

# Setting Up a Cardioid Subwoofer Array for a Performance Venue

A cardioid subwoofer array is a powerful technique used in performance venues to control low-frequency dispersion, focusing bass energy towards the audience while minimizing unwanted bass spill onto the stage or into adjacent areas. This setup is especially important in live sound environments where excessive low-frequency energy can cause issues such as stage rumble, microphone feedback, or noise complaints.

## 1. Fundamentals of a Cardioid Subwoofer Array

A cardioid subwoofer array works by manipulating the phase and timing of multiple subwoofers to create a directional low-frequency pattern. The term "cardioid" refers to the heart-shaped polar pattern that focuses sound in one direction while reducing it in the opposite direction.

- **Key Concept:** The cardioid pattern is achieved by using at least two subwoofers arranged in such a way that their outputs combine constructively in front of the array (towards the audience) and destructively behind the array (towards the stage or unwanted areas).

## 2. Planning the Setup

### a. Understanding the Venue's Acoustic Needs

Before setting up a cardioid subwoofer array, it's essential to assess the venue's specific needs:

- **Stage Requirements:** Determine the level of low-frequency spill that needs to be minimized on stage. Excessive bass on stage can interfere with performers' monitoring and lead to feedback issues.
- **Audience Coverage:** Ensure that the bass is concentrated in the audience area. Consider the size and shape of the audience area, including any balconies or side areas that need coverage.
- **Neighboring Areas:** Identify areas adjacent to the venue (e.g., backstage, nearby residential areas) where bass spill should be minimized.

### b. Choosing the Right Subwoofers

Selecting the appropriate subwoofers is crucial for an effective cardioid setup:

- **Matching Subwoofers:** Use identical subwoofers to maintain a consistent phase and frequency response across the array. This is important for achieving a uniform cardioid pattern.
- **Subwoofer Quantity:** The number of subwoofers will depend on the venue size and the desired low-frequency coverage. A minimum of two subwoofers is required for a basic cardioid setup, but larger venues may require more subwoofers arranged in a more complex pattern.

## 3. Physical Setup of the Cardioid Array

The physical arrangement of the subwoofers is critical to achieving the cardioid pattern.

## a. Subwoofer Placement Strategies

There are several common configurations for arranging subwoofers in a cardioid array:

- **Front-Rear Configuration:**
  - **Setup:** Place one or more subwoofers facing the audience and one or more subwoofers directly behind them, facing the opposite direction (toward the stage).
  - **Spacing:** The distance between the front and rear subwoofers should be approximately  $1/4$  of the wavelength of the frequency you wish to target for cancellation. For example, at 80 Hz, which has a wavelength of approximately 4.3 meters, the spacing should be around 1.1 meters.
- **Side-by-Side Configuration:**
  - **Setup:** Position subwoofers side by side, with one subwoofer inverted in polarity and delayed relative to the other.
  - **Spacing:** The spacing in this configuration will also depend on the target frequency and the desired pattern width.
- **Vertical Stack (for flown arrays):**
  - **Setup:** Subwoofers can be stacked vertically, with alternating front and rear-facing subwoofers. This setup can be used in situations where ground space is limited or where a flown array is required.
  - **Advantages:** Vertical stacks offer tighter vertical dispersion control, which can be useful in venues with balconies or tiered seating.

## b. Considerations for Placement Height

- **Ground Placement:** Ground-stacked subwoofers provide a coupling effect with the floor, reinforcing low frequencies. This is the most common placement in many venues.
- **Flown Subwoofers:** In larger venues or where ground space is limited, subwoofers can be flown (suspended from above). Flown subwoofers require careful delay and phase alignment to maintain the cardioid pattern.

## 4. Signal Processing for Cardioid Arrays

Signal processing is a critical component in creating the cardioid pattern. The process involves delaying and potentially inverting the polarity of the signals sent to the subwoofers.

### a. Polarity Inversion

- **Rear-Facing Subwoofer:** The signal to the rear-facing subwoofer(s) is typically inverted in polarity (phase). This inversion is what initially sets up the conditions for destructive interference behind the array.
  - **Inversion Process:** This is usually done within the DSP or the subwoofer amplifier settings. It's essential to ensure that only the rear-facing subwoofer(s) have their polarity inverted, while the front-facing subwoofer(s) remain at their normal polarity.

## b. Time Delay Calculation

- **Purpose of Delay:** The delay applied to the rear-facing subwoofer(s) ensures that the sound waves from the front and rear subwoofers align in such a way that they cancel each other out behind the array while reinforcing each other in front.
- **Calculating Delay:**
  - **Basic Formula:** The delay is generally set to match the time it takes for sound to travel the distance between the front and rear subwoofers, taking into account the speed of sound (approximately 343 meters per second in air).
  - **Example Calculation:** If the front and rear subwoofers are 1 meter apart, the delay would be around 2.9 milliseconds (1 meter / 343 meters per second  $\approx$  2.9 ms).
- **Fine-Tuning Delay:**
  - After applying the calculated delay, use measurement software to fine-tune the delay setting. Small adjustments can significantly improve the cardioid pattern, especially in real-world conditions where environmental factors come into play.

## c. Additional Signal Processing Considerations

- **High-Pass and Low-Pass Filters:** Apply appropriate high-pass and low-pass filters to the subwoofers to ensure they operate within their optimal frequency range. This can help avoid unnecessary strain on the subwoofers and improve overall system efficiency.
- **EQ Adjustments:** Depending on the characteristics of the venue and the subwoofers, you may need to apply EQ adjustments to flatten the frequency response and remove any resonances introduced by the cardioid setup.

## 5. Testing and Optimization

After the physical setup and signal processing are complete, thorough testing and optimization are crucial to ensure the cardioid pattern is effective.

### a. Measurement and Analysis

- **Use Measurement Software:** Tools like Smaart or similar measurement systems allow you to analyze the system's performance in real-time. Measure the SPL and phase response both in front of and behind the subwoofer array to confirm the cardioid effect.
  - **Front Response:** In the audience area, the measurement should show strong and even low-frequency coverage.
  - **Rear Response:** Behind the array, the measurement should indicate significant attenuation of low frequencies, ideally 15-20 dB or more of reduction.
- **Adjust Based on Measurements:** If the measurements show inadequate cancellation or uneven coverage, adjust the delay, polarity, or physical placement of the subwoofers as necessary.

## b. Listening Tests

- **Critical Listening:** After completing measurements, perform listening tests at various points in the venue. Focus on the clarity and balance of the low frequencies, both in the audience area and on stage.
- **Stage Area:** Walk around the stage area to ensure that low-frequency spill is minimized, which is important for preventing feedback and ensuring clear monitoring for performers.

## 6. Documentation and Final Adjustments

After achieving the desired cardioid pattern, it's important to document the setup for future reference and make any final adjustments based on the performance needs.

### a. Documentation

- **Record Settings:** Document the final DSP settings, including delay times, polarity inversion, EQ adjustments, and subwoofer placement. This ensures that the setup can be easily replicated or adjusted in the future.
- **Measurement Data:** Save the measurement data from your analysis software. This data can be invaluable for troubleshooting or for future tuning sessions.

### b. Final Adjustments Before Performance

- **Recheck Before Each Event:** Before each performance, recheck the subwoofer setup, especially if the subwoofers have been moved or the stage setup has changed. Small changes in placement or environmental conditions can affect the cardioid pattern.
- **Audience and Environmental Considerations:** Be aware that the presence of an audience can slightly alter the low-frequency response due to the absorption characteristics of a large crowd. Consider this when fine-tuning the system.

## Conclusion

Setting up a cardioid subwoofer array in a performance venue requires a detailed understanding of acoustics, careful physical setup, and precise signal processing. By focusing bass energy towards the audience and minimizing unwanted low-frequency spill, a cardioid setup can significantly improve the sound quality in a venue, providing a better experience for both the audience and the performers. Through careful planning, measurement, and optimization, you can achieve a cardioid subwoofer array that delivers powerful, controlled bass where it's needed most.