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EFFECTIVE IMPLEMENTATION OF BRAND SOUNDS IN EXCLUSIVE PASSENGER CARS

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ABSTRACT

A distinct brand sound is one important aspect in selling exclusive passenger cars. Such a brand sound has to be defined on the one hand via customer expectations which are different for different world markets. On the other hand, the implementation of a once desired brand sound into the vehicle requires extensive knowledge how this brand sound has to be composed and how this composition can be transferred into the relevant hardware modifications in the vehicle. In this paper the procedure of tailor made compositions of interior sounds and their implementation by the necessary changes to the powertrain will be discussed and presented.

1 - INTRODUCTION

The interior sound of a passenger cars becomes a more and more important marketing aspect for increasing the market share of its own brand. The success of one particular vehicle on the market depends how well the sound fits the customer expectations. This particular sound has to be provided in the process of the acoustic development of the car. Here two aspects are of great importance:

- To assess correctly the customer expectations with respect to brand sound of a certain vehicle.
- To provide the required tailor made interior sound very effectively by predictable hardware modifications in the development process.

The first aspect can be covered by statistical evaluations of customer preferences by using questionnaires, listening sessions, etc. The second aspect has to be based ideally on an objective description of vehicle interior sound. From such a basis it is then possible to develop a software procedure for the exact definition of the required composition of the perceived interior sound which will be readily accepted as the preferred brand sound by the relevant vehicle buyers. In this paper both aspects will be covered to describe a comprehensive approach to the subject of publication.

The objective description of the subjectively perceived noise quality has been developed at AVL starting 10 years ago [1, 2, 3]. The subject of this former R&D work was the objective description of the airborne sound radiated from I.C. engines. Based on the Know-How gained during this R&D work a software tool for the objective description of passenger car interior noise quality has been developed in recent years [4, 5]. Since a particular brand sound is today still of more importance for exclusive passenger cars than for normal passenger cars, additional R&D work has been performed to cover the aspects of assessing customer expectations [6, 7] and to obtain an objective description of the interior sound by a software tool for sports executive cars and luxury cars [8]. In parallel an objective description of the optimum composition of a brand sound for sports cars was developed [9].

For the work mentioned above, the subjective assessment of vehicle interior sound by selected and reliable assessors is of maximum importance. Contrary to assessments on the road the assessments in the laboratory depend in parallel to the quality of the replay system also on the quality of the vehicle interior noise recording system [6], [10]. Some additional R&D work was in parallel performed on this

subject by AVL [11, 12] in recent years, to improve the results of the subjectively perceived noise quality by the assessors in the laboratory as far as possible.

The final step, how to define the optimum composition of the interior noise spectrum and how it can be derived and consequently implemented into the vehicle by hardware modifications to provide a well perceived brand sound by the car buyers will be discussed in the following chapters.

2 - ASSESSMENT OF CUSTOMER EXPECTATIONS WITH RESPECT TO A BRAND SOUND

For a valid objective description of vehicle interior sound the subjective perception of the individual drivers of such classes of passenger cars must be obtained as a basis for further correlation with psychoacoustic parameters. For establishing a database of the subjective perceptions of exclusive cars such as luxury cars, sports cars and sports executive vehicles the individual feelings of the driver stereotypes of such cars concerning vehicle acoustic features have to be analysed in detail. For such an analysis not the predetermined opinion of acoustic engineers will lead to useful results, only a basic survey of the needs of the vehicle buyers and owners will produce a realistic basis for further R&D work [7]. This has been performed within our R&D work by a large market survey in Austria, where the interaction of the subjective perceptions of different driver stereotypes with respect to general and acoustic vehicle features for different vehicle classes and vehicle brands have been obtained. In this market survey an evaluation of the preferences of a large number of Austrian vehicle owners (317 persons) was performed. This work task was designed together with the Institute of Applied Statistics from Joanneum Research [7]. After a number of test trials a questionnaire was produced for obtaining the drivers preferences. To suit this work, a large number of "prestige" car owners was included in the survey. Apart from enquiring on a number of other personal vehicle aspects, 23 questions were asked which contributed to the evaluation of the drivers preferences also for acoustic aspects. Out of the 317 tested Austrian passenger car owners, 269 persons were men, 48 were women. The first aspect we realised was, that the women did produce different results than the men [7, 8]. However, the number of 48 women is quite small to produce statistically valid results. Six main vehicle attributes and five main clusters of driver stereotypes (out of 269 male test persons) could be found and extracted by statistical methods. The clusters obtained consisted of 39 to 68 drivers, which is a number large enough to establish statistically reliable results [7, 8]. The results shown in Fig. 1 are an overall view of one important result obtained by the statistical evaluation of the 269 individual questionnaires produced by men. This figure shows just the main trends, individual results behind these trends are very valuable and useful, however, due to restricted space they are not further discussed in this article.

The 5 different driver stereotypes are grouped by the different importance's of the six main vehicle attributes. The main vehicle attributes are extracted from the overall data by factor analysis. Cluster 1 of Fig. 1 is described by the dominance of family aspects. In this cluster mid-class cars, mostly diesel powered are preferred. The persons in Cluster 2 have a high emotional interest on cars, but not always the financial background to buy their most preferred vehicle. This cluster is mostly made up of younger men who prefer, strongly, certain vehicle brands and reject other brands in their emotional view. Cluster 3 can afford luxury vehicles. These men drive the most miles per year, are mostly older men and buy new luxury cars. For Cluster 4 low cost is very important. In this group mostly used cars are bought and sub-compact vehicles are preferred. For Cluster 5 convenience is most important followed by family aspects.

For the objective description of a brand sound for luxury vehicles the opinion of the men from cluster 2 and cluster 3 are most important. The cluster 2 men are emotionally very interested on a brand sound, the cluster 3 men have the financial background to afford the vehicle with their required brand sound.

Out of the clusters 2 and 3 (Fig. 1) with 54 and 68 persons each, the representative assessors of such vehicles are now available. The next step we performed was the subjective evaluation of luxury cars, sports cars and sports executive vehicles with respect to their optimum brand sound on the road and in the laboratory [8, 9].

Furthermore, we observed, that using very detailed acoustic aspects to describe interior sound does not produce useful results. The test series are getting too complicated for the test persons (also for cluster 2 and 3). This is shown in one example in Fig. 2 where sports car interior sound was assessed by 22 selected test persons for 9 different sound attributes at 2 acceleration conditions especially for sports cars. As can be seen from Fig. 2 only for the two attributes (out of 9) "solid sound" and "powerful sound" some reasonable correlation could be found for most of the cars [13].

These results might seem unrealistic for acoustic engineers because such vehicles are usually described by a combination of a number of acoustic aspects. However, for a subjective evaluation by the vehicle owners

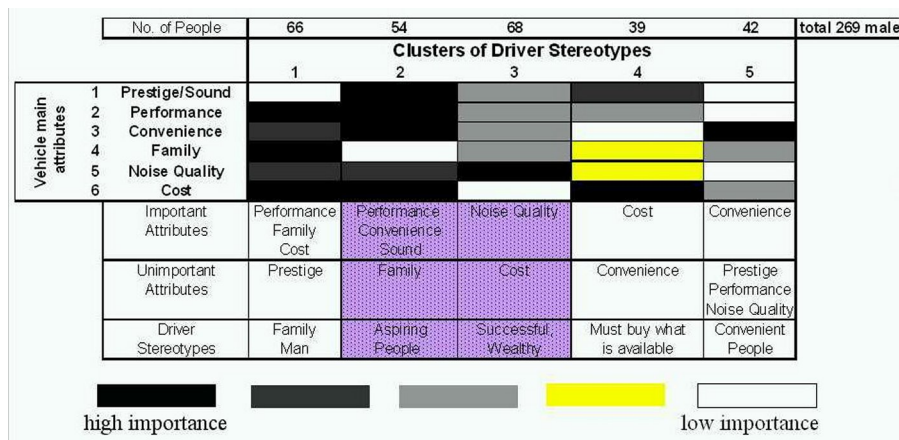


Figure 1: Results of a survey of Austrian passenger car owners with respect to driver stereotypes versus passenger car attributes (269 male test persons).

which evaluate their cars on the road only, such a combined description by different positive acoustic aspects will not deliver statistically reliable data since their individual understanding and perception of these aspects has been found in our work to be individually different. One reason for this is, that for each assessor the optical sense, the feeling sense and the hearing sense, together with a very emotional view for such luxury cars, are in competition with each other when assessing an accelerating luxury car on the road. The different acoustic aspects are perceived individually different according to the different strengths and contribution of their personal senses to the complete subjective perception and are therefore assessed in a different manner. A further aspect resulting from the above thoughts is how to arrange these individual aspects to each other for an assessment purpose. Each individual person will prefer for each single assessment the different acoustic aspects in some individual characteristic location and magnitude to each other. For other people only one or two of these characteristics will be important. Therefore, the number of acoustic aspects and their magnitude and location to each other is likely to be different nearly for every individual test person [6], [8, 9].

Vehicle	solid	powerful	rough	low frequent	roaring	engine dominate	growling	metallic harsh	harmonic balanced
Sports Car 1									
Sports Car 2									
Sports Car 3									
Sports Car 4									
Sports Car 5									
Sports Car 6									
Sports Car 7									
Sports Car 8									
Sports Car 9									
Sports Car 10									
Sports Car 11									

Figure 2: Magnitude of the correlation between the sporty sound character and 9 sound attributes for 11 sports cars and 2 acceleration conditions.

In order to produce reliable and useful subjective results as a basis to describe an interior sound or single aspects of the overall sound by objective numbers one possibility is to evaluate one or two single aspects at the same time (like e.g. sportiness) [9]. Such results have been presented in [8, 9]. One of these result is shown in Fig. 3 for 11 sports cars at three different driving conditions. The subjective evaluations of such cars on the road and in the laboratory produced different results for the reasons discussed before [8, 9]. The difference could be explained and can be evaluated from other vehicle data [9].

3 - OBJECTIVE DESCRIPTION OF INTERIOR SOUND BY PSYCHOACOUSTIC PARAMETERS

Using regression analysis [4, 5] the most significant objective parameters describing the subjective perception of interior sound attributes can be determined [8, 9]. Some of these objective parameters had to be established from scratch by AVL, since most known parameters from literature did not fit the subjective impressions to an adequate extend. The description of certain sound aspects of luxury cars, sports

cars and sports executive vehicles has been found to be quite complex. It is dependent on vehicle acceleration performance, frequency range, "combination of relevant engine orders" (CEO) and the "ratio of engine orders to background noise" (REO). As an example the equations for the objective description of sportiness and luxury for sports executive cars and can be written as [8]:

$$\text{Sportiness} = f\left(CEO, REO_{sport}, \frac{\Delta rpm}{\Delta t}\right) \quad (1)$$

$$\text{Luxuriosity} = f(\text{BandpassLoudness}, REO_{Lux}, \text{NoiseQualityIndex}) \quad (2)$$

With these formulas which describe objectively the above aspects of the interior sound character, the time consuming subjective evaluation procedure of vehicle interior sound by test persons can be replaced very effectively by a software tool. However, which is much more important, the optimum sound aspects can be calculated now and from their individual psychoacoustic parameters the optimum composition of engine orders, the necessary background noise level etc. can be evaluated. From this knowledge the relevant hardware modifications on the intake and exhaust system and other vehicle and engine components can be designed and applied successfully.

A similar description has been found for the aspect sporty in pure sports cars [9].

The relevant objective parameters as derived for this class of cars are:

- engine order to noise ratio (ONR) within a frequency band of the dominant engine orders
- tonality parameter (TP)
- and an AVL-engine speed parameter (ESP)

The optimum combination of these acoustic parameters describe now the interior sporty sound character to a very large extend with a very high correlation coefficient on an objective basis – see following equation.

$$\text{Interior sporty sound character} = f(\text{ONR}, \text{TP}, \text{EPS}) \quad (3)$$

For a better understanding of all the parameters which define the interior sound it is possible to display the most important areas of interior sound in a frequency – speed map [8]. In Fig. 3 the areas are indicated which are relevant for the aspects powerful and sportiness. The perception of luxury shows up in a larger but similar frequency range than sportiness.

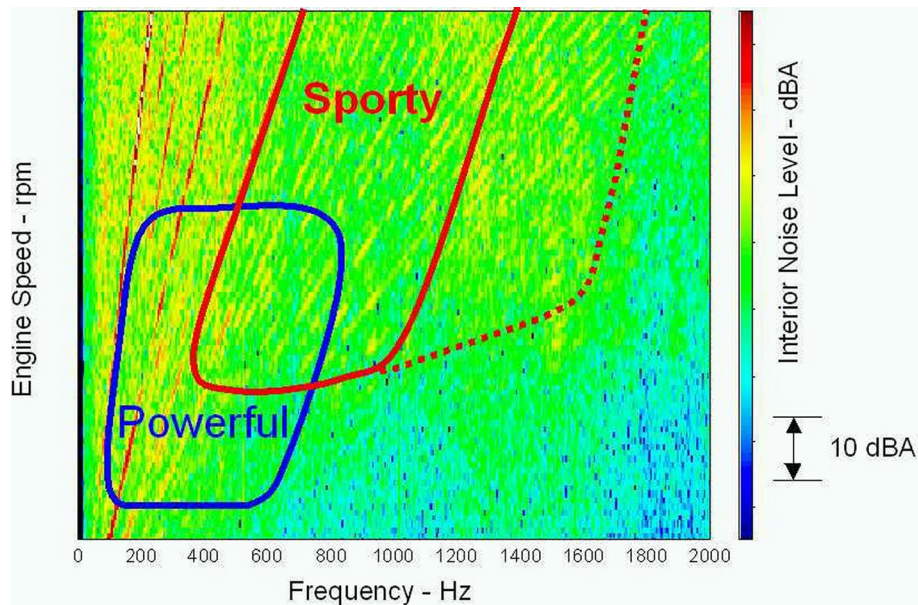


Figure 3: Range of vehicle interior sportiness and powerfulness on an engine speed / frequency map.

It has been found that it is very important that the optimum arrangement and combination of engine orders are a well defined degree above the "background noise level" present in such vehicles. This

background noise level in certain frequency bands has to be extraordinary low in cars which have to transmit mainly a luxury feeling to their occupants since the levels of the optimum combination of engine orders are by 12 to 18 dB lower in such cars as in luxury sports cars.

By knowing the hard facts which are necessary to obtain certain sound aspects like sporty, powerful, luxury, etc. it is now possible to determine from the objective description of interior sound the optimum combination of the distinct engine orders for composing a unique brand sound suiting a special type of vehicle to be positively accepted by its customers.

4 - GENERATING A TAILOR MADE INTERIOR BRAND SOUND BY PREDICTABLE HARDWARE MODIFICATIONS

The magnitude and combination of engine orders necessary to produce the required brand sound can be generated by sound engineering in designing and applying the necessary hardware modifications. They are in the frequency range which can be best influenced by changes to the powertrain mounting, intake and exhaust system in parallel with sound cleaning procedures to reduce "background noise" by the necessary extend.

As one example the improvement of interior sound is demonstrated in Fig. 4. In modifying the composition of engine orders and background noise levels according to equation 1 and 3 the original interior noise level can be slightly reduced in parallel to an improvement of sportiness and powerfulness at the same time. The result is a successful improved interior sound with a reduced interior noise level in dBA, however, representing at the same time a much better sportiness and powerfulness as the original vehicle.

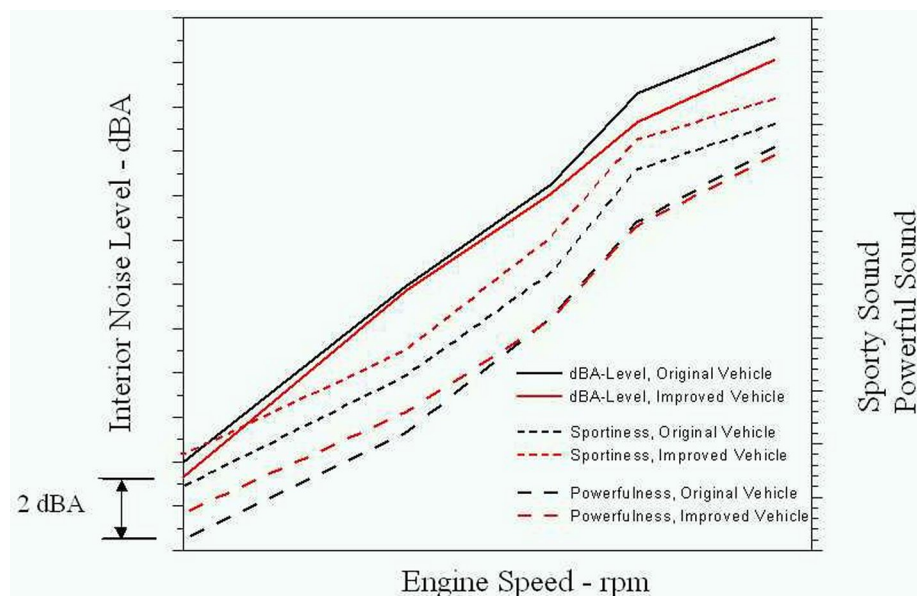


Figure 4: Optimized interior sound at acceleration condition.

A further advantage of the method presented is, that an optimum interior brand sound or noise character can now be artificially created by the use of this software tool for target setting or subjective assessment prior to the necessary and predictable hardware modifications, instead of using current methodologies for interior sound engineering mainly based on trial and error.

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