inter-noise 2023
CHIBA, GREATER TOKYO 20-23 AUGUST

Evolution of acoustic performance on residential buildings: An analysis from the acoustic tests database since the release of Brazilian acoustic standard performance.

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ABSTRACT

In 2013, the Brazilian Association of Technical Standards released the first version of the ABNT NBR 15575 standard, increasing the quality of Brazilian civil construction. The standard presents criteria for acoustic performance levels for residential buildings. A Brazilian acoustic laboratory from São Paulo city, since the release of the performance standard, has carried out more than 700 acoustic tests in different buildings to evaluate the standard requirements. The purpose of this paper is to investigate the evolution of acoustic performance in the new Brazilian buildings using this database. It was observed greater interest of the construction companies in the acoustic quality of the buildings from the release of the standard, registering a significant increase in the acoustic tests performed. In 2020, the number of different construction companies hiring acoustic tests exceeded by 1800% compared to 2013, the date of the performance standard appeared. Additionally, between 2014 and 2022 there was a considerable increase in the acoustic performance of construction systems. Considering only bedroom environments, there was an average increase of 7 dB in the acoustic performance of internal vertical partitions. As for air noise and floor impact insulation, 7 dB and 10 dB higher performance was observed, respectively.

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1. INTRODUCTION

In 2007, the Association of Technical Standards (ABNT) release for public consult the first version of the performance standard ABNT NBR 15575:2021 [1–3]. After comments and improvements, the ABNT NBR 15575:2021 [1–3] was officially released in 2013. The norm adds international standards of diverse knowledge areas that help to improve the Brazilian civil construction quality. The standard performance evaluates the residential buildings in diverse aspects among them acoustic, lighting, thermal, health, hygiene, air quality, and accessibility. The performance is rating at minimum, intermediate, and higher. For acoustic, the minimum is required, and the others are optional. For acoustic performance, the standard carried measurement tests methodologies based on international standards and parameters for the performance rating of floor, vertical systems, facades, and hydrosanitary systems acoustic insulation, floor impact acoustic insulation and building machines acoustic insulation. The last review of the standard was made in 2021.

Giner is an acoustic test laboratory based in São Paulo, Brazil. Has more than 20 years of experience in the acoustic Brazilian market and realized more than 700 acoustic tests in residential buildings since 2013. The Giner's technical team realized an investigation of Brazilian residential building acoustic performance evolution since the release of the ABNT NBR 15575:2021 [1–3], in 2013, until the last years using the database tests for acoustic measurements made with higher frequency: facades, vertical systems and floor acoustic insulation. The objective of this study is made a survey to analyze the evolution of Brazilian market construction companies in relation to construction systems acoustic performance.

2. THEORY OF PERFORMANCE STANDARD METHODOLOGIES

This section addresses the main definitions of the international standards cited by Brazilian standard performance ABNT NBR 15575:2021 [1–3]. These parameters below are used for rating the acoustic insulation performance of the construction systems as floors, vertical systems, and facades in residential buildings.

2.1. Weighted standardized level difference ($D_{nT,w}$)

Level differente (D) is the difference in the energy-average sound pressure levels between the source room (L_1) and receiver room (L_2). D is expressed in decibels and calculated using formula (1).

$$\mathrm{D} = L_1 - L_2. \tag{1}$$

The level difference is standardized to a value of the reverberation time (0,5 s) in the receiving room. D_{nT} is expressed in decibels and calculated using Formula (2).

$$D_{nT} = D + 10\lg\frac{T}{T_0} \tag{2}$$

where the D is the difference in the energy-average sound pressure levels between the source and receiver, T is the reverberation time in the receiver room and T_0 is the reference reverberation time (0,5 s for dwellings).

The weighted standardized level difference ($D_{nT,w}$) is the unique value of the standardized level difference obtained fitting the ISO 717-1 [2] reference curve. For 1/3 octave bands measurements, the ISO 717-1 [2] curve is fitted in 1 dB step concerning the measurement curve (D_{nT}) until obtained the biggest sum difference less than 32 dB between the curve frequency bands. The value of the fitting reference curve on 500 Hz is the $D_{nT,w}$.

2.2. Weighted standardized impact sound pressure level ($L'_{nT,w}$)

Standardized impact sound pressure level (L'_{nT}) is the energy-average impact sound pressure level standardized to a value of the reverberation time (0,5 s for dwellings) in the receiving room. L'_{nT} is expressed in decibels and calculated using Formula (3).

$$L'_{nT} = L_i - 10\lg\frac{T}{T_0}, \tag{3}$$

where the L_i is the energy-average impact sound pressure level obtained with a tapping machine in the source room, T is the reverberation time in the receiver room and T_0 is the reference reverberation time (for dwellings, 0,5 s).

The weighted standardized impact sound pressure level is the unique value of the standardized impact sound pressure level obtained fitting the ISO 717-2 [3] reference curve. For 1/3 octave bands measurements, the ISO 717-2 [3] curve is fitted in 1 dB concerning the measurement curve (L'_{nT}) until obtained the biggest sum difference less than 32 dB between the curve frequency bands. The value of the fitting reference curve on 500 Hz is the $L'_{nT,\mathbf{w}}$.

2.3. Weighted standardized level difference at 2 m in front of the facade ($D_{2m,nT,w}$)

The weighted standardized level difference at 2 m in front of the facade is the unique value obtained with the difference of the sound pressure level at 2 m in front of the facade and the sound pressure level in the receiving room. $D_{2m,nT}$ is expressed in decibels and calculated using Formula (4).

$$D_{2m,nT} = L_{1,2m} - L_2 + \left(10\ \lg\left(\frac{T}{T_0}\right)\right) \tag{4}$$

where the $L_{1,2m}$ is the average sound pressure level at 2 m in front of the façade including the reflecting effects from the facade, in decibels, L_2 is the average sound pressure level in the receiving room, in decibels, T is the reverberation time at receiving room, in seconds and T_0 is the reference reverberation time, in seconds; for dwellings given as 0,5 s.

The weighted standardized level difference at 2 m in front of the façade ($D_{2m,nT,w}$) is the unique value obtained fitting the ISO 717-1 [2] reference curve. For 1/3 octave bands measurements, the ISO 717-1 [2] curve is fitted in 1 dB concerning the measurement curve ($D_{2m,nT}$) until obtained the biggest sum difference less than 32 dB between the curve frequency bands. The value of the fitting reference curve on 500 Hz is the $D_{2m,nT,w}$.

3. PERFORMANCE STANDARD PARAMETERS AND RATING

This section addresses the ABNT NBR 15575:2021 [1–3] parameters and rating. The Brazilian performance standard classify the performance of floor airborne and impact sound insulation, intern vertical systems and facades sound insulation using the $L'_{nT,w}$, $D_{nT,w}$, and $D_{2m,nT,w}$ parameters respectively. The rating is done in Minimum, Intermediate and Higher what only the Minimum is required, and the others are optionally.

3.1. Vertical System noise insulation rating

The wall noise insulation rating is made using the weighted standardized level difference ($D_{nT,w}$) according to the part 4 of the ABNT NBR 15575:2021 [5] and can be seen in the Table 1.

Table 1: ABNT NBR 15575:2021 [5] vertical system noise insulation rating parameters.

Parameter	Vertical system	Performance		
		Minimum	Intermediate	Higher
Weighted standardized level difference ($D_{nT,w}$)	Vertical systems between the autonomous housing units, in situations where there is no bedroom environment	≤ 40 dB	≤ 45 dB	≤ 50 dB
	Vertical systems between the autonomous housing units, if at least one of the rooms is a bedroom	≤ 45 dB	≤ 50 dB	≤ 55 dB
	Bedroom blind Vertical systems between a housing unit and the common areas of occasional traffic	≤ 40 dB	≤ 45 dB	≤ 50 dB
	Blind Vertical systems between a housing unit and the common areas of occasional traffic, such as corridors	≤ 30 dB	≤ 35 dB	≤ 40 dB
	Blind Vertical systems between the bedroom or living room of a housing unit and the common areas where people stay, leisure activities and sports activities	≤ 45 dB	≤ 50 dB	≤ 55 dB
	Set of Vertical systems and doors of different units, separated by the Hall, in situations where there is no dorm environment.	≤ 40 dB	≤ 45 dB	≤ 50 dB

Set of walls and doors of different units, separated by the hall, if at least one of the environments be bedroom.	≤ 45 dB	≤ 50 dB	≤ 55 dB

3.2. Floor airborne insulation rating

The rating of the floor airborne insulation is made using the weighted standardized level difference ($D_{nT,w}$) according to the part 3 of the ABNT NBR 15575:2021 [4] and can be seen in the Table 2.

Table 2: ABNT NBR 15575:2021 [4] floor airborne insulation rating parameters.

Parameter	**Floor system**	**Performance**		
		Minimum	**Intermediate**	**Higher**
Weighted standardized level difference ($D_{nT,w}$)	Floor system between autonomous housing units, if at least one of the rooms is a bedroom	≥ 45 dB	≥ 50 dB	≥ 55 dB
	Floor system separating autonomous housing units from common areas of eventual transit	≥ 40 dB	≥ 45 dB	≥ 50 dB
	Floor system between autonomous housing units, in situations where there is no bedroom environment	≥ 40 dB	≥ 45 dB	≥ 50 dB
	Floor systems separating dormitories from autonomous housing units from common areas for collective use for leisure and sports activities	≥ 45 dB	≥ 50 dB	≥ 55 dB

3.3. Floor impact insulation rating

The rating of the floor impact insulation is made using the weighted standardized impact sound pressure level ($L'_{nT,w}$) according to the part 3 of the ABNT NBR 15575:2021 [4] and can be seen in the Table 3.

Table 3: ABNT NBR 15575:2021 [4] floor impact insulation rating parameters.

Parameter	**Floor system**	**Performance**		
		Minimum	**Intermediate**	**Higher**
Weighted standardized impact sound pressure level ($L'_{nT,w}$)	Floor system of autonomous housing units over bedroom	≤ 80 dB	≤ 65 dB	≤ 55 dB
	Floor system of areas of collective use over bedroom of autonomous housing units	≤ 55 dB	≤ 50 dB	≤ 45 dB

3.4. Facades noise insulation rating

The rating of the facade noise insulation is made using the Weighted standardized level difference at 2 meters in front of the facade ($D_{2m,nT,w}$) according to the part 4 of the ABNT NBR 15575:2021 [5]. The noise incident on the facades (L_{inc}) is simulated or calculated from sound pressure level representative of the day or night period according to the ABNT 10151:2019 [6] (Brazilian standard sound pressure level measurement inhabited areas). The rating of the facade noise insulation is doing in Noise class and Performance according to Table 4.

Table 4: ABNT NBR 15575:2021 [5] facade noise insulation rating parameters.

Parameter	**Noise class**	**Sound pressure level incident on façade (L_{inc})**	**Performance**		
			Minimum	**Intermediate**	**Higher**
Weighted standardized level difference at 2 m in front of the facade ($D_{2m,nT,w}$)	I	≤ 60 dB	≥ 20 dB	≥ 25 dB	≥ 30 dB
	II	61 to 65 dB	≥ 25 dB	≥ 30 dB	≥ 35 dB
	III	66 to 70 dB	≥ 30 dB	≥ 35 dB	≥ 40 dB

4. ACOUSTIC MEASUREMENTS DATABASE RESULTS

This section addresses the acoustic tests database results since the release of Brazilian acoustic standard performance ABNT NBR 15575:2021 [1–3] until the last years.

4.1. Number of acoustic measurements over the years

The number of total residential building acoustic performance measurements in 2013, year of the ABNT NBR 15575:2021 [1–3] standard performance release, was 6 acoustic tests. In 2021, year with the highest number of Giner's tests performed, that number was 182 acoustic tests, registering an increase of 2933%. The number of measurements over the years can be seen in Figure 1.

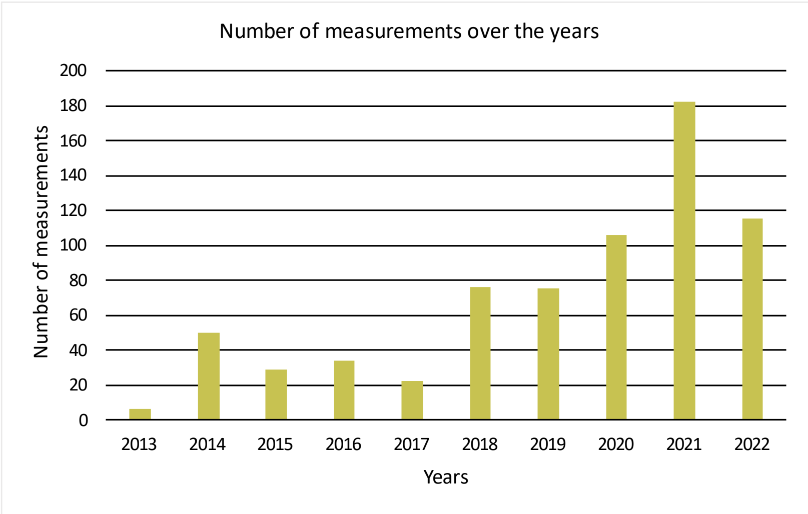

Figure 1: Number of performance acoustic measurements over the years.

These data show the construction companies increase interest in acoustic measurements for validation of the performance standard ratings.
Over the years, the number of different construction companies hiring acoustic test is increased. With the minimum exigences of the performance standard, very companies began to consider acoustic projects and acoustic performance measurements reports. We can see in Figure 2 the number of different construction companies over the year.

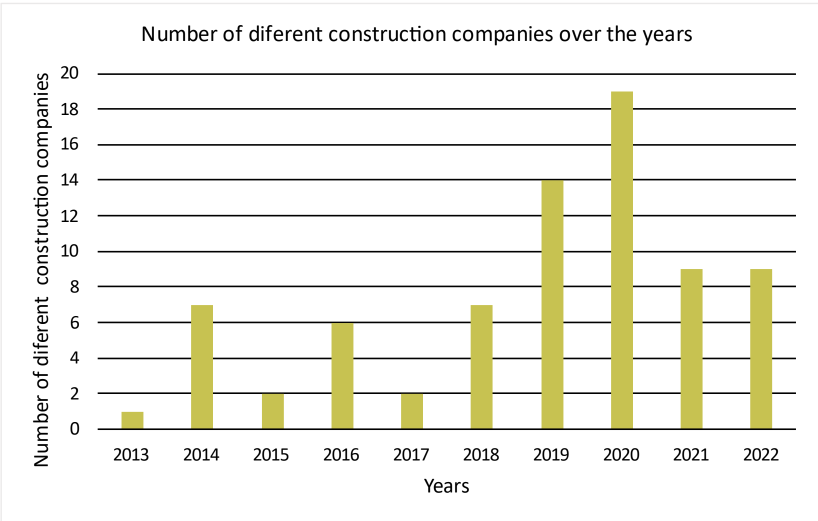

Figure 2: Number of different construction companies over the years.

To the first year after the standard performance release to last year, the number went from 1 to 7. Between the years 2018 and 2022 was the period with the biggest increase: the number of different companies went from 7 in 2018 to 19 in 2020.

4.2. Bedroom environments acoustic insulation measurements result over the years

Over the years, all the measurements result between the construction companies started too nearby. This highlights the acoustic quality performance standardization and the interest of companies in get the ratings of ABNT NBR 15575:2021 [1–3]. The bedroom is the most restrictive criteria and was the room analysed. Can be seen the results of vertical systems airborne sound insulation measurements over the years in bedrooms in Figure 3.

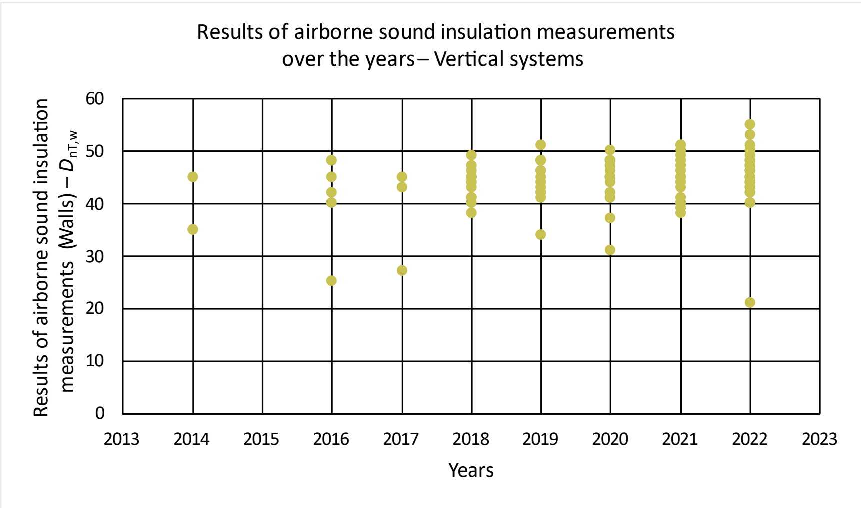

Figure 3: Result of bedroom vertical systems airborne sound insulation over the years.

We can see that the maximum results value for the vertical systems airborne sound insulation measurements are increased over the years.
For the facade sound insulation measurements, seen in Figure 4, happened the same that wall airborne insulation. The results between the construction companies started to nearby over the years.
The number of measurements is increased and the distance between the minimum and maximum results value decreased. The variation of minimum and maximum result value in 2020 is 21 dB. In 2022 this variation decreased to 10 dB.

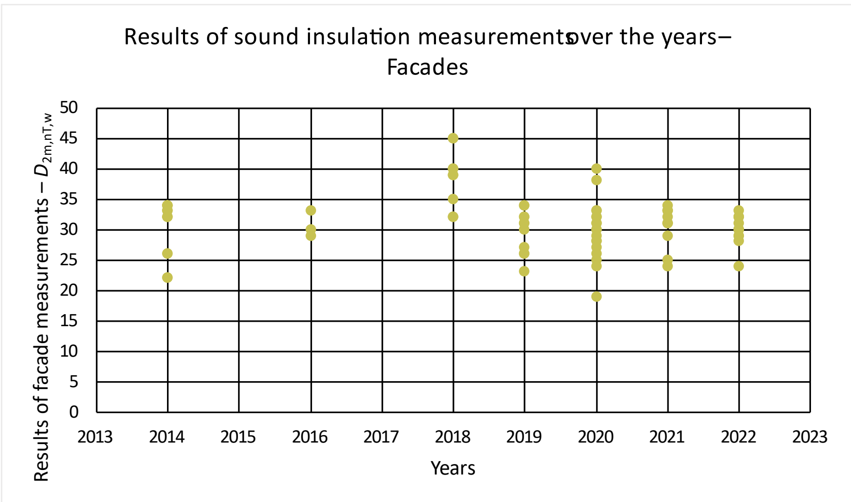

Figure 4: Result of bedroom facade sound insulation over the years.

We can see in Figure 5 the results for floor airborne sound insulation over the years. The results had a big increase between 2017 and 2021.

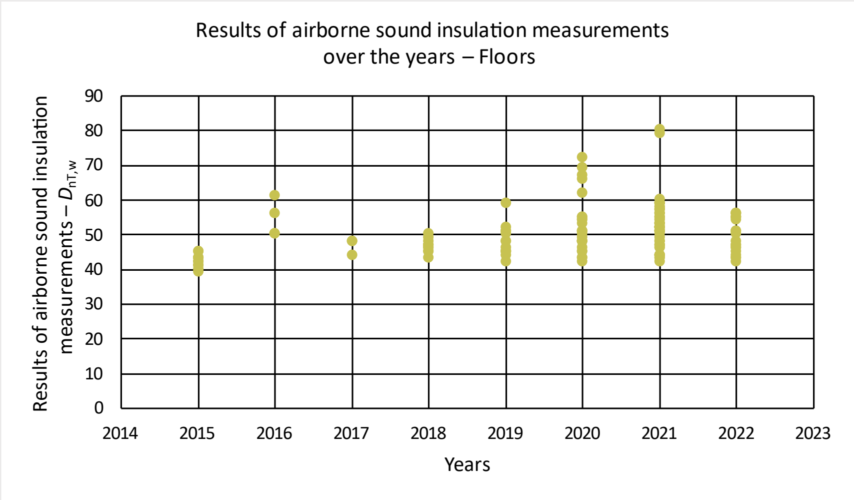

Figure 5: Result of floors airborne sound insulation measurements over the years.

In figure 6, we can see the results for impact sound insulation measurements over the years. Between each one measurement test analyzed, the impact insulation measurements were the ones that presented the most regularity in maximum and minimum values over the year. Also, were the ones that the biggest difference between the minimum and maximum sound insulation results value.

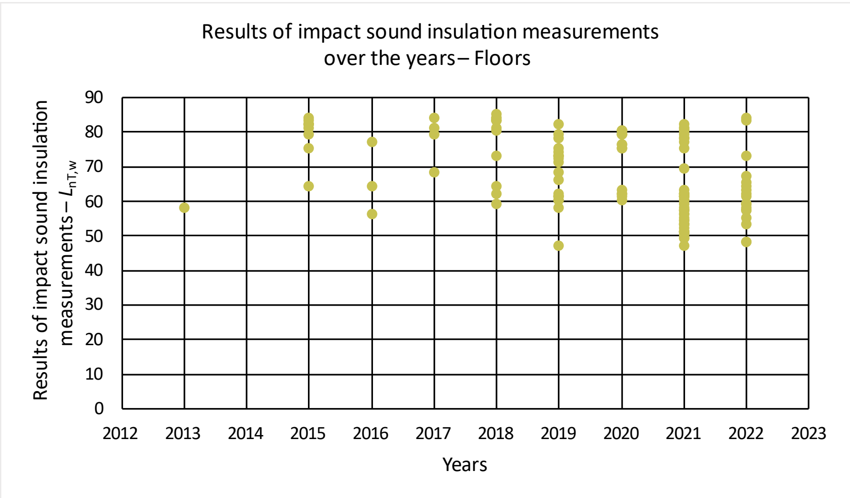

Figure 6: Result of bedroom floors impact sound insulation measurements over the years.

Seeing only bedroom results, we can see in Figure 7 that average results for each one measurement type is increased between 2014, one year after the standard performance release, and 2022.

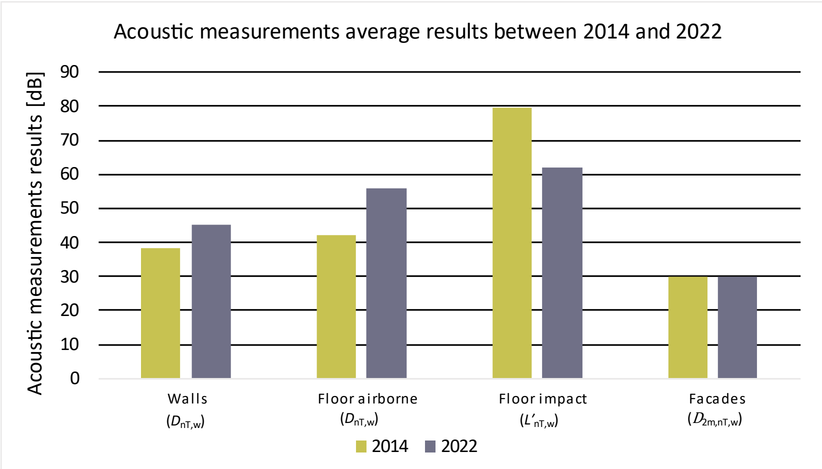

Figure 7: Bedroom environments acoustic measurements average results between 2014 and 2022.

For vertical systems acoustic insulation measurements, the average results increase 18%, result in 7,0 dB increase. For floor airborne, the results increase 33%, result in 13,8 dB increase. Facades average results increase only 1%, it is the smaller result increase, with 0,2 dB. Floor impact insulation average results increase 22%, getting the biggest increase with 17,6 dB. Remembering that the floor impact insulation results is opposite to the others. How biggest value in dB, less performance and how smaller result, big performance.

5. FINAL COMMENTS AND CONCLUSIONS

This study presented a analyze about the acoustic performance database construct since the release of Brazilian performance standard ABNT NBR 15575:2021 [1–3]. More than 700 measurements were performed by Giner in 10 years. Since the release of the standard, the acoustic measurements result for the more frequency acoustic tests (vertical systems, floors and facades) are increased, showing the evolution of system construction acoustic performance. The results show an improvement in Brazilian civil construction quality after the release of the standard performance and highlight its importance. The ABNT NBR 15575:2021 [1–3] to bring the interest of the construction companies in follow the requirements of civil construction performance, especially acoustic requirements. This increased the number of acoustic projects, measurements and reports and the comfort of the new residential buildings.

ACKNOWLEDGEMENTS

We wish to thank the staff at Giner and as well as all those who took part in this study, either directly or otherwise, during the performance of acoustic measurements.

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