Setting up a sub-arc in a performance venue is a sophisticated technique aimed at achieving optimal low-frequency coverage and directivity control. Here's an in-depth guide, breaking down each step with greater technical detail.

1. Understanding the Sub-Arc Concept

- **Sub-Arc Definition:**
    - A sub-arc is a configuration where multiple subwoofers are arranged in an arc formation to create controlled low-frequency directivity. The goal is to focus the bass energy towards the audience area, reduce overlap and interference between subs, and minimize unwanted low-frequency spill into non-audience areas, such as the stage or side walls.
- **Why Use a Sub-Arc?**
    - **Even Bass Coverage:** In large venues, bass tends to vary greatly across different areas, with some spots receiving too much bass and others too little. A sub-arc helps distribute low frequencies more evenly across the venue.
    - **Directional Control:** By controlling the direction of bass energy, a sub-arc reduces unwanted reflections from walls and ceilings, which can cause phase cancellation and muddy the sound.
    - **Minimized Interference:** The arrangement helps prevent destructive interference between subwoofers, which can cause uneven bass response and dead spots.

2. Designing the Sub-Arc: Number and Placement of Subwoofers

- **Determining the Number of Subwoofers:**
    - **Venue Size and Shape:** The number of subwoofers needed depends on the size and shape of the venue. Larger venues require more subs to achieve uniform coverage.
    - **Frequency Range:** The number of subs also correlates with the desired low-frequency range. To effectively control lower frequencies, more subs are needed because the wavelength of low frequencies is longer, requiring a broader physical arrangement to control directionality.
- **Arc Geometry:**
    - **Arc Radius:** The radius of the arc is crucial as it affects the coverage pattern. The radius is typically based on the width of the audience area, and the arc should be centered on the primary listening area or the stage.
    - **Placement Strategy:** Subwoofers should be evenly spaced along the arc. Spacing is typically set between 1/4 to 1/2 of the wavelength of the lowest frequency you wish to control. For example, if the lowest frequency is 40 Hz (with a wavelength of about 8.6 meters), subwoofers should be spaced approximately 2 to 4 meters apart.
- **Example Setup:**
    - For a large venue with a 40 Hz control target, if you have 8 subwoofers and aim for 3-meter spacing, you would place them along an arc with a radius that allows the subs to cover the entire audience area effectively.

3. Delay Calculation for Each Subwoofer

- **Understanding Delay Usage:**
  - Delay is used to align the arrival time of sound from each subwoofer so that the low-frequency energy combines constructively towards the audience, enhancing bass response where needed and reducing it where it's not.
- **Basic Delay Calculation:**
  - The delay for each subwoofer is calculated based on its distance from a reference point (usually the center subwoofer in the arc). The formula for calculating delay is: Delay=dref−dsubc\text{Delay} = \frac{d_{\text{ref}} - d_{\text{sub}}}{c}Delay=cdref −dsub where:
    - drefd_{\text{ref}}dref is the distance from the center subwoofer to the reference point (typically the center of the audience area),
    - dsubd_{\text{sub}}dsub is the distance from each subwoofer to the same reference point,
    - ccc is the speed of sound (~343 m/s at room temperature).
- **Practical Example:**
  - If the center subwoofer is 20 meters from the reference point and another subwoofer is 25 meters away, the delay for the second subwoofer would be: Delay=20−25343≈−14.6 ms\text{Delay} = \frac{20 - 25}{343} \approx -14.6 \text{ ms}Delay=34320−25≈−14.6 ms This negative delay means you would add 14.6 ms delay to the closer subwoofer to align it with the further subwoofer.
- **Advanced Delay Tuning:**
  - **All-pass Filters:** Sometimes, all-pass filters are used to control phase without affecting amplitude, allowing for fine-tuning of the phase response across different frequencies.
  - **Directional Steering:** Delays can be used to steer the bass energy towards specific areas of the venue. By introducing progressive delays across the arc, the sound wavefront can be angled to focus on particular parts of the audience.

4. Phase Alignment

- **Importance of Phase Alignment:**
  - Phase alignment ensures that sound waves from all subwoofers reinforce each other rather than cancel out. Poor phase alignment can lead to comb filtering, where certain frequencies are reduced or amplified, leading to inconsistent bass response.
- **Tools for Phase Alignment:**
  - **Measurement Microphone and Analyzer:** A real-time analyzer (RTA) with a measurement microphone is used to measure the phase response across the audience area.

- **Phase Optimization:** Adjust the phase of each subwoofer to ensure that low-frequency waves are in phase at the key listening positions. This might involve fine-tuning delays or using phase shift controls available on the subwoofers or in the DSP.

- **In Practice:**
  - Measure phase response at multiple locations within the venue. Adjust the delays and phase settings to achieve consistent phase alignment across these locations. The goal is to have a smooth, coherent wavefront with minimal phase cancellation.

5. Level Adjustment

- **Balancing Levels:**
  - Even after setting delays and phase, level adjustments are necessary to ensure that each subwoofer contributes appropriately to the overall sound. Subs closer to the audience might need to be attenuated to avoid overpowering those further away.
- **Tools for Level Adjustment:**
  - **SPL Meter:** Use a sound pressure level (SPL) meter to measure the output from each subwoofer. Adjust the levels in the DSP or amplifier settings to achieve uniform SPL across the venue.
  - **Subwoofer Array Balancing:** Some advanced systems allow for automated array balancing, where software optimizes the level and delay of each subwoofer based on the venue's acoustic measurements.
- **Optimization:**
  - The goal is to achieve a flat bass response across the audience area, without hotspots (areas of excessive bass) or nulls (areas of reduced bass). This might require iterative adjustments, balancing the levels after each round of delay and phase tuning.

6. Testing and Fine-Tuning

- **Testing the Setup:**
  - **Use Test Signals:** Start with test signals such as sine sweeps, pink noise, and bass-heavy music to evaluate the system's performance. Walk through the audience area to listen for consistency in the bass response.
  - **Measurement Verification:** Use RTA and SPL meters to verify the consistency of the bass response across different locations. Pay attention to any discrepancies in phase or level and adjust accordingly.
- **Fine-Tuning Process:**
  - **Iterative Adjustments:** Fine-tuning involves small, iterative adjustments to delays, phase, and levels. After each adjustment, re-measure and re-listen to assess the impact.

- **Room Considerations:** Consider the room's natural acoustics, such as reflections from walls, floors, and ceilings. Sometimes, additional acoustic treatment (e.g., bass traps) might be necessary to mitigate room modes that the sub-arc cannot control alone.

7. Advanced Techniques: Cardioid and End-Fire Arrays

- **Cardioid Subwoofer Arrays:**
  - **Concept:** A cardioid array reduces low-frequency radiation behind the array, directing more energy towards the audience. This is achieved by placing a second subwoofer behind the main sub, delaying and inverting its phase.
  - **Implementation:** In a sub-arc, cardioid arrays can be incorporated by adding rear-facing subs behind the arc, with delays and phase settings adjusted to cancel out rearward energy.
- **End-Fire Arrays:**
  - **Concept:** An end-fire array involves placing subwoofers in a straight line, each delayed so that their outputs combine constructively in the forward direction.
  - **Combination with Sub-Arc:** In some cases, end-fire arrays are used in combination with a sub-arc to further focus bass energy towards the audience. This requires careful delay and phase calculations to ensure the outputs align correctly.
- **Considerations:**
  - Both cardioid and end-fire arrays add complexity to the setup but offer greater control over low-frequency directivity. These techniques are particularly useful in venues with challenging acoustics or where minimizing rearward bass is essential (e.g., outdoor stages or venues near noise-sensitive areas).

8. Documentation and Configuration Management

- **Saving the Setup:**
  - Once the sub-arc is optimized, save the settings (delays, phases, levels) in the DSP or mixing console. This allows for quick recall and ensures consistency across different events or performances.
  - **Backup Settings:** It's advisable to create multiple backups, including physical documentation and digital files, to prevent loss of configuration data.
- **Documentation:**
  - **Positioning Details:** Document the exact positioning of each subwoofer, including the distance from reference points and spacing between subs.
  - **Configuration Settings:** Record all DSP settings, including delay times, phase settings, and levels, along with the rationale for each choice. This helps in troubleshooting and refining the setup for future performances.

9. Monitoring During the Performance

- **Real-Time Monitoring:**
  - During the performance, monitor the bass response, especially if environmental conditions change (e.g., temperature, humidity, audience size). These factors can affect sound propagation and may require real-time adjustments.
  - **Remote Control:** If possible, use remote control tools to make on-the-fly adjustments to delays, levels, or phase settings based on real-time feedback.
- **Audience Impact:**
  - Observe the audience's reaction to the bass response. If certain areas appear to have issues (e.g., too much or too little bass), consider making minor adjustments during intermissions or between performances.

Conclusion

Setting up a sub-arc in a performance venue requires a deep understanding of acoustics, sound system design, and advanced audio engineering techniques. By carefully designing the arc, calculating precise delays, aligning phases, and balancing levels, you can achieve an even and controlled low-frequency response that enhances the overall sound quality of the performance. The process involves iterative testing, fine-tuning, and real-time monitoring to ensure the best possible experience for the audience.