The American Journal of Engineering and Technology
ISSN 2689-0984 | Open Access

TYPE Original Research
PAGE NO. 112-117
DOI 10.37547/tajet/Volume07Issue03-10

Check for updates

Problems of Subwoofer Installation in Vehicles with Limited Space

Grigorenko Aleksei

Member of the Management Board in SE Pluss Corp OU Tallinn, Estonia

OPEN ACCESS

SUBMITED 23 January 2025
ACCEPTED 19 February 2024
PUBLISHED 12 March 2025
VOLUME Vol.07 Issue03 2025

CITATION

Grigorenko Aleksei. (2025). Problems of Subwoofer Installation in Vehicles with Limited Space. The American Journal of Engineering and Technology, 112–117. https://doi.org/10.37547/tajet/Volume07Issue03-10

Abstract: This article addresses the challenges associated with subwoofer installation in vehicles with limited interior space, a pressing issue in car audio systems. Modern vehicles, especially compact models, often feature constrained dimensions, complicating the selection and installation of acoustic equipment. This study aims to analyze the issues related to subwoofer installation in vehicles with restricted space. Recommendations to improve the acoustic performance of such systems are proposed. The methodology includes a theoretical examination of existing methods for subwoofer installation in confined spaces.

The findings indicate that acoustic performance is influenced not only by the choice of subwoofer type and enclosure but also by the proper placement of the device within the vehicle. Installing a subwoofer in the trunk compartment, with appropriately adjusted enclosure parameters and amplifier settings, enhances the efficiency of low-frequency sound transmission. For vehicles with limited space, such as compact crossovers or hatchbacks, the placement of the subwoofer significantly impacts the overall cabin acoustics, along with the effects of noise and vibration. The choice of enclosure material plays a crucial role in determining resonance characteristics.

The information presented is valuable for engineers working with automotive audio systems and car enthusiasts interested in improving the sound quality of their vehicles. The results obtained can serve as a foundation for the development of new subwoofer models designed for use in restricted spaces.

Keywords: subwoofer, car audio, limited space, acoustic system, design, car sound, enclosure, resonance.

Introduction: In recent years, interest in automotive

audio systems has grown significantly, driven by evolving driver demands for higher sound quality in vehicle interiors. The subwoofer is a key component responsible for reproducing low frequencies. However, installing such a device in a vehicle with limited space presents a considerable challenge, as the dimensions of the cabin or trunk impose constraints on the selection of the subwoofer, its placement, and the overall system performance. Incorrect installation can result in a decline in acoustic quality.

The increasing number of compact vehicles has intensified the issue of insufficient space for the proper placement of audio systems. Under these conditions, the selection of the subwoofer, its enclosure, and its location within the vehicle becomes critical. Designing an audio system requires a tailored approach that considers the structural characteristics of the vehicle.

This article aims to analyze the challenges associated with subwoofer installation in vehicles with limited space and to propose recommendations for improving the acoustic performance of such systems.

MATERIALS AND METHODS

One method to improve the efficiency of design processes is the use of computational models. The study by Bokhari A. H. et al. [1] presents an approach combining two-dimensional and three-dimensional calculations. This method reduces computational costs, which is crucial for designing audio systems for vehicles. Optimized models expedite calculations and provide accurate parameter assessments while eliminating the need for complex 3D simulations. This approach is particularly applicable to the design of subwoofers for limited spaces where high sound quality is required.

Another critical aspect involves improving product quality. The work of Pacheco D. A. J. and Librelato T. P. [2] explores methods to enhance subwoofer manufacturing processes. The authors emphasize the importance of selecting appropriate materials and optimizing production technologies. These measures allow for a reduction in component size while maintaining their acoustic performance, which is vital for vehicles with constrained space. The study highlights the significance of precision in manufacturing processes to prevent defects that could lead to sound distortion.

Modern technologies play a significant role in enhancing acoustic performance. Duran E. [3] describes a method utilizing directional subwoofer arrays to minimize uncontrolled sound reflections and ensure a more uniform distribution of low-frequency sound in limited spaces.

The issue of subwoofer placement in restricted spaces has also been actively examined. The research by Mouterde T. and Corteel E. [4] discusses the impact of various subwoofer configurations on acoustics and noise levels. In vehicles with limited space, proper component placement is essential. Incorrect installation can result in acoustic problems, such as echoes or uneven low-frequency distribution.

The optimization of subwoofer placement in complex acoustic environments is discussed in the study by Hyon J. and Jeong D. [5]. The authors provide recommendations for subwoofer placement in diverse acoustic settings, including residential spaces. While these recommendations are primarily designed for spacious environments, they can be adapted for vehicles. Proper placement minimizes acoustic issues such as standing waves and resonances.

Au E. et al. [6] investigate the impact of architectural features on low-frequency sound reproduction. The authors propose methods to compensate for sound reflection effects. These approaches apply to automotive audio systems, helping to reduce sound distortions caused by the vehicle's structural characteristics.

Methods for acoustic tuning in small spaces are described in the work of Torresin S. et al. [7]. This approach can be adapted for vehicles, as the interior of a car presents unique conditions, such as dynamic operational environments. Applying these methods can contribute to improved acoustics in vehicles.

Despite the wealth of scientific studies, several issues require further investigation. Gaps remain between theoretical methods and real-world operating conditions, hindering the practical implementation of proposed solutions. Additionally, dynamic factors such as vibrations and environmental changes during vehicle operation are still underexplored. These aspects demand further analysis to develop more accurate and efficient solutions for designing audio systems for vehicles with limited space.

The methodology includes a theoretical study of existing methods for subwoofer installation in restricted spaces.

RESULTS AND DISCUSSION

The installation of subwoofers in vehicles with limited interior space presents an engineering challenge that requires meticulous attention to detail at every stage of designing a car audio system. Such conditions

necessitate consideration not only of the technical specifications of components but also of the specific characteristics of the vehicle, complicating the development process. Modern vehicles often have compact cabin dimensions, leading to numerous difficulties in equipment placement and tuning [2, 4]. Table 1 outlines subwoofer installation methods.

Table 1. Subwoofer installation methods [2, 4].

Installation Method	Description	Advantages	Disadvantages
Compact subwoofers	Installing smaller subwoofers designed specifically for vehicles with limited space. Their reduced diameter allows installation in confined areas.	- Space-saving. - Easy to install in tight spaces.	- Lower power compared to larger subwoofers.
Integration into seats	Subwoofers embedded in seats are suitable for vehicles with minimal trunk space.	- Maximizes space usage.	- Impacts passenger comfort.
Installation under the floor	Creating recesses or enclosures in the vehicle floor for subwoofers.	- Saves space in the cabin and trunk. - Keeps the vehicle's appearance unchanged.	- Not compatible with all vehicle types.
Low-profile enclosures	Enclosures with reduced depth while maintaining necessary acoustic properties.	- Suitable for small trunk volumes. - Balanced power and compactness.	- Limited power and bass quality.

The data presented in Table 1 indicate that the primary challenge in subwoofer installation is the limited space available for the enclosure. This constraint directly influences the choice of subwoofer model and the characteristics of the enclosure. A subwoofer's acoustic performance is size-dependent, limiting the options for compact vehicles. In such cases, models with a volume of 20–40 liters are preferred. However, these dimensions can negatively affect the reproduction of low frequencies if the subwoofer has high sound pressure levels.

To address these issues, various methods are employed, such as increasing the diaphragm size or utilizing technologies that enhance performance in smaller volumes. The material of the enclosure is another critical factor. Modern composite or polyurethane materials reduce weight while maintaining structural strength.

Equally significant is the shape and placement of the subwoofer. Standard design methods that assume symmetrical or linear structures are not always suitable for unconventional vehicle interiors. Installing the subwoofer in the trunk or under a seat requires careful consideration of cabin geometry and the placement of other components, such as the fuel tank or exhaust system. Solutions to these challenges involve different types of enclosures, such as bass reflex or sealed systems. Each type imposes specific tuning requirements, making the installation process highly individualized and requiring careful attention to detail.

The acoustic properties of a car's interior affect sound perception. Surfaces made of glass, plastic, and metal can alter the phase response and cause resonance. Low-frequency waves from a subwoofer are amplified in areas prone to vibration, such as doors, the roof, or the floor. To mitigate these issues, a combination of acoustic tuning and vibration damping is employed. Installing multilayer materials such as acrylic or polyurethane on rear panels

and the roof reduces the impact of vibrations and enhances sound quality. However, this alone is often insufficient, requiring additional system tuning through equalizers and crossovers [1, 3, 5]. Table 2 highlights the specific acoustic characteristics of car interiors and their impact on sound quality.

Table 2. The existing features of the acoustic characteristics of the interior of the car and their impact on sound quality [1, 3, 5].

Acoustic Feature	Description	Impact on Sound
Cabin size	Directly affects sound wave propagation. Larger vehicles with spacious cabins offer better conditions for acoustics.	- In larger spaces, the sound is more balanced but may encounter issues with reverberation.
Reflections and resonance frequencies	Reflections of sound waves from walls, glass, floors, and ceilings can create resonances at specific frequencies, leading to distortions or abrupt changes in sound levels.	- Can cause a "boomy" effect or a "boxy" sound.
Interior materials	Affect sound due to varying absorption and reflection coefficients of sound waves.	- Hard materials promote strong reflections. - Soft materials absorb sound and reduce echoes.
Speaker placement	Proper distribution ensures balanced sound.	- Poor placement may result in frequency imbalances, insufficient bass, or uneven sound distribution.
External noise	Alters sound perception inside the vehicle. Effective soundproofing reduces this effect.	- External noise can suppress certain frequencies, particularly at low volume levels.

Dense wiring and the presence of sensors, such as parking or navigation systems, can cause interference, negatively affecting their operation.

To address these issues, shielded cables and filters are used to suppress high-frequency interference [1, 6, 7]. Table 3 summarizes methods for solving subwoofer installation problems.

Table 3. Methods for solving subwoofer installation problems [1, 6, 7].

Problem	Solution Methods	Advantages	Disadvantages
Limited	1. Use of compact	- Compact models save	- Compact subwoofers

space in the car	subwoofers. 2. Embedding subwoofers into seats. 3. Installing subwoofers under the floor. 4. Use of active subwoofers.	space. - Embedding in seats or the floor does not require trunk space.	have lower power. - Seat or floor installation requires vehicle modifications.
Lack of bass and deep frequencies	1. Use of subwoofers with bass reflex systems. 2. Optimized installation with specialized enclosures. 3. Use of speakers with large diaphragm areas.	- Bass reflex systems enhance low frequencies. - Enclosures improve low-frequency response in limited spaces.	- Bass reflex systems are bulky. - Enclosures require additional installation space.
Insufficient system efficiency	1. Use of high-power amplifiers. 2. Installation with enhanced acoustic materials. 3. Use of active subwoofers with built-in amplifiers.	- Amplifiers increase system power. - Acoustic materials enhance sound quality and efficiency. - Active subwoofers are convenient and effective.	- High power requires modifications to the vehicle's electrical system. - Acoustic materials can be costly.
Spatial installation constraints	1. Use of low-profile enclosures. 2. Installing subwoofers in unconventional locations. 3. Use of flat or flexible subwoofers.	- Low-profile enclosures reduce volume. - Installation in unconventional locations saves space and keeps the system discreet. - Flexible models can be placed anywhere.	- Low-profile enclosures may not provide powerful bass like standard designs.
Noise and vibration from subwoofer installation	1. Use of vibration-damping materials. 2. Installation of shock absorbers or special platforms. 3. Use of materials to absorb vibrations and noise.	- Vibration damping reduces unwanted sounds and improves playback clarity. - Special platforms stabilize the subwoofer.	- Vibration damping increases vehicle weight, affecting performance. - Requires additional budget.
Low sound selectivity and phase distortion	1. Proper speaker placement. 2. Use of bass reflex systems or phase filter adjustments. 3. Audio system tuning considering acoustic features.	- Proper speaker placement minimizes sound distortion. - Bass reflex systems and filters improve sound balance.	- Tuning requires professional expertise.
Cooling issues	1. Use of subwoofers with low heat emission. 2.	- Low-heat subwoofers prevent overheating during	- Ventilation systems are bulky and require

	Installation with adequate ventilation. 3. Use of subwoofers with built-in cooling.	extended use. - Ventilation prevents overheating.	additional installation effort. - Subwoofers with cooling systems are more expensive.
Installation safety concerns	1. Use of high-quality mounts and materials. 2. Subwoofer installation compliant with technical standards. 3. Use of protective covers and cushioning pads.	- High-quality mounts and materials enhance system safety. - Protective covers prevent equipment damage.	- Compliance with technical standards and instructions is required.

Thus, the installation of a subwoofer in a vehicle with limited space requires thorough consideration of all factors, from acoustic characteristics to energy constraints. The successful implementation of such projects necessitates a comprehensive approach that includes the appropriate selection of models and materials, as well as precise system tuning. Solutions such as the use of specialized subwoofers, modular designs, and digital signal processing enable achieving the desired sound quality, meeting the demands of even the most discerning users.

CONCLUSION

In summary, the primary challenges associated with subwoofer installation in vehicles with limited interior space have been identified. The constrained dimensions of most modern vehicles limit the selection and placement of audio systems, affecting the reproduction of low frequencies.

The findings of this study demonstrate that the effectiveness of subwoofer installation depends not only on the type and design of the enclosure but also on the proper placement of the device within the restricted space. Incorrect placement significantly reduces subwoofer efficiency.

The practical significance of this work lies in the development of recommendations for the selection and installation of subwoofers in vehicles with limited interior volume. These recommendations are valuable for professionals working in the field of automotive audio systems.

REFERENCES

Bukhari A. H. and others. Computationally efficient hybrid 2D–3D subwoofer model //Scientific reports. – 2021. – Vol. 11. – No. 1. – p. 255.

Pacheco D. A., Librelato T. P. Optimization of processes and product characteristics in complex systems: a study in the automotive industry //International Journal of Quality and Reliability Management. – 2023. – Vol. 40. – No. 4. – pp. 922-941.

Duran E. Modeling and application of arrays of subwoofers in the form of a beam // Reproducible sound, 2010. – 2023. – Volume 32 (5). – pp. 1-10.

Muterde T., Kortil E. On the comparison of configurations of subwoofers with suspended and ground arrangement from the point of view of noise pollution //151st Convention of the Society of Sound Engineers. – Society of Sound Engineers, 2021.5.

Hyun J., Jeong D. Variable acoustics in Concert Halls - review //Journal of the Korean Acoustic Society. – 2021. – Vol. 40. – No. 6. – pp. 626-648.

Au E. et al. Speech intelligibility in noise with varying spatial acoustics in an ambisonic-based sound reproduction system //Applied acoustics. – 2021. – Vol. 174. – p. 107707.

Torresin S. et al. Assessment of the indoor soundscape: a model of the main components of acoustic perception in residential buildings //Building and environment. – 2020. – Vol. 182. – p. 107152