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A suggested method to be used to measure scattering coefficients of full scale samples.

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ABSTRACT

In attempting to follow ISO 17497-1[1] as a method for measuring full-scale scattering coefficients, it was observed that many of the recommended steps needed to be modified for those full-scale measurements. Variations were tried to aid in these measurements. These variations are described, and suggested solutions to the problems observed are presented. It was observed that continuous rotation of the sample, rather than step action rotation, worked better for taking consistent data from the sample. Also, a stable chamber environment is necessary with humidity reaching at least 50% and temperature variations should not vary by more than 2 degrees Celsius throughout all four parts of the test. It was also observed that a less directional source than recommended was needed so two dodecahedron loudspeakers were chosen to reproduce a combined Weighted Noise stimulus source. Six data microphones were placed at random locations and varying heights to collect data. Data was compared between the suggested method and the ISO-17497-1 Standard.

1. INTRODUCTION

The scattering coefficient was introduced as a new idea in a paper[2] authored by Vorlander and Mommertz in 1999. It defined scattering as the difference between the total reflected energy and the specular reflected energy. The methods described in the paper were then implemented in the Standard ISO-17497-1 in May of 2004. During and since that time there have been studies done by Vorlander, Embrechts, Geetere, Vermeir and Gomes[3] as well as Cox and D'Antonio[4] in 2004 and 2005.

"Together with the absorption coefficient, the scattering coefficient is useful in room acoustic calculations, simulations and prediction models. For some time it has been known that the modeling of scattering from surfaces is very important for obtaining reliable predictions of

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room acoustics”[1]. This part of ISO-17497-1 represented recognition that absorption of materials was not the only parameter affecting the reverberation time of a room. The scattering coefficient was made to replace generally accepted estimation methods or “fudge factors” applied by acousticians to make calculations come closer to the real world answers. The standard represented the “best practices” at that time based on experimental data from scale model scattering devices.

This paper represents about 4 years of work performed while trying to implement ISO-17497-1 at NWAA Labs using full scale samples. The use of a full scale sample size has presented a unique set of problems and answers. The recommended methods described in the standard will be discussed as well as the problems they revealed in the standard. We will conclude with methods developed to overcome these problems.

2. TERMS

A. Diffusion

The reflection or refraction of radiation such as light or sound by an irregular surface, tending to scatter it in many directions.

Diffusion has many different types of energy as components. One part is specular and is defined as a reflection that follows Snell’s Law, which is the angle of the reflection is equal to the angle of incidence. The other part is diffractive and is the energy that changes direction or spreads based on passing an edge or going through an aperture.

The geometry has a great deal to do with the direction of the diffusion. A specimen that is shaped so that the reflections are in one plane is called a 2-D diffuser. A different specimen that reflects in multiple planes is called a 3-D diffuser. Diffusion can be caused by surface roughness or by the use of geometrically shaped surfaces. Diffusers can be infinite in size such as a wall or ceiling or they can be panels of a finite size affixed to a surface. The “Diffusion Coefficient” is a measure of quality and not a measure of quantity and is not used in computer aided modeling programs at this time.

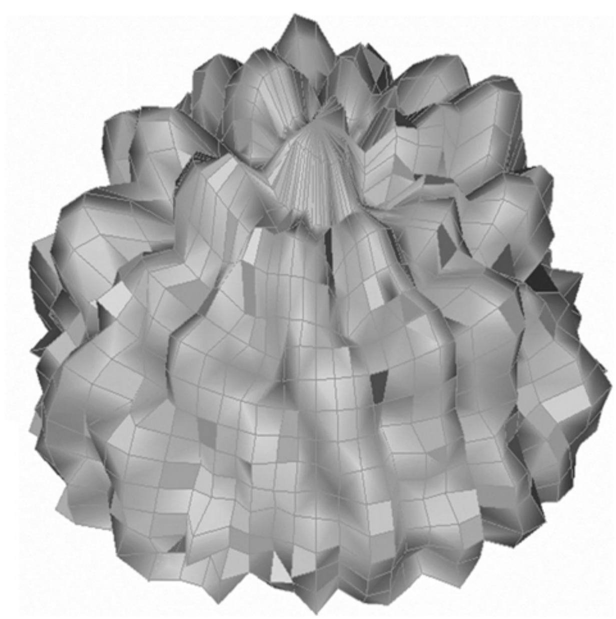

Figure 1: Diffusion balloon measurements done using Standard AES-4id-2001.[5]

Figure 1 shows the resultant energy balloon measured using the AES method and is the inverse equivalent to a directionality balloon of a sound source.

B. Scattering

The reflection or refraction of radiation such as light or sound by an irregular surface, tending to scatter it in many directions.

Scattering has many different types of energy as components. One part is specular and is defined as a reflection that follows Snell's Law, which is the angle of the reflection is equal to the angle of incidence. The other part is diffractive and is the energy that changes direction or spreads based on passing an edge or going thru an aperture. Up to this point the definitions are the same except when we get to the physical properties of a scattering surface.

Scattered energy is defined as the energy from the specular reflections that is subtracted from the total energy scattered or diffused. The geometry has little to do with the scattered energy since in most cases it is specular in nature. Scattering is caused by surface roughness and not by the use of geometrically shaped surfaces. Scatterers can be infinite in size such as a wall or ceiling or they can be panels of a finite size affixed to a surface. The "Scattering Coefficient" is a measure of quantity and not a measure of quality and is used in computer aided modeling programs as another kind of "absorption". It has limits in topology clearly defined in the standard. The structural depth of the sample cannot exceed 1/16 of the total sample diameter.

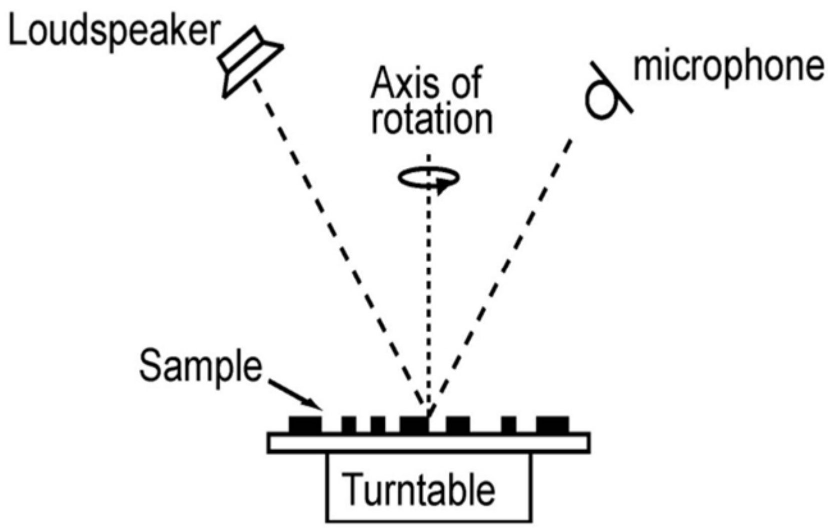

Figure 2: Schematic arrangement of a test. [1]

Figure 2 shows an illustration of a typical measurement system in a reverberation room. As can be seen, the overall turntable size at low frequencies would provide a specular reflection because of its size and flatness. The surface detail would "scatter" the sound waves at higher frequencies depending on their physical sizes. When the depth of this detail becomes too large we then convert the scattered energy into specular reflections.

B. Scattering (Cont)

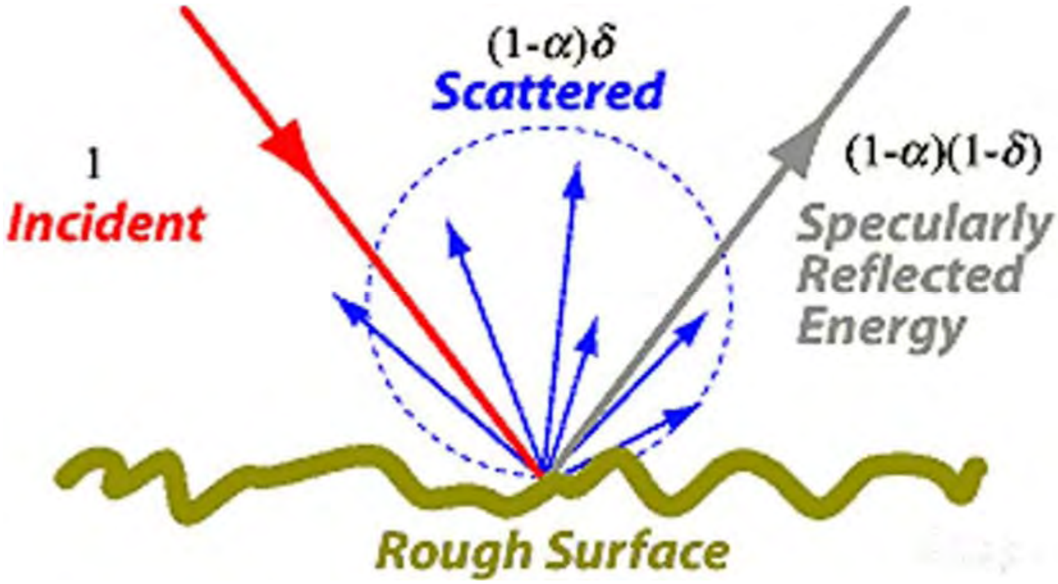

Figure 3: An illustration of the different types of energy in Scattering.[1]

As can be seen in Figure 3 all of the energy contained in the incident energy is then reflected as either specular energy or scattered energy. The rough surface is proportional to the wavelengths that need to be scattered or reflected.

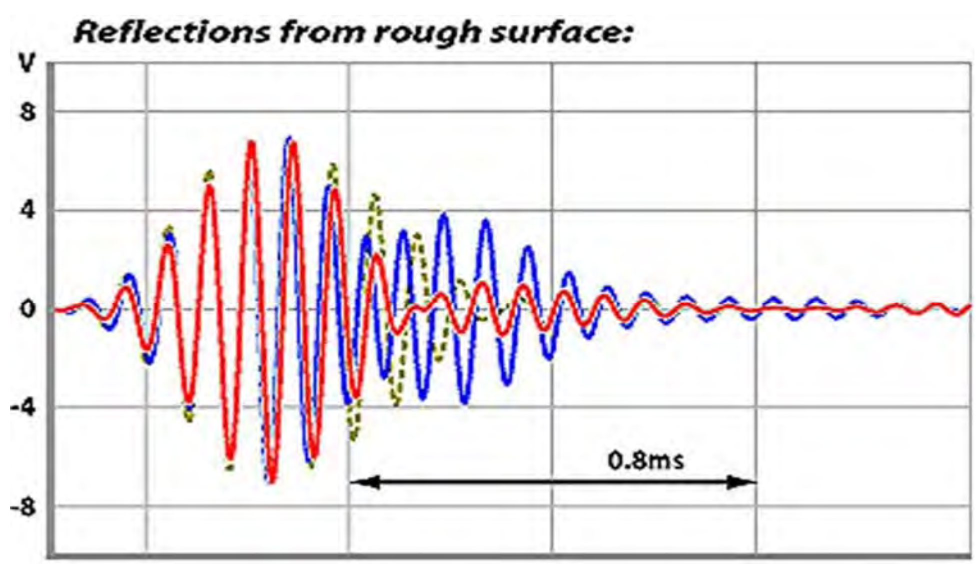

Figure 4: Impulse Response correlations of 3 different time based measurements.[1]

Figure 4 shows that the early parts of the measurements are highly correlated and are the part of the measurement that is identical with the specular part of the reflection. The later parts are not in phase and depend on the orientation of the sample. When summed together the early parts will coherently add together and the later parts add destructively and will cancel the energy. The difference is then the scattered energy.

3. ISO-17497-1 Requirements

A. What is the sample shape and size required by ISO-17497-1

ISO-17497-1 describes the sample as being circular (as a preference) or square and imbedded in the surface of the turntable. The dimensions shall be a minimum diameter of 3 meters (118.11 inches). The square sample should be wholly contained within the recommended diameter.

B. What are the methods to be used to gather data in ISO-17497-1

ISO-354 recommends the sample be rotated or stepped thru 360 degrees during the measurement process.

The stimulus to be used is recommended to be MLS or some other time invariant source to develop impulse response data. The number of samples should be a minimum of 6 and then averaged together using a phase locked process.

4. Observations

A. Sample shape and size

During the process of measuring hundreds of full sized samples it has been observed that the shape and size are critical to the gathering of accurate data. At lower frequencies the sample size is inadequate to observe enough differences in the reverberation times so that they exceed the amount of error inherent in the measuring process. Increases in sample size were tried and it seems that an increase in size does help. During the same process square samples with turntable fill pieces were measured and compared to similar samples that were measured in the circular format. The results showed that a square sample had significant errors that were beyond the normal measurement errors. Similar areas were compared and the circular sample consistently showed a smaller coefficient of scattering.

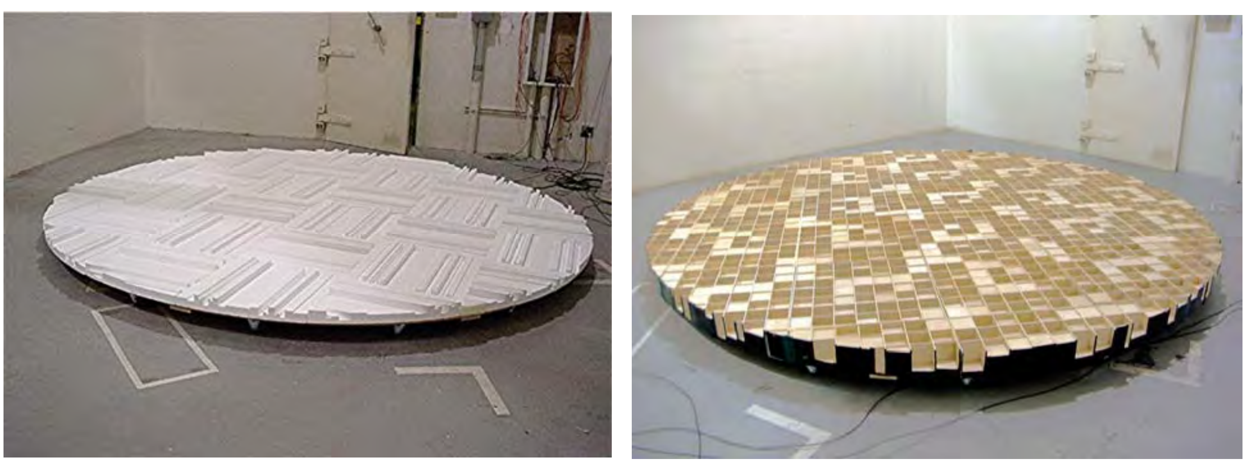

Figure 5: Typical specimens of scattering elements

B. Methods

Comparing measurements done with the turntable stepping vs. constantly turning showed that the stepped measurements were always higher at lower frequencies than the constantly turning

B. Methods (Cont)

samples. This follows the observations that were written about in the papers from Vorlander and Vermeir. As part of the experiments that were done it was decided to increase the total number of turns of the turntable and to sample the data at random times creating multiple measurements over the increased number of turns. The data correlation and consistency of the lower frequency data increased by a significant amount.

The experiments with stimulus also caused the author to rethink the process. When MLS signals were used the results were inconsistent and sometimes random. After investigation it was discovered that like any viscous fluid, air can be thought of in the same way. As a full sized sample was rotated in the room there seemed to be a column of air that started moving slowly. Because of the air movement the time invariant nature of MLS came back to bite the experimenter. MLS is not useable where there are variations in the air mass since it has to be time invariant. It was then decided that the use of pink noise should be tried and impulse responses were then developed from them using EASERA. The results instantly became much more stable and predictable. This also led to a reversal of the order of the sample tests for the same reasons.

4. CONCLUSIONS

A. Sample sizes and shapes recommended

a. It is recommended that the shape of the sample be fixed as a circle.

b. The size of the sample should exceed 3.5meters (137.8 inches) in diameter since a smaller diameter allows too much variation in the measurements at lower frequencies.

B. Methods recommended

a. The sample should be rotated constantly over at least 3 full turns

b. The stimulus should be a stimulus that has less sensitivity to air movement, temperature and humidity such as pink noise or log sweep.

c. The temperature cannot vary more than 2 degrees C during the process of measuring each set. i.e. (T1 and T3) or (T2 and T4).

d. Humidity must be kept above 50% and constant within 2 %.

e. Waiting time after closing the door to the chamber should be a minimum of 15 minutes to allow air movement to stabilize.

f. Because of the requirements of the simulation programs the frequency range should be extended from 100Hz to 10KHz".

g. The number of microphones should be increased to 6 and the number of samples should be increased to 12

5. ACKNOWLEDGMENTS

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