THE EFFECT OF PURPORTED ACOUSTICALLY TRANSPARENT MATERIALS ON SOUND PROPAGATION

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1 INTRODUCTION

Banners in an outdoor venue are used for advertising and spreading information to the participants of the event. These banners are also used to conceal certain areas or equipment from event attendees. This includes production areas, power generators, roads, and PA systems. Banners are used to cover loudspeakers to help stages be more cosmically appealing. Ideally such banners are acoustically transparent, meaning that the material lets sound transmit without any losses. In all events, sound engineers spend significant effort to keep the stage area as quiet as “reasonably practicable” for performers and to achieve democracy of sound for the audience, “which means there is consistent tonality across all audience areas” (Hill, 2021). The introduction of non-transparent material in the form of banners directly in front of a sound system has the potential to negatively impact these goals. This paper details an investigation into various purported acoustic materials or devices in order to determine their effect on sound propagation from a typical sound reinforcement system.

2 BACKGROUND

In cinemas, loudspeakers are placed behind the screen (Garcia, 2013). The issue with placing a speaker directly behind a standard projection screen is that there will be sound loss (Rodgers, 2017). The solution to this problem was introduced in the 1990s, when cinema surround sound became digital and there were great changes to cinema sound systems (Grainger, 2021). Acoustically transparent screens were introduced so that the screen does not compromise the sound propagation in any way (Rodgers, 2017). Ideally, this means that the sound can go through the material with no sound energy loss. Garcia (2013) states that these screens are not entirely acoustically transparent in terms of sound transmission as manufacturers often provide limited information regarding the characteristics of sound transmission through their screens.

Imaginators (2023), a recognised large format digital print production company, states that the PA scrims play a vital role in branding a music festival stage and attracts significant attention during live television broadcasts. These PA scrims should not impact sound energy but at the same time should allow stage branding (Stage Branding, 2023). Additionally, these PA scrims “are a valuable marketing tool and provide a memorable, eye-catching experience when combined with stage backdrops and stage headers” (Stage Branding, 2023). There is limited data, however, to support the suggestion that all such material is acoustically-transparent.

Due to the limited availability of acoustically transparent LED walls, there is a lack of research conducted specifically on these screens. Consequently, in the absence of direct studies on acoustically transparent LED walls, it was hypothesized that the behaviour of such an LED wall, which is a perforated screen as depicted in Figure 1, resembles that of a cinema screen.

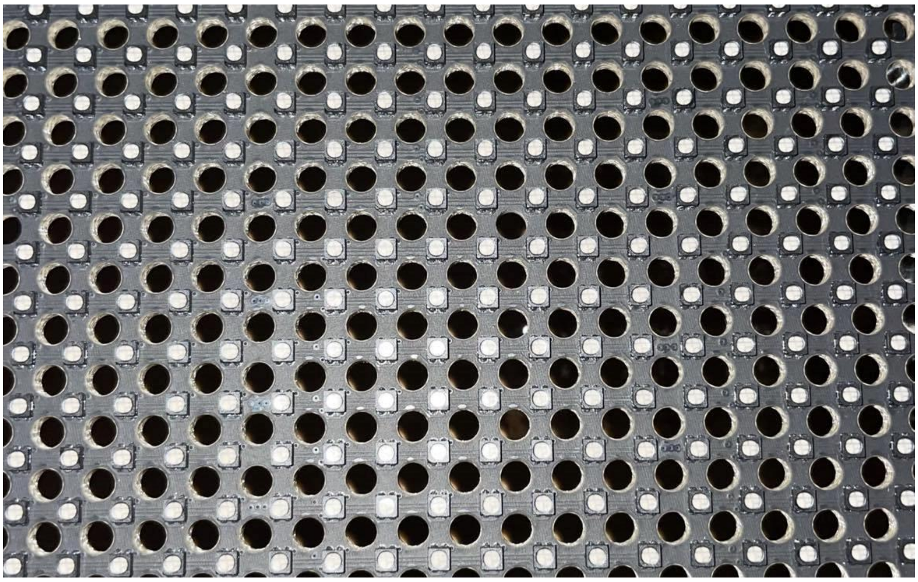

Figure 1 Acoustically Transparent LED Screen (Szoke, 2023)

Rettinger (1982) discusses the high-frequency attenuation of sound waves passing through perforated motion picture screens. The study found that smaller-diameter circular holes result in fewer high-frequency losses compared to larger-diameter holes, but there is a limit to this effect when the diameter of the hole is equal to or smaller than the thickness of the screen. The paper serves as a starting point for further investigation by screen and loudspeaker manufacturers.

Further, Chen depicted that when comparing perforated panels made from different materials, it is observed that they have similar levels of transmission loss when they have the same thickness, radius, and percentage of perforation. This means that it does not matter what material the surface is, the key factors are the radius, thickness and perforation of the material (Chen & Jan, 2001). Moreover, as the diameter of the holes increase, there is a decrease in the attenuation of the high frequencies (Acoustical Transmission Report, 2008). This characteristic implies that perforated screens have a low-pass filter behaviour overall (White & Bolser, 2017). This is also supported by Rettinger (1982), he states that when the diameter and the distance between the holes stay constant, but the frequency is increased the transmission loss for normal incidence increases. Lastly, according to Garcia (2013) comb filtering was observed across all frequencies and at various distances between the speaker and the screen. Comb filtering arises when sound waves interact in a coherent manner within a short time frame.

3 METHODOLOGY

Experiments were conducted in a hemi-anechoic chamber. To obtain precise and relevant measurements, it was important to consider the variables involved. Through discussions with a sound engineer who regularly works with speakers behind video walls the following was determined:

- The distance between speakers and an acoustically transparent LED wall is typically 1 meter.
- Speaker cabinet angles vary from on-axis to the material to a maximum of 50° off-axis. In a recent project, the angle of the last speaker cabinet in an array did not exceed 34°, as shown in Figure 2.

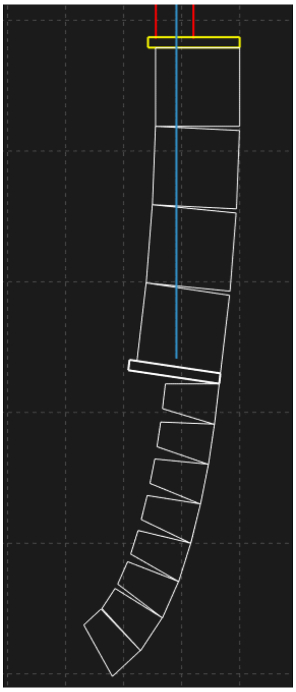

Figure 2 Example loudspeaker array for placement behind an LED wall (Bland, 2023)

To observe variations among these variables, the dependent variables considered are frequency and sound pressure level (SPL). Testing was completed in one session to minimize any temperature or humidity changes.

To test the effects of these materials, two microphones were required. One placed behind the material and one in front. The microphone behind the material was labelled ‘Mic A’ and the microphone in front of the material was labelled ‘Mic B’. Mic A was placed on the same side as the sound source. The purpose of Mic A is to measure the initial sound source’s signal as well as any reflections from the materials. The purpose of Mic B is to measure the sound source signal after passing through the surface. This setup was done so that the effect of the wall on sound can be clearly demonstrated. The distance of the microphones between the material was fixed at 0.5 m, resulting in a total of 1.0 m between the microphones.

The following scenarios were tested:

1. Mic A without the material vs. Mic A with the material
2. Mic B without the material vs. Mic B with the material
3. Mic A with material vs Mic B with material

Firstly, to see the difference these materials make, the response of the microphones were captured before any materials were introduced into the room (Figure 3).

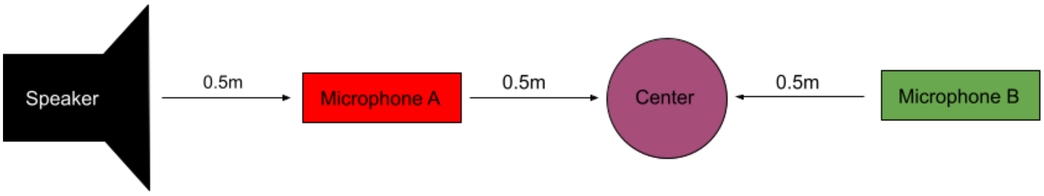

Figure 3 System diagram for testing without material

The first test was carried out with the LED wall. The wall was suspended in the centre of the chamber, where the microphones were positioned in line with the centre of the LED wall. The LED wall height was 0.96 m, therefore the microphones were placed at a height of 0.48m (Figures 4 and 5).

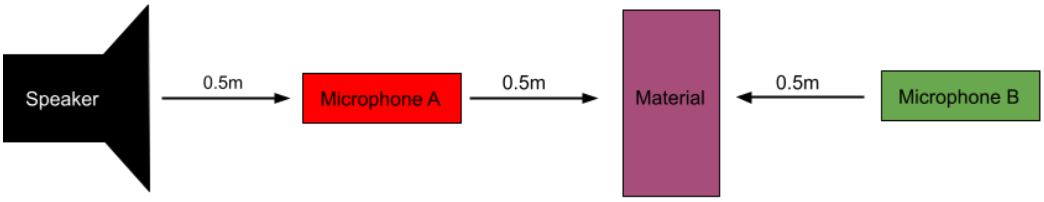

Figure 4 System diagram for testing with materials

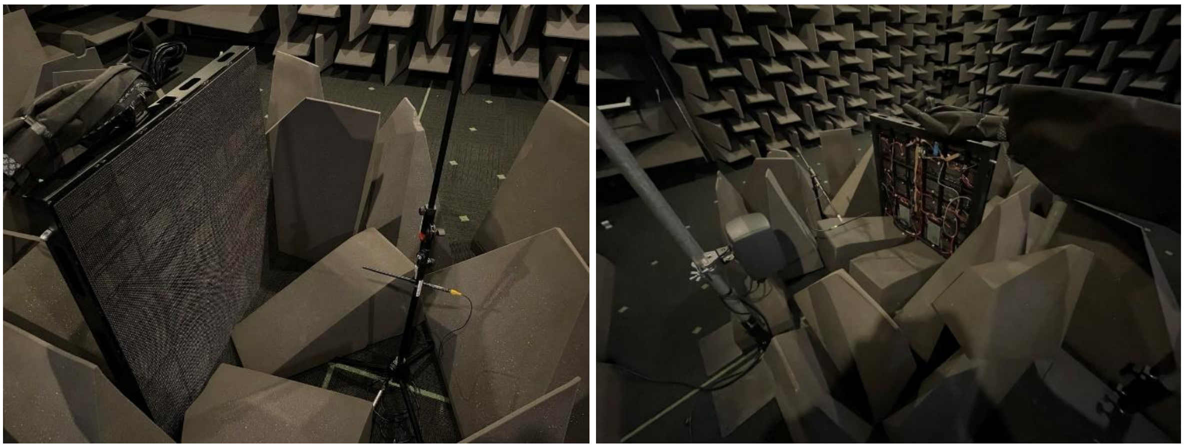

Figure 5 System setup for testing with LED wall front (left) and rear (right)

The effect of changing the angle of incidence of the loudspeaker was also inspected (Figure 6). The angles were measured using the chamber's labelled floor. An example of 50° is shown below.

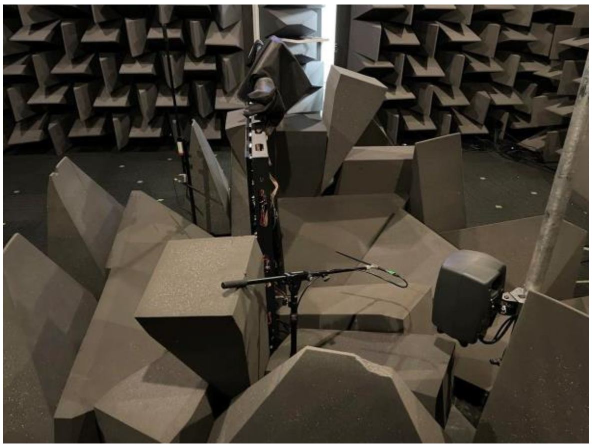

Figure 6 System setup for testing with LED wall with a 50° loudspeaker angle of incidence

To conduct the tests, Audiomatica's CLIO 10 was utilized, which serves as a comprehensive audio and electro-acoustic measurement tool designed for laboratory, on-field, and production quality control applications (CLIO, 2023). One of its key features is the ability to perform logarithmic chirp measurements. This measurement method has been widely used to assess the direct and harmonic responses of audio systems (Electronics Weekly, 2020).

The results of the measurements were presented in the form of magnitude response graphs, depicting the relationship between frequency (on a logarithmic scale) and sound pressure level. Additionally, CLIO captured impulse responses, which show the relationship between time and sound pressure. To ensure accuracy and minimize errors, eight log chirp sequences recorded and averaged. Moreover, to prevent the microphones from clipping, the signal level from the speaker was reduced to 0.2 V (output from CLIO).

There are limitations associated with using the hemi-anechoic chamber for testing. One of these limitations is the presence of room reflections due to the untreated floor. To address this limitation, acoustic foam was placed around the materials and microphones to minimize reflections. Figure 6 provides a visual representation of this setup. This limitation mainly affects low-frequency sounds. To address this, trends will be analysed between measurements to gain insight into the material's influence on the measurements.

Furthermore, since materials were suspended using a scaffolding pole, an acoustic material was wrapped around it to minimize reflections. Like the previous limitation, the use of cardboard within the chamber introduces additional reflections. To address this issue, a significant amount of absorption foam was placed near the cardboard and throughout the chamber. By enhancing the acoustic treatment of the room with additional foam, these limitations may persist, but with a reduced impact.

4 RESULTS

4.1 Loudspeaker on-axis to the LED wall

A comparison was made between measurements with the LED wall and the measurements conducted without any materials in the room (Figure 7). When evaluating the magnitude response of Mic A, it was found that the presence of the LED wall resulted in a generally similar response. However, there was a notable increase in comb filtering. This was as expected, based on the background research presented earlier in this paper. Comb filtering is more prominently illustrated in Figure 8, which shows the transfer function resulting from the introduction of the LED wall into the experimental setup, as measured by Mic A (in between the wall and the loudspeaker).

Upon examining Mic B (in front of the wall), a significant difference in the magnitude response is observed (Figure 9). As anticipated based on previous research, the perforated screen behaves as a low pass filter. From the transfer function, it becomes evident that the low pass filtering effect commences at approximately 1 kHz (Figure 10). When examining the impulse response of both microphones, significant differences are observed due to the presence of the LED wall (Figure 11).

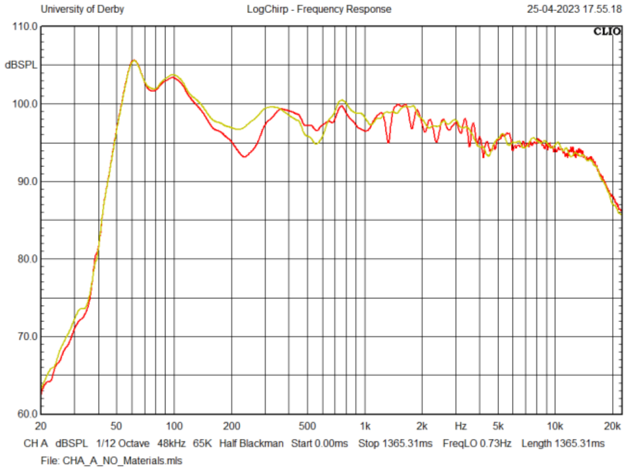

Figure 7 Magnitude response of Mic A with wall (red) vs Mic A without wall (yellow)

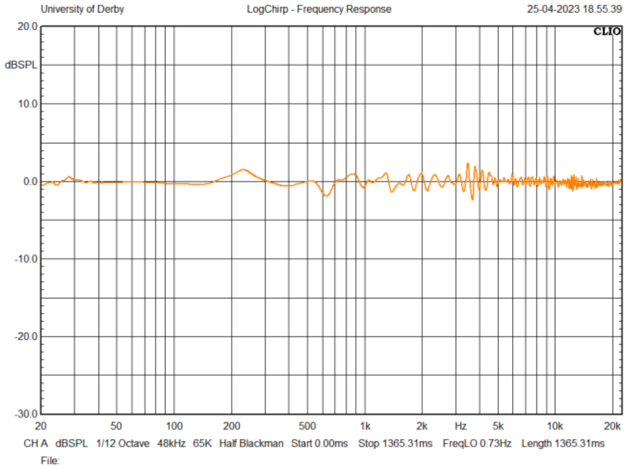

Figure 8 Transfer function due to the introduction of the wall, as measured by Mic A (in between the wall and the loudspeaker)

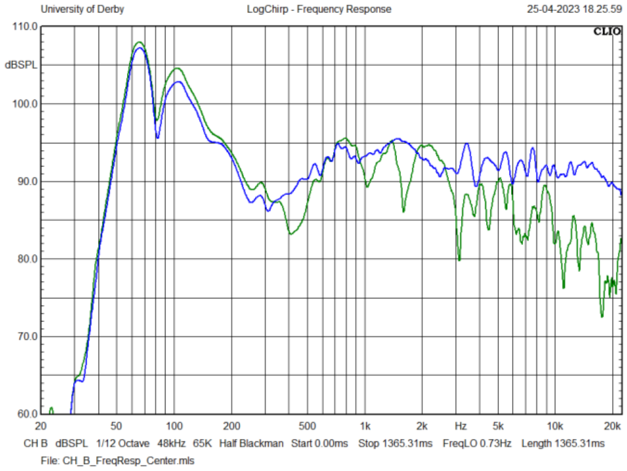

Figure 9 Magnitude response of Mic B with wall (blue) vs Mic B without wall (green)

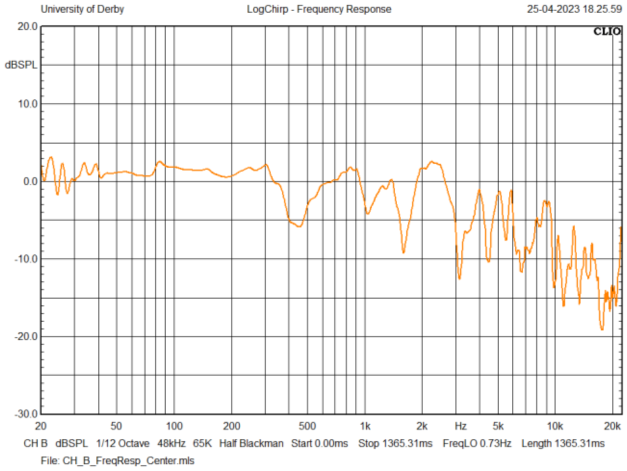

Figure 10 Transfer function due to the introduction of the wall, as measured by Mic B (in front of the the wall)

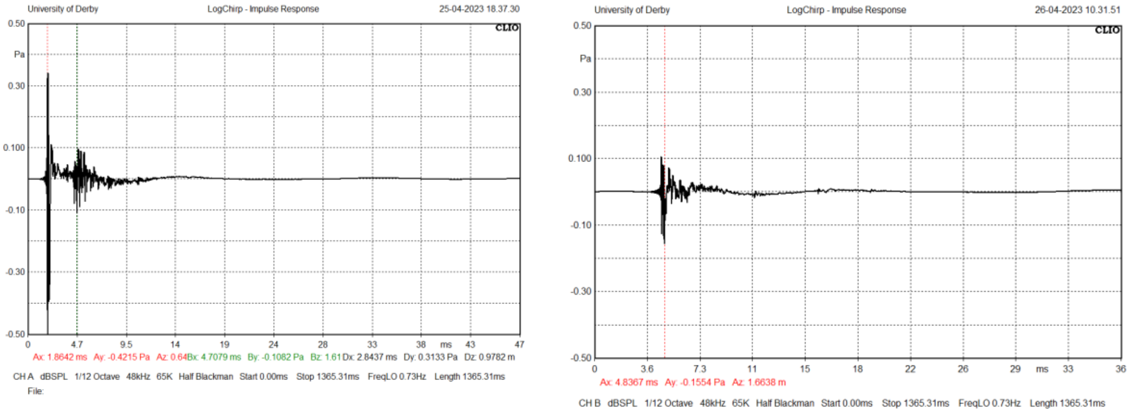

Figure 11 Impulse response of Mic A (right) and Mic B (left) with LED wall

4.2 Loudspeaker off-axis to the LED wall

When the loudspeaker's angle of incidence was altered, only minor differences were observed (Figure 12). It is evident that the trend remains consistent across all angles. Consequently, the angle of incidence appears to have minimal impact on the magnitude response of the sound. Upon examining the impulse responses across various angles, the only notable distinction observed is that the reflected sound pressure remains consistent regardless of the angle. This outcome does not align with the expected behaviour of a reflective surface. However, it makes more sense when considering that the LED wall functions as a diffuser.

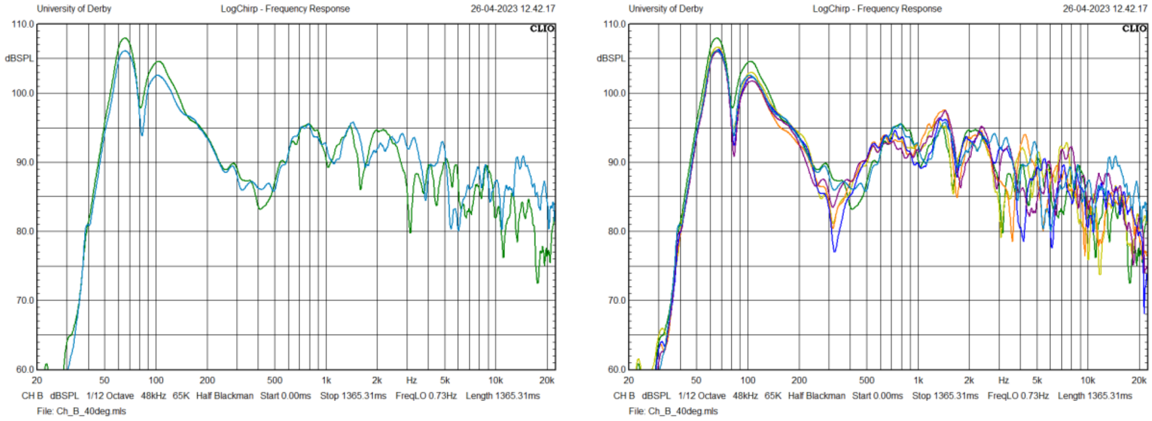

Figure 12 Mic B on-axis (left, blue) and at 50° (left, green) and measurements across all inspected angles of incidence (right) of 0 - 50° in 10° steps

4.2.1 Loudspeaker on-axis to acoustic scrim

To assess the LED wall's effect on sound propagation in comparison to an industry-standard acoustic scrim, a second test was conducted using acoustic scrim (Figure 13). The test procedure matched that of the LED wall tests. The acoustic scrim was mounted on a wooden frame and positioned in the center of the chamber.

When comparing the reflected signal level from the LED wall to that of the acoustic scrim, the former registers at 74 dB, whereas the latter measures 70 dB. However, a key distinction between the two lies in the duration and decay rate of the reflections. The reflection from the LED wall exhibits a longer duration and dissipates more slowly compared to the reflection caused by the scrim indicating that the scrim does not behave as a diffuser like the LED wall (Figure 14). The primary distinction between these materials becomes evident in the sound pressure level observed at Mic B. As Mic A experiences increased reflection, there is a corresponding loss of sound pressure at Mic B.

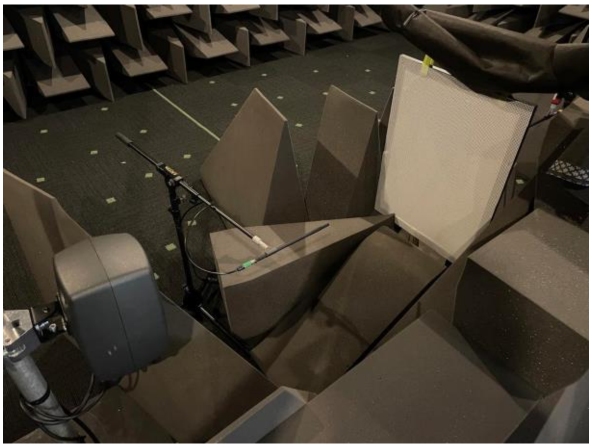

Figure 13 Setup of acoustic scrim tests

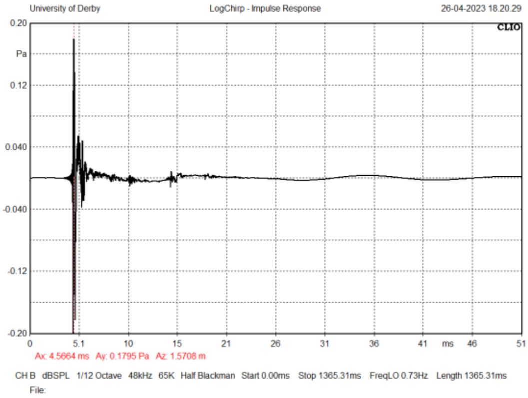

Figure 14 Impulse response of Mic B with acoustic scrim

5 CONCLUSIONS

The findings suggest that LED wall do not actually behave as acoustically transparent structures; they act more like diffusers with a low-pass filter. LED walls will create problems with reflection and noise behind a loudspeaker array. This is problematic because the intention is to project sound towards the audience, not backwards towards the stage. Moreover, sound engineers must compensate for high-frequency losses by amplifying those frequencies, which in turn amplifies the reflections and causes more noise pollution. The insights gained from this research hold value for manufacturers seeking to enhance the acoustic properties of LED walls and sound engineers interested in optimizing sound systems that are required to sit behind such materials.

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