inter•noise 96
25th Anniversary Congress – Liverpool
INCE: 76

CHARACTERIZATION OF SCATTERING USING NEAR-FIELD ACOUSTIC HOLOGRAPHY

M Kleiner & P Svensson

Dept Applied Acoustics, Chalmers Univ, Gothenburg, Sweden

1. INTRODUCTION

The scattering response of quasi-plane scatterers which have dimensions of the order of a few meters, whether planar, curved, or corrugated, is of considerable interest in room acoustics. This is primarily due to the need to predict the sound field from reflecting objects as well as the need to take the scatterers influence on the diffusitivity of the reverberant sound field into account.

Lambert's law behaviour is often assumed for scatterers by default and implies that the scattered energy is spread equally in all directions, corresponding in a sense to Paris' law for sound absorbers. However, Lambert's law has less physical validation than Paris' law, which can be justified by the behaviour of many porous sound absorbing materials.

Many authors have suggested the use of spatially averaged scattering coefficents, c.f. for example Kuttruff [1], that have been measured by for example Mommertz & Vorländer [2]. These scattering coefficients, often called diffusitivity coefficients are primarily of interest as an average measure of a surface's scattering properties. D'Antonio has suggested a method to measure more precise directional scattering coefficients based on conventional measurement techniques [3].

By using a near field acoustic holography, NAH, approach to the measurement and data storage of scatterer characteristics, it is possible to gain several advantages over the methods previously suggested, such as (1) simplified measurement because of less stringent requirements for measurement surroundings, (2) impulse response at any scatter angle can be calculated. The primary drawback of using NAH for such measurements is that the estimation of directivity far away from the scatterer requires much computing power if Fourier transform techniques are to be used.

An analogous application of the NAH method coupled with spatial transformation of sound fields to the measurement of the directional characteristics of transducers has recently been reported by Rowell and Oldham [4].

2. METHOD

The objective of this study was to investigate the possibility of using NAH-measurements to estimate the directional behaviour of various scatterers. The scatterer is mounted in a sound absorbing baffle. Since the scattered field is obtained as a consequence of the incident field, it is necessary to separate the incident and the scattered sound fields. First a reference measurement was made at all measurement points in the measurement plane without the scatterer present, i.e. with the plane in principle entirely non-reflecting. Then a measurement was made at all measurement points in the measurement plane with the scattering object present. The measured impulse response without scatterer was then simply subtracted from the measured impulse response with the scatterer in order to yield the scattered sound field.

The impulse responses in various points of the sound field in the holography plane were measured using an MLSSA measurement system. To remove the influence of the loudspeaker's impulse response, its free-field impulse response was deconvolved from all scattered field impulse responses. The sampling frequency was 105 kHz and the analyzed frame size of the impulse response of the scattered field was 512 points. A one-half Hanning window was used to taper off the late part of the impulse response of the scattered field. The sampling requirements for the spatial sampling is to have at least two samples per spatial variation period across the scatterer. A sampling distance of 0.005 m was estimated from the Green's function to give negligible spatial aliasing and was choosen for all measurements. A 32 times 32 array of measurement points was choosen. Since computation of the far field sound pressure was of interest, the sound pressure data for the holography plane area had to be synthetically extended using zero padding. A glass wool baffle was used to approximate the ideal sound absorbing baffle. Its outer surface was mounted parallel to the holography, i.e. measurement, plane at a distance of a few centimeters.

The scatterers were chosen for simple implementation while still being similar to actual scattering elements that can be of practical use in room acoustics. For practical reasons 1:10th scale models were used. All scatterers had the length 120 mm and width 60 mm. Due to their respective design however, the scattering cross section at various frequencies and its angular dependence varied. The following scatterers were used: circular plane surface, quadratic residue diffusor (qrd), rectangular plane surface, semi-cylinder diffusor. It was decided to let the semi-cylinder scatterer have the same height as the well depth of the quadratic residue diffuser.

A 1/8" Brüel & Kjær type 4138 microphone, placed with its membrane perpendicular to the holography plane, was moved between positions by the use of a computer controlled XY-positioning device. The sound source used was the treble element in a Yamaha NS-10M loudspeaker, which was covered with glass wool to avoid edge diffraction just leaving a hole in front of the element. The loudspeaker was positioned approximately 2.0 m away from the scattering surface.

3. PRINCIPLE

The sound pressure impulse responses on the hologram plane due to the scattered sound are measured as described earlier. A Fourier transformation of these impulse responses into the frequency domain is made. The wave field in any plane parallell to the measuring plane can then be reconstructed by making a two dimensional convolution of this pressure field with the spatial transfer function from one plane to another, as shown by Maynard et al [5], and Maynard & Veronesi [6]. A description of our implementation is given in Kleiner et al [7]. The error introduced in the sound pressure values of the spatially transformed sound fields, at reasonable distances from the hologram plane, by using a limited measurement area on the hologram plane, is small, since the sound pressure is small at distances far from the scatterer, in the hologram plane. The discrete convolution theorem assumes that the convolution is a cyclic convolution. Because of this, the discrete arrays representing the pressure field and the spatial transfer function, can be thought of as surrounded with periodic, identical, arrays. When doing the cyclic convolution, these "side arrays" will leak in into the convolution sum, unless care is taken by using zero padding.

4. RESULTS

For the calculation of the far-field directivity all receiving points were calculated to be at a distance of 0.64 m from the center of the scatterer. In order to obtain the 3D polar diagrams, the spatial transforms had to be calculated for 50 planes. One such magnitude 3D polar plot for a quadratic residue diffusor of the scattered field for one frequency, is shown in figure 1.

The levels in the 2D polar plot were all normalized to the level at a distance of 2.64 m from a point source. Figure 2 shows one such 2D polar plot. The polar plots indicate the expected behaviour of more pronounced wide angle scatter from the quadratic residue diffusor than from the semi-cylinder scatterer, although the difference is not as large as could be expected.

5. CONCLUSIONS

Reconstruction of scattered sound fields by using NAH and spatial transformation has one major drawback, which is the limitation in forward propagation distance introduced by the use of discrete Fourier transforms. The reduced requirements for the measurement surroundings plus the advantage of not having to build a hemi-spherical microphone array are however pointing in favor of the method.

6. ACKNOWLEDGEMENTS

The authors gratefully acknowledge the financial support of the Johnson foundation and the National Swedish Science Research Council, and the measurements done by H. Gustafsson, and J. Backman.

7. REFERENCES

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8. FIGURES

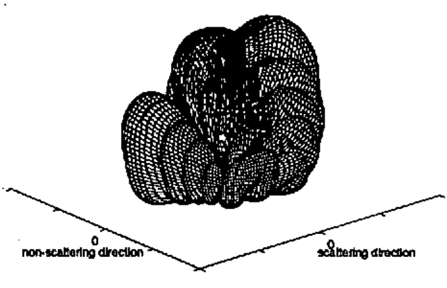

Figure 1.
Sample 3D directivity plot for a qrd 1:10 scale diffusor (60*120 mm) at 30° angle of incidence at a frequency of 15 kHz.

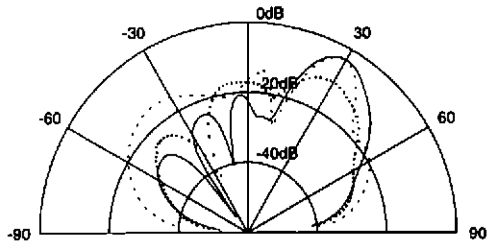

Figure 2. Sample 2D directivity plots for scattered field at 30° inc. 15 kHz from qrd (···), semicylindrical (- -) and flat surface (——).