UNIVERSITI PUTRA MALAYSIA

SACTIVE NOISE CONTROL TECHNIQUE APPLICATION IN AIR CONDITIONING DUCTS

ALOYSIUS DECRUZ

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ACTIVE NOISE CONTROL TECHNIQUE APPLICATION IN AIR CONDITIONING DUCTS

By

ALOYSIUS DECRUZ

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

March 2009

DEDICATION

To my wife Juno and to my daughter Shalini

Abstract of thesis presented to the Senate of Universiti Putra Malaysia
in fulfillment of the requirement for the degree of Master of Science

ACTIVE NOISE CONTROL TECHNIQUE

APPLICATION IN AIR CONDITIONING DUCTS

By

ALOYSIUS DECRUZ

March 2009

Chair: Associate Prof Ir. Nor Mariah Adam, PhD

Faculty: Faculty of Engineering

Active Noise Control (ANC) is a technique for reducing noise by destructive interference of noise sound wave by out-of-phase secondary sound wave. In air conditioning installations, high frequency noises are effectively attenuated by porous-structured medium; but the low frequency noise produced by the fan needs a more sophisticated approach. An algorithm, ‘Hardware-Tuned Feedback ANC (HTFA)’, has been developed to implement the ANC technique for the noise reduction application in an air conditioning duct element, where Digital Signal Processing is used to sample noise and produce a complete anti-phase noise produced by the HTFA algorithm. Typical blade pass frequency in the vicinity of 100 Hz require sampling frequency of minimum twice that value. A 600 MHz fixed point Digital Signal Processor (DSP) from Texas Instrument, TMS320C6416DSK, is used to generate a secondary sound field by using an adaptive algorithm of Least Mean Square (LMS) principle for convergence. A duct section is used for the experiment and the effectiveness of low frequency attenuation by the secondary sound field is measured. Low and medium frequency tonal noises of octave bands 63 Hz – 1000 Hz were tested, low frequency below 250 Hz being the range of interest. Optimum frequency values for which ANC is more effective are determined. It was found that Active Noise Cancellation is effective at 63 Hz and 125 Hz. This is a simple, economic and effective method for noise cancellation compared to existing feed-forward software tuned method.

Abstrak tesis yang dikemukakan kepada Senat Univerisiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

ACTIVE NOISE CONTROL TECHNIQUE

APPLICATION IN AIR CONDITIONING DUCTS

Oleh

ALOYSIUS DECRUZ

Mac 2009

Pengerusi: Associate Prof Ir. Nor Mariah Adam, PhD

Fakulti: Fakulti Kejuruteraan

Kawalan hingar aktif (ANC) adalah teknik mengurangkan hingar oleh gangguan yang memusnahkan gelombang hingar oleh gelombang hingar sekunder yang berada di luar-fasa. Di tempat penyamanan udara bangunan, hingar frekuensi tinggi secara efektif ditipiskan oleh bahantara struktur berongga; tetapi hingar frekuensi rendah yang dihasilkan oleh kipas memerlukan pendekatan yang lebih canggih. Algoritma ‘Hardware-Tuned Feedback ANC (HTFA)’ sudah diperkembangkan untuk melaksanakan teknik ANC untuk penerapan penurunan hingar di elemen salur penyamanan udara. Pemproses Isyarat Digital dipakai untuk meninjau hingar dan untuk menghasilkan kontra-hingar diperhitungkan mengikut algoritma HTFA. Frekuensi laluan bilah(blade pass) yang tipikal di sekitar sebanyak 100 Hz memerlukan meninjau frekuensi minimum dua kali nilai itu. Sebanyak 600 MHz Pemproses Isyarat Digital dengan titik tertentu dari

Texas Instrument, TMS320C6416DSK, telah digunakan menjana lapangan hingar sekunder dengan menggunakan algoritma Least Mean Square (LMS) sesuai. Sebahagian salur telah digunakan untuk ujian dan keberkesanan attenuasi pada frekuensi rendah disukat. Hingar tonal frekuensi rendah dan sederhana dalam band octave 63 Hz – 1000 Hz telah diuji, frekuensi rendah di bawah 250 Hz menjadi julat kepentingan. Frekuensi Optima untuk ANC yang efektif telah ditentukan pada 63 Hz dan 125 Hz. Kaedah ANC ini amat mudah, murah tetapi berkesan untuk melenyapkan hingar secara aktif berbanding dengan kaedah menalakan feed-forward yang ada.

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Thanks to my fellow students Farayi for reminding me on the dates and helping me to review my thesis. Thanks to Thina for convincing me not to quit. Big thanks to all my young classmates at UPM for accommodating this ‘elderly’ man in the class and not showing the difference.

Deep gratitude is expressed to my wife, Juno, for reminding me time and again that how simple it is if we start from basics and to my little girl Shalini for lending her eraser and reminding me that ‘grown-ups are not supposed to make mistakes anyway’.

I certify that a Thesis Examination Committee has met on 26 March 2009 to conduct the final examination of Aloysius D'cruz a/l Joachim Decruz on his thesis entitled "Active Noise Control Technique Application in Air Conditioning Ducts" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

Members of the Examination Committee were as follows:

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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Date: 9 July 2009

DECLARATION

I declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

ALOYSIUS DECRUZ

Date: 14 May 2009

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LIST OF ABBREVIATIONS

Abbreviation	Full form
AHU	Air Handling Unit
AIC	Analogue input circuit
ANC	Active Noise Control
CCS	Code Composer Studio
codec	Coding and decoding
CPLD	Complex programmable logic device
DIP	Dual In-line Package
DMA	Direct memory access
DRAM	Dynamic random access memory
DSK	DSP starter kit
DSP	Digital Signal Processor
EMIF	External Memory Interface
FIR	Finite Impulse Response
FXLMS	Filtered X Least Mean Square
GI	Galvanized Iron
HPI	Host Port Interface
IAQ	Indoor Air Quality
IL	Insertion Loss
JTAG	Joint Test Action Group
LED	Light emitting diode
LMS	Least Mean Square
McBSP	Multi-channel Buffered Serial Port

MIPS	Million instructions per second
MSE	Mean Square Error
RPM	Revolutions Per Minute

CHAPTER 1

INTRODUCTION

It is a well established fact in our industrialized age, that noise is regarded as an environmental pollutant. With the improved quality of life, a change of attitude is perceived on the level of the population, by which, the noise emitted by motor vehicles, trains and planes is becoming less and less tolerable. New regulations have also evolved to control and regulate the sound levels in indoor and outdoor facilities [e.g. Air Conditioning and Refrigeration Institute 2001- ARI-370-2001 and International Organization for Standardization 1993 - ISO Standard 9613-2, 1993-06-01]. Such and similar regulations underline the importance of creating quiet zones.

In many industrial applications noise radiated by machines is a persistent problem as indicated in the ‘Factories and Machinery [Noise Exposure] Regulations, 1989’. Consequently, many noise control methods have been developed including; (a) methods based on absorbing the sound energy into a porous medium, and (b) methods based on isolating the sound source by the insulation along the noise propagation path. These methods are generally known as passive noise control methods. Although a number of successful applications of these methods have been reported (Guckelberger, 2000) a number of limitations have been identified. For example, the noise reduction capability of acoustical material is effective only at middle (such as 1000 Hz) and high frequencies and due to the high reflection and high transmission properties*.* ***It is the low frequency noise which is a serious engineering problem*** (Gelin, 1997).

1.1 BACKGROUND

Air conditioning plants generate substantial noise. Of particular nuisance is noise produced by the Air Handling Unit [AHU] which is easily guided to the occupied space through air conditioning ducts. The return duct also provides an easy passage for the noise. Figure 1.1 illustrates various paths of noise propagation in an air conditioning installation (Trane Engineers Newsletter, 1996).

The range of sound frequency audible to human is 20 Hz – 20000 Hz (Sharland, 1990). This range is divided in a logarithmic scale into bands which are called octave bands. The octave bands are identified by their mid-frequency values. The octave bands that are used normally in acoustic calculations are 63Hz, 125 Hz, 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz and 8000 Hz. Of this 500 Hz -1000 Hz are considered medium frequencies which include most part of the human voice. Frequencies below them are called low frequencies and those above are called high frequencies.

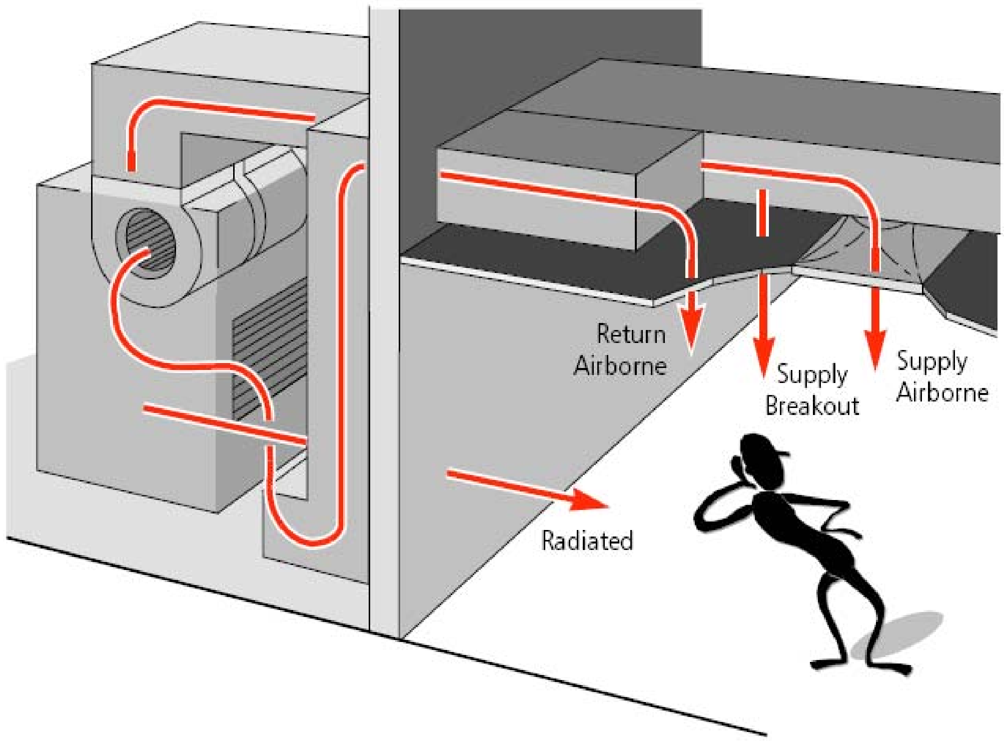

Figure 1.1. Typical Noise Paths between an Air Conditioning System Installation and Occupied Space (Trane Engineers Newsletter, 1996)

The high frequency noise is easily attenuated by static acoustic attenuators or "Sound Traps" as known in US literatures (ASHRAE Handbook HVAC Applications, 2007). The technology involves introducing textile like porous structures in the passage way of sound which introduces high impedance for the high frequency [short wavelength] sounds. A typical attenuator has less than 10 dB insertion loss [IL] for frequencies below 125 Hz as shown in the performance characteristic in Figure 1.2 (Meisseur, 2003)

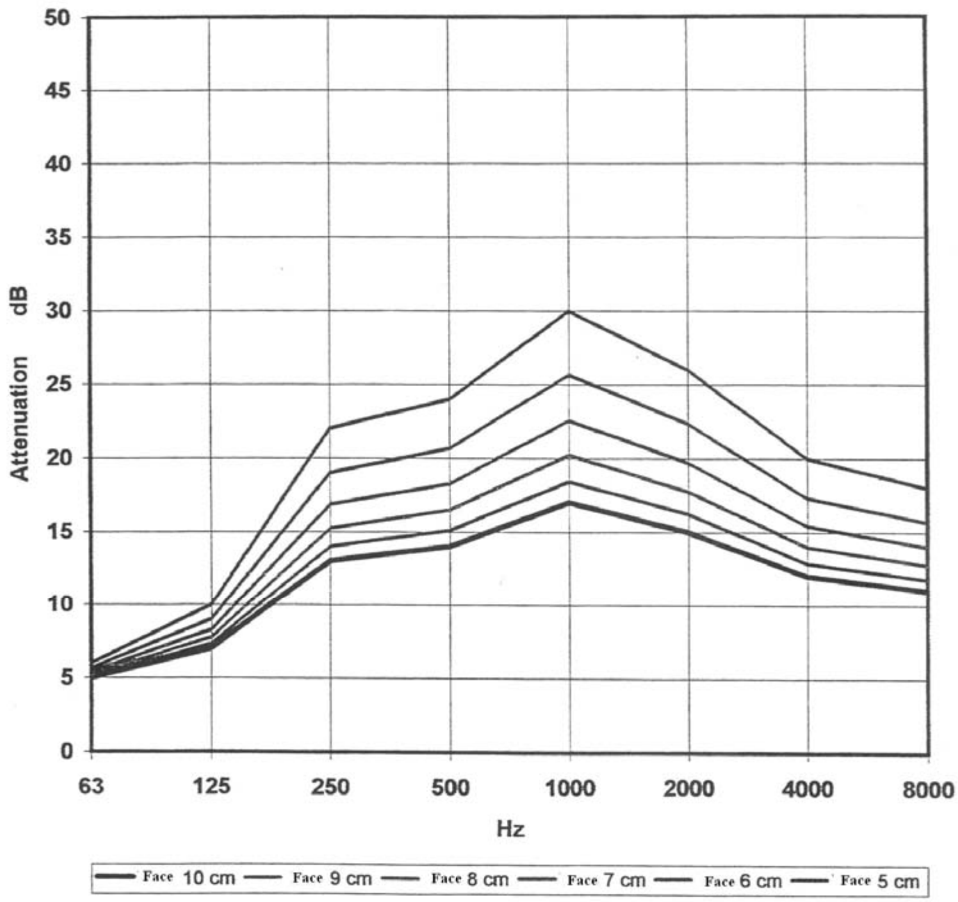

Figure 1.2. Attenuation of Parallel Baffle Plate Silencer of 1 m Length, Baffle Thickness 10 cm and Openings of Various Sizes 5 cm – 10 cm (Meisseur, 2003)

A drawback for attenuators is the pressure drop they introduce in the air flow path which in turn increases the energy consumption of the AHU.

Another problem at the supply air duct is the question of condensation. The relative humidity of the supply air is typically close the vicinity of 100%. Any obstruction to the passage of air flow will cause turbulence and separation of water from air. This can be deposited at the fabric structure, which could cause bacteria growth. Indoor Air Quality [IAQ] problems of this nature have been experienced in hospitals in Malaysia. For example, a 740-bed hospital, Sultan Ismail Specialist Hospital in Pandan, Johor was reported to have closed down in June 2004 due to fungal infections which originated from the air conditioning system. It was eventually re-opened to the public in February 2006 after the source of the contamination was removed. (Cruez, New Straits Times, February 12, 2006)

The AHU noise mostly consists of low frequency noise. The fan rotational speed is typically in the vicinity of 1000 revolutions per minute [rpm] or 16.67. With 6 or 8 blades in a typical backward curved blade fan, the blade pass frequency will be around 100 Hz or 133 Hz. These low frequency noises are not addressed by static acoustic attenuators.

An effective method, therefore, is Active Noise Cancellation, by which an equal and opposite sound wave is created and synchronized in time and space so as to cancel the original noise. This is illustrated in Figure 1.3. Although it involves energy consumption in the form of sound energy, the consumed energy is very small i.e. in the order of 90 dB = 0.001 W (Nelson et al., 1992).