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A NOVEL NOISE REDUCTION TECHNIQUE FOR AN AIR-COOLED CASE

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The paper describes a method to reduce the fan noise from sealed rugged case that contains electronics. Such cases are used in harsh environments and need to be cooled to protect the electronic components usually using forced air. The fan noise has to be reduced to a level for operator comfort. Fan used in such applications pulls air through a tortuous path with obstacles and path geometry introducing noise as the air moves. The dominant contributions to overall noise were investigated through measurements and CFD analyses. The fan used not only generates noise but also transmits the noise generated by the flow path inside the case. A novel design was introduced that reduced the noise by 12 dB while allowing flow through without loss of efficiency.

Keywords: fan noise, noise reduction, honeycomb

1. Introduction

The main difference between the harsh environment electronic equipment and commercial electronics is the environment in which they perform. Operational temperature ranges of harsh environment microelectronics are higher than those of electronics of domestic appliances. Several heat transfer mechanisms are used to remove heat from the chip to the surrounding environment through three basic heat transfer methods, namely, conduction, convection and radiation. [1] For decades, forced air cooling method in which an air handling device is used to move the air through the equipment is preferred because it removes more heat from natural convection technique. Determining the thermal management method as forced air cooling, the fan noise has to be considered because of comfort of the operator and confidence when using the equipment at rural area. Fan rotation is the main source of noise emitted by a fan. [2]

This study presents a noise control for a rugged chassis cooled with fan. The chassis structure is real case application and such rugged devices normally have higher noise levels than cooling fan alone due to mechanical design effects.

In this paper, firstly, measurements and comparisons for acoustics sources identification are discussed. Secondly, iteratively, noise reduction techniques are applied. Also the effects of inlets, filters, board cooling channels and unsymmetrical turbulent flow on noise is discussed briefly.

2. Noise Measurements [3,4]

Flow and noise measurements were made in an anechoic chamber using a handheld spectrum analyser at a distance 1 m from the fan and a handheld flow meter.

2.1 Diagnostic Measurements to Isolate Noise Source

In the forced convection units as shown in Fig.1, the dominant type of noise is observed to be aerodynamic and appears to have two sources: fan itself and airflow through the inlet and exhaust ports, where jets may be formed. The four slots are where the sealed circuit boards are inserted. These slots also provide the airflow through the covered boards.

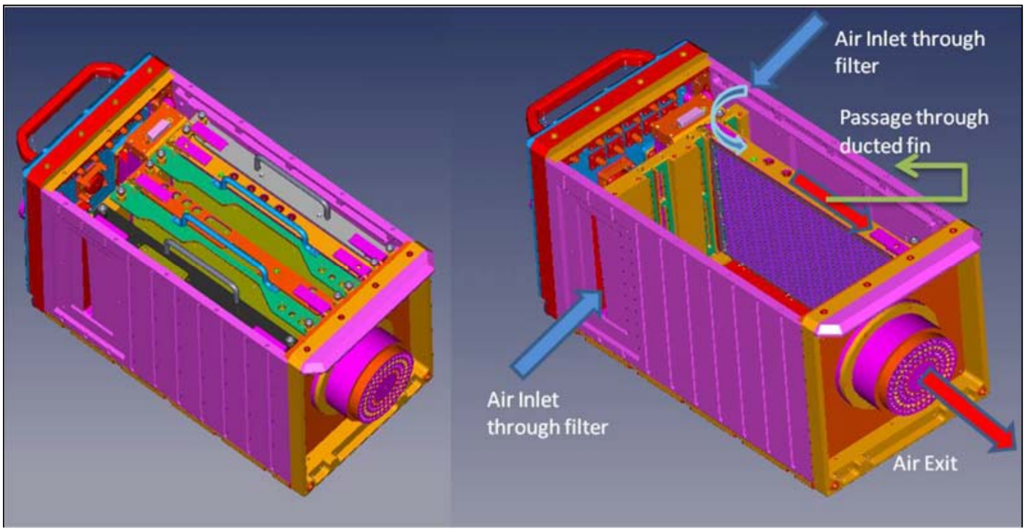

Figure 1: Schematic view of the units indicating the airflow paths

Some measurements are performed to understand which part of the unit is acoustic source.

First of all is reference measurement that showed the noise limit of the unit. Second one is performed to see the effect of fin inside the boards. So the boards without fin are placed into the unit. After that, boards are removed to obtain duct effect. Finally fan noise is measured alone which means the freely operating without shroud.

Table 1: Comparison of CFM and noise levels

Condition	Airflow (cfm)	Air speed (m/s)	Overall dBA
Fan Alone	112	8.05	72.2
Empty Box*	81.3	5.88	86.5
Boards w/o fins	53	3.8	83.6
Boards w/fins**	44.3	3.2	83.1

*Empty Box: The boards and all covers are removed.

**It is reference measurement of the unit.

The results of noise measurement are tabulated in Table 1. The geometry of unit and air duct cause increase the sound level of fan by 10.9 dBA. The air flow is also forced and decreased to 44.3 CFM. Secondly, boards are changed with boards without fins to see the effect of fin on noise. Figure 2 shows that there is no significant difference between sound levels of them. However, it is seen that the fins cause pressure drop.

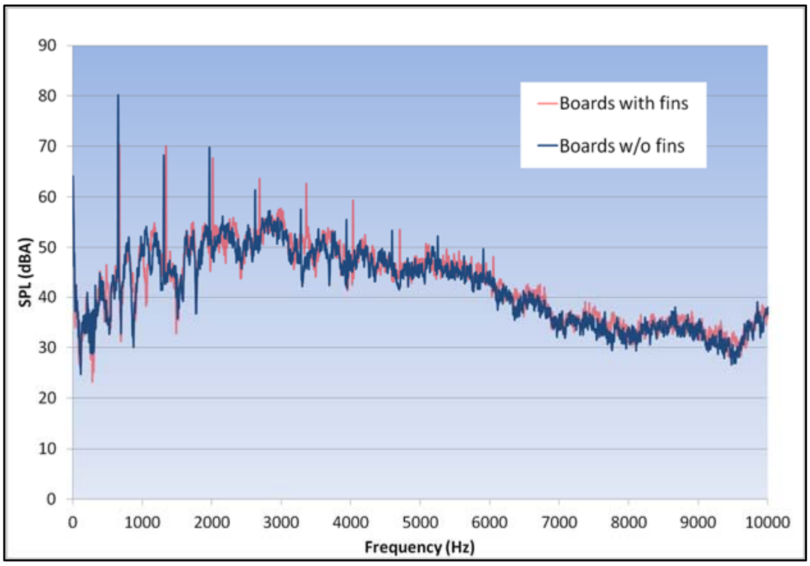

Figure 2: FFT curves and comparison of with and w\o fin effects

The extracting the all boards increasing the sound level by 3.4 dBA, but this is actually caused by the opening all side of the unit. As can be seen from Fig.3, there is no significant difference in spectrum and peaks. The noise level difference of empty box and fan alone cases, shown in Fig.4, shows that the most important effect on the noise is the geometry in front of the fan case, because empty box case eliminates the other parts of the air duct. There are two slots, unevenly placed at the inlet side of the fan. Flow meets the fan blades unevenly. All of these combined lead to a 14.3 dBA increase, while reducing airflow and speed.

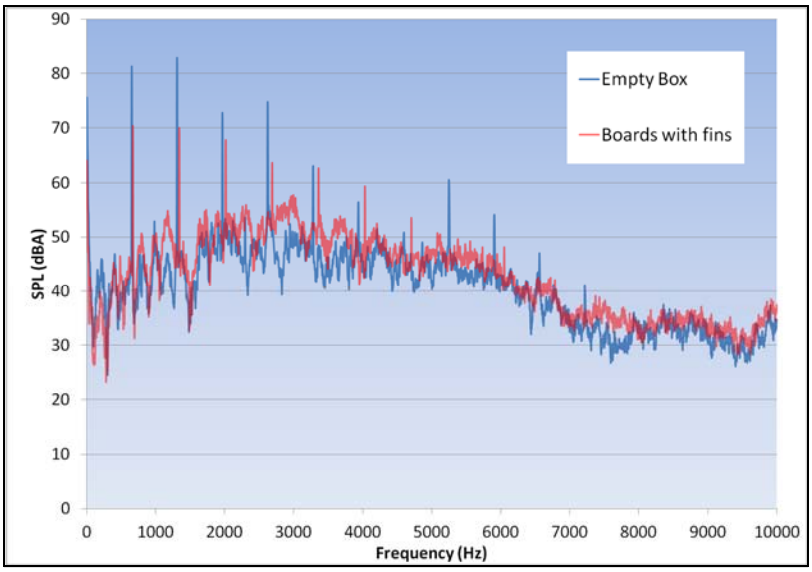

Figure 3: FFT curve comparison of empty case board cooling channels with fins

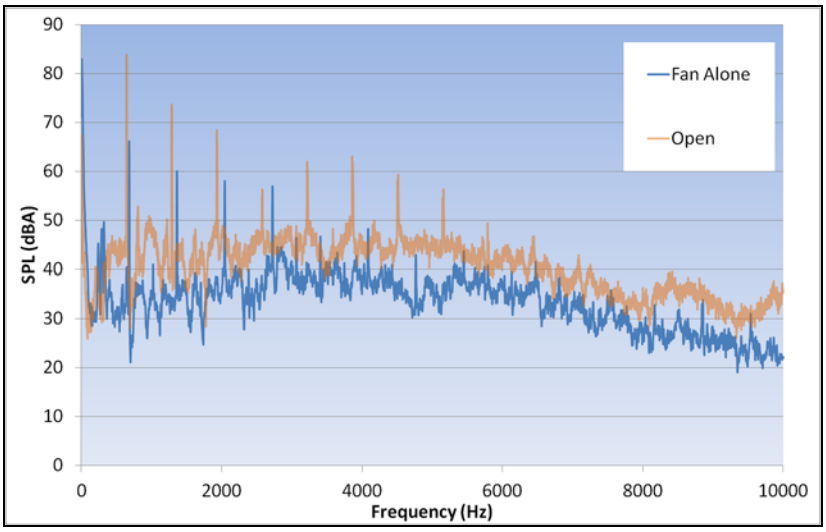

Figure 4: FFT curve comparison of empty case and single fan

As can be seen from Fig.4, after 2000 Hz there are extra domes that are not formed in fan alone case. These domes can be explained as there are harmonics of air flow because of slot geometry.

2.2 Measurements to Reduce the Noise

Based on the observations described above, a set of measurements were made by increasing the distance between the fan and the wall of the casing where the slots are placed. The extension was accomplished by inserting between the box and the fan 2 cm wide circular spacers (duct slices) starting with a distance of 2 cm and extending the total length up to 10 cm. The extension schematic view is presented in Fig.5. The purpose of this exercise was to allow enough space for the flow to develop uniformity prior to meeting with the fan.

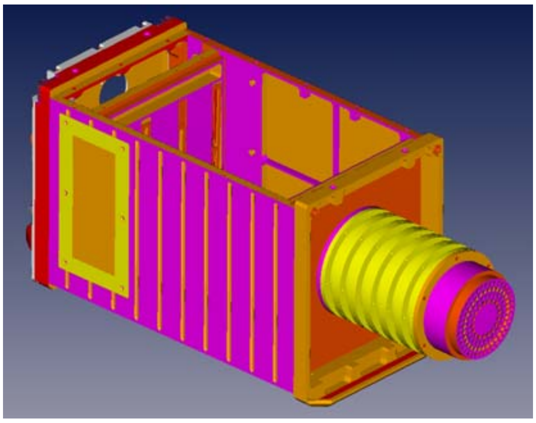

Figure 5: View of total 10 cm extension made of 2 cm wide circular spacers empty box configuration

The results showed that as the distance, or duct length increased, the noise level at 1 m from the fan decreased. According to Fig.10 at 10 cm length, qualitatively it sounded like a broad band noise without the harshness associated with high frequencies. The measurements confirmed that the frequency peaks, the fundamental and its harmonics, were significantly suppressed. Above the second harmonic, they all but disappeared and the first two peaks were reduced by tens of dB compared with the case when the fan was directly attached to the box.

Table 2 shows that the overall sound level with 10 cm long duct was nearly the same as a freely hanging fan, at about 74 dBA. The FFT comparison of empty box and that with 2,4,6,8 and 10 cm tube is shown in Fig.6-Fig.10. The measurements also showed that as the length increased at 2 cm increments, the overall sound level dropped by about 2 dBA, with comparable reduction in the peak values in the spectra. There seem to be from Fig.6-Fig.10 a detectable decrease starts from 6 cm.

Table 2: Comparison of noise level of duct slices

Condition	Overall dBA
Fan Alone	72.2
Empty Box	86.5
Duct Slice (2 cm)	83.7
Duct Slice (4 cm)	80.3
Duct Slice (6 cm)	78.9
Duct Slice (8 cm)	76.7
Duct Slice (10 cm)	74.4

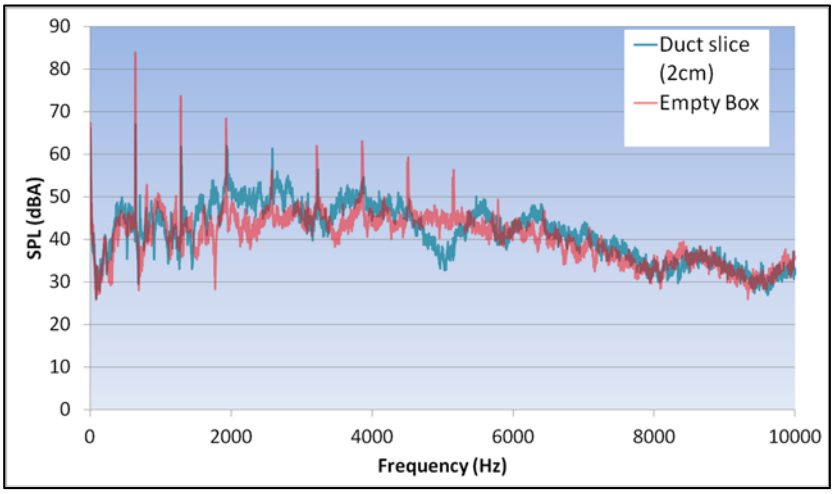

Figure 6: FFT comparison of 2 cm tube and empty box configuration

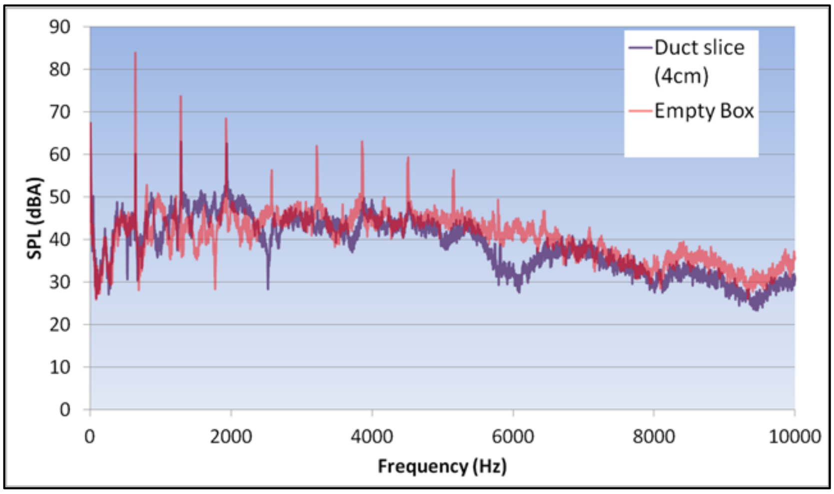

Figure 7: FFT comparison of 4 cm tube and empty box configuration

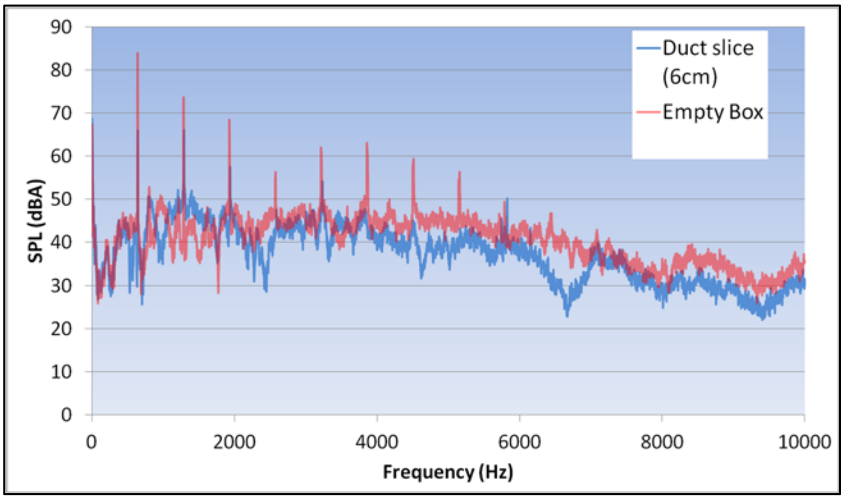

Figure 8: FFT comparison of 6 cm tube and empty box configuration

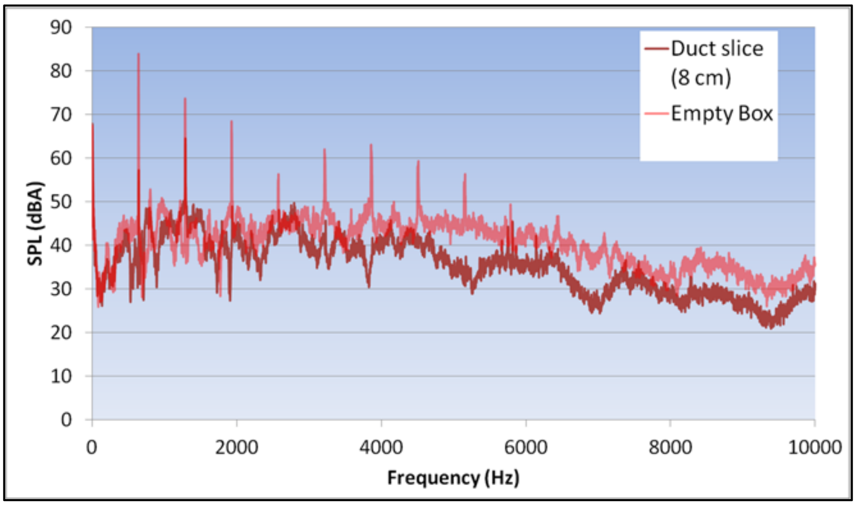

Figure 9: FFT comparison of 8 cm tube and empty box configuration

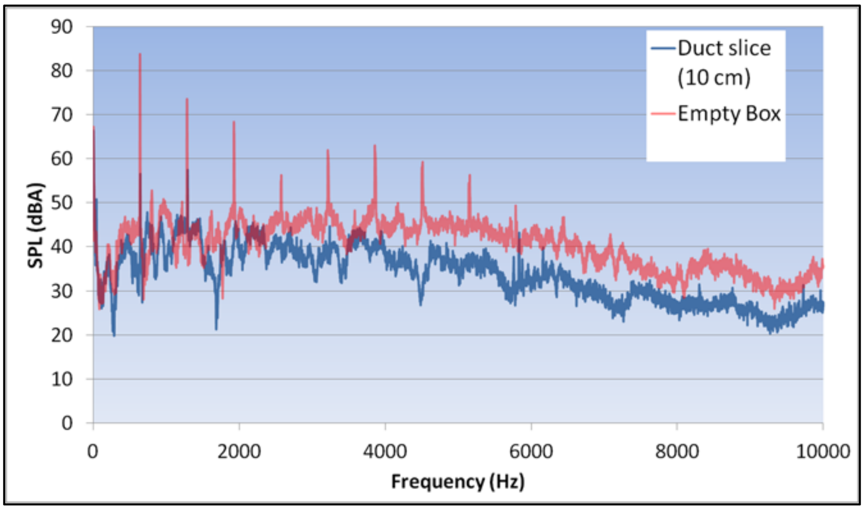

Figure 10: FFT comparison of 10 cm tube and empty box configuration

The next issue was to address the packaging; how to achieve the same reduction with shorter duct length. Considering the reason for high noise with fundamental and harmonics being mostly likely due to turbulent or non-uniform flow at the intake of the fan, the reasoning behind the duct was that it would allow increased uniformity of the flow. With this interpretation, we used a honeycomb shown in Fig.11 at the intake of the fan, somewhere between the casing wall and the fan to "channel" the flow toward the fan more uniformly.

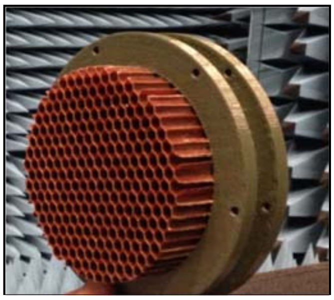

Figure 11: Honeycomb example used to get more uniform air at intake of the fan

As can be seen from Table 3, inserting the honeycomb at intake of fan provides a reduction with shorter duct length. In fact, overall sound level with 10 cm duct is achieved by 6 cm duct with honeycomb.

Table 3: Comparison of noise level of duct slices and duct slices with honeycomb

Condition	Overall dBA
Fan Alone	72.2
Empty Box	86.5
Duct Slice (6 cm)	78.9
Duct Slice (8 cm)	76.7
Duct Slice (10 cm)	74.4
Duct Slice with honeycomb (6cm)	75.4
Duct Slice with honeycomb (8cm)	73.4

After these comparison studies, a prototype is produced and mounted an electronic equipment operating properly. The prototype of duct with honeycomb length of which is 6 cm is shown in Fig.12.

Figure 12: Prototype of the duct mounted on an electronic equipment

The noise levels of the operating electronic equipment cooled with fan are shown in Table 4. The mechanical chassis and fan are same with before studies. At this time electronic equipment has all electronic boards with fin, covers and fan.

Table 4: Noise level of an operating electronic equipment

Condition	Overall dBA
Fan Alone	72.2
Electronic equipment w/o duct	84.3
Duct (6 cm)	73.6
Duct (8 cm)	72.3

3. Conclusion

Diagnostic and experimental results showed that the underlying cause for the fan noise is a result of irregular interaction of flow with the fan blades due to asymmetric positioning of downstream flow characteristic at the fan inlet, slots behind the fan. When the uniformity of a flow interacting with fan blades is disturbed, noise level rises. If the distance from the slots to the fan is large enough, that is ducting, for flow re-establish uniformity sound level is reduced.

For an acoustically important fan cooled unit mechanical design efforts should be spend on appropriate flow channelling for fan inlet and leaving the fan alone in free field.

Many real life designs are space limited applications so that one cannot leave enough space between fan inlet and downstream obstacles freely. As an alternative design approach, honeycomb structures can be used to achieve free field conditions with a reasonably short distance, because of increased uniformity of the flow at the fan intake.

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