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NUMERICAL SIMULATION AND ANALYSIS OF SURFACE SCATTERING - PART 2

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ABSTRACT

Directional scattering patterns of surface contain much more detail information than the single number quantities of scattering and diffusion coefficients. In the development of acoustic computer simulation, more accurate results and natural sound perception of auralization requires more detail information about sound propagation. In this paper, we present an approach for spatial clustering of scattered pattern in dependence on frequency, incidence angles and reflection angles. We also analyze spatial distribution characteristics of reflected energy in different incident angles and the relationship with surface pattern and frequency. Finally, we discuss a more specific evaluation of the directional scattering effect.

Keywords: *scattering coefficient, scattered sound, spatial distribution.*

1. INTRODUCTION

The random incidence scattering coefficient [1] characterizes the ratio of the scattered sound energy to the total reflected sound energy. It can be measured with reverberation chamber method [1] or free-field method [2]. So far, scattering coefficient has been frequently used in sound field simulations, in which the scattering direction differences are not taken into consideration. Hereby the scattered sound is assumed to follow the Lambert's law.

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In this paper, numerical simulations are used to determine the scattered sound pressure. We present a method to determine the reflection directivity of a surface, depending on frequency and incident sound wave direction. As an example, a sinusoidal and a rectangular surface are investigated. Furthermore, we analyze the directivity of scattered sound to figure out their relationship with surface pattern, incidence sound direction and ratio of period length to wavelength (Λ/λ).

2. SIMULATION AND ANALYSIS METHOD

In this paper, the mesh2scattering [3-4] toolbox is used to simulate the scattered sound pressure p_R of a finite-size surface in far field. This needs to be normalized against an omnidirectional sound source to calculate the directivity $|G(\vartheta_S, \varphi_S, \vartheta_R, \varphi_R)|$, where ϑ and φ are the incident and the azimuth angle, S and R indicate the source and the receiver grids.

$$\left|G(\vartheta_S, \varphi_S, \vartheta_R, \varphi_R)\right| = \left|\frac{p_R(\vartheta_S, \varphi_S, \vartheta_R, \varphi_R)}{p_{ref}(r)}\right| \quad (1)$$

Where the reference sound pressure of a point source is as follows [5].

$$p_{ref}(r) = \frac{p_0}{4\pi r} \cdot e^{j\frac{2\pi f}{c} \cdot r} \quad (2)$$

Here, p_0 is an arbitrary constant in Pa m, r equals the acoustics path from the source to the surface center r_S and from the acoustic center to the receiver r_R.

3. RESULTS AND DISCUSSION

We took a sinusoidal and a rectangular surface as examples to study the spatial distribution of scattered sound in dependence on incidence angles, ratio of period length to wavelength (Λ/λ) and surface pattern. These two surfaces have the same structure height (h = 0.05m) and period length (Λ = 0.07m). Here, we define the distance of receiver and source to the surface center r_R = 5m, r_S = 10m. The receiver grid has an angular resolution of $\Delta\vartheta_R = \Delta\varphi_R$ = 1°, and the source grid has an angular resolution of $\Delta\vartheta_S = \Delta\varphi_S$ = 10°. A series of comparison are made, and the results are shown below.

3.1 Different incident angle

Figure 1 and 2 show the spatial distribution of scattered sound with different incidence angles. Different directivity characteristics are observed when sound is incident from different sound incidence (ϑ_S) and azimuth(φ_S) angles.

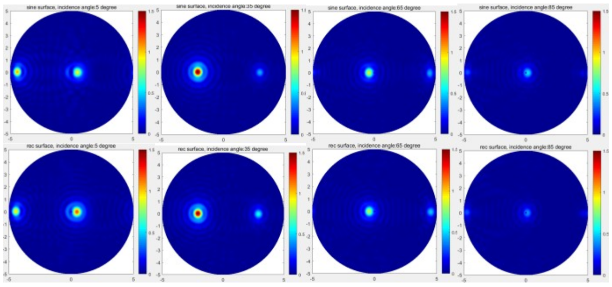

Figure 1. Directivity of the sinusoidal (top figures) and the rectangular (bottom figures) surfaces with different incidence angles (ϑ_S = 5°, 35°, 55° and 75°). The azimuth angle of source is φ_S = 0°, Λ/λ = 1.023.

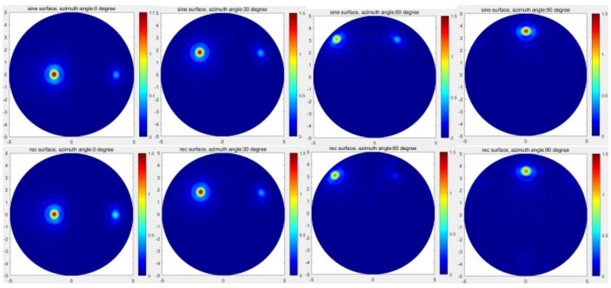

Figure 2. Directivity of the sinusoidal (top figures) and the rectangular (bottom figures) surfaces with different azimuth angles (φ_S = 0°, 30°, 60° and 90°). The azimuth angle of source is ϑ_S = 45°, Λ/λ = 1.023.

As the ϑ_S and φ_S increase, the scattered sound directions of both surfaces shift with the incidence angle in a similar way.

3.2 Different Λ/λ values

As shown in Figure 3, more scattering patterns are observed when the Λ/λ value increases. For both surfaces, the spatial distribution of scattered sound varies with Λ/λ. For each Λ/λ, their directions of scattered sound match well.

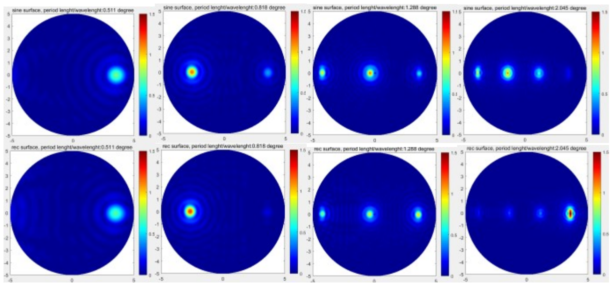

Figure 3. Comparison of the directivity of the sinusoidal (top figures) and rectangular (bottom figures) surfaces, with the same incidence sound (ϑ_S = 15° and φ_S = 50°), but different Λ/λ values (Λ/λ = 0.818, 1.023, 1.288, 1.636 and 2.045).

4. CONCLUSIONS AND OUTLOOKS

In this paper, we present a method to calculate the directivity of surfaces based on the scattered sound pressure. A sinusoidal and a rectangular surface are taken as examples to investigate their directivities in dependence on sound incidence direction, Λ/λ value and surface patterns. It was shown that the directivities of the test surfaces do not follow the Lambert's law.

In the following work, other 1D and 2D surfaces with different profiles will be investigated to classify the surface and extract its directivity. More analysis will be made to propose a new metric for more specific evaluation of the directional scattering effects.

5. ACKNOWLEDGMENTS

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