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Design of Active Noise Control System Applied to Helicopter Cabins

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ABSTRACT

The high low-frequency tonal noise in the helicopter cabin has strongly negative influences on safety, personnel mind and body health of the pilots and passengers. In order to control such type of noises, an active noise control (ANC) system is developed for a mock-up of the helicopter cabin. The presented ANC system is divided into three parts: acoustic signal inputs, SMJ320C6415 DSP based active control algorithm implementation, and the generation of secondary sound sources. The main characteristics for the active controller are given by (1) power supply with DC 27V, 500W, (2) 14 error signal channels and 16 secondary signal channels, (3) 2 reference signal channels, and (4) total weight of 15kg (including microphones and speakers). Finally, a series of experiments within a helicopter cabin mock-up are carried out using the designed active control system. It is shown from the experimental results that the active control system can operate smoothly and steadily.

Keywords: Helicopter Cabin, ANC, FxLMS algorithm, DSP, FPGA

1. INTRODUCTION

The high low-frequency tonal noise in a helicopter cabin has strongly negative influences on safety, personnel mind and body health for the pilots and passengers. To control such type of noises, the FxLMS algorithm has been studied theoretically for a long time and excellent results have been achieved, but no such practical ANC system has been used in the helicopter cabin. This study aims to develop an ANC system that can be applied to such a field. Such a system is firstly designed to apply into a mock-up of the helicopter cabin, and then it will be used in a real cabin. Batches of experiments within a mock-up of helicopter cabin are carried out using the designed active control system. It is shown from the experimental results that the active control system can operate smoothly and steadily.

2. SYSTEM HARDWARE DESIGN

2.1 Requirements

To achieve a good performance on the given cabin, the overall requirements on the ANC system is given in detail on the basis of the cabin structure and dimension, which are shown as follows

(1) Error signal: 14 channels;
(2) Accelerated velocity of the helicopter: 1 channel;
(3) Rotary velocity of the airfoil: 1 channel;
(4) Secondary sound: 16 channels and the power of each channel is more great than 20W;
(5) Switched on/off automatically the ANC controller;
(6) Upgraded or updated automatically the active control software; Total weight: 15Kg.

2.2 Hardware Scheme

The block diagram of ANC system is shown in Figure 1, and it is divided into 5 modules presented in different filled pattern and color according to modularization design. They are (1) the front-analog

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conditioning module consisting of the analog signal conditioner and A/D converter; (2) ANC controller module comprising of DSP, Flash-RAM and FPGA; (3) the secondary signal source with D/A converter and signal reconstruction conditioner; (4) the power amplifier.

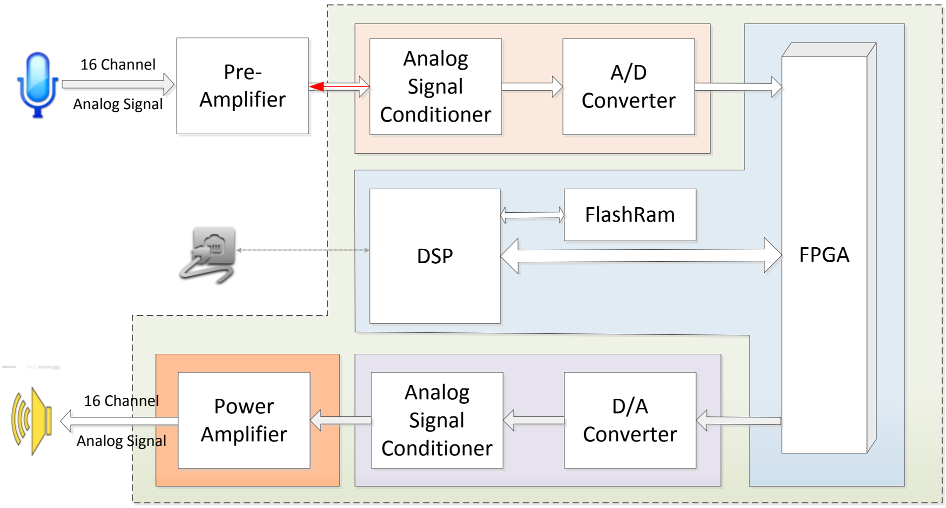

Figure 1 – The block diagram of ANC system

2.3 Key chips and its performance

Whether the ANC system can run real-time is depended on the performance of the key chips. The DSP is the most important chip in this system which must meet the performance requirement and temperature grade meanwhile. So we choose the SMJ320C6415 as the DSP after comparing all available DSPs. SMJ320C6415 is highest-performance fixed-point DSP in military grade and its performance reaches to 4800 MIPS, and its on-chip memory size is 8M-Bit RAM and additional 128K-Bit program cache and 128K-Bit data cache. SMJ320C6415 can almost run all programs and calculates all data in the largest on-chip memory without frequently accessing data stored in off-chip memory, so extremely eliminates the access time and promotes its efficiency. Another key chip is FPGA that play important role in the ANC system, which is responsible for the system timing and logic implement include interface between peripheral and DSP. In addition, the FPGA can perform some digital signal pre-processing, such as filtering, down-sampling. Therefore we adopt EP3C120F484 as FPGA in the system which has 119088 logic element, 3888K-Bit memory and 288 embedded multiplier, and an embedded multiplier is configured as either one 18 × 18 multiplier or two 9 × 9 multipliers. Due to the abundant hardware resource, the EP3C120F484 is fit for digital signal process.

3. ADAPTIVE ANC ALGORITHM

The goal of the ANC system is to produce an "anti-noise" that attenuates the unwanted noise in a desired quiet region using an adaptive filter. A conventional adaptive algorithm such as the LMS algorithm (1) is likely to be unstable in this application due to the phase shift (the delay) introduced by the forward path (2). The well-known Filtered-XLMS (FxLMS) algorithm is, however, an adaptive filter algorithm which is suitable for active control applications (3). It is developed from the LMS algorithm, where a model of the dynamic system between the filter output and the estimate, i.e., the forward path is introduced between the input signal and the algorithm for the adaptation of the coefficient vector (3,4). So in this system, we apply FxLMS algorithm to active noise control.

4. TEST AND VERIFICATION

There is no opportunity to verify the performance of the ANC system in a real helicopter cabin, so we build up a mock-up of helicopter cabin as Figure 2 refer to the given cabin in structure and size (5). Firstly stimulate the noise field in mock-up of helicopter cabin according to the real noise power distribution and spectrum characteristic shown Figure 3. Then optimize the position of the microphones and loudspeakers according to batches of the experiment. The final experiment results are shown in Figure 4~7.

Figure 2 –The mock-up of helicopter cabin

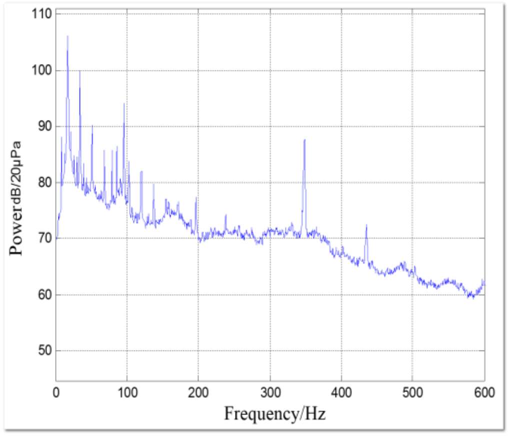

Figure 3 – The noise spectrum characteristic

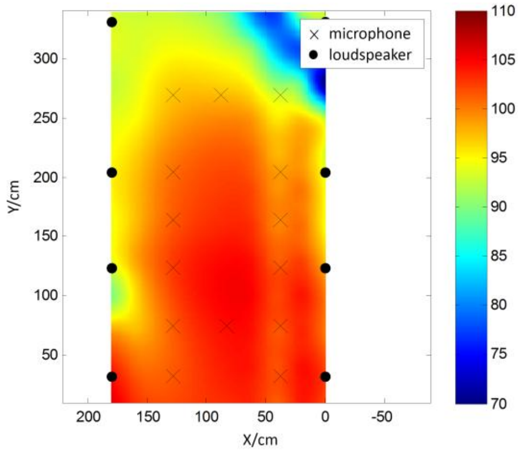

Figure 4 –The noise power distribution (ANC off)

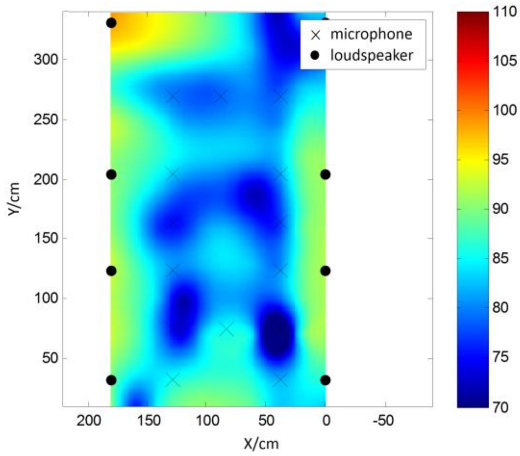

Figure 5– The noise power distribution (ANC on)

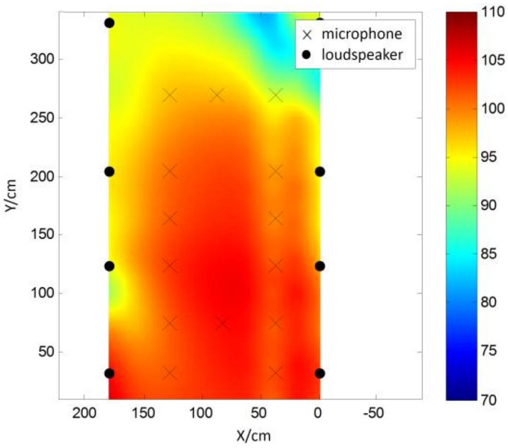

Figure 6 –The noise power distribution (ANC off)

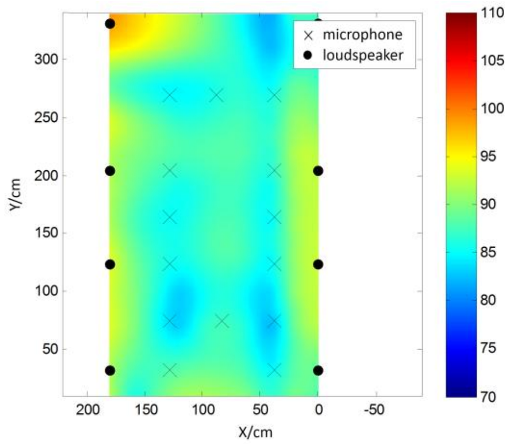

Figure 7– The noise power distribution (ANC on)

Figure 3 tells us that the noise almost is low-frequency tonal noise and the noise power can reach up to 90dB at some frequency, such as 350 Hz and 96 Hz. Both Figure 4 and Figure 7 show the noise power distribution in different conditions in the mock-up of cabin whose head is up. Here, "×" indicates the microphone position, and "." indicates the position of loudspeaker. Figure 4 shows the result that when ANC system is turn off and only 96Hz noises take effect. Figure 5 shows the result that while ANC system is turn on at the same noise background as Figure 4. Figure 6 shows the results that when the ANC system is off and all noise take effect. Figure 7 shows the result that while ANC system is on at the same noise background as Figure 6.

Comparing Figure 4 with Figure 5, it is obviously known that the noise power is suppressed down more than 13 dB at 96Hz; Comparing Figure 6 with Figure 7, it is shown that the total noise power is reduced more than 10dB.

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