Design and Experiment of a Multi-channel Spatial Mixing System for Sound Image Control

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1. Problem Statement and Background

In many real-world scenarios, standard stereo sound reinforcement systems for live performances effectively function as mono. Especially in small clubs or mid-sized halls, the influence of direct sound from the stage is so significant that forming a stable phantom image using only left and right speakers is difficult. In such environments, there are few practical ways to fix the vocal image at the center of the audience without employing a dedicated center speaker.

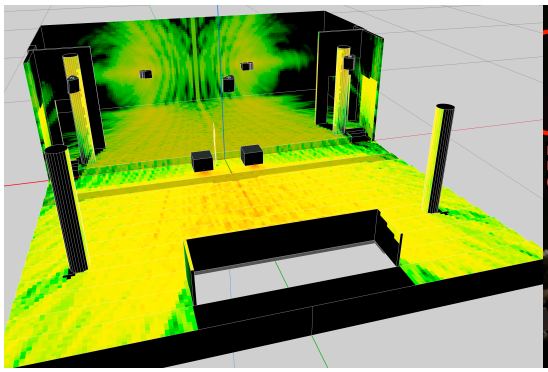
Instead of adhering to traditional stereo concepts, this project aimed to implement a more intuitive **spatial distributed mixing** system through a multi-channel speaker layout where the "line of hearing" physically aligns with the "line of sight." This was an experimental setup designed to achieve spatial sound image separation using only the audio console's routing and bus structure, without a separate immersive processor.

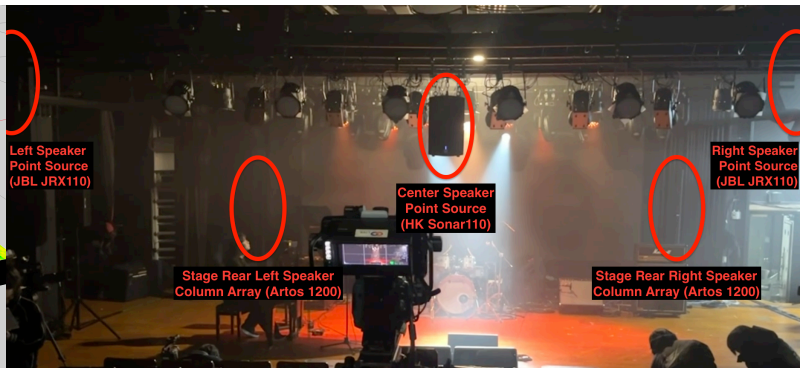
2. System Configuration and Mixing Design

The system was designed with a **3.1-channel base structure**. The Left, Right, and Center (LCR) speakers were rigged as the main system, while column array speakers were placed at the back of the stage to serve as **Stage Rear** speakers. The subwoofer was operated independently.

Mixing Strategy:

- **Front-heavy Sources:** Elements that require a definitive front-center image (Vocals, Kick, Snare, Bass) were routed exclusively to the **Center speaker**.
- **Spatial Balancing:** Line sources like keyboards, which tend to "jump" forward compared to microphone sources, were routed to the **LR and Stage Rear speakers** to create spatial depth.
- **Ambience:** Spatial effects such as reverb and delay were assigned to the LR and Stage Rear speakers to enhance the sense of envelopment.
- **LR Utility:** The LR speakers functioned primarily as **delay speakers** to compensate for potential sound pressure drops from the Stage Rear system, rather than for primary image formation.





3. System Tuning and Alignment

The tuning was approached by treating the setup as two independent systems:

1. **Alignment between LR and Stage Rear:** Using the Stage Rear speakers as the time reference, the LR speakers were calibrated for delay, level, frequency response, and phase response.

2. **Alignment between Center and Subwoofer:** Focused on stabilizing the integration of low-frequency energy with the front-center sound image.

Beyond basic level adjustments, no further inter-system tuning was performed between these two groups. This was a deliberate design choice to maintain physical separation between the distinct sound image zones.

4. Results and Observations

The Stage Rear speakers successfully doubled as artist monitors. Interestingly, the stage monitor spill—which is usually a nuisance that interferes with the house sound—actually contributed positively as an element of the spatial ambience.

However, contrary to the initial hypothesis that aligning the lines of hearing and sight would increase immersion, feedback indicated that **individual sources were perceived as being in isolated locations.** Rather than a cohesive performance space, the audience felt as though different instruments were playing from disconnected physical points.

5. Limitation Analysis and Future Improvements

Equipment Heterogeneity: Due to logistical constraints, speakers from different brands and with different characteristics were mixed. This likely hindered the cohesive integration of the sound image.

Simulation vs. Perception: While pre-production simulations can predict coverage and frequency response, they cannot account for how the human brain perceives sound image localization in a physical space. To mitigate the "detached" feeling of the rigged center speaker, it was supplemented with ground-stacked units post-rehearsal to pull the center image downward toward the stage.

This project highlighted that physical placement and electrical tuning alone are insufficient for spatial audio design. It underscored the necessity of a **psychoacoustic approach** that considers how listeners actually perceive space and localization. Moving forward, I intend to evolve this research into system designs centered on human-perceived sound images through advanced immersive processing.