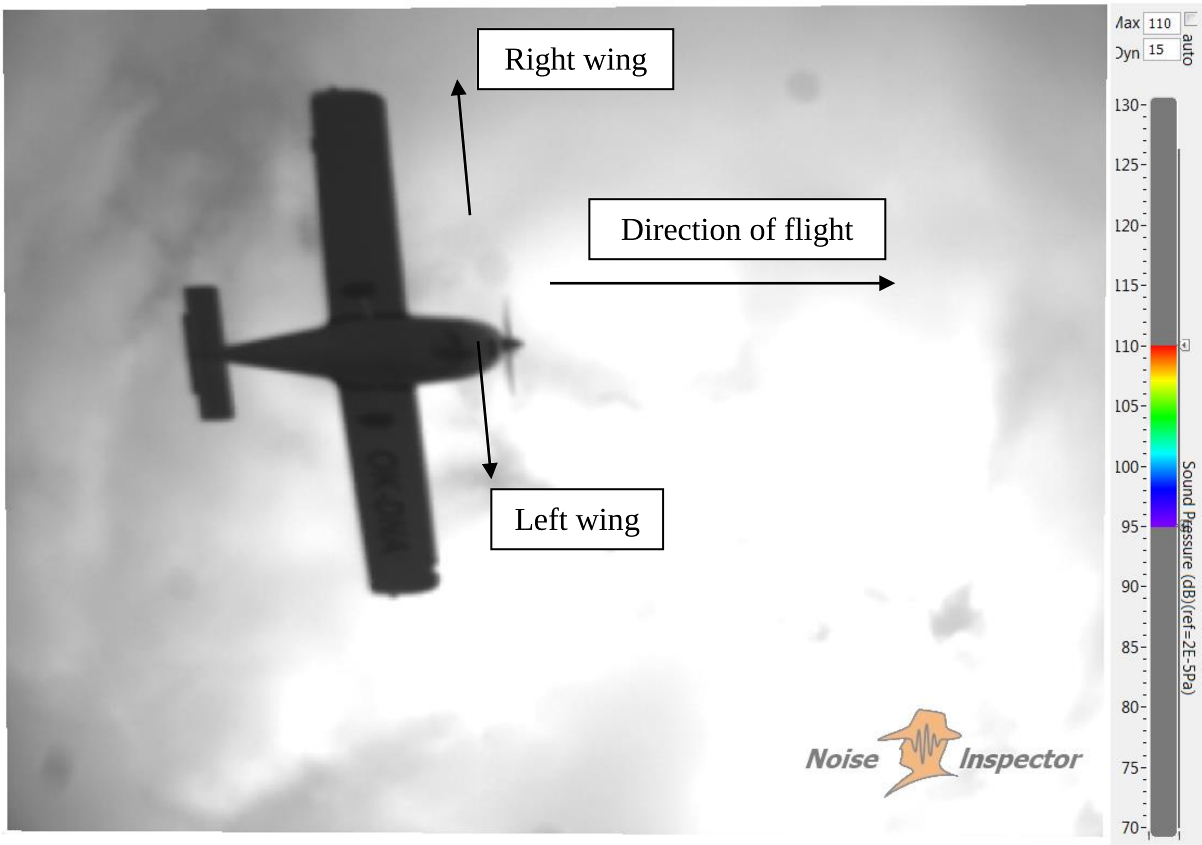


**Figure 5** Flyover for the calibration of devices and the system (winter 2019, fly over measurement point 10m), axis for the flight direction and left/right wing according to the pilot's cockpit view.

Figure 5 shows one of first flights over the measurement point for check of all procedures and set of devices. On this Figure can see axis of cockpit view according to the flight direction. The acoustic camera was focused to the nose of aircraft for detecting propeller and exhaust noise. The bigger noise field is on the left side of aircraft (in the flight direction) because the exhaust is positioned on this side. The full sound pressure level in this image is given background of area and aircraft. For noise source detection the ratio between the background and aircraft is not necessary. In the middle of circle there is a small point that was used as place for calculating offline methods. The full picture is the results of global sound pressure level and local pressure level (can see on the Figure 7).

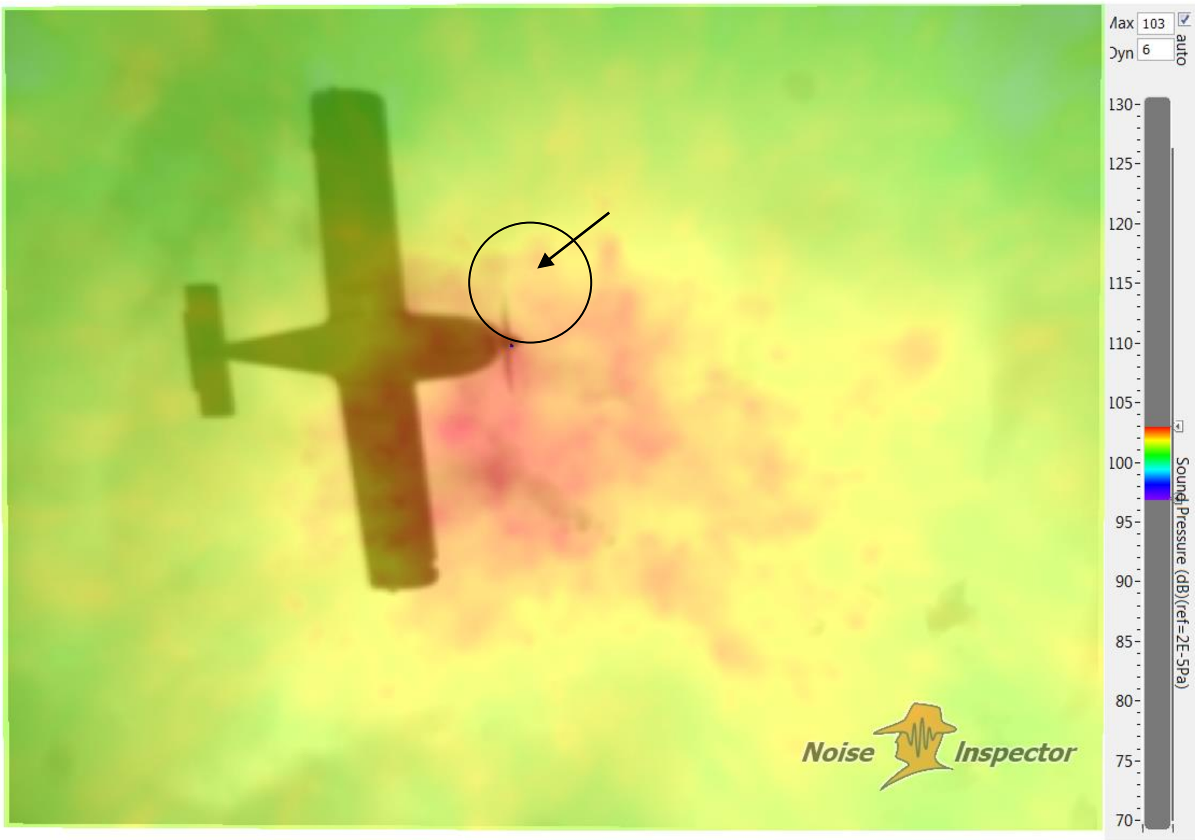


**Figure 6** Dynamic picture of a flyover for main sound pressure level – flight over measurement point with acoustic camera (scheme shows full acoustic exposition during flight)

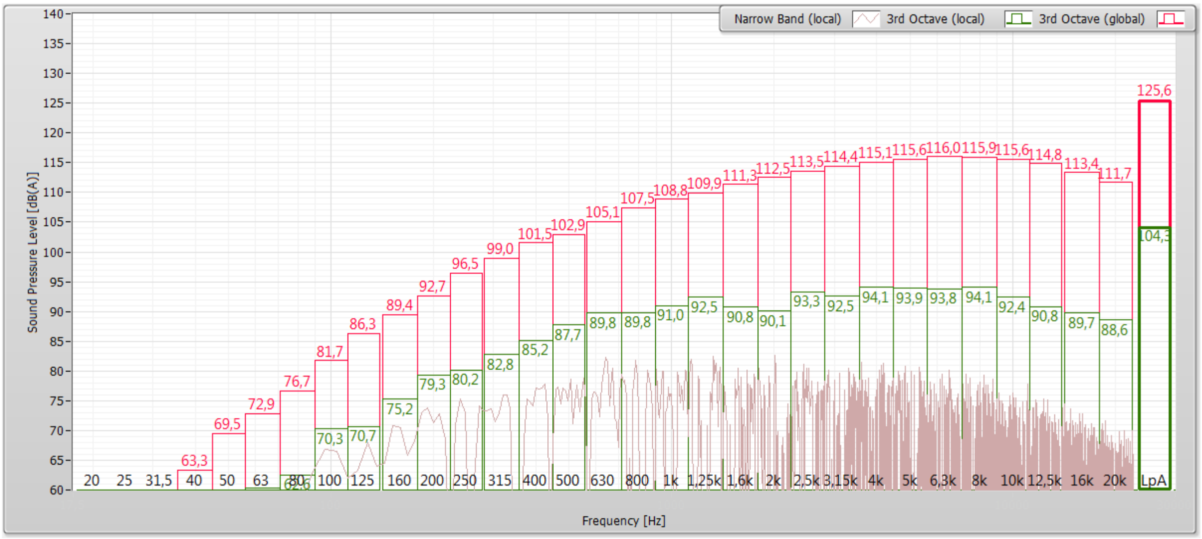


**Figure 7** Frequency analysis for the sound pressure level of selected point on Figure 6 (1/3 octave band), the scheme shows full acoustic exposition during flight, graphs show red – global SPL of picture and green values for the point on the propeller cone)

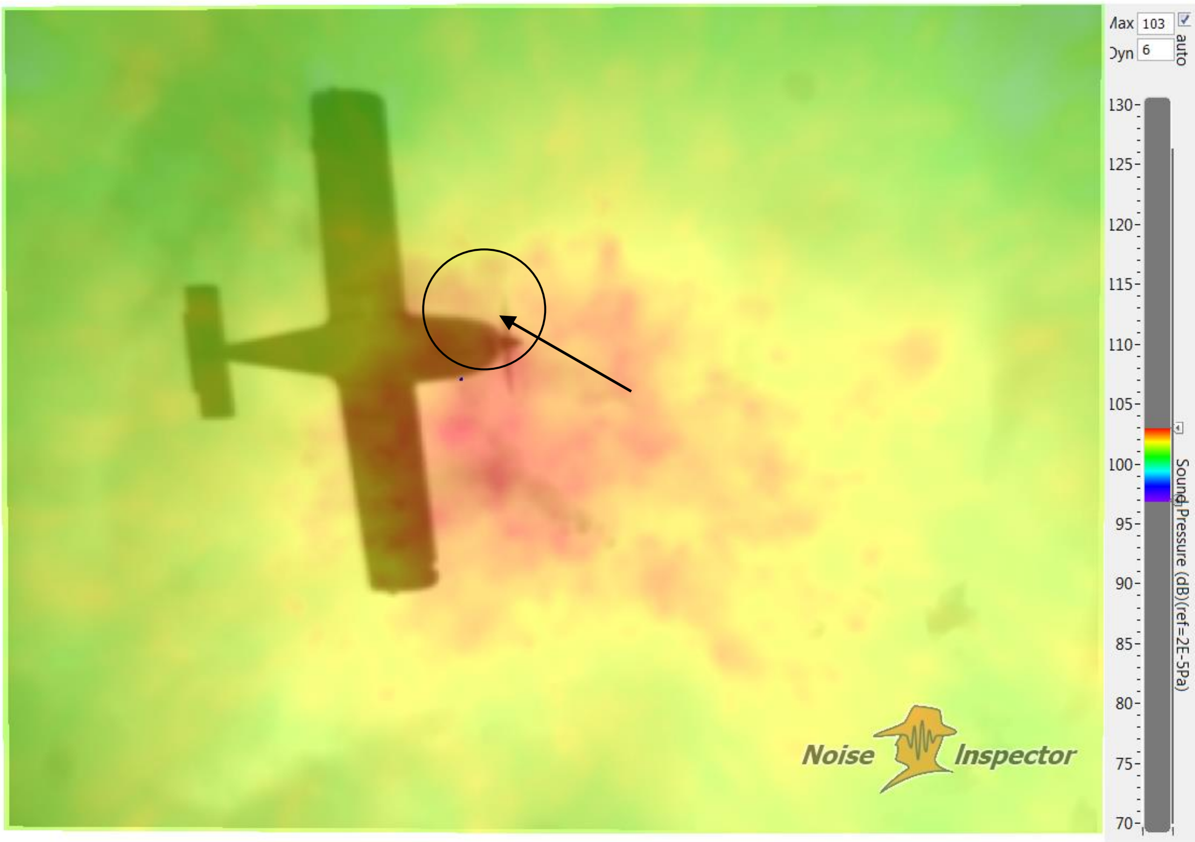


**Figure 8** Dynamic picture of the flyover for the main sound pressure level – flight over the measurement point with an acoustic camera (the scheme shows the full acoustic exposition during flight), point on the left side of engine (near the exhaust)

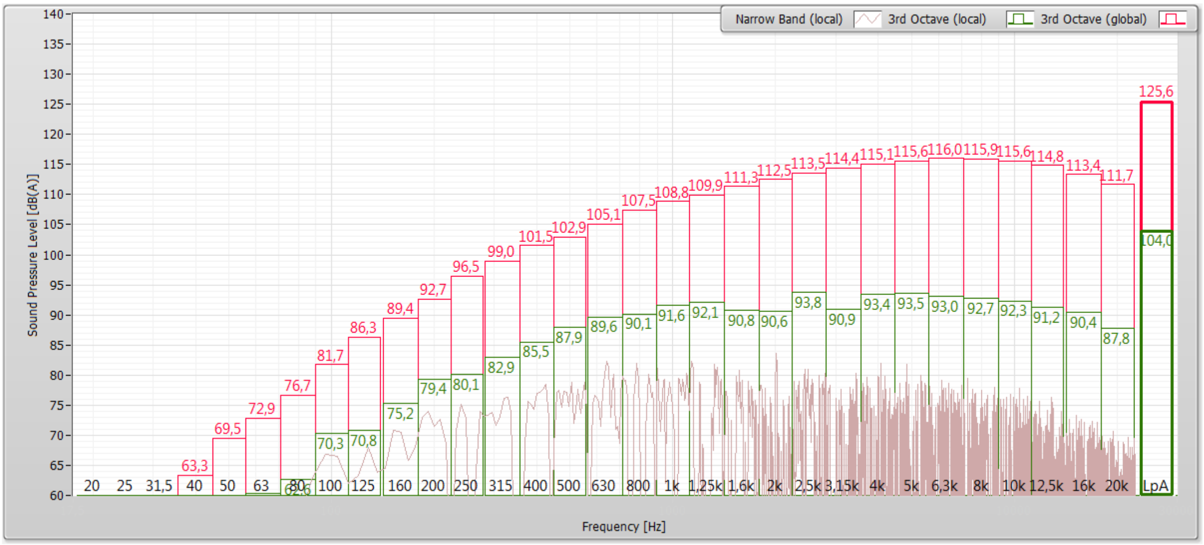


**Figure 9** Frequency analysis for the sound pressure level of the selected point on Figure 8 (1/3 octave band), the scheme shows the full acoustic exposition during flight, graphs show red – global SPL of the picture and green values for the point on the left side of engine)

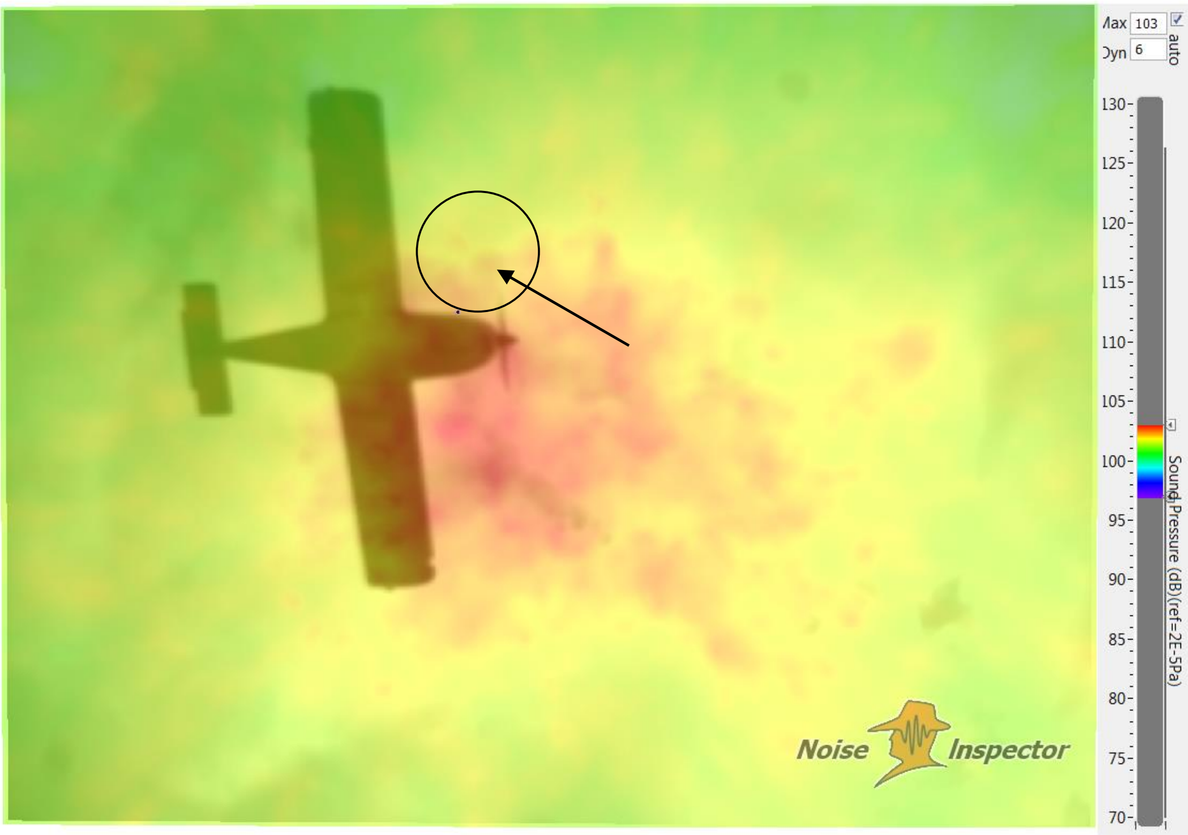


**Figure 10** Dynamic picture of the flyover for the main sound pressure level – flight over the measurement point with an acoustic camera (the scheme shows the full acoustic exposition during flight), point on the right side of engine

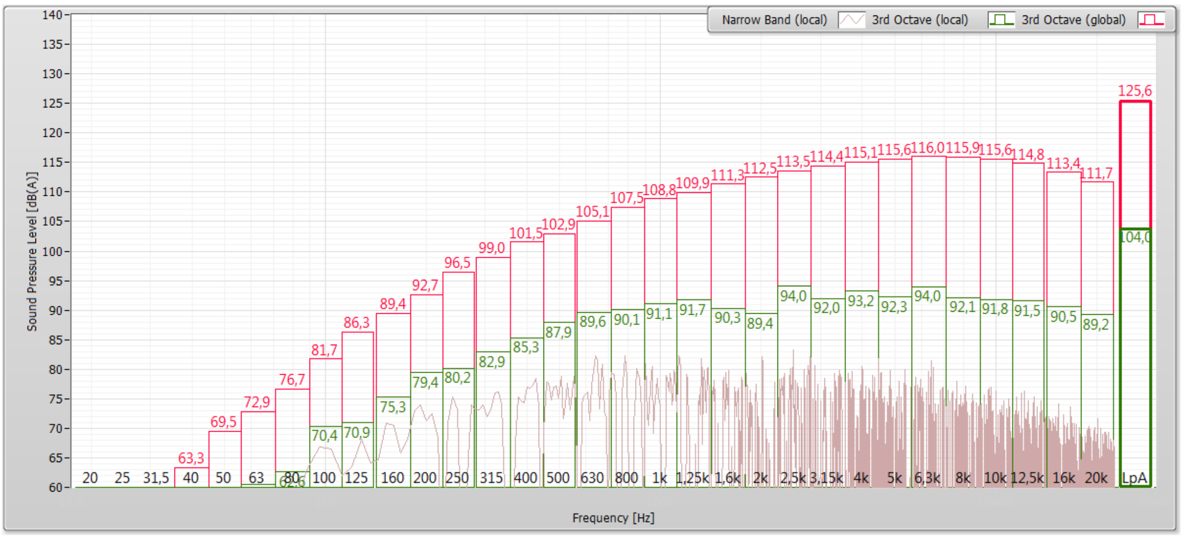


**Figure 11** Frequency analysis for the sound pressure level of the selected point on Figure 10 (1/3 octave band), the scheme shows the full acoustic exposition during flight on the right side of engine)

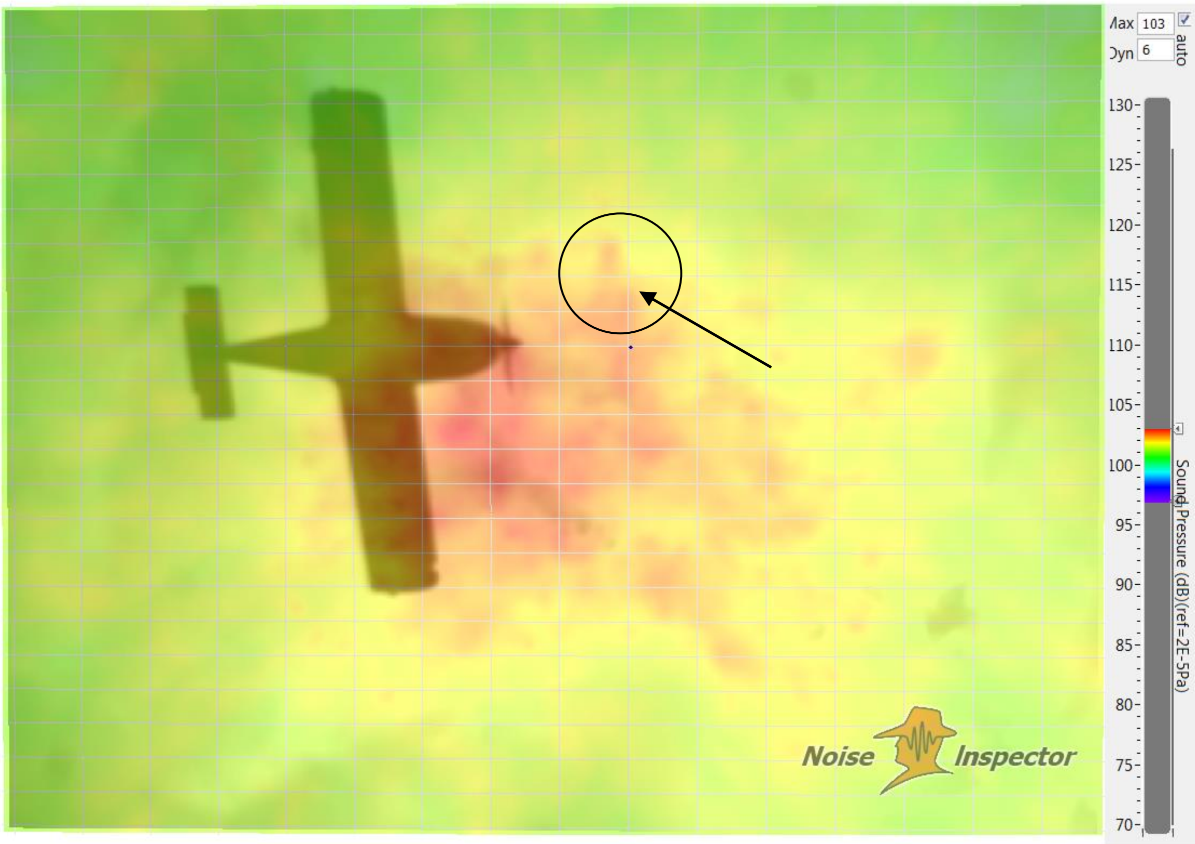


**Figure 12** Dynamic picture of the flyover for the main sound pressure level – flight over the measurement point with an acoustic camera (the scheme shows the full acoustic exposition during flight), the point is in front of propeller in distance = 2metres

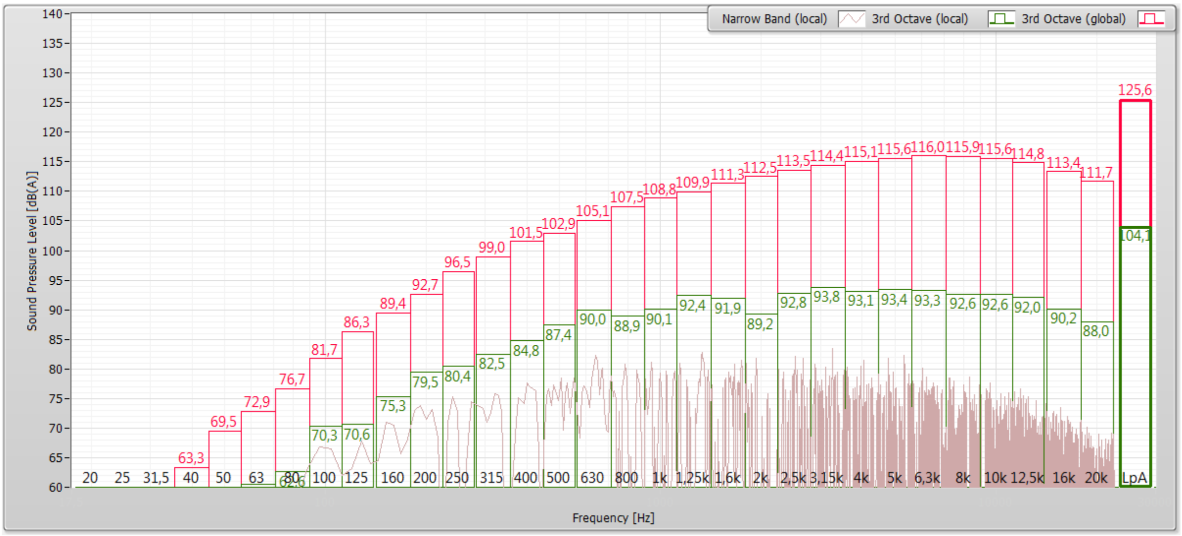


**Figure 13** Frequency analysis for the sound pressure level of the selected point on Figure 12 (1/3 octave band), the scheme shows the full acoustic exposition during flight in front of propeller)

## 4. CONCLUSION

An innovative and multi-purpose VR simulation capability for aircraft noise was presented, which was achieved an interdisciplinary collaboration of TBU in Zlin and Evektor Aerotechnik for Aircraft UL.

The new methods and devices for noise source detection during flight of small aircraft such as usability of these systems for users shows new trends in process of acoustic solutions. Obtained data, modelling and calculation provide over software local point(s) with higher noise exposition value. Algorithm of calculating methods transforms real images to the images as pictures, videos and sound record. Solution based on obtained figures and values of calculated images provide sound mapping critical parts of aircraft.

A validation and calibration with measured aircraft noise audio is planned for future work and improving the current technique. It would be beneficial for further validation and to obtain even more realistic images, audio and recording to employ the use of higher-fidelity source noise models, which would also give the capability of incorporating temporal changes of shorter durations of aircrafts.

**Acknowledgement**

The authors would like to express their gratitude to Ladislav Galetka (test pilot UL Scout). A special thanks to the management of Kubíček AIRCRAFT and Airport Štípa Mr. Habrovansky for using RWY and technical support. This article was written with support of the Research and Development for Innovations Operational Programme, co-funded by the European Regional Development Fund (ERDF) and the national budget of the Czech Republic, within the framework of the project Centre of Polymer Systems (reg. number: CZ.1.05/2.1.00/03.0111). This work was supported by the Ministry of Education, Youth and Sports of the Czech Republic – Programme NPU I (LO1504) and by the European Regional Development Fund (Grant No. CZ.1.05/2.1.00/19.0409). This study was also supported by TBU grant numbers IGA/FT/2016/013, IGA/FT/2017/002 and IGA/FT/2017/011, funded from the resources of specific university research.

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Received 01, 2020, accepted 07, 2020