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# INSONORISATION OF A CAR AIR CONDITIONING SYSTEM: APPLICATION OF AN ACTIVE / PASSIVE ABSORBER

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## INTRODUCTION

Since the first experiments done by Lueg [1] in 1936, Active Noise Control in ducts has been significantly improved. The first theoretical decisive studies had been the ones carried out by (i) Jessel [2] and (ii) Swinbanks [3]. Following their papers, there have been many investigations of these theories [4, 5]. The efforts were concentrated on the problem due to the upstream component which is reflected back to the source and which is sensed by the microphone as another source, producing acoustic feedback instability. These problems were overcome through the use of directional microphone and loudspeakers and by more complex speaker arrays [6]. Unfortunately, in spite of good laboratory results, industrial realisations were very difficult to execute. Advances in digital processing make it possible to overcome some of these drawbacks. Many of the traditional problems with this technology can now be treated more effectively with proper signal processing rather than with the direct acoustical approaches of the past. Therefore, the use of a simple loudspeaker becomes more realistic for industrial applications.

The present work is part of a project examining the implementation of Active Noise Control in a car air conditioning system. In our system, a part of the problem is related to the flow itself. Indeed, the more the duct system geometry is complex, the more the internal flow is disturbed, leading to a high degree of turbulence. So, the signal spectrum recorded by the microphone is the sum of this uncorrelated turbulent signal and the true noise signal.

But, for Active Noise Control methods, any algorithm is able to work correctly only if the value of the coherence between the reference signal and the control signal is as great as possible (problem due to the identification of the secondary transfer function).
In order to perform any Active Noise Control method it is necessary to use an appropriate system to eliminate the problems due to the turbulence.

Taking into account these considerations, the purpose of the present work is to find the best strategy in order to cancel the noise coming from a centrifugal fan using Active Noise Control on a real car air conditioning system. To do this, first we need a good knowledge of the system and understanding of the characteristics of the various flow noises generated in the ducts. Afterwards we discuss how to improve the coherence. Eventually, some tests in the car air conditioning system are presented.

## THE CAR AIR CONDITIONING SYSTEM

**Description Of The System.** The car air conditioning system is a very complex physical system. Therefore the aim of this paragraph is to have a very good knowledge of the system to realise the best noise cancelling control.The car air conditioning system consists of : Cf. Figure 1

- a centrifugal fan
- an "air conditioning system" : - the filters
  - the hot water radiator
  - the evaporator
  - the shutters in order to guide the flow
- the connecting ducts
- the outlet grids

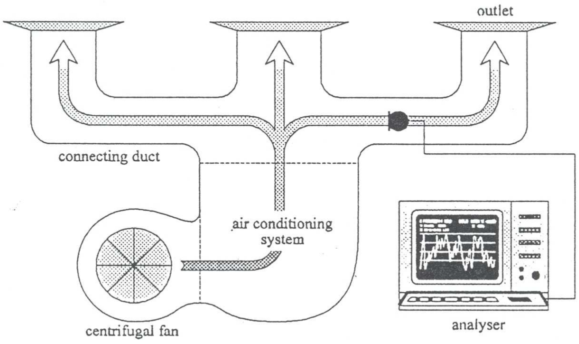


Figure 1 - Car Air Conditioning System Diagram

In our system under test, we observed a predominance of the random noise generated by the air flow. In all the measured spectra, we find a characteristic frequency or frequency band without any correlation with the rotation frequency of the ventilator. These frequencies are due to the varying shutter configurations of the system. Ex. of these spectra are shown on Figure 2 and 3.

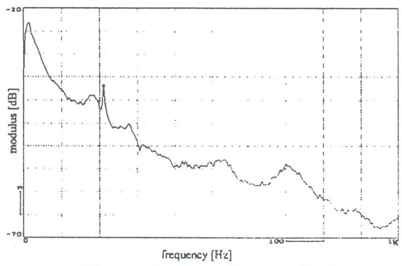


Figure 2 - Low flow velocity
Shutter configuration 1

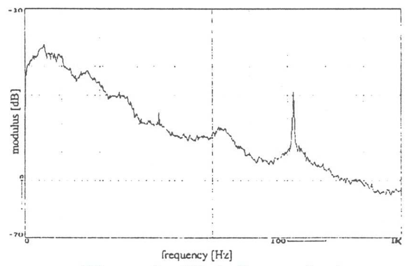


Figure 3 - High flow velocity
Shutter configuration 2

**Control Strategies.** A practical cost strategy for an active noise control system is to reduce the number of loudspeakers and microphones. Suppose you control inside the cabin, for example at the driver's or the passenger's heads, it would be necessary to use several loudspeakers or microphones. Moreover, the signal would be affected by other vehicle interior noises like passenger voices, engine noise, aerodynamic noise, road noise, etc. Another solution would be to control directly at the outlets, but it is difficult to imagine a good positioning of the loudspeaker to control the noise without disturbing the direction of flow inside the cabin. Also, every outlet behaves substantially as independent random noise.

Taking into account these considerations we decided to control the noise in the connecting ducts. On the other hand, the internal flow is disturbed due to the complex geometry of the car air conditioning system, leading to a high degree of turbulence. The turbulence in the connecting ducts shows turbulent eddies of various scales. The large scale eddies create uncorrelated noise at low frequencies whereas the smaller ones generate noise at higher frequencies. The air flow impinging on the microphone diaphragm is not homogeneous, so that the microphone signal is contaminated by these pressure fluctuations. To reduce this incoherent noise, and thereby increase the performances of the active noise control in the ducts, (i) the microphones have been protected by a nose cone and (ii) a passive system was included in the connecting ducts to eliminate the larger scale eddies. In fact, the most effective means is to place a honeycomb grid (3mm mesh and 30mm thickness) in the flow section just a few centimetres in front of the microphones.

## SYSTEM PERFORMANCES

**Passive Absorber Performances.** The coherence between input and output microphones in the connecting duct are shown in Fig. 4a (system with honeycomb) and 5a (system without honeycomb). The associated autospectra at the output microphone are shown in Fig. 4b and 5b.

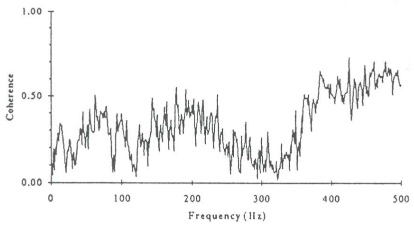


Figure 4a - Coherence without honeycomb

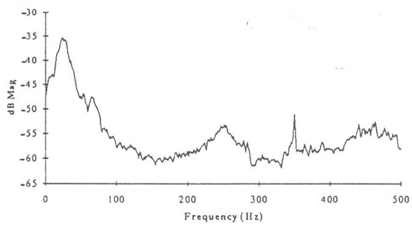


Figure 4b - Output Microphone spectrum

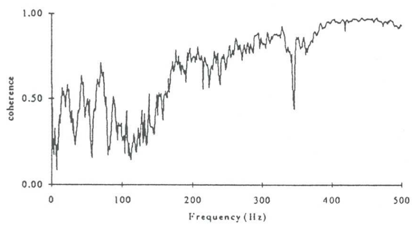


Figure 5a - Coherence with honeycomb

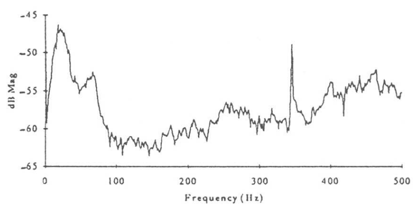


Figure 5b - Output Microphone spectrum

As expected, the coherence is greatest when the honeycomb pieces are used. The very low frequency band below 100 Hz in the spectrum of the Figure 4b not disappear in the spectrum see in the Figure 5b but is significantly reduced. In the case of the system without honeycomb the performance of the Active Noise Control system must be very poor with these relatively low values of coherence. It should not be the case for the system performed with the honeycomb.

**Active / Passive Control Performances.** In a first approach, and to show the performances of the association of an Active/Passive absorber the adaptive control algorithm is the Filtered-x LMS algorithm of B. WIDROW and S.D. STEARNS [7].
The result of the Active/Passive Noise Control is shown on Fig.6. The example illustrates the attenuation obtained within a characteristic frequency band, in this case 200-300Hz. It should be noted that the LMS only controls this narrow band and not the entire frequency range.
At the moment, a study is in progress to validate the simulation results of the control strategy presented in the article [8] based on the more generalised "Prediction Error method".

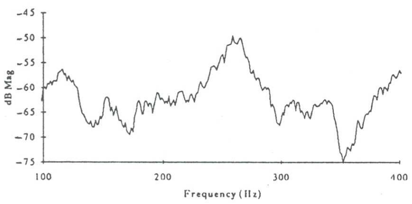


Figure 6a - Output Microphone spectrum
ANC OFF

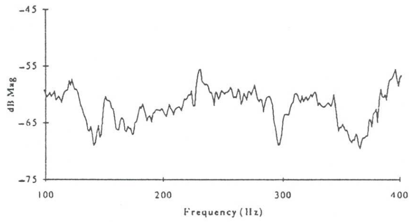


Figure 6b - Output Microphone spectrum
ANC ON

## CONCLUSION

An Active/Passive Noise Control system has been developed and tested in a car air conditioning system. The results showed clearly, that in order to perform an Active Noise Control in a very complex physical system, it is necessary to eliminate the larger scale eddies within the turbulent flow. Therfore the Active part has to be coupled with a Passive system.

## ACKNOWLEDGEMENTS

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