Characterising Scattering From Room Surfaces

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Abstract: This paper discusses methods for characterising diffusion from surfaces. A method for measuring hemispherical scattering from a surface is detailed and parameters derived from such measurements discussed.

INTRODUCTION

There is a need to characterise the scattering from surfaces in terms of a diffusion coefficient. Such a coefficient is needed for geometric room acoustic models. A round robin test (1), found that successful computer models were those which included diffusion modelling. A diffusion coefficient is also required to evaluate the worth of diffusing products and other architectural features in dispersing sound. In the acoustics and building industries the role of diffusion is poorly understood, this may in part be due to the lack of a measure by which diffusion can be quantified.

MEASUREMENT OF POLAR DISTRIBUTIONS

Previous work on characterising scattered polar distributions by single parameters has concentrated on two dimensional measurements (2). A new capability to measure full hemispherical scattering has been developed. Figure 1 shows part of the system - a semicircular track approximately 3m in diameter which is traversed by a microphone mounted on a trolley. The trolley is moved via a cable by a stepper motor and a second stepper motor rotates the track around the sample surface, which remains stationary. The microphone can be remotely positioned anywhere on a hemisphere centred on the sample and is interfaced to an Maximum Length Sequence measurement system.

FIGURE 1. Hemispherical Measurement System (part)
DERIVATION OF DIFFUSION PARAMETERS

There are a number of possible approaches to deriving diffusion parameters from polar distributions:

The standard deviation quantifies diffusion via the sum of the squared deviations from the mean value (3). Normalisation using the worst case of all energy scattered in one direction yields a parameter bounded between 0 (complete diffusion) and 1 (no diffusion) but the values for practical surfaces are bunched at the lower end of the scale.

A directivity measure (4) defines complete diffusion as when the fraction of intensity scattered in any direction is the same as the reciprocal of the number of measurements. It is closely related to the standard deviation parameter.

A diffusion coefficient can be derived from the ratio of energy scattered in non-specular directions to the total scattered energy. In this case, complete diffusion is defined as a 'notched' polar distribution but there are no current diffusers which can produce such a response. In any case, it is sometimes difficult to define the specular directions and this type of parameter can be easily fooled by rotating the diffuser to produce redirection rather than dispersion.

A new measure based on the autocorrelation function is proposed. This defines complete diffusion as the case where the scattering in each direction is identical; an autocorrelation function quantifies the similarity between different sections of a signal. A circular autocorrelation of the polar response produces a distribution bounded between 0 and 1, the mean of this distribution then forms a single bounded parameter. The process simplifies to a straightforward equation for the diffusion coefficient, $e_{auto}$:

$$
e_{auto} = \frac{\sum_i \sum_{j>i} i_j}{(n-1) \sum_i i_i^2}$$  

where $i_j$ is the scattered intensity and $n$ the total number of measurements. This autocorrelation diffusion coefficient ranks the scattering from surfaces in the same order as the measure derived from standard deviation but the values for real surfaces are better spread over the range from 0 to 1.

All of the above parameters have been used to quantify single plane scattering. This can be simply extended to hemispherical scattering provided the polar response has approximate circular symmetry about the surface normal. For surfaces which have very different scattering properties in two or more planes, such as cylinders, the suggested solution is to quote a separate diffusion coefficient for each significant direction.

One problem with all of the parameters is that they have difficulty in dealing with large surfaces. An infinite smooth baffle will be rated as a perfect diffuser even though this contradicts received wisdom. It might be best if the parameters were evaluated in the far field but for large surfaces and oblique measurement positions this is not possible and in any case listeners are often located in the near field. To quantify the diffusing worth of large surfaces, the change in scattered energy when diffusion is applied to a plane baffle might be used (5) or it may be possible to define appropriate ranges of the diffusion coefficient to design for. Alternatively, there are other methods such as those of Mommeritz and Vorlander (6) and Lam and Pantelides (7) which enable a single measure of diffusion to be obtained without measuring the polar distribution, the former explicitly deals with the large surface case.

ACKNOWLEDGEMENTS

This ongoing work is funded by the EPSRC (UK) (GR/L13124), with support from RPG Diffusor Systems, Inc.

REFERENCES