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The hologram application effect on the interior design of concert halls and the sound system

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Abstract: Holograms are an emerging technology increasingly utilized in musical concerts and shows. This technological advancement is becoming prevalent and is expected to play a significant role in the future of live performances. Incorporating a hologram into a concert involves projecting a three-dimensional virtual avatar onto the stage, synchronized with pre-recorded music. This can impact both the sound quality and the architectural design of the concert venue. As a result, the design process may need to be altered or optimized to accommodate evolving technology. As Concert halls have specific design principles to achieve optimal sound quality without relying on complex artificial sound systems, this paper explores the interior design process of concert halls before and after the implementation of hologram technology. This paper also will discuss the problem of applying the hologram technology and its negative effect on the sound quality as its mechanism of setting causes sound distortion. A comparative analysis based on decibel level measurements in both cases before and after applying the hologram technology, highlights the advantages and disadvantages of integrating holograms in concert halls. Lastly, the paper presents recommendations on optimizing concert hall designs to incorporate this technology while maintaining sound quality.

1. Introduction

Concert halls have specific design principles to achieve optimal sound quality without relying on complex artificial sound systems. Traditional concert halls are designed as natural sound equalizers, distributing sound waves equally between the audience and musicians. This balance is achieved through precise interior design, including ideal dimensions, materials, and spatial arrangements. However, the emergence of hologram technology in concerts has significantly altered these design principles to accommodate the necessary equipment and installations. This paper explains the traditional interior design of concert halls, covering hall dimensions, stage configurations, and orchestra seating arrangements. It then explores the technical aspects of hologram devices, their installation process, and modifications required for stage dimensions and musician placement. A

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comparative analysis between decibel levels, sound clarity and reflection follow, depending on 3D simulation for (Coachella concert hall) using (ORASE acoustic simulation software) to highlight the impact on sound quality and overall performance experience. Finally, there will be a conclusion that approves the big defect in sound quality caused by using the hologram device and applying the stage modifications and a list of recommendations.

2. Hologram definition

The term "hologram" was introduced by Dennis Gabor in 1949, a Hungarian British electrical engineer and physicist, who later won the Nobel Prize in Physics in 1971 for his pioneering work on holography (Gabor, 1949). The word "hologram" combines two Greek words: "holos," meaning "whole," and "gramma," meaning "message," signifying a complete image or message. Holograms create three-dimensional images, often requiring a body double filmed in front of a green screen (Figure 1). The footage is then digitally enhanced using motion-capture data. While small-scale holograms, such as those on credit cards, serve security purposes, large-scale holograms in entertainment provide lifelike, dynamic projections [7]. Although the concept of holography was first proposed in 1947, it became fully developed after the invention of the laser in 1960 [2]. Today, holographic technology is used in fields ranging from entertainment to medical imaging.

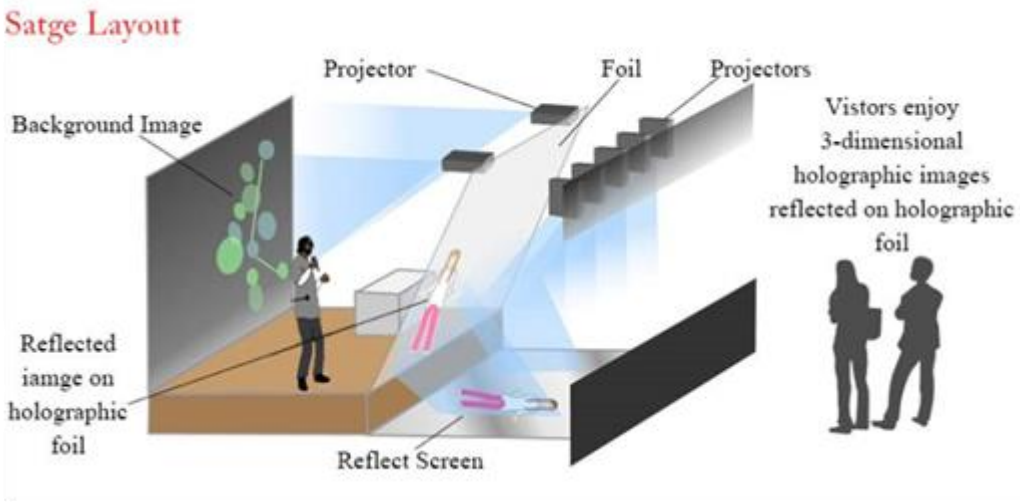


Fig. (1) Hologram mechanism. [6]

The figure shows how the mechanism of the hologram works on stage to create an avatar for the performer. Not every video can be transformed into a convincing hologram. Although archival footage can serve as a reference for creating digital performers, it usually isn't ideal for directly converting into a hologram, and the limitations go beyond just resolution issues [4]. To create an effective holographic display, the person or object must be filmed against a blank backdrop to prevent any background elements from being projected along with the subject. Additionally, the lighting in the original footage must be carefully matched to the live stage lighting to preserve the illusion.

2.1. How does the hologram work?

Hologram projection involves the interference of light waves. The process begins by splitting a laser beam into two parts using a half-mirror—a semi-silvered glass surface that reflects half of the light while allowing the rest to pass through [5]. One part of the beam, called the **object beam**, is reflected off a mirror and then onto the object, where it captures the object's shape. The other part, called the **reference beam**, is directed onto a photographic plate without interacting with the object (Figure 2). When these two beams recombine on the photographic plate, the resulting interference pattern records the object's three-dimensional image [6].

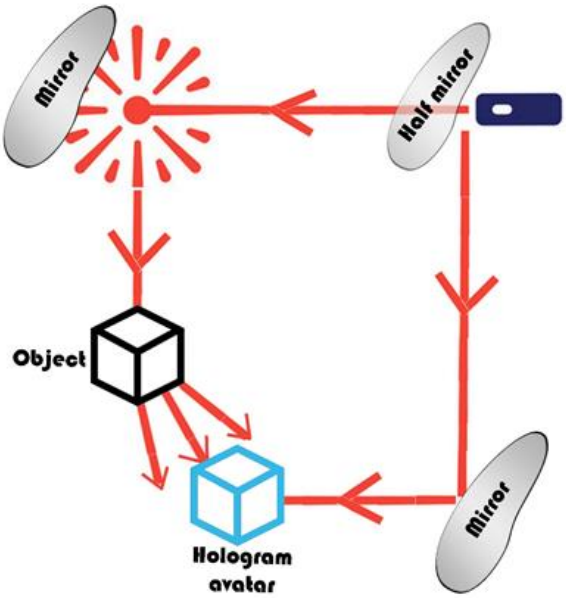


Fig. (2) Diagram showing how the hologram works.

Laser light is more coherent than conventional light, meaning its waves move in synchronization. This property is crucial in forming sharp, high-resolution holographic images [9]. Additionally, breaking a hologram into smaller fragments does not erase the full image—each piece still contains the entire visual representation, a phenomenon attributed to the principles of Fourier optics [3]. Slightly different path and been altered by reflecting off the object's surface, interacts with the reference beam (Figure 3). Because the beams were originally in perfect sync, their recombination reveals how the object beam's light has been modified compared to the reference beam. This comparison shows how the object affects the light that strikes it, essentially capturing its appearance. This information is permanently etched into the photographic plate by the laser beams, making the hologram a lasting record of how the object looks from any angle.

Every point on a hologram captures light waves from every part of the object. This means that from any angle you view the hologram, you see how light would have travelled to that point if you were looking at the actual object. As you move your head, the holographic image shifts in a way that mimics how a real object's image would change, giving the illusion of three dimensions. Additionally, if you break a hologram into small pieces, each piece still displays the entire object (Figure 4). For example, if you shatter a glass hologram

of a cup, you can still see the whole cup in each fragment. This phenomenon, where each fragment contains the full image, is explained in more detail by hyper physics [6].

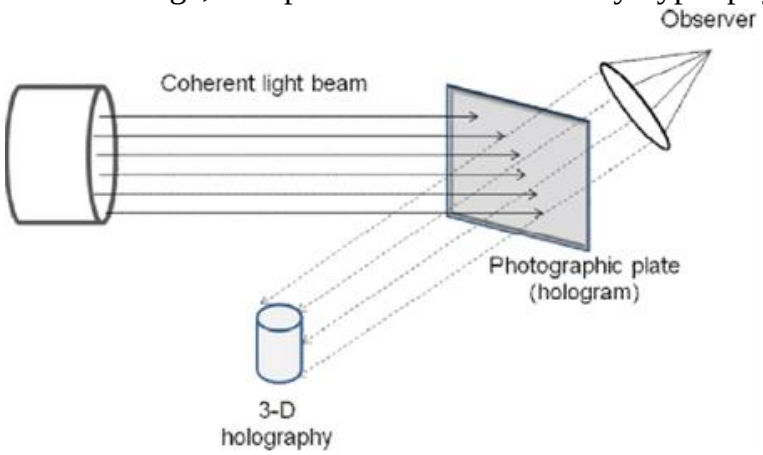


Fig. (3) The hologram beam reflection. [6]

2.2. Key Components of a Hologram Projector

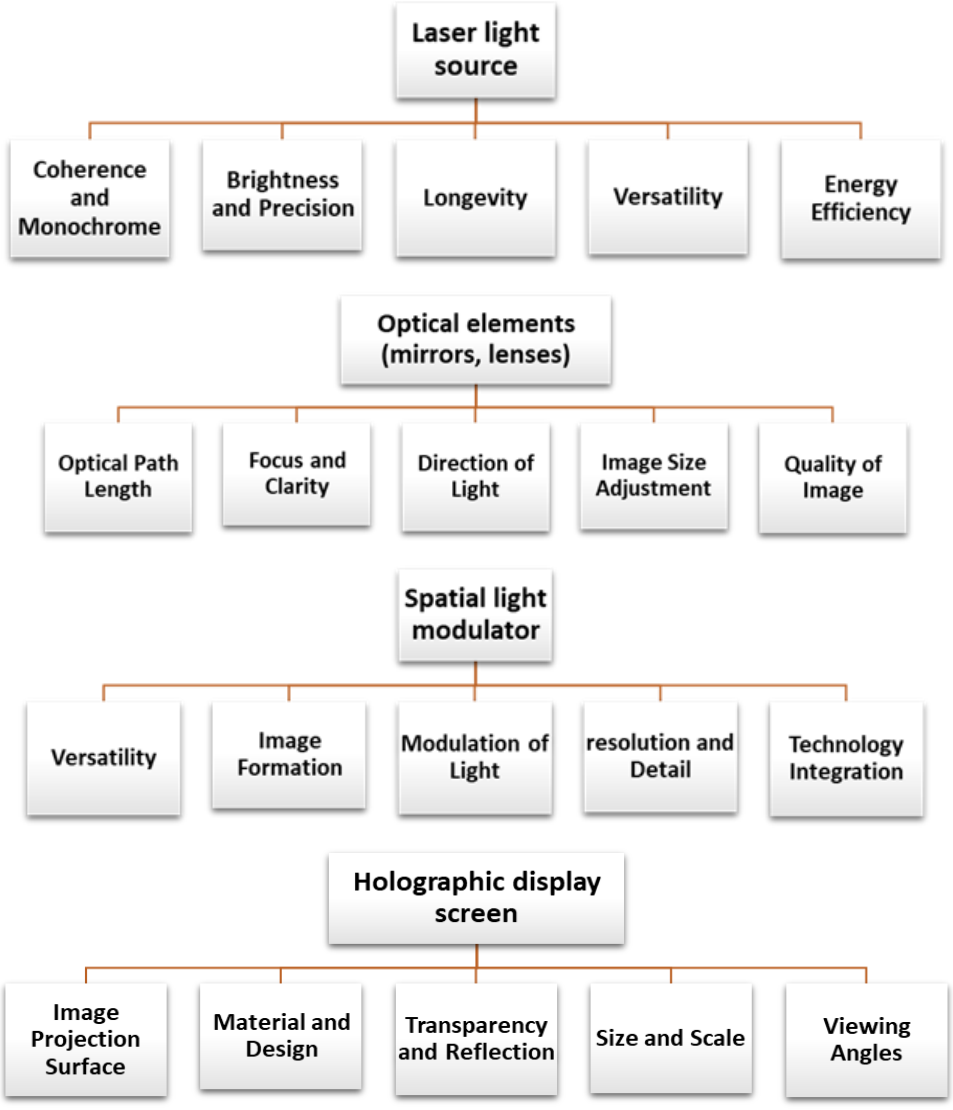


Fig. (4) Key Components of a Hologram Projector

3. Interior design of stage in concert halls

Traditional concert hall stages are meticulously designed to enhance acoustics, visuals, and audience engagement. Key elements include:

3.1. Acoustic Considerations

- **Stage Materials**: Hard surfaces like wood and fabric panels ensure optimal sound reflection and absorption.
- **Orchestra Pit and Shells**: Designed to project sound towards the audience.
- **Reflectors and Baffles**: Help distribute sound evenly throughout the hall [1].

3.2. Stage Shape and Configuration

- **Traditional Shapes**: Rectangular or fan-shaped stages optimize sound projection.
- **Risers and Platforms**: Elevate specific instruments to balance sound levels.
- **Adjustable Layouts**: Allow flexible configurations for various performances.

The seating arrangement of an orchestra plays a crucial role in natural sound amplification, ensuring musicians hear one another without electronic assistance [8].

Fig. (5) Sound waves in two different concert halls.

The two diagrams visually show the ideal sound distribution among the orchestra seats without using the hologram in two types (on the left chamber music concert hall and on the right symphonic music concert hall). In figure 6 we can see the orchestra position and seating around the whole stage in two different cases of orchestra types and hall types. We can see visually from the blue arrows the effect of the surrounding music due to the sound distribution around the different instruments playing side by side (Figure 5). Beside that the interior design of the stage helps in sound amplification that helps the players themselves to hear their music well without applying complicated sound systems [16].

Fig. (6) Seat distribution in concert halls. [14].

The two figures show different cases for the ideal seat distribution on the stage to reach the perfect sound distribution in the normal case without applying the settings of the hologram device.

Fig. (7) Diagram shows the seat location on stage [13].

Figures 6, 7 show the ideal distribution of the seats on stage which helps the interior design to distribute the sound around the stage and among the audience, so that the concert hall can act like a natural equalizer.

4. Applying Hologram technology in concert halls

Hologram technology has the potential to bring a sense of magic to concert halls. Here are some ways it could be applied:

- **3D light shows:** Animated 3D visuals can be created for musicians or music-related themes, crafting an immersive atmosphere
- **Audience interaction:** Apps could allow audiences to interact with holograms, such as voting for songs or participating in parts of the performance.
- **Virtual live experience:** Musicians unable to attend in person could perform as holograms, offering a virtual live experience to the audience.
- **Dynamic backgrounds:** Holograms can generate dynamic, evolving backgrounds that shift in sync with the music, enhancing the audio-visual effect.
- **Visual storytelling:** Holograms could be used to tell stories that accompany the music, adding a new dimension to the performance.

Figure 8 explains the mechanism used to hold a musical concert featuring a hologram alongside live musical instruments involves a complex blend of advanced technology, precise synchronization, and live performance elements [10].

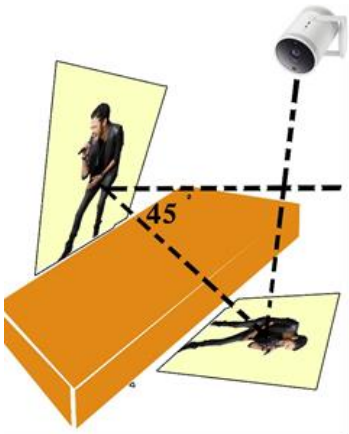


Fig. (8) Reflection angle of hologram

The diagrams shows the mechanism used to apply the hologram technology during a concert.

4.1. It also needs a special Stage Setup like:

- **Projection Surfaces and Screens:** Special transparent projection screens or reflective glass surfaces are positioned on stage. These surfaces are angled to allow the hologram to be visible to the audience without being too noticeable themselves [12]. The image of the hologram is projected onto these screens using high-definition projectors, creating the illusion that the hologram is standing or moving on stage alongside the live musicians.
- **Lighting and Visual Effects:** Proper lighting is essential to blend the hologram with the live performers. Lighting must be carefully controlled to avoid creating shadows or distortions on the hologram. Special lighting effects are often used to highlight the hologram and enhance its presence on stage without overshadowing the live performers [11].

Fig. (9) Interruption in spatial sound balance.

The diagrams show the effect of applying the hologram technology in different concerts on the sound wave spread around the stage and musicians.

Figure 9 shows two different musical concerts held on different stages using the hologram techniques for departed singers. It's very obvious that the orchestra seat's location is very different, we can see that there is no surrounding sound like the original case of the stage that we discussed before.

That can create a very strong barrier between music players on stage which in turn can cause a very strong interruption in spatial sound balance in sound distribution surrounding the stage. So, we can easily notice that the stage had lost its architectural function in equalizing and distributing the sound surrounding the players and forward to the audience. To support the research paper's objective and demonstrate the difference in sound quality in concert halls before and after installing the hologram device, a 3D simulation was conducted for the sound quality in the (Coachella concert hall) using ORASE software acoustic simulation.

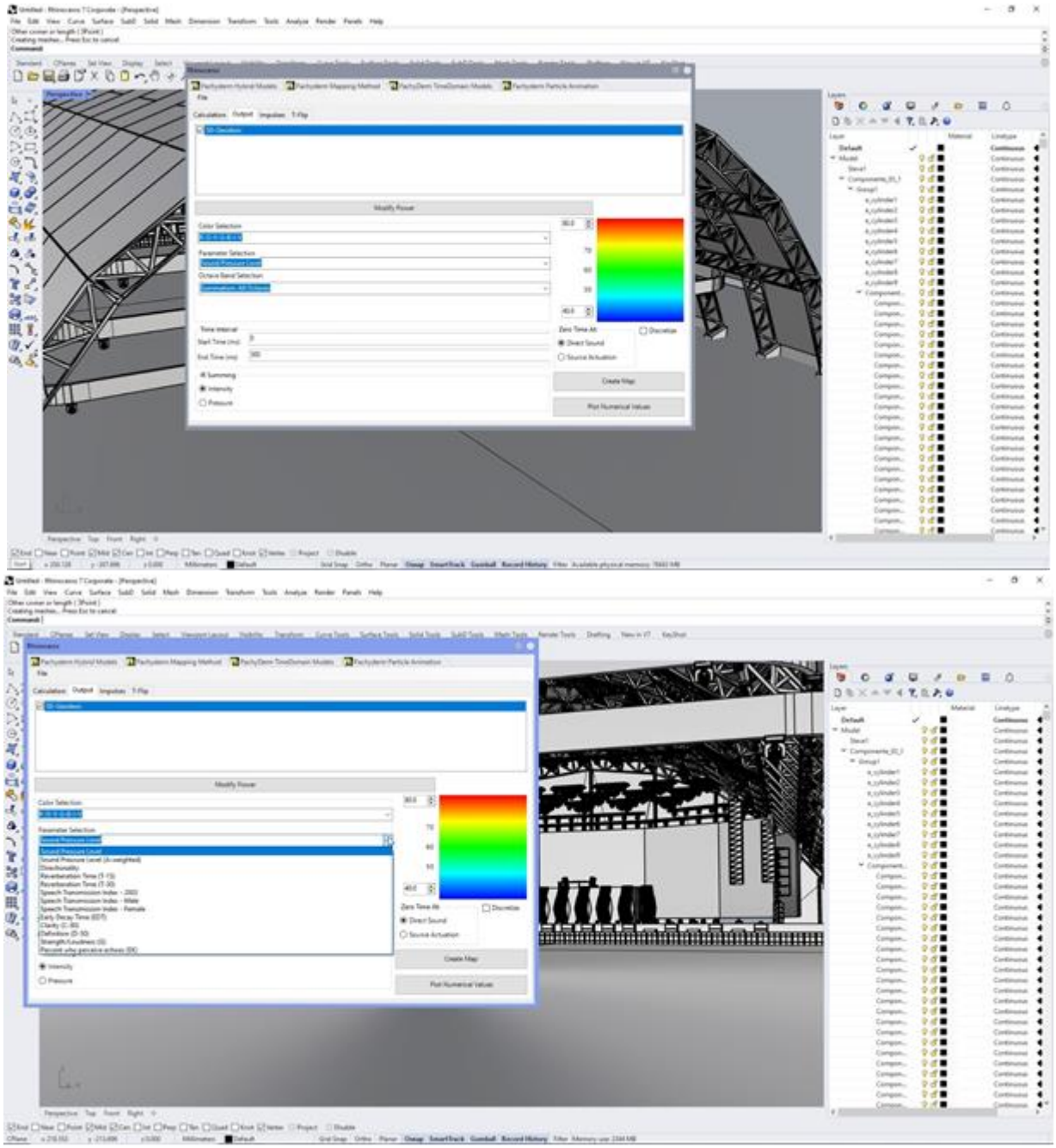


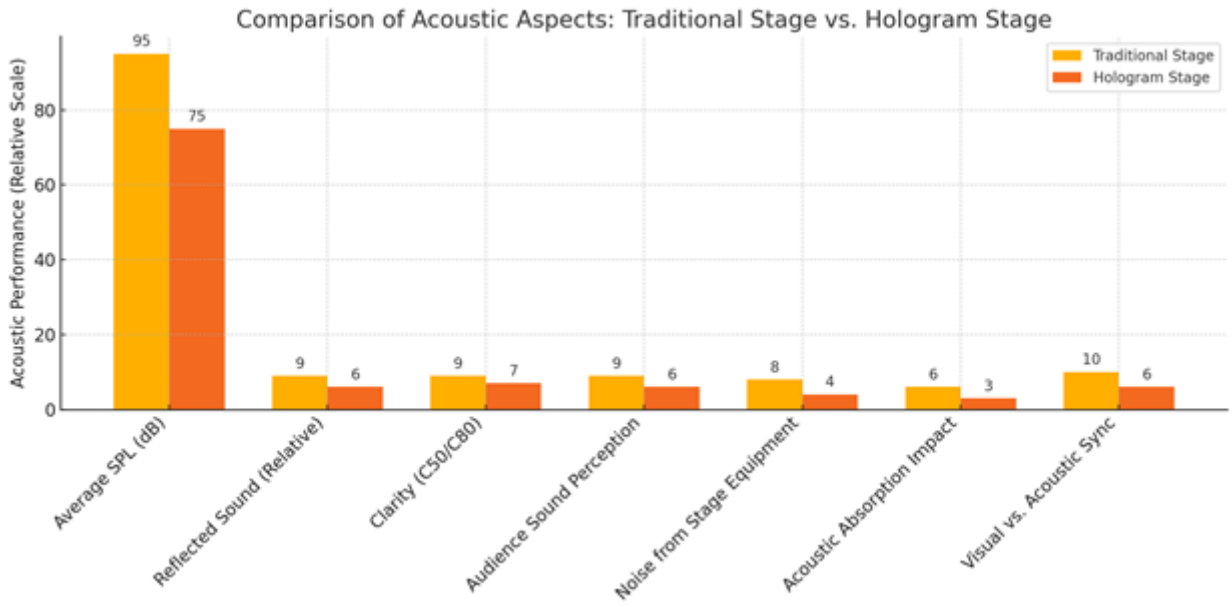
Fig. (10) Software simulation results.

The two figures are screenshots for the software simulation of the sound measurements in the Coachella concert hall before and after applying the hologram technology.

Here are the results of the software comparison between decibel levels and sound quality and clarity inside the (Coachella concert hall) in two cases presented in a table and a chart. First case in comparison is the hologram-based concert that was held in that hall in 2012 (Tupac hologram concert), and the second case is the normal concerts that were held in the same hall.

Table 1: Comparison results.

Aspect	Before Hologram (Traditional Stage)	After Hologram Applied
Average SPL (Sound Pressure Level)	~85–100 dB (depending on performance type)	~50–90 dB (less than before)
Reflected Sound	Higher reflections from performers, instruments, and stage props	Slightly reduced direct reflections depending on hologram screen material
Clarity	(C80) High clarity if acoustically treated	(C50) May be affected slightly by screen interference
Audience Sound Perception	Direct, strong source localization	Can be slightly diffused if sound is not well-matched to hologram position
Noise from Stage Equipment	Present (amps, monitors, etc.)	Possibly reduced if sound is routed digitally and fewer physical sources are on stage
Acoustic Absorption Impact	Depends on materials used on stage	Holographic screens (especially transparent types) usually have low absorption
Visual vs. Acoustic Sync	Direct alignment	Requires perfect audio-video sync for realism, especially for vocals



From the results of the comparison, we can obviously approve that the application of the hologram settings and hardware which includes (the hologram devise, the glass screen, and the reflectors) will negatively affect the sound quality inside the concert hall.

5. Conclusion and recommendations.

While hologram technology offers innovative possibilities in concert hall design, it poses challenges to natural sound distribution. To balance its advantages and drawbacks, the following recommendations should be considered:

- **Interior Design Adaptations**:
  - Flexible stage layouts to accommodate both traditional and holographic performances.

- Examples of the flexible stage design:

1- **StageTek Modular Staging System:** A modular platform system that allows for rapid reconfiguration to suit various performance types. Enhances interaction between performers and audiences by enabling diverse stage layouts. Ideal for venues hosting both traditional and holographic shows [17].

Eric Prydz's EPIC 5.0 Show

Featured a 110-meter "megastructure" with a V-shaped video display and a cube configuration called the Vanish. Integrated 600 laser beams and 20-meter-wide holograms to create an immersive experience.

Demonstrates the fusion of live performance with advanced holographic technology [19].

2- **Thunderdome's Holographic Performances**

Artists like Excision have utilized large-scale holographic projections, such as a giant Shrek, to enhance live shows.

Combines traditional stage elements with holographic visuals for a unique audience experience [18].

3- **360-Degree and 3D Stage Designs**

Stages designed to immerse the audience from all angles, often incorporating 3D backdrops and animations.

Allows for seamless integration of live and holographic elements, enhancing the overall performance [19].

- Virtual walls and interactive visuals to enhance audience experience.

- **Sound Quality Enhancements**:
  - Integration of 3D audio elements to maintain sound realism.
  - Directional sound projection for improved acoustic balance [15].
- **Key Considerations**:
  - **High Costs**: The expense of hologram technology limits widespread adoption.
  - **Infrastructure Upgrades**: Specialized projectors and sound systems are required.
  - **Preserving Atmosphere**: A balance between holographic and traditional elements is crucial to maintaining concert authenticity [20].

Hologram technology offers exciting possibilities for both interior design and sound experiences in concert halls. However, its cost and infrastructure demands must be considered before adoption. Hologram technology revolutionizes live performances, but careful planning is necessary to preserve the acoustic integrity of concert halls.

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