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LOCATION OF DISTANT SOURCES OF INFRASONIC NOISE

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1. INTRODUCTION

Infrasound which occurs in the environment may be of a natural or artificial origin, especially an industrial one. Exposure to infrasound at levels normally experienced by man does not tend to produce any dramatic health effects, but it causes considerable disturbances and annoyance [3]. Owing to its long wavelength, infrasound can propagate over very long distances and can have an impact on the human organism, even when far from its source.

This paper presents a practical application of a three-element microphone method for locating distant sources of infrasound described in literature [4],[5].

2. PRINCIPLES OF A THREE-ELEMENT MICROPHONE METHOD

The main part of the measuring system is a probe which consists of three microphones placed in the corners of a right-angled isosceles ABC triangle (AB=AC=a). Such a system is at its optimum when a=1/2 λ (λ-wavelength).

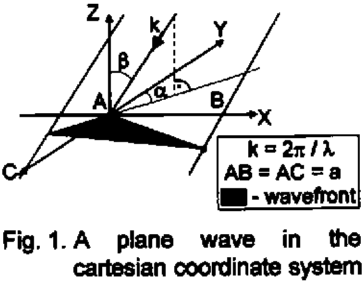


Fig. 1. A plane wave in the cartesian coordinate system XYZ.

If a plane wave arrives at angles α and β, as in Fig. 1, the phase differences between microphone pairs A-B ($\Delta\phi_{A\text{-}B}$) and A-C ($\Delta\phi_{A\text{-}C}$) can be expressed as (1),(2):

$$\Delta\phi_{A\text{-}B} = ka \sin\alpha \sin\beta; \qquad (1)$$

$$\Delta\phi_{A\text{-}C} = -ka \cos\alpha \sin\beta. \qquad (2)$$

Combining equations (1) and (2) we obtain the following formulas for α and β (3),(4):

$$tg\alpha = - \Delta\phi_{A\text{-}B} / \Delta\phi_{A\text{-}C}; \qquad (3)$$

$$\sin^2\beta = (\Delta\phi^2_{A\text{-}B} + \Delta\phi^2_{A\text{-}C}) / (ka)^2; \qquad (4)$$

They allow an accurate determination only of the angle α, which is sufficient for locating the source of infrasound. In order to obtain the above, the measurements ought to be performed at two different positions of the probe.

When a three-microphone probe is to be used for determining the infrasonic noise (2÷50 Hz), the optimum distance required between the microphones should be from 3.4÷85.0 m. Using the tape measure and flagpoles this distance can be measured with the accuracy of 0.01÷0.10 m; the right angle can be set with the accuracy of ±6' using the square, while by applying a levelling instrument one can position the microphones with the accuracy of ±0.001 m. The placement of microphones with such accuracies makes the uncertainity of the angle α not higher than $\pm 3.0^0$.

3. LABORATORY EXPERIMENTS AND PRACTICAL APPLICATION OF A THREE-ELEMENT MICROPHONE METHOD

Measuring system

A block diagram of the assembled measuring system of a three-element microphone method is presented in Fig. 2. The acoustic pressure levels in 1/12 octave-bands are measured as autospectrums of microphones A (S_{AA}), B (S_{BB}) and C (S_{CC}). Furthermore, the phase differences $\Delta\phi_{A\text{-}B}$ and $\Delta\phi_{A\text{-}C}$ are determined basing on the cross spectrums of the pairs of microphones A-B (S_{AB}) and A-C (S_{AC}), respectively.

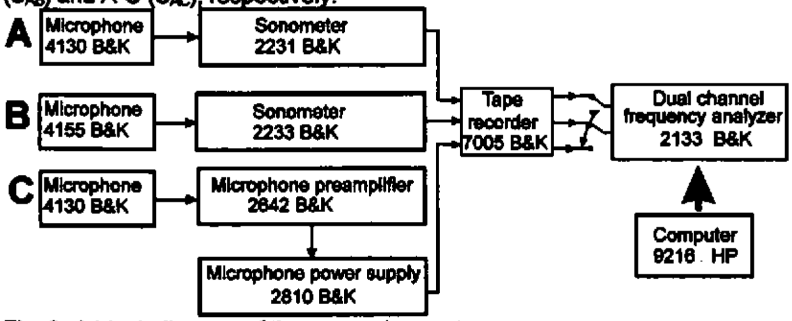


Fig. 2. A block diagram of the measuring system;
(B&K - Bruel and Kjaer - Denmark, HP - Hewlett-Packard - USA).

The optimum measuring system should consist of 3 microphones, preamplifiers, amplifiers, channels of tape recorder with identical phase response, and have a flat amplitude response as a function of the frequency in the range considered (2÷50 Hz). Thus, in order to perform the correction of phase-mismatching of the chains A, B, C of the measuring system, the ratios of the transfer functions H_A/H_B and H_A/H_C were determined using special calibration procedure in the plane wave field (in a standing-wave tube) [2].

Laboratory experiments

In the natural environment infrasound propagates usually as spheric waves [1]; however, the formulas for calculating the angle α have been developed for plane waves. Generally, an error of measurement for the angle α which results from the measuring principle for a spheric wave of 0 order within the distance of $r \geq 10\lambda$ is not higher than $\pm 10.0^0$ (for β from the range $10^0 \div 170^0$).

To check the usefulness of this method for determining the direction of wave vector, laboratory experiments in an anechoic chamber were conducted with a model of the probe adjusted to a frequency of 170 Hz..The microphones and preamplifiers were mounted on a triangular support, the centre of which was fixed horizontally on a tripod. This arrangement was stable and enabled a controlled rotation of the array. The results obtained using a loudspeaker generating pure tone revealed that the directional resolution of the probe approximated $\pm 2.2^0$ (mean value). These findings confirm the usefulness of this method for determining the direction of wave vector of acoustic wave in the far field ($r \geq 2.5\ \lambda$).

Practical application

An example of the practical application of the described method are the measurements made around a power plant. The plant is located about 10 km from a small town and is surrounded by woodlands. In the wide-band noise spectrum measured around the plant, the tone components in the frequency range of 16.3÷30.7 Hz have been found (Fig. 3).

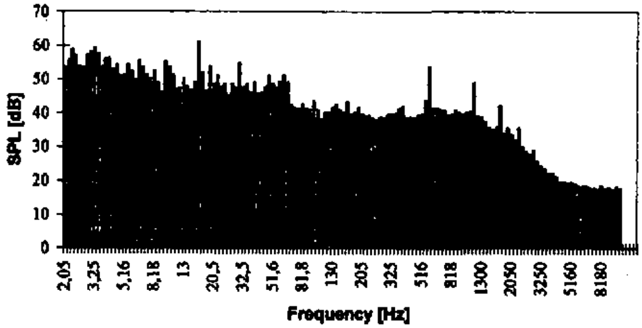
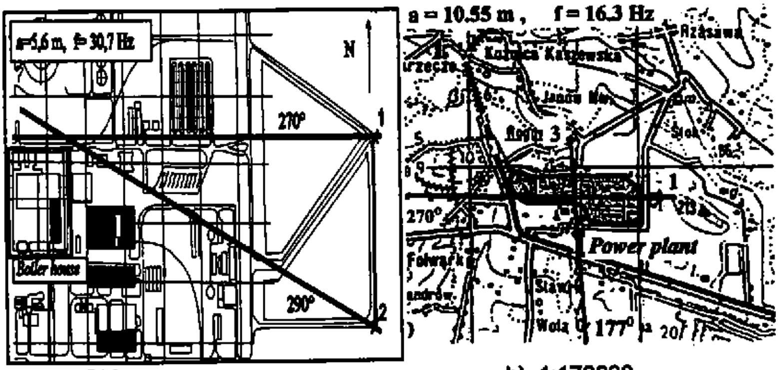


Fig. 3. 1/12 octave-band spectrum measured around a power plant.

The measurements were made using different locations of the probe. The distance between the microphones was adjusted to the frequency of 16.3 and 30.7 Hz. Each microphone was mounted on its own tripod at the height of 1.4 m. They were arranged using a tape measure, square, leveller and flagposts.

The results obtained are presented in Fig. 4. They allow locating a source of infrasonic noise - a boiler house placed in the power plant. The findings confirmed the usefulness of the three-microphone method for locating distant sources of infrasonic noise in the open space.



a) 1:15700 b) 1:170000

Fig. 4. Directions of wave's propagation determined at different probe locations around a power plant; a) at locations 1 and 2; b) at locations 1 and 3.

4. CONCLUSIONS

• A three-element microphone method can be used for the open-space monitoring or locating distant sources of infrasonic noise. The measurements ought to be performed at two different positions of the probe.

• In fact the propagation of acoustic waves in air differs from free-field conditions.Thus some measurements conditions are advantageous for the application of a three-element microphone method e.g.: flat ground with no or with a small number of reflecting or blocking objects; locating the probe (each microphone) relatively high from the ground; conducting the measurements during night-time; favourable weather conditions (no precipitations or wind and relatively high humidity).

References

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