LEAN TRANSDUCERS FOR ANC APPLICATIONS

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Active resonator silencers are particularly effective in attenuating low-frequency noise, practically applied since more than ten years. The essential electroacoustic components such as loudspeaker, microphone and electronics are moderately priced. But regarding the complete products, such as silencers in ducts of ventilation systems mostly produced in small series, it often leads to uneconomical solutions caused by the costs of the necessary cabinets. Usually the cabinets are manufactured from metal sheets to comply with the requirements of sound insulation as well as to enclose the air volume as one of the crucial resonator elements. In order to reduce the manufacturing expenses small or flat cabinets are required. But a small volume contradicts the performance of the active silencers. Thus, the applicability of lean active silencer was investigated with respect to lean transducers and optimized volume of the cabinets. Starting from the point of an application with standard active resonator cassettes, the specific requirements and restrictions of this type of silencers are presented. The scope of appropriate designed transducers is discussed. A concept of a lean active silencer array is presented together with first prototypes and completed by measurements in terms of noise attenuation.

1. Introduction

A short introduction of the approach of active resonators is given here. Fig. 1 shows the components of an active silencer cassette (ASC), which essentially is a mass-spring system, consisting of the mass of the loudspeaker membrane and the spring provided by the enclosed air volume in the cabinet.

![Figure 1. Left: Set-up and components of an active silencer cassette (ASC). Right: Sound absorption of an ASC at normal incidence.](image-url)
Adding the electro-acoustic components (microphone, electronics) and activating the system by a feedback loop, the effectiveness of the resonator is changed and improved. To describe the activation it is necessary to combine the acoustic and control models and methods\(^1\), as the interaction of the resonator elements is detected and simultaneously influenced by the respective sound field parameters (sound pressure etc.). The frequency range and the absorption are determined by the mechanical and geometrical parameters of the active silencer cassette as well as the electro-acoustic tuning. If the ASC cassette is mounted to an impedance tube and not activated by the electro-mechanical components, we found the typical absorption of a spring-mass system (passive) shown in the diagram of Fig. 1. Activating the electro-mechanical components increases and broadens the absorption (active). In comparison to a porous absorber of same size the efficiency of the ASC at low frequencies is obvious. This basic concept of active resonators with modifications is used in a wide range of practical applications.

2. **Range of application**

Several design variations have already gained practical importance as silencers in technical noise control\(^{2,3,4}\). A typical set-up of ASCs splitter silencers in ventilation systems is illustrated in Fig. 2. Just as splitter silencers or in combination with passive absorber splitters, the ASCs are placed in the ventilation duct.

![Figure 2. Left: Sketch of ASC splitters in a ventilation duct. Right: Insertion loss according to ISO 7235 (position of the ASC detection microphone is varied).](image)

According to behaviour of the splitter silencers the attenuation depends on the gap width between the splitters, but in contrast to porous absorbers the attenuation is increased at low frequencies. This is shown in the diagram of the insertion loss in Fig. 2. Additionally, the insertion loss of a splitter arrangement of the same size but made of porous absorbers is plotted. Furthermore, the attenuation maximum of the ASCs varies with the microphone position: upstream or centre, this tuning is simply done by rotating the cassette along its quadratic cross-section.

![Figure 2.](image)

Driven by the presence of high attenuation at low frequencies the approach of active resonators in ventilation systems was transferred to heating systems. Burners exhibit noise with highest levels in the low-frequency range which is fed into the exhaust line. In order to meet the immission values, silencers for low-frequencies are required. Therefore, an active resonator combined with a porous absorber was developed. This is shown in Fig. 3. The electro-mechanical components are protected by a foil against condensate. To reduce the temperature impact, the loudspeaker is placed in a branch out of flow. The length of this branch determines the resonance frequency with the maximum of attenuation. In Fig. 3, the insertion loss of this silencer is plotted. The effect of the active
resonator at the low frequencies, in the range of 63 Hz, is obvious. At high frequencies the typical behaviour of a porous absorber is evident. With this combination of active resonator and porous absorber an effective compact silencer was designed. But mostly it is applied if other options do not meet the space requirements, despite of the costs of the component.

![Diagram](image)

**Figure 3.** Left: Sketch of a combination ASC and porous absorber. Right: Insertion loss of the combined silencer.

Finally, a project study for building and enclosure walls is presented. Wall constructions contain openings for ventilation and exhaust. The modification of the installation from a straight duct as standard configuration to an active ‘labyrinth system’ is shown in Fig. 4.

![Diagram](image)

**Figure 4.** Left: Installation of active silencers in ducts and at wall openings (comparison) Right: Measured difference of sound insulation of the labyrinth.

The sound insulation between activated and inactivated resonator are compared in the diagram. The elevated sound insulation between 250 Hz and 500 Hz is clearly visible. This is in contrast to the ‘amplification’ at 2 kHz, but if this had any practical importance it could be avoided by means of an extended labyrinth.

Photos of applications of active silencers are presented in Fig. 5. All these products have the assets to increase the attenuation at low frequencies in comparison to porous absorbers with the drawback of the price, which in general is caused by the manufacturing expenses of the cabinets. This price is only accepted in the case of shortage of space.
3. Active silencer arrays

In order to reduce the manufacturing expenses, small or flat cabinets are required. Furthermore, the possibility of application is directly associated with the size of the cabinets. This is obvious in the example of sound insulation, because it is not applicable to place an active resonator silencer outside the wall construction as shown in Fig. 4. Hence, a concept of active array silencer was introduced. Therefore, a standard active silencer cassette with one large loudspeaker and cabinet is separated into several small resonator units, as shown in Fig. 6. At a first glance, the costs for the electro-mechanical components rise, but these are fabricated in a large-scale production with minimum costs at high batch size. Additionally, the production of numerous flat units, with the ability to form any necessary array-geometry, reduces the manufacturing expenses and due to the small size of the cabinets other materials and manufacturing processes can be applied.

In general, a small volume contradicts the performance of active silencers. By use of small loudspeakers nearly the same active area could be achieved, but with less volume velocity due to the maximum displacement of the membranes. Moreover, the resonance frequency of the active resonators caused by the small volumes in connection with the stiffness of the membrane had to be taken into account. Several studies are carried out to find suitable components for this array concept.

4. Design and tests

A set-up for small active resonators was designed. Different selected types of loudspeakers where mounted to small cabinets with outer dimensions of 50x50x50 mm³ (Fig. 7). According to the principle of active resonator silencers the microphone is placed close to the loudspeaker.
For the measurements a test duct with a cross section area of 50x50 mm², noise source and anechoic termination was constructed. The samples of the active resonators are mounted to the test duct. Some porous absorber is placed on the opposite duct side to stabilize the active system. The insertion loss of the active resonators with different loudspeakers is plotted in Fig. 7. As known from the standard ASC, also in the case of small active resonators considerable attenuation can be achieved. Depending on the type of loudspeaker, the insertion loss is at roughly 10 dB, but in a broad frequency range from 125 Hz up to 500 Hz.

Due to these results, the effect of expanding the single unit to a 1-D array was studied. Four active resonators were connected, as shown exemplarily in Fig. 8. Each unit is assembled with microphone and external electronics.

The insertion loss of different array configurations is plotted in Fig. 8. In the case where all resonators are deactivated (all Off), the insertion loss depends only on the porous absorber installed at the opposite side as becomes evident at high frequencies. If one of the resonators is activated (1 On) the attenuation at low frequencies increases. Compared to the measurement of a single unit, less attenuation is obtained. This is caused by the demands for getting a stable array configuration and so the amplification is reduced. By activating the second unit (2 On), the insertion loss rises to about 10 dB and is similar to the single unit configuration, as shown in Fig. 7. Activating the third (3 On) and fourth unit (4 On) further increases the attenuation up to 20 dB. But in this case sound radiation in the range of 800 Hz occurs, which leads to a negative insertion loss. With respect to
high attenuation at low frequencies, the noise radiation at high frequencies could be solved by additional porous absorbers if necessary.

These basic studies of active resonator arrays show that it is possible to connect single units to a 1-D array configuration. Even if the attenuation of the single units had to be reduced to get stable array configurations, considerable attenuation at low frequencies is achieved.

### 5. Conclusion and Outlook

First tests with lean active silencers show that the concept of active arrays seems to be applicable. In the basic approach of 1-D arrays with single active resonator silencers - each unit active controlled – are examined and considerable attenuation at low frequencies is achieved. From the view of manufacturing expenses other materials and manufacturing processes can be applied due to the small cabinets. Uniform components – each unit actively controlled – seem also to be advantageous by the reason of the moderate price of additional electronic components.

But from the point of view of acoustics the question arises, if an advantage is obtained when controlling two or more units by only one microphone, with respect to the attenuation increase. For this aspect, further investigations presently are carried out with a view to optimize structures for 1-D arrays. Also the extension to 2-D arrays will be implemented to find a basic component of an active small volume resonator array in terms of acoustics, manufacturing expenses as well as for practical applications.

### REFERENCES