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ACTIVE CONTROL APPLIED TO FAN NOISE IN A DUCT

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ABSTRACT
Attenuation of fan noise, which contains both random and discrete components, is a difficult problem particularly at low frequencies. In this paper, the solution of this problem in a rectangular duct using a two-channel active noise control system is presented. The simple a low-cost ANC system was based on a standard PC equipped with data acquisition card. Significant attenuation of broadband noise was achieved.

1 - INTRODUCTION
Active noise control methods have been under significant development for 30 years, even though the basic principle of destructive interference was first established by Lord Rayleigh. One of the very first implementations of ANC concerned the subject of attenuation of noise in ducts. In particular, ANC was applied in ducts with narrow cross-section when the noise spectrum was below the cut-off frequency of a duct. Due to the analytical simplicity, the application in a narrow duct is straightforward, and is usually realized as single-channel system.
Above the cut-off frequency, higher-order acoustic modes must be developed. For this case, a multi-channel ANC system containing multiple secondary sources and multiple error microphones would be used. Theoretically, $2N$ secondary sources and $2N$ error microphones are needed to control N propagating modes.

2 - EXPERIMENTAL SETUP
All experiments were done on the experimental rectangular duct with cross-section of 200 ×300 mm and length of 3.5 m located at the Department of Physics at CTU in Prague. The experimental setup is shown in figure 1. The distance between the plane of secondary sources and the plane of error microphones was 17 cm. As secondary sources, the loudspeakers Eminence ME6-758 were used. For testing of the functionality of the ANC system, a loudspeaker placed at the end of the experimental duct driven by a noise generator was used.
The arrangement of the primary loudspeaker, secondary loudspeakers and error microphones is illustrated in figure 2. The dimensions of the duct correspond to cut-off frequency of about 570 Hz.
The controller was realized using a standard PC with a Pentium processor, containing a low-cost acquisition card PC30 PGH with resolution of 12 bits without sample & hold function.
The experiments were performed on a two-channel system. The reference signal was picked up by the reference microphone placed at the beginning of the tube.
The block scheme of the system is given in figure 3. The part in the dashed box represents the numerical control part of the ANC system implemented in the PC. The $G_1(z)$ and $G_2(z)$ are the main noise control filters (because of the two modes). These main noise filters were realized as FIR filters and updated by the two filtered-x LMS algorithms. The updating algorithm can be described by the equations

$$g_1(n+1) = g_1(n) + \mu\left\{[C_{11}(n) * x(n)]\, p_1(n) + [C_{21}(n) * x(n)]\, p_2(n)\right\}$$
$$g_2(n+1) = g_2(n) + \mu\left\{[C_{12}(n) * x(n)]\, p_1(n) + [C_{22}(n) * x(n)]\, p_2(n)\right\}$$

$\boldsymbol{R}_1(z)$ and $R_2(z)$ are the transfer functions representing the D/A converters, filters, amplifiers and loudspeakers. $S_1(z)$ and $S_2(z)$ are the transfer functions representing A/D converters, filters, microphone

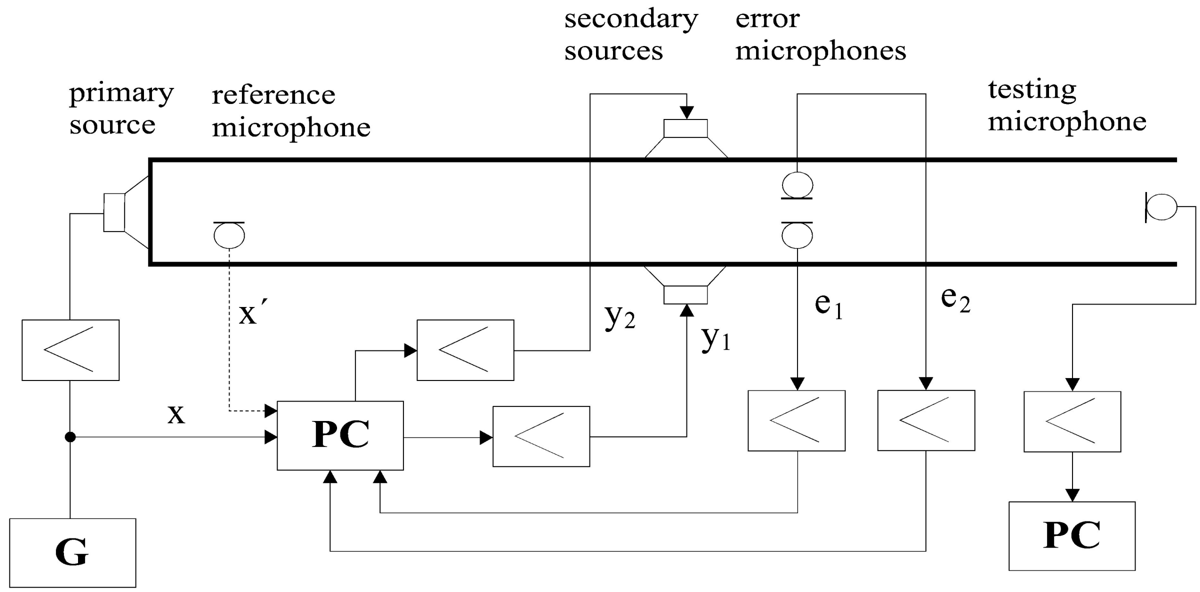

Figure 1: Experimental setup of the ANC system in the duct.

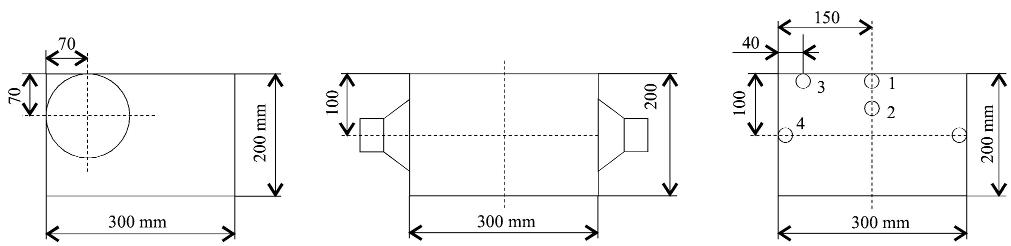

Figure 2: Arrangement of primary and secondary sources and error microphones for a two-channel system.

preamplifiers, and microphones. $P_1(z)$ and $P_2(z)$ are the transfer functions representing the primary acoustical paths from the reference signal $x(n)$ and the sound generated by the primary source in the place of the secondary loudspeaker. $N_1(z)$ and $N_2(z)$ represent the measuring noise.
In the numerical controller, the secondary paths were modeled by FIR filters $C_{11}(z)$, $C_{12}(z)$, $C_{21}(z)$ and $C_{22}(z)$, where

$$\begin{array}{c} C_{11}(z) = R_1(z)\,S_1(z) \\ C_{21}(z) = R_2(z)\,S_1(z) \\ C_{12}(z) = R_1(z)\,S_2(z) \\ C_{22}(z) = R_2(z)\,S_2(z) \end{array}$$

From these equations, it can be seen that the signals from both channels are mixed together.
The acoustical system used was stable in time, so the off-line identification method was employed to calculate these transfer functions. In the experiments described in this paper, the computer-generated MLS signals were used for identification of error paths of the system.
The performance of the system was tested using octave band noise as the primary signal. The primary signal was generated by a loudspeaker driven by white noise filtered by the octave band filters.

3 - SUMMARY

The two-channel feed-forward adaptive ANC system in a duct has been examined in this paper. This system was designed to suppress broadband noise propagating in rectangular duct above the cut-off frequency assuming first cross-mode. Thanks to the dimensions and construction of the actual duct, the experiment was intended to simulate a workable method of noise suppression in air-conditioning systems. The experiments were successful in achieving a global attenuation of broadband noise up to 20 dB. It can be assumed that the present system shows great promise, in particular because of its low cost and potential for further development.

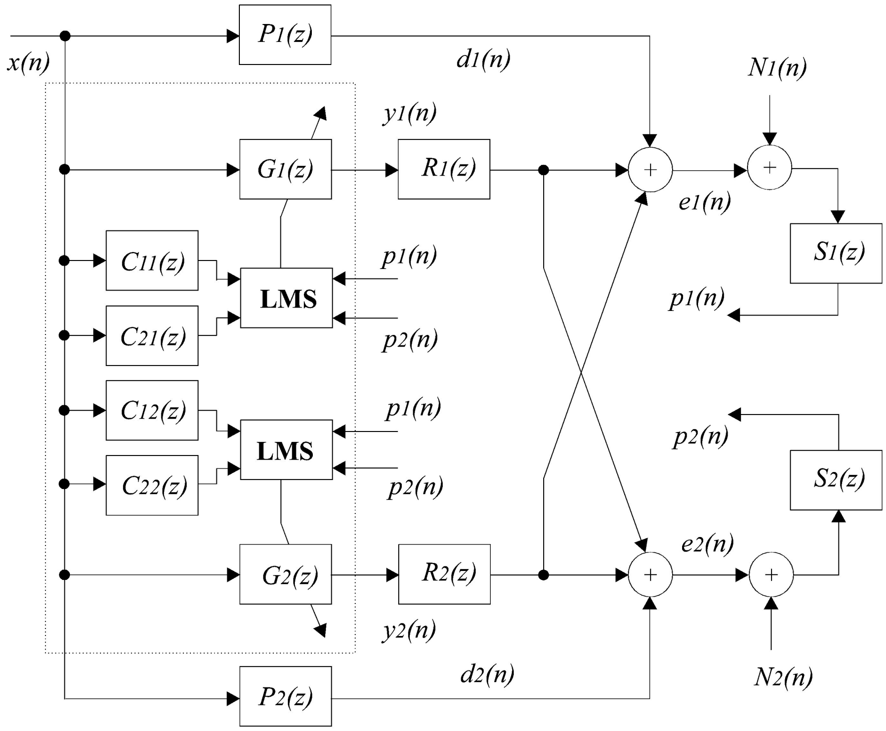

Figure 3: Block diagram of the two-channel system.

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REFERENCES

1. **S.M. Kuo**, *Active Noise Control Systems - Algorithms and DSP Implementation*, John Wiley, 1996

2. **O. Jiricek, P. Konicek**, Application of Methods of Acoustic Feedback Compensation, In *Active'99*, pp. 961-972, 1999

3. **O. Jiricek, P. Konicek**, Adaptive Feed-forward Control of Broadband Noise, In *Inter-Noise 99*, pp. 675-678, 1999

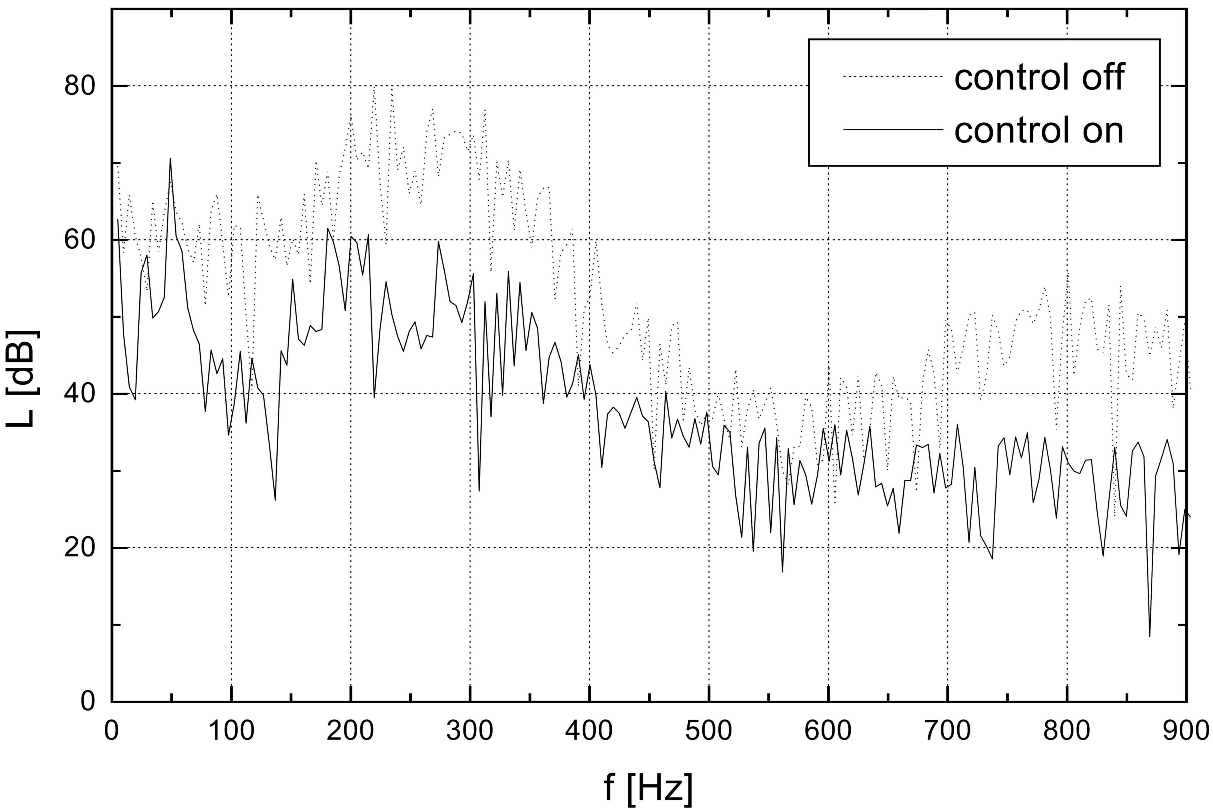

Figure 4: Typical performance of the ANC system with reference signal from microphone.