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STRUCTURE BORN VIBRATION IN HOME PRODUCTS

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ABSTRACT
Vibrations produced by refrigerators, washing machines, etc are transmitted to the floor and surrounding. To satisfy customer expectations it is crucial to identify sources of vibration and understand the mechanisms of transmission, as well as to control the transmission paths. These issues become particularly important for a wide range of built-in products, as the producer of "White Goods" is blamed immediately for any discomfort such as noise or vibration. The objective of the Electrolux Research Program on Low Noise 2000 is to reduce noise and vibration level in the Home Products®. The work presented is focused on understanding and control of structure born vibration, measuring techniques and the assessment methods. A sub-structure approach was utilized to characterize the dynamic properties of the components and to identify the origin of vibration. Such an approach enables not only the reduction of vibration at the source but also gives the opportunity to control vibration along the transmission paths. Experimental testing methods are discussed to obtain the sub-structure characteristics that can be used to predict noise and vibration of the whole assembly.

1 - INTRODUCTION
An important task for Electrolux acoustic group is to ensure that the regulations and requirements concerning noise and vibrations of different Home Products® are fulfilled. Because of high cost required to modify the already existing products the work leading to low noise and vibration machines is expected to start at the design stage or even in a planning stage. A great deal of efforts is put not only on the overall sound power level but also on frequency contents and a sound quality. A number of Electrolux products are tested at steady-state conditions but also quite often measurements are taken to detect and resolve short-duration transients produced by a gas injection or by a snapping ice inside the evaporator. These do not effect overall sound power level but are quite annoying.
Acoustic measurements on Home Products® use specialized techniques. For example the measurements of refrigerators require sound power measurements in one-third octave bands taken over the period of a few compressor cycles. For this purpose the Electrolux, CTI-A has developed a dedicated measuring system, which is capable of acquiring up to 8 hours of data with a high sampling rate (i.e. 50 kHz per channel). Continuously monitored signals are directly written to the computer hard disk. Resulting data (up to 13Gb) can then be analyzed both in time and frequency domains.
A great deal of time and money has been spent on testing facilities. The Electrolux has two high quality acoustic chambers: anechoic room (Fig. 1) and semi-reverberation room (Fig. 2). Apart from these a number of Electrolux factories have reverberation rooms to test both products in the production and their new designs. The Electrolux, CTI-A in Stockholm assists them with developing the instrumentation, software and provides a technical support.
For long time Electrolux is also concerned with vibrations and dynamic forces produced by Home Products®. For example, industrial washing machines can excite the building structure and cause extensive vibration. A number of measurements are conducted on a floating floor to assess dynamic forces transmitted to the ground.

2 - COMPONENT COMPOSITION TECHNIQUE
The Electrolux, CTI-A over last few years has been actively involved in a number of research projects concerning acoustic and vibration performance of Home Products®. This includes, among the other, the

Figure 1: Electrolux anechoic chamber.

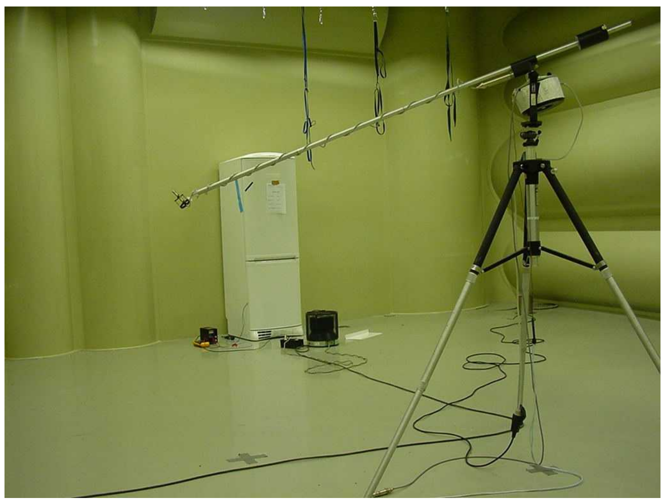

Figure 2: Electrolux semi-reverberation chamber.

Electrolux project on Low Noise 2000 and two European projects OSCAR and NABUCCO. The goal is to develop technique that provides individual characterization of dynamic properties of the components, characterizes source strength and enables prediction of noise and vibration of the whole assembly. By characterizing individually the components such as motors, pumps, drums, etc. these can be easily replace in software to optimize dynamic and acoustic performance of the whole assembly.
The component composition approach is successfully used a number of techniques such as modal analysis, finite element methods, statistical energy analysis, energy influence coefficient method, mean value method, and multiport technique. An advantage of the component composition approach is in its ability to analyze the complex structure by analyzing its components. However, the main drawback and practical serious limitations are the amount of information required to characterize each sub-structure or component. It is not only the size of information but also its quality such as e.g. amplitude-phase characteristics taken with high frequency resolution. The information of this type is rarely available and perhaps its measure is not always justified in practice. For the purpose of product development there is, however, a need for rapid technique, which can still produce meaningful results.

3 - GENERIC SYSTEM MODEL

The approach being developed within the Electrolux Low Noise 2000 project and the European Nabucco project investigates the effects induced by the simplification of the frequency response function (FRF). Instead of using a detailed information in the frequency domain on amplitude and phase, the new approach preserves only the amplitude bandwidth information deliberately ignoring the phase information. The amplitudes are specified by e.g. band-pass and band-stop limits. Then, by using Yule-Walker [1] or

Parks-McClellan [2], [3] algorithms the best fitted frequency characteristics are derived. Convoluting the frequency characteristics with input signals produces different system responses. These are transformed to the WAV format to be compared to the output signals produced by the original system.
Figure 3 shows the frequency response functions of a sub-system modeled by a single mode. Frequency is specified in the range between zero and one, where one corresponds to half the sampling rate in Hz (Nyquist frequency). The differences in terms of amplitude and phase are clearly apparent (Fig. 2). To test system response a swept sine was used among the others. The frequency limits and frequency-swapping rates were chosen to observe the system behavior before, at and after resonance. The results were compared with the response of the original system. Figure 4 represents the outcomes. Both signals were identical in terms of amplitude and phase over the entire frequency range.

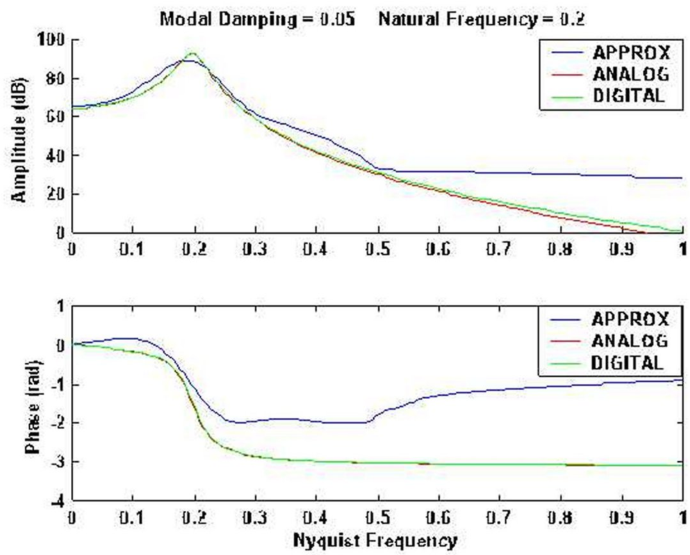

Figure 3: Generic structure model.

4 - CONCLUSIONS

Initial results produced some encouraging outcomes. However, further investigation concerning different approximation of FRF, multi-modes interaction is required. Also the phase analysis due to multi-point excitation needs to be performed to understand both the advantages and limitations of a new method prior to its use to the actual systems.

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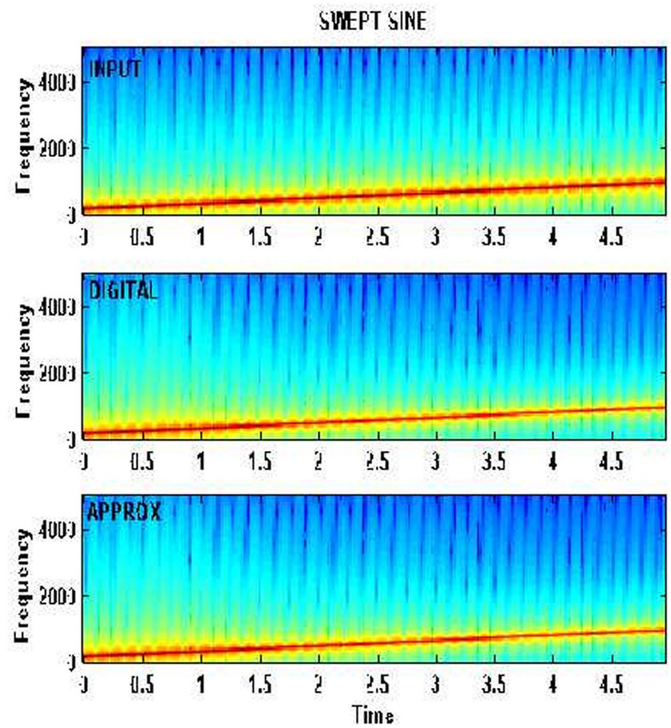

Figure 4: System response.