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INCE: 10

AIR CONDITIONING NOISE SOURCES IDENTIFICATION USING ACOUSTIC HOLOGRAPHY

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1 Introduction

Direct problems of sources characterisation from their underlying causes are sometimes difficult to solve. This is for example the fan noise case, where it is necessary to know the upstream flow characteristics perfectly in order to be able to determine the radiated noise. Another approach consists in solving the inverse problem of determining the sources parameters from simple pressure or intensity measurements. This is the approach used in acoustic holography and parametric methods that we first tested on simple cases before applying them to more complex sources.

2 Principle of acoustic holography

Formal expression : This method allows the acoustic field in the whole space to be determined by measuring it over a surface situated in the near-field of the sources [1]. Thus, in plane geometry, the field in z_s plane can be deduced from the field measured in z_h.

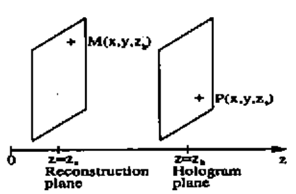

Figure 1:

$$P(x,y,z_h) = P(x,y,z_s) * G(x,y,z_h - z_s) \tag{1}$$

where $*$ is the convolution product, G is the free space Green function.
$G(x,y,z_h - z_s) = \exp(-jkR)/4\pi R \qquad R = \|\vec{MP}\|$.
Equation (1) can be deconvoluted using a two dimensional Fourier Transform.

$$\hat{P}(k_x,k_y,z_h) = \hat{P}(k_x,k_y,z_s) \times \hat{G}(k_x,k_y,z_h - z_s) \tag{2}$$

$$\begin{cases} \hat{G}(k_x,k_y,z) = \exp(jz\sqrt{k^2 - k_x^2 - k_y^2}) & k^2 \geq k_x^2 + k_y^2 \\ \hat{G}(k_x,k_y,z) = \exp(-z\sqrt{k_x^2 + k_y^2 - k^2}) & k^2 < k_x^2 + k_y^2 \end{cases} \tag{3}$$

The interest of near-field acoustic holography compared with it's conventional form lies in the fact that it takes evanescent waves into account (if $k^2 < k_x^2 + k_y^2$), these ones containing information about small details of field image.

Implentation problems : Several hypothesis were used in order to establish these relationships. The field is assumed to be known in a plane with infinite accuracy and extent and, morever, the waves were taken to be purely progressive (free field measurements). In practice, acquisition takes place in finite dimension plane with sampling in the x and y directions with finite dynamic measuring system. These constraints set a limit on measurement of evanescent waves and thus on the details of the back-scattered field.

To reduce manufacturing and computing cost, we made an instrumentation that moved the probe sequentially over the plane. The sources studied therefore had to be stationary and the phase reference problem arose. The use of STSF (Spatial Transform of Sound Field) method enabled this difficulty to be overcome for the case of partially coherent fields [2].

Initial mesurements : The method was tested on the simple case of two loudspeakers inserted in a flat baffle. We could thus check that taking the evanescent waves into consideration gave a resolution of better than half a wavelenght. It was, however, necessary to filter the highest spatial frequencies so as not to build up exponentially from waves drowned in noise [3]. A single reference phase was chosen on the exciting signal for the case of two coherent sources. For partially coherent fields, at least one reference per source needed to be used. Figures 2a and 2b show a simulation of the pressure field in the hologram plane. Figures 2c and 2f are for a measurement with two baffled loudspeakers in the same configuration (two coherent sources in phase, having the same power and separated by $\lambda/2$). Figures 2d, 2e, 2g and 2h are the active and reactive intensities in the hologram plane and the source plane calculated from the measured pressure field. These results show that two sources can be dessociated using a near-field pressure measurement; but this method is limited to narrow band use and cannot be applied in industrial cases when wide band sources are being studied; it demands, also, a large number of measurements.

3 Parametric method

This method consists in trying to work back to the sources parameters (powers, phases, correlations) from far-field intensity measurements. This can be done by minimizing error between intensity actually measured and that calculated from a model by optimizing the parameters it depends on. We started from the hypothesis that we knew the number of sources and their positions (parameters that can be established by a holographic measurement) and the assumption that they were point, omnidirectional sources. For the general case, the intensity can be written:

$$\vec{I}(x,y,z) = \sum_{i}^{N}\sum_{j}^{N} \gamma_{ij} \times P_i(x,y,z) \times \vec{U}_j(x,y,z) \quad (4)$$

where γ_{ij} is the coherence function between sources i and j.

Measurements made with the two baffled loudspeakers showed it was possible to work back to the parameters we were looking for with fairly good accuracy for power and phase but more difficultly coherence. We also noted that the number of measurements needed to make the algorithm converge toward the right solution rose very quickly. It seems that this method can be envisaged for simple sources sufficiently far appart, but may well give results that are not so good when the system under study is compact and composed of a large number of sources; which is the case for the air conditioning systems we intend to study.

Signal	Source number	Power	Phasis	Coherence
Sinus	2	94.8, 93.6	0, π	1
Sinus	2	104.2, 105.0	0, 0	1
Random	2	72.5, 74.5	0, 0	1

Table 1: Sources configuration

Power	Phasis	Coherence	Iterations	Point number
95.5, 94.0	0, 3.16	0.83	90	1024
103.7, 103.9	0, 0.03	1	520	1024
73.0, 74.2	0, 0	1.01	250	1024

Table 2: Algorithm convergence

4 Conclusion

Acoustic holography has shown that it can give good results when locating sources in the case of measurements made in good conditions, that can hardly be envisaged in an industrial environment. Characterizing the sources by optimisation methods seems more suitable but, for the time being, does not allow the position or source number to be adjusted.

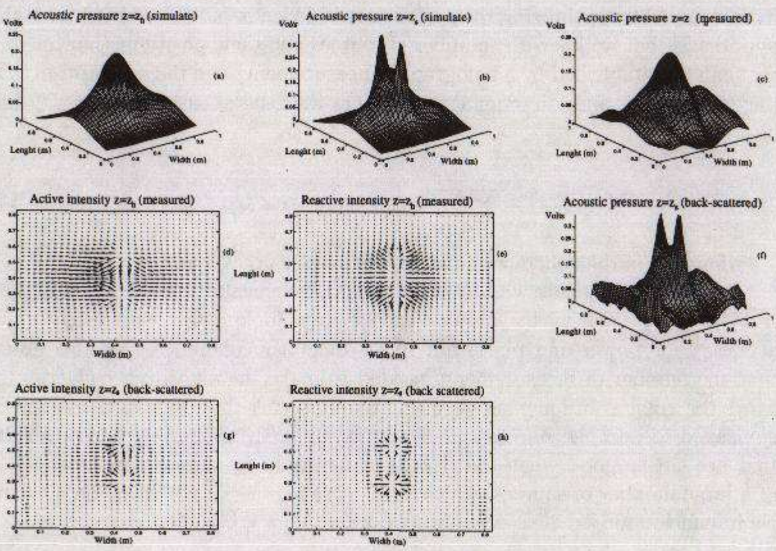

Figure 2:

References

[1] J. D. Maynard, E. G. Williams, and Y. Lee, "Nearfield acoustic holography: I. theory of generalized holography and the development of NAH," *Journal of Acoustical Society of America*, vol. 78, pp. 1395–1412, Oct. 1985.

[2] J. Hald, "STSF – a unique technique for scan-based Near-field Acoustic Holography without restrictions on coherence.," Tecnnical Review 1, Brüel & Kjær, 1989.

[3] J.-F. Li, *Identification des sources industrielles par des techniques d'intensimétrie et d'holographie acoustique.* PhD thesis, Université de technologie de Compiègne, Dec. 1993.