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Evaluation and Noise Impact of Car Audio Systems

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Abstract

This paper presents the effects of, and the problems caused by, high-end audio systems used in passenger cars. Two major aspects of the problem were investigated: first, what is the quality of the sound reproduction that can be achieved in the car interior, and how, and to what extent, car audio systems can contribute to the noise pollution of residential areas. Correspondingly, both the interior and the surrounding sound field of the test vehicles was investigated for various operating conditions of the car (including switched off engines), with three different kind of music pieces. In order to assess the environmental impact, the overall insertion loss of the car was measured. Standard by-pass measurements were also performed to demonstrate the difference in sound levels between a standard car audio and a car equipped with a high-end audio system.. For better illustration of the growing problem, we calculated noise maps for a peaceful holiday resort too. The results have shown that currently used high-end audio systems are not really appropriate for good quality sound reproduction, caused both by disadvantageous acoustic characteristics of the cavity and artificially modified transfer characteristics of the electro acoustic system. Significant exterior sound level differences were found between different audio systems, ranging up to 20 dB. Exterior noise predictions have shown that high-end systems can significantly deteriorate the noise environment, especially for quiet places in the night period.

1. Introduction

Ability to listening to good-quality music in a good car has become a common demand by now. Therefore, large consumer-electronics firms have all been developing their own car stereo systems. It is a question whether an amplifier and a woofer in a car can be called a car stereo. Considering the aspects of noise reduction and environmental protection, an even more important question is whether high-performance amplifiers located in cars affect the noise level of their environment, and if so, to what extent.

Our lecture attempts to study both sides of the question in case of an average car type, using different sound systems and pieces of music and pre-estimation of environmental noise levels.

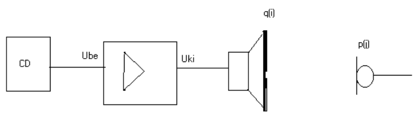
Experimental vehicle is equipped with a five-channel amplifier with the power of 4*60 W + 1* 180 W, 4 pieces of 2-way speaker sets and a band pass-type woofer mounted into the boot.

2. Internal examination

Quality of noise systems and fidelity is significantly affected by frequency distortion caused by the speakers. To obtain a suitable quality, an equable frequency response is needed in the whole frequency range. In addition, it should be noted that relatively small volume of the car frame also alters frequencies.

Sound from music source reaches the ear through a lot of complicated systems. (See Fig. 1.) Music from a CD player, considerable as noiseless and relatively perfect, is affected by a large amount of factors, including amplifier, speakers and noise space of the car frame.

To analyse subsystems affecting response thoroughly, response system can be broken into parts and parts can be examined apart from each other. Features of subsystems are determined by measuring electric or electro-acoustic features. Response function measured by us is product of several partial responses.



$H_{amp}=U_{ki}/U_{be}$

$H_{speaker}(i)=qi/U_{ki}$

$H_{frame}(i,j)=p(j)/q(i)$;

$H= H_{amp} * H_{speaker} * H_{frame} =p(j)/U_{be}$

Fig. 1. Car Sound System Model

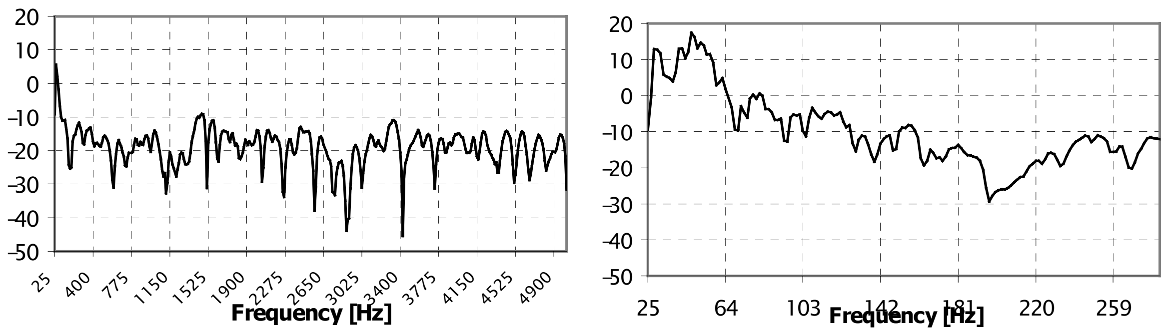


Fig. 2. a. Response at the driver's ear b. critical freq range zoomed

Measurement signal is white noise from CD. Measurement microphones had been mounted on several points. Response function of the noise system in case of unmanned car interior at the microphone at the driver's ear is illustrated in Fig. 2. Unevenness of measurement signal and the significant increase (+30 dB) until app. 200 Hz is illustrated well. Response function shaped as expected apart from the significant increase. 6 dB increases and -∞ attenuations took place. (as it is normal in an indoor acoustic response.) We determined by further measurements that amplifications and attenuations strongly depend on location and passengers. Fig. 2.b clearly shows the significant low-frequency increase that partly distorts even frequency response, partly plays an important role in external noise load increase, as shown in the next chapter. (We presume that the manufacturer has created this increase deliberately, in order to fulfil young users' demands.) It can be stated therefore that equipment labelled as Hi-Fi due to marketing aspects have in practice a distorted sound response.

Improvement of response could be performed by a feedback filter. Knowledge that is more exact is necessary for this.

3. External Noise

We have measured Insertion Loss of the car frame too. One of the microphones had been mounted at the driver's ear, the other 2 metres far from the car. The result: with windows up, difference is 15 – 20 dB until 1600 Hz, increasing to 50 dB at 10000 Hz; with windows down, frequency-dependent fluctuation of noise pressure level difference is 15 – 20 dB in the entire frequency range

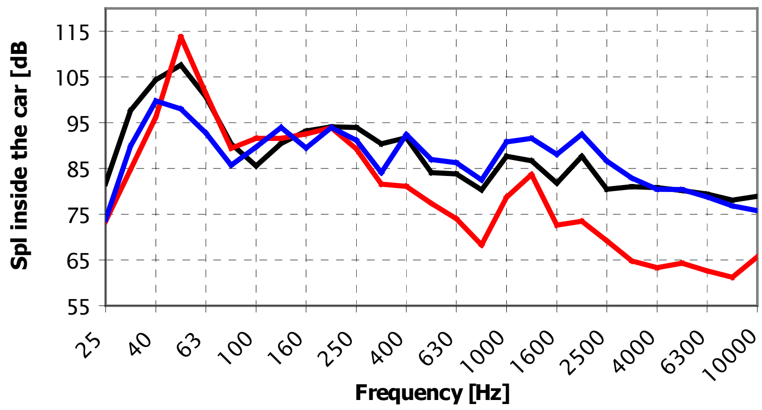


Fig. 3. Frequency dependence of internal noise pressure level while listening to a track of Classic ; Pop ; Techno music

That means, with windows down, noise pressure level is still 90 dB 2 metres far from the car.

In Hungary and the EU-countries, measurement and evaluation of noise load from vehicles is regulated by the prescription No. E/ECE/324; E/ECE/TRANS/505/rev.1/Add.50/Rev.1 published by UN – EGB on 11th March 1996. Vehicle should pass along the entire measurement section at a constant 50 km/h, in 4th gear. We have performed measurements of two kinds: standard passing-by measurement with sound system off and sound system set to maximum volume.
Considering the fact that standard A-filter is primarily for measurements close to subjective sense but subjective sense of musical sounds can significantly differ from this, it is worth to examine third-band resolution, apart from standard dB(A) and dB(C)-filter evaluation which considers low-frequency components more. It can be mentioned in advance that standard dB(A) won't show the significant difference between the three passings-by. It should be noted hereby that in our subjective opinion, hardly-differing noise pressure levels with the standard A-filter do not point clearly out acoustic conditions affected by the music. Thus, we have transformed third-band values into Sone, based on ISO 532 B, with Zwicker's outdoor loudness calculation.

	no music	max. music	max music windows down
Sone (Gf)	**29,9**	**38,5**	**40,1**
dB(A)	**72,9**	**74,9**	**75,1**
dB(C)	**74,8**	**81,2**	**83,7**

Maximum noise pressure from vehicle passing by, in dB(A), dB(C) and loudness

The table clearly shows that dB(A) gives no suitable results in this case. Sensing difference between the three experiments is best shown of course by loudness expressed in Sone. With this linear value it is obvious that passing-by peak level of vehicles originally also noisy increases by + 35% with Hi-Fi on and windows down.

Nevertheless, basis of environmental judgement is the equivalent noise pressure level A. We have measured only 2,5 dB(A) difference between equivalents of passings-by. Siófok's noise map had been prepared based on these data. Siófok is one of the entertainment centres of Lake Balaton in Hungary, it is no wonder therefore that residents living by discos feel disturbed by car-stereoed cars heading for the discos.

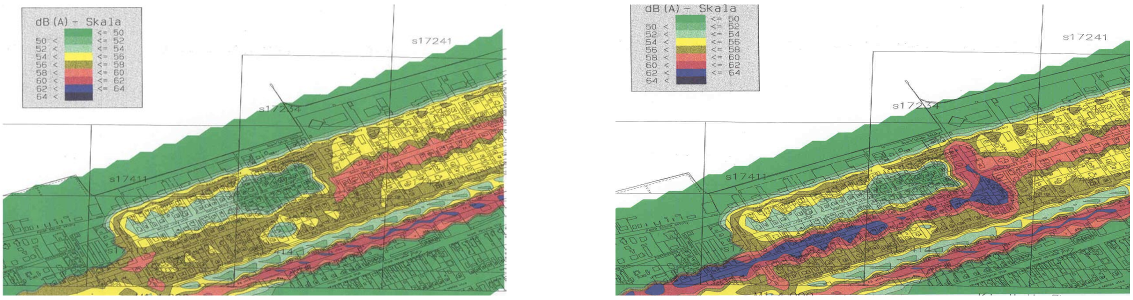


Fig. 4. Noise map of Siófok with and without car stereo

Noise maps show 8-hour night equivalent with and without car stereo. It is clear that in streets leading directly to discos increase is + 6 dB (A).

It should be noted that noise level is 58 dB(A) without car stereo and 64 dB(A) with it. This 6 dB(A) increase is very important because subjective acoustic shows a sudden noise-perceiving increase around 60 dB. While one feels no significant difference between 40 and 46 dB(A), noise is felt many times more disturbing between 58 and 64 dB(A).

Conclusions

We have shown by measurements that in an average car, no good-quality sound response can be obtained with presently sold equipment labelled as Hi-Fi. Primary causes of this are high internal noise level of average vehicles, artificial low-frequency increase of car frame and/or sound chain and significant dependence of car frame's noise space on location.
Typical vehicles cause significant environmental noise load increase even with windows up and presently this is not regulated by any standard, prescription or limit value. Until international or local prescriptions limiting environmental noise of car-built sound systems, any improvement can be obtained only by individual fairness.

References

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