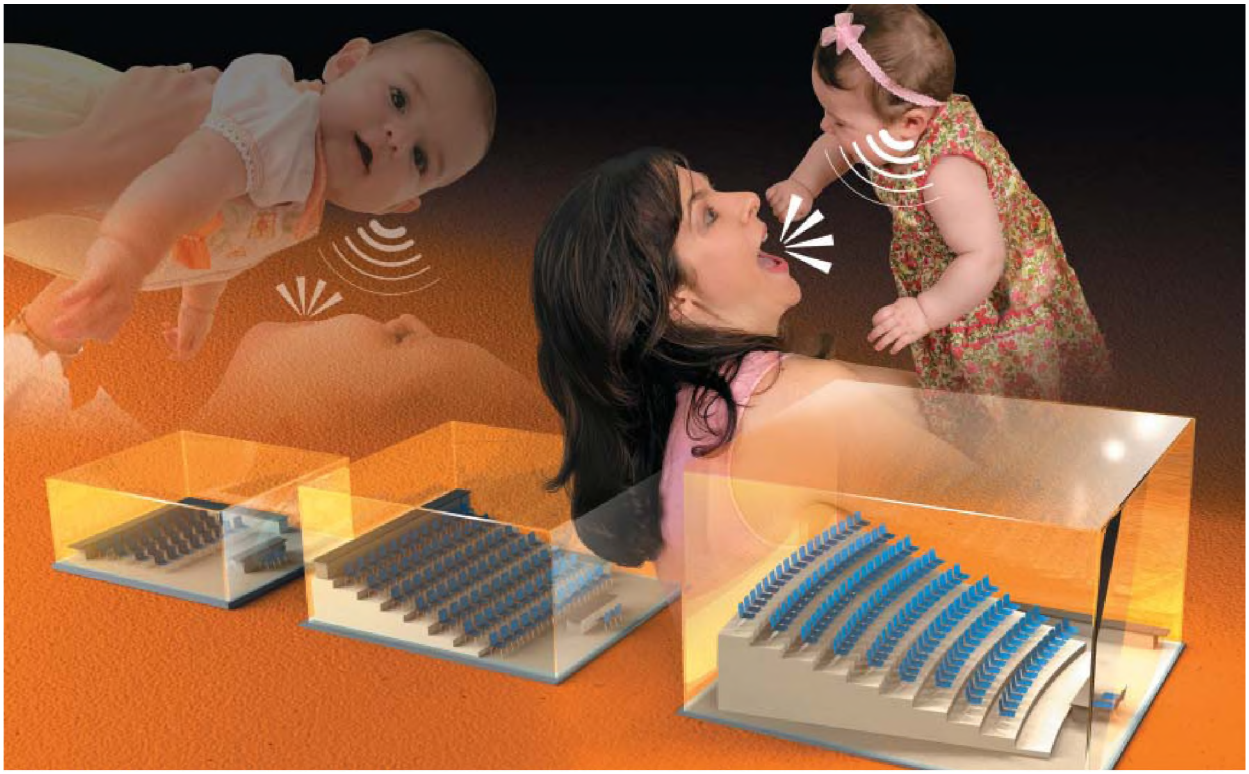
ISSN 0711-6659

canadian acoustics
acoustique canadienne

Journal of the Canadian Acoustical Association - Journal de l'Association Canadienne d'Acoustique

DECEMBER 2005	DECEMBRE 2005
Volume 33 -- Number 4	Volume 33 -- Numéro 4



canadian acoustics

THE CANADIAN ACOUSTICAL ASSOCIATION
P.O. BOX 1351, STATION “F”
TORONTO, ONTARIO M4Y 2V9

CANADIAN ACOUSTICS publishes refereed articles and news items on all aspects of acoustics and vibration. Articles reporting new research or applications, as well as review or tutorial papers and shorter technical notes are welcomed, in English or in French. Submissions should be sent directly to the Editor-in-Chief. Complete instructions to authors concerning the required camera-ready copy are presented at the end of this issue.

CANADIAN ACOUSTICS is published four times a year - in March, June, September and December. The deadline for submission of material is the first day of the month preceeding the issue month. Copyright on articles is held by the author(s), who should be contacted regarding reproduction. Annual subscription: $20 (student); $60 (individual, institution); $250 (sustaining - see back cover). Back issues (when available) may be obtained from the CAA Secretary - price $10 including postage. Advertisement prices: $600 (centre spread); $300 (full page); $175 (half page); $125 (quarter page). Contact the Associate Editor (advertising) to place advertisements. Canadian Publication Mail Product Sales Agreement No. 0557188.

acoustique canadienne

L’ASSOCIATION CANADIENNE D’ACOUSTIQUE
C.P. 1351, SUCCURSALE “F”
TORONTO, ONTARIO M4Y 2V9

ACOUSTIQUE CANADIENNE publie des articles arbitrés et des informations sur tous les domaines de l’acoustique et des vibrations. On invite les auteurs à soumettre des manuscrits, rédigés en français ou en anglais, concernant des travaux inédits, des états de question ou des notes techniques. Les soumissions doivent être envoyées au rédacteur en chef. Les instructions pour la présentation des textes sont exposées à la fin de cette publication.

ACOUSTIQUE CANADIENNE est publiée quatre fois par année - en mars, juin, septembre et décembre. La date de tombée pour la soumission de matériel est fixée au premier jour du mois précédant la publication d’un numéro donné. Les droits d’auteur d’un article appartiennent à (aux) auteur(s). Toute demande de reproduction doit leur être acheminée. Abonnement annuel: $20 (étudiant); $60 (individuel, société); $150 (soutien - voir la couverture arrière). D’anciens numéros (non-épuisés) peuvent être obtenus du Secrétaire de l’ACA - prix: $10 (affranchissement inclus). Prix d’annonces publicitaires: $600 (page double); $300 (page pleine); $175 (demi page); $125 (quart de page). Contacter le rédacteur associé (publicité) afin de placer des annonces. Société canadienne des postes - Envois de publications canadiennes - Numéro de convention 0557188.

PRESIDENT'S MESSAGE / MESSAGE DU PRÉSIDENT

Given the chance annually to write a short message to the CAA membership, I'd like to take the opportunity this year to acknowledge and thank a number of people who make major contributions to the Association, and are in a large part responsible for the steady growth and stability the CAA has enjoyed in recent years (in terms of membership, journal, conference participation, finances, etc.).

First and foremost are the members of the CAA Executive, who do much of the actual work (volunteer, of course) in the daily operations of running the CAA. Our Editor-in-Chief, Ramani Ramakrishnan, has great energy and a personal vision for our journal, Canadian Acoustics. Our Treasurer, Dalila Giusti, does a superb job not just in tracking income and expenses, but in predicting and budgeting our activities a year and more ahead, which has proved instrumental for stable operations and future planning. Our Executive Secretary, David Quirt, is the model of efficiency and very knowledgeable about CAA procedures and history. John Bradley, now our Past-President, contributed enormously as CAA President from 1998–2003, and continues to be a voice of wisdom and experience on the Executive.

CAA operations are over-seen by an elected Board of Directors (BoD) with eight members. In addition to fulfilling these responsibilities, many BoD members take on active roles in contributing to the CAA. For example, Christian Giguère has coordinated the CAA Awards Program for several years, and been pro-active in publicizing the program so that we have awarded all but one of the prizes in each of the last two years. Alberto Behar has been very active in establishing and promoting acoustics standards in Canada. BoD members often contribute in a major way in organizing Acoustics Week in Canada meetings. Corjan Buma and Megan Hodge (completed her BoD term in 2005) organized the 2003 Edmonton meeting. Vijay Parsa and Meg Cheesman (former BoD mem-

Avec cette occasion annuelle d'écrire un court message aux membres de l'ACA, j'aimerais prendre l'opportunité cette anneé de reconnaître et de remercier plusieurs personnes qui font des contributions majeures à l'Association, et qui sont en grande partie responsables pour la croissance régulière et la stabilité desquelles l'ACA a jouit ces dernières anneés (en ce qui concerne adhésion, journal, participation aux conférences, finances, etc.).

Tout d'abord, il y a les membres du comité executif de l'ACA, qui font une grande partie du travail (de façon bénévole) en ce qui concerne les tâches quotidiennes nécessaires pour le fonctionnement de l'ACA. Notre éditeur-en-chef, Ramani Ramakrishnan, a beaucoup d'énergie et une vision personnelle pour notre journal, Canadian Accoustics. Notre trésorier, Dalila Giusti, fait du travail excellent non seulement pour la traque les revenus et dépenses, mais aussi pour prévoir et budgéter nos activités une année et plus à l'avance, nous permettant d'avoir des opérations stables et de faire des planifications pour le futur. Notre secrétaire exécutif, David Quirt, est un model pour l'efficacité et il est instruit en ce qui concerne les procédures et l'histoire de l'ACA. John Bradley, notre dernier président, a contribué énormément en tant que président durant 1998-2003, et il continue d'être une voix de raison et d'expérience sur le comité exécutif.

Les opérations de l 'ACA sont gérées par un conseil d'administration élu, comptant huit membres. En plus de satisfaire ces responsabilités, plusieurs membres du conseil contribuent activement à l'ACA. Par exemple, Christian Giguère a coordonné le programme de mérites de l'ACA pendant plusieurs années, et a fait beaucoup de publicité pour le programme. Le résultat est que tout sauf un des prix a été remis pour chaqu'un des deux dernières anneés. Alberto Behar a été très actif dans l'établissement et la promotion de standards acoustiques au Canada. Les membres du

WHAT'S NEW ?? QUOI DE NEUF ?

Promotions
Deaths
New jobs
Moves

Retirements
Degrees awarded
Distinctions
Other news

Promotions
Décès
Offre d'emploi
Déménagements

Retraites
Obtention de diplômes
Distinctions
Autres nouvelles

Do you have any news that you would like to share with Canadian Acoustics readers? If so, send it to:
Avez-vous des nouvelles que vous aimeriez partager avec les lecteurs de l'Acoustique Canadienne? Si oui, écrivez-les et envoyer à:

Steven Bilawchuk, aci Acoustical Consultants Inc., Edmonton, Alberta, Email: **stevenb@aciacoustical.com**

ber) organized the very successful London meeting held in October of this year, and Mark Chen was instrumental in the Local Organizing Committee for the Joint ASA/CAA Meeting held in Vancouver in May, 2005. Nicole Collison is organizing the 2006 CAA meeting to be held in Halifax (plan to attend—it'll be good!). I'd also like to take this opportunity to welcome two new BoD members elected at the London Meeting: Richard Peppin and Anita Lewis.

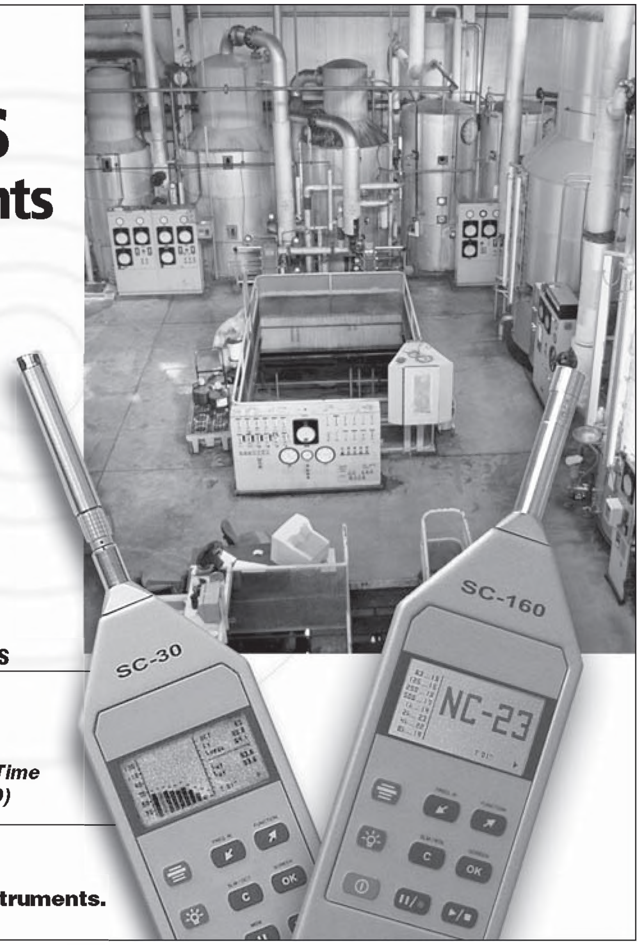
Having served two years now as CAA President, I can say that it's truly a pleasure to work with the Executive and BoD, and that they are serving the Association well indeed.

Stan Dosso

comité d'administration contribuent souvent de grande façon à l'organisation des réunions pour la Semaine de l'acoustique canadienne. Corjan Buma et Megan Hodge (a fini son terme sur le conseil en 2005) ont organisé la réunion 2003 à Edmonton. Vijay Parsa et Meg Cheesman (ancienne membre du conseil) ont organisé la réuion à Londres en octobre de cette année, qui a été un grand succès, et Mark Chen a joué un rôle essentiel dans le comité d'organisation local pour la réunion jointe de la SAA/ACA tenue à Vancouver en Mai 2005. Nicole Collision organise la réunion 2006 de l'ACA, qui se tiendra à Halifax (soyez présent—ça sera à ne pas manquer!). J'aimerais aussi profiter de l'occasion pour souhaiter le bienvenu à deux nouveaux membres élus au conseil d'administration durant la réuion à Londres : Richard Peppin et Anita Lewis.

Ayant servi comme président de l'ACA pendant deux ans, je peux sincèrement dire qu'il m'a fait plaisir de travailler avec le comité exécutif ainsi que le conseil d'administration, et qu'ils servent bien l'Association.

Stan Dosso




Photon
DACTRON

Noise Pollution

The SLARM™ Solution

The **SLARM**™ developed in response to increased emphasis on hearing conservation and comfort in the community and workplace incorporates **ACOustAlert**™ and **ACOustAlarm**™ technology. Making the **SLARM**™ a powerful and versatile sound monitoring/alarm system.

Typical Applications Include:

Community

- ♦Amphitheaters
- ♦Outdoor Events
- ♦Nightclubs/Discos
- ♦Churches
- ♦Classrooms

Industrial

- ♦Machine/Plant Noise
- ♦Fault Detection
- ♦Marshalling Yards
- ♦Construction Sites
- ♦Product Testing

FEATURES

√ **Wired and Wireless (opt)**
√ **USB, Serial, and LAN(opt) Connectivity**
√ **Remote Display s and Programming**
√ **SPL, Leq, Thresholds, Alert and Alarm**
√ **Filters (A,C,Z), Thresholds, Calibration**
√ **Multiple Profiles (opt)**
√ **100 dB Display Range:**
√ **20-120 dBSPL and 40-140 dBSPL**
√ **Real-time Clock/Calendar**
√ **Internal Storage: 10+days @1/sec**
√ **Remote Storage of 1/8 second events**
√ **7052S Type 1.5™ Titanium Measurement Mic**

ACO Pacific

2604 Read Ave., Belmont, CA 94002 Tel: 650-595-8588 FAX: 650-591-2891
www.acopacific.com acopac@acopacific.com

ACOustics Begins With ACO™

EMPIRICAL PREDICTION OF THE EFFECT OF CLASSROOM DESIGN ON VERBAL-COMMUNICATION QUALITY

Murray Hodgson and Anthony Martella
School of Occupational and Environmental Hygiene and Department of Mechanical Engineering,
University of British Columbia, Vancouver, BC, Canada V6T 1Z3

ABSTRACT

This study used empirical prediction models to investigate how verbal-communication quality in 'small', 'medium' and 'large' classrooms varies with classroom design, and identified the optimal designs. Verbal-communication quality was quantified by the room-average speech intelligibility. The design parameters studied were the occupancy, the unoccupied background-noise level, and whether or not the rooms were carpeted, had ceiling and/or wall absorption, or upholstered seats. The design parameters were varied, and the following quantities calculated: average classroom surface-absorption coefficient at 1 kHz, 1-kHz early-decay time, A-weighted background-noise level, and A-weighted speech-signal to background-noise level difference. The conditions under which optimal verbal-communication quality occurred were identified. Quality did not vary with absorption or early-decay time in any systematic way. High background noise, combined with either high absorption or low early-decay time, can lead to very low verbal-communication quality. Quality was low for negative values of signal-to-noise level, but increased quickly for higher values. In the 'small' and 'medium' classrooms, the optimal verbal-communication quality occurred with carpeting and absorption, and with un-upholstered seats. In the 'large' classroom, the optimal quality occurred with carpeting, absorption and upholstered seats. The most significant design factor in determining the verbal-communication quality of the rooms was the background noise.

RÉSUMÉ

A l'aide de modèles prévisionnels empiriques, l'influence de la conception de la salle sur la qualité de communication verbale est étudiée dans le cas d'une 'petite', une 'moyenne' et une 'grande' salle de classe, et les critères de conception optimale sont identifiés. La qualité de communication verbale a été quantifiée au moyen de l'intelligibilité verbale moyenne. Les paramètres de conception étudiés ont été le nombre d'occupants, le niveau de bruit de fond dans la salle non-occupée, et si, oui ou non, la salle était équipée d'un tapis, de matériau absorbant sur les murs et/ou le plafond, ou de sièges absorbants. Ces paramètres ont été variés et les quantités suivantes ont été calculées: le coefficient moyen d'absorption des surfaces à 1 kHz; le temps de décroissance initiale à 1 kHz; le niveau de bruit de fond pondéré A; le rapport signal-bruit pondéré A. Les conditions donnant une qualité de communication verbale optimale ont été identifiées. La qualité ne varie pas de façon systématique avec l'absorption ou le temps de décroissance initiale. Des niveaux élevés de bruit de fond, associés soit à une absorption élevée ou à un faible temps de décroissance initiale, aboutissent à une qualité verbale médiocre. La qualité est faible pour des valeurs négatives du rapport signal-bruit, mais augmente rapidement pour des valeurs plus élevées. Dans les 'petite' et 'moyenne' salles, on obtient une qualité de communication verbale optimale avec un tapis et un traitement absorbant des parois/plafond, et avec des sièges non-absorbants. Dans la 'grande' salle, il faut un tapis, un traitement absorbant et des sièges absorbants. Le facteur le plus important régissant la qualité de communication verbale dans les salles est le bruit de fond.

1. INTRODUCTION

Non-optimal classroom acoustical design directly affects verbal communication by students and instructors, and reduces student learning proficiency. This is particularly true for students who are young, have a hearing loss or are working in a second language. Furthermore, it may cause voice problems for the instructor. Acoustical quality for verbal communication ('verbal-communication quality') is quantified here by the Speech Intelligibility (SI), the percentage of speech material which would be expected to be correctly identified by an average, normal-hearing listener working in their first language. A number of physical correlates of SI exist - Speech Transmission Index (STI) was used here. Ignoring factors related to instructor accent or enunciation, the STI and SI at a listener position in a classroom depend on two main factors – the speech-signal to background-noise level difference in decibels, and the classroom reverberation.

The speech level depends on the instructor voice level and on the classroom acoustical design – in particular, how the speech level decreases with distance from the instructor to the listener. The background-noise level comprises noise from the ventilation system, in-class equipment (such as projectors), in-class student-activity noise, and noise originating outside the classroom. In this study, noise from in-class equipment, and from outside the classroom was assumed negligible. Reverberation depends mainly on classroom size and on the amount of sound absorption - including that contributed by the classroom occupants. It is generally considered that, for excellent speech conditions, reverberation in the furnished, occupied classroom should be in the range 0.4 to 0.6 s, increasing with classroom volume, and that the speech-to-noise level difference should exceed a value of at least 15 dB. Given typical instructor speech levels, it is considered that classroom background-noise levels should not exceed about 35 dBA [1, 2].

The objective of the present research was to study, using previously developed empirical prediction models [3, 4, 5], the relationship between verbal-communication quality and classroom design, and thus to identify the optimal designs. This was done by predicting the variations of measures related to classroom verbal-communication quality with relevant classroom design parameters. Speech intelligibility is the main measure of interest in this study, because it quantifies verbal-communication quality.

Three sizes of classroom - referred to as 'small', 'medium' and 'large' - with capacities of 25, 100 and 400 students, were selected, with characteristics typical of university lecture rooms [5]. The 'small' classroom was 7.4 m by 7.6 m by 3.0 m high, the 'medium' classroom 10.7 m by 10.4 m by 3.5 m high, and the 'large' classroom was 24.1 m by 21.5 m by 5.7 m high. In each classroom, the source was at some distance from the front wall, denoted as the front-wall distance (*fwdist*) [5]. Nine symmetrically located receiver positions, with coordinates determined from the classroom dimensions, were selected, as defined in Figure 1. Room-average results were then calculated.

All of the classrooms were studied under the conditions of half occupancy and full occupancy. For each occupancy condition, the following design parameters were systematically changed, one at a time: A-weighted unoccupied background-noise level (BNA_u); carpet factor (*carpet*); wall/ceiling-absorption factor (*absorb*); and upholstered-seat factor (*upseat*). The *carpet*, *absorb* and *upseat* factors took values of either 0 or 1, corresponding to no or complete floor carpeting, wall/ceiling absorption and upholstered-seating, respectively. The three levels of background noise used were 30 dBA ('low' noise level), 40 dBA ('medium' noise level) and 50 dBA ('high' noise level).

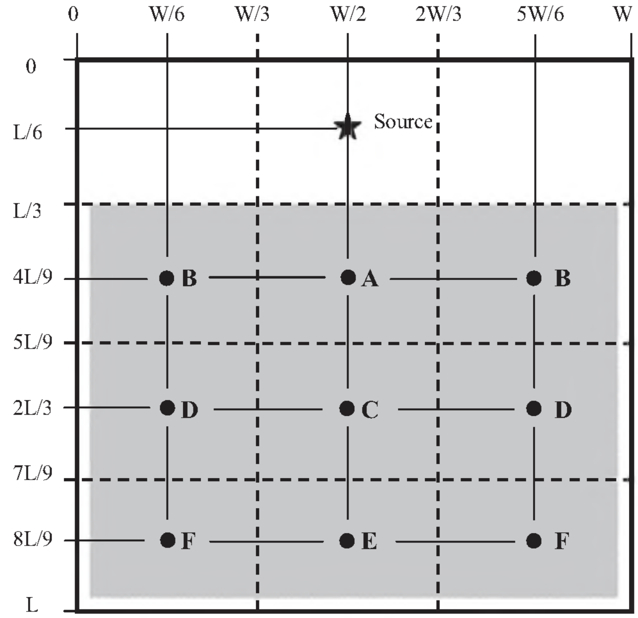


Figure 1. Diagram of a generic classroom, showing the generic source and received positions, with coordinates.

From the input data, a number of acoustical parameters that indicate verbal-communication quality were calculated. The main acoustical parameters of interest were the average unoccupied 1-kHz surface-absorption coefficient ($\alpha 1$), the 1-kHz occupied early-decay time ($EDT1_o$), the A-weighted occupied speech-to-noise level difference (SNA_o) and the A-weighted occupied background-noise levels (BNA_o). Based on these and other acoustical parameters, and the source-receiver distances, the classroom-averaged occupied speech intelligibility (SI_o) was calculated. From this, a qualitative verbal-communication-quality descriptor was assigned, as follows: $SI \geq 98$ % = 'Excellent' (E); $SI_o \geq 96$ % = 'Very Good' (VG); $SI_o \geq 93$ % = 'Good' (G); $SI_o \geq 88$ % = 'Fair' (F); $SI_o \geq 80$ % = 'Poor' (P); $SI_o < 80$ % = 'Bad' (B). Note that the assignment of these descriptors is conjectural and has not been validated experimentally.

2. STI / SI PREDICTION

Speech intelligibility *SI* was calculated from *STI* using a regression equation fitted to pairs of corresponding *STI* and 'short-sentence' *SI* values from Barnett and Knight [6]:

$$SI = -270.9\,STI^4 + 817.4\,STI^3 - 923.3\,STI^2 + 476.8\,STI - 0.009. \qquad (1)$$

STI was calculated from the A-weighted speech-to-noise level difference (*SNA*) and the 1-kHz early-decay time (*EDT1*) using the procedure described by Steeneken and Houtgast [7]. At any position *r*, *SNA* can be determined from values of the A-weighted speech level ($SLA(r)$) and the background-noise level ($BGNA$):

$$SNA = SLA(r) - BGNA. \qquad (2)$$

As discussed in detail in [5], an important question is how to estimate realistic speech levels. Various options were considered and the following optimal one chosen. It predicts speech levels which both vary in a realistic way with source/receiver distance in individual classrooms, and which are derived from vocal output powers which vary with the prevailing acoustical conditions. Two empirical models were combined, as follows:

- first, instructor output-power levels LWA_{emp} were predicted using [4]:

  $$LWA_{\mathrm{emp}} = 54.8 + 0.5\,SANA + 0.016\,V - 9.6\log(A_o), \quad (3)$$

  in which V is the classroom volume in m^3, A_o is the total classroom absorption in m^2, and $SANA$ is the total A-weighted student-activity-noise level in dBA, calculated from [4];

  $$SANA = 83.0 + 10.0\log(n) - 34.4\,A_o + 0.081\,A_o, \quad (4)$$

  where n is the number of seats;

- second, SLA_u intercepts, I_u in dBA, and slopes, s_u in dBA/dd (dd=distance doubling) were predicted using [3]:

  $$I_u = 65.79 - 0.0105\,L + 1.5198\,fwdist - 1.4061\,absorb - 4.3186\,upseat; \quad (5a)$$

  $$s_u = -1.208 - 0.0877\,L + 1.1401\;basic, \quad (5b)$$

  in which L and W are the classroom length and width, respectively, in m, and *fwdist* is the distance of the speech source from the nearest classroom surface (usually the front wall), in m. *absorb* indicates the amount of ceiling and/or wall absorption, and is equal to 1 with a full-coverage ceiling absorption. *upseat* is zero if the seats are non-absorptive, and 1 if they are padded and, therefore, sound-absorptive. *basic* is 1 if the classroom contains no sound-absorbing features, and 0 otherwise. These models were developed assuming vocal output levels corresponding to an average person speaking at between a normal and a raised voice. The output-power level LWA_{nr} corresponding to these levels can be easily estimated. Of course, if the output-power level changes, the intercept (SLA at 1 m), but not the slope, changes by the same amount;

- thus, for a given classroom, predicted intercepts were adjusted by an amount equal to the difference between the power levels predicted by Eq. (3) and that corresponding to levels used to predict the intercept by Eq. (5a):

  $$I_u' = I_u - (LWA_{\mathrm{nr}} - LWA_{\mathrm{emp}}); \qquad (6)$$

- speech levels, $SLA_u(r)$ in dBA, at any source/receiver distance, r in m, were calculated from the resulting adjusted intercept I_u and the slope s_u predicted by Eq. (5b), as follows:

  $$SLA_u(r) = I_u + s_u\log(r). \qquad (7)$$

Unoccupied SLA_u's were then corrected to the occupied condition (SLA_o) on the assumption of 70% classroom occupancy, typical of UBC classrooms, using diffuse-field theory:

$$SLA_o(r) = SLA_u(r) + 10\log\frac{\left(\dfrac{1}{4\pi r^2} + \dfrac{4}{A_u}\right)}{\left(\dfrac{1}{4\pi r^2} + \dfrac{4}{A_o}\right)}, \qquad (8)$$

in which $A_o = A_u + 0.7nA_p$ is the occupied-classroom absorption, in m^2, and A_p=0.81 m^2 [8].

As for $EDT1_u$, values were predicted using diffuse-field reverberation theory and the total 1-kHz surface absorption coefficient $\alpha 1_{\mathrm{tot}}$, as follows [4]:

$$EDT_u = 0.16\,V / (\alpha 1_{\mathrm{tot}}\,S + 4mV), \qquad (9a)$$

with $$\alpha 1_{\mathrm{tot}} = \alpha 1_{\mathrm{basic}} + \alpha 1_{\mathrm{carpet}}carpet + \alpha 1_{\mathrm{absorb}}absorb + \alpha 1_{\mathrm{upseat}}upseat. \qquad (9b)$$

The resulting values were corrected to the occupied condition ($EDT1_o$) on the assumption of 70% occupancy:

$$EDT1_o = \frac{0.16V}{\left(\dfrac{0.16V}{EDT1_u}\right) + 0.7nA_p}. \qquad (10)$$

This empirical model can be criticized for using the *EDT* to describe reverberation, instead of measures such as *TI* and *C50* that more accurately account for details of the reverberation, and in not using frequency-varying values. However, it has been shown to give very similar predictions to those by more accurate models [9].

3. VARIATION OF VERBAL-COMMUNICATION QUALITY WITH DESIGN PARAMETERS

Let us consider how verbal-communication quality varies with the design parameters. As an example, Table 1 shows the variation of room-average speech intelligibility (*SI*) and quality with the four classroom design parameters, for the 'medium' classroom with half occupancy – the data is presented in order of decreasing quality.

Table 1. Predicted room-average SI and verbal-communication qualities for various design parameters in the 'medium' classroom with half occupancy, presented in order of decreasing quality.

'MEDIUM' CLASSROOM, HALF OCCUPANCY				
BNA (dBA)	*carpet*	*absorb*	*upseat*	*SI* (%) / Quality
30	1	1	0	97.0 / VG
30	0	1	0	96.7 / VG
30	1	1	1	96.4 / VG
30	0	1	1	96.3 / VG
30	1	0	1	96.3 / VG
30	1	0	0	96.2 / VG
30	0	0	1	96.1 / VG
30	0	0	0	95.7 / G
40	0	0	0	95.1 / G
40	1	0	0	94.9 / G
40	0	1	0	94.5 / G
40	1	1	0	94.5 / G
40	0	0	1	93.2 / G
40	1	0	1	92.9 / F
50	0	0	0	91.9 / F
40	0	1	1	90.9 / F
40	1	1	1	90.4 / F
50	1	0	0	87.4 / P
50	0	1	0	81.1 / P
50	1	1	0	78.9 / B
50	0	0	1	71.9 / B
50	1	0	1	67.4 / B
50	0	1	1	50.5 / B
50	1	1	1	46.3 / B

Results were similar at all positions in a given classroom, and for both occupancies. Verbal-communication quality generally decreased with increasing background noise. It generally decreased with increased occupancy, but the effect was small. Quality varied in a complex way with the absorptive features present. The optimal and worst-case verbal-communication qualities are highlighted in Table 1. The worst cases are predicted for a background noise of 50 dBA, and values of 1 for *carpet*, *absorb* and *upseat* (*i.e.* full-coverage carpeted floor, wall or ceiling absorption and upholstered seats – the maximum absorption). The optimal cases occur at a background noise of 30 dBA, with *carpet* and *absorb* equal to 1, but with *upseat* = 0 (*i.e.* non-upholstered seats). Strictly speaking, the worst case for both the 'small' and 'medium' rooms occurred at half occupancy. However, the verbal-communication qualities of both rooms in the optimal and worst cases fall into the ranges of 'Very Good' and 'Bad', respectively, for both occupancies.

The results were somewhat different for the 'large' classroom. The worst verbal-communication quality occurred with a background noise of 50 dBA, as in the other rooms, but with *carpet* = 0 (*i.e.* a non-carpeted floor) and 1 for *absorb* and *upseat*. The optimal verbal-communication quality occurred with a background noise of 30 dBA, as in the other cases, but with values of 1 for the absorption factors. In other words, more absorption was needed to achieve optimal quality than was the case in the smaller rooms. Again, *SI* and quality decreased with increased occupancy for the 'large' classroom, but corresponded to 'Good' verbal-communication quality for the optimal case, and to 'Bad' quality for the worst case, regardless of occupancy. The 'large' classroom had far less of an overall variation of speech intelligibility than the other two rooms, the best-case quality being lower and the worst-case quality being higher than in the 'small' and 'medium' rooms. The reason for such a contrast between the 'large' and the 'small' and 'medium' rooms is likely the fact that the former has a much greater volume than the others (2932.1 m^3 compared to 165.8 m^3 for the 'small' classroom and 389.0 m^3 for the 'medium' classroom). There is more of a volume difference between the 'large' classroom and either of the other two rooms than there is between the 'small' and 'medium' rooms.

In general, the background noise is the predominant design factor affecting verbal-communication quality in all rooms. It is interesting to note that, in all cases, at the highest level of background noise, the best verbal-communication quality occurs when there is no carpet, surface absorption or upholstered seats. It is also interesting to note that a change from non-upholstered seats to upholstered seats can significantly decrease the speech intelligibility when carpet and wall/ceiling absorption are present in a classroom with 'high' background noise.

4. ROOM-ACOUSTICAL PARAMETERS AND OPTIMAL VERBAL-COMMUNICATION QUALITY

Let us discuss in more detail the optimal verbal-communication qualities found for each classroom/ occupancy combination, and for what acoustical parameters they are attained. Table 2 shows the optimal verbal-communication quality predicted for each classroom/ occupancy combination, along with the corresponding design parameters and the predicted values of $\alpha 1$, $EDT1_o$, SNA_o and BNA_o. As can be seen from Table 2, the optimal verbal-communication quality ('Very Good') occurs at a

Table 2. Optimal verbal-communication quality for each classroom/occupancy combination with predicted $\alpha 1$, $EDT1_o$, SNA_o and BNA_o, and corresponding design parameters.

Classroom size, occupancy	BNA_u (dBA)	*carpet*	*absorb*	*upseat*	$\alpha 1$	$EDT1_o$ (s)	BNA_o (dBA)	SNA_o (dBA)	*SI* (%) Quality
'small', 0.5	30	1	1	0	0.23	0.42	29.2	16.3	97.3 VG
'small', 1	30	1	1	0	0.23	0.36	28.6	16.5	97.2 VG
'medium', 0.5	30	1	1	0	0.23	0.45	28.5	15.3	97.0 VG
'medium', 1	30	1	1	0	0.23	0.35	27.4	15.6	96.9 VG
'large', 0.5	30	1	1	1	0.34	0.64	29.5	13.7	95.8 G
'large', 1	30	1	1	1	0.34	0.57	29.0	14.5	95.7 G

value of $\alpha 1 = 0.23$ in the case of the 'small' and 'medium' class-rooms, regardless of occupancy. However, the optimal verbal-communication quality in the 'large' classroom ('Good', though at the top of the range) occurs at the slightly higher value of $\alpha 1 = 0.34$ for both occupancies.

Regarding *EDT*, the optimal verbal-communication quality occurs at a value of 0.42 to 0.45 s for the half-occupied 'small' and 'medium' rooms. The value is reduced to 0.35 to 0.36 s for these cases when the rooms are fully occupied. However, the optimal verbal-communication quality in the 'large' classroom occurs at a much higher value of 0.64 s when half occupied and 0.57 s when fully occupied. Class-room occupancy makes little difference to the range of optimal verbal-communication qualities attainable in any of the rooms. These results are fully consistent with current recommendations that reverberation times should increase from 0.4 to 0.6 seconds with classroom volume.

Referring again to Table 2, it can be seen that the optimal verbal-communication quality occurs in each classroom at slightly higher values of BNA_o when half occupied than when fully occupied. However, the values of BNA_o for the optimal cases of all classroom/occupancy combinations are within approximately 2 dBA of each other (27.4 to 29.5 dBA). This implies that the classroom size and occupancy are not major factors in determining the required BNA_o.

Although there is a single value of BNA_o corresponding to the optimal speech intelligibility attainable in each case, there is a range of values for which the optimal verbal-communication quality can be attained. Table 3 shows the range of BNA_o for which the optimal verbal-communication quality can be attained in each case. The results are also consistent with the belief that background noise should be less than 35 dBA.

Regarding speech-to-noise level difference, the optimal verbal-communication quality occurs in each classroom at slightly lower values of SNA_o when half occupied than when fully occupied (15.3 and 15.6 dBA for the 'medium' classroom when half and fully occupied, respectively). The optimal values of SNA_o get progressively lower as the room size is increased. Note that the optimal values are consistent with the recommendation that signal-to-noise levels should be at least 15 dBA to ensure high quality.

Although there is a single value of SNA_o corresponding to the optimal speech intelligibility attainable in each case, there is a range of values for which the optimal verbal-communication quality is attained. Table 3 shows these ranges of SNA_o.

Table 3. Ranges of SNA_o and BNA_o for which optimal verbal-communication quality is attainable, for the six classroom cases studied.

Classroom size, occupancy	Best verbal-communicatio	Optimal BNA_o range (dBA)	Optimal SNA_o range (dBA)
'small', 0.5	Very Good	< 40	5-25
'small', 1	Very Good	< 30	5-25
'medium', 0.5	Very Good	< 30	10-20
'medium', 1	Very Good	< 30	10-20
'large', 0.5	Good	< 40	7.5-20
'large', 1	Good	< 40	7.5-20

5. RELATIONSHIPS BETWEEN VERBAL-COMMUNICATION QUALITY AND ROOM-ACOUSTICAL PARAMETERS

Let us now look at the variation of speech intelligibility with each of the four predicted room-acoustical parameters $\alpha 1$, $EDT1_o$, BNA_o and SNA_o in each of the three rooms to see if there are interesting correlations. This was done for all three classrooms at half and full occupancies.

5.1 Classroom Absorption

In the six classroom-size and occupancy cases, $\alpha 1$ varied from 0.05 to 0.35. Figure 2 shows the variation of classroom-average SI with $\alpha 1$ for the case of the 'medium' classroom at half occupancy. The ranges of the various verbal-communication-quality categories are also indicated. As can be seen in the figure, a wide range of values of $\alpha 1$ is associated with 'Very Good' verbal-communication quality – the best attainable in the 'medium' classroom. However, these same values of $\alpha 1$ are also associated with lower verbal-communication qualities. Most of the values of SI are between 90 and 100 %, but there is a slight divergence at higher values of $\alpha 1$, for which the value of SI can be much lower. This occurs at high values of $\alpha 1$, with 'high' background noise. Therefore, it is expected that the worst verbal-communication quality for any of the given classrooms occurs with the highest value of $\alpha 1$ combined with the highest value of the unoccupied background noise (*i.e.* $SI < 50$ % for $\alpha 1 > 0.3$ and $BNA_u = 50$ dBA for the case of the 'medium' classroom at half occupancy). The results are quite similar in the other rooms. That a range of verbal-communication qualities is observed for a given value of $\alpha 1$ shows that there is not a predictable relationship between the two. Given this, and the fact that all six cases of classroom type and occupancy showed results similar to those in Figure 2, it can be concluded that the average surface-absorption coefficient alone does not determine the verbal-communication quality of the rooms.

5.2 Early-Decay Time

Regarding early-decay time, in the six cases, the values of $EDT1_o$ increased with increasing classroom size and decreased with occupancy. Values varied from 0.36 to 0.85 s. Figure 3 shows the variation of SI with $EDT1_o$ for the case of the 'medium' classroom at half occupancy. As can be seen in the figure, a wide range of values of $EDT1_o$ is associated with the optimal 'Very Good' verbal-communication quality in the classrooms. However, these same values of $EDT1_o$ are also associated with lower verbal-communication qualities. Most of the values for SI are between 90 and 100 %, but there is a slight divergence at lower values of $EDT1_o$, where the value of SI can be much lower. This occurs at low values of $EDT1_o$ with 'high' background noise. This trend is opposite in nature to that seen in the case of classroom absorption, where the divergence is at high values of $\alpha 1$. This makes sense, since high values of absorption imply low early-decay times. Thus, it is expected that the worst verbal-communication quality for any of the given rooms occurs at the lowest value of $EDT1_o$ combined with the highest value of unoccupied background noise (*i.e.* $SI < 50$ % for $EDT1_o < 0.4$ s in the case of the 'medium' classroom at half occupancy). The results are quite similar for the other rooms. The fact that a range of verbal-communication qualities is observed for a given value of $EDT1_o$, shows that there is no predictive relationship between the two. Given this and the fact that all six cases of classroom type and occupancy produce similar results, it can be concluded that the occupied early-decay time alone does not determine the verbal-communication quality of the rooms. This result contradicts common thinking that reducing reverberation increases verbal-communication quality. In fact, if reverberation is very low, due to high classroom absorption, then so too are speech levels and speech-to-noise level differences, a more significant detrimental effect.

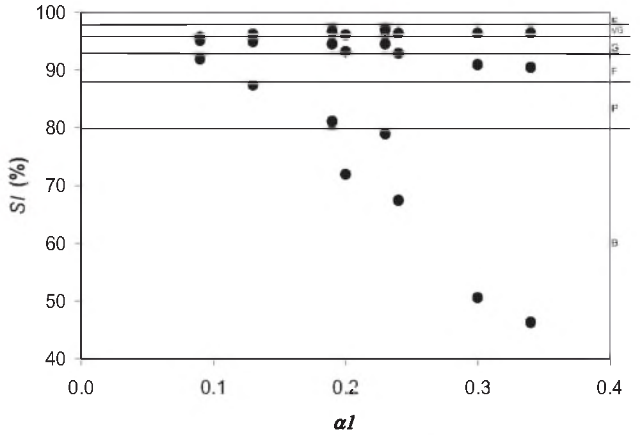


Figure 2. Variation of room-average SI with $\alpha 1$ for the 'medium' classroom with half occupancy.

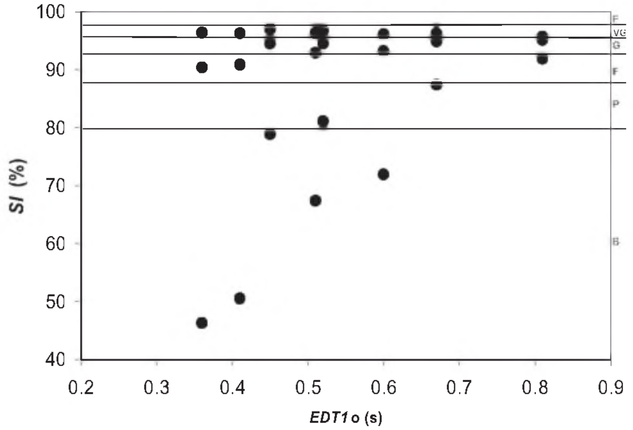


Figure 3. Variation of room-average SI with $EDT1_o$ for the 'medium' classroom with half occupancy.

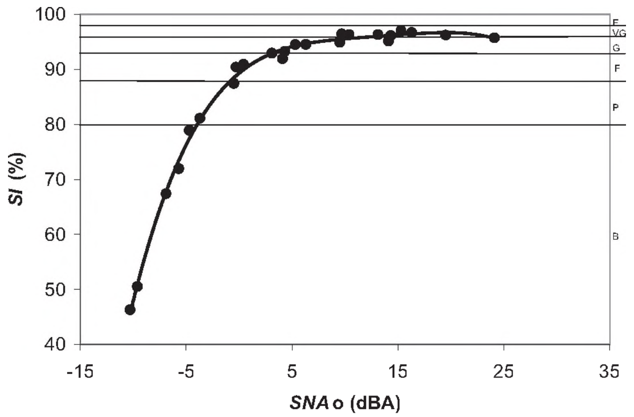


Figure 4. Variation of room-average SI with SNA_o for the 'medium' classroom with half occupancy.

5.3 Speech-to-Noise Level Difference

With respect to the signal-to-noise level difference, Figure 4shows the variation of *SI* with SNA_o for the case of the 'medium' classroom at half occupancy. The fourth-order trend polynomial fitted to the data is also shown. The plots for the other cases of *SI vs.* SNA_o are very similar. That is, there is a fairly constant level of *SI*, between 90 and 100%, at moderate to high levels of SNA_o, but a decrease of *SI* at lower levels of SNA_o. In particular, *SI* decreases rapidly for negative values of SNA_o. This decrease is very rapid for half and full occupancy in the 'small' and 'medium' classrooms, and less so for the 'large' classroom. From Figure 4, it can be seen that the speech intelligibility decreases with decreasing SNA_o. Thus, for a given classroom, the worst case of verbal-communication quality occurs at the lowest value of SNA_o (*i.e.* $SI < 50$ % for $SNA_o <$ -10 dBA for the case of the 'medium' classroom at half occupancy).

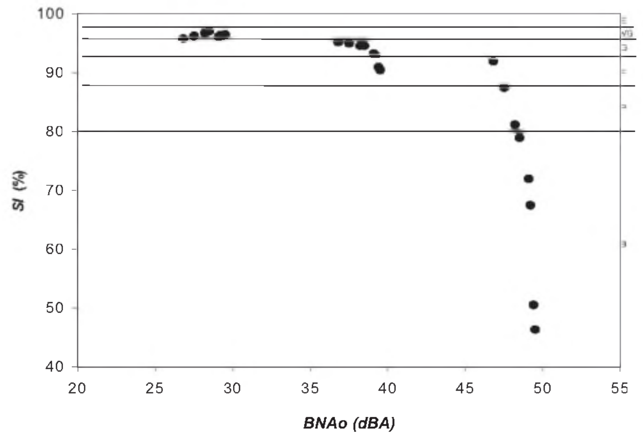


Figure 5. Variation of room-average SI with BNA_o for the 'medium' classroom with half occupancy.

5.4 Background-Noise Level

As for background-noise level, Figure 5 shows the variation of *SI* with BNA_o for the case of the 'medium' classroom at half occupancy. Plots of the other cases are similar. Of course, the data points are clumped around BNA_o values of 30, 40 and 50 dBA, the values tested here. With BNA_o near 30 and 40 dBA, most of the values of *SI* are at least 90%. However, with BNA_o near 50 dBA, there is a sharp decrease in *SI* in all six cases. This decrease is less steep with greater occupancy and/or increasing classroom size. Moreover, with increasing occupancy and/or increasing classroom size the 'clumps' of data mentioned above show more spread to lower levels of BNA_o. From Figure 5, it can be seen that the speech intelligibility decreases with increasing BNA_o. Thus, for a given classroom, the worst case of verbal-communication quality occurs at the lowest value of SNA_o (*i.e.* $SI < 50$ % for $BNA_o > 49$ dBA for the case of the 'medium' classroom at half occupancy).

6. CONCLUSION

From this study, the following conclusions can be drawn:

- Speech intelligibility (and verbal-communication quality) in the classrooms of the study did not depend solely on either classroom absorption or early-decay time in any systematic, predictable way. It is possible to get a wide range of values of *SI* for any given value of classroom absorption or early-decay time. However, it can be concluded that 'high' unoccupied background-noise levels, combined with either high absorption or low early-decay time, can lead to extremely low speech intelligibility;

- A common trend in the relationship between speech intelligibility and occupied background-noise level was observed. The speech intelligibility gradually decreased with increasing background noise until the highest levels of BNA_o, at which there was a very sharp decrease in verbal-communication quality. This decrease of *SI* gets less steep with increasing classroom size. 'Bad' verbal-communication qualities are possible in all of the cases, and these levels occur at slightly lower levels of BNA_o as the classroom size is increased. 'Very Good' and 'Good' verbal-communication qualities are attainable if BNA_o is sufficiently low, but this does not depend on occupancy;

- There was a close relationship between speech intelligibility and the speech-to-noise level difference. A fourth-order trend polynomial can be fit to the data with very high correlation. The speech intelligibility is low for negative values of the speech-to-noise level difference, but it increases sharply (more gradually for the 'large' classroom) to a fairly constant value. 'Bad' verbal-communication qualities are possible in all classroom/occupancy combinations studied for SI vs. SNA_o, where these verbal-communication qualities tend to appear at lower values of SNA_o as the classroom size is increased. Both ‘Very Good’ and ‘Good’ verbal-communication qualities are possible if SNA_o is sufficiently high, but size or occupancy does not make much of a difference;

- The most significant design factor in determining the verbal-communication quality of the rooms was the background noise. It was found that the verbal-communication quality generally decreases with increasing background noise. The ‘large’ classroom had less of a range of verbal-communication quality than the other two rooms.

REFERENCES

1. B. Seep, R. Glosemeyer, E. Hulce, M. Linn, P. Aytar and R. Coffeen, ‘Classroom acoustics – a resource for creating learning environments with desirable listening conditions’, Acoustical Society of America (2000).
2. S. R. Bistafa and J. S. Bradley, ‘Reverberation time and maximum background-noise level for classrooms from a comparative study of speech intelligibility metrics’, *J. Acoust. Soc. Am.* **107**(2), 861-875 (2000)
3. M. R. Hodgson, “Empirical prediction of speech levels and reverberation in classrooms”, *J. Build. Acoust.* **8**(1) 1-14 (2001).
4. M. Hodgson, R. Rempel and S. Kennedy, ‘Measurement and prediction of typical speech and background-noise levels in university classrooms during lectures,’ *J. Acoust. Soc. Am.* **105**(1) 226-223 (1999).
5. M. R. Hodgson, “Rating, ranking and understanding acoustical quality in university classrooms”, *J. Acoust. Soc. Am.* **112**(2) 568-575 (2002).
6. P. W. Barnett and R. D. Knight, ‘The common intelligibility scale’, *Proc. Inst. Acoust.* **17**(7) 199-204 (1995).
7. H. J. M. Steeneken and T. Houtgast, ‘A physical method for measuring speech-transmission quality’, *J. Acoust. Soc. Am.* **67**(1) 318-326 (1980).
8. M. R. Hodgson, ‘Experimental investigation of the acoustical characteristics of university classrooms,’ *J. Acoust. Soc. Am.* **106**(4) 1810-1819 (1999).
9. M. R. Hodgson, "Prediction of speech intelligibility in rooms – a comparison of five methods", *J. Acoust. Soc. Am.* **116**(4, Pt.2) 2638 (2004).

---

architecture|music|acoustics

International Cross-Disciplinary Conference Toronto, Canada June 7-10, 2006

In conjunction with the **soundaXis** festival of music, acoustics, and architecture, **Ryerson University** Department of Architectural Science is pleased to announce an international conference dedicated to a study of the same themes.

Among the critical fault-lines within architectural practice and discourse is that which privileges sight, conceiving of architecture as primarily a visual art form. Despite the multi-sensorial, embodied nature of our being in space, architectural discourse has been largely silent where senses other than the visual are impacted.

This conference proposes to move outside the visual paradigm to investigate the relationships between architecture, music, and acoustics. These intermeshed relationships have tended to one extreme or the other: either sound is understood by architects instrumentally, as an element to be controlled if not eliminated, or music is understood by architects as a metaphorical structure needing to be translated to visual terms before becoming available to architecture.

Framing the conference is the premise that Architecture, Music, and Acoustics have real relationships not requiring translation between visual and sonic terms, and not limited by the instrumental. The conference will involve both historical and critical studies of these relationships, focusing on the strategies and techniques used by architects in dealing with sound and with ideas borrowed from music. The conference will encourage an active mode of engagement with sound in architectural design.

Session Themes: **Acoustic Ecology | Situated Sonic Practices | Spaces for Performance | Intersections of Music and Architecture | The Poetics of Closure | Sound in Architectural Education | The Architectural Representation of Sound** .

Keynote Speakers: **R. Murray Shafer, Canada | Bob Essert, London | Juhani Pallasmaa, Helsinki | Bernhard Leitner, Vienna**

soundaXis
Architecture • Music • Acoustics

RYERSON UNIVERSITY

INFANT-DIRECTED SPEECH: FINAL SYLLABLE LENGTHENING AND RATE OF SPEECH

Church, Robyn[1], Bernhardt, Barbara[2], Pichora-Fuller, Kathy[3], and Shi, Rushen[4]

[1]BC Family Hearing Resource Centre, 15220-92nd Avenue, Surrey, British Columbia V3R 2T8
[2]School of Audiology & Speech Sciences, 5804 Fairview Avenue, University of British Columbia, Vancouver, BC, V6T 1Z3
[3]University of Toronto at Mississauga, Department of Psychology, 3359 Mississauga Rd N, Mississauga, Ontario L5L 1C6
[4]Dept of Linguistics, Dept of Psychology, Université du Québec à Montréal, 3150 rue Jean-Brillant, Montréal, PQ, H3T 1N8

ABSTRACT

The present study compared infant-directed speech (IDS) and adult-directed speech (ADS) for two mothers of preverbal infants. Each mother participated in two recording sessions, one with her child, and one with an adult friend. The primary objective of the study was to determine the influence of exaggerated utterance-final syllable lengthening on the rate of IDS. A secondary objective was to compare the rate of speech read to infants with the rate of spontaneous IDS. The results showed an overall slower rate of speech in IDS to preverbal infants compared with ADS, replicating previous research. However, when the utterance-final syllable was excluded from the calculation of rate, the rate of speech in spontaneous IDS and ADS did not differ significantly. Speech was read to infants at a slower rate than spontaneous IDS. Implications for future research are suggested.

SOMMAIRE

La présente étude a comparé les discours de deux mères dirigés soit vers leur enfant d'âge préverbal soit vers un adulte. Chacune des mères a participé à deux sessions d'enregistrement, dont une avec son enfant et une seconde avec une amie adulte. L'étude avait comme objectif principal de déterminer l'influence de l'allongement exagéré des syllabes en position finale d'énoncés sur la vitesse du discours dirigés vers l'enfant. L'objectif secondaire était de comparer la vitesse des discours lus aux enfants avec celle des discours spontanés dirigés vers l'enfant. Les résultats ont démontré une vitesse globale plus lente des discours dirigés vers les enfants préverbaux comparativement aux discours dirigés vers unadulte, en répliquant des recherches antérieures. Cependant, lorsque les syllabes en position finale d'énoncés étaient exclues des calculs, la vitesse des discours spontanés dirigés vers l'enfant ou vers l'adulte ne différait pas de façon significative. Les discours étaient lus aux enfants à une vitesse plus lente que les discours spontanés dirigés vers l'enfant.

1. INTRODUCTION

Adults often modify their speech when talking to infants, a speech style which researchers have referred to as 'motherese' (Garnica, 1977; Fernald & Simon, 1984; Grieser & Kuhl, 1988; Fernald & Mazzie, 1991). The current paper focuses on one characteristic of 'motherese,' the rate of infant-directed speech (IDS) in comparison with adult-directed speech (ADS). Research has shown rate of speech to be slower in IDS than ADS (e.g. Swanson et al., 1992, Albin & Echols, 1996, Bernstein Ratner, 1985, 1996). In Bernstein Ratner's (1985) study, mothers' overall spontaneous speech rate to their children was slower in IDS compared with ADS by almost 25% (184 wpm for ADS, compared with 138 wpm for IDS), although individual segment durations were not different. Comparing speech in read and spoken texts, Morgan (1986) stated that mothers' rate of speech was slower in spontaneous speech than read text, although presented no measurements. In recent studies by Shute & Wheldall (1999, 2001), fathers and grandmothers took longer to read a passage to children than to adults, although speaking rate was not specifically determined nor compared with that of spontaneous speech.

The slower rate of IDS has often been attributed to the overall lengthening of stressed syllables, whatever their utterance position (Swanson, Leonard & Gandour, 1992; Albin & Echols, 1996; Bernstein Ratner, 1996). However, there could be another explanation for the slower rate of speech of IDS. Utterances are consistently shorter in IDS than in ADS (Fernald & Simon, 1984) and the length of the final word tends to be exaggerated (Albin & Echols, 1996; Bernstein Ratner, 1996). The oft-noted slower rate of IDS may simply reflect the presence of extra-long final syllables in very short utterances. As suggested early on by Oller (1973), any study concerned with speaking rate needs to take final-syllable lengthening into account. The current study set out to compare ADS and IDS in terms of the utterance-final syllable and the remainder of the utterance, in order to determine the particular impact of the exaggerated final syllable on speaking rate. The following discussion outlines previous findings on ADS and IDS with respect to speaking rate and phrase-final lengthening and implications for language acquisition.

In English ADS, prosodic changes such as pausing, pitch changes, and vowel lengthening have been shown to occur at utterance boundaries and even at within-utterance phrase boundaries (Cooper & Paccia-Cooper, 1980). Syllables that end utterances, clauses, and phrases tend to be lengthened relative to syllables elsewhere in utterances (Cooper & Sorensen, 1981). As noted above, several researchers have found phrase-final lengthening to be more exaggerated in IDS compared with ADS (Morgan, 1986; Swanson et al., 1992; Albin & Echols, 1996; Bernstein Ratner, 1996).

Different explanations have been put forward for the exaggeration of various prosodic cues in IDS. One hypothesis ('prosodic bootstrapping') suggests that exaggerated prosodic cues may provide language learners with segmentation information that can serve as a basis for syntactic category development (Morgan, 1986; Kemler Nelson, Hirsh-Pasek, Jusczyk, & Wright Cassidy, 1989; Gerken, Jusczyk & Mandel, 1994; Fernald & McRoberts, 1996; Shi, Morgan & Allopenna, 1998). Because long pauses in IDS are nearly always at the ends of utterances (Broen, 1972; Fernald & Simon, 1984), the exaggerated lengthening of the pre-pausal syllable may serve as an accentuated cue to grammatical boundaries. Another hypothesis suggests that the exaggerated prosodic cues may serve as an implicit word teaching strategy. Woodward and Aslin (1990) hypothesized that mothers have tacit knowledge that infants can better attend to and remember words placed in utterance-final position. In word teaching studies by Woodward and Aslin (1990) and Fernald and Mazzie (1991), mothers consistently placed target words in utterance-final position in IDS, whereas in ADS, positioning of target words was variable.

Currently, it is unclear whether exaggerated pre-pausal lengthening in IDS serves as a cue to grammatical phrase segmentation or to word segmentation or both. Differences in design of the various studies have perhaps contributed to the alternative findings and explanations. The following section outlines results of pertinent studies in terms of the various ages of infant addressees for both spontaneous and read speech samples, and in terms of the different phrasal positions of the measured words or syllables. Various interpretations of the impact of exaggerated prosodic cues on rate of speech in IDS are discussed.

Studies of spontaneous English IDS to preverbal infants have consistently shown exaggerated utterance-final lengthening. For example, in Bernstein Ratner's (1986) study of IDS to preverbal children aged 9 to 13 months, utterance-final vowels in IDS were almost twice as long as those in ADS. Albin and Echols (1996) observed exaggerated utterance-final lengthening in spontaneous IDS to young preverbal infants (6 to 9 months), even for unstressed utterance-final syllables.

Results have differed across studies of older children, however. These differences may reflect the type of speech samples used. Bernstein Ratner (1985, 1986) found a general decrease in utterance-final lengthening in spontaneous IDS from the one-word to the two-word phase of development; by the time children combined words, utterance-final lengthening in IDS was much more similar to that observed in ADS. These findings contrast with those of Morgan (1986) and Swanson et al. (1992), who found exaggerated utterance-final lengthening in IDS to older verbal toddlers and preschoolers when mothers were reading prepared texts.

Results regarding exaggerated lengthening in IDS compared with ADS have also diverged regarding position of stressed syllables in the utterance, and again may reflect type of speech sample used. In Bernstein Ratner's (1985, 1986) studies using spontaneous speech, there was no main effect of addressee on the duration of utterance-*medial*, phrase-final, stressed syllable durations. Durations of utterance-medial phrase-final syllables remained almost constant across all groups of child and adult listeners. When using prepared read texts, however, Swanson et al. (1992) found exaggerated lengthening in utterance-medial, phrase-final position. In their study, the increase in phrase-final lengthening in IDS was, on average, 11.8 ms longer than phrase-final lengthening in ADS. Using prepared read texts, Morgan also reported that phrase-final target word durations were significantly longer in IDS than in ADS. However, only three of the seven phrase-final target words in the mothers' IDS showed exaggerated lengthening in IDS as compared with ADS.

In summary, the results outlined above have differed depending on the age of the addressee, phrasal position, and the type of speech sample (read versus spontaneous). In studies with younger infants, exaggerated utterance-final lengthening has been found in spontaneous IDS. With older children, only the studies using read texts have shown exaggerated lengthening of stressed syllables, independent of phrasal position. Generally, rate of speech appears slower in IDS when compared with ADS, although rate in read texts may differ from rate in spontaneous speech. The source of the slower rate of IDS in spontaneous speech is unclear.

The present study was constructed to address questions arising from the literature regarding the interaction of rate and utterance-final lengthening in IDS to preverbal infants, and the effect of speech sample type (read versus spontaneous speech). The first objective was to determine whether and to what extent the slower rate of speech in IDS might be a result of exaggerated utterance-final syllable lengthening. The second objective was to determine whether the rate of speech read to infants was slower or faster than that of spontaneous IDS. We chose to examine speech directed to preverbal infants, because infants even as young as 6 to 9 months have shown perceptual sensitivity to utterance-boundary pauses and pre-boundary syllable lengthening, particularly in IDS (e.g., Kemler Nelson, et al., 1989).

2. METHOD

Participants

Two mothers, their infants, and two adult female friends participated in the study. Small n studies may limit the generalizability of results but do allow for larger data samples and more in-depth analyses of individual data. The adults were speakers of standard Canadian English, and were both middle-class Caucasians in their early 30's. The infants were firstborn preverbal males, aged 8.5 months and 11 months.

Each mother participated in two 45-minute audio recording sessions, the first with her child, and the second with her friend. The recording sessions with the mother-child dyads were made in the mother's home an hour after the infant had awoken. To provide some consistency between the conversational contexts, the investigator brought children's toys and books to the sessions. Each mother was instructed to interact with her child as naturally as possible, and to read the books to her child at some convenient point. The recording sessions with the adult female friend were held at the home of the friend without any children present. The adults were instructed to have a natural conversation. The mothers were instructed to read the same children's books to the friend at some point in the conversation and to do so as they might to an adult. For all four recordings the investigator was nearby but not in the same room. Audio recordings were made using a Marantz tape recorder model number PMD420, a VHF wireless receiver and transmitter, and a Lavalier microphone that was clipped to the mother's collar.

Transcription and data selection procedures

For the current study, an utterance was defined acoustically as a section of speech bounded by pauses greater than 300 ms (following Jaffe & Feldstein, 1970, and Fernald & Simon, 1984). Because the final syllable of many longer English words is short and unstressed, only utterances ending in monosyllabic stressed words were used, in order to be able to observe utterance-final lengthening more easily (following Bernstein Ratner, 1985, 1986; Morgan, 1986; Swanson et al., 1992). A total of 413 utterances ending in stressed monosyllabic words were identified for analysis, and coded as spontaneous or read. The first and second authors made independent orthographic transcriptions of the utterances, and agreed on over 99% of the words. Table 1 shows a breakdown of the number of utterances per participant, addressee, and condition.

From the audiotapes each selected utterance was digitized at 22.050 kHz (16 bits) using the SoundEdit 16 version 2 program (1996) on a Macintosh computer. Individual soundfiles (AAIF) were created for each utterance. For each soundfile, Macquirer version 6.0 (2000) was used to produce a spectrogram of the waveform, with a bandwidth of 344 Hz and a frequency range of 6000 Hz. Because an utterance was defined acoustically as a section of speech bound by pauses greater than 300 ms, there were no between-utterance segmentation difficulties.

Table 1. Number of utterances per participant, addressee, and condition

Participant	Addressee	Total utterances per session	Coded utterances per session
1	Infant	480	94 spontaneous 22 read
1	Adult	430	75 spontaneous 16 read
2	Infant	470	91 spontaneous 20 read
2	Adult	386	79 spontaneous 16 read

Measurements of duration

Two measurements of duration (in milliseconds) were made for each selected utterance: the total utterance time and the duration of the final stressed syllable. Segmentation decisions for durational measurements were made using the waveform and the spectrogram, according to the following criteria. Over 90% of the utterances began with a voiced segment; in these cases, onset of phonation was a reliable cue to the beginning of the utterance. For the few utterances with initial voiceless fricatives (e.g. *she, should, shall, so, see*), frication noise on both the waveform and the spectrogram was taken to mark the beginning point. The cues for the onsets of voiceless stops could not be reliably determined in the data and therefore the onset of vowel phonation was used as the beginning point.

Determining the end of the utterance proved more difficult. For fricatives, the spectrogram was used to determine cessation of frication. To determine the terminal boundary of a stop, the first step was to establish the presence or absence of a release burst by identifying frication on the waveform and the spectrogram. The cessation of frication on the spectrogram was taken as the indication of the terminal boundary for voiced stops with a voiced release (e.g. *crib, ride, dog*, etc.) and voiceless stops with a voiceless release burst (e.g. *flap, boat, think*, etc.). For unreleased voiceless stops in which there was no frication, the point of closure for the stop was used to mark the terminal boundary for the syllable (e.g. *night, milk*, etc.). The cessation of pitch pulses on the waveform was taken as the indication of the terminal boundary for unreleased voiced stops (e.g. *bed, egg*, etc.) and other voiced segments (except for voiced fricatives).

The delineation of successive syllables was challenging because of co-articulatory effects between segments. In many instances the transitions between segments occurring at syllable boundaries had overlapping cues, making segmentation difficult. Criteria for syllable segmentation were derived from Fant (1962), in which phonemes are broken down into successive sound segments. The beginning point of co-articulation was consistently clearer than the ending point, especially for formant transitions, and was thus considered the syllable boundary. Where either the same segment or two acoustically indistinguishable segments occurred at syllable boundaries (e.g. *her-ROOM, that-can*, etc.), the total time of the two segments was halved, and that halfway point delineated as the syllable boundary.

Ten utterances were selected randomly from each audiotape and measured three times each over a three-month period by the first author. The mean error for utterance onsets was 3.4 ms (range = 0-6 ms), for unstressed syllables it was 9.7 ms (range = 0-19 ms), and for utterance endings it was 20.6 ms (range = 3-37 ms). For 10 randomly selected utterances, the fourth author confirmed consistent use of the above procedures through independent measurement. The first author consulted with the fourth author if there was any doubt about measurement decisions; the measurement agreed upon by both coders was taken in these cases.

Calculation of rate

Rate of speech was calculated in syllables per second. Pauses over 300 ms were excluded following studies such as Fernald & Simon (1984). Calculating rate in this way eliminated possible confounding differences in length and frequency of between-utterance pauses in IDS compared with ADS. Two measurements were made. For Rate 1, the number of syllables for each utterance was divided by the utterance's total duration. In order to determine the influence of the exaggerated utterance-final syllable on rate, a second calculation was made excluding the final stressed syllable. Rate 2 was computed by dividing the total number of syllables minus one in each utterance by the total utterance duration minus the final syllable duration.

3. RESULTS

Results are given for (a) durations of stressed utterance-final monosyllables in ADS and IDS, and (b) speech rates in ADS and IDS, including and excluding the utterance-final syllables. Comparisons are made for spontaneous and read text samples.

Duration of utterance-final syllables in ADS and IDS

Table 2 lists the mean durations and standard deviations (in milliseconds) of the utterance-final stressed syllables for each participant.

In spontaneous ADS, the duration of the utterance-final stressed syllable was similar for both participants. It was longer for each participant in IDS compared to ADS, although Participant 1 showed greater utterance-final syllable lengthening in IDS than did Participant 2. The ADS-IDS difference was significant for both participants: $F(1,167)=79.99$, $p<0.01$ for Participant 1; $F(1,168)=23.66$, $p<0.01$ for Participant 2 (2 one-way ANOVAs).

Table 2. Mean durations of the final stressed syllables for each participant and addressee condition

Participant	Addressee Condition	# of utterances	Mean syllable duration (ms)	S.D. (ms)
1	ADS-S	75	386.3	112.9
	ADS-R	16	459.0	124.8
	IDS-S	94	586.1	165.1
	IDS-R	22	631.1	180.4
2	ADS-S	79	385.9	115.7
	ADS-R	16	502.3	91.3
	IDS-S	91	489.1	154.7
	IDS-R	20	636.4	139.9

Note. ADS = adult-directed speech; IDS = infant-directed speech; S = spontaneous; R = read texts.

Rate of speech

Two different calculations of speech rate were made for both spontaneous and read speech across addressee conditions as described above. Spontaneous speech rates were slower in IDS than in ADS for both participants. (See Table 3 and Figure 1.)

The Rate 1 differences between spontaneous IDS and ADS were significant for both participants: $F(1,167) =$

45.31, $p<0.01$ for Participant 1; $F(1,168) = 11.93$, $p<0.01$ for Participant 2 (two one-way ANOVAs). The Rate 2 differences between spontaneous IDS and ADS (excluding the duration of the final syllable) were not significant for either participant: $F(1,167)=1.48$, $p=0.23$ for Participant 1; $F(1,168)=0.54$, $p=0.46$ (two one-way ANOVAs).

Table 3. Mean rates in syllables/sec for spontaneous and read speech with the utterance-final syllable included and excluded.

Participant	Addressee condition	Rate[a]	# of utterances	Mean rate (syllables/ second)	S.D.
1	ADS-S	1	75	5.30	1.28
	ADS-S	2	75	6.37	1.81
	IDS-S	1	94	4.14	0.94
	IDS-S	2	94	6.03	1.85
	IDS-R	1	22	3.31	0.79
	IDS-R	2	22	4.91	1.79
2	ADS-S	1	79	5.92	0.71
	ADS-S	2	79	7.63	1.30
	IDS-S	1	91	5.25	1.29
	IDS-S	2	91	7.87	2.06
	IDS-R	1	20	3.47	0.71
	IDS-R	2	20	4.87	1.30

Note. ADS = adult-directed speech; IDS = infant-directed speech; S = spontaneous; R = read texts.

[a]Rate 1 was calculated including the duration of the utterance-final syllable; rate 2 was calculated excluding the duration of the final syllable.

These results differed from rate of speech in read texts. The rate of speech that was read to the infants was slower than the rate of spontaneous IDS for both participants. This was the case in <u>both</u> the Rate 1 and 2 calculations (Table 3): Rate 1 -- $F(1,114)=14.47$, $p<0.0005$ for Participant 1, and $F(1,109)=35.81$, $p<0.0005$ for Participant 2; Rate 2 -- $F(1,114)=6.57$, $p<0.01$ for Participant 1 and $F(1,109)=38.71$, $p<0.01$ for Participant 2 (one-way ANOVAs).

4. DISCUSSION

The results of the present study for IDS showed exaggerated lengthening of the utterance-final syllable and an overall slower rate of speech in IDS compared to ADS. These two results replicate previous research findings with preverbal infants, but using both spontaneous and read texts.

The first objective was to determine whether and to what extent the slower rate of speech in IDS might be a result of exaggerated utterance-final syllable lengthening. The present study indicates that the slower rate of IDS appears to be a product of extra-long final syllables occurring in very short utterances. When the final syllable was excluded from the calculation, the rate of spontaneous speech for the earlier portion of the IDS utterances was not significantly different from the rate of speech in ADS. The articulation rate of the syllables in utterances preceding the final syllable was similar in IDS and ADS.

The second objective of the current study was to determine whether the rate of spontaneous and read IDS might differ. For the two mothers, read IDS was slower than spontaneous IDS and in this case the utterance-final syllable was not solely responsible for the slower rate of speech. Comparisons with previous studies are outlined below, and implications for future research suggested.

Duration of utterance-final syllable vs remainder of utterance

The mean utterance-final syllable duration was significantly longer in IDS than in ADS for both participants in the present study. These results generally replicate earlier studies on utterance-final syllables in IDS with preverbal infants (Bernstein Ratner, 1986; Albin & Echols, 1996). However, the rate of articulation of the syllables preceding the final syllable was found to be similar in spontaneous IDS and ADS, a finding which has not been previously reported. Bernstein Ratner (1985) had noted that the ‘global rate adjustment [in IDS] did not translate directly into longer segmental durations’ (Bernstein Ratner, 1985: 262) but offered no explanation for the overall slower rate. The present study suggests that the overall slower rate is in large part due to the occurrence of extra- long final syllables in typically short utterances. This differs from previous interpretations, which suggest that the slower rate of IDS was due to the overall lengthening of stressed syllables regardless of phrasal position (Morgan, 1986; Swanson et al., 1992; Albin & Echols, 1996; Bernstein Ratner, 1996).

‘Prosodic bootstrapping’ versus word teaching strategies?

The advocates of the prosodic bootstrapping hypothesis suggest that the more extreme pre-pausal lengthening in IDS compared to ADS may serve as an accentuated acoustic marker of utterance boundaries (1984), and serve as a cue to grammatical categories. An alternative hypothesis suggests that pre-pausal lengthening may be used to attract the infants' attention as a way to teach new words. In this study, it was only the utterance-final syllable in spontaneous IDS that showed exaggerated lengthening. It is not clear how a syntactic category could be inferred from a single extra-long syllable, especially when the rest of the utterance is articulated at the same rate as an utterance in ADS. Considering the preverbal stage of the infants in this study, the exaggerated lengthening may have served as a more general attentional cue and/or as a specific grammatical bootstrapping cue. More research is needed to compare spontaneous IDS to infants at early versus later developmental phases, and to relate it to actual language perception, comprehension and production..

Rate of speech in spontaneous IDS and the issue of pauses

Earlier studies from the 1970s comparing rate of speech in IDS and ADS were calculated in words per minute. Between-utterance pauses were not excluded from these calculations of rate. However, the between-utterance pauses would account for some of the slower rate of speech in IDS compared to ADS because in IDS pauses are longer and more frequent (Garnica, 1977; Fernald & Simon, 1984; Grieser & Kuhl, 1988; Fernald & Mazzie, 1991). Studies in the 1980s, as in the present study, calculated the rate of speech in syllables per second excluding pauses over 300ms (e.g. Fernald & Simon, 1984). This calculation is a more accurate depiction of the rate of articulation because the confounding difference in length and frequency of between-utterance pauses in IDS compared to ADS has been eliminated. However, differences due to length and frequency of the utterance-final syllable in IDS compared to ADS are still confounded. Perhaps a more accurate portrayal of the rate of articulation in IDS compared to ADS would involve a calculation of rate in which both the between-utterance pauses and the duration of the final syllable are excluded, a possibility for future research.

Read text versus spontaneous speech

Morgan commented that IDS samples from prepared read texts appeared to have a faster rate of speech than spontaneous IDS, although he provided no instrumental measurements to support that claim (1986: 121). In the current study, acoustical measures revealed that read text was slower overall than spontaneous speech in IDS. Other methodological differences between the current study and that of Morgan (1986) may also have led to different results, for example, age of child addressee, number of participants, and type of read text. The children in Morgan's (1986) study were verbal and older than the preverbal children in this study (2 and 4 years of age compared with 8 1/2- and 11 months of age). The results of the present study are more in line with those of Bernstein Ratner (1985), who found exaggerated utterance-final lengthening in spontaneous IDS to preverbal infants but not to older verbal toddlers. In terms of number of participants, the present study only included two mothers, compared with 34 in the Morgan (1986) study. The particular adults in this study may have had slower oral reading rates. The type of read text may also have been relevant. Both studies used stories, but in the Morgan study (1986) experimentally designed sentences were embedded within the story. In the current study, the books were typical children's books.

For read texts, even when the utterance-final syllable was excluded from rate calculations, speech rate in IDS remained significantly slower than spontaneous IDS. Thus, syllables preceding the utterance-final syllable were also lengthened. The slower rate of the syllables preceding the final syllable in the read speech can be attributed to longer segmental durations in read IDS compared with spontaneous IDS. These results are consistent with the observed overall exaggerated lengthening of stressed syllables (phrase-final and non-phrase-final) in studies of read IDS (Morgan, 1986; Swanson et al., 1992). These researchers proposed that the observed vowel lengthening was due to the addressee condition; i.e., that the speech was IDS versus ADS. Morgan stated: 'Thus, as expected, the slower speech rate evident in child-directed speech is due in part to the lengthening of at least stressed vowels in content words' (1986: 118). The syllable-level analysis of the utterances in the present study does not examine the specific lengths of particular types of segments, and thus supports only a syllable-level interpretation of data, with evidence of syllable lengthening in utterance-medial content words but only in speech that is read to infants and not in spontaneous IDS. Both Morgan (1986) and Swanson et al. (1992) acknowledged that the read speech in their studies might not be fully representative of spontaneous speech. However, neither discussed the possibility that the type of speech (read vs spontaneous) might be the source of the differences in utterance-medial vowel durations and the related differences in rate that they previously observed. Further research comparing speech rates of read and spontaneous IDS and ADS is required to resolve this apparent confound. In addition, these findings could also have implications for infant word recognition research, which typically use read texts as experimental stimuli. No study has used spontaneous IDS as stimuli. It might be necessary for future infant speech segmentation research to focus on infants' word segmentation for spontaneous IDS in comparison with read IDS.

5. CONCLUSIONS

The present study showed exaggerated lengthening of the utterance-final syllable and an overall slower rate of speech in IDS compared to ADS. The utterance-final lengthening was solely responsible for the slower rate of spontaneous IDS compared with ADS, but was only partially responsible for the slower rate of read text in IDS compared to spontaneous IDS. Previous researchers have suggested that the exaggerated prosodic cues of IDS accentuate syntactic boundaries and are indirect evidence for prosodic bootstrapping. However, these suggestions have been based primarily on observed acoustic properties of mother's reading of prepared texts to verbal children (Morgan, 1986; Swanson et al., 1992). Research using spontaneous speech has found less exaggerated utterance-final lengthening in speech to children at the one-word phase and negligible exaggeration in speech to children at the two-word phase (Bernstein Ratner, 1986) This study, like others to preverbal infants, found exaggerated utterance-final syllable lengthening in spontaneous IDS to preverbal infants, but no lengthening of non-utterance-final syllables, suggesting that the duration cue for utterance boundary is indeed more reliable in ID than AD spontaneous speech. Further cross-linguistic research is needed with children at different ages, and with both spontaneous and prepared text samples, to resolve some of the conflicts in the literature. In addition, in order to understand the function of the various exaggerated cues of IDS, studies need to include data from the children in the mother-child dyads.

ACKNOWLEDGMENTS

This work was supported by funding from NSERC, SSHRC and the UBC Peter Wall Institute for Advanced Studies Major Thematic grant on 'Acoustic Ecology'. We would like to thank Trudy Adams, Bryan Gick, and Joseph Stemberger, as well as the participants. This paper is based on the Master's thesis of Robyn Church.

REFERENCES

Albin, D. D. & Echols, C. H. (1996). Stressed and word-final syllables in infant-directed speech. *Infant Behaviour and Development* **19**, 401-418.

Bernstein Ratner, N. (1985). Dissociation between vowel durations and formant frequency characteristics. *Journal of Speech and Hearing Research* **28**, 255-264.

Bernstein Ratner, N. (1986). Durational cues which mark clause boundaries in mother-child speech. *Journal of Phonetics* **14**, 303-309.

Bernstein Ratner, N. (1996). From "signal to syntax": But what is the nature of the signal? In J. L. Morgan, and K. Demuth (eds.), *Signal to syntax: Bootstrapping from speech to grammar in early acquisition.* Mahwah, NJ: Lawrence Erlbaum Associates, pp. 135-150.

Broen, P. A. (1972). The verbal environment of the language-learning child. *Monograph of American Speech and Hearing Association* **17**, December, 1972.

Cooper, W., & Paccia-Cooper, J. (1980). *Syntax and speech.* Cambridge: Harvard University Press. Cooper, W. E., & Sorensen, J. M. (1981). *Fundamental frequency in sentence production.* New York: Springer - Verlag.

Fant, C. G. M. (1962). Descriptive analysis of the acoustic aspects of speech. *Logos* **5**,3-17.

Fernald, A., & Mazzie, C. (1991). Prosody and focus in speech to infants and adults. *Developmental Psychology* **27**, 209-221.

Fernald, A., & McRoberts, G. (1996). Prosodic bootstrapping: a critical analysis of the argument and the evidence. In J. L. Morgan, and K. Demuth (eds.), *Signal to syntax: Bootstrapping from speech to grammar in early acquisition.* Mahwah, NJ: Lawrence Erlbaum Associates, pp. 126-143.

Fernald, A., & Simon, T. (1984). Expanded intonation contours in mother's speech to newborns. *Developmental Psychology* **20**, 104-113.

Garnica, O. (1977). Some prosodic and paralinguistic features of speech to young children. In C.E. Snow and C. A. Ferguson (eds.), *Talking to children: Language input and acquisition.* Cambridge, England: Cambridge University Press.

Gerken, L., Jusczyk, P. W., & Mandel, D. R. (1994). When prosody fails to cue syntactic structure: Nine-month-olds' sensitivity to phonological vs. syntactic phrases. *Cognition* **51**, 237-265.

Grieser, D. L., & Kuhl, P. K. (1988). Maternal speech to infants in a tonal language: Support for universal prosodic features in motherese. *Developmental Psychology* **24**, 14-20.

Jaffe, J., & Feldstein, S. (1970). *Rhythms of dialogue.* New York, NY: Academic Press.

Kemler Nelson, D., Hirsh-Pasek, K., Jusczyk, P.W. & Wright Cassidy, K. (1989). How the prosodic cues in motherese might assist language learning. *Journal of Child Language* **16**, 55-68.

Macquirer 6.0, 2000. (Los Angeles, CA: Scicon R & D., Inc.).

Morgan, J. L. (1986). *From simple input to complex grammar.* Cambridge, MA: MIT Press.

Oller, D. K. (1973). The effect of position in utterance on speech segment duration in English. *Journal of the Acoustical Society of America* **54,** 1235-1246.

Shi, R., Morgan, J., & Allopenna, P. (1998). Phonological and acoustic bases for earliest grammatical category assignment: A cross-linguistic perspective. *Journal of ChildLlanguage 25,* 169-201.

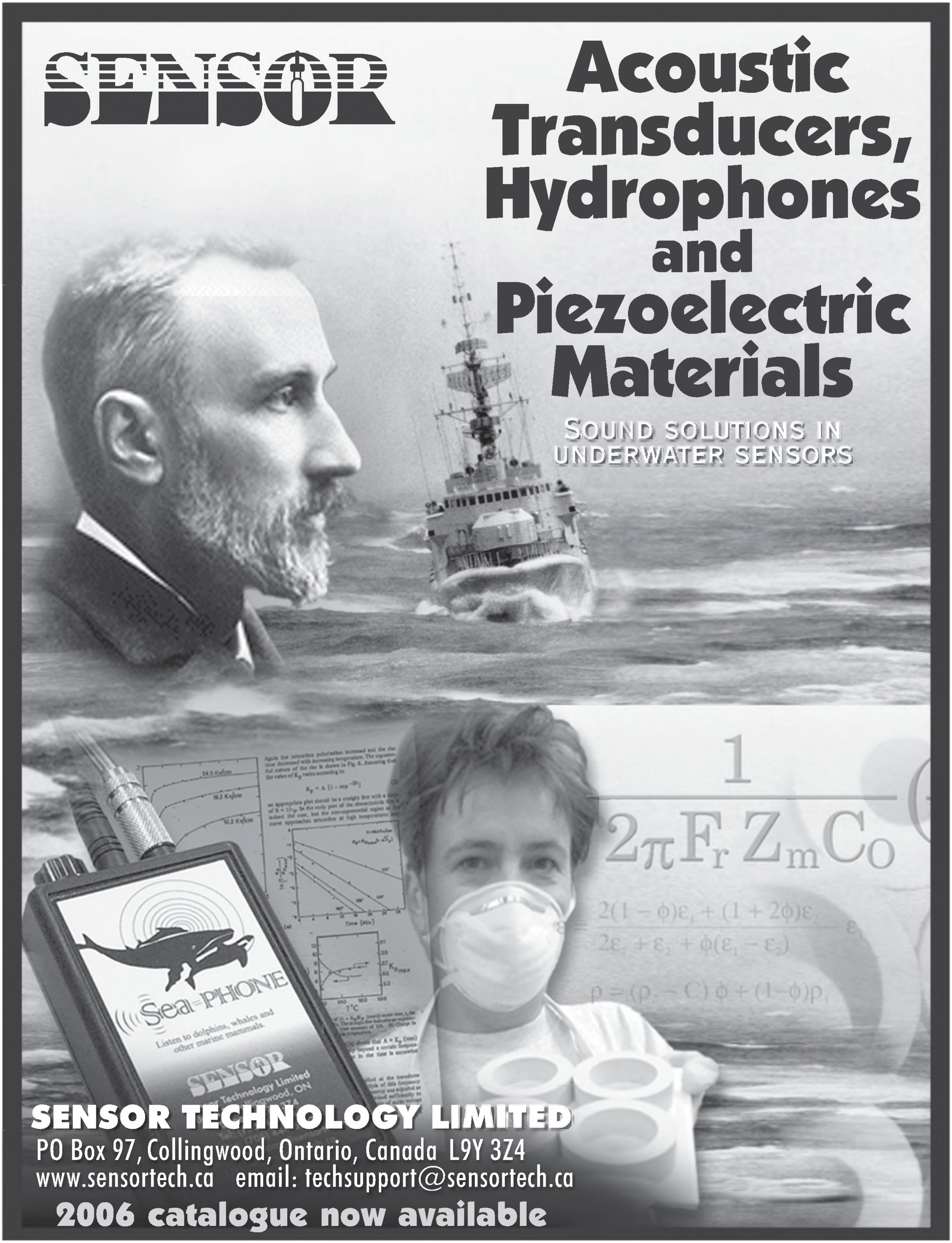
Shute, B. & Wheldall, K. (1999). Fundamental frequency and temporal modifications in the speech British fathers to their children. *Educational Psychology*, *19*, 221-233.

Shute, B. & Wheldall, K. (2001). How do grandmothers speak to their grandchildren? Fundamental frequency and temporal modifications in the speech of British grandmothers to their grandchildren. *Educational Psychology, 21,* 493-503.

SoundEdit 16 (2) (1996). (San Francisco, CA: Macromedia).

Swanson, L., Leonard, L., & Gandour, J. (1992). Vowel duration in mothers' speech to young children. *Journal of Speech and Hearing Research* **35,** 617-625.

Woodward, J. Z. & Aslin, R. N. (1990). Segmentation cues in maternal speech to infants. Paper presented at the *International Conference on Infant Studies,* Montreal, April, 1990.


Sea-PHONE
Listen to dolphins, whales and other marine mammals.
SENSOR

HEARING LOSS PREVENTION PROGRAM IN THE MILITARY ENVIRONMENT

Christian Giguère and Chantal Laroche
Programme d'audiologie et d'orthophonie, Université d'Ottawa, 451 Smyth Road, Ottawa, Ontario K1H 8M5

ABSTRACT

The military personnel regularly face a wide range of noise-hazardous situations, many of which are seldom encountered in other work environments. This paper reviews the essential elements of a hearing loss prevention program proposed for the Canadian Armed Forces. The program has been designed to meet the noise measurement and hazard investigation procedures, limits on noise exposure, use of hearing protection and other regulatory measures contained in the Canadian Occupational Health and Safety (COHS) Regulations (Part VII: Levels of Sound), while addressing the particular nature of the military environment. The focus of the paper is on the scientific basis and issues that are not typically found in other occupational environments (variable work schedules, excessive impulse noise, exposure over sustained durations, communications devices, etc.).

SOMMAIRE

Le personnel militaire doit régulièrement faire face à des conditions de bruit nocives, lesquelles ne se manifestent pas souvent dans les autres milieux de travail. Cet article couvre les éléments essentiels d'un programme de prévention de la perte auditive proposé pour les Forces Armées Canadiennes. Le programme a spécialement été conçu pour satisfaire les méthodes de mesure du bruit et d'évaluation du risque, les limites d'exposition, les exigences en matière d'utilisation de protecteurs contre le bruit et les autres mesures contenues dans le règlement canadien sur la santé et la sécurité au travail (Partie VII : Niveaux acoustiques), tout en tenant compte de la spécificité de l'environnement militaire. L'article traite plus particulièrement de la base scientifique du programme de prévention et des aspects qui ne sont pas généralement retrouvés dans les autres milieux de travail (horaires de travail variables, bruits impulsionnels excessifs, exposition sur de longues durées, casques protecteurs avec système de communication intégré, etc.).

1. INTRODUCTION

Noise can be particularly noxious to hearing in the military setting [1,2]. The personnel regularly face a wide range of noise-hazardous situations, many of which are seldom encountered in other work environments. High noise levels are associated with the operation of small arms and large calibre weapons, combat vehicles, fixed and rotary wing aircrafts, ships, vessels, and industrial equipment [3, 4].

It is well documented that hearing abilities are of utmost importance in offensive and defensive military operations [4]. Localization of snipers, determination of the position of the enemy, hearing of radio messages, and small arms identification are only a few examples of military tasks for which hearing is crucial.

Exposure to high noise levels, either continuous or impulsive, can cause permanent hearing loss in those exposed if no noise engineering or administrative controls are considered, or if hearing protectors are not worn when required. In addition, high noise levels can cause temporary loss of hearing, compromise speech communication, localization of sound sources and detection of warning sounds and thus, can jeopardize life or safety of the military and civilian personnel. Other physiological and psychological effects of noise affecting the personnel and work performance include sleep interference, increased stress and fatigue, and inability to concentrate [5, 6].

The Canadian Forces Health Services Group (CF H Svcs Gp) is currently implementing a comprehensive health care reform process, referred to as Rx2000, to review all aspects of health services in the Canadian Forces (CF) from clinical care to administration. One of the main objectives of Rx2000 is to "establish programs for the mitigation of preventable injuries and illnesses thereby protecting CF members and meeting requirements of DND/CF operations" [7]. In this context, the ultimate goal of a hearing-loss prevention (HLP) program in the Canadian Forces (CF) is to preserve hearing health as well as all hearing abilities necessary for effective operations.

The CF introduced hearing conservation procedures into its preventive medicine program in the early 1950s [8], and had a full program in place since 1968 [1]. The current policy (medical order CFMO 40-01 [9]) dates back from the early 1970s and now requires a thorough review as part of the Rx2000 process.

Several reports and studies throughout the 1980s and 1990s [1, 8, 10-12] addressed a number of shortcomings in CMFO 40-01, and provided recommendations on a number of areas including (1) noise monitoring and database, (2) audiometric testing, interpretation and record keeping, (3) hearing protection procedures, (4) use of special devices, and (5) training of personnel. In addition, a comprehensive study on the effects of impulse noise has just been completed by the Research and Technology Organisation (RTO) of NATO [13].

This paper reviews the essential elements of a new hearing loss prevention (HLP) program proposed for the Canadian Forces. The HLP program consists of the following elements: (1) hazard assessment and identification, (2) engineering noise control, (3) administrative controls, (4) hearing protection, (5) monitoring audiometry, (6) education, (7) program evaluation and (8) documentation. The program is based on evidence-based practices, reflects major findings from past reviews of CFMO 40-01, and is consistent with current federal regulations (Treasury Board OSH Directives, Canada Labour Code Part II, Canadian Occupational Health and Safety Regulations). The paper will focus on the scientific basis of the proposed HLP program and address issues that are not typically found in other occupational environments (variable work schedules, excessive impulse noise, exposure over sustained durations, communication devices). A draft policy based on this proposal is currently under review by DND/CF.

2. PROGRAM ELEMENTS

2.1 Hazard Assessment and Identification

2.1.1 Objectives

An effective hearing loss prevention program is based on accurate and up-to-date sound level measurements for all noise-hazardous areas, facilities and operational equipment. Valid decisions and actions regarding most program requirements are possible only with a systematic scheduling of noise surveys, proper data management, and timely and effective reporting of results.

2.1.2 Regulatory equipment and procedures

The instrument description, accessories and selection criteria to measure occupational noise exposure must comply with article 4 in CAN/CSA-Z107.56-94 (R 2001) [14] as specified under COHS regulations [15]. Sound level meters (SLM) and dosimeters must be of Type 2 tolerance or better.

- A sound level meter without integrating capability is to be used only when the noise field can be divided into one or more discrete time segments in which sound levels remain steady (±3 dB). The instrument must be set to the A-weighting scale and the slow response setting.
- An integrating SLM or noise dosimeter can be used in all environments. They are required in environments containing impulse sounds and/or when the noise field is fluctuating and cannot be divided into discrete time segments in which sound levels remain steady. The instrument must be set to the A-weighting scale and for a 3-dB exchange rate. The threshold level for noise dosimeters must be set at least 10 dB below the criterion level of 87 dBA specified in COHS.

All measurements must be carried out under the most realistic conditions possible. The acoustical environment and the work activities at the time of measurement must be representative of the normal environment and work patterns. All noise types present in the environment (including impulse sounds) must be included in the measurements. The exact procedures and information to be recorded must comply with articles 5 and 6 in CAN/CSA-Z107.56 [14].

2.1.3 Special equipment and methods

In addition to the regulatory provisions above, additional equipment and methods are necessary to specify the spectral characteristics of the noise field for engineering noise control and hearing protector selection purposes, and to measure intense transient sounds from weapons impulses.

To perform octave-band (or narrower bandwidth) frequency analysis of the noise field, the instrument will include filters complying with ANSI S1.11-1986 (R1998) [16]. For impulse noise exceeding peak levels of 140 dBC, the measurement methods will be based on ANSI S12.7-1986 (R1998) [17]. To measure the parameters and record the time variation of the sound pressure wave for single impulse sounds, a SLM with special characteristics as defined in ANSI S1.4-1983 (R2001) [18] is required. Special purpose microphones capable of handling very high peak sound pressure levels must be used.

2.1.4 Types of noise surveys

Different types of noise surveys are required to implement the elements fully effective HLP program from initial hazard assessment to detailed noise control and hearing protector selection.

Basic noise surveys:

- These surveys are conducted by CF Base/Wing or Area/Formation Preventive Medicine Technicians to provide an initial assessment of suspected noise hazard in all industrial-type and military environments characterized by steady state or fluctuating noises.
- Basic surveys are to be carried out immediately after the installation of new or retrofitted equipment or change in operations for existing equipment.
- Basic surveys are to be scheduled on an annual or semi-annual basis for periodic monitoring of noise-hazardous sites with the purpose of revisiting each noise-hazardous site at least once every three years.

- The occupational noise exposure ($L_{ex,T}$) or equivalent sound level ($L_{eq,T}$) in dBA will be measured.

Detailed and operational equipment surveys:

- Detailed surveys are conducted by internal or external acoustical experts when the results of basic noise surveys in a specific environment require the initiation of hearing loss prevention procedures (> 84 dBA).
- Operational surveys are conducted by internal or external acoustical experts to specify noise levels on-board ships, aircraft, army vehicles and other noise-hazardous military equipment. The results on a limited number of items for each piece of equipment can be applied to all others used in the different DND/CF military facilities, given the same technical specifications and operational conditions.
- The $L_{eq,T}$ in dBA and the frequency analysis of the noise in octave bands (or narrower bandwidth) will be measured along with any other parameter necessary for engineering noise control measures and/or detailed hearing protection device selection.

Impulse noise surveys:

- These surveys are conducted by internal or external acoustical experts, in collaboration with other NATO countries, and apply to all weapons systems or other equipment producing impulse or transient sounds with peak levels in excess of 140 dBC.
- In this type of survey, the results on a limited number of items for each weapons system can be applied to all others used in the DND/CF and NATO military facilities, given the same technical specifications and operational conditions.

The main measurement parameter is the single-event sound exposure level (SEL) in dBA. Recording of the instantaneous time variation of the sound pressure wave is recommended to derive additional impulse noise parameters as necessary, until widely-accepted damage-risk criteria are firmly established by the international community.

2.1.5 Hazard identification

In all cases, noise hazard must be assessed against the regulatory limits in COHS [15]. The maximum noise exposure limit from all sources is 87 dBA for an 8-hour work shift in any 24-hour period (or according to a 3 dB exchange rate or exposure schedule in Section 7.4 of COHS regulations for exposure durations other than 8 hours). Additional provisions beyond COHS regulations are also necessary to address the particular nature of the military environment. Noise exposures sustained over extended work shifts and damage-risk criteria for weapons impulse noise are discussed below.

General occupational noise regulations, like COHS, are based on a typical workday of about 8 hrs followed by a long rest period. In the military, sustained exposure largely exceeding an 8-hour workday can occur on a regular or irregular basis. For exposures lasting 12 hrs or more, a rest period at least as long as the exposure duration is recommended [19]. In all cases, the rest period should be sufficiently long to ensure that the temporary threshold shift (TTS) induced by the exposure has decreased to a value 2.5 dB or less, which is the residual TTS expected after an exposure to 87 dBA for 8 hrs and 16 hrs of rest. Data in [20] can be used to estimate such a minimum rest period, given exposure duration and level. The rest environment should be lower than 74 dBA.

An alternative method for assessing extended noise exposures is proposed by the Canadian Centre for Occupational Health and Safety [21]. The method is based on the Brief and Scala method sometimes used to calculate exposure limits for chemicals, which takes into account the decreasing period of recovery following extended work shifts. It gives a more conservative noise level limit than a 3 dB exchange rate for extended work shifts, especially for exposure durations beyond 10-12 hours. However, the validity of using the Brief and Scala method for noise exposure is unknown.

Noise hazard from weapons systems must also be assessed against the latest damage-risk criteria for impulse noise. Data from a recent RTO/NATO study (2003) [13] generally indicate that the risk from small calibre weapons (or short impulse duration) are under-estimated using current damage-risk criteria based on CHABA [22, 23], while the risk from large calibre weapons (or long impulse duration) may be over-estimated. Moreover, no simple trade-off relationship to establish exposure limits could be found between impulse exposure level and number of impulses (a 5 dB reduction was proposed in CHABA for each ten fold increase in the number of impulses). The use of the A-weighted SEL is also favored by RTO/NATO to describe impulses instead of the peak level proposed by CHABA.

The SEL is the level of a constant sound lasting 1 sec that would contain the same amount of acoustical energy as the impulse. The concept is illustrated in Figure 1. The A-weighted SEL avoids the sometimes difficult assessment of impulse duration and peak level [13] with standard equipment, and can be easily used to calculate the daily noise exposure ($L_{ex,8h}$) using the equal-energy principle as follows:

$$L_{ex,8h} = \text{SEL} + 10 \log (N/28800) \qquad (1)$$

where SEL is the sound exposure level in dBA per single impulse, N is the number of impulses and 28800 is the number of seconds in an 8-hour period.

The RTO/NATO study [13] points towards the concept of a critical level that should not be exceeded, even for a single impulse. Critical limits based on 95% of the exposed population not exceeding a temporary threshold shift or TTS of 25 dB (averaged over 4 and 6kHz) two minutes after exposure (TTS_2) have been derived. The critical SEL appears to depend on the impulse duration properties. For small-calibre weapons (e.g. rifle) with A-durations in the range from 0.2 to 0.3 ms, the unprotected SEL limit per single impulse measured in the free field at normal incidence is 116 dBA, for up to N=50 impulses at a rate of one every 5-10 sec. From equation 1, COHS daily noise exposure limit of 87 dBA would be exceeded for N=35 impulses at a SEL of 116 dBA. Thus, COHS limits ($L_{ex,8h} \leq$ 87 dBA) must be supplemented with an additional SEL limit of 116 dBA per impulse for small-calibre weapons for up to 35 impulses.

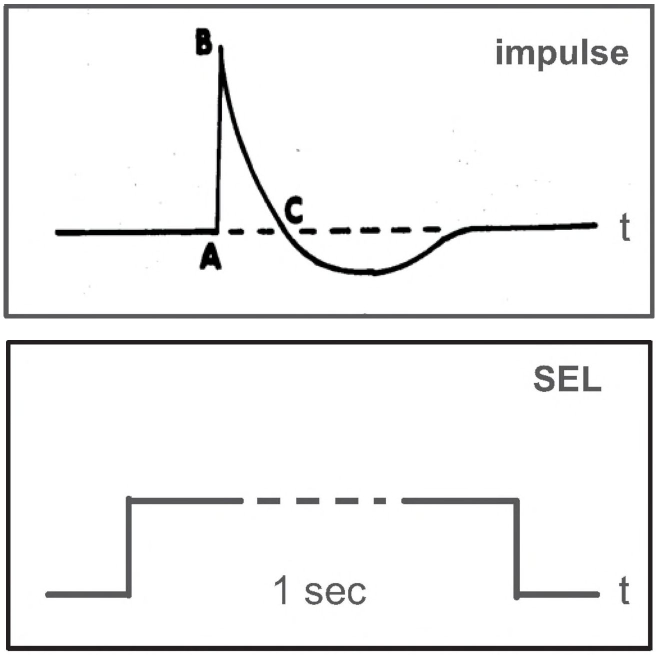


Figure 1: Example of a weapons impulse waveform (top) and equivalent SEL (bottom). The most common measure of impulse duration, the A-duration, is defined as the time from A to C.

For blast overpressures from explosions and large-calibre weapons with A-durations in the range from 0.9 to 3 ms, the protected SEL limit per single impulse measured at the ear under the hearing protector is 135 dBA, for up to N=100 impulses at a rate of one per minute [13]. From equation 1, only a single impulse at the critical level of 135 dBA under the protector would exceed COHS daily exposure limit. Thus, no additional provisions appear necessary beyond COHS limits ($L_{ex,8h} \leq$ 87 dBA) for large-calibre weapons.

2.1.6 Central noise database

Noise surveys related to all operational military equipment (ships, aircraft and vehicles) and weapons systems used at several DND/CF facilities should be included in a central noise database to be maintained and updated for access by all CF personnel involved in the implementation or evaluation of the HLP program.

- For ships, aircraft, army vehicles and other operational equipment characterized by steady-state or fluctuating noises, the equivalent sound pressure level (L_{eq}) in dBA and the octave-band frequency analysis in dB SPL will be included in the database for all measurement locations and operational conditions surveyed.
- For each weapons system, the sound exposure level (SEL) in dBA per single impulse will be included for all conditions of use and operator positions. It is also recommended to document the A-duration and instantaneous peak sound level in dBC until accepted damage-risk criteria are firmly established.

2.2 Engineering Noise Control Measures

Engineering noise control and abatement measures are the preferred method of reducing noise exposure to safe levels and are an integral part of an effective HLP program. No other prevention method can match the long-term health, safety and workplace communication efficiency benefits of a quieter environment. Noise control solutions can be achieved at the source (e.g. installation of silencers), along the transmission path (e.g. noise barrier, enclosure) and at the receiver (e.g. control booth around operator) [24].

Decisions and actions regarding the implementation of engineering noise control measures should be made immediately following recommendations from detailed, operational or impulse noise surveys (Section 2.1), and during the procurement process for all new and retrofitted equipment. When assessing the costs of engineering control measures, consideration must also be given to the long-term economic impact of not implementing them, and therefore having to address future compensation claims and rehabilitation measures for the exposed personnel.

The documentation for all new or retrofitted equipment and facilities should include noise performance specifications. The requirements should ensure that all state-of-the-art engineering control measures be considered to deliver the quietest possible products such that:

- Noise levels for all operators will not exceed 87 dBA during normal use, if technically feasible;
- Noise levels for all retrofitted equipment will not exceed levels before the retrofitting process; and
- All equipment exceeding the limit of 87 dBA will be supplied with: (1) measured noise levels in conformance with the detailed/operational or impulse noise surveys described in Section 2.1, (2) visible and permanent warning signs to indicate a risk to hearing; and (3) specific measures (e.g. hearing protectors) that must be taken to ensure exposure within safe limits.

2.3 Administrative Controls

Administrative controls refer to measures used to inform personnel of potentially noise-hazardous areas, and to staffing procedures used to further limit the duration and level of noise exposure once all engineering controls have been implemented.

The following procedures are required by COHS Part VII:

- Informing any personnel in writing of the potential risk to hearing whenever the daily noise exposure is likely to exceed 84 dBA;
- Evaluating the suitability of using hearing protectors when the daily noise exposure is from 84 to 87 dBA;
- The supplying of hearing protectors when the daily noise exposure is likely to exceed 87 dBA; and
- The installation of visible and permanent warning signs clearly identifying noise-hazardous areas where noise levels (slow weighting) are likely to exceed 87 dBA.

The following measures should also be considered:

- Restriction on the number of personnel required to enter noise-hazardous areas;
- Restriction on the time spent by the personnel in noise-hazardous areas and/or the adjustment or rotation of job schedules to lessen the exposure in a 24-hour or continuous period; and
- Increasing the distance between noise sources and the personnel whenever possible.

2.4 Personal Hearing Protection

2.4.1 Objectives

Personal hearing protection devices (HPDs) are to be used to reduce noise exposure only once all engineering and administrative control measures have been exhausted. HPDs must be carefully selected for optimal effectiveness in the workplace, taking into consideration the noise exposure, the attenuation achieved, the operational and environmental constraints, the auditory task requirements, and the user preferences.

2.4.2 Guiding principles

The calculation of the daily noise exposure ($L_{ex,8}$) for individuals at risks requires accurate noise level data from each hazardous site as well as duration of exposure data for each member [14]. In a working environment as complex as the military, the daily duration of noise exposures for each individual member in each hazardous site on a typical workday is very difficult or impossible to track down and estimate reliably. The work schedule is too variable from day to day, from month to month and from member to member to hope to obtain valid duration of exposure data (and thus valid $L_{ex,8}$ data) for each member or even for groups of members from which to base HPD decisions.

Instead, an approach based only on the level at each noise hazardous site is more suitable and practical for making HPD decisions in the military. In order to ensure that the daily noise exposure ($L_{ex,8}$) for all DND/CF personnel members do not exceed the regulatory limit of 87 dBA, the noise exposure ($L_{ex,T}$) at each noise-hazardous site should be made below 87 dBA by proper use of hearing protectors, irrespective of the duration of the exposure T. If noise exposure at each site visited during an 8-hr workday is below 87 dBA, then the daily exposure limit will not be exceeded. For working days longer than eight hours, the exposure level limit at each site needs to be decreased on the basis of a 3-dB exchange rate.

An approach to hearing protection by noise-hazardous site, as proposed here, is directly compatible with engineering and administrative noise control measures. Engineering noise control measures provide solutions to specific equipment or site facilities, not to specific individuals in a typical workday. Many administrative measures like warning signs and distance from noise sources also apply to specific areas or equipment.

2.4.3 Basic Methods and Application Issues

For steady-state or fluctuating noise, the selection of hearing protectors will be based on one of the three approved methods in Article 9.8 of CSA Standard Z94.2-02 [25].

Method 1: Grade or Class

Grades or Classes are assigned to hearing protectors based on attenuation data by the manufacturer.

- Grades (0-4) are assigned according to Appendix A in CSA Standard Z94.2-02 on the basis of attenuation data measured under Method B (subject fit) in ANSI S12.6-1997 [26].
- Classes (A-C) are assigned according to Table 3 in CSA Standard Z94.2-02 on the basis of attenuation data (experimenter fit) measured under ANSI S3.19-1974 [27]. It is to be noted that this standard has been withdrawn by ANSI. However, it is still widely used to calculate noise reduction ratings as required by the Environmental Protection Agency in the USA [28].

Selection based on grades or classes requires only the A-weighted noise exposure or sound level in the environment. The use of grades is preferred over classes. The latter are acceptable until a sufficient number of hearing protectors is tested under Method B in ANSI S12.6-1997.

Method 2: Single-Number Rating or SNR(SF_{84})

The single number rating (Subject Fit 84th percentile) or SNR(SF_{84}) provides a more accurate method based on a single value of attenuation (in dB) computed according to Appendix A in CSA Standard Z94.2-02 [25]. This number represents the protection achieved by at least 84% of users in a well-managed program.

The SNR(SF_{84}) rating can be used to calculate the resulting noise exposure after application of a hearing protector according to:

$$A = C - \mathrm{SNR}(SF_{84}) \tag{2}$$

where "A" is the A-weighted noise exposure or sound level in dBA when the hearing protector is worn, "C" is the C-weighted unprotected noise exposure or workplace sound level in dBC, and SNR(SF_{84}) is the hearing protector rating in dB.

Method 3: Octave-band (OB) computation

This method, described in Appendix B in CSA Standard Z94.2-02 [25], is the most complex method to select a hearing protector but it provides the best estimate of the A-weighted noise exposure or sound level in dBA when a hearing protector is worn. The OB computation is based on measurements of the one-octave band sound pressure levels describing the noise environment from 125-8000 Hz, and on the complete hearing protector sound attenuation data in third-octave bands from Method B in ANSI 12.6-1997 [26].

Table 1 lists the recommended HPDs to use according to the noise level. This table has been adapted from CSA Standard Z94.2-02 [25] to reflect the 87 dBA regulatory limit specified in COHS, instead of the 85 dBA limit assumed in the standard. When used, the SNR(SF_{84}) and OB methods should predict a resulting exposure level ≤ 87 dBA, and preferably in the range 77-82 dBA for optimal protection (i.e. 5-10 dB below the regulatory limit). Over-protection is not recommended as it can disrupt speech communication or detection/localization of important sounds [25]. Dual protection, where required for noise exposure ≥ 108 dBA, will consist of a minimum Grade 2 or Class B earmuff or helmet combined with a Grade 3 or Class A earplug. Unless measured dual protection attenuation data according to Method B in ANSI 12.6-1997 are available, the attenuation provided by dual protection can be assumed to be 5 dB higher than the highest attenuation of any of the two protectors in the combination [25].

Table 1: Recommended hearing protection devices (adapted from [25] to apply at each noisy site).

Level (dBA)	Recommended Hearing protection device(s)
≤ 84	not required
84-87	not required but shall be made available
88-92	Grade1/Class C **or** selected from SNR(SF_{84}) **or** OB method
93-97	Grade2/Class B **or** selected from SNR(SF_{84}) **or** OB method
98-102	Grade3/Class A **or** selected from SNR(SF_{84}) **or** OB method
103-107	Grade4/Class A **or** selected from SNR(SF_{84}) **or** OB method
108-112	Dual protection required; Exposure levels confirmed with SNR(SF_{84}) **or** OB method
≥ 112	Dual protection required Exposure levels confirmed with OB method Exposure duration limits may be required

Additional factors need to be considered when selecting and using hearing protectors to ensure optimal effectiveness in the workplace (Articles 10 and 11 in CSA Standard Z94.2-02) [25].

- The devices will be compatible with all other protective gear being used (e.g., hardhats, helmets, face masks, goggles);
- The physical durability and comfort of the devices will be compatible with the environmental constraints (e.g., extreme temperature, chemical agents);
- The devices will be compatible with the operational demands and auditory task requirements; and

All users will be provided with a range of devices to choose from, including different types and sizes of earplugs, to address comfort and preference issues

2.4.4 Special Measures, Devices and Methods

All CF weapons systems are potentially harmful to hearing, and permanent damage can occur from single impulses. This issue highlights the critical importance of proper use of HPDs in the field, so that their properties for protection against impulse noise from weapons do not render the wearer incapable of hearing shouted orders or radio/intercom communications.

- Hearing protectors will be used on all firing ranges and by all personnel in the vicinity of weapons systems;
- The area within which hearing protectors must be worn will be clearly indicated and enforced;
- The maximum number of daily rounds allowable per weapons system will be determined and limits will be adhered to, taking into consideration all other noisy activities during the day and the noise from other weapons systems on the firing range; and
- Special firing restrictions will be developed and enforced for each weapons system, where possible, to limit exposure (e.g., spatial locations or orientations of personnel that must be avoided with respect to the weapons system).

The actual protection achieved by hearing protectors against impulse noise from weapons systems may not be accurately reflected in the manufacturers' attenuation data (ANSI S3.19-1974 or ANSI S12.6-1997), as discussed in [13, 25]. The measurement procedures specified in the above standards are carried out with low-level continuous-type noises in a diffuse-field type environment, whereas weapons impulses may reach extreme peak pressures and strike at specific angles of sound incidence. Thus:

- Only a restricted set of approved hearing protectors will be used for protection against weapons systems; and
- The attenuation achieved by these protectors against specific weapons impulses will be confirmed under realistic conditions using special methods of assessing attenuation (see below). The recommended angle of incidence for assessing attenuation is 45° [13].

To determine the amount of protection achieved by special devices (e.g. active noise reduction, electronic sound restoration, level-dependent) or in special circumstances (e.g. impulse sounds from weapons systems), measurement methods based on ANSI S12.42-1995 (R1999) [29] are required. This standard specifies Microphone-in-the Ear (MIRE) and Acoustic Test Fixture (ATF) methods for measuring the attenuation of hearing protectors. Use of these special methods is warranted in situations where basic HPD selection methods (Section 2.4.3) are not suitable or cannot be used.

Communications headsets, with either passive or active noise-attenuation technology, pose a specific selection problem: How to account for the exposure that arises from the audio communication signal? Research at DRDC Toronto [30] shows the audio signal is typically set by the users to about 5-15 dB above the environmental noise permeating through the headset. The audio signal contribution to the overall exposure will also depend on the proportion of time that communications take place. Table 2 shows different listening scenarios at a signal-to-noise ratio of 10 dB during communications. The number in the second column is the additional exposure due to the audio signal over that from the environmental noise that is permeating through the communication headset or device. Thus, the second column indicates the additional attenuation required for the communication headset over that calculated from the environmental noise alone for the listed scenarios. Table 2 should only be used as a guide for initial assessment. The signal-to-noise ratio inside the headset set will depend on such factors as the quality of the audio signal, the spectrum of the noise and the hearing status of the user. Higher signal-to-noise ratios are typically required for individuals with hearing loss. Only CF-approved communications headsets will be selected in harsh environments after testing using realistic conditions of use.

Table 2: Estimated exposure from the combined audio signal and noise, assuming a signal-to-noise ratio of 10 dB during communications.

% Time Communicating	Exposure contribution over noise alone (dB)
100	10.4
50	7.8
25	5.4
10	3.0
5	1.8

2.4.5 HPD database

A central database of hearing protector data should be maintained and updated for access by all personnel involved in the implementation of the CF hearing loss prevention program and integrated with the noise database (section 2.1.6). The database will allow identifying proper HPDs given the environmental noise levels (either actual measurements or measurements from previous operational or impulse noise surveys).

- For steady-state or fluctuating noise: selection will be made according to one of the three methods in section 2.4.3.
- For impulse noise from weapons systems: selection will be restricted from a range of devices tested or approved by the CF for each weapons system. The maximum daily number of rounds (N_{max}) or events allowable will be included in the database. The latter will be calculated according to:

$$N_{max} = 28880 \times 10^{-(SEL-ATT-87)/10} \quad (3)$$

where 87 dBA is the COHS noise exposure limit [15], SEL is the free-field sound exposure level in dBA per single impulse at the location of the noise-exposed personnel, and ATT is the measured or assumed attenuation (dB) of the hearing protector for the particular weapons impulse. When the SEL is measured under the protector, this SEL value is used instead of SEL-ATT in the equation above.

- For protection against small-calibre weapons (e.g. rifle), a minimum hearing protector attenuation (ATT) is necessary in addition to the N_{max} restriction in eq. (3) to ensure the critical level from RTO/NATO [13] is not exceeded for an impulse, as follows:

$$ATT \geq SEL - 116 \text{ dBA} \quad \text{(small-calibre)} \quad (4)$$

where 116 dBA is the critical SEL limit for a single unprotected impulse. When the SEL is measured under the protector, then the protected SEL per single impulse will not exceed 116 dBA.

- For large-calibre weapons (e.g. blasts), the critical SEL limit of 135 dBA from RTO/NATO [13] per single impulse measured under the protector results in a daily exposure above 87 dBA, thus the N_{max} restriction in eq. (3) is sufficient to both meet COHS [14] and RTO/NATO [13] criteria.

2.5 Monitoring Audiometry

2.5.1 Objectives

Audiometric monitoring of the CF personnel at risk is needed to (1) identify and document the hearing status of individuals with hearing loss, (2) provide proper care, protection, employment follow-up for those who incur hearing loss, and (3) monitor the effectiveness of the HLP program. It important to note, however, that audiometric testing is not in itself a prevention method if there is no effective intervention to limit noise exposure, such as engineering and administrative control and hearing protection [24].

2.5.2 Reliability

There are reliability issues associated with the use of audiograms in occupational settings. Typically, the growth of permanent hearing loss is about 2dB/year for the first five years of exposure at 95 dBA/8hrs, 1dB/year for the next five years, and less than 1dB/year after 10 years [31]. Yet, the measurement accuracy for screening audiometry is around 10 dB in occupational settings [32], several times the potential yearly growth of permanent hearing loss in noise exposed individuals. Thus, noise-induced hearing loss may remain undetected for several years in an individual, and conversely, erroneous identification of hearing loss may occur despite any real change in hearing status.

Nonetheless, audiometric monitoring is required in the military setting, where the daily noise exposure of individual personnel is difficult to evaluate due to variable work schedules (Section 2.4.2), the efficiency of hearing protectors against weapons impulsive noise is poorly documented (Section 2.4.4) and the methods not yet standardized, and where permanent or temporary hearing loss can occur from a single intense acoustic event.

2.5.3 Procedures

Hearing examinations should consist of a recording of the noise exposure history (occupational and recreational) and an audiometric evaluation. There are three types of audiometric evaluations:

- A baseline audiogram will be conducted on all persons entering the CF, to serve as a reference for detecting any subsequent hearing threshold shifts. The baseline audiogram should always be conducted after at least 14 hours away from noise exposure (occupational or not), and within 30 days after initial noise exposure.
- A periodic audiogram will be conducted in conjunction with each periodic health evaluation (PHE) for the military personnel and upon request or following incidents that could potentially affect hearing. The periodic audiogram can be performed any time during the work shift (preferably late in the shift) so as to identify any TTS in hearing level before it becomes permanent. A “late-in-shift” audiogram is now often recommended as the best practice [6, 24]. Warning: The presence of TTS may only become apparent in noise exposed individuals with normal or near normal hearing. Individuals with hearing loss show decreased or no TTS for equivalent noise exposures [33]. Thus, the absence of TTS does not necessarily mean a safe workplace.
- A release audiogram will be conducted as part of the release medical for all persons leaving the CF. The release audiogram should be taken at least 2 weeks prior to departure from CF, to allow for follow-up.

Audiograms should be recorded with automatic audiometers to standardize the measurement process across CF facilities, and conducted by qualified personnel in quiet test environments not exceeding the maximum background noise levels specific in ANSI S3.1-1999 (R2003) [34]. Audiometers and calibration procedures should comply with CSA Standard Z107.4-M86 (R2001) [35].

The hearing thresholds must be determined by the Ascending method as described in CSA standard Z107.6-M90 (R1999) [36]. A trained physician, an audiologist, or an audiometric technician who has completed a certified military training comparable to the program certified by the US Council for Accreditation in Occupational Hearing Conservation must administer audiometric tests. Audiometric technicians must do the testing under the supervision of a trained physician or an audiologist. Upon completion of the audiogram, the examiner will explain the results of the hearing test to the personnel member.

2.5.4 Data interpretation and actions

A computerized record keeping system should be put in place to automatically identify hearing conditions requiring follow-up. It is highly recommended to use audiometers that allow automatic transfer of data in a format compatible with the computerized record keeping system, to minimize potential errors associated with manual transfers.

A standard threshold shift (STS) due to noise is to be defined as a change in the baseline audiogram of 15 dB or more at 500, 1000, 2000, 3000, 4000 or 6000 Hz, in either ear. This definition of STS calculation is the same as that recommended by NIOSH [37], but differs from other definitions based on averaging the threshold shift over a limited set of frequencies (typically at 2000, 3000 and 4000 Hz) as discussed in [24]. The criterion recommended here covers a wider range of frequencies and will generally be more sensitive in detecting early noise-induced hearing loss progressing from the higher frequencies to the lower frequencies.

Upon completion of an audiogram, the member and his/her supervisor are immediately notified in writing of any STS result. A follow-up audiogram is required as soon as possible but not more that 30 days after the first STS identification. This follow-up audiogram must be done after at least 14 hours away from noise:

- If the STS is confirmed after this second audiogram, the member and his/her supervisor are notified in writing within 21 days. In such cases, appropriate hearing prevention activities must be implemented to limit further hearing damage.
- If the STS is not confirmed after a rest from noise, the employee and the supervisor must be informed that the STS result identified after the first audiogram could have been the result of a temporary hearing loss. In such a situation, the monitoring of noise levels, the use of engineering and administrative noise control measures and the proper fit of the hearing protectors must be reassessed in order to avoid further temporary threshold shifts and prevent the future occurrence of a permanent hearing loss.

If a STS is detected and confirmed (or whenever the average hearing threshold levels at 1000, 2000, 3000 and 4000 Hz are greater than 25 dB HL in either ear), the member must be referred to a physician and an audiologist in order to fulfill a complete medical and audiological examination of his/her hearing system. As needed, hearing aids and rehabilitation services will be made available.

2.6 Education

An educational component is required (1) to ensure the CF personnel is aware of the effects of noise on health and safety, and (2) to explain the advantages and limits of each element contained in the HLP program.

Training should be provided to all personnel whose essential job requires working in areas where noise levels are in excess of 84 dBA. To ensure maximum effectiveness of the program, all personnel must be aware of the possible effects of exposure to hazardous noise and the correct procedures to follow to eliminate or minimize these harmful effects. The Education program should be provided annually and cover:

- The effects of noise on hearing;
- The purpose, advantages and limits of engineering and administrative noise controls;
- The purpose, advantages and disadvantages of the various types of hearing protectors;
- The selection, fit, care and use of hearing protectors;
- The interpretation of warning signs; and
- The purpose and procedures of audiometric evaluations.

The education program is a continuous process initiated at the recruit level and continued at the unit and base levels. In the military environment, a major challenge is to ensure continuity in the training process, given the mobility of the work force, the variable work schedules, and the distributed responsibility for the different elements mentioned above.

2.7 Program Evaluation

The objective of program evaluation is to assess or monitor the effectiveness of the HLP program in preventing hearing damage in the CF personnel. The use of general program evaluation tools based on audiometric databases [38] is questionable in the military environment, where exposure can vary widely across workers and is highly variable over time (Section 2.4.2). Instead, specific activities can include but should not be limited to (1) the identification of high-risk tasks or military occupations, (2) the field evaluation of the attenuation of hearing protectors, and (3) the validation of impulse noise damage risk-criteria and prevention measures.

2.8 Documentation

The critical documents (acoustical standards, regulations, etc.) necessary to implement the daily procedures contained in the HLP program should be easily accessible by the responsible base personnel. In addition to a copy of the HLP program, these include references [14, 15, 25, 35].

3. DISCUSSION AND CONCLUSIONS

In the military, the importance of accurate noise surveying, engineering and administrative noise controls, proper fit of hearing protection and regular audiometric monitoring of the hearing of exposed personnel cannot be over-emphasized. It is only through the utilization of all available methods that the hearing of the personnel will be protected.

The hearing loss prevention program described in this paper is based on current scientific knowledge of noise-induced hearing loss and damage-risk criteria, and on evidence-based practices for hearing conservation in industry. It also reflects major findings from past reviews of the current hearing conservation policy in the CF and complies with Canadian federal regulations. A draft policy based on this proposal is currently under review by DND/CF. Considerations of costs, operational constraints during military operations, and other implementation and personnel issues must be factored in a final policy.

The success of any hearing loss prevention program, such as the one proposed here, requires the contribution of a large number of civilian and military personnel for the implementation and interpretation of the various program elements. The program can only be fully effective if the personnel are given clear lines of responsibility for each task, and that provisions are made to coordinate their effort into a cohesive endeavour throughout the CF. Care must also be taken to ensure the program is regularly reviewed and kept up to date as new scientific evidence, regulatory documents and acoustical/noise standards are being published or reviewed.

Finally, the current proposal does not specifically address factors other than noise that can affect hearing in the workplace. These factors include excessive vibration and infrasounds, ultrasounds, and ototoxic agents like organic solvents, heavy metals and certain gases [39]. Likewise, the proposed hearing prevention program does not address the issue of fitness to work, only the prevention of hearing loss. The issue of hearing fitness is addressed elsewhere [40].

ACKNOWLEDGEMENTS

This work was carried out under a contract from the Canadian Forces Health Services Group (CF H Svcs Gp). The assistance and guidance of Dr. Sami Mohanna, Dr. Ian Fleming and Dr. Stephen Tsekrekos at CF H Svcs Gp throughout this project are very gratefully acknowledged. We would also like to thank all the civilian and military personnel we met during our field trips at CFB Valcartier and CFB Bagotville for their generous help and insights into hearing loss prevention, safety and medical procedures in the CF. Dr. Sharon Abel and M. Brian Crabtree of DRDC Toronto also made their time available to the authors and provided useful suggestions and insights. We extend our thanks to all DND/CF personnel that made comments on earlier versions of the draft policy proposal. M. Michael Houghton of IBM Business Consulting greatly facilitated the administrative aspects this project.

REFERENCES

[1] Pelausa, E.O., Lamontagne, P. and Niquette, F. (1991). "Noise and the Military Profession," Canadian Forces Hearing Conservation Program Evaluation (CFHCP-E), Phase I, 38 pp.

[2] Dancer, A., Buck, K., Parmentier, G., Hamery, P. (1998). "The specific problem of noise in military life," Scand. Audiol. vol. 27 (Suppl. 48): 123-130.

[3] Gasaway, D.C. (1994). "Occupational hearing conservation in the military," Chapter 14 in David M. Lipscomb (Ed.): Hearing Conservation in Industry, Schools and the Military (Singular Publishing Group, San Diego), pp. 243-262.

[4] Department of the Army – USA (1998). Hearing Conservation Program. DA Pamphlet 40-501 (10 December 1998), 17 pp.

[5] Berglund, B., Lindvall, T., Schwela, D. H., Goh, K.-T. (Eds.) (2000). Guidelines for Community Noise (Institute of Environmental Epidemiology, Singapore and World Health Organisation, Geneva), 138 pp.

[6] Goelzer, B., Hansen, C.H., Sehmdt, G.A. (Eds.) (2001). Occupational Exposure to Noise: Evaluation, Prevention and Control (Federal Institute for Occupational Health and Safety, Dortmund and World Health Organization, Geneva), 336 pp.

[7] Boys, A. (2001). "Canadian Forces Health Services: Canada's Military Health System," Health Systems Update

[8] Rylands, J.M. and Forshaw, S.E. (1988). Future Efforts to Control Hearing Loss in the Canadian Forces. Defence and Civil Institute of Environmental Medicine (Toronto, Ontario). Technical Report DCIEM 88-TR-17, 8 pp.

[9] Canadian Forces Medical Order 40-01. Hearing Conservation Program. CFP 175(2).

[10] Rylands, J. M. (1990). "Proposed revision of CFMO 40-01", Defence and Civil Institute of Environmental Medicine (Toronto, Ontario). Memorandum, 10 May.

[11] Pelausa, E.O., Abel, S.M., Simard, J. (1995). "Prevention of noise-induced hearing loss in the Canadian military," The Journal of Otolaryngology, vol. 24 (5), 271-280.

[12] Whitehead, G. (2000). "Hearing Loss Review: An initial investigation into the effectiveness of hearing conservation activities of the Canadian Forces," Final Project Report, Contract #1200-00-0001, 15 December 2000. Veterans Review and Appeal Board Canada.

[13] RTO/NATO (2003). Reconsideration of the Effects of Impulse Noise. Technical Report RTO TR-017/HFM-022.

[14] CAN/CSA-Z107.56-94 (R2001). Procedures for the Measurement of Occupational Noise Exposure.

[15] Canadian Occupational Health and Safety (COHS) Regulations Part VII: Levels of Sound (SOR/2002-208, 30 May 2002).

[16] ANSI S1.11-1986 (R1998): Specifications for Octave-band and Fractional Octave-band Analog and Digital Filters.

[17] ANSI S12.7-1986 (R1998): Methods for Measurement of Impulse Noise.

[18] ANSI S1.4-1983 (R2001): Specifications for sound level meters.

[19] Shaw, E.A.G. (1985). Occupational Noise Exposure and Noise-Induced Hearing Loss: Scientific Issues, Technical Arguments and Practical Recommendations (APS707; NRCC/CRNC No 25051).

[20] Shaw, E.A.G. (1983). "On the Growth and Decay of Asymptotic Threshold Shift in Human Subjects," 4th Int. Cong. on Noise as a Public Health Problem, Vol. 1: 297-308 (Turin, Italy).

[21] Canadian Centre for Occupational Health and Safety (www.ccohs.ca/oshanswers/phys_agents): Noise – Occupational Exposure Limits for Extended Workshifts.

[22] Forshaw, S. (1970). Guide to Noise-Hazard Evaluation. Defence Research Establishment Toronto, Review Paper No. 771.

[23] CHABA (1968). Proposed damage-risk criterion for impulse noise (gunfire). National Academy of Sciences, National research Council (US) Committee on Hearing, Bioacoustics, and Biomechanics, Report on Working group 57.

[24] Suter, A. H. (2002). Hearing conservation Manual, Fouth Edition (Council for Accreditation in Occupational Hearing Conservation, Milwaukee USA), 312 pp.

[25] CAN/CSA Z94.2-02 (2002). Hearing Protection Devices – Performance, Selection, Care, and Use.

[26] ANSI S12.6-1997: Method for the Measurement of Real-Ear Attenuation of Hearing Protectors.

[27] ANSI S3.19-1974: Method for Measurement of Real-Ear Protection of Hearing Protectors and Physical Attenuation of Earmuffs.

[28] Behar, A. (2004). "Hearing protectors – Calculations of the noise level at the protected ear," Canadian Acoustics 32(1), 15-19.

[29] ANSI S12.42-1995 (R1999): Microphone-in-the-ear and acoustic test fixture methods for the measurement of insertion loss of circumaural hearing protection devices.

[30] Crabtree, R. B. (2002). Hercules Audio Enhancement: Project Report. Defense Research and Development Canada (DRDC) Toronto, 20 September, 41 pp.

[31] Burns, W. and Robinson, D.W. (1970). Hearing and Noise in Industry. London: Her Majesty's Stationary office.

[32] Hétu, R. (1979). "Critical analysis of the effectiveness of secondary prevention of occupational hearing loss," J. Occup. Med., 21, 251-254.

[33] Berger, E.H., Royster, L. H., Royster, J.D, Driscoll, D.P, Layne, M. (2000). The Noise Manual, Fifth Edition.

[34] ANSI S3.1-1999 (R2003): Maximum permissible ambient noise levels for audiometric test rooms.

[35] CAN/CSA Z107.4-M86 (R2001): Pure tone air conduction audiometers for hearing conservation and for screening.

[36] CSA Z107.6-M90 (R1999): Pure tone Air Conduction Threshold Audiometry for Hearing Conservation.

[37] NIOSH (1998). "Criteria for a recommended standard: Occupational noise exposure: Revised Criteria 1998". DHHS (NIOSH) 980126. Dept. of Health and human Services, Public Health Service.

[38] ANSI S12.13 TR-2002: Evaluating the effectiveness of hearing conservation programs through audiometric data base analysis.

[39] Henderson, D. (2003). "Combined effects: Biological requirements for noise interactions," 8th International Congress on Noise as a Public Health Problem, Rotterdam, Netherlands, June 29-July 3. Proceedings Volume pp. 38-39.

[40] Laroche, C., Giguère, C., Soli, S., Lagacé, J., Vaillancourt, V. (2003). "An approach to the development of hearing standards for hearing-critical jobs," Special Issue on Noise, Communication and Task Performance, Journal of Noise and Health, 6;21, 17-37.

THE EFFECT OF WAVES IN SOIL ON SEED GERMINATION AND PLANT GROWTH

John E. K. Foreman
Professor Emeritus, University of Western Ontario (UWO), London, Ontario

ABSTRACT

A preliminary test was conducted to study the effects of vibratory waves on seed germination. It was observed that in some cases, when the wave length was the same as the seed mean dimension, the seeds sprouted sooner than a similar control group of seeds under identical environmental conditions. The heights of the plants when sprouted showed a measurable increase for the test seeds (with vibration waves) as compared with control seeds (no vibration).

SOMMAIRE

Un test préliminaire a été mené afin d'étudier l'effet des ondes vibratoires sur la germination des graines. Il fut observé dans quelques cas que lorsque la longueur d'onde est égale à la dimension moyenne des graines, celles-ci poussent plus tôt que les graines d'un groupe témoin sous des conditions environnementales identiques. Un accroissement mesurable de la hauteur des plantes provenant des graines soumises aux ondes vibratoires a été observé par rapport aux graines du groupe témoin non soumises aux ondes vibratoires.

1. INTRODUCTION

Several years ago, one of my students (the late Margaret E. Collins) and I worked with the Department of Plant Services of the University on the effect of sinusoidal sound waves on the growth of leafy plants. Ms. Collins is now deceased, but her work was of such significance that I had written a paper based on this work to her memory. It was published in the Journal of the Canadian Acoustical Association in June, 2001.

This previous work stimulated further interest in wave effects and a preliminary test was arranged, by propagating a vibration wave over seeds planted in soil (Figure 1). It was observed that in some cases, when the wave length was the same as the seed mean dimension, the seeds sprouted sooner than a similar control group of seeds under identical environmental conditions. The heights of the plants when sprouted showed a measurable increase for the test seeds (with vibration waves) as compared with control seeds (no vibration).

2. PROCEDURE AND APPARATUS

The details of the tests are schematically shown in Figure 1. The basic instrumentation consisted of a Bruel & Kjaer electro-dynamic vibration shaker. The sinusoidal signal generator (20 Hz to 20 KHz range) and the amplifier were built by the electronics shop of the University. The planting beds were simple plant window boxes, measuring 3ft. x 8in. x 8in. (See Figure 1 and Photo 1), mounted on a table on a back deck. A hole was drilled in the end of the test box, and the head of the shaker was inserted in the hole, flush with the soil in the box. Separate tests were carried out on different kinds of seeds. The details of the tests are presented below.

2.1 Test 1

Commercial Soya Beans, obtained from the Great Canadian Bean Co. of Ailsa Craig, Ontario, were used. The bean seeds were planted in soil (President's Choice Black Earth, provided by Sun Fresh Ltd. of Toronto Canada), and were approximately ½" deep and 3" apart. The excitation frequency for the bean seeds was determined as follows. The seed diameter was approximately 0.25", the wave propagation in moist soil was 75 m/sec (or 240.6 ft/sec), as obtained from the Geotechnical Research Centre at UWO. The frequency needed for the size of seed is $f = c/\lambda$, where c is the wave velocity, and λ is the wave length equal to the 0.25" diameter of seed (Reference 6).

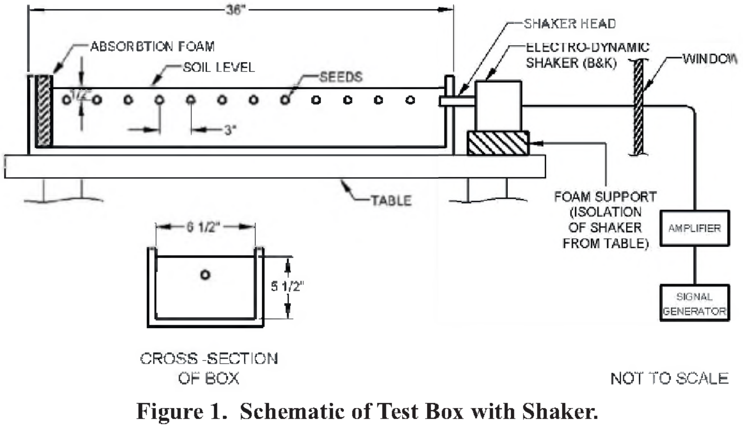


Figure 1. Schematic of Test Box with Shaker.

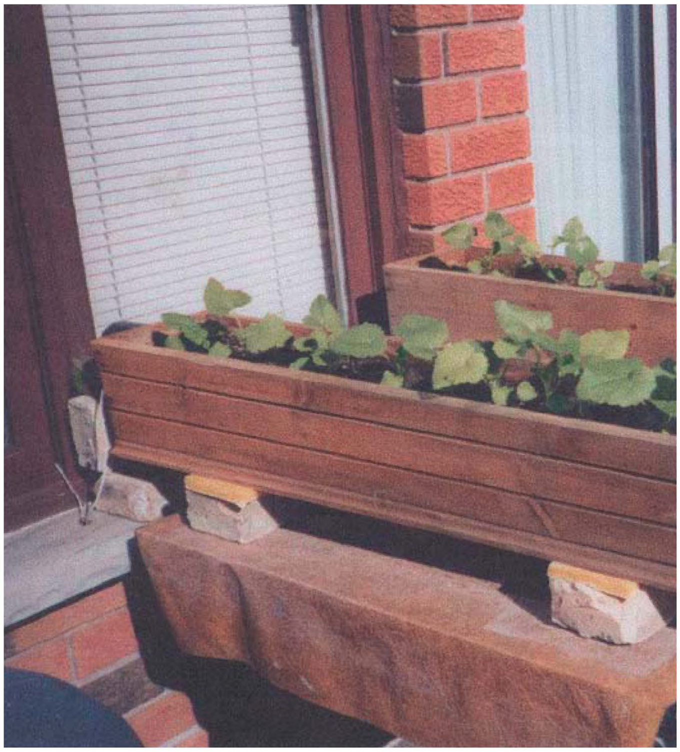


Photo 1

After 15 days, the bean seeds germinated and sprouted. The seeds in both the test box and the control box had sprouted at the same time. The heights of the sprouts are given in Table 1.

Table 1. Heights of Bean Sprouts, in.

Test Box	Control Box
5	3
4.5	5
4	4.75
4.5	4.25
5	4.5
4	4
5	4.75
4.5	5.25
Average: 4.56 in.	**Average: 4.40 in.**

As can be seen in Table 1, there was marginal difference in the average heights of the bean plants when exposed to vibration and with no vibration. An explanation as to why there was little difference, it was thought that the energy in the wave in the test box was insufficient to cause sufficient agitation of the large bean seeds, and consequent jacket splitting. Hence, a different seed was tested and is described below.

2.2 Test 2

Impatiens seeds were planted in the soil in the boxes, again approximately 3" apart with a light soil covering of 0.25" to 0.5". The signal generator was set at 15 KHz according to the previous calculations for the bead seeds. There was rain overnight at this time. The time-table for watering, temperature, etc. was identical to that carried out in Test 1.

After 16 days of observing the two plant boxes, it was noted that no sprouts had occurred in either the test or control boxes. This was two days after sprouts had occurred in the previously mentioned test with soybeans. After searching the literature (References 3, 4, 5), and talking with some experts (botanists in the Plant Sciences Department, and growers of flowers in greenhouses), it was noted that Impatiens plants are very hard to grow from seeds. It would appear that they require pre-planting procedures such as chilling the seeds, scarification or rubbing the seeds to loosen their jackets (Reference 1). To date, none of these pre-planting procedures were applied during the current investigation. The test was repeated using Nasturtium seeds in the boxes, as noted next.

2.3 Test 3

The Nasturtium seeds were planted with a light soil covering 0.25" and 3" apart. The excitation frequency for the shaker was determined for these seeds, as per the previous methods at 11, 550 Hz. In this test, in addition to moistening the soil before planting, two applications of Miracle Grow nutrient, one at the beginning and one approximately midway through the test, were given. These seeds were watered daily. After 10 days, it was observed that the test box had sprouted 5 healthy sprouts averaging 2.5" high, and the control box had only 1 sprout 1.25" high. However, this increase in the number of sprouts and in the average heights cannot be accepted as de rigueur. There are too many other factors which have affected the results, not much of which is the uncertainty associated with the germination of "store bought" seeds.

Lyn MacIntosh of Sandhill Nurseries, near Hunstville Ontario in the Muskoka district, confirmed that certain seeds need pre-treatment before planting, and some seeds will not germinate at all. In order to ensure that the test used good seeds, Ms. MacIntosh suggested that pre-treated seeds from Stokes Seeds in St. Catherines, Ontario be used in future tests. Further, she suggested that sweet pea seeds be used for the tests.

2.4 Test 4

Pre-treated sweet pea seeds from Stokes Seeds were planted after soaking for four hours. The nutrient used was Miracle Grow 15-30-15. The shaker was set for a sinusoidal frequency of 13000 Hz, determined as before for the bean seeds, and nutrient was mixed with water during watering. There was no visible showing of sprouts after five days, and hence the boxes were covered as testing was discontinued.

2.5 Test 5

Sweet Pea seeds were used (again, obtained from Stokes Seeds in St. Catherines, Ontario), and were soaked overnight for at least 8 hours. Their average diameter was 0.256". Again, as before, the preferred frequency was determined as 11278Hz. The seeds were planted in the test box and the control box (10 seeds to each box) at an average depth of 0.5", approximately 3" apart in-line with the shaker head. The seeds were watered, and nutrient was added (nutrient was Miracle Grow 15-30-15).

The seeds in both boxes were watered from May 5 to May 9. The seeds were not watered on May 10 to May 12, as there was heavy rain during this period. Up until May 24, watering and nutrient continued. When only 6 sprouts and 5 sprouts were observed in test and control boxes, and because of small showing of sprouts, the testing on this set of seeds was discontinued.

2.6 Test 6

Finally, it was decided to use commercial wheat field crop seeds with watering and nutrition. Planting started in early August, (with nutrient at the start and mid-point of test period) for 17 days. The results are recorded in Table 2.

Table 2. Heights of Wheat Crops, mm.

Seed Number	Test Box	Control Box
1	25.0	25.5
2	24.5	18.6
3	23.0	19.0
4	26.5	21.5
5	25.5	
6	22.0	23.0
7	29.0	27.0
8	27.0	11.0
9	28.0	26.0
10	19.7	21.0
11	28.3	25.5
Average	25.3	21.6
Percentage Increase = 14.9%		

3. CONCLUSION

From these tests, it can be seen that in most cases, the test box produced more and higher plant shoots (with the exception of impatiens seeds, which as noted before, were an exceptionally different seed to grow from the seed itself. Most of these plants are grown from cuttings from mature plants (Reference 7).

The testing was changed to a wheat field crop, where the seeds were obtained from a local farmer who had grown these in his field. These seeds are relatively easy to grow from scratch. When the test-seeds were subjected to a pressure wave in the soil with a wavelength comparable to the seed diameter, the test seed produced a marked increase in the sprouts and height of the plants when compared with the control seeds under the same conditions as the test seeds with no vibrating pressure wave in the soil (Table 2 and Photo II).

Although there are many factors which affect germination of seeds, such as the variation of store-bought seeds, light, wind, temperature, nutrients in the soil, moisture and exposure to the sun, it would appear from the foregoing tests, that sinusoidal pressure wave of sufficient amplitude passing over the seeds in a soil test bed with a wave length comparable to the wheat seed diameter, all other influencing factors being the same for the both test beds, results in the an earlier germination of the seeds and greater plant growth. (See Photo II)

Photo 2

As far as further study is concerned, the tests above should be replicated. It would be also advantageous to test other seeds that are recommended by growers. Further it would be useful to ascertain the shape of the wave form in the soil from the face of the sine-wave generator to the last seed planted. This could be done by placing (or lightly hanging) an accelerometer attached to a charge amplifier and oscilloscope. Any changes in the wave-form profile and strength of wave-front could be recorded.

4. REFERENCES

1. Lord, A.C "Proceedings of the Technical Program" National Noise and Vibration Control Conference, Chicago, Illinois, Acoustical Publication Inc. (1975).
2. Ponniah, S. "On the Effects of Musical Sounds of Stringed Instruments on the Growth of Plants", Proc, Indian Science Cong. vol. 42 no. 3, p. 255, (1955).
3. Weinberger, P. and M. Measures, "The Effects of Two Audible Frequencies on the Germination and Growth of a Spring and Winter Wheat", Canadian Journal of Botany, vol. 46, pp 1151-1158 (1968).
4. Woodlief, C.B. et al, "Effects of Noise on Plant Growth" Acoust. Soc. Am., vol. 46, pp 481-482 (1969).
5. Pixton, B.M. "Plant Growth in a Sound Polluted Environment." <byu.edu/~pixtonb/sprout.html>.
6. Foreman, J.E.K. "Sound Analysis and Noise Control", Van Nostrand-Reinhold Ltd., New York, (1990).
7. Lyn Macintosh, Sandhill Nurseries, Huntsville, Ont.
8. Foreman, J.E.K. "The Effect of Sound on the Growth of Plants", Canadian Acoustics Journal, vol. 29, (2001).

ACOUSTICS STANDARDS ACTIVITY IN CANADA
2005 UPDATE AND INVITATION TO PARTICIPATE

Tim Kelsall
Hatch, 2800 Speakman Drive
Mississauga, Ontario L5K 2R7, tkelsall@hatch.ca

ABSTRACT

This article is an update for 2005 of Acoustics Standards activities in Canada, especially those of the Canadian Standards Association. CSA currently has 10 Acoustics Standards and three more with significant acoustics content. More than twice that number of acoustics standards from other organisations, such as ANSI and ISO, have been reviewed and either endorsed or adopted as suitable for use in Canada. We intend in the coming year to replace these with a major omnibus standard which will act as a guide on the contents and use of all these standards. Canadian acousticians are invited to contact the author to become involved with the many standards activities, currently underway in Canada and on behalf of Canada around the world.

SOMMAIRE

Cet article est une mise à jour des activités de normalisation en acoustique au Canada pour 2005, spécialement celles de l'Association canadienne de normalisation (ACNOR). L'ACNOR a présentement 10 normes acoustiques et 3 autres comportant un contenu acoustique important. Plus du double de ce nombre de normes provenant d'autres organisations telles que ANSI et ISO ont été revues et soit endossées ou soit adoptées comme étant acceptable pour une utilisation au Canada. Pour l'année qui s'en vient, nous avons l'intention de remplacer celles-ci par un recueil majeur de normes qui va agir à titre de guide sur leur contenu et leur utilisation. Les acousticiens canadiens sont invités à contacter l'auteur pour s'impliquer dans les nombreuses activités en rapport avec les normes acoustiques actuellement en cours au Canada et pour le Canada parcours le monde.

1. INTRODUCTION

Technical Committee Z107 – Acoustics and Noise Control and its subcommittees look after all but one of the 10 Canadian Acoustics Standards (the exception is Z94.2 Hearing Protection Devices, which has its own technical committee). Z107 also coordinates all Canadian acoustics standards activity, with representatives from Z94.2 and from Canada's international standards effort providing liaison to their activities. The major goals of this article are to inform Canadian acousticians of progress in Canadian Standards activities and to invite those who are interested to become involved with these activities. Participation is one of the best ways to stay in touch with this fast moving field and an excellent way to meet the leaders in the many acoustic fields. Any acoustician interested in becoming involved with Acoustics standards in Canada is invited to contact the author or any of the subcommittee chairs. Most chairs welcome newcomers willing to work. The following is an overview of the areas involved.

2. Z107.10 OMNIBUS STANDARD

The most important progress made by Z107 is the drafting by Cameron Sherry and his Editorial Subcommittee of Z107.10, Guide For The Use Of Acoustical Standards In Canada, a new omnibus standard. The first draft is being balloted this fall, less than a year after drafting commenced, which is acknowledged as a new speed record for writing an acoustics standard. One reason for this is that most of the drafting was done by the committee chairs responsible for the various acoustics standards of concern to Z107. Another is that the standard is designed to be easily updated each year and will be published electronically to expedite this.

The standard summarises all acoustics standards for which Z107 has an interest, including CSA standards, as well as the ISO, ASTM, ANSI, IEC standards that Z107 considers of importance to Canada. This gives the reader a single source for information relating to Acoustics standards of interest to Canada, including those referred to by regulations and guidelines within Canada.

The following is an example of the contents of the standard:

> **ASTM E492,** Test Method for Laboratory Measurement of Impact Sound Transmission Through Floor-Ceiling Assemblies Using the Tapping Machine. This test method covers the procedures for laboratory measurement of impact sound transmission of floor-ceiling assemblies, using

a standardized tapping machine. It is assumed that the test specimen constitutes the primary sound transmission path into a receiving room located directly below. Measurements may be conducted on floor-ceiling assemblies of all kinds, including those with floating-floor or suspended ceiling elements, or both, and floor-ceiling assemblies surfaced with any type of floor-surfacing or floor-covering material. The corresponding single-figure rating is the impact insulation class (IIC), which is determined according to ASTM E989.

Architects, builders, and code authorities can use the IIC rating for acoustical design purposes, to specify the attenuation of sound from impacts due to footsteps for specific building constructions. The use of IIC to define the required impact sound insulation is recommended in the National Building Code of Canada, but is not mandatory.

The above example shows an entry for a typical standard from elsewhere which is endorsed for use in Canada. It describes the standard, its results and the relevance in a Canadian context.

The omnibus standard is breaking new ground for CSA by streamlining the way in which acoustics standards from other organisations are reviewed and approved in Canada. Before, it was necessary to consider and ballot each standard separately. Each would then be re-examined in 5 years. With this new approach, each endorsed standard is reviewed and re-approved annually. Given the speed with which ISO and other groups are changing standards, this new approach is not only convenient, it is essential.

3. COMMITTEE ACTIVITIES

3.1 Z107 Acoustics and Noise Control

The Z107 main committee meets once a year, during the Canadian Acoustics Week conference in October. Its executive, consisting of all the subcommittee chairs and representatives of other committees, meets in the spring. The main committee reviews progress by each subcommittee and votes on any new work proposals. The main committee is also the last technical hurdle for a standard before CSA editors put it into final form. The steering committee, to which the main committee reports, approves work and reviews completed standards; however they cannot make technical changes.

The main activities are within the Z107 subcommittees, which are responsible for the following standards:

Hearing Measurement, chaired by Alberto Behar, responsible for **CAN3-Z107.4-M86** Pure Tone Air Conduction Audiometers for Hearing Conservation and for Screening and **CAN/CSA-Z107.6-M90** Pure Tone Air Conduction Threshold Audiometry for Hearing Conservation.

Vibration, chaired by Tony Brammer, which provides liaison between Z107 and the Technical Advisory Committee of Standards Council on ISO standards on vibration. Tony is active on the ISO group for ISO 2631, the definitive standard on measurement of whole body vibration.

Industrial Noise, chaired by Stephen Bly, is responsible for the following standards :

- **Z107.52-M1983** (R1994) Recommended Practice for the Prediction of Sound Pressure Levels in Large Rooms Containing Sound Sources. This standard is in need of major updating and a chair is being sought to do this work. The intent is to provide guidance to Canadian industry on how to design quiet plants. It is seen as building upon Z107.58, which provides advice on buying quiet equipment.
- **Z107.56-94** Procedures for the Measurement of Occupational Noise Exposure is referenced in Federal and some provincial regulations and has been updated by a working group chaired by Alberto Behar. A new draft indicates that the primary measurement method should be to use a 3 dB exchange rate, but a method using a 5 dB exchange rate is still provided to be useful to Ontario and Quebec. Final editing by CSA is now in progress before the latest revision goes to ballot.
- **Z107.58-2002** Noise Emission Declarations for Machinery was written by a group chaired by Stephen Bly and was published[3] in 2002. It became a National Standard of Canada in 2003 It is a voluntary guide on noise emission declarations for machinery to be used in Canada and is compatible with European regulations to allow Canadian machinery to be sold into that market. It is intended to help workplace managers (purchasers) to purchase quieter machinery and plan noise control strategies. It does so by enabling manufacturers to formally provide sound-level data in an agreed format.
  A Noise Emission Declaration is a statement of sound levels produced by equipment, which would usually be included with the instruction or maintenance manual and in technical sales literature. Measurements are made according to ISO standards and include estimates of the likely variability of the measurements. Canada recommends use of either a declaration stating the level and uncertainty as two numbers, or adding them together into a single number.

In addition, the Industrial Noise subcommittee undertakes reviews of proposed federal and provincial regulations,often at the request of the regulators, and other activities affecting industrial noise.

Environmental Noise, chaired by Bill Gastmeier is taking over responsibility for standards which have been part of Industrial Noise, Transportation Noise and Powered Machines. These include:

- **Z107.53-M1982** (R1994) Procedure for Performing a Survey of Sound Due to Industrial, Institutional, or Commercial Activities. This standard will be replaced with the new ISO1996-2, which will be balloted shortly. A working group chaired by Chris Krajewski and including several Ontario consultants examined using the ISO 1996 series that existed prior to 2003 as a way of updating the way tonal and impulse sounds are handled in community noise[1]. They have run several round robin tests of the procedures with sample sounds[2]. Stephen Keith of Health Canada is acting as liaison with the ISO committee. However, ISO recently came out with a new standard, which will require a re-examination of how the new standard fits the Canadian context. Meanwhile, the most recent versions of ISO 1996 have been adopted without change as Canadian standards, with any needed deviations to be balloted later.

- **CAN3-Z107.54-M85** (R1993) Procedure for Measurement of Sound and Vibration Due to Blasting Operations. A working group, chaired by Vic Schroter, is revising this standard. This activity is just getting started.
- **CAN/CSA-Z107.55-M86** Recommended Practice for the Prediction of Sound Levels Received at a Distance from an Industrial Plant. A joint CSA/ANSI working group co-chaired by Rich Peppin and Tim Kelsall is looking at ISO9613. This standard was originally written by an ISO working group chaired by Joe Piercy of NRC. It may ultimately replace or become the basis for a revised version of Z107.55, however the group has identified a number of shortcomings which need to be addressed. A new draft has recently been pulled together and is being reviewed. A recent meeting of this working group in Ottawa was standing room only.
- **CAN/CSA-Z107.9-00:** Standard for Certification of Noise Barriers. This standard is an adaptation of the Ontario MTO Highway Noise Barrier specification. It provides municipalities, developers, road and highway departments, railways and industry with a standard specification which can be used to define the construction of barriers intended to be durable enough for long term use in Canadian conditions.
  Manufacturers and their specific barrier designs are certified as complying with the standard in such areas as: plant facilities, design concept, materials used, quality control, durability, and acoustical performance. In addition, each barrier installation is reviewed and certified for compliance with such items as structural and foundation design, quality assurance, field assembly and installation.
  The US Department of Transportation, Federal Highway Administration, Highway Noise Barrier Design Handbook is already harmonized with the CSA standard, as is the Ontario Provincial Standard, and numerous US state transportation agencies, making this the de-facto standard for barriers across North America.

This group is also responsible for endorsing standards on powered machines and vehicle noise.

Editorial, chaired by Cameron Sherry, (which reviews all proposed standards) and is responsible for reviewing and endorsing ANSI S1.1-1994 Acoustical Terminology. They recently reviewed the latest revision to Z107.56. In addition, they were the main group pulling together the omnibus standard from input by each subcommittee chair. Cameron is actively looking for new members to assist in this work and can be contacted directly or through the author.

Building Acoustics, chaired by David Quirt, does not have its own standards, but review other standards from a Canadian viewpoint, mostly from ASTM and ISO. They recently were reviewing endorsed standards on building acoustics (a large part of the current Z107 list) and preparing appropriate entries for the new Z107 omnibus document. David Quirt is also chair of the Standards Council of Canada Steering Committee for ISO TC 43 SC2, Building Acoustics.

Instrumentation and Calibration: George Wong, is the chairman (and the CSA liaison) for the SCC Canadian Subcommittee of IEC/TC 29: Electroacoustics. This group deals with all instrumentation pertaining to acoustical measurements, such as WG 4: Sound level meters; WG 5: Microphones; WG 10: Audiometers; WG 13: Hearing aids; WG 17: Sound calibrators; WG 21: Ear simulators; and maintenance teams (MT) MT19: Filters; and MT20: Hearing aids induction loops. All of the above international Working Groups have Canadian members, with calibration and measurement data supported by the Institute for National Measurement Standards of the National Research Council of Canada.

Liaison with the Canadian Steering Committee for ISO TC43 (Acoustics) and TC43(1)(Noise), chaired by Stephen Keith provides Canadian comments and votes on ISO standards and coordinates the work of Canadian representatives on several ISO working groups. The Steering committee is run by the Standards Council of Canada and is harmonised with the Z107 committee to which Stephen reports regularly on progress. Draft international standards are provided on a private website to which members have access in order to review them and recommend Canada's position. Stephen is working closely with Z107 to expand the pool of reviewers and actively seeking new volunteers.

3.2 Z94 – Hearing Protection

The second CSA Acoustics Standards Committee, Z94 is responsible for a single standard, the Hearing Protection Standard Z94.2 which defines Type A, B, and C type hearing protectors and is widely referred to in Canadian occupational noise regulations. They have recently approved a major new version of this standard in light of changes to the ANSI hearing protector standards and procedures. This will mean the introduction of user-fit hearing protector measurements, similar to those used by ANSI and now recognized as being more representative of how hearing protectors are used in practice than the old technician-fitted testing methods. This standard also has extensive information for users on how to select and use hearing protection.

4.0 CANADIAN ACOUSTICS STANDARDS

The following list shows all the Canadian Standards currently in force and also lists three standards with significant acoustical content. This table will also soon be found at the CAA website and will be kept up to date there. Meanwhile the list can be found at http://www.csa-intl.org/onlinestore/GetCatalogDrillDown.asp?Parent=430, although at the time of writing, the following list was more up to date.

There are also 24 acoustics standards from ANSI, ISO and ASTM endorsed by Canada.

CAN3-Z107.4-M86 Pure Tone Air Conduction Audiometers for Hearing Conservation and for Screening / Audiomètres tonals à conduction aérienne pour la préservation de l'ouïe et pour le dépistage

CAN/CSA-Z107.6-M90 Pure Tone Air Conduction Threshold Audiometry for Hearing Conservation

CAN/CSA-Z107.9-00: Standard for Certification of Noise Barriers

Z107.52-M1983 (R1994) Recommended Practice for the Prediction of Sound Pressure Levels in Large Rooms Containing Sound Sources

Z107.53-M1982 (R1994) Procedure for Performing a Survey of Sound Due to Industrial, Institutional, or Commercial Activities (soon to be replaced by ISO 1996).

CAN3-Z107.54-M85 (R1993) Procedure for Measurement of Sound and Vibration Due to Blasting Operations / Méthode de mesure du niveau sonore et des vibrations émanant des opérations de dynamitage

CAN/CSA-Z107.55-M86 Recommended Practice for the Prediction of Sound Levels Received at a Distance from an Industrial Plant / Pratique recommandée pour la prévision des niveaux sonores reçus à une distance donnée d'une usine

Z107.56-94 Procedures for the Measurement of Occupational Noise Exposure / Méthode de mesure de l'exposition au bruit en milieux de travail

Z107.58-2002 Noise Emission Declarations for Machinery

Z94.2-02 • Hearing Protection Devices - Performance, Selection, Care, and Use / Protecteurs auditifs

Standards with Acoustics Component:

Z62.1-95 Chain Saws

CAN/CSA-Z412-M00 Office Ergonomics / L'ergonomie au bureau

CAN/CSA-M5131-97 (R2002)Acoustics - Tractors and Machinery for Agriculture and Forestry - Measurement of Noise at the Operator's Position - Survey Method (Adopted ISO 5131:1996)

Endorsed Standards

ANSI S1.1-1994 Acoustical Terminology(R1999)

ANSI S1.4-1983 Specification for Sound Level Meters (R2001)

ANSI S1.11-1986 Specifications for Octave-band and Fractional (R1998) Octave-band Analog and Digital Filters

ANSI S1.13-1995 Measurement of Sound Pressure Levels in Air (R1999)

ANSI S12.31-1990 Precision Methods for the Determination of (R1996) Sound Power Levels of Broad-band Noise Sources in Reverberation Rooms

ANSI S12.32-1990 Precision Methods for the Determination of (R1996) Sound Power Levels of Discrete-frequency and Narrow-band Noise Sources in Reverberation Rooms

ANSI/ASTM Standard Test Method for Sound Absorption and C423:00 Sound Absorption Coefficients by the Reverberation Room Method

ANSI/ASTM Standard Test Method for Laboratory E492-90 (1996) E1 Measurement of Impact Sound Transmission Through Floor-ceiling Assemblies Using the Tapping Machine

ASTM C384-98 Standard Test Method for Impedance and Absorption of Acoustical Materials by the Impedance Tube Method

ASTM E90-99 Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements

ASTM E336-97 Standard Test Method for Measurement of Airborne Sound Insulation in Buildings

ASTM E596-96 Standard Test Method for Laboratory Measurement of the Noise Reduction of Sound-isolating Enclosures

ASTM E795-00 Standard Practices for Mounting Test Specimens During Sound Absorption Tests

ASTM E966-99 Standard Guide for Field Measurement of Airborne Sound Insulation of Building Facades and Facade Elements

ASTM E989-89 Standard Classification for Determination of (1999) Impact Insulation Class (IIC)

ASTM E1007-97 Standard Test Method Field Measurement of Tapping Machine Impact Sound Transmission Through Floor-ceiling Assemblies and Associated Support Structures

IEC 60651-2001 Sound Level Meters

ISO 4872-1978 Acoustics – Measurement of Airborne Noise Emitted by Construction Equipment Intended for Outdoor Use – Method for Determining Compliance with Noise Limits

ISO 6393:1998 Acoustics – Measurement of Exterior Noise Emitted by Earth-moving Machinery – Stationary Test Conditions

ISO 6394:1998 Acoustics – Measurement at the Operator's Position of Noise Emitted by Earth-moving Machinery –Stationary Test Conditions

ISO 6395-1988 Acoustics – Measurement of Exterior Noise Emitted by Earth-moving Machinery – Dynamic Test Conditions

ISO 6395:1998 Acoustics – Measurement of Exterior Noise Emitted by Earth-moving Machinery – Dynamic Test Conditions – Amendment 1

SAE J919-1995 Sound Measurement – Off-road Work Machines – Operator Singular Type

SAE J1096-2000 Measurement of Exterior Sound Levels for Heavy Trucks under Stationary Conditions

5.0 REFERENCES

1. C. Krajewski, Rating Sound Level- An Overview of Amendment 1 to ISO 1996-2, Canadian Acoustics, Volume 29, No. 3, September, 2001.
2. William J. Gastmeier and James L. Fielders, ISO 1996 Acoustics – Description and Measurement of Environmental Noise Round Robin Testing, Canadian Acoustics, Volume 29, No. 3, September, 2001 presented at CAA Conference 2001.
3. Stephen Keith, Stephen Bly, Tim Kelsall, A preview of the Draft CSA Guideline – Noise Emission Declarations for Machinery, Canadian Acoustics, Volume 29, No. 3, September, 2001.

EDITORIAL BOARD / COMITÉ EDITORIAL

ARCHITECTURAL ACOUSTICS: ACOUSTIQUE ARCHITECTURALE:	**Vacant**		
ENGINEERING ACOUSTICS / NOISE CONTROL: GÉNIE ACOUSTIQUE / CONTROLE DU BRUIT:	**Vacant**		
PHYSICAL ACOUSTICS / ULTRASOUND: ACOUSTIQUE PHYSIQUE / ULTRASONS:	**Werner Richarz**	Aercoustics Engineering Inc.	(416) 249-3361
MUSICAL ACOUSTICS / ELECTROACOUSTICS: ACOUSTIQUE MUSICALE / ELECTROACOUSTIQUE:	**Annabel Cohen**	University of P. E. I.	(902) 628-4331
PSYCHOLOGICAL ACOUSTICS: PSYCHO-ACOUSTIQUE:	**Annabel Cohen**	University of P. E. I.	(902) 628-4331
PHYSIOLOGICAL ACOUSTICS: PHYSIO-ACOUSTIQUE:	**Robert Harrison**	Hospital for Sick Children	(416) 813-6535
SHOCK / VIBRATION: CHOCS / VIBRATIONS:	**Li Cheng**	Université de Laval	(418) 656-7920
HEARING SCIENCES: AUDITION:	**Kathy Pichora-Fuller**	University of Toronto	
HEARING CONSERVATION: Préservation de L'Ouïe:	**Alberto Behar**	A. Behar Noise Control	(416) 265-1816
SPEECH SCIENCES: PAROLE:	**Linda Polka**	McGill University	(514) 398-4137
UNDERWATER ACOUSTICS: ACOUSTIQUE SOUS-MARINE:	**Garry Heard**	DRDC Atlantic	(902) 426-3100
SIGNAL PROCESSING / NUMERICAL METHODS: TRAITMENT DES SIGNAUX / METHODES NUMERIQUES:	**David I. Havelock**	N. R. C.	(613) 993-7661
CONSULTING: CONSULTATION:	**Corjan Buma**	ACI Acoustical Consultants Inc.	(780) 435-9172
ADVISOR: MEMBER CONSEILLER:	**Sid-Ali Meslioui**	Pratt & Whitney Canada	(450) 647-7339

WHOLE BODY VIBRATION MEASUREMENTS OF FORKLIFT TRUCK DRIVERS*

A. Behar[1] and S. Libich[2]
1 - Behar Noise Control, behar@sympatico.ca
2 - WESA, slibich@rogers.com

* - Excerpts presented at the 149th ASA joint meeting with CAA. Vancouver 16 – 20 May 2005

ABSTRACT

Measurements of vibrations on the body of forklifts, driven by standing operators, were conducted to assess possibility of health hazards. The instrument used was a Larson-Davis HVM100 Digital Triaxial Vibration Meter, and the measured magnitudes were acceleration (m/s2) and Vibration Dose Value (m/s1.75). Measured values were assessed using the corresponding EU Directive. Even though, some of the values did exceed the recommended limits, it was found that, because of the limited use of the trucks (an average of 2 hr/day) the time-weighted averages were well below the action limit. Therefore it was concluded, that the measured vibrations did not constitute health hazard for the drivers.

SOMMAIRE

L'existence de risques pour la santé des ouvriers conduisant des chariots élévateurs à fourche en position debout a été examinée en mesurant les vibrations de ces machines. L'instrument utilisé pour mesurer ces vibrations était un Larson Davis HVM100 Digital Triaxial Vibration Meter. Les données d'amplitude recueillies étaient l'accélération (m/s2) et le VDV (la valeur de la dose des vibrations) en m/s1.75. Les résultats obtenus ont été comparés avec les valeurs recommandées par la Directive de l'Union Européenne. Même si certaines mesures surpassaient les limites recommandées, on a trouvé que les moyennes durées vs poids étaient inférieures aux limites prescrites puisque l'utilisation des chariots est limitée (une moyenne de deux heures par jour). On a conclu que les vibrations mesurées ne représentaient aucun risque pour la santé des conducteurs de chariots.

1. INTRODUCTION

There are some 8 to 10 million workers, in the United States alone, who are regularly exposed to occupational vibrations and there are many more in the rest of the world [1]. Although there are no published statistics, it can be assumed that the number of exposed workers is also large in Canada. The effects from those vibrations can include muscular fatigue, low-back pain, degraded circulatory functioning, and headaches [2, 3].

Depending on the type of work, there are two major occupational vibration exposures:

a) Whole Body Vibrations (WBV) that applies mainly to seated or standing operators of moving equipment such as tractors, farm vehicles, forklift trucks, etc, and
b) Hand-Arm Vibration (HAM), where the energy enters the body through the hands of the operator. This is the case of individuals who use regularly vibrating tools such as pneumatic pavement breakers, gasoline powered tools, chain saws, etc.

In some rare occasions, the operator may even be subjected to a combination of both types of vibrations. This will be the case of drivers of all-terrain vehicles or similar.

The reason the two types of vibrations are considered separately is because their effects on the human body are completely different as well as their measurements and assessment. Even within the WBV, there are two types of vibrations that are considered separately because of their effects as well the way they are assessed. They refer to the standing operator and to the seated one.

Depending of the type of forklift trucks, the operators work in a standing or seated position. The trucks that are the object of the present study are only operated by standing operators.

2. EXISTING STANDARDS

Several standards deal with whole body vibrations. All of the standards specify that measurement should be performed simultaneously in the three axes: x (front and back), y (sideways) and z (vertical). This is done using three separate accelerometers or one tri-axial acclerometer. Each signal is filtered in 1/3-Octave band in the low range of frequencies, between approximately 0.4 and 100 Hz (the ISO standard) simultaneously. A weighting factor is then applied, that is different for each one of the three signals.

8-hr Daily Exposure	**Acceleration**	**VDV**
Limit Value	**1.15 m/s^2**	**21 $m/s^{1.75}$**
Action Value	**0.5 m/s^2**	**9.1 $m/s^{1.75}$**

Table 1. Whole-Body Vibration Values (EU Directive 2002/44/EC)

The standard that Occupational Hygienists usually consult is the American Conference of Governmental Industrial Hygienists (ACGIHs) Threshold Limit Values (TLVs) 4]. It specifies the maximum accelerations a person can be exposed to for a given length of time. In other words, the measured accelerations in each direction are compared to a set of accelerations values between 0.4 and 80 Hz, for exposures between 1 minute and 24 hours. Those limits have been adapted from the 1985 version of the ISO Standard 2631, (superseded by the ISO Standard 2631-1:1997 [5]). The British Standard BS 6841 [6], similar to the ISO Standard 2631 – 1:1997.

The latest ISO whole-body vibrations standard, ISO 2631-1:1997, deals with three situations: health, comfort and perception. When dealing with health, it states: “It applies primarily to seated persons, since the effects of vibration on the health of persons standing, reclining or recumbent are not known.”

As mentioned above, the output from the three accelerometer’s signals are filtered in 1/3- Octave bands. They are combined and treated in two different manners depending of the nature of the signals. If the signals is of a relatively low crest factor the weighted r.m.s. values are reported as m/s^2. In the presence of high crest factors, occasional shocks, transient vibrations, etc. signals are treated differently and results are presented as Vibration Dose Value (VDV), in $m/s^{1.75}$. The crest factor is defined as the modulus of the ratio of the maximum instantaneous peak value of the acceleration signal to its root-mean-square (r.m.s.) value.

The easiest to use document regarding the assessment of the vibration is the European Directive 2002/44/EC [7]. It establishes two values: the Action Value, above which the employer should implement a program of technical and administrative measures, intended to reduce or eliminate the exposure to mechanical vibrations. The second set of limits is the Limit Value above which no worker should be exposed. Both values are provided for exposure of 8 hr/day.

Table 1 shows the Limit and the Action values as per the Directive.

3. MATERIALS AND METHODS

3.1 Forklift trucks and operations

Measurements were performed in a medium sized paint-manufacturing factory that has eight truck-loading bays for the receiving and shipment of materials.

The forklift trucks (Figure 1) used in the facility are designed to work in narrow aisles between storage facilities and to load trucks and trailers. They are electric driven (because of the requirements in a potentially explosive environment). They are narrow and their wheelbase is relatively short. The driver is standing all the time, since there is no seat for him. The wheels of the trucks are lined with hard rubber and have small diameter. That accentuates the vibration caused while driving over loading ramps and imperfections and bumps of the floor that are transmitted to the driver.

The trucks are used for:

a) Unloading of raw materials and supplies from trucks. To do so, they have to enter the body of the truck or trailer through a loading ramp.
b) Loading of the finished products, drums or pallets, or both on the trucks.
c) Moving totes (large drums) between locations in the plant and storage areas.
d) Staging raw materials for production runs.

3.2 Instrumentation

The instrument used was a Larson Davis Mod HVM 100, equipped with a PCB triaxial accelerometer. It was calibrated in the factory. Larson Davis Blaze 4.11 software was used to calibrate the instrument in the field and to retrieve the measured data.

The instrument was mounted on the frame of the truck (Figure 2). The accelerometer was attached to the frame right next to the operator using a magnet. The vibrations transmitted to the operator are thus measured without attenuation. Care was taken to have the proper orientation of the accelerometer (Z – up, X – front to back and Y – sideways).

The instrument is equipped with the filters needed to measure the acceleration according to the above-mentioned standards so the results are provided with the proper weightings. Using the software, one can also obtain the history of

Figure 1. View of one of the forklift trucks used in the facility

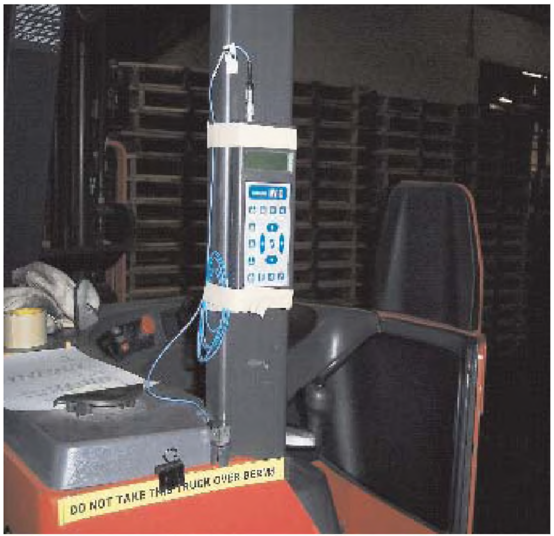


Figure 2. View of the accelerometer and the vibration meter attached to the body of the truck.

the individual accelerations (X, Y, Z) RMS, as well as their peak values. Also, the software calculates the VDV values as explained above.

3.3 Procedures

Before each run, the instrument was calibrated using the software and attached to the truck under test. Then, the driver was allowed to perform his normal activities for approximately 20 m. At the end of this period, the information from the instrument was downloaded into the computer using the same software.

Samples were taken of all the major activities involving forklift trucks in this facility.

3.4 Measurement Results

The results of the measurements are shown in Table 2. The table also lists the duration of the test, the test's number and the acceleration in each direction as well as the calculated total acceleration ("Sum") and the Vibration Dose Value ("VDV").

Run Name	Duration min	X m/s^2	Y m/s^2	Z m/s^2	Sum m/s^2	VDV $m/s^{1.75}$	Truck No
Test 1	10:00	0.404	0.344	0.653	0.839	9.02	PR58
Test 2	22:02	0.439	0.379	0.58	0.849	9.39	PR41
Test 3	9:56	0.386	0.332	0.583	0.771	8.23	PR58
Test 4	18:26	0.758	0.476	1.14	1.45	17.6	PR58
Test 5	14:00	0.544	0.53	0.754	1.07	8.8	PR39
Test 6	13:43	0.444	0.342	0.473	0.731	8.62	PR43
Test 7	23:24	0.422	0.291	0.409	0.653	9.4	PR43
Test 8	21:53	0.553	0.347	0.843	1.06	15.8	PR58
Test 9	20:56	0.299	0.277	0.324	0.519	6.5	PR38
Test 10	14:55	0.501	0.351	0.545	0.816	11	PR45
Test 11	44:31	0.398	0.357	0.492	0.725	9.77	PR42

Table 2. Summary of Acceleration Measurement Results

4 ANALYSIS OF THE RESULTS

4.1 General Observations

As expected, the largest acceleration levels are observed in the Z direction. This corresponds to the vertical motion caused by the vibrations due to the floor irregularities.

The second dominant vibration levels are the X-component. The forklift truck, shown in Figure 1, has a large width between the front and the rear wheels. This causes large oscillations of the truck body in the front-to-back (X) direction. Finally, because of the narrow body of the truck, it is obvious that the oscillations in the lateral (Y) direction are small.

4.2 Risk Assessment

A comparison between the values of both SUM and VDV columns in Table 1 to the measured results in Table 2, shows that some of the vibration levels exceed the Action Values.

The ISO Standard 2631-1:1997 specifies that in the case that a worker is exposed to more than one type of vibration during the workday, or if the exposure duration is shorter than 8 hs, the daily exposure should be calculated using the formula:

$$a = [(1/t_s)\ (\Sigma(a_i)^2\ t_i)]^{1/2} \qquad (1)$$

Where:

a is the resulting acceleration
t_s is the duration of each portion of the shift
$(a_i)^2$ are the individual accelerations, and
t_i are the individual durations.

The average usage duration of the trucks, for the current study, was 2 hr/day. So, the results were corrected using Formula (1). The final results with the corrected exposures are shown in Table 3.

4.2 VDV or SUM?

To determine which descriptor, VDV or SUM, to use, two tables, Table 4 and Table 5 were prepared. Table 4 shows the results where the tests were ordered in descending VDV values, while in Table 5, the test were orederd in descending SUM values.

Analysis of the two tables show that there is no clear relation between the two indices. Tests that are on the top of one table are not at the top of the other, nor the middle positions of both tables are consistent. Therefore, both results were examined and found to be below the recommended limits.

5 CONCLUSION

An assessment of the health risk of forklift truck drivers was performed by measuring the vibrations of the truck body.

Run Name	Sum Measured m/s^2	Sum 8 hr TWA m/s^2	VDV Measured m/s$^{1.75}$	VDV 8 hr TWA m/s$^{1.75}$
Test 1	0.839	0.42	9.02	4.5
Test 2	0.849	0.42	9.39	4.7
Test 3	0.771	0.39	8.23	4.1
Test 4	1.45	0.73	17.6	8.8
Test 5	1.07	0.54	8.8	4.4
Test 6	0.731	0.37	8.62	4.3
Test 7	0.653	0.33	9.4	4.7
Test 8	1.06	0.53	15.8	7.9
Test 9	0.519	0.26	6.5	3.3
Test 10	0.816	0.41	11	5.5
Test 11	0.725	0.36	9.77	4.9
Guideline (EU)		**1.15**		**21**

Table 3. Measured and Corrected Acceleration Values

Tests were conducted on six trucks resulting in 11 runs in total. Results show that workers are not at risk while driving the trucks.

6 REFERENCES

1 Wasserman, D. and Wasserman J.: The Nuts and Bolts of Human Exposure to Vibration. Sound and Vibrations, 36,1,40-41, 2002.

2 Cann, A.P. et al.: An Exploratory Study of Whole-Body Vibration Exposure... Applied Occupational and Environmental Hygiene 18:999-1005, 2003.

3 Wasserman, D.: Occupational Vibration. Quest Technology Special Report.

4 American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs), pp. 126-133, ACGIH, Cincinnati, OH (2002) (124-131).

5 International Standards Organization: Evaluation of Human Exposure to Whole-Body Vibration, ISO 2631-1. ISO, Geneva (1997).

6 British Standard Institute: Measurement and Evaluation of Hyman exposure to Whole-Body Mechanical Vibration and Repeated Shock, BS 6841. BSI, London (1987)

7 Directive 2002/44/EC of the European Parliament and of the Council, June 2002. Official Journal of the European Communities,L177/13-19 (6.7.2002).

Run Name	Sum m/s^2	VDV m/s$^{1.75}$	Truck No
Test 4	1.45	17.6	PR58
Test 8	1.06	15.8	PR58
Test 10	0.816	11	PR45
Test 11	0.725	9.77	PR42
Test 7	0.653	9.4	PR43
Test 2	0.849	9.39	PR41
Test 1	0.839	9.02	PR58
Test 5	1.07	8.8	PR39
Test 6	0.731	8.62	PR43
Test 3	0.771	8.23	PR58
Test 9	0.519	6.5	PR38

Table 4. Accelerations by Descending VDV Results

Run Name	Sum m/s^2	VDV m/s$^{1.75}$	Truck No
Test 4	1.45	17.6	PR58
Test 5	1.07	8.8	PR39
Test 8	1.06	15.8	PR58
Test 2	0.849	9.39	PR41
Test 1	0.839	9.02	PR58
Test 10	0.816	11	PR45
Test 3	0.771	8.23	PR58
Test 6	0.731	8.62	PR43
Test 11	0.725	9.77	PR42
Test 7	0.653	9.4	PR43
Test 9	0.519	6.5	PR38

Table 5. Accelerations by Descending SUM Results

INCE Publication 05-1 "A Global Approach to Noise Control Policy" [1]

Alberto Behar[1] and Tim Kelsall[2]
1 - IBBME, University of Toronto, behar@sympatico.ca
2 - Hatch Associates, Mississauga, Ontaio, tkelsall@hatch.ca

1. INTRODUCTION

The International Institute of Noise Control Engineering (I-INCE, http://www.i-ince.org/), founded in 1974, is a worldwide consortium of organizations concerned with noise control, acoustics and vibration. It is the sponsor of the INTER-NOISE Series of International Congresses on Noise Control Engineering and the co-sponsor of symposia on specialized topics within the I-INCE fields of interest. I-INCE and the Institute of Noise Control Engineering of the USA (INCE/USA) jointly publish the quarterly magazine "Noise/News International". In 1992, I-INCE instituted a program to undertake technical initiatives on critically important issues of international concern. This initiative has resulted in three reports and the creation of five ongoing Technical Study Groups (TSG).

The Draft Report "A Global Approach to Noise Control Policy" (called "the document" further in this article) was produced by TSG No 5. Like all other TWGs, it comprises members from different Member Societies.

The Report was to be presented at the General Assembly Meeting scheduled for August 7, 2005. It has been circulated for comment and approval by the I-INCE Member Societies, one of which is the Canadian Acoustical Association. This request was considered at a CAA Board of Directors meeting held in Vancouver in May 2005. There, it was decided not to endorse the Report, but to circulate it among the CAA members for their information. The main reason for the decision was that the Association does not have an established protocol for review and endorsement of such documents.

The aim of the Report is to underline the fact that in this era of globalization and international trade, noise has become an international issue now that manufactured products are exported worldwide. If noisy, they create problems not only to consumers within the country of origin but also to inhabitants of the countries to which they are exported. Those problems can be occupational, if products are used for manufacturing or transportation. They can also be environmental if they are radiating noise to the environment. For those reasons, the authors of the document concluded that noise control policies have to be coordinated worldwide to ensure uniformity in the way noise is controlled.

The Report is divided into five sections:

- General
- Occupational noise
- Community noise
- Consumer product noise, and
- Summary of I-INCE positions

A complete analysis of the Report would be almost as extensive and time-consuming as the document proper and hence the current review deals only with the section on Occupational noise.

It must be pointed out that the comments herein are that of the authors and is not a reflection of the CAA position.

2. PART 2: OCCUPATIONAL NOISE

2.1 Introduction

As stated in the introduction of the document, Part 2 is largely based on the I-INCE publication 97-1 [2] . It provides I-INCE recommendations for action to alleviate damaging exposures to noise in the workplace.

The document points out three main reasons for the failure to conserve hearing of noise exposed workers, even in the most developed countries. They are:

a) Over-reliance of the use of hearing protectors as the only hearing conservation measure,

b) Lax, irregular or non-existent legislation regarding hearing conservation and

c) Inadequate or non-existent application of noise control engineering techniques in the design of industrial buildings and machines.

The document states that the most important factor for reducing hearing losses is the engineering noise control that should take priority in any hearing conservation program. A necessary element to it is the institution of regulations at a national level specifying noise exposure limits [3].

To these reasons, the authors would like to add:

- Lack of instruction and awareness among workers
- Lack of strict enforcement of existing noise exposure limits,
- Lack of adequate and knowledgeable review of occupational noise controls before plants are permitted to be constructed or retrofitted, and
- Lack of standards for noise control design of industrial facilities

2.2 Terms and definitions

Section 2, Part 2, refers to terms and definitions in the document and there is a surprise: when dealing with noise exposure, the authors have chosen to use the term “Sound (noise) exposure” expressed in Pa^2h instead of the now commonly used term “A-weighted equivalent sound level”, Leq (dBA) or the “Normalized A-weighted noise exposure level”, LEx (dBA).

This is rather odd, since:

a) Sound level measurement results are invariably expressed in terms of sound pressure level (dB) and not as sound pressure (Pa).

b) Most instruments measuring sound exposure, (at least on this side of the ocean) show their results in terms of noise exposure (Leq, Lex or LOSHA), or some times noise dose (%), but certainly not as noise exposure (Pa^2h).

c) National and international standards such as Z107.56, ANSI S12.19 or ISO 1999 use the term Leq. Even the most recent draft of CSA Z107.56 has eliminated the term Pa^2s in the text. [4, 5, 6]

d) The ISO WG 53, working Draft standard on noise exposure measurements, also specifies A-weighted Leq and LEx as the terms to be used. Again, the term Pa^2h is not even mentioned [7]

A serious omission in the section is the term “Noise Immission”. Although used in the text, it is not defined.

2.3 Effects of Noise

The Report reviews the issue of noise as a cause not only of noise induced hearing loss but also of masking of safety signals. It also points to the fact that high noise levels are stressful, tiring and unpleasant. The Report concludes that the introduction of policies requesting the use low-noise level machines and equipment in the workplace will eliminate the above-mentioned effects.

2.4 Issuing authorities and international non-governmental organization

Here the Report presents nine different entities dealing with noise, beginning with the European Union down to I-INCE. It describes what they are, including some pertinent information. A list of the websites would have been most useful, but, unfortunately is missing. Missing are other important organizations, such as the FIA (Iberoamerican Federation of Acoustics). It is not clear why the EU is singled out while other federal authorities (e.g. Washington or Ottawa) are not referred to.

2.5 Immission specifications (Section 6)

The term “Immission”, a term rarely used nowadays, deals with the sound level at the point of reception or receiver. This is a descriptor needed to assess the risk of hearing loss and should be specified, as it is used in the report.

The Report recommends an upper limit of 85 dBA time-averaged sound level, something most jurisdictions have already adopted. However, it still mentions the noise exposure limit of 1 Pa^2 h and even provides a formula for transforming this limit into noise exposure level for a given exposure duration.

For impulse noise it recommends an upper limit of 135dB, C weighted peak sound level, (interesting, no sound pressure but sound pressure level is used here). The reasons for limiting the peak level for hearing conservation purposes have been for the longest time a controversial issue. It is a well known fact that hearing loss from impulse noise is dependant not only of the peak level, but also on the rise time, decay time, frequency content, number of impulses and duration of the exposure. However, the exact limits for the above variables are still very much debated.

Only the peak value is ever specified in regulations/specifications/standards that these authors have had access to. The limit most frequently is set at 135 or 140 dBC. Those levels are equivalent to an Leq of 85 dB for durations of approximately 0.3 and 0.1 s respectively. For such short duration sounds the A and C weightings will likely give similar results. Thus for any practical purposes, in the workplace, especially because of the reverberant characteristic of the environment, the presence of impulsive noise will likely cause the limit of LEx = 85 dBA to be exceeded before the 135 dBC limit can come into effect. Thus the latter is not necessary. One would expect at least a mention that the use of the 135 dB Peak is a very crude, approximate way of assessing the risk from impulse noise.

In addition, there is a problem that the 135/140 dBC limit causes the practicing noise control engineer who uses a dosimeter to assess the noise exposure of a worker. If, by any chance, there has been even a single clap of the hands or the microphone cable has rubbed on clothing during the measurement period, the instrument will often show that the peak level limit has been exceeded. The obvious conclusion will be that the worker was over-exposed, even if the measured Leq was below 85 dBA. The net effect of this “use” of the peak level limit is, therefore, a false positive risk assessment.

It is surprising that the document recommends engineering controls to be implemented only when the hazard limits are exceeded. This is in contradiction with current industrial hygiene practice and many hearing conservation programs that introduce the concept of “action level” a level, lower than the limit, when some action must be taken.

2.6 Emission specifications (Section 7), Path control specifications (Section 8)

Those two sections repeat concepts found in most hearing conservation and noise control texts. There are also some repeats from the previous sections.

2.7 Noise control engineering actions required in an operating industrial enterprise (Section 9) and Follow-on actions (Section 10)

These should probably be the most important sections of the document. Unfortunately this is not the case. The steps to be followed and actions recommended are those well known by any industrial hygienist, and too general for a noise control practitioner.

It is surprising that even the reference to a hearing conservation program is taken from a chapter of a book written almost 15 years ago [8] when there are many more books on such an important issue that could have been quoted [9].

Two more issues that should have been included in this sections are:

a) New and retrofit facilities should undergo knowledgeable and independent review for noise control design prior to permitting their installation. This approach has proven quite effective in environmental regulation.

b) There should be standards for design of new and retrofit industrial facilities, including minimum criteria for reverberation, prediction of sound levels and employee noise exposure, effective use of noise emission declarations and the quality control required to provide effective results.

3 CONCLUSIONS

The INCE initiative is clearly worthwhile and any document that will help all countries and industries adopt up to date criteria is useful. While the criteria proposed are currently used by many well informed countries, they represent the state of the art of perhaps a decade ago. These days, Pa^2h is virtually unused and there is growing recognition that peak levels have limited use in a regulation (although widely used). Finally, many industries are already aiming for levels lower than 85 dBA.

At the same time, there is a real need for unifying criteria around the world. If this document can promote the criteria it suggests towards universality, it will have accomplished a good deal.

4 REFERENCES

1 Noise Control Eng. J. 52 (6), 2004 Nov-Dec (251-298)

2 I-INCE Publication 97-1, Technical Aspects of Upper Limits on Noise in the Workplace, T.W.F. Embleton, Ed., NOISE/NEWS International, 5(4), 203-216 (1977)

3 This does not take into account countries like Canada where this would be unconstitutional (even though it might indeed be simpler).

4 CSA Z107.56: Procedures for the Measurement of Occupational Noise Exposure. It has to be noted that the original version of this Standard did contain the term Noise Exposure and explained how it could be converted to Leq. In the latest draft, the term was dropped because of the lack of application and use.

5 ANSI S12.19-1996, Measurement of Occupational Noise Exposure.

6 ISO 1999:1990 Acoustics - Determination of occupational noise exposure and estimation of noise-induced hearing impairment

7 ISO/WD 9612 Acoustics – Measurement and calculation of occupational noise exposure – Engineering method.

8 Larry H. Royster and Julia D. Royster, “Hearing Conservation Programs” Chap.22 in Handbook of Acoustical Measurements and Noise Control, edited by Cyril M. Harris, 3rd ed.,(McGraw-Hill, Inc., New York, NY, 1991)

9 As an example see Alice H. Suter: “Hearing Conservation Manual” Fourth Ed., CAOHC, Milwaukee, NY, 2002.

One of Our longstanding Memebrs, Prof. Hugh Jones sends us the following message

“Hugh Jones wishes to make you aware of the website www.stuns.info”

From Acoustics Week in Canada 2005/De l'acte semaine candienne d'acoustique 2005

THE ROLE OF IN-FLIGHT VOCALIZATIONS OF THE CHIMNEY SWIFT, *CHAETURA PELAGICA*.

Jenn Bouchard
Dept. of Biology, University of Western Ontario, 1151 Richmond St., London, Ontario, Canada N6A 5B7

1. INTRODUCTION

From the elaborate songs of birds to the echolocating bat acoustic signals represent an efficient and rich medium for sending and receiving information (Hauser 1997). Varied as these systems are, there remains a great deal to learn about animal acoustics.

This gap in knowledge is illustrated by the Chimney swift, *Chaetura pelagica*, the basic biology of which is poorly known (Cink and Collins; 2002). While the swifts are not uncommon, they are among the most aerial of land birds, feeding on aerial insects, they land to roost and breed, often in abandoned chimneys (Blodgett and Zammuto; 1979) , but remain airborne otherwise; making them difficult subjects to study.

While it is known that the Chimney swift is extremely vocal while in flight (Chantler and Driessens; 2000), the full vocal repertoire of the bird has yet to be recorded. The first objective of my study was to catalogue the full vocal array. In addition, I was also interested in deducing what role these acoustic signals play in the lives of the birds.

Chimney swifts are remarkably fast as they course for flying insects in the air. They are also highly gregarious and have been known to roost and sometimes forage in large groups. I hypothesized that individuals were using their calls as a means of traffic control. In other words, in situations where several fast-flying individuals are together in space, an acoustic signal could be used to indicate one's presence; a sort of collision avoidance tactic.

In echolocating bats, a form of jamming avoidance is observed whereby individuals will change the frequency at which a signal is broadcast so as to avoid jamming of returning echos. This jamming avoidance may also serve to prevent collision among aerial foragers (Ulanovsky *et al*; 2004).

2. METHOD

Audio and visual recordings of chimney swifts while in-flight were obtained from June to October of 2005. Recordings were made from various elevations (from ground level to 6 stories up) at various sites in London, Ontario. The audio recordings were obtained using a Sennheiser K6 microphone and Avisoft Recorder (version 2.9). This system allows for immediate spectrogram and energy displays while providing flexibility in the range of recording frequencies.

Visual recordings were obtained using two digital cameras (Panasonic PV-GS35) placed on either side of the microphone at 1.5, 2 or 2.5 meter distances. By simultaneously recording audio and visual data, the acoustic signals of individuals at a given time and the position of individuals relative to each other can be captured.

A notebook was used to catalogue various behaviours, number of individuals, call type and time.

3. RESULTS

Over 500 useable call sequences and approximately 15 hours of video recordings were obtained.

Preliminary foraging observations made in June, indicated that chimney swifts forage mainly alone (n=49), during the breeding season, or in pairs (n= 65) and infrequently forage in groups (n=6). In addition, vocalizations were seldom recorded in all three scenarios.

The majority of call sequences were obtained while the birds prepared for entry into their roost at dusk, or after they left their roost at dawn. Call structure within a sequence was at times uniform, however individual calls within a structure often varied greatly in structure as well.

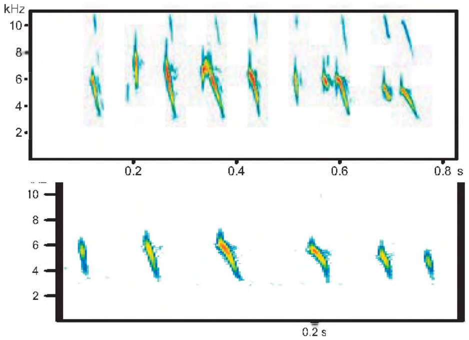


Figure1. Spectrogram of individual call sequences. Sequences ranged from varying calls (top) to more uniform calls (bottom)

In addition, individuals often synchronized their calls, producing overlapping sequences. At times, individuals seem to avoid overlap, and produced instead sequences of calls separated in time.

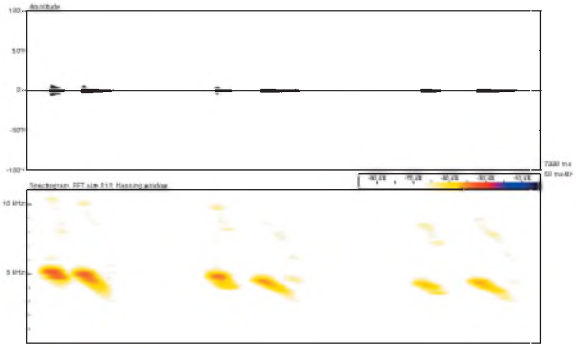


Figure 2. Ocsillogram (top) and spectrogram (bottom) of sequence of 3 calls produced by two individuals. Note that calls are separated in time.

Interestingly, individuals in the act of descending into the chimney opening were almost never observed vocalizing.

4. DISCUSSION

While the results discussed above are preliminary, it would appear as though chimney swifts are employing their acoustic signals not as a means of collision avoidance while foraging, but instead while entering and exiting their roosts. While the swifts are foraging and returning to the roost alone throughout the day, the dusk and dawn periods are marked by entire groups entering and exiting the chimneys. The risk of collision is hence heightened at this time especially in the fall when swifts occupy large roosts that can hold over 600 individuals. It is perhaps not surprising then that at these precarious times the swifts vocalize most intensely.

By staggering their calls in time, individuals may be able to keep track of one another's positions. Overlapping calls on the other hand, may serve to aid individuals in synchronizing their movements and in maintaining group cohesion.

The in-flight vocalizations of chimney swifts may also serve an important social function. Calls emitted by others circling the roost may serve as a beacon to individuals arriving from foraging. In addition, synchronized calls seem to occur in groups of 2-4 individuals flying closely together. Call synchrony may thus allow pairs (Kaiser; 1997) and small social groups (perhaps related) to maintain contact amidst the chaos of hundreds of roosting birds.

If the vocalizations of Chimney swifts do indeed server an important function, we can ask how the birds manage to roost in areas with high levels of noise. Are they capable of changing the frequency at which they send out their signals in order to remain distinct from city noise (Hans and Peet; 2003)?

The calls of chimney swifts appear to be quite variable in structure as is the context in which they are used. Further analysis is needed to shed light on both call characteristics and their role in chimney swift vocalization.

5. REFERENCES

Blodgett, K.D. & Zammuto, R.M. (1979) Chimney Swift nest found in hollow tree. *Wilson Bulletin*. 91: 154.

Chantler, P. & Driessens, G. (2002) Swifts: a guide to the Swifts and Treeswifts of the World. 2nd ed. Pica Press. Sussex.

Cink, C.L. and Collins, C.T. (2002) Chimney Swift In: The Birds of North America, No. 646

Hans, S.and Peet, M. (2003) Ecology: Birds sing at a higher pitch in urban noise. *Nature (London)* **6946**: 267.

Hauser, M.D. (1997) The Evolution of Communication. The MIT Press, Cambridge Massachusetts.

Kaiser, E. (1997) Sexual Recognition of Common Swifts. *British Birds*, **90**, 167-174.

Ulanovsky, N., Fenton, M.B., Tsoar, A. and Korine, C. (2004) Dynamics of Jamming avoidance in echolocating bats. *Proceedings of the Royal Society (London)*, **271**, 1467-1475.

NOISE EXPOSURE CAUSED BY ARTIFICIAL VENTILATION IN THE NEONATAL INTENSIVE CARE UNIT

A. Mayrand[1], S. Scollie[1], H. Roukema[2], M. Cheesman[1]

[1]National Centre for Audiology, School of Communication Sciences and Disorders, University of Western Ontario, London, Ontario, Canada, N6H 1R1 cheesman@uwo.ca

[2] St. Joseph's Health Care Centre, Neonatal Intensive Care Unit, London, Ontario, Canada,

1. INTRODUCTION

Children who graduate from the neonatal intensive care unit (NICU) are at 10-15 times greater risk for sensorineural hearing loss than other children (Doyle & Casalaz, 2001; Veen, et al, 1993).The possible causes of this increased risk for hearing loss are multiple: these children are born with predisposing medical conditions, are treated with potentially ototoxic medications, and live in a noisy environment while in the NICU that may contribute to noise-induced hearing loss (NIHL).

Noise levels measured in the NICU range from 54 – 87 dBA (Levy, Woolston & Browne, 2003) with ambient room L_{eq} of 55.8 dBA (Robertson, Cooper & Vos, 1999). Incubator levels of 60-65 dBA have been reported (Long, Lucey & Philip, 1980).

While the effects of noise exposure on the hearing of adults are well described, the susceptibility of neonates to NIHL is not. The developing ear may be more sensitive than the adult ear to noise damage. For example, Douek et al (1976) demonstrated loss of outer hair cells in newborn guinea pigs when subjected to incubator noise, but no damage to the cochlea of adult guinea pigs subjected to the same noise.

In humans, cochlear cell differentiation begins at 9-10 weeks gestational age (Glass, 1999). The cochlea begins to function around 20 weeks when it may become susceptible to noise damage (Hayes & Northern, 1996). In animal models, noise overstimulation had the greatest negative effect during period of rapid growth and neuronal differentiation which occurs between 28 – 40 weeks (Glass, 1999). It is very likely, therefore, that preterm infants are particularly susceptible to NIHL.

In addition to the hearing risk, noise exposure causes physiological effects in the premature infant that include increases to heart rate, blood pressure, and respiratory rate, and decreased oxygen saturation (Bremmer, Byers, & Kiehl, 2003). As a result, recommendations for NICU sound level limits have been developed. Nzama, Nolte and Dorfling (1995) recommended that levels inside incubators should be are below 60 dB. The U.S. EPA limits average daytime levels to 45 dB and average nighttime levels to 35 dB (American Academy of Pediatrics Committee on Environmental Health, 1997). The *Consensus Committee to Establish Recommended Standards for the NICU Design* recommends a maximum hourly L_{eq} of 50 dBA and an impulse maximum of 75 dBA (Bremmer, et al, 2003).

Neonates in the ICU who are being artificially ventilated are exposed to addition sound from the ventilation equipment. For example, Surenthiran et al. (2003) measured noise levels in the ear canal and nasopharynx of infants and reported alarmingly high levels of over 100 dB SPL in the nasopharynx with continuous positive airway pressure (CPAP). Other ventilation options are also available in the NICU. With little knowledge of the relative noise exposures produced by alternative ventilators and the effect on infant's hearing, further research is needed to evaluate the potential harm of such exposures.

2. Purpose

The goals of our research are to (1) determine the noise levels and the spectra of the noises produced by five different modes of artificial ventilation and by spontaneously breathing neonates in the NICU, (2) compute the noise exposure for each type of artificial ventilation, and (3) determine the possible risk of noise-induced hearing loss for ventilated neonates. Preliminary noise measurements for neonates in the NICU are presented here.

3. Methods

3.1 Participants

Sound measures were obtained with 21 medically stable neonates at 24.4 - 41.0 weeks gestational age. The neonates weighed between 490 and 3935g at the time of the recordings. Consent of the parent(s) or guardian was received prior to participation.

Neonates were spontaneously breathing, spontaneously breathing with low flow oxygen, or artificially ventilated. Five artificial ventilation systems were in use: conventional ventilation, Vapotherm 2000i, CPAP, high frequency jet, and high frequency oscillation ventilation.

3.2 Procedures

Dosimetric measures. The microphone of a Larson Davis Spark 703+ dosimeter was placed inside the incubator at a location approximately 15 cm above the infant's head (standard position). Noise levels were measured over a 24-hour period

Probe tube measures. ER-7 probe tube microphones and a two-channel recording system (SpectraPlus software) were used to record one-minute samples of the incubator sound. For each sample, one probe tip was located at the standard position and the other in the ear canal or nasopharynx.

A minimum of five one-minute recordings were made for each of the artificial ventilators and four recordings were made with the spontaneously breathing infants. The sound recordings were then analyzed in 1/3-octave bands and A-weighted to obtain overall A-weighted, peak frequency band, and level in the band.

4. Results and Discussion

Table 1 displays two samples of the sound level measurements obtained in the incubators of the spontaneously breathing and ventilated neonates. The 24-hour A-weighted L_{eq} values ranged from a low of 53.7 dB with a conventional ventilator to a high of 66.2 dB in the incubator of spontaneously breathing neonate. The range of levels was greatest for spontaneously breathing neonates.

Table 1: Examples of dosimetric measures in occupied incubators

Ventilation Mode	L_{eq} (dBA)	L_{max} (dBA)	L_{min} (dBA)
Conventional	53.7	89.3	50.4
Conventional	55.9	84.9	52.1
CPAP	64.7	90.8	46.2
CPAP	65.3	91.9	56.6
High freq. jet	60.3	94.5	54.4
High freq. jet	59.8	93.1	49.4
High freq. osc.	56.4	82.6	53.5
High freq. osc.	57.2	92.4	48.9
Spontaneous	61.1	100.0	37.1
Spontaneous	66.2	100.6	42.0
Vapotherm	53.9	87.6	50.4
Vapotherm	60.7	96.8	49.8

Table 2 displays the levels measured in the ear canals of the neonates in the different ventilation conditions. Again, the lowest levels were observed in the conventional ventilation condition. Ear canal levels exceeding 70 dBA were found with several of the ventilators. The 1/3-octave band containing the highest level is also listed in Table 2. Peak frequencies varied considerably both from one ventilation condition to another and within condition. Sound levels in the nasopharynx followed a similar pattern, with some of the levels in spontaneously breathing neonates being higher than those using artificial ventilation.

Data collected in this study will be used to compute the transfer function from the standard microphone location to the ear canal and the nasopharynx. The relative intensity of ear canal sound levels produced by the different artificial ventilators and the individual differences between neonates using the same type of ventilation will be examined.

Table 2: Example of overall sound levels measured in the ear canal during artificial ventilation and 1/3-octave peak frequency and band levels

Ventilation Mode	Overall level (dBA)	Peak Freq. (Hz)	Peak band Level (dBA)
Conventional	40.9	3150	37.4
Conventional	59.4	4000	53.0
CPAP	73.3	6300	67.5
CPAP	70.3	6300	67.5
High freq. Jet	65.0	2500	55.9
High freq. Jet	73.7	800	67.8
High freq. osc.	58.2	315	51.9
High freq. osc.	58.5	5000	50.1
Spontaneous	54.9	125	48.0
Spontaneous	55.8	125	45.7
Vapotherm	70.8	1000	66.6
Vapotherm	70.2	10000	63.6

REFERENCES

Am. Acad. of Pediatrics Committee on Environmental Health (1997). Noise: A hazard for the fetus and newborn. *Pediatrics*, 100(4):724-727.

Bremmer, P., Byers, J. & Kiehl, E. (2003). Noise and the premature infant: Physiological effects and practice implications. *JOGNN*, 23(4):447-454.

Douek, et al. (1976). Effects of incubator noise on the cochlea of the newborn. *Lancet,* 2:1110-1113.

Doyle, L.& Casalaz, D. (2001). Outcomes at 14 years of extremely low birthweight infants: a regional study. *Arch Dis Child Fetal Neonatal*, 85(3):F159-164.

Glass, P. (1999). The vulnerable neonate and the neonatal intensive care environment. G.Avery, M.Fletcher, & M. MacDonald (Eds.), *Neonatal physiology and management of the newborn (5th Ed.)* (91-108). NY:Williams & Wilkins.

Hayes, D. & Northern, J. (1996). *Infants and Hearing*. San Diego: Singular.

Levy, G., Woolston, D. & Browne J. (2003). Mean noise amounts in level II vs level III neonatal intensive care units. *Neonatal Network*, 22(2):33-38.

Long, J., Lucey, J. & Philip, A. (1980). Noise and hypoxemia in the intensive care nursery. *Pediatrics*, 65:143-145.

Nzama, N., Nolte, A, & Dorfling, C. (1995). Noise in a neonatal unit: guidelines for the reduction or prevention of noise. *Curationis*, 18:16-21.

Robertson, A., Cooper-Peel, C. & Vos, P. (1999). Sound transmission into incubators in the neonatal intensive care unit. *J Perinat*, 19(7):494-497.

Surenthiran, S.S., Wilbraham, K., May, J., Chant, T., Emmerson, A.J.B. & Newton, V.E. (2003). Noise levels within the ear and post-nasal space in neonates in intensive care. *Arch Dis Child Fetal Neonatal* , 88:F315-F318.

Veen, S., Sassen, M. Schreuder, A. et al. (1993). Hearing loss in very preterm and very low birthweight infants at the age of 5 years in a nationwide cohort. *Int J Pediatr Otorhinolaryngol*. 26(1):11-28.

RECONSTRUCTING THREE-DIMENSIONAL TONGUE TRAJECTORIES USING MULTIPLANAR PACED SONOGRAPHY

Heather Flowers[1], Tim Bressmann[1],
Brent Carmichael[2], Chiang-Le Heng[1], Willy Wong[3]
[1]University of Toronto, Department of Speech-Language Pathology
[2]University of Toronto, Institute for Biomechanics and Biomedical Engineering
[3] University of Toronto, Electrical and Computer Engineering Department

1. INTRODUCTION

The tongue has been characterized as a non-rigid three-dimensional hydrostat (Smith & Kier, 1989). However, investigations of tongue movement in speech are usually limited to the midsagittal plane (electromagnetic articulography, videofluoroscopy, B-mode ultrasound). This is unsatisfactory because tongue movement in speech is a three-dimensional process, and the position of the lateral free margins of the tongue cannot be automatically inferred from the midsagittal plane. The goal of our research is to develop a feasible method of 3D ultrasound imaging of surface tongue movement for qualitative and quantitative analysis. Previous 3D research in ultrasound imaging of the tongue has focused on the reconstruction of sustained sounds (Watkin & Rubin, 1999; Bressmann et al., 2005; Stone & Lundberg, 1996). Recently, Yang & Stone (2002) demonstrated a method of reconstructing 3D tongue movement during sentence-level speech from multiple two-dimensional B-mode scans. However, the authors found considerable temporal variability between tokens even when their speaker tried to repeat every sentence with exactly the same speed and intonation. Therefore, they used a dynamic programming algorithm to time-stretch and compress their tokens before reconstructing smooth three-dimensional tongue surface movement. The purpose of our exploratory study was to build on the research by Yang & Stone (2002) and to develop a more practical method of reconstructing three-dimensional tongue movement in speech. We investigated biomechanical aspects of tongue movement such as its surface velocity and functional segmentation.

2. METHOD

The participants were seven normal adults (two males and five females, 22 to 34 years of age). They sat in an office chair with their foreheads resting against the Comfortable Head Anchor for Sonographic Examinations (CHASE). The apparatus stabilized the participant's head and held the ultrasound transducer in a constant position under the subject's chin. A lever system allowed the examiner to move the transducer to different preset view angles. For the present study, the ultrasound transducer was angled at -20°, -10°, 0° and 10° (see Figure 1). The data was collected using a General Electric Logiq Alpha 100 MP ultrasound machine with a 6.5 MHz micro convex curved array scanner with a 114 degree view (Model E72, General Electric Medical Systems, PO Box 414, Milwaukee, Wisconsin 53201). The ultrasound video and acoustic signal were simultaneously recorded to digital video.

Fig. 1. CHASE II set-up with four coronal scan angles

The participants recited the last stanza from William Wordsworth's poem "I wandered lonely as a cloud" (1815), which was chosen for its regular iambic foot. The participants read the stanza double-time to a digital metronome set at 108 beats per minute. Subjects recited the passage with a neutral intonation on a single breath stream. Four repetitions were recorded, one at each coronal plane.

Ultra-CATS, a software tool developed by our lab for semi-automatic tongue contour tracings, was used to analyze the data. Data from the four coronal planes were assembled into a 3D surface graph to create a moving image (see Figure 2). The seven speakers' results were compiled to analyze tongue velocity and functional segments. We calculated total surface velocity at 28 points in meters per second and used a principal component analysis with Varimax rotation to identify functional segments on the tongue surface.

Fig. 2. Sample frames from moving tongue reconstructions. The anterior tongue is toward the lower left side of each frame

3. RESULTS

3.1 Velocity

Figure 3 shows a topographical map of the tongue indicating the average speed at the 28 surface points. The centre of the tongue moved with greater velocity than the sides, and the front with greater velocity than the back.

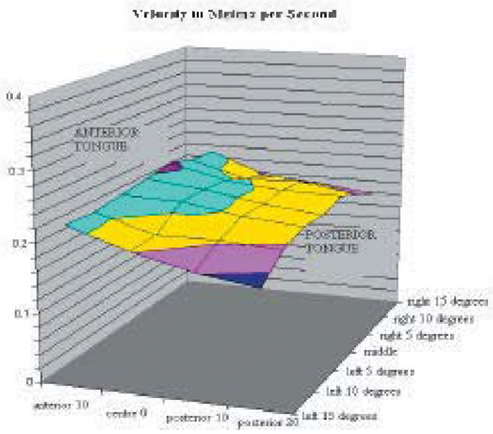


Fig. 3. Velocity map of the tongue surface

3.2 Functional Segments

A principal component analysis was used to identify functional segments in tongue movement. Three functional segments were identified. Component 1 included all 14 data points in the posterior tongue (-10° and -20°), accounting for 87% of the variance. Component 2 included all seven data points in the anterior plane (10°), as well as the four most extreme lateral points on the coupling plane (0°). This component accounted for an additional 5 % of the data. Finally, a third component included the three remaining central points of the tongue blade (0°), accounting for 3% of the variance. The three components combined accounted for 95% of the variance.

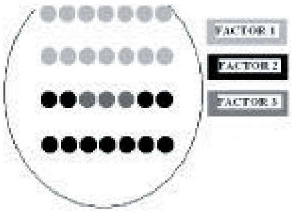


Fig. 4. Functional segments in the moving tongue

4. DISCUSSION

By simply using a digital metronome to pace the participants' speech and the CHASE lever system to control transducer position, we reconstructed visually and phonetically plausible three-dimensional tongue surface movement from seven speakers. The length of the speech sample and the number of participants make our data set the largest and most extensive yet reported. Important parameters of tongue function in speech were identified for further investigation. We found a consistent pattern in the velocity of different parts of the tongue. We posit that the anterior tongue moved most rapidly because the tongue blade has more degrees of freedom than the posterior tongue, which is anchored to the pharynx. The greater speed in the centre of the tongue compared to the sides can be explained by the activity of the midline genioglossus furrow. The principal component analysis revealed a certain degree of independence in the anterior and posterior parts of the tongue, which confirmed findings from our previous research (Bressmann et al., 2005).

The results reported here are the first steps toward a more comprehensive investigation of complex three-dimensional tongue movement tongue in speech. In future research, we will expand our data collection and develop quantitative functional indicators for the mathematical description of biomechanical principles governing lingual movement in speech. A long-term goal is to appropriate the method for the analysis of speech disorders resulting from structural defects or neurogenic movement disorders.

REFERENCES

Bressmann, T., Thind, P., Bollig, C.M., Uy, C., Gilbert, R.W., & Irish, J.C. (2005). Quantitative three-dimensional ultrasound analysis analysis of tongue protrusion, grooving and symmetry: Data from twelve normal speakers and a partial glossectomee. *Clinical Linguistics and Phonetics*, *19,* 573-588.

Gu, J., Bressmann, T., Cannons, K., Wong W. (2004). Ultrasonographic Contour Analyzer for Tongue Surfaces (Ultra-CATS) [Computer software and manual]. Department of Speech-Language Pathology, University of Toronto.

Smith, K.K., & Kier, W.M. (1989). Trunks, tongues, and tentacles: Moving with skeletons of muscle. *American Scientist, 77,* 29-35.

Stone, M., and Davis, E. (1995). A head and transducer support system for making ultrasound images of tongue/jaw movement. *Acoustical Society of America, 98,* 3107-3112.

Stone, M., and Lundberg, A. (1996). Three-dimensional tongue surface shapes of English consonants and vowels. *Journal of the Acoustical Society of America,* 99, 3728-3737.

Watkin, K.L., and Rubin, J.M. (1989). Psuedo-three-dimensional reconstruction of ultrasonic images of the tongue. *Journal of the Acoustical Society of America,* 85, 496-499.

Yang, C., and Stone, M. (2002). Dynamic programming method for temporal registration of three-dimensional tongue surface motion from multiple utterances. *Speech Communication*, 38, 201-209.

SYSTEM IDENTIFICATION WITH ADAPTIVE LATTICE FILTERS FOR SPEECH DATA

Wenxia Shi, Vijay Parsa, and Jagath Samarabandu
Dept. of Electrical and Computer Engineering, The University of Western Ontario
London, Ontario, Canada N6A 5B9, wshi7@uwo.ca

1. INTRODUCTION

In this paper, we investigate the application of adaptive lattice filter structures in modeling the response of hearing aids to speech signals. Adaptive lattice filters are a class of linear adaptive filters whose designs are based on algorithms that involve both order-update and time-update recursions. Although the popular transversal structure is easy to implement, the lattice structures have their own advantages and are attractive in several adaptive filtering applications. Some of the highly desirable properties of the lattice-based filters include: modularity, computational efficiency and statistical decoupling of the individual stages. The lattice structure inherently has the orthogonalization property between the backward prediction errors which helps in faster convergence rates [1].

There are two approaches for lattice-based adaptive filter implementation: the stochastic-gradient approach known as the gradient adaptive lattice (GAL) filter, and the least-squares approach known as the least squares lattice (LSL) filter.

In this paper, the performance of LSL and GAL algorithms is evaluated in the context of adaptive modeling of hearing aids. Speech signals processed through modern digital hearing aids are analyzed using the GAL and LSL algorithms. The performance of these algorithms is compared with the classical Least Mean Square (LMS), Recursive Least Square (RLS), and Affine Projection Algorithm (APA) in terms of computational complexity and modeling performance.

2. METHOD

2.1 Adaptive Lattice Filter Structure and Algorithm

In this section, we outline the structures and algorithms of the GAL filter and the LSL filter. Figure 1 shows the block diagram of the multistage lattice predictor that performs both forward and backward predictions. Here the desired response *d(n)* is estimated by the lattice filter using the input signal *u(n)*. The coefficients in the lattice stages are updated using either the GAL or LSL algorithm. The GAL algorithm is simple to implement, but is approximate in nature due to the fact that each stage of the lattice predictor is characterized by a single reflection coefficient. In contrast, the LSL filters are exact but more complicated due to the fact that each stage of a least-squares lattice predictor requires two different reflection coefficients for its characterization—one for forward prediction and the other for backward prediction [1].

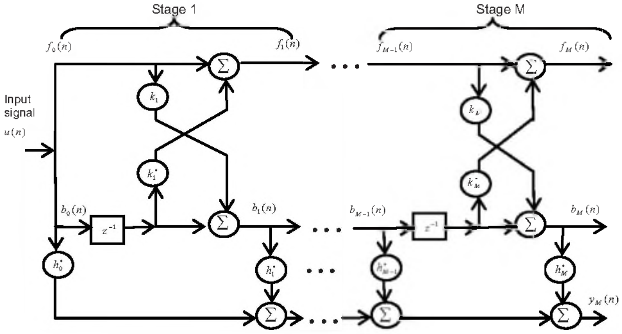


Figure 1. Lattice-based structure for joint-process estimation

2.2 Adaptive Modeling of Digital Hearing Aids

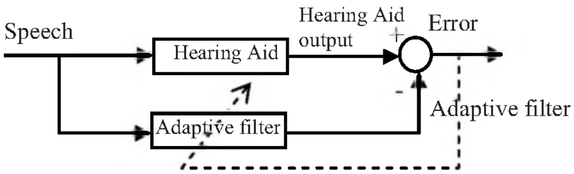


Figure 2. System identification for speech dataset

Figure 2 shows the block diagram of adaptive modeling of digital hearing aids. This system facilitates electroacoustic measurement of hearing aid performance using natural speech and music signals. The adaptive filter models the time-varying behaviour of the hearing aid, leaving the noise and distortion components in the error residual. These components can be used to quantify the quality of the hearing aid. Hearing aid data were collected using a custom Hearing Aid Test System (HATS) developed at the National Centre for Audiology (Figure 3). The speech signal is played back through the speaker in a portable anechoic test box and the response of the hearing aid and a reference microphone are recorded and stored in the computer. The reference microphone input and the hearing aid output are then used to drive the GAL and LSL algorithms.

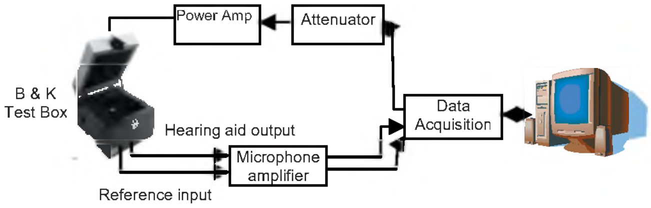


Figure 3. Block diagram of the Hearing aid test system (HATS)

2.3 Relative Performance Comparison

Previous hearing aid modeling studies have exclusively used transversal filter structures and LMS based algorithms [2]. The LMS-based algorithms included the Normalized Least Mean Square (NLMS), and the Affine Projection Algorithm (APA) [1]. In this paper, we have undertaken a preliminary investigation of the relative performance of transversal and lattice filter architectures and algorithms in the context of hearing aid modeling. In particular, the performance of GAL, LSL, LMS, RLS, and APA algorithms was compared in terms of modeling performance, i.e., signal to noise ratio and computational time.

3. RESULTS AND DISCUSSION

3.1 System Identification for Hearing Aid Data

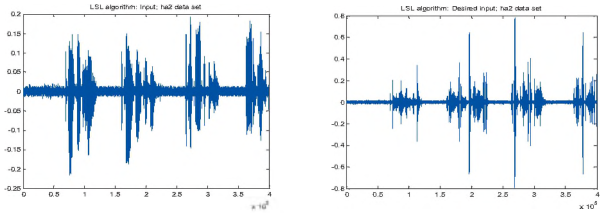
The hearing aid output and the reference input were given to the adaptive filter algorithms. All five adaptive filter algorithms were implemented in MATLAB. Figure 4 shows the results of system identification using the LSL and GAL algorithms for data obtained from a commercial digital hearing aid. The filter length was set 50 and 400000 samples were used for both the LSL and GAL filters. Figure 4(a) shows the speech input and 4(b) displays the corresponding hearing aid output. The predicted hearing aid responses are shown in Figures 4(d) and 4(f) for LSL and GAL algorithms respectively with the corresponding modeling residuals in Figures 4(c) and (e).

3.2 Performance Comparison

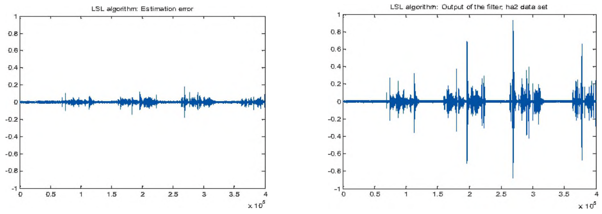
Modeling performance and computational complexities of different adaptive algorithms are compared in Table 1. The modelling performance was measured as the ratio of the hearing aid output and error residual powers. Computational time for each of the algorithms was measured in MATLAB as an average of about 50 runs for each algorithm.

Comparison results show that LSL and RLS can obtain very good performance results. LSL is a bit better than its transversal counterpart RLS, and computational time of LSL is less than that of RLS. If the filter length and data length are further enlarged, these differences between LSL and RLS will be increased correspondingly.

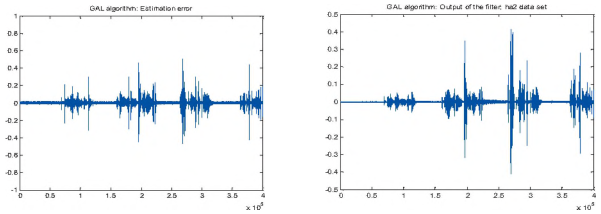
From Table 1, we observe that the GAL and NLMS algorithms display poor performance. Although the NLMS is omputationally the most efficient, its modelling performance is quite poor in the context of speech-based modeling of hearing aids.



(a) Speech Input (b) Hearing Aid Output



(c) LSL Estimation Error (d) LSL Output



(e) GAL Estimation Error (f) GAL Output

Figure 4. System identification of speech data for LSL and GAL

TABLE 1. COMPARISON OF DIFFERENT ALGORITHM

	LSL	**GAL**	**NLMS**	**RLS**	**APA**
SNR(dB)	12.9149	2.9019	0.7143	12.8692	9.9465
Running time (s)	25.75	26.95	13.63	26.92	28.59

4. CONCLUSIONS

In this exploratory study, the relative performance of various adaptive filtering algorithms and structures was investigated in the context of hearing aid system identification using speech stimuli. The Least Squares Lattice (LSL) algorithm provided the best performance and computational efficiency. Our future work is to develop a subband LSL algorithm in order to model the performance of multichannel compression hearing aids better [3].

REFERENCES

[1] Haykin,S. (2002). Adaptive Filter Theory. 4th edition, Prentice Hall, NJ, ISBN-0-13-090126-1.

[2] V. Parsa & D.G. Jamieson, "Hearing Aid Distortion Measurement Using the Auditory Distance Parameter," Audio Engineering Society, Convention Paper 5434, September 2001.

[3] M.R. Wirtzfeld & V. Parsa, "On Subband Adaptive Modeling of Compression Hearing Aids," in ICASSP 05', Volume 3, Page(s): 45-48, Philadelphia, PA, March 18-23, 2005.

ENVIRONMENTAL CONSIDERATIONS FOR NOISE BARRIERS

Scott Penton, P.Eng.,[1] and **Jason Tsang, B.Sc.Eng.**[2]
RWDI AIR Inc. 650 Woodlawn Road West, Guelph, Ontario

1. INTRODUCTION

Rooftop noise barrier walls are often used as a low-cost, low-tech solution to control rooftop equipment noise from industrial and commercial facilities. However, these wall structures can cause structural loading issues. Thought should be given to environmental effects on barriers, since they can influence the structural design of roof systems, and the operation and performance of rooftop mechanical equipment.

Winds striking a barrier can create wind loads and torque on a rooftop barrier. These forces are transmitted into the building roof structure. The barrier itself also creates areas of localized shelter from the wind. As a result, snow particles slow down and drop to the nearest surface causing snow build up. The additional snow build-up can cause a significant weight increase on the roof and building structure. Snow loading is generally the dominant environmental effect resulting from the addition of the barrier. Since these additional loads are not typically taken into account during the initial building design, the weight can overload the roof and lead to roof structural failure. In fact, snow loading is one of the major causes of this type of structural collapse [1].

Snow accumulation can also inhibit or block airflow at intake and exhaust louvers [2]. Consequently, the performance of the HVAC system is reduced because of moisture intake and because the static pressure on the system increases. This can inevitably lead to a reduction in airflow and generate noise and vibration problems inside the building. Based on past experience, it is not uncommon for air handling units to become almost completely buried due to a heavy snowstorm. For these reasons, snow loading is an important factor that should be taken into account when considering a rooftop noise barrier.

Figure 1: Photo of Snow Accumulation on Roof

2. CONTROL OF SNOW BUILD-UP

Incorporating a gap (approximately 0.25 m (10 inches)) below the barrier wall can help reduce the additional snow accumulation. The gap enables air to flow underneath the barrier, allowing snow scouring and preventing large drifts and accumulation of snow. This method has been employed in past RWDI projects such as the New Amundsen-Scott South Pole Station.

This effect can be illustrated using water flume simulations. Water flowing over a scale model simulates wind, and fine sand is used to replicate drifting snow. The simulation consisted of a 1:300 scale model of a 60 m long, square building, 6 m high, with a 0.3 m tall roof curb. For simplification, a single AHU was located at the center of the building, surrounded by a 3 m tall full perimeter barrier.

The model was used to investigate the drift patterns with and without a gap underneath the barrier. Two orientations were examined: "perpendicular," which is the longest barrier face perpendicular to the prevailing wind direction, and "45 degrees," which is the barrier at a 45° angle to the prevailing wind direction.

The water flume tests show that a barrier flush to the roof may result in large drifts between the barrier and AHU (up to 1 m high), as well as against the barrier (up to 1.5 m high), as illustrated in Figures 2 and 3.

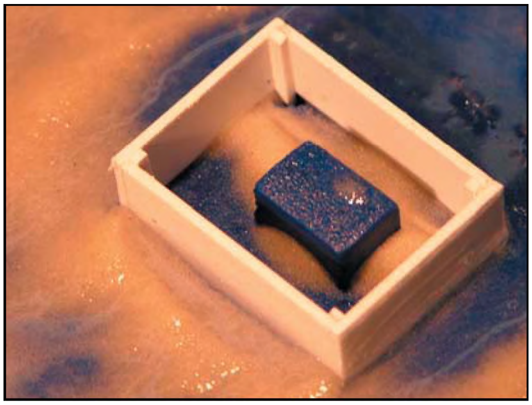


Figure 2: Barrier Flush to Roof, Perpendicular Orientation

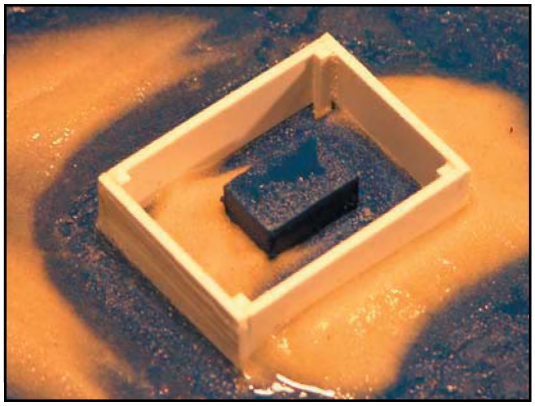


Figure 3: Barrier Flush to Roof, 45 Degree Orientation

An elevated barrier (0.25 m (10 in), full scale) results in little snow accumulation and increased snow scouring (see Figures 4 and 5). The gap causes increased wind flow under the barrier, with the resultant effect of reduced snow deposits in areas with accelerated wind flows. The elevated barrier causes the drift to form away from the barrier.

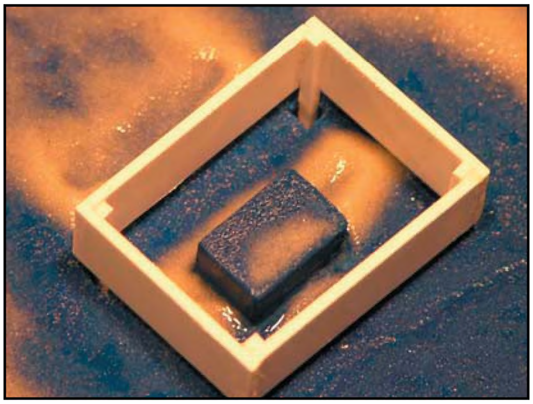


Figure 4: Elevated Barrier, Perpendicular Orientation

Figure 5: Elevated Barrier, 45 Degree Orientation

3. ACOUSTICAL EFFECTS

Although incorporating a gap below the barrier is beneficial from a snow loading perspective, it can also provide a major path for noise to escape, thereby lessening its ability to reduce sound. To investigate the behavior of sound around the barrier configurations, an idealized 3D computer model was created. Receptors were located 15, 55, and 100 meters away from the facility, and at various heights of 1.5 to 12 meters. Cadna/A version 3.4.109, a computerized version of ISO 9613, was used to calculate the data.

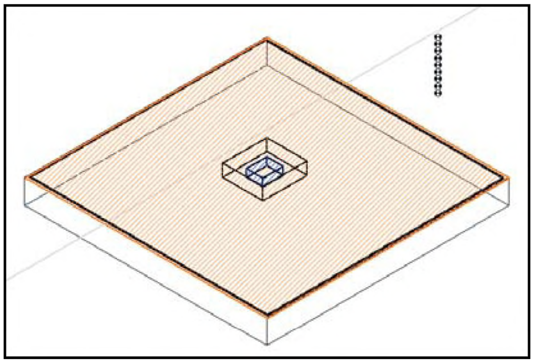


Figure 6: 3-D Cadna Computer Model

Three scenarios were examined:

- Building without rooftop barrier
- Building with 3.0 m high rooftop barrier, with no gap
- Building with 3.0 m high rooftop barrier, with a 0.25 m (10 inch) gap

The assumptions used for the computer model:

- The surrounding ground is acoustically absorptive (G = 0.8)
- The rooftop is generally acoustically reflective (absorption α = 0.1)
- Barrier is sound absorptive on the equipment side (1" fiberglass behind perforated metal)
- The casing of the AHU is reflective sheet steel
- Order of reflection of 2

The results of the analysis are presented in Table 1.

Table 1: Summary of Results

Receptor Height (m)	Resultant Sound Level (dBA)								
	No Barrier			Barrier Flush to Roof			Barrier with 10 inch Gap		
	15m	55m	100m	15m	55m	100m	15m	55m	100m
1.5	42	45	42	38	38	36	40	39	36
3	45	46	43	39	39	35	42	39	35
4.5	49	47	43	43	39	35	43	39	36
6	53	49	45	42	38	35	43	39	35
7.5	58	51	46	46	39	35	47	40	36
9	60	52	47	53	42	36	56	43	37
10.5	60	53	47	56	47	36	58	48	37
12	60	53	48	57	48	42	58	49	42

The plots presented in Figures 7, 8, and 9 provide a graphical illustration of the sound level results in Table 1. The results are for the receptors outlined above.

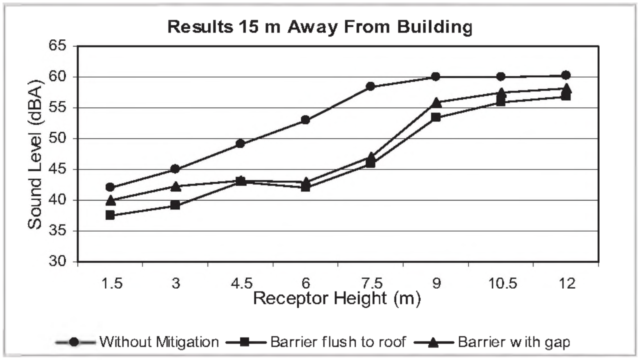


Figure 7: Results 15 Meters Away from Building (fixed font size)

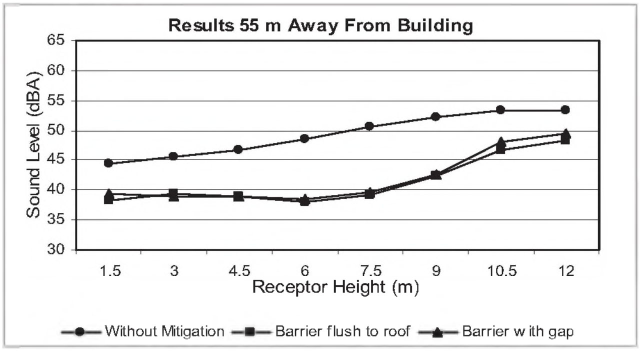


Figure 8: Results 55 Meters Away from Building

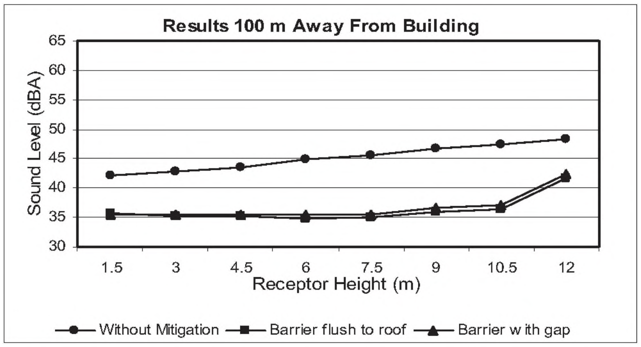


Figure 9: Results 100 Meters Away from Building

As shown in Figure 7, close to the barrier, the gap reduces the barrier's performance by up to 3 dB. However, as shown in Figures 8 and 9, as the source-receiver distance increases, the effect of the gap on barrier performance decreases. At 55 m and 100 m from the facility, the gap results only in minor sound level increases of up to 1 dB, a level considered to be imperceptible to humans.

As an additional comparison, a cross section illustrating noise contours for the non-elevated and elevated barriers are shown below in Figures 10 and 11.

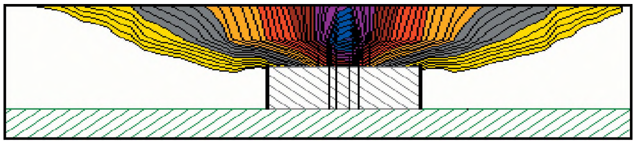


Figure 10: Section of Noise Contours for Non-Elevated Barrier (adjusted picture dimensions)

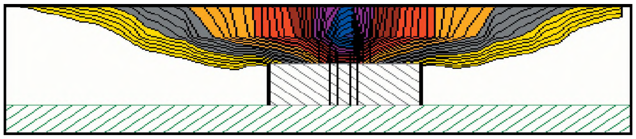


Figure 11: Section of Noise Contours for Elevated Barrier (adjusted picture dimensions

The noise contours with the elevated barrier (Figure 11) extend slightly wider than the non-elevated barrier (Figure 10) above the building. However, the overall noise contours are still similar in shape, further illustrating that the gap has a minor affect on the barrier's performance.

4. CONCLUSION

Environmental snow loading issues associated with rooftop noise barriers can be reduced with proper mitigative strategies. Placing a small gap (0.25 m (10 in)) at the base of the barrier can reduce snow accumulation with minimal acoustical effects at distant receptors. Where receptors are to be located closer than 50 m to the source, the acoustical effects of the gap should be considered, using a proper ray-tracing model.

5. REFERENCES

[1] RWDI Technote Issue 1, "Assessing Snow Loads", Colin J. Williams, Ph.D., P.Eng.

[2] RWDI Technote Issue 5, "Working with Nature", Bill Waechter, C.E.T.

FLEXURAL SENSING USING PIEZOELECTRIC TRANSDUCERS

M. R. Kermani, R. V. Patel and M. Moallem
Department of Electrical and Computer Engineering
University of Western Ontario, London, Ontario

ABSTRACT

Abstract: In this paper the application of piezoelectric transducers for flexural measurements in simple flexible structure as well as multibody systems is presented. A multibody system as part of a large-scale robotic manipulator is considered and a sensor arrangement for measuring its modal components is presented.

1. INTRODUCTION

In modal identification, feedback control, condition monitoring and damage detection, vibration measurement is an essential part of the process (Hung and Ko (2002), Jackson (1962)). In fact, the first step of almost any vibration control problem is the modal measurement of the system. It is only then that design engineers start to build a model or evaluate their mathematical model of the system and make a decision towards control design. In this regard, piezoelectric materials, due to their large bandwidth are promising candidates. The main idea behind using a piezoceramic as a sensor is to expose it to the strain of the vibrating structure. This can be achieved either by direct bonding of the piezoceramic to the structure as will be explained later on or indirect transferring of the motion to the piezoceramic using an extra mass (Scheeper et al. (1996)).

The direct piezoelectric effect can be utilized for measuring strain in a mechanical structure. The idea is to bond a piezoceramic to the structure such that the amount of strain developed along the sensor is equal to the strain of the structure. This contains all the information about vibration in a flexible structure. Each vibration mode of the system can be measured in time domain, should a single sensor be dedicated to that particular mode. In the frequency domain, on the other hand, the information of each state can be extracted from the original signal using a bandpass filter. This is due to the fact that the output signal of a piezoelectric sensor measures a weighted sum of all states (vibration modes) of the system. Thus, using appropriate filters whose central frequencies are set to the frequencies of the desired states, all states of the model can be theoretically measured from the signal of a single sensor. In order to illustrate this method for measuring the states of a model, Figure 1 shows the original signal (power spectral density) of a piezoelectric sensor bonded to a flexible beam as well as the output signals of three bandpass filters designed to extract the first three states of the system. The filters used here are relatively low order, yet the distinctiveness of the states allows each filter to extract the information

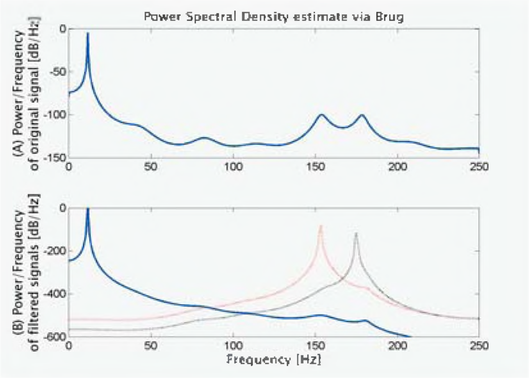


Fig. 1. The state measurement in frequency domain.

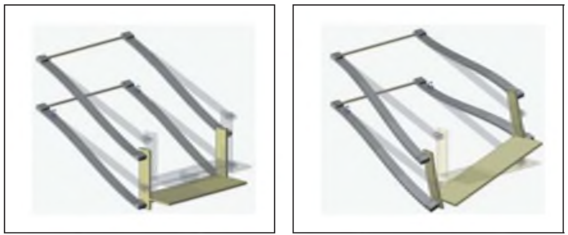
---

[1] This research was supported in part by grants RGPIN227612 from the Natural Sciences and Engineering Research Council (NSERC) of Canada.

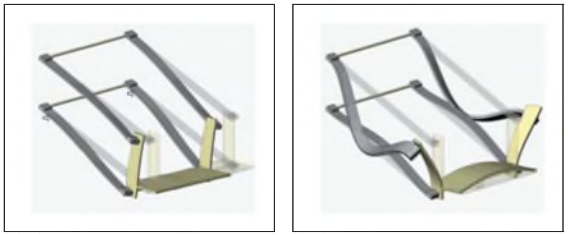
of one particular state for which the filter has been designed. In multibody systems, the frequencies of the high-order states may happen to be close to each other. Hence, the separation of such states in the frequency domain requires high order filters with sharp slopes which are not always practical in real-time control applications.

2. MULTIBODY FLEXURAL SENSING

In order to measure the flexural modes of a system with high modal density, dedicating a separate sensors to each mode is a more suitable method. Additionally, using a specific electrode profile (sensor shape) or sensor arrangement, it is possible to make some of the modal components unobservable. The placement of sensors for the first-time testing of a large and complex structure is not an easy task by any means. See, for example, (DeLorenzo (1990), Lim (1992), Lindberg, Jr. and Longman (1984)). In a large structure with a large number of possible locations for sensors, the number of possible combinations is overwhelming. In practice, engineering judgment is combined with heuristic investigations to determine sensor locations. In most cases, a trial and error approach is used to obtain acceptable results. In this regard, Finite Element Method (FEM) can be utilized to classify the mode shapes and hence, to conjecture a possible sensor arrangement. Such information about mode shapes also facilitates the selection of sensor type in a complex structure. For instance, if an accelerometer is used as a sensor, the best location of the sensor to measure a particular mode would be where the mode shape is maximum. On the other hand, if a strain-based measurement device, such as piezoceramics or strain gages are used as sensors, the best location of the sensor for a particular mode would be where the curvature of the corresponding mode shape is maximum. To illustrate this, let us consider the first four mode shapes (Figure 2) of a multibody structure as part of a more complex robotic manipulator known as macro manipulator. As seen, the first mode shape is a pure bending mode. The second and third mode shapes are torsional modes which involve twisting of the manipulator links. The fourth mode is a mixture of bending and torsional motions. It is clear that if pizeocermaics are used as sensors, for the first mode, they should be placed near the base. For the torsional mode, the strain is measured by the angle of rotation of a link cross-section. Thus, to have the best measurement for the second mode, the sensors should be placed near the base but in the middle of each link. Now, if the sensors are symmetrically placed off the middle, then their measurements for the second mode will be out of phase. In this way, one can obtain the information of the first mode by adding the two signals from each sensor and similarly the information of the second mode by subtracting the two sensors signals, assuming that the higher modes are negligible. It is worth noting that, with regard to the second mode, the further the sensors are placed from the middle of the link, the weaker their measurements become. The third mode is also a torsional mode. However, inspecting the mode shapes of the system shows that the most effective location for this mode is on the sides of the links rather than on the top or bottom surface. Nevertheless, if the sensors are placed on the link's top surface but off its middle, the third mode will still produce a net strain and as a result the third mode is still can be observed in output signal of the sensors used for the first and second modes. In this case, this mode also creates out of phase signals on two sensors. The best locations for the sensors for the first three mode shapes of the structure are indicated in Figures 2(A) ,2(B) ,2(C) using arrows.



(A) First Mode Shape (B) Second Mode Shape



(C) Third Mode Shape (D) Fourth Mode Shape

Fig. 2. The first four mode shapes of a multibody system.

REFERENCES

M. L. DeLorenzo. Sensor and actuator selection for large space structure control. *Journal of Guidance, Control and Dynamics*, 13:249–257, 1990.

C. F. Hung and W. J. Ko. Identification of modal parameters from measured output data using vector backward autoregressive model. *Journal of Sound and Vibration*, 256(2):249–270, 2002.

J. D. Jackson. *Classical Electrodynamics*. John Wiley and Sons Inc, New York, 1962.

K. B. Lim. Method for optimal actuator and sensor placement for large flexible structure. *Journal of Guidance, Control and Dynamics*, 15:49–57, 1992.

R. E. Lindberg, Jr. and R. W. Longman. On the number and placement of actuators for independent modal space control. *Journal of Guidance, Control and Dynamics*, 7:215–223, 1984.

Patrick Scheeper, J. O. Gullov, and L. M. Kofoed. A piezoelectric triaxial accelerometer. *Institute of Physics: Micromechincs and Microengineering*, 6(1):131–133, 1996.

Canada Wide Science Fair

From File Reports

Chetley L.C.Gervais is the winner of this year's Special Award from the Canadian Acoustics Association for his project - Co-registration of Digital Mammography with 3Dimensional Breast Ultrasound Simulating use of a Full-Field Matrix of Piezoelectric Crystal Transducer Elements - a Phantom Study.

Chet Gervais, 17 yrs old, is now attending Trinity Collge School (TCS) in Port Hope Ontario as a grade 12 student. He has represented Ontario at the Canada Wide Science Fair 2001, 2002, 2003, 2004, 2005 and Canada at the Intel International Science Fair in 2004 and 2005.

He is an Essex Regional Gold medalist 5 times, he has won over 100 Regional, National and International Science Awards including: the Best Jr Engineering project in Canada at the CWSF 2002, a Gold Medalist in Intermediate Engineering at CWSF 2004 , a 2004 Manning Young Canadian Innovator Award Winner, a Senior Bronze Medalist in Medicine at CWSF 2005, and winner of the Acoustical Sociey Award .

At the 2005 INTEL ISEF in Phoenix AZ, Chet won the First Award in Medicine and Health and Kodak Award as part of Team Canada Science 2005 (world first place) . At INTEL he was also recognized by MIT who are submitting his name to the International Astronomical Union (IAU) to have a minor planet named after him!

Chet is also the starting running back for the undefeated TCS Bears football team, an avid soccer and squash player and reader. Chet has a US/World patent pending on his Matrix Probe technology. He hopes it will result in the earlier and more accurate diagnosis of breast cancer.

Chet Gervais' full article is reproduced below.

Co-registration of Digital Mammography with 3-Dimensional Breast Ultrasound using a Full-Field Matrix of Piezoelectric Crystal Transducer Elements - a Phantom Study*

Chetley L.C.Gervais
Sandwich Secondary School, LaSalle, Ontario, Canada

Editor's Note: The submission by Chet Gervais was reformatted and edited to fit in to the Journal format.

ABSTRACT

The Matrix Probe "fusion" prototype co-registered digital mammography and 3D medical ultrasound system demonstrates the successful manual production of a 3D high resolution block of DICOM3 data which can be reviewed in any plane or reconstructed in sequence like a CT or MRI scan. This embodiment eliminates the previous requirement for an external hybrid spatial position sensor, significantly improves image resolution and incorporates the medical DICOM3 image standard. This new biomedical engineering technology allows precise correlation of multi-planar reconstructed 3D ultrasound images with standard digital mammography images improving spatial accuracy during investigation of breast cancer. The Matrix Probe "fusion" device also demonstrates the feasibility of RHESUS - Remote Hybrid Endoscopic Surgical Ultrasound System using the real-time (4D) capabilities of this device.

SOMMAIRE

Le prototype Sonde Matrix "fusion", co-enregistré sous les noms manunographie digitale et système médical d'ultrasons 3D, démontre la production manuelle réussie d'un bloc 3D à haute résolution de données DICOM3 qui peuvent ètre passées en revue dans n'importe quel plan ou qui peuvent ètre reconstruites de façon séquencielle comme un balayage de CT ou MRI. Cette combinaison élimine la nécessité précédente d'une sonde de position spaciale hybride exteme, améliore de manière significative la résolution de l'image et incorpore l'image standard du DICOM3 médical. Cette nouvelle technologie de génie biomedical permet la corrélation prècise d'images multiplans d'ultrasons 3D reconstruites avec celles de de mammographie digitale standard, ce qui améliore l' exactitude spatiale lors d' investigations de cancer du sein. Le dispositif Sonde Matrix "fusion" démontre également one capacité RHESUS (système chirurgical endoscopique hybride d'ultrasons à distance) du système, c'est-à-dire la possibilité d'employer sa capacité 4D en temps réel.

1. INTRODUCTION

The objective of this study was to design and build a functional integrated synergistic system to produce co-registered 3D ultrasound data sets using a modified mammography compression paddle. Over the past decade the clinical advantages of 3Dimensional imaging in medical practice has become dogma. Multi-planar reconstructed CT and MRI studies are the foundation of modern hospital practice. Sophisticated image storage and archival systems (PACS) and diagnostic radiology workstations enhance the accuracy and speed of medical diagnosis and facilitate surgical treatment.

Recently the advent of "phased array" ultrasound transducers has resulted in the inclusion of 3D imaging capabilities in many high end ultrasound machines. Although these probes produce dramatic images in 3D or even 4D they have shown relatively little clinical medical benefit to patients. One persistent shortfall of all ultrasound imaging, including the current 3D probe systems is that, unlike CT or MRI, the resulting images or "small field" 3D data blocks are not registered in 3D space relative to the patient.

This lack of spatial registration of conventional ultrasound images prevents the accurate correlation in 3D space between objects visualized in one modality, for example digital mammography with breast ultrasound. Current conventional radiology protocols involve imaging a patient mammographically, followed by technician/radiologist review. If a specific area on mammography is of concern or if the breast tissue is very radiographically dense then a breast ultrasound is performed.

With the advent of digital imaging, specifically digital mammography and the widespread use of large field imaging modalities such as CT and MRI, there has been considerable interest in developing a multi-modality imaging system which would incorporate both digital mammography and high resolution soft tissue ultrasound in the production of a single co-registered dual modality image series which is precisely correlated in 3-Dimensional space. The need for this type of system is widely known to all radiologists involved with breast cancer screening and diagnostic investigation of positive mammograms or clinically suspicious findings. Presently the investigative protocols involve performing mammography with the patient in (upright) compression followed by breast ultrasound (supine) without compression. These examinations are generally performed in different rooms and by different technicians. Mammography imaging the entire extent of the breast tissue in the MLO and CC projections and breast ultrasound consisting of 20-30 technician selected small field images with particular emphasis on the region of clinical or radiographic concern. Based on localizing information identifying the approximate position in the uncompressed breast supplied by the technician onto a crude locater icon during each image, the radiologist issues a correlative report relating the two modalities and makes a diagnosis of the significance of the demonstrated abnormalities in the context of breast cancer diagnosis.

There are significant shortcomings to this method of correlated multi-modality investigation. First, it is simply impossible to accurately correlate the location of any lesion seen in a CC mammogram in compression, with a subsequent uncompressed 2D breast ultrasound study comprising a handful of images when both studies are entirely un-registered in 3D space relative to each other. The second and equally important problem with the current standard of care in breast cancer diagnosis is in the actual amount of breast tissue being reviewed by the radiologist prior to issuing a diagnostic consultative report. Assuming a basic effective scan thickness of 1 mm and reviewing 20-30 2D scans per breast ultrasound the radiologist in fact only sees about 1% of the actual volume of the breast being examined during diagnostic review. While it is true that in theory this 1% is representative of the findings present in that breast as determined by an experienced breast ultrasound technician, the fact remains that this tiny fraction of the available information is all that is ever actually seen by the diagnostic radiologist during reporting of any breast ultrasound. To justify this from a patient care perspective, a radiologist needs only to randomly remove 99% of the letters in this monograph prior to reading it and then accurately submit a diagnostic report concerning it's contents as if the patients life depends on it.

There are well know and widely investigated significant False Positive and False Negative rates during the investigation of breast disease by mammography and breast ultrasound. These result in significant patient morbidity and mortality due to missed breast cancers and unnecessary breast surgery for benign disease. These unacceptably high rates of misdiagnosis are exacerbated by poor image quality, dense breast tissue and the inability of the radiologist to precisely correlate lesions seem on both modalities. Once a lesion is correctly diagnosed as requiring treatment this lack of a true 3D spatial relationship between the available ultrasound and mammography tissue images again increases morbidity and mortality due to the inability to accurately establish the relationship between True Positive lesions and surrounding normal and abnormal structures in the breast. This inhibits optimal surgical and radiation treatment of these patients based on a reduced or inaccurate knowledge of their anatomy.

In recent years there has been widespread use of registered images series, such as CT and MRI to create both sequential uniform thickness parallel image full field datasets and subsequently to perform sophisticated segmentation on these image sets to produce spectacular 3D images featuring the selected aspects of that dataset most adventitious to improved patient care. This includes 3D vascular, cardiac and bone window reconstructions which improve diagnosis and treatment. Advanced medical 3D image review software has also been developed which in conjunction with more powerful computer workstations and segmentation algorithms allow rapid and complete review of entire data sets.

Most recently equipment manufacturers have been developing "fusion" imaging systems which link the image information of two complimentary technologies such as CT and PET scans into a single co-registered multi-modality diagnostic imaging device which facilitates improved patient care by linking information from two modalities into the same 3D spatial coordinates. Despite numerous attempts by a variety of developers, to date no practical solution to this problem of mammography/ultrasound "fusion" system has been developed.

In my original project, the Matrix Probe System, I attempted to develop a co-registered data set by putting together a large number of small field images, each of which was registered in 3D space by being tagged with 3D spatial position information using an NDI hybrid external position sensor which monitored the position of reflective tools attached to a plate fixed on to a standard ultrasound probe. This produced a registered 3D databock and demonstrated 3D reconstruction but was not practical for clinical use. The original design was unsuitable for clinical medical use however because of the requirement for an external spatial position indictor, the relatively low resolution of the resulting 3D data block multiplanar reconstructions and the non-DICOM3 image format preventing incorporation of the images into conventional PACS or review using existing sophisticated DICOM3 medical image review software. The images were also not co-registered with simultaneous mammography. A number of investigators have proposed solutions to these problems. They are generally based in attempting to co-register a large number of small field 2D ultrasound images with concurrent mammography and enable an accurate 3D data block reconstruction by post processing of the ultrasound images and mammogram.

There have been a number of attempts to produce a functional digital mammography/breast ultrasound "fusion" imaging system, several of these are detailed in recent bio-medical patents. Generally they consist of mechanical systems which involve a modified or mobile mammography compression paddles which allow both production of a mammography image and subsequent movement, mechanically, of a standard linear high resolution ultrasound probe over a prearranged course to ensure complete co-registered coverage of the full breast tissue. These devices provide solutions to several of the important technical problems of producing co-registered mammography/ultrasound images of the breast but remain intrinsically flawed. This is because any system which incorporates a mechanical scanner subjects the breast tissue to variable and uneven tissue compression resulting in displacement of one part of the breast tissue relative to other parts reducing accuracy of the constructed 3D data block and effective multi-planar image resolution. The time required to complete a mechanical ultrasound during mammography and the heavy and cumbersome nature of the devices required to guide the probe head across the breast are not suitable for clinical practice or use with existing mammography equipment. The objectives of this study were to solve these major bio-engineering problems in an innovative way, to design a new and unique multi-modality fusion device which could be incorporated into existing digital mammography systems and integrate with existing commercial PACS.The system presented demonstrates the feasibility and important patient care benefits of constructing a full field fixed piezoelectric array, electronically controlled to fire sequentially producing a pre-registered series of contiguous parallel 1mm slices in seconds which are co-registered with the patient remaining in compression during a standard digital mammography examination.

2. SYSTEM DESIGN

A novel large format fixed array of piezoelectric crystals is proposed which could be incorporated into a modified digital mammography compression paddle. This array would approximate the size of a conventional mammography compression paddle surface and be designed to be placed in uniform contact with the entire compressed breast during production of the ultrasound data set but which can be removed or rotated out of the way during the mammography exposure without modifying the position or compression of the breast. This avoids the intrinsic problems of variable compression and heavy, complex and unreliable mechanical devices but allows simultaneous production and co-registration of mammography and breast ultrasound data sets creating a functional multi-modality "fusion" imaging system. This design requires incorporation of a sonolucent plastic insert into the compression paddle to maintain compression during the mammography portion of the examination.

The use of this prototype manual system produces a co-registered digital mammogram and high resolution full field set of sequential breast ultrasound images. This achieves all of the bio-engineering objectives of this project and provides a data set which is comparable to that which would be produced by a large field crystal array. This sonolucent insert in the modified mammography compression paddle was constructed from low density polyethylene. This readily available material was salvaged from a spare black wastepaper basket and selected because of the cost and low acoustic impedance of this material - 1.77 Rayl - combined with a relatively low attenuation of x-ray beams 10.7% / 3mm thickness. These compare with the acoustic impedance of polycarbonate thermoplastic - 2.68 Rayl - and x-ray attenuation 14.8% /3mm (standard compression paddle) the significance of these values is that this material, while potentially less optimal than other more exotic plastics such as poly 4-methyl, 1-pentene (PMP) with and acoustic impedance of only 1.84 Rayl , an x-ray attenuation of 9.4% /3mm but retaining a high tensile modulus (stiffness) desirable in a mammography compression paddle. However as home

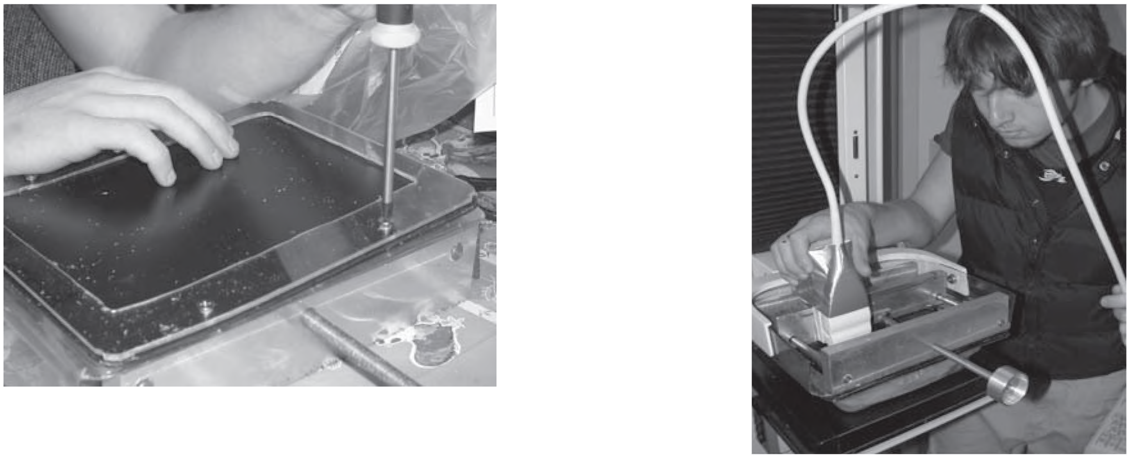


Figure 1: Photographs of construction of sonolucent mammography compression plate insert construction and during production of parallel 1mm large field turkey breast phantom images in compression through the sonolucent plastic insert. This creates a sequential parallel full field set of high resolution breast ultrasound images in DICOM3 medical image format.

wastepaper baskets are not generally constructed of PMP and it is no doubt expensive, use of that or other more "perfect insert material" will be deferred for future research.

3. METHODOLOGY

A realistic organic breast tissue "phantom" was created using a boneless turkey breast into which target objects were inserted to represent solid and cystic breast masses. Wherever possible air, which would disrupt the ultrasound beam was displaced by ultrasound gel and the entire "phantom" was wrapped in a "skin" of latex trans-rectal probe sheath. I had initially planned to use a "stand-off" pad or "water bath" to avoid uneven tissue compression or distortion resulting from the probe head pushing the tissue away as it passed from side to side of the phantom. However, the panoramic imaging software provided with the ATI5000 ultrasound machine requires a stable initial baseline for image creation and without one, the image "wanders". This roadblock actually provided the opportunity for me to move closer to the final Matrix Probe embodying a "fusion" design.

The most difficult problem was how to achieve uniform direct compression of the breast phantom tissue when conventional polycarbonate plastic compression paddles (although rigid and invisible to x-ray beams during mammography) are very resistant to the transmission of sound waves (high acoustic attenuation). Ultrasound impedance increases with material density and rigidity, both of which are desirable in a mammography compression paddle. What I had to find was an available plastic material with low acoustic impedance. After researching the acoustic impedance of plastics I decided that my best candidate was low density polyethylene and sacrificing a waste paper container I obtained my "sonolucent plastic tissue compression interface". Using a Dremel tool, I made a Lexan plastic frame with a polypropylene insert and attached this to my converted standard mammography compression paddle.

By adjusting the height of the ultrasound probe head pre-registration bracket to match the "sonolucent plastic" insert and using ultrasound gel as a probe surface/insert interface to reduce artifact, a "pre-registered" image of uniformly compressed tissue phantom was obtained! This confirmed the feasibility of my Matrix Probe "fusion" combined digital mammography and 3D breast ultrasound "add-on" device for standard mammography systems.

Slice by slice manual image production was time consuming but eventually the entire breast phantom tissue block was

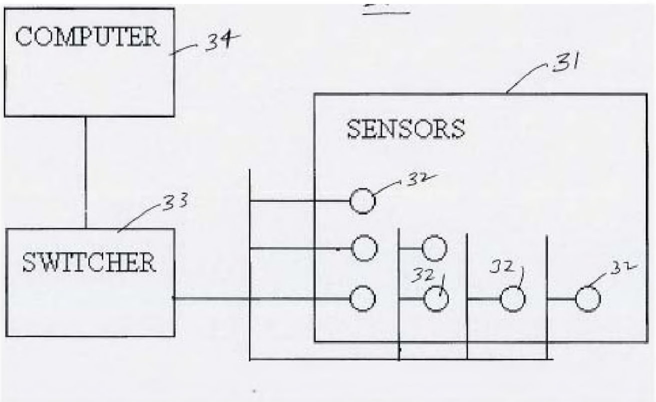


Figure 2: Basic schematic for electronic switching of Matrix Probe array elements.

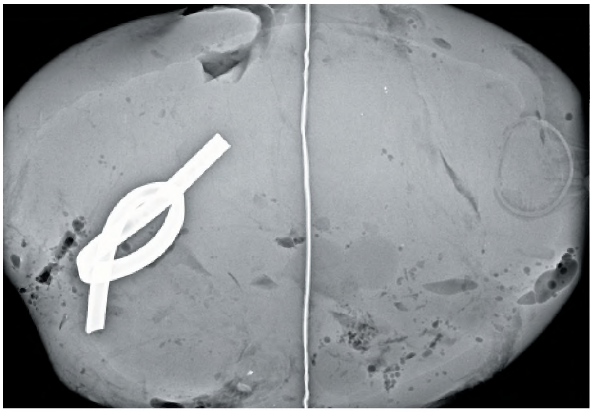


Figure 3: High resolution digital mammography of co-registered turkey breast tissue phantom

imaged. This produced a parallel series of "pre-registered" high resolution ultrasound tissue slices. A DICOM3 header using "patient demographic information" (name, date, type of examination, image number, modality, ID number, accession number) was attached to the image using the existing ultrasound machine "worklist software" allowing these images to be sent to the radiology clinic PACS (picture archiving and communication system).

After the collection of multiple "full-field" DICOM3 image sequences, these were reviewed using the advanced PACS viewing software confirming successful production of sequential DICOM3 medical images. Next, a test of the 4D capabilities of this system was performed using colourflow doppler vascular imaging (vascular tissue phantom created using surgical tubing) and "real-time" endoscopic motion of a probe through the tissue phantom was recorded.

4. RESULTS

I was able to create "full field", high resolution DICOM3 images of the turkey breast tissue phantom which are comparable to those which could be produced by a fixed piezoelectric crystal array (although a single image series which took me 30-40 minutes to obtain could be produced in "real time" 10-15 fps by the actual Matrix Probe device).

In order to complete these goals and demonstrate the potential of this innovation I redesigned and then built (with assistance from the Sandwich S.S. Machine shop teacher, Mr Levesque) a mammography compression paddle with a sonolucent plastic insert. This will be the basis of the Matrix Probe "fusion" add-on mammography paddle which will allow both digital mammography and "instant" high resolution 3D/4D breast ultrasound with the patient still in compression.

Review of these unique sequential "full field" parallel DICOM3 images (using existing diagnostic radiology review software) has significant patient care advantages to Radiologists and surgeons including:

i Far more complete tissue imaging (approximately 100 times more high resolution breast ultrasound imaging information provided to the Radiologist for review than during conventional breast ultrasound imaging). This review is facilitated by existing 3D ultrasound software.

ii The Matrix Probe System images are "**co-registered**" in 3D space, like a CT scan or MRI and can be subjected to multi-planar re-slicing to demonstrate the relationship of any objects within the tissue and to existing normal structures. This confirms the successful creating of a multi-modality "fusion" imaging system.

iii Co-Registration as the breast is imaged simultaneously (in compression) therefore for the first time exact correlation between digital mammography and a 3D breast ultrasound is now possible. This should significantly improve diagnostic accuracy and localization of breast masses and allow earlier and more accurate diagnosis of breast cancer (please see "fusion" compression mammography paddle display).

iv The electronic switching of the proposed Matrix Probe System large field array coupled with a powerful computer work station and appropriate real time auto-segmentation algorithms provides for the opportunity to perform "real time (4D) large field soft tissue ultrasound with the associated potential for guided robotic endoscopic surgery

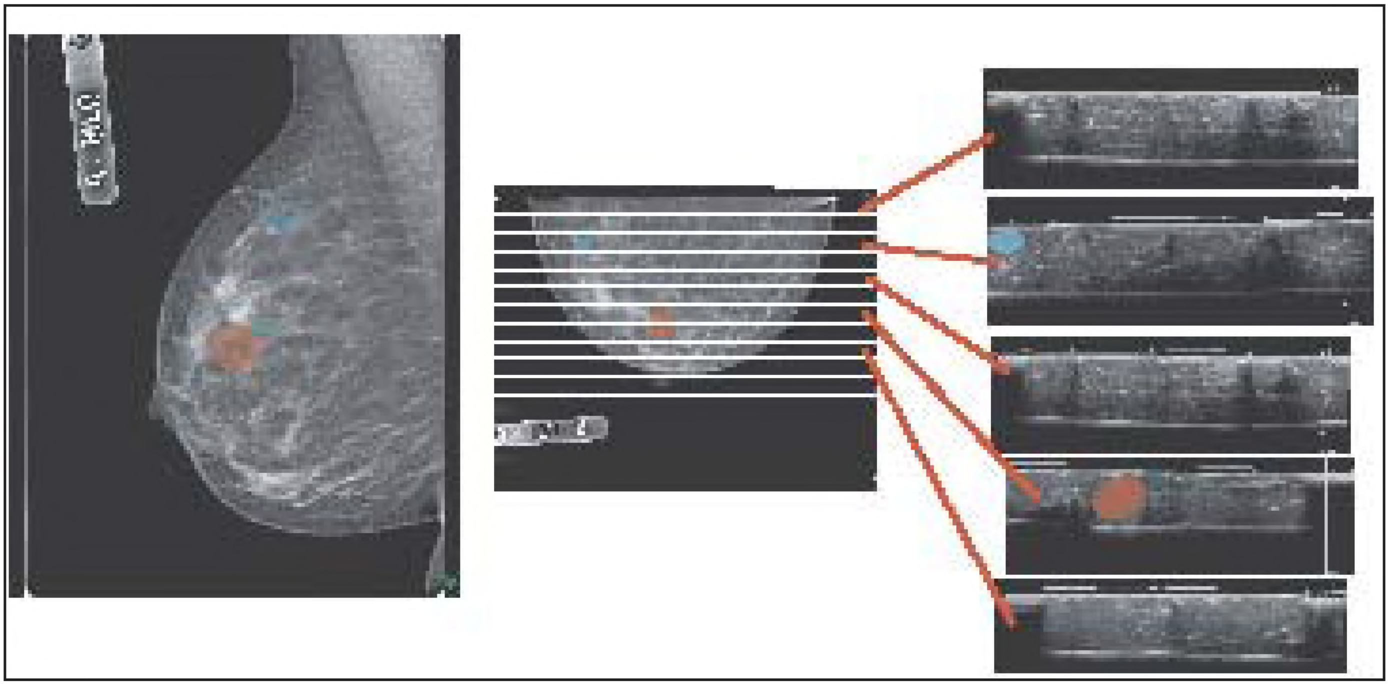


Figure 5: Co-registration of SIMULTANEOUS digital mammography and sequential parallel high resolution DICOM3 medical image format breast ultrasound.

and enhanced vascular imaging in appropriate soft tissues further increasing the medical usage of this device.

5. CONCLUSIONS

This study demonstrates a unique and elegant solution to the conundrum of co-registration of digital mammography and breast ultrasound. It avoids the pitfalls of mechanical scanning devices and demonstrates the potential of "real-time" 4D large field ultrasound. The manually obtained images confirm the feasibility of all aspects of this USA patent pending device. Further research would be facilitated by the construction of a functional large field array of piezoelectric crystal elements.

6. ACKNOWLEDGEMENTS

I would llike to acknlowedge the assistance provided by Essex X-Ray Ultrasound and Mammography, R. Levesque, the Machine Shop Director, Sandwich Secondary School, Goran Tosic, Chief Ultrasound Technician, Essex X-Ray, Ultrasound and Mammography, Dr. and Mrs. Gervais, Dr. Y. Ted Wu, Founder/CEO Able Software - 3D Doctor and and Dr. Giles Stevenson, Former Head of Radiology at McMaster University Medical Centre, Hamilton Ontario.

8. RELATED REFERENCES

1. R. W. Prager, A. H. Gee and L. Berman. "Stradx: Real-Time Acquisition and Visualization of Freehand Ultrasound." April 1998
2. R.W. Prager, R.N. Rohling, A.H. Gee and L. Berman. "Automatic Calibration for 3D Free-Hand Ultrasound." September 1997
3. A.H. Gee, R.W. Prager, G.M. Treece, and L. Berman. "Narrow-Band Volume Rendering for Freehand 3D Ultrasound." September 2000
4. M. Tuomola, A. H. Gee, R. W. Prager, and L. Berman. "Body-Centered Visualisation for Freehand 3D Ultrasound." October 1999
5. A. H. Gee, R. W. Prager, and G. M. Treece. "Sequential 3D Diagnostic Ultrasound Using the Stradx System." June 2001
6. A.H. Gee, R.W. Prager, L. Berman. "Non-Planar Reslicing for Freehand 3D Ultrasound." January 1999.
7. G.M. Treece, R.W. Prager, A.H. Gee, L. Berman. "Fast Surface and Volume Estimation from Non-Parallel Cross-Sections, for Freehand 3-D Ultrasound." July 1998
8. G.M. Treece, R. W. Prager, and A. H. Gee. "Regularised Marching Tetrahedra: Improved Iso-surface Extraction." September 1998
9. G.M. Treece, R. W. Prager, A. H. Gee, and L. Berman. "Surface Interpolation from Sparse Cross-Sections Using Region Correspondance." March 1999
10. G. M. Treece, R. W. Prager, A. H. Gee, and L. Berman. "3D Ultrasound Examination of Large Organs." December 1999
11. G.M. Treece, R.W. Prager, A.H. Gee, and L. Berman. "Correction of Probe Pressure Artifacts in Freehand 3D Ultrasound- Initial Results." April 2001
12. R. W. Prager, A. H. Gee and L. Berman. "Sequential 3D Diagnostic Ultrasound Using the Stradx System." June 2001
13. A. Fenster, S. Tong, H. N. Cardinal, C. Blake, D. B. Downey. "Three-Dimensional Ultrasound Imaging System for Prostate Cancer Diagnosis and Treatment." November 1998
14. A. Fenster, S. Tong, H. N. Cardinal, C. Blake, D. B. Downey. "Three-Dimensional Ultrasound Imaging System for Prostate Cancer Diagnosis and Treatment." December 1998
15. S. Tong, H. N. Cardinal, R. F. McLoughlin, D. B. Downey, A. Fenster. "ntra- and Inter-Observer Variability and Reliability of Prostate Volume Measurement Via Two-Dimensional and Three-Dimensional Ultrasound Imaging." March 1998
16. T. L. Elliot, D. B. Downey, S. Tong, C. A. McLean, A. Fenster. "Accuracy of Prostate Volume Measurement In Vitro Using Three-Dimensional Ultrasound." January 1996
17. Z. Guo and A. Fenster. "Three-Dimensional Power Doppler Imaging: A Phantom Study To Quantify Vessel Stenosis." May 1996.
18. Y. Wang, H. N. Cardinal, D. B. Downey, A. Fenster. "Semiautomatic three-dimensional segmentation of the prostate using two-dimensional ultrasound images." May 2003
19. N Hu, D. B. Downey, A. Fenster and H. M. Ladak. "Prostate Boundary Segmentation from 3D Ultrasound Images." June 2003
20. A. Landry and A. Fenster. "heoretical and Experimental Quantification of Carotoid Plaque Volume Measurments Made by Three-Dimensional Ultrasound Using Test Phantoms." September 2002
21. K. J. M. Surry, W. L. Smith, L. J. Campbell, G. R. Mills, D. B. Downey and A. Fenster. " The Development and Evaluation of a Three-Dimensonal Ultrasound Guided Breast Biopsy Apparatus." 2002
22. A. Fenster and D. B. Downey. "Three-Dimensional Ultrasound Imaging and Its Use In Quantifying Organ and Pathology Volumes." June 2003
23. H. N. Cardinal, J. D. Gill and A. Fenster. "Analysis of Geometrical Distortion and Statistical Variance in Length, Area, Volume in a Linearly Scanned 3-D Ultrasound Image." April 2000
24 W. L. Smith and A. Fenster. "Optimum Scan Spacing for Three-Dimensonal Ultrasound by Speckle Statistics." December 1999
25. A. Fenster, D. B. Downey and H. N. Cardinal. "Three-Dimensonal Ultrasound Imaging." November 2000

26. A. Fenster and D. B Downey. "3-D Ultrasound Imaging: A Review." November 1996
27. R.W. Prager, R.N. Rohling, A.H. Gee and L. Berman. "Automatic Calibration for 3-D Free-Hand Ultrasound." September 1997.
28. S. Tong, D. B. Downey, H. N. Cardinal and A. Fenster. "A Three-Dimensional Ultrasound Prostate Imaging System." March 1996
29. C. Cardinez, V. Cokkinides, T. Gansler, R. Greenlee, A. Harris, M. B. Hill- Harmon, T. Murray, D. Saslow, K. A. Sawyer, J. Schellenbach, R. Smith, S. Summers, D. Willis, and H. Zoller. "Breast Cancer Facts and Figures 2001-2002." 2001-2002
30. A. Fenster, K. Surry, W. Smith, J. Gill and D. B. Downey. " 3-D Ultrasound Imaging: Applications in Image Guided Therapy and Biopsy." 2002
31. A. Fenster and D. B. Downey. "Advanced Signal Processing Handbook." 2001
32. Y. Saijo, A. F. W. van der Steen. "Vascular Ultrasound." 2003
33. A. Fenster, D. Lee, S. Sherebrin, R. Rankin and D. B. Downey. "Ultrasonics." 1998
34. S. Tong, H. N. Cardinal, D. B. Downey and A. Fenster. "Analysis of linear, Area and Volume Distortion in 3D Ultrasound Imaging." October 1997
35. N. Skubas. "Principles of Echocardiography for the Anesthesiologist." 2003.

Why Purchase from a Single Manufacturer...

...When You Can Have the Best in the Industry From a Single Supplier?

Scantek is the company to call when you want the most comprehensive assortment of acoustical and vibration equipment. As a major distributor of the industry's finest instrumentation, we have the right equipment at the right price, saving you time and money. We are also your source for instrument rental, loaner equipment, product service, technical support, consulting, and precision calibration services.

Scantek delivers more than just equipment. Since 1985, we have been providing solutions to today's complex noise and vibration problems with unlimited technical support by acoustical engineers that understand the complex measurement industry.

Suppliers of Instruments and Software:

- *Norsonic*
- *RION*
- *CESVA*
- *DataKustik (Cadna & Bastian)*
- *KCF Technologies*
- *BSWA*
- *Castle Group*
- *Metra*
- *RTA Technologies*
- *G.R.A.S.*

Scantek

Sound and Vibration Instrumentation and Engineering

Applications:

- *Building Acoustics & Vibration*
- *Occupational Noise and Vibration*
- *Environmental and Community Noise Measurement*
- *Sound Power Testing*
- *Calibration*
- *Acoustical Laboratory Testing*
- *Loudspeaker Characterization*
- *Transportation Noise*
- *Mechanical Systems (HVAC) Acoustics*

Scantek, Inc. • 7060 Oakland Mills Road • Suite L • Columbia, MD 21046 • 800•224•3813 • www.scantekinc.com

Acoustic Absorbers and Diffusers – Theory, Design and Application

Trevor J. Cox and Peter D'Antonio, Pages 405

Spon Press 2004 - ISBN 0-415-29649-8, US$175.00

Acoustic absorbers have been applied in diverse control situations for a long time and are well understood. Many standards are also available to measure, quantitatively, the absorber performance. Diffusers have also been applied, extensively since the advent of spaces, large and small, for performances. The understanding of the diffuser properties and their usage has not kept pace with that of absorbers. Since the advent of special diffusers, such as Schroeder Diffusers and their by-product, the patented RPG diffusers, over the last two decades or so, has provided an interesting theoretical framework for diffuser understanding. The research material, available in the literature, is considerable. A textbook, collating, culling and formatting all these material, has been waiting to happen. Who better to write a textbook in English than the serious practitioners of absorber and diffuser technology than Trevor Cox and Peter D'Antonio? Of course Prof. Manfred Schroeder could have written a book also. In his absence, Cox and D'Antonio have provided an excellent introduction as well as a complete compendium of information, an acoustical engineer would need for a performance space design.

The book begins with an interesting story by D'Antonio and Cox that sets the basis for the book. The book contains an introduction, 13 chapters and three interesting appendices over 405 pages. The chapter titles are: 1) Application and basic principles of absorbers; 2) Application and basic principles of diffusers; 3) Measurement of absorber properties; 4) Measurement and characterization of diffuse reflections or scattering; 5) Porous absorbers; 6) Resonant absorbers; 7) Miscellaneous absorbers; 8) Prediction of scattering; 9) Schroeder diffusers; 10) Geometric reflectors and diffusers; 11) Hybrid surfaces; 12) Absorbers and diffusers in rooms and geometric models and 13) Active absorption and diffusion. Appendix A lists the conventional absorption coefficient values. Appendix B provides simple Matlab codes (scripts) for the evaluation of many of the equations contained in the textbook. Appendix C lists the diffusion coefficients for many standard products available in the market.

After a brief introduction that defines absorption, reflection and diffuse reflection, the book proper gets down to business in earnest. The book, conveniently, ordered into three main groupings: application and basic principles; measurement of properties that define absorbers and diffusers; and the practical design forms that are available for applications. Chapters 1 and 2 provide ample information of the areas of application of absorbers and diffusers as well as the basic principles that describe the process of their performance.

Chapters 3 and 4 are primers to assist to understand and conduct measurements that describe the acoustical properties of absorbers and diffusers. They contain conventional descriptions and procedures contained in the various standards, such as impedance tube techniques, reverberation room techniques, and free-field techniques. In addition, Chapter 3 contains an interesting section on in-situ measurements, a handy aid to field engineers. Chapter 4 discusses the pitfalls of attempting to define a single parameter for diffusion and or scattering performances. Cox and D'Antonio provide a lucid description of the complex measurements, such as polar responses, needed to understand diffuse reflections and scattering. One can only conclude that the jury is still out as to the measures and processes needed to determine the diffusion and scattering for manufacturers, room modelers and room designers.

Chapters 5, 6 and 7 provide a complete description of the many absorbers, porous, resonant and such, that can be designed and used in acoustic spaces. Enough information is provided to evaluate their performance characteristics. Similar information is provided for diffusers, such as Schroeder, Geometric and such, in Chapters 9, 10 and 11. The authors are honest enough to point out the shortcomings when a designer applies these models and attempts to evaluate the performance in actual acoustic spaces. Chapter 8 provides the thoretical models that can be used to predict the scattering from the application. Numerical techniques such as BEM (Boundary Element Method), FEA (Finite Element Analysis) and other algorithms to solve the fundamental Helmholtz-Kirchoff integral equation are touched upon in this chapter.

Chapter 12 is the highlight of this book. The authors show the difficulties encountered when the basic performance coefficients of the absorbers and diffusers are used in geometric modeling schemes to evaluate the performance of the acoustic spaces. The chapter provides guidelines to effectively use the models profitably. The book concludes with a brief introduction, in Chapter 13, to the virgin field of active control technology to design absorbers and diffusers.

The book focuses on diffusers more than absorbers, which is truly welcome since considerable amount of information is already available for absorbers. The theoretical development of fundamental acoustics, in various chapters, is skimpy and hence the audience of this book must have considerable theoretical background to truly appreciate the value of this book. However, a practicing acoustician involved with designing the spaces used for listening and producing sound, would find this book valuable. The book is filled with copious examples of actual applications and the image quality of these examples are topnotch. These examples make the book interesting and easy to read and appreciate. In the event, the authors have achieved the goal set for themselves. To conclude, "Acoustic Absorbers and Diffusers – Theory, Design and Application" is a must book in any acoustician's shelf.

Ramani Ramakrishnan, Ph. D., P. Eng.
Ryerson University, Toronto, ON, Canada
rramakri@ryerson.ca

The Physics of Sound, 3rd ed.
By Richard E. Berg and David G. Stork
Pearson Prentice Hall, 2005
398 + xvii pp., Price: US$64.95 (hardcover)
ISBN: 0-13-145789-6.

Introductory courses on acoustics for musicians and other nonscientists offer excellent opportunities to show how physics works and how an understanding of basic principles provides both practical knowledge and insight into everyday phenomena. The third edition of The Physics of Sound is one of several possible texts for such a course. It comes with several improvements, more problems, and some modern topics not in the first edition. Music majors with no background in physics and no mathematics beyond high-school algebra form its principal target audience, but the first two-thirds of the book is designed to be of interest to non-musicians as well.

I have had the good fortune to teach such a course in acoustics for several years. It is a joy to see music students who approach any physics course with trepidation gradually blossom and learn that physics is not so tough after all, and that a few common principles can lead to many practical applications and considerable insight. Even the seasoned physics student can learn from the course: the math is simple but there are many subtleties in the applications of general concepts such as impedance and reflections, coupled oscillators and normal modes of vibration, and Fourier analysis, as well as instructive lessons on the perception of sound.

The authors of The Physics of Sound are professional physicists at the University of Maryland with training and experience in music. Berg plays clarinet, piano, harpsichord, and recorder; Stork plays tympani and other percussion. One would expect them to provide not only a solid background in acoustics, but also a keen appreciation of details in applications to music. They have divided their text into three parts of roughly equal size: cc 1-4 provides physics background on waves with little mention of music; cc 5-8 cover topics of general interest in applied acoustics, including electronic production and reproduction of music, room acoustics, and a chapter covering both hearing and the human voice; and cc 9-14 give in-depth applications to musical temperament and the instrument families. In addition, the book has three appendices (basic music notation, mathematical symbols and units, and metric prefixes) and a glossary. A mixture of metric and English units is used.

There's much to like about the book. A number of interesting applications of acoustics are included that are usually omitted from such texts: active noise cancellation, the use of resonance phenomena to simulate psychokenesis, ultrasound, infrasound, sonoluminescence, and cochlear implants. There are many figures (but see also below), the influence of the Bernoulli effect in reeds is appropriately emphasized, MP3 recordings are discussed, the Sabine formula is given as an equation valid in any consistent set of units instead of just as a formula, each chapter has a summary, questions and problems, and an annotated bibliography, and in the last third of the book, some history of musical instruments is given.

Unfortunately, there are also some problems: omissions and missed opportunities, some potential for confusion, and a couple of curious errors. Among the omissions are the end corrections for resonant modes of an air column and the cut-off frequencies of wind instruments. These can be explained in terms of three fairly obvious unifying themes for the course: (1) Terms such as "large" or "small" are relative and imply a standard for comparison. In acoustics, sizes are usually compared to the wavelength (or better: the reduced wavelength $\lambda/2\pi$) of the sound wave. (2) The impedance is a general concept for waves that gives the amount of "push" required to achieve a given "flow". (3) Energy is conserved. Changes in impedance control what portion of the wave energy is radiated and how much is reflected. Waves can propagate through gradual changes in impedance but are reflected by "sudden" changes (large fractional changes over distances short compared to $\lambda/2\pi$). Any instructor using the text will do well to emphasize unifying themes ignored by the text. Berg and Stork define impedance for an electric circuit and briefly mention the role of impedance matching in radiating sound from brass bells and piano sound boards, but the impedance concept should also be used to explain the strength of resonances sustained by the partial reflection of waves at the ends of air columns or in strings at bridges.

There is also no definition or use of cents (hundredths of a semitone), although on the illustration of a Korg tuner (Fig. 9-11, p. 255) one can read a pitch scale in units of cents. Musical intervals are discussed in cc 3 and 9 and in Appendix A, but there is no explanation why octaves, fifths, and fourths are called perfect whereas thirds, sixths, and other intervals are major or minor, and there is nothing about augmented or diminished intervals. On p. 77, the tension in a wire is referred to in Mersenne's laws without any definition. Students usually need help with this concept. The Q of a band-pass filter is defined, but not the more general Q of a resonance. The fact that the speed of sound in air increases with increasing temperature is mentioned on p. 40 in the discussion of refraction, but there is no indication of how much the speed changes with temperature or how it changes with humidity. Such changes are of practical importance to musicians playing in an ensemble. Also the authors do not distinguish between "soft reeds" (whose vibration frequency is controlled by feedback from the air column) and "hard reeds" (whose vibration is largely independent of any supporting air column. And no harmonic spectra of plucked and bowed strings are shown.

The influence of note duration on perceived loudness is not mentioned, although this is essential for organists and harpsichordists and important for all instrumentalists. No examples of musical passages are given, and indeed there is no discussion of musical notation for notes of different durations. Loudness in sones is mentioned (p. 156), but the relation between loudness level and loudness is not given or plotted. Indeed, in spite of the large number of figures, several important illustrations are missing. For example, it would be nice to have a picture (or realistic drawing) of the cochlea, a drawing of a violin bridge and its rocking motion, a plot of the phase shift of a driven oscillator as the frequency passes through resonance, pictures of Lissajous figures with frequencies in nonunison integer ratios, and a plot of approximate critical-band width as a function of frequency. When pipe organs are discussed at the end of the chapter on woodwinds, no mention is made of mixture stops, in which ranks at octave, fifth and other intervals are combined to produce more powerful sounds with new tone qualities.

In the half of c. 6 that treats the human ear, the authors promote the discredited Weber-Fechner "psychophysical law" about logarithmic response to stimuli (the response more closely follows a fractional power law). Also, there is no mention of the cochlear duct, endolymph or perilymph. The text states on p. 147 that the ossicles (middle-ear bones) "convert small-amplitude vibrations of the eardrum into the larger amplitude pressure oscillations" at the inner ear. This appears to compare amplitudes of different physical dimensions: the displacement amplitude of the eardrum to pressure amplitudes at the oval window. The authors do not mention work-conserving action of the middle-ear bones as a lever converting a smaller force over larger displacement of motion at the eardrum into a larger force and smaller displacement at the oval window of the inner ear in order to improve the impedance match. The authors emphasize that the width of the cochlea decreases along its length from the base to the apex but fail to mention the more important fact that the width of the basilar membrane has the opposite behaviour. Fig. 6-3 shows the location of maximum vibration amplitude of the basilar membrane for different frequencies, but it does not explain why this dependence occurs or how it is related to upward masking. In c. 11 on brass instruments, the authors follow the common (but oversimplified) classification of modern brasses into either the "cylindrical" or "conical" families. While the renaissance cornetto, the serpent, and the alphorn are approximately conical, all of the modern brasses are much closer to Bessel horns than to either cylinders or cones. This has been emphasized by Benade[1] and by Fletcher and Rossing[1] but is not mentioned by Berg and Stork.

The third edition has improved its discussion of resonances in musical instruments in a number of places, but students are still likely to confuse modes of resonance of musical instruments with the harmonics of steady tones. In fact, the concept of normal (natural) modes of resonance is missing from the book entirely. Instead, the authors frequently write about the harmonics of a musical instrument or other oscillating system, and they use "overtones" as synonymous with harmonics, but not entirely consistently. Thus, on p. 167, referring to the vocal tract as being like a closed tube, the authors state that its resonant frequencies are "its odd harmonics" (emphasis added), and on p. 311, they describe how a trombonist can play (with the slide in first position) "a fifth harmonic (the D above middle C), which is sharp with respect to the exact harmonic of the overtone series…." And on p. 341, the second overtone (meaning second harmonic) is said to beat with the note an octave above. This would logically make the first overtone synonymous with the first harmonic and the fundamental. However, musicians usually equate the first overtone to the second harmonic, and indeed on p. 354, the authors write that "the first overtone [in a xylophone bar] is tuned to three times the fundamental frequency."

There are several instances in which more care in definitions or drawings might have improved understanding. For example, on p. 76 we learn that "true" musical intervals such as "true perfect fifths" or "true major thirds" are beatless, but so far the authors have discussed only beats between tones of nearly the same frequency (and, incidently, with the same amplitude, see p. 50). Only on p. 245 is it explained how beats arise in nonunison intervals. The discussion of musical temperaments in c. 9 provides good historical material on the development from Pythagorean tuning to equal temperament, including a concise but reasonable understanding of why baroque-music performers often prefer unequal closed (or circulating) temperaments. The commas of Pythagoras and of Didymus are both defined but not compared. This and some other aspects of c. 9 would have been simpler if the unit of a cent had been introduced. A nice extension would be to the problems of tuning a six-stringed guitar or viola da gamba, or to how performers in small ensembles need to adjust the thirds away from equal-tempered positions to reduce the beating of major and minor triads.

Some inaccurate drawings detract from the text. These include sine waves with different shapes (too many with too great a slope when they cross the axis, approaching sometimes a pair of semicircles; compare "sinusoidal curves" in Figs. 3.2 and 3.3 on p. 70), misplaced points that should be equally spaced on a circle to show the relation of uniform circular motion and SHM (Fig. 1-6), inconsistent curves in Fig. 2-45 (the discontinuity in the slope of the intensity (b) is not consistent with the finite slope in the frequency (a) for the Doppler shift), a diffracted wave (Fig. 2-32) with sharp changes in the wave fronts, a misdirected arrow in Fig. 2-13, a shifting horizontal perspective in the sequence of Fig. 2-14, an extraneous line segment at the bottom right of Fig. 2-37, and an impossibly exaggerated dispersion of light by a prism in Fig. 4-23.

Some confusion may result from the discussion of the bowed string on pp. 323-4. A well-bowed flexible string moves approximately with the Helmholtz motion, correctly described by the authors as a triangular shape with the vertex circulating around the string and shown in Fig. 12-2. Although it is not pointed out in the text, the direction of circulation changes when the bow direction does, with interesting implications for string players. The authors describe this circulating motion as a "standing wave" and state that it is more complex than the sum of sinusoidal waves at harmonic frequencies. In fact the Helmholtz motion has a very simple Fourier decomposition as the sum of $\sin(nx)\sin(nt)/n^2$. The authors remark that if the bow were thin and drawn across the string at 1/Nth the length of the string that the Nth harmonic would be missing just as it is when a string is plucked there. While this is a commonly held assumption, researchers agree that it is of little practical value. It is more significant to contrast the motion of a bowed string from the standing wave in a plucked string. The Fourier amplitudes of a plucked string are proportional to $\sin(nx_0)/n^2$ where x_0 is the plucking point in a string of length π, and they thus drop to zero for harmonics with nodes at the plucking position. However, the ideal Helmholtz motion of a bowed string contains all harmonics with amplitudes decreasing as $1/n^2$ and independent of the bow position. Measurements[2] on real, flexible strings closely conform to this prediction. The plucked-string motion can be obtained from two Helmholtz motions that coincide at the plucking position and circulate in opposite directions, but the simple construction of Helmholtz motion from plucked oscillations is not possible. Of course there is a difference in tone quality between sul ponticello and sul tasto playing, as the authors mention, and much of the cause for this is associated with important changes required in bow speed and pressure[2] that the authors fail to mention.

A couple of errors should be mentioned, especially ones that students may not recognize as such. At the bottom of p. 125, a frequency variation of a few tenths of one per cent is said to cause a pitch oscillation somewhat less than one half tone, whereas a half tone shift in pitch actually requires a 6% change in frequency. On p. 155, the authors state that "increasing the SIL of a 1000-Hz tone in 10-dB steps will be interpreted by the listener as increasing the loudness of the tone by roughly equal increments." That should be "equal factors of roughly 2", not equal increments. The definitions in the chapter Summary on p. 115 are imprecise: "White noise contains all audio frequencies with equal intensities… Pink noise drops off at a rate of 3 dB per octave." Of course, one should use a measure such as the power per unit frequency to compare continuous frequency distributions.

A surprising slip occurs on p. 157, where the authors state that "aural harmonics … become significant when the tone is 'loud'—that is, when the pressure varies over several orders of magnitude" (emphasis added). In the accompanying Fig. 6-5, they compare a sine curve and a curve "related to the logarithm of this function." In fact, the actual pressure fluctuation of any bearable sound wave is tiny compared to the total atmospheric pressure, reaching only 2 parts in 10,000 even at the threshold of pain. Could the authors have meant pressure fluctuations? No, because the fluctuations pass through zero, oscillating on either side of the background pressure. The logarithm of the total pressure does not differ significantly in shape from the pressure itself, whereas the logarithm of the pressure fluctuation would become imaginary during half the cycle.

On p. 204 the text refers to the diffraction limit as "the inherent quantum mechanical limitation of the light", but of course it is simply a property of waves, classical as well as quantum. In the explanation of MP3 recordings on p. 211, it is correctly stated that the various compression techniques can reduce the storage by a factor of about 10, but the numbers given actually match the storage rate for standard CDs fairly closely. The problem is that the authors have used the wrong units for the MP3 storage; their numbers should be kilobits per second, not kilobytes per second. Fig. 8-3 on p. 3 for the decay of intensity in a room after the sound source stops shows a smooth exponential decay that is inconsistent with the stepped rise in intensity shown in the same figure; the same reflections that give the steps of increasing intensity after the source starts should give steps in the initial decay when the source is cut off.

Of course practically every text contains ambiguities and errors, and I have critically raked the text by Berg and Stork with a fine-toothed comb. Nevertheless, my overall impression is that they have not taken sufficient care to be as clear and accurate as they might, and they have missed opportunities to emphasize overall unifying themes and to apply principles to some practical problems of concern to musicians. Among similar texts for courses in acoustics for music students, I would suggest instructors also look at the book by D. E. Hall[3], which, even though its section on technology is dated, seems to me more carefully organized and better suited for music students. The text by Berg and Stork would be useful for supplemental material and comparative discussions of alternative presentations.

1. Arthur Benade, Fundamentals of Musical Acoustics, Oxford U. Press, 1976; N. H. Fletcher and T. D. Rossing, The Physics of Musical Instruments, Springer-Verlag, 1991.
2. J. C. Schelling, J. A. S. A. 53, 26 (1973), especially Figure 6.
3. Donald E. Hall, Musical Acoustics, Third Edition, Brooks/Cole, 2002.

William E. Baylis
University Professor of Physics
University of Windsor
Windsor, Ontario

NEWS / INFORMATIONS

CONFERENCES

If you have any news to share with us, send them by mail or fax to the News Editor (see address on the inside cover), or via electronic mail to stevenb@aciacoustical.com

2006

05-07 January: First International Conference on Marine Hydrodynamics. Visakhapatnam, India. Web: www.mahy2006.com

17-19 January: Anglo-French Physical Acoustics Conference. Kent, UK. Web: www.ioa.org.uk/viewupcoming.asp

14-16 March: 2006 Spring Meeting of the Acoustical Society of Japan. Tokyo, Japan. Web: www.asj.gr.jp/index-en.html

20-23 March: Meeting of the German Acoustical Society (DAGA 2006). Web: www.daga2006.de

03-04 April: Futures in Acoustics. Southampton UK. Web: www.ioa.org.uk

02-05 May: International Conference on Speech Prosody. Dresden, Germany. Web: www.ias.et.tu-dresden.de/sp2006

05-07 May: 6th International Conference on Auditorium Acoustics. Copenhagen, Denmark. Web: www.ioa.org.uk/viewupcoming.asp

08-10 May: 12th AIAA/CEAS Aeroacoustics Conference. Cambridge MA, USA. Web: www.aiaa.org

15-19 May: IEEE International Conference on Acoustics, Speech, and Signal Processing (IEEE ICASSP 2006). Toulouse, France. Web: http://icassp2006.org

16-19 May: Oceans '06 Asia Pacific IEEE Conference. Singapore. Web: www.oceans06asiapacific.org

23-26 May: 17th Session of the Russian Acoustical Society. Moscow, Russia. Web: www.akin.ru

May 30 - June 1: 6th European Conference on Noise Control (Euronoise 2006). Tampere, Finland. Web: www.euronoise2006.org

5-7 June: 6th European Conference on Noise Control (Euronoise2006). Web: www.acoustics.hut.fi/asf

5-9 June: 151st Meeting of the Acoustical Society of America, Providence, Rhode Island. Contact: Acoustical Society of America, Suite 1NO1, 2 Huntington Quadrangle, Melville, NY 11747-4502; Tel: 516-576-2360; Fax: 516-576-2377; E-mail: asa@aip.org; Web: asa.aip.org

12-15 June: 8th European Conference on Underwater Acoustics. Carvoeira, Portugal. Web: www.ecua2006.org

26-28 June: 9th Western Pacific Acoustics Conference. Seoul, Korea. Web: www.wespac8.com/WespacIX.html

26-29 June: 11th International Conference on Speech and Computer. St. Petersburg, Russia. Web: www.specom.nw.ru

CONFÉRENCES

Si vous avez des nouvelles à nous communiquer, envoyez-les par courrier ou fax (coordonnées incluses à l'envers de la page couverture), ou par courriel à stevenb@aciacoustical.com

2006

05-07 janvier: Premiere International Conference sur Marine Hydrodynamics. Visakhapatnam, India. Web: www.mahy2006.com

17-19 janvier: Anglo-French Physical Acoustics Conference. Kent, UK. Web: www.ioa.org.uk/viewupcoming.asp

14-16 mars: 2006 Spring Meeting de l'Acoustical Society de Japan. Tokyo, Japan. Web: www.asj.gr.jp/index-en.html

20-23 mars: Meeting de le German Acoustical Society (DAGA 2006). Web: www.daga2006.de

03-04 avril: Futures dans l'Acoustics. Southampton UK. Web: www.ioa.org.uk

02-05 mai: International Conference sur Speech Prosody. Dresden, Germany. Web: www.ias.et.tu-dresden.de/sp2006

05-07 mai: 6th International Conference sur Auditorium Acoustics. Copenhagen, Denmark. Web: www.ioa.org.uk/viewupcoming.asp

08-10 mai: 12th AIAA/CEAS Aeroacoustics Conference. Cambridge MA, USA. Web: www.aiaa.org

15-19 mai: IEEE Conference Internationale sur Acoustics, Speech, et Signal Processing (IEEE ICASSP 2006). Toulouse, France. Web: http://icassp2006.org

16-19 mai: Oceans '06 Asia Pacific IEEE Conference. Singapore. Web: www.oceans06asiapacific.org

23-26 mai: 17th Session de le Russian Acoustical Society. Moscow, Russia. Web: www.akin.ru

mai 30 - juin 1: 6th European Conference sur Noise Control (Euronoise 2006). Tampere, Finland. Web: www.euronoise2006.org

5-7 juin: 6th European Conference on Noise Control (Euronoise2006). Web: www.acoustics.hut.fi/asf

5-9 juin: 151e rencontre de l'Acoustical Society of America, Providence, Rhode Island. Info: Acoustical Society of America, Suite 1NO1, 2 Huntington Quadrangle, Melville, NY 11747-4502; Tél.: 516-576-2360; Fax: 516-576-2377; Courriel: asa@aip.org; Web: asa.aip.org

12-15 juin: 8th European Conference sur Underwater Acoustics. Carvoeira, Portugal. Web: www.ecua2006.org

26-28 juin: 9e Conférence Western Pacific Acoustics. Seoul, Korea. Web: www.wespac8.com/WespacIX.html

26-29 juin: 11th International Conference sur Speech et Computer. St. Petersburg, Russia. Web: www.specom.nw.ru

3-7 July: 13th International Congress on Sound and Vibration (ICSV13). Vienna, Austria. Http://info.tuwien.ac.at/icsv13

17-19 July: 9th International Conference on Recent Advances in Structural Dynamics. Southampton, UK. Web: www.isvr.soton.ac.uk/sd2006/index.htm

13-15 September: Autumn Meeting of the Acoustical Society of Japan. Web: www.asj.gr.jp/index-en.html

17-21 September: Interspeech 2006 - ICSLP. Web: www.interspeech2006.org

18-20 September: International Conference on Noise and Vibration Engineering (ISMA2006). Leuven, Belgium. Web: www.isma-isaac.be

18-20 September: ACTIVE 2006, 6th International Symposium on Active Noise and Vibration Control. University of Adelaide, South Australia, Australia. Web: www.active2006.com

18-20 September: 12th International Conference on Low Frequency Noise and Vibration and its control. Bristol, UK. Web: www.lowfrequency2006.org

18-21 September: INTERSPEECH 2006 - ICSLP. Pittsburgh, PA, USA. Web: www.interspeech2006.org

03-06 October: IEEE International Ultrasonics Symposium. Vancouver, Canada. Contacts TBA

25-28 October: 5th Iberoamerican Congress on Acoustics. Satiago, Chile. Web: www.fia2006.cl

20-22 November: Joint Australia/New Zealand Acoustical Conference. Christchurch, New Zealand. Web: www.acoustics.org.nz

28 November – 2 December: 152nd meeting, 4th Joint Meeting of the Acoustical Society of America and the Acoustical Society of Japan, Honolulu, Hawaii. Contact: Acoustical Society of America, Suite 1NO1, 2 Huntington Quadrangle, Melville, NY 11747-4502; Tel: 516-576-2360; Fax: 516-576-2377; E-mail: asa@aip.org; Web: asa.aip.org

3 - 6 December: INTER-NOISE 2006, Honolulu HA, USA (Same Hotel at ASA meeting the week preceeding)

2007

17-20 April. IEEE International Congress on Acoustics, Speech, and Signal Processing (IEEE ICASSP 2007). Honolulu, HI, USA

16-20 May: IEEE International Conference on Acoustics, Speech, and Signal Processing (IEEE ICASSP 2007). Honolulu, HI, USA. Web: www.icassp2007.org

04-08 June: 153rd Meeting of the Acoustical Society of America. Salt Lake City, Utah, USA. Web: www.asa.aip.org

9-12 July: 14th International Congress on Sound and Vibration (ICSV14). Cairns, Australia. Email: n.kessissoglou@unsw.edu.au

26-29 August: Inter-noise 2007. Istanbul, Turkey. Web: www.internoise2007.org.tr

27-31 August: Interspeech 2007. E-mail: conf@isca-speech.org

3-7 juillet: 13th Congress Internationale sur Sound et Vibration (ICSV13). Vienna, Austria. Http://info.tuwien.ac.at/icsv13

17-19 juillet: 9th International Conference sur Recent Advances in Structural Dynamics. Southampton, UK. Web: www.isvr.soton.ac.uk/sd2006/index.htm

13-15 septembre: Autumn Meeting de l'Acoustical Society du Japan. Web: www.asj.gr.jp/index-en.html

17-21 septembre: Interspeech 2006 - ICSLP. Web: www.interspeech2006.org

18-20 septembre: International Conference sur Noise et Vibration Engineering (ISMA2006). Leuven, Belgium. Web: www.isma-isaac.be

18-20 septembre: ACTIVE 2006, 6th International Symposium sur Active Noise et Vibration Control. University d'Adelaide, South Australia, Australia. Web: www.active2006.com

18-20 septembre: 12th International Conference sur Low Frequency Noise et Vibration et control. Bristol, UK. Web: www.lowfrequency2006.org

18-21 septembre: INTERSPEECH 2006 - ICSLP. Pittsburgh, PA, USA. Web: www.interspeech2006.org

03-06 octobre: IEEE International Ultrasonics Symposium. Vancouver, Canada. Contacts TBA

25-28 octobre: 5th Iberoamerican Congress sur Acoustics. Satiago, Chile. Web: www.fia2006.cl

20-22 novembre: Joint Australia/New Zealand Acoustical Conference. Christchurch, New Zealand. Web: www.acoustics.org.nz

28 novembre – 2 decembre: 152e rencontre, 4e Rencontre acoustique jointe de l'Acoustical Society of America, et l'Acoustical Society of Japan, Honalulu, Hawaii. Info: Acoustical Society of America, Suite 1NO1, 2 Huntington Quadrangle, Melville, NY 11747-4502; Tél.: 516-576-2360; Fax: 516-576-2377; Courriel: asa@aip.org; Web: asa.aip.org

3 - 6 decembre: INTER-NOISE 2006, Honolulu HA, USA (Same Hotel at ASA meeting the week preceeding)

2007

17-20 avril. IEEE Congress Internationale sur Acoustics, Speech, et Signal Processing (IEEE ICASSP 2007). Honolulu, HI, USA

16-20 mai: IEEE International Conference sur Acoustics, Speech, et Signal Processing (IEEE ICASSP 2007). Honolulu, HI, USA. Web: www.icassp2007.org

04-08 juin: 153rd Meeting de l'Acoustical Society d'America. Salt Lake City, Utah, USA. Web: www.asa.aip.org

9-12 juillet: 14th Congress Internationale sur Sound et Vibration (ICSV14). Cairns, Australia. Email: n.kessissoglou@unsw.edu.au

26-29 août: Inter-noise 2007. Istanbul, Turkey. Web: www.internoise2007.org.tr

27-31 août: Interspeech 2007. E-mail: conf@isca-speech.org

2-7 September 19th International Congress on Acoustics (ICA2007), Madrid Spain. (SEA, Serrano 144, 28006 Madrid, Spain; Web: www.ia.csic/sea/index.html)

9-12 September: ICA2007 Satellite Symposium on Musical Acoustics (ISMA2007). Barcelona, Spain. Web: www.ica2007madrid.org

November 27 - December 02: 154th Meeting of the Acoustical Society of America. New Orleans, LA, USA. Web: www.asa.aip.org

2008

June 29 - July 04: Joint Meeting of European Acoustical Association, Acoustical Society of America, and Acoustical Society of France. Paris, France E-mail: phillipe.blanc-benon@ec-lyon.fr

28 July - 1 August: 9th International Congress on Noise as a Public Health Problem. Mashantucket, Pequot Tribal Nation, (CT, USA). Web: www.icben.org

2010

23-27 August: International Confress on Acoustics 2010. Sydney, Australia. Web: www.acoustics.asn.au

2-7 septembre 19e Congrès international sur l'acoustique (ICA2007), Madrid Spain. (SEA, Serrano 144, 28006 Madrid, Spain; Web: www.ia.csic/sea/index.html)

9-12 septembre: ICA2007 Satellite Symposium sur Musical Acoustics (ISMA2007). Barcelona, Spain. Web: www.ica2007madrid.org

novembre 27 - decembre 02: 154th Meeting de l'Acoustical Society d'America. New Orleans, LA, USA. Web: www.asa.aip.org

2008

juin 29 - juillet 04: Rencontre jointe de l'European Acoustical Association, l'Acoustical Society of America, et l'Acoustical Society of France. Paris, France E-mail: phillipe.blanc-benon@ec-lyon.fr

28 juillet - 1 août: 9th International Congress sur Noise as a Public Health Problem. Mashantucket, Pequot Tribal Nation, (CT, USA). Web: www.icben.org

2010

23-27 août: International Confress sur Acoustics 2010. Sydney, Australia. Web: www.acoustics.asn.au

NEWS

We want to hear from you! If you have any news items related to the Canadian Acoustical Association, please send them. Job promotions, recognition of service, interesting projects, recent research, etc. are what make this section interesting.

NOISE POLICY WORKSHOP IN RIO DE JANEIRO IS A SUCCESS

More than 60 attendees participated in the Noise Policy Workshop held at the Copacabana Praia Hotel, Rio de Janeiro, on August 6, 2005. Present were members of national and local government agencies, acoustical engineers, educators, and environmental consultants.

The workshop panelists presented papers, which emphasized the need for a global noise policy covering occupational noise, community noise, and consumer product noise. Following each of the three sessions, a discussion period reinforced the need for and interest in establishing a global noise policy. Much of the discussion involved the feasibility of such a policy and how to realize it.

Because of the success of this workshop and the overwhelming interest in moving forward toward international agreements on noise, the Noise Control Foundation is planning a third international Noise Policy Workshop, which will present a more focused approach on achieving this goal. This workshop will be held on May 30, 2006 in Tampere, Finland (see above).

For more information contact Dr. William W. Lang, Noise Control Foundation, P.O. Box 3067, Arlington Branch, Poughkeepsie, NY 12603, Phone: (845) 471-5493, Fax (845) 473-9325, email: langww@alum.mit.edu

INCE/USA Publishes the NOISE-CON 2005 CD-ROM

NOISE-CON 2005, the 2005 National Conference on Noise Control Engineering, was held jointly with the 150th meeting of the Acoustical Society of America in Minneapolis, Minnesota, USA on October 17-19, 2005.

A CD-ROM was prepared for the conference containing 947 technical papers, 198 papers presented at the joint NOISE-CON/ASA conference as well as 749 papers from NOISE-COM conferences held in 1996, 1997, 1998, 2000, 2001, 2003, and 2004 as well as papers from the Sound Quality Symposia held in 1998 and 2002.

The CD-ROM (stock number CD-NC05) is available for USD $70 plus $3 Shipping and Handling ($6 for foreign shipments). Telephone 1-800-247-6553; Fax 1-419-281-6883, e-mail order@bookmaster.com; also at the Atlas Bookstore website www.atlasbooks.com/marktplc/00726.htm

West Caldwell Calibration Laboratories, Inc.

uncompromised calibration

YOUR SOURCE FOR CALIBRATION AND REPAIR OF SOUND AND VIBRATION INSTRUMENTATION

West Caldwell Calibration Laboratories Inc.

offers 30 years of experience in calibration and repair of electronic instruments. Our specialty is acoustic and vibration test instruments. As a medium sized efficient organization we are able to fulfill our customers requirements with fast delivery of calibrated and repaired equipment at competitive pricing.

ACCREDITATION

CERTIFICATION

COMPLIANCE

TRACEABILITY

ISO/IEC 17025

A2LA ACCREDITED

1533.01/02

ISO 9001:2000

BVQi

Accreditation: **ISO/IEC 17025-1999**
ANSI/NCSL Z540-1- 1994
Certification: **ISO 9001:2000**
Compliance: **ISO/IEC Guide 25**
MIL-STD-45662A
ISO 10012-0-1992 (E)
Calibrations are traceable to N.I.S.T.

REPORTS AND CERTIFICATES ARE SUPPLIED WITH ALL CALIBRATED ITEMS

SPECIALTIES • OTHER SERVICES

West Caldwell Calibration Laboratories specializes in the calibration and repair of
Accelerometers
Audiometric Equipment
Field Calibrators
Frequency Analyzers
Sound Level Meters
Vibration meters and Test Equipment

Additional services offered are On-site Calibrations, customized System Integration and Purchase Assistance of any instrument from the following manufacturers:
ACO PACIFIC • BRUEL & KJAER • CEL • DYTRAN • ENDEVCO • G.R.A.S. • LARSON-DAVIS METROSONICS • NORSONIC • NORWEGIAN ELECTRIC • PCB • RION • SYMINEX

Your cost of the instrument is the manufacturer's list price and we include a FREE initial or next calibration.
For a complete listing of manufacturers and the types of instruments calibrated and repaired see attachment

U.S.A.: 1575 State Route 96, Victor, NY 14564
Phone: 585-586-3900 Fax: 585-586-4327 E-mail: info@wccl.com

Canada: 220 Rutherford Rd. S. Suite 210, Brampton, ON L6W 3J6
Phone: 905-595-1107 Fax: 905-595-1108 E-mail: info@wccl.ca

Web site: www.wccl.com

Award-winning *Innovation*

Created for You

With over 60 years as pioneers within the world of sound and vibration, Brüel & Kjær presents its innovative, award-winning, 4th generation of hand-held instruments for sound and vibration measurement. Development of this latest generation – Type 2250 – was instigated and inspired entirely by the requirements of users participating in in-depth workshops around the world. The hardware has been designed to meet the specific ergonomic requirements of users, and the application software covers everything from environmental noise, troubleshooting, and occupational health, to quality control. The software packages can be licensed separately, so you can get what you need when you need it and won't get left behind if your requirements change. This way, the platform ensures the safety of your investment now and in the future. Created, built and made for you personally, you'll find it will make a difference toy our work and all your measurement tasks.

New Sound Recording Option

The Sound Recording Option works with all other software modules, and lets you record measurement signals in order to identify and document sound sources. Recordings are automatically attached to the measurement and kept with it, even after transfer of the data to a PC.

If you need more information
please go to **www.type2250.com**

BA 0782–11

HEADQUARTERS: DK-2850 Nærum · Denmark · Telephone: +45 45 80 05 00
Fax: +45 45 80 14 05 · www.bksv.com · info@bksv.com

USA: 2815 Colonnades Court · Norcross, GA 30071
Toll free (800) 332-2040 · www.BKhome.com · bkinfo@bksv.com

Australia (+61) 2 9889-8888 · Austria (+43) 1 865 74 00 · Brazil (+55) 11 5188-8166
Canada (+1) 514 695-8225 · China (+86) 10 680 29906 · Czech Republic (+420) 2 6702 1100
Finland (+358) 9 521300 · France (+33) 1 69 90 71 00 · Germany (+49) 421 17 87 0
Hong Kong (+852) 2548 7486 · Hungary (+36) 1 215 83 05 · Ireland (+353) 1 807 4083
Italy (+39) 0257 68061 · Japan (+81) 3 5715 1612 · Korea (+82) 2 3473 0605
Netherlands (+31) 318 55 9290 · Norway (+47) 66 77 11 55 · Poland (+48) 22 816 75 56
Portugal (+351) 21 4711 4 53 · Korea (+82) 2 3473 0605 · Singapore (+65) 377 4512
Slovak Republic (+421) 25 443 0701 · Spain (+34) 91 659 0820 · Sweden (+46) 8 449 8600
Switzerland (+41) 44 880 7035 · Taiwan (+886) 2 2502 7255 · United Kingdom (+44) 14 38 739 000
USA (+1) 800 332 2040 · Local representatives and service organisations worldwide

Type *2250 – Inspired by Users*

Brüel & Kjær

Canadian Acoustical Association

Minutes of the Board of Directors Meeting
11 October 2005
London, Ontario

Present: S. Dosso (chair), D. Giusti, D. Quirt, A. Behar, V. Parsa
C. Buma, C. Giguère, R. Ramakrishnan, J. Bradley, N. Collison

Regrets: D. Stredulinsky

The meeting was called to order at 7:00 p.m. After a brief review of progress on action items, the minutes of Board of Directors meeting on 17 May 2005 were approved as published in Canadian Acoustics (June 2005 issue). *(moved A. Behar, seconded R. Ramakrishnan, carried).*

President's Report

Stan Dosso reported that there have been no major changes or problems in the affairs of the Association. He noted the success of the joint meeting of ASA and CAA in Vancouver in June, and encouraged future collaborations of this nature.

Secretary's Report

David Quirt reported that gradual increase in membership has continued through FY2004/05. As of the end of August, total paid membership was 395 (an increase of 29); about 85% of the members are from Canada. The number of Sustaining Subscribers is up, and there were surges of new memberships associated with both the Ottawa and Vancouver meetings, especially for Student Members.

Mailing list (1 October)	**Canada**	**USA**	**Other**	**Change**
Member	219	17	10	**+14**
Emeritus	2		1	**+1**
Student	66		7	**+14**
Sustaining	38	3	1	**+2**
Direct	9			**– 2**
Indirect	9	6	7	**–**
	Total = 395			**+29**

To ease membership renewal, the Secretary and Treasurer have continued the option of payments by VISA, and 40% used this method. To strengthen CAA communication via e-mail, and to reduce errors in mailing *Canadian Acoustics*, systematic updating of all membership address data including e-mail was continued in the renewal process.

Secretarial operating costs for FY2004/05 were $1031.35, mainly for mailing costs and postal box rentals. Issues of Noise News International were mailed as they arrived, to the 42 members who have requested this optional service, but shipment from the publisher in the USA is usually late. A budget increase to $1200 for the next fiscal year was requested, to cover increasing costs for mailings. Immediate transfer of $1000 from the Treasurer was also requested. *(D. Giusti moved acceptance of report and the approval of the funding transfer, seconded N. Collison, carried)*

Treasurer's Report

The Treasurer, Dalila Giusti, submitted a report and a financial statement prepared by our auditor, Paul A. Busch, for the fiscal year ending August 31, 2005. It was a good year financially. Interest on our capital fund ($5122) exceeded the $4750 requirement for prizes this year. Most major expenses were essentially as budgeted, and the conference in Ottawa made a significant profit. Overall, total assets at fiscal year-end had risen by ~$11k to $269,812.

Movement of $15,000 from the operating to the capital fund, and investment of available capital funds at discretion of the Treasurer, were authorized. *(Moved A. Behar, second by D. Quirt, carried).*

A draft budget for FY2004/05 was presented and discussed. Given the small increases forecast in most expenses, the projected revenue would be $2275 below expenses if fees are held constant and there is no additional revenue due to the conference in London or increased memberships and advertising. It was unanimously agreed not to recommend an increase in membership and subscription fees. Instead there will be a focus on increasing advertising revenue, by recruiting two advertising managers and raising the fee for a full-page advertisement to $300, with pro-rated increases for smaller ones. *(Moved A. Behar, seconded by V. Parsa, carried.)*

The Board decided that fees for early registration at the annual conference should be at least $300 for members and $100 for students, with increases for late registration and/or expensive locales. *(Moved by R. Ramakrishnan, second N. Collison, carried.)*

The Board commended both the Treasurer's detailed budget plan, and her accurate budget forecast for the past years, and strongly encouraged her continued service. *(A. Behar moved acceptance of Treasurer's report, C. Buma seconded, carried.)*

Editor's Report

The Editor, Ramani Ramakrishnan, presented a brief report on issues related to content, appearance, and publication process for *Canadian Acoustics*. A special issue is planned in June 2006 featuring papers on wind turbine noise from a conference in Banff. Ramani announced that he has a comfortable backlog of publishable papers, including many from international sources, but he recommended that moving to 6 issues per year be postponed until advertising revenue is brought above the 2004 levels. To support this objective and reward our frequent advertisers, the editor was authorized to offer a special at 2005 rates for those willing to pay in advance for advertisements in all four issues in 2006. *(Moved D. Quirt, seconded by D. Giusti, carried.)*

The relationship with the current printer is very smooth, and each issue goes out promptly. Overall, the publication is proceeding smoothly with substantial technical content, and the Board expressed their thanks for the huge effort by the Editor. *(D. Giusti moved acceptance of Editor's report, D. Quirt seconded, carried.)*

Conferences – Past, Present & Future

<u>2004 Ottawa</u>: John Bradley reported that the conference was among the largest in CAA history. Total registration was 153, and income exceeded expenditures by $14,161, plus $1500 for 37 membership fees. John Bradley was Conference Chair, Brad Gover was Technical Program Chair, and many other CAA members in Ottawa helped. The Board congratulated the Ottawa team on their success.

<u>2005 (Vancouver):</u> Stan Dosso reported the resounding success of the joint ASA/CAA meeting in Vancouver in May 2005. Attendance was excellent, and those who participated commented on the outstanding facilities, sessions, and social events. Murray Hodgson was Conference Chair, Stan Dosso was Technical Program Chair, and other CAA members in Vancouver had key roles on the organizing team. There was strong consensus that such joint ventures are worth supporting.

<u>2005 (London):</u> Meg Cheesman presented a preliminary report on the London Ontario conference just beginning (with M. Cheesman as Conference Chair, Vijay Parsa as Technical Chair, and other London members in significant roles). Pre-registration was 80, with about 70 abstracts submitted, 10 exhibitors expected, and 3 plenary speakers. Special sessions in hearing aids, speech sciences, and biomedical ultrasound are scheduled, and student participation seems above average. The Board thanked and encouraged the London team.

<u>2006 (Halifax):</u> Nicole Collison reported on arrangements for the meeting planned in downtown Halifax. Hotel negotiations are near completion, and a detailed announcement will be in December's *Canadian Acoustics*. The team has proposed that CAA implement a database for online submission of abstracts and papers. There was strong agreement that this would be an extremely useful extension of the CAA website, and Dave Stredulinsky's willingness to pilot this improvement was

applauded. *(Allocation of $600 for the fees and setup proposed by N Collison, seconded D. Giusti, carried.)*

2007 (Undecided locale): Options for 2007 were briefly discussed, and the President offered to pursue potential organizers.

(InterNoise 2009 in Ottawa): The possibility of hosting the InterNoise conference in Ottawa in collaboration with INCE-USA was presented to the Board. An organizing team (Trevor Nightingale as Chair, Brad Gover as Technical Chair, and a large supporting cast) has prepared a preliminary proposal, which was considered by the Board. The Board endorsed the proposal in principle, on the proviso that INCE-USA would assume financial risk. *(Approval for co-sponsoring the proposed InterNoise 2009 in Ottawa moved by A. Behar, seconded C. Buma, all in favor.)*

Awards

Christian Giguère presented a report, based on submissions from the Awards Coordinators. Specific progress for various awards was:

- Shaw Prize not awarded,
- Bell Prize awarded,
- Fessenden Prize awarded,
- Eckel Prize awarded,
- Hétu Prize awarded,
- Award for the Canada-Wide Science Fair presented.
- Directors' Award for Student awarded.
- Directors' Award for Professional awarded,
- Student travel subsidies and presentation awards for CAA conference will use the full budget allocation (strong competition).

Awards are distributed well across Canada.

CAA Website

Stan Dosso led an informal discussion of the CAA website. The Board expressed their heartfelt thanks to Dave Stredulinsky, who has agreed to continue as webmaster for the time being. Overall, there was enthusiastic support for the content, especially the pages used for the annual conference, and the proposed implementation of database capability for the website as presented in Halifax Conference plans.

Addition of identifying categories and brief descriptions (text supplied by Subscriber, or a link to their website) to the section for Sustaining Subscribers was approved in principle. *(Proposed by D. Quirt, seconded by D. Giusti, approved).*

Nominations / Change of Directors

All members of the Executive have agreed to continue for another year. Thanks were expressed to Raymond Panneton and Megan Hodge who came to the end of terms at this time, and to Corjan Buma who has agreed to an extension of his term. A slate of nominees has been established for presentation at the AGM, with due regard for regional distribution.

Other Business

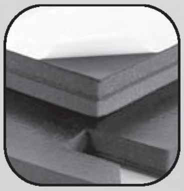
S. Dosso will investigate using teleconferencing on a trial basis for May 2006 Board meeting. Some requests for sponsorship were discussed, but no contributions were approved.

Adjournment

D. Giusti moved to adjourn the meeting, seconded by R. Ramakrishnan, carried. Meeting adjourned at 10:40 p.m.

Special Action Items (Continuing or Arising from the Meeting)

- *D. Quirt:* Communicate with Sustaining Subscribers, to assemble supplementary information for the website listing of Sustaining Subscribers.
- *D. Giusti:* Transfer funds to secretarial account for administrative expenses, and transfer advance funds for Halifax conference. Transfer $15,000 from Operations to Capital account, and proceed with investments from Capital Fund.
- *S.* Dosso: Recruit team for 2007 CAA conference. Send letter of thanks to Auditor. Arrange Board teleconference in May, if members support this option.




Blachford
ACOUSTICS LABORATORY

Canadian Acoustical Association

Minutes of Annual General Meeting

Lamplighter Inn, London, Ontario
13 October 2005

Call to Order

President Stan Dosso called the meeting to order at 5:00 p.m. Minutes of the previous Annual General Meeting on 7 October 2004 in Ottawa were approved as printed in the December 2004 issue of Canadian Acoustics.

(Moved by Ramani Ramakrishnan, seconded by Dalila Giusti, carried)

President's Report

Stan Dosso summarized the results of the Board meeting on 11 October. He emphasized that the society is in good condition, and he thanked all those who have made major contributions to our activities, both in ongoing executive activities, and in the annual conferences.

Secretary's Report

David Quirt presented a brief report. CAA membership and subscriptions have increased 8%, to 395 as of 31 August. There was a small surplus in the administrative budget of $1100 for mailing, database, and correspondence expenses in the last fiscal year; an itemized account was presented to the Board of Directors. An increase to $1200 has been approved for next year, to cover anticipated costs for mailings. All activities are proceeding smoothly. Details are in the report from the Board of Directors meeting on 11 October.

(Acceptance of the report was moved by Nicole Collison, seconded Cameron Sherry, carried.)

Treasurer's Report

Dalila Giusti reported on CAA finances. We are in good shape, with assets of $269,812 at fiscal year end and a variety of securities that provided $5122 in interest last year, which more than covered the cost of awards. Financially successful meetings and income from advertising and subscriptions have also generated funds. There has been steady expansion of financial assets for several years.

We budget each year's expenses and track costs and revenues; this allows us to plan. This year, the budget predicts a small deficit if the conference in London breaks even and other income is the same as in 2004-05. The Board is proposing no increase in fees this year, but has implemented changes to gradually increase future advertising and conference revenue to maintain a balanced budget.

(Acceptance of this report and an unchanged fee structure was moved by Meg Cheesman, seconded Vijay Parsa, carried.)

Editor's Report

Ramani Ramakrishnan gave the Editor's report. *Canadian Acoustics* production has proceeded smoothly throughout the year, with all issues printed on schedule. Late delivery of the September issue (especially in Alberta) was acknowledged; this is always a difficult balance between just-in-time submissions and delivery. Earlier submission deadline and mailing will be considered next year. A special conference proceedings issue on wind turbine noise is planned for June 2006. Advertising revenue is down this year (evidence of the huge historic contribution of Karen Fraser as Advertising Manager) and rebuilding that revenue stream is an immediate objective that must be achieved before moving to six issues per year. Content and the submission/review/publication process are generally satisfactory.

(Acceptance of the report was moved by Dalila Giusti, seconded David Havelock, carried.)

Award Coordinator's Report

Christian Giguère acknowledged the continuing hard work of our awards coordinators, and reported the awards to be presented this year. CAA is not awarding the Shaw Prize, but the Bell Prize, Fessenden Prize, Eckel Prize, Hétu Prize, Directors' Awards (Student and

Professional), and Award for the Canada-Wide Science Fair have all been awarded. In addition, there are the student paper awards. (See separate announcement in this issue for names of recipients.)

Past/Future Meetings

Brief reports were presented on meeting status:

Ottawa (2004): John Bradley gave a brief report. Attendance was 153, and there was a full slate of technical papers (118 abstracts and 101 printed summaries) including excellent plenary sessions. The exhibition was well-attended, and exhibitors provided outstanding hospitality at the coffee breaks. There was a significant financial surplus. The President repeated the thanks from the Association for a great success

Vancouver (May 2005): Stan Dosso reported that the joint ASA/CAA meeting in May 2005 in Vancouver was very successful with over 1000 papers and 1400 attendees. Murray Hodgson was Chair, and Stan Dosso was Technical Program Chair; numerous other CAA members participated as organizers and attendees.

London (October 2005): Meg Cheesman reported that the meeting seemed to be proceeding well, with 79 papers submitted, registration near 100 including many students, and very supportive exhibitors who sponsored great coffee breaks. Meg acknowledged the contributions by mebers of the London team, especially Vijay Parsa, and those present applauded the efforts of the London team.

Halifax (October 2006): Nicole Collison reported preliminary organization for Halifax. The team plans numerous organized sessions on a range of topics, including underwater sound, and Cameron Sherry volunteered to organize a special session on technical standards. Online submission of abstracts and papers will be tested at this meeting. (See announcement in this issue for conference details)

CAA Website

Stan Dosso reported that David Stredulinsky has agreed to continue as webmaster, in addition to his activity as webmaster for the Halifax meeting. There were many comments supportive of the very useful and effective website.

Nominations and Election

CAA corporate rules require that we elect the Executive and Directors each year.

This year Raymond Panneton and Megan Hodge will end their terms and leave the Board, with our thanks. Corjan Buma also reached the end of his term, but has agreed to an extension. John Bradley presented the slate of proposed new Directors: Corjan Buma, Rich Peppin, and Anita Lewis. A request for nominations from the floor brought no response.

(Cameron Sherry moved that nominations be closed, seconded by Dalila Giusti, loudly approved.)

John Bradley read the names of the proposed (continuing) members of the executive: Stan Dosso as President, David Quirt as Secretary, Dalila Giusti as Treasurer, and Ramani Ramakrishnan as Editor. There were no other nominations from the floor, so these nominees were declared elected by acclamation.

Adjournment

Meg Cheesman moved and Dalila Giusti seconded, that the meeting be adjourned. Carried. Meeting adjourned at 5:33 p.m.

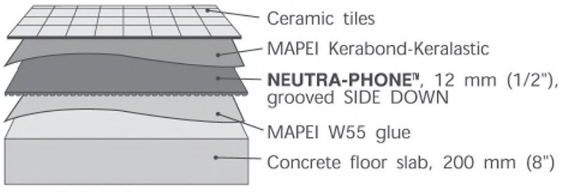
Structural sound membrane

Neutra-Phone

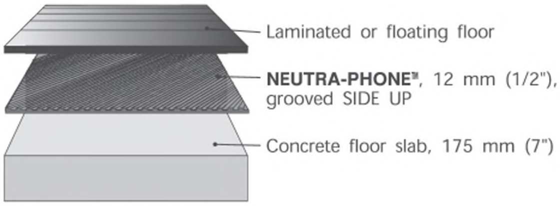
Airborn noise, the sound of foot steps and other impact on floors can cause problems in residential buildings. The Royal Mat company, in collaboration with the National Research Council and soundproofing specialists, has perfected a soundproofing panel made out of recycled rubber by-products called NEUTRA-PHONE®.

Used primarily as a subfloor in construction and renovation, NEUTRA-PHONE® is effective at muffling noise and vibrations. Designed with cutting edge technology, NEUTRA-PHONE® is suitable for all types of concrete or wooden framework, regardless of the floor covering. Structural, you cant install directly ceramic, marble or granit tiles on NEUTRA-PHONE®.

Installation is quick and easy.



F.I.I.C. 60



F.I.I.C. 64

1-888-301-3694
1-514-267-0060

www.royalmat.com

The Canadian Acoustical Association
L'Association Canadienne d'Acoustique

PRIZE ANNOUNCEMENT • ANNONCE DE PRIX

A number of prizes and subsidies are offered annually by The Canadian Acoustical Association. Applicants can obtain full eligibility conditions, deadlines, application forms, past recipients, and the names of the individual prize coordinators on the CAA Website (http://www.caa-aca.ca). • Plusieurs prix et subventions sont décernés à chaque année par l'Association Canadienne d'Acoustique. Les candidats peuvent se procurer de plus amples renseignements sur les conditions d'éligibilités, les échéances, les formulaires de demande, les récipiendaires des années passées ainsi que le nom des coordonnateurs des prix en consultant le site Internet de l'ACA (http://www.caa-aca.ca).

Deadline for Underwater Acoustic and/or Signal Processing Student Travel Subsidy: **31 March 2006**
Échéance Subvention de Voyage pour Étudiants en Acoustique Sous-marine ou Traitement du Signal: **31 Mars 2006**

EDGAR AND MILLICENT SHAW POSTDOCTORAL PRIZE IN ACOUSTICS • PRIX POST-DOCTORAL EDGAR AND MILLICENT SHAW EN ACOUSTIQUE

$3,000 for full-time postdoctoral research training in an established setting other than the one in which the Ph.D. was earned. The research topic must be related to some area of acoustics, psychoacoustics, speech communication or noise. • $3,000 pour une formation recherche à temps complet au niveau postdoctoral dans un établissement reconnu autre que celui où le candidat a reçu son doctorat. Le thème de recherche doit être relié à un domaine de l'acoustique, de la psycho-acoustique, de la communication verbale ou du bruit.

ALEXANDER GRAHAM BELL GRADUATE STUDENT PRIZE IN SPEECH COMMUNICATION AND BEHAVIOURAL ACOUSTICS • PRIX ÉTUDIANT ALEXANDRE GRAHAM BELL EN COMMUNICATION VERBALE ET ACOUSTIQUE COMPORTEMENTALE

$800 for a graduate student enrolled at a Canadian academic institution and conducting research in the field of speech communication or behavioural acoustics. • $800 à un(e) étudiant(e) inscrit(e) au 2e ou 3e cycle dans une institution académique canadienne et menant un projet de recherche en communication verbale ou acoustique comportementale.

FESSENDEN GRADUATE STUDENT PRIZE IN UNDERWATER ACOUSTICS • PRIX ÉTUDIANT FESSENDEN EN ACOUSTIQUE SOUS-MARINE

$500 for a graduate student enrolled at a Canadian academic institution and conducting research in underwater acoustics or in a branch of science closely connected to underwater acoustics. • $500 à un(e) étudiant(e) inscrit(e) au 2e ou 3e cycle dans une institution académique canadienne et menant un projet de recherche en acoustique sous-marine ou dans une discipline reliée à l'acoustique sous-marine.

ECKEL GRADUATE STUDENT PRIZE IN NOISE CONTROL • PRIX ÉTUDIANT ECKEL EN CONTRÔLE DU BRUIT

$500 for a graduate student enrolled at a Canadian academic institution and conducting research related to the advancement of the practice of noise control. • $500 à un(e) étudiant(e) inscrit(e) au 2e ou 3e cycle dans une institution académique canadienne et menant un projet de recherche relié à l'avancement de la pratique du contrôle du bruit.

RAYMOND HÉTU UNDERGRADUATE PRIZE IN ACOUSTICS • PRIX ÉTUDIANT RAYMOND HÉTU EN ACOUSTIQUE

One book in acoustics of a maximum value of $100 and a one-year subscription to *Canadian Acoustics* for an undergraduate student enrolled at a Canadian academic institution and having completed, during the year of application, a project in any field of acoustics or vibration. • Un livre sur l'acoustique et un abonnement d'un an à la revue *Acoustique Canadienne* à un(e) étudiant(e) inscrit(e) dans un programme de 1er cycle dans une institution académique canadienne et qui a réalisé, durant l'année de la demande, un projet dans le domaine de l'acoustique ou des vibrations.

CANADA-WIDE SCIENCE FAIR AWARD • PRIX EXPO-SCIENCES PANCANADIENNE

$400 and a one-year subscription to *Canadian Acoustics* for the best project related to acoustics at the Fair by a high-school student • $400 et un abonnement d'un an à la revue *Acoustique Canadienne* pour le meilleur projet relié à l'acoustique à l'Expo-sciences par un(e) étudiant(e) du secondaire.

DIRECTORS' AWARDS • PRIX DES DIRECTEURS

One $500 award for the best refereed research, review or tutorial paper published in *Canadian Acoustics* by a student member and one $500 award for the best paper by an individual member • $500 pour le meilleur article de recherche, de recensement des travaux ou d'exposé didactique arbitré publié dans l'*Acoustique Canadienne* par un membre étudiant et $500 pour le meilleur article par un membre individuel.

STUDENT PRESENTATION AWARDS • PRIX POUR COMMUNICATIONS ÉTUDIANTES

Three $500 awards for the best student oral presentations at the Annual Symposium of The Canadian Acoustical Association. • Trois prix de $500 pour les meilleures communications orales étudiant(e)s au Symposium Annuel de l'Association Canadienne d'Acoustique.

STUDENT TRAVEL SUBSIDIES • SUBVENTIONS POUR FRAIS DE DÉPLACEMENT POUR ÉTUDIANTS

Travel subsidies are available to assist student members who are presenting a paper during the Annual Symposium of The Canadian Acoustical Association if they live at least 150 km from the conference venue. • Des subventions pour frais de déplacement sont disponibles pour aider les membres étudiants à venir présenter leurs travaux lors du Symposium Annuel de l'Association Canadienne d'Acoustique, s'ils demeurent à au moins 150 km du lieu du congrès.

UNDERWATER ACOUSTICS AND SIGNAL PROCESSING STUDENT TRAVEL SUBSIDIES • SUBVENTIONS POUR FRAIS DE DÉPLACEMENT POUR ÉTUDIANTS EN ACOUSTIQUE SOUS-MARINE ET TRAITEMENT DU SIGNAL

One $500 or two $250 awards to assist students traveling to national or international conferences to give oral or poster presentations on underwater acoustics and/or signal processing. • Une bourse de $500 ou deux de $250 pour aider les étudiant(e)s à se rendre à un congrès national ou international pour y présenter une communication orale ou une affiche dans le domaine de l'acoustique sous-marine ou du traitement du signal.

Canadian Acoustical Association
Association canadienne d'acoustique

2005 PRIZE WINNERS / RÉCIPIENDAIRES 2005

BELL GRADUATE STUDENT PRIZE IN SPEECH COMMUNICATION AND BEHAVIOURAL ACOUSTICS / PRIX ÉTUDIANT BELL EN COMMUNICATION VERBALE ET ACOUSTIQUE COMPORTEMENTALE

Geoffrey Morrison, University of Alberta
"Modeling L2 Perception of English and Spanish vowels"

FESSENDEN GRADUATE STUDENT PRIZE IN UNDERWATER ACOUSTICS / PRIX ÉTUDIANT FESSENDEN EN ACOUSTIQUE SOUS-MARINE

Jan Dettmer, University of Victoria
"Geoacoustic Reflectivity Inversion: A Bayesian Approach"

ECKEL GRADUATE STUDENT PRIZE IN NOISE CONTROL / PRIX ÉTUDIANT ECKEL EN CONTRÔLE DU BRUIT

Katrina Scherebnyj, University of British Columbia
"Prediction of Community Reaction to Aircraft Run-up Noise at YVR"

RAYMOND HÉTU UNDERGRADUATE PRIZE IN ACOUSTICS / PRIX ÉTUDIANT RAYMOND HÉTU EN ACOUSTIQUE

Daniel Graves, Thompson Rivers University (BC)
"SANDRA - Speech and Noise Differentiation for Classroom Analysis: Procedure and Software Overview"

CANADA-WIDE SCIENCE FAIR AWARD / PRIX EXPO-SCIENCES PANCANADIENNE

Chet Gervais, Amherstburg (Ontario)
"The Matrix Probe - Evolution: Co-registration of Digital Mammography with 3Dimensional Breast Ultrasound Using a Full-Field Matrix of Piezoelectric Crystal Transducers"

DIRECTORS' AWARDS / PRIX DES DIRECTEURS

Student Member / Membre Étudiant :

Dora Chan, University of Calgary

"Identifying the Number of Instruments in Pairs of Simultaneously Sounding Timbre"
Canadian Acoustics 32(4):5-13

Individual Member / Membre Individuel :

Colin Novak, University of Windsor

"Intake Noise Cancellation Using a Manifold Bridging Technique"
Canadian Acoustics 32(1): 21-29

STUDENT PRESENTATION AWARDS / PRIX POUR COMMUNICATIONS ÉTUDIANTES
LAMPLIGHTER INN, LONDON (ON), OCTOBER 11-14, 2005

Elisabeth van Stam, University of Western Ontario

"Recognizing Individual Wild Big Brown Bats (Eptesicus fuscus) Using their Echolocation Calls"

Ralph Baddour, University of Toronto

"The Effect of Pecking Order on Ultrasound Backscatter from Cells at Different Volume Fractions"

Jenn Bouchard, University of Western Ontario

"Characteristics of Chimney Swift In-flight Vocalizations"

Julianne Tenhaaf, Brock University

"Normative Threshold Levels for a Calibrated, Computer-Assisted Version of the Ling Six-Sound Test"

CONGRATULATIONS / FÉLICITATIONS

CAA Annual Conference in Halifax Nova Scotia
October 11-13, 2006 www.caa-aca.ca/halifax-2006.html

Organizing Committee

Conference Chair – Nicole Collison (nicole.collison@drdc-rddc.gc.ca); Technical Chair – Francine Desharnais (francine.desharnais@drdc-rddc.gc.ca); Treasurer – Dave Chapman; Logistics – Jim Milne and Cheryl Munroe, Exhibit Coordinators – Joe Hood (jhood@mdacorporation.com) and Derek Burnett (dburnett@mdacorporation.com); and Website Manager – Dave Stredulinsky (dave.stredulinsky@drdc-rddc.gc.ca).

First Announcement

The 2006 annual conference of the Canadian Acoustical Association will be held in Halifax, 11-13 October 2006. There will be two and a half days of parallel sessions of papers on all areas of acoustics and auditory perception, as well as an interesting array of exhibits detailing acoustical products.

Special Sessions

There will be a number of special sessions. Please contact the Conference or Technical Chairs to suggest topics or people to organize a session.

Venue and Accommodation

The conference will be held at the Citadel Halifax Hotel (www.citadelhalifax.com; 1-800-565-7162). Standard rooms are being offered for $145/night (+ taxes) based on single or double occupancy; additional adults will be an extra $15/night. Parking is available for an overnight charge of $9/day. Please stay at this hotel to be with your friends and support the CAA.

Travel

The Citadel Halifax Hotel is located in downtown Halifax, within walking distance to many restaurants and amenities. Taxis to/from the Halifax International Airport to/from Halifax are a flat fee of $53 one way and there is an Airport Bus Service that goes to/from local hotels (including Citadel Halifax) for $14 one way and $24 for a return ticket (Note: prices may vary by Oct 2006). October is a beautiful time to visit Nova Scotia, for more tourist information log onto www.novascotia.com.

Exhibits

The exhibition of acoustical products and the interaction between various industry partners is an important aspect of our annual meeting. The exhibit area will be connected to the main session rooms and will be the central coffee break area. Please contact the Exhibit Coordinators for early information on the planned exhibit and sponsorship of various aspects of this meeting.

Student Participation

CAA encourages and supports student participation in the annual conference. Student members who make presentations can apply for travel support and can apply to win one of a number of student presentation awards. See the CAA website for details.

Submissions

The abstracts' submission deadline will be 16 June 2006. Details of the electronic submission process will be contained in the March 2006 issue of Canadian Acoustics.

ACA Congrès Annuel à Halifax, Nouvelle Écosse
11-13 Octobre, 2006 www.caa-aca.ca/halifax-2006.html

Comité d'Organisation

Présidente du Congrès – Nicole Collison; Directrice Scientifique – Francine Desharnais; Trésorier – Dave Chapman; Administration – Jim Milne et Cheryl Munroe, Coordinateurs de l'Exposition – Joe Hood et Derek Burnett; Responsable du site internet – Dave Stredulinsky.

Première Annonce

Le congrès annuel 2006 de l'Association Canadienne d'Acoustique se tiendra à Halifax, du 11 au 13 octobre 2006. Il y aura deux jours et demi de sessions parallèles de présentations, portants sur différents sujets reliés à l'acoustique et la perception auditive. De plus, plusieurs exposants présenteront leurs produits acoustiques.

Sessions Spéciales

Un certain nombre de sessions spéciales seront offertes sur les sujets proposés par les délégués. Pour suggérer un sujet particulier ou pour organiser une session, veuillez contacter la Présidente ou la Directrice Scientifique.

Lieu et Hébergement

Le congrès se tiendra à l'hôtel Citadel Halifax (www.citadelhalifax.com; 1-800-565-7162). L'hôtel offre ses chambres régulières, occupation simple ou double, au prix de 145$/nuit (+ taxes); 15$/nuit additionnel par adulte supplémentaire. Le stationnement est disponible à 9$ par jour. Nous vous invitons à choisir cet hôtel afin de participer pleinement au congrès et d'encourager l'ACA.

Directions

L'hôtel Citadel Halifax est situé en plein cœur du centre-ville. Les compagnies de taxis offrent un tarif fixe pour le trajet entre l'aéroport international d'Halifax et le centre-ville (53$ pour un aller). Un service de navette est aussi offert entre plusieurs hôtels du centre-ville (incluant l'hôtel Citadel Halifax) et l'aéroport (14$ aller, 24$ aller-retour). Pour information sur la Nouvelle Écosse, visitez le www.novascotia.com.

Exposition

L'exposition de produits acoustiques et l'interaction entre les différents partenaires industriels est un aspect important de cette rencontre annuel. Le hall d'exposition sera joint aux salles de conférence et sera aussi l'endroit désigné pour la pause-café. Veuillez contacter le Coordinateur de l'Exposition pour plus d'information sur les exposants et commanditaires.

Participation Étudiante

Le ACA encourage et supporte la participation des étudiants au congrès annuel. Les membres étudiants qui présenteront au congrès pourront soumettre une demande de subvention pour leurs frais de déplacement et pourront se mériter l'un des prix offerts pour communications étudiantes. Pour plus de détails, visitez le site de l'ACA.

Appel de Communications

La date d'échéance de soumission des résumés est le 16 juin 2006. Les détails sur le processus de soumission électronique des résumés seront publiés dans la revue Acoustique Canadienne de mars 2006.

The Canadian Acoustical Association / l'Association Canadienne d'Acoustique

MEMBERSHIP DIRECTORY 2005 / ANNUAIRE DES MEMBRES 2005

The number that follows each entry refers to the areas of interest as coded below.
Le nombre juxtaposé à chaque inscription réfère aux champs d'intérêt tels que condifés ci-dessous

Areas of interest		Champs d'intérêt
Architectural acoustics	1	Acoustique architecturale
Engineering Acoustics / noise Control	2	Génie acoustique / Contrôle du bruit
Physical Acoustics / Ultrasonics	3	Acoustique physique / Ultrasons
Musical Acoustics / Electroacoustics	4	Acoustique musicale / Electroacoustique
Psycho- and Physio-acoustics	5	Psycho- et physio-acoustique
Shock and Vibration	6	Chocs et vibrations
Hearing Sciences	7	Audition
Speech Sciences	8	Parole
Underwater Acoustics	9	Acoustique sous-marine
Signal Processing / Numerical Methods	10	Traitement des signaux / Méthodes numériques
Other	11	Autre

Adel A. Abdou
King Fahd Univ.of Petroleum & Minerals
Architectural Engineering Dept.
P.O. Box 1917
Dharan 31261, Saudi Arabia
+966 03 860-2762, FAX:+966 03 860-3785
adel@dpc.kfupm.edu.sa
Member, Interest:1,2,10

Dr. Sharon M. Abel
DRDC Toronto
Human Factors Res. & Engineering Section
P.O. Box 2000, 1133 Sheppard Ave. W
Toronto, ON, M3M 3B9, Canada
(416) 635-2037, FAX:(416) 635-2013
Member, Interest:2,5,7,8

ACI Acoustical Consultants Inc.
Mr. Steven Bilawchuk
Suite 107
9920-63 Ave.
Edmonton, AB, T6E 0G9, Canada
(780) 414-6373, FAX:(780) 414-6376
stevenb@aciacoustical.com
Sustaining Subscriber

ACO Pacific Inc.
Mr. Noland Lewis
2604 Read Ave.
Belmont, CA, 94002, USA
(650) 595-8588, FAX:(650) 591-2891
acopac@acopacific.com
Sustaining Subscriber

Acoustec Inc.
Dr. J.G. Migneron
1381 rue Galilée
Suite 103
Québec, QC, G1P 4G4, Canada
(418) 682-2331, FAX:(418) 682-1472
courrier@acoustec.qc.ca
Sustaining Subscriber, Interest:1,2,6

Acoustik GE Inc.
M. Gilles Elhadad
5715 Kincourt
Cote St Luc, QC, H4W 1Y7, Canada
(514) 487 7159, FAX:(514) 487 9525
ge@acoustikge.com
Sustaining Subscriber

Acoutherm Insulation Ltd.
704 Garyray Drive
Weston, ON, M9L 1R3, Canada
(416) 744-0191, FAX:(416) 744-6189
Direct Subscriber, Interest:1,5,7

Aercoustics Engineering Ltd
Mr. John O'Keefe
50 Ronson Drive, Suite 127
Rexdale, ON, M9W 1B3, Canada
(416) 249-3361, FAX:(416) 249-3613
aercoustics@aercoustics.com
Sustaining Subscriber, Interest:1,2,3,4,6,10

Akakpo Agbago
NRC / ILTG
Ottawa, ON, K1A 0R6, Canada
(819) 934-3904
Akakpo.Agbago@nrc-cnrc.gc.ca
Member

Alberta Energy & Utilities Board
Library
640 5 Ave
Calgary, AB, T2P 3G4, Canada
Indirect Subscriber

Katherine Albion
University of Western Ontario
Thompson Engineering Bldg
London, ON, N6A 5B9, Canada
kjalbion@uwo.ca
Student member

Salem Al-Hertil
239 Covington Cl NE
Calgary, AB, T3K 4L8, Canada
(403) 292 7945, FAX:(403) 292-7782
salem.hertil@atconoise.com
Member, Interest:2,5,6

Kachina Allen
315 W33rd Street
New York, NY, 10001, USA
(917) 779-8579
kachina_allen@yahoo.com
Student Member, Interest:5,10

Dr. D.L. Allen
Vibron Limited
1720 Meyerside Dr.
Mississauga, ON, L5T 1A3, Canada
(416) 670-4922, FAX:(416) 670-1698
Member, Interest:1,2,6

Mr. Chris Andrew
30 Grovepark St.
Richmond Hill, ON, L4E 3L5, Canada
(905) 773-9837
candrew@aci.on.ca
Member, Interest:1,2

Horst Arndt
Consultant
6 Old Forest Crescent
Kitchener, ON, N2N 2A3, Canada
(519) 742-1313
harndt1636@rogers.com
Member, Interest:4,5,7,8

G. Robert Arrabito
DCIEM
P.O. Box 2000
1133 Sheppard Ave. West
Toronto, ON, M3M 3B9, Canada
(416) 635-2033, FAX:(416) 635-2104
robbie@dciem.dnd.gc.ca
Member, Interest:5,9

Jean-Pierre Arz
Ecole de Technologie Supérieure
5011, La Fontaine
Montréal, QC, HiV 1R9, Canada
(514) 253-4934
jeanpierre_arz@yahoo.fr
Student Member

ASFETM
3565 rue Jarry Est
Bureau 202
Montréal, QC, H1Z 4K6, Canada
(514) 729-6961, FAX:(514) 729-8628
Direct Subscriber

Youssef Atalla
1533 rue de Malaga
Rock Forest, QC, J1N 1R8, Canada
(819) 821-8000x2122, FAX:(819) 821-7163
yatalla@gme.usherb.ca
Student Member, Interest:1,2,6

Noureddine Atalla
Université de Sherbrooke
G.A.U.S., Dép. génie mécanique
2500 boul. Université
Sherbrooke, QC, J1K 2R1, Canada
(819) 821-7102
Member, Interest:2,6,9

Frank Babic
John Swallow Associates Ltd
Unit 23
366 Revus Ave
Mississauga, ON, L5G 4S5, Canada
(905) 271-7888, FAX:(905) 271-1846
babic@canada.com
Member, Interest:1,2

Penelope Bacsfalvi
1957 E. 22nd Ave.
Vancouver, BC, V5N 2R2, Canada
(604) 731-9513
penelope@audiospeech.ubc.ca
Student Member, Interest:3,7,8

Ralph Baddour
55 Centre Ave., Suite 801
Toronto, ON, M5G 2H5, Canada
(416) 977-6354
rbaddour@uhnres.utoronto.ca
Student Member, Interest:2,3,10

Jeffery S. Bamford
1196 McCraney Street East
Oakville, ON, L6H 4S5, Canada
(416) 465-3378, FAX:(416) 465-9037
jBamford@EngineeringHarmonics.com
Member, Interest:2,10,11

Patrick Barriault
2630 Prospect, app 305
Sherbrooke, QC, J1J 4G2, Canada
(819) 563-4684
patrick.barriault@usherbrooke.ca
Student Member, Interest:4,7,10

Laura Anne Bateman
3325 Fulton Road
Victoria, BC, V9C 2V1, Canada
Member

Magella Bedard
1480 Laterrière, App. 13
Sherbrooke, QC, J2K 3A9, Canada
(819) 347-3511
magella.bedard@usherbroooke.ca
Student Member, Interest:4

Mr. Alberto Behar
45 Meadowcliffe Dr.
Scarborough, ON, M1M 2X8, Canada
(416) 265-1816, FAX:(416) 265-1816
behar@sympatico.ca
Member, Interest:1,2,7,8

Beijing Book Co. Inc.
701 East Linden Avenue
Linden, NJ, 07036-2495, USA
908-862-0909, FAX:(908) 862-4201
Direct subscriber

Elie Bellama
248 Lavergne St.
Ottawa, On, K1L 5E5, Canada
(613) 552-3543
e_bellama@yahoo.ca
Student Member, Interest:4,1,3

Elliott H. Berger
Aearo Company
7911 Zionsville Rd
Indianapolis, IN, 46268, USA
Member

Lucie Bériault
ADRLSSSS Montérégie
Centre de documentation
1255, rue Beauregard
Longueuil, Québec, J4K 2M3, Canada
(450) 928-6777x4137, FAX:(450) 928-6781
l.beriault@rrsss16.gouv.qc.ca
Member, Interest:2,5,7,8

Benjamin R. Biffard
University of Victoria
School of Earth and Ocean Sciences
PO Box 3055, Stn. CSC
Victoria, BC, V8W 3P6, Canada
(250) 472-4343
bbiffard@uvic.ca
Student Member, Interest:9

Steven Bilawchuk
2228 Brennan Court
Edmonton, AB, T5T 6M3, Canada
(780) 414-6373, FAX:(780) 414-6376
stevenb@aciacoustical.com
Member, Interest:1,2,10

Mr. J. Blachford
H.L. Blachford Ltd.
977 Lucien l'Allier
Montréal, QC, H3G 2C3, Canada
(514) 938-9775, FAX:(514) 938-8595
jblach@blachford.ca
Member, Interest:2

Chris T. Blaney
Ministry of Transportation
Planning and Environmental Office
3rd Floor, Building 'D'
Downsview, ON, M3M 1J8, Canada
(416) 235-5561, FAX:(416) 235-4940
Chris.Blaney@MTO.GOV.ON.CA
Member, Interest:2,6

Stephen Bly
Health Canada
Radiation Protection Bureau
775 Brookfield Rd., Room 228A
Ottawa, ON, K1A 1C1, Canada
(613) 954-0308, FAX:(613) 941-1734
stephen_bly@hc-sc.gc.ca
Member, Interest:2,3

The Boeing Company
62-LF / Renton Technical Library
P.O. Box 3707
Seattle, WA, 98124-2207, USA
Indirect Subscriber

Eugene H. Bolstad
51 Arcand Drive
St. Albert, AB, T8N 5V1, Canada
(780) 458-3140, FAX:(780) 458-1560
Member Emeritus, Interest:1,2,6

Matt Borland
22682 Hyde Park Road
Ilderton, ON, N0M 2A0, Canada
Student Member, Interest:2,4,10

Jenn Bouchard
University of Western Ontario
Biological & Geological Sciences
London, ON, N6A 5B7, Canada
jboucha2@uwo.ca
Student member

Mr. P.G. Bowman
Union Gas Ltd.
P.O. Box 2001
50 Keil Dr. North
Chatham, ON, N7M 5M1, Canada
(519) 436-4600x2873, FAX:(519) 436 5292
pbowman@uniongas.com
Member, Interest:2

J.S. Bradley
National Research Council Canada
Institute for Research in Construction
Acoustics Lab., Building M-27
Ottawa, ON, K1A 0R6, Canada
(613) 993-9747, FAX:(613) 954-1495
john.bradley@nrc-cnrc.gc.ca
Member, Interest:1,2,4

Dr. A.J. Brammer
4792 Massey Lane
Ottawa, ON, K1J 8W9, Canada
(613) 744-5376, FAX:(613) 744-4023
Member, Interest:2,5,6

Lauren Briens
University of Western Ontario
Faculty of Engineering
London, ON, N6A 5B9, Canada
lbriens@uwo.ca
Member

British Library
Acquisitions Unit (DSC-AO)
Boston Spa
Wetherby - W Yorks, LS23 7BQ, ENGLAND
Indirect Subscriber

Mr. David W. Brown
Brown Strachan Assoc.
Two Yaletown Sq.
1290 Homer St.
Vancouver, BC, V6B 2Y5, Canada
(604) 689-0514, FAX:(604) 689-2703
Member, Interest:1,2,6

Bruel & Kjaer North America Inc.
Mr. Andrew Khoury
6600 Trans Canada Highway, Suite 620
Pointe-Claire, QC, H9R 4S2, Canada
(514) 695-8225, FAX:(514) 695-4808
Sustaining Subscriber

Julie Buchan
Queen's University
Dept. of Psychology
62 Arch Street
Kingston, ON, K7L 3N6, Canada
(613) 533-6275
2jnb@qlink.queensu.ca
Student Member, Interest:8

Ellen Buchan
Alberta Infrastructure
Technical ServicesBranch
3rd Floor, 6950-113 Street
Edmonton, AB, T6H 5V7, Canada
(780) 422-1847, FAX:(780) 422-7474
ellen.buchan@gov.ab.ca
Member, Interest:1,2,3

Mr. Claudio Bulfone
531 - 55A St.
Delta, BC, V4M 3M2, Canada
(604) 943-8224, FAX:(604) 666-3982
bulfonc@tc.gc.ca
Member, Interest:1,2,6

Corjan Buma
10408 - 36 Ave.
Edmonton, AB, T6J 2H4, Canada
(780) 984-2862, FAX:(780) 465-2862
bumacj@superiway.net
Member, Interest:1,2,4

Todd Busch
Colin Gordon & Associates
883 Sneath Lane, Suite 150
San Bruno, CA, 94066, USA
(650)-358-9577, FAX:(650) 358-9430
todd.busch@colingordon.com
Member, Interest:2,6,10

Charlene Buske
National Capital Engineering
202-100 Craig Henry Drive
Ottawa, ON, K2G 5W3, Canada
(613) 228-8654, FAX:(613) 228-5453
charlene.buske@nceltd.com
Member, Interest:2

C S I,I894
Direction Mediatheque - Physique
30 avenue Corentin Cariou
75930 Paris Cedex 19, FRANCE
Indirect Subscriber

Mr. Angelo J. Campanella
Campanella Assoc.
3201 Ridgewood Drive
Columbus, OH, 43026-2453, USA
(614) 876-5108, FAX:(614) 771-8740
a.campanella@worldnet.att.net
Member, Interest:1,3,5

William J. Cavanaugh
Cavanaugh Tocci Assoc. Inc.
3 Merifield Lane
Natick, MA, 01760, USA
(978) 443-7871, FAX:(978) 443-7873
wcavanaugh@cavtocci.com
Member, Interest:1,2,5,6

Dora Chan
155 Sandarac Pl. N.W.
Calgary, AB, T3K 2Y6, Canada
(403)-274-5160
dhhchan@hotmail.com
Student Member, Interest:4,5,8

Watson Chan
8565 Odessa
Brossard, QC, J4Y 3C3, Canada
(514) 808-2377
watsonchan@icgmail.com
Student Member

David M.F. Chapman
Defence Research Establishment Atlantic
P.O. Box 1012
Dartmouth, NS, B2Y 3Z7, Canada
(902) 426-3100, FAX:(902) 426-9654
dave.chapman@drea.dnd.ca
Member, Interest:9,4

N. Ross Chapman
University of Victoria
School of Earth & Ocean Sciences
P.O. Box 3055
Victoria, BC, V8W 3P6, Canada
chapman@uvic.ca
Member, Interest:9

Brian Chapnik
HGC Engineering Ltd.
2000 Argentia Rd.
Plaza One, Suite 203
Mississauga, ON, L5N 1P7, Canada
(905) 826-4044, FAX:(905) 826-4940
chapnik@me.me.utoronto.ca
Member, Interest:2,5,7

Mr. Marshall Chasin
34 Bankstock Dr.
North York, ON, M2K 2H6, Canada
(416) 733-4342
marshall.chasin@rogers.com
Member, Interest:2,5,6

M. Cheesman
University of Western Ontario
Dept. Communication Sciences & Disorders
Faculty of Health Sciences, Elborn College
London, ON, N6G 1H1, Canada
(519) 661-2111x82214, FAX:(519) 661-3805
cheesman@uwo.ca
Member, Interest:5,7,8

Zhenhe Chen
University of Western Ontario
Faculty of Engineering
London, ON, N6A 5B9, Canada
zchen56@uwo.ca
Student member

Ping Chen
1502 - 1201 Marinaside Crescent
Vancouver, BC, V6Z 2V2, Canada
(604) 988-2508, FAX:(604) 988-7457
ping_calgary@yahoo.com
Member

Mark Cheng
Vancouver Int.l Airport Authority
P.O. Box 23750 Airport Postal Outlet
Richmond, BC, V7B 1Y7, Canada
(604) 276-6366, FAX:(604) 276-6699
mark_cheng@yvr.ca
Member

Wladyslaw Cichocki
University of New Brunswick
Dept. of French
Fredericton, NB, E3B 5A3, Canada
(506) 447-3236, FAX:(506) 453-3565
cicho@unb.ca
Member, Interest:8

CISTI
Serials Acquisition
National Research Council Canada
Ottawa, ON, K1A 0S2, Canada
Indirect Subscriber

David Cmar
Phase TO of Canada
860 Minto
Windsor, ON, N9J 3M1, Canada
(519) 734-7001, FAX:(519) 734-7009
davecmar@phaseto.com
Member, Interest:1,2,7

Mr. John B. Codrington
Acres International Ltd.
4342 Queen Street
Niagara Falls, ON, L2E 6W1, Canada
(905) 374-5200, FAX:(905) 374-1157
jcodrington@acres.com
Member, Interest:2,6

Dr. Annabel J. Cohen
University of Prince Edward Island
Dept. of Psychology
Charlottetown, PE, C1A 4P3, Canada
(902) 628-4331, FAX:(902) 628-4359
acohen@upei.ca
Member, Interest:4,5,7,8

Jeff Collins
DND - Royal Military College
1143 Wintergreen Crescent
Kingston, ON, K7P 2G5, Canada
(613) 389-5704
jeff.collins@rmc.ca
Student Member

Nicole Collison
DRDC Atlantic
9 Grove St.
PO Box 1012
Dartmouth, NS, B2Y 3Z7, Canada
(902) 426-3100x394, FAX:(902) 426-9654
nicole.collison@drdc-rddc.gc.ca
Member, Interest:3,9,10

Maureen Connelly
1614 W 65th Ave.
Vancouver, BC, V6P 2R3, Canada
(604) 451 7029, FAX:(604) 454-0348
maureen_connelly@bcit.ca
Member, Interest:1,2

Brian Csermak
Gennum Corp.
970 Fraser Drive
Burlington, ON, L7L 5P5, Canada
(905) 632-2999
Member

Dr. Lola Cuddy
Queen's University
Dept. of Psychology
Kingston, ON, K7L 3N6, Canada
(613) 533-6013, FAX:(613) 533-2499
cuddyl@psyc.queensu.ca
Member, Interest:4,5,7

Dr. Gilles Daigle
National Research Council Canada
Inst. for Microstructural Science
Ottawa, ON, K1A 0R6, Canada
613-993-6188, FAX:(613) 952-3670
gilles.daigle@nrc.gc.ca
Member, Interest:3,2

Dalimar Instruments Inc.
Mr. Daniel Larose
193 Joseph Carrier
Vaudreuil-Dorion, QC, J7V 5V5, Canada
(514) 424-0033, FAX:(514) 424-0030
daniel@dalimar.ca
Sustaining Subscriber, Interest:1,4,5

Davidson & Associés Inc.
12 Lafleur St. N
St-Sauveur, QC, J0R 1R0, Canada
(450) 227-4248, FAX:(450) 227-1613
Direct Subscriber, Interest:1,2,6

Peter Davis
Faszer Farquharson & Associates Ltd.
Suite 304
605 - 1st Street S.W.
Calgary, AB, T2P 3S9, Canada
(403) 508-4996, FAX:(403) 508-4998
ffa@telusplanet.net
Member, Interest:2,4,5

Jack L. Davis
6331 Travois Crescent NW
Calgary, AB, T2K 2S8, Canada
Member, Interest:2,7

Nico F. Declercq
Stationsstraat 189
, B-8540, Belgium
+32 9 264 3436
declercq@ieee.org
Member, Interest:3,9,10

Carolyn Decock
Golder Associates
1000, 940-6th Ave SW
Calgary, AB, T2P 3T1, Canada
(403) 260-2242, FAX:(403) 299-5606
cdecock@golder.com
Member, Interest:2,6,9

David DeGagne
Alberta Energy and Utilities Board
640 - 5th Ave. SW
Calgary, AB, T2P 3G4, Canada
(403) 297-3200, FAX:(403) 297-3520
david.degagne@gov.ab.ca
Member, Interest:2,11

Francine Desharnais
DRDC Atlantic
P.O. Box 1012
Dartmouth, NS, B2Y 3Z7, Canada
(902) 426-3100x219, FAX:(902) 426-9654
desharnais@drdc-rddc.gc.ca
Member, Interest:9

Jay Detsky
42 Misty Crescent
Toronto, ON, M3B 1T3, Canada
(416) 443-0889
jay.detsky@rogers.com
Student Member

Jan Dettmer
University of Victoria
School of Earth & Ocean Sciences
Victoria, BC, V8W 3P6, Canada
(250) 472-4342
jand@uvic.ca
Student Member

Terry J. Deveau
3 Shore Road
Herring Cove, NS, B3V 1G6, Canada
(902) 481-3541, FAX:(902) 468-7795
deveau@chebucto.ns.ca
Member, Interest:3,9,10

Andrew Dimitrijevic
5804 Fairview Ave. Ste 205
Vancouver, BC, V6T 1Z3, Canada
(604) 822-7424, FAX:(604) 822-6569
andrew@audiospeech.ubc.ca
Member, Interest:5,7,8

Heping Ding
National Research Council Canada
IMS, Acoustics & Signal Processing Group
Bldg. M-36, 1200 Montreal Rd.
Ottawa, ON, K1A 0R6, Canada
(613) 991-2601, FAX:(613) 952-3670
heping.ding@nrc-cnrc.gc.ca
Member, Interest:2,5,10

Borko Djurkovic
University of New Brunswick
Physics, 8 Bailey Drive
Fredericton, NB, E3B 5A3, Canada
borkod@gmail.com
Student member

Dodge-Regupol
Mr. Paul Downey
33 Craighurst Avenue
Toronto, ON, M4R 1J9, Canada
(416) 440-1094, FAX:(416) 440-0730
pcd@regupol.com
Sustaining Subscriber, Interest:1,2,6

Stan Dosso
University of Victoria
School of Earth and Ocean Sciences
P.O. Box 3055
Victoria, BC, V8W 3P6, Canada
(250) 472-4341, FAX:(250) 721-4620
sdosso@uvic.ca
Member, Interest:9,10,11

DRDC Atlantic
Library
P.O. Box 1012, 9 Grove St
Dartmouth, NS, B2Y 3Z7, Canada
Indirect Subscriber

Teresa Drew
1000, 940-6th Avenue SW
Calgary, AB, T2P 3T1, Canada
((403) 532-5768, FAX:(403) 299-5606
Teresa_Drew@Golder.com
Member, Interest:1,2,11

Guangsheng Du
210 Oak St. Apt. 701
Toronto, ON, M5A 2C9, Canada
(416) 214-5865, FAX:(416) 214-5865
dugs1968@yahoo.com
Member, Interest:2,1,10

Kirsten Dugdale
RR#5, STN. LCD 1
Calgary, AB, T2P 2G6, Canada
Student Member

Bruce Dunn
University of Calgary
Dept of Psychology
2500 University Dr. NW
Calgary, AB, T2N 1N4, Canada
(403) 220-5218, FAX:(403) 282-8249
Member, Interest:2,5

Allyson Dykstra
52 Essex Street
London, ON, N6G 1B2, Canada
apage2@uwo.ca
Student member

Audny T. Dypvik
3208-27 Street S.W.
Calgary, AB, T3E 2G8, Canada
(403)-246-4096
atdypvik@ucalgary.ca
Student Member, Interest:5,7,8

Earth Tech Canada Inc.
Ms. Deborah Olsen
105 Commerce Valley Dr. W. 7th Fl
Markham, ON, L3T 7W3, Canada
(905) 886-7022x2209, FAX:(905) 886-9494
noisevibration@earthtech.ca
Sustaining Subscriber

Stuart Eaton
Workers' Compensation Board of BC
Engineering, Prevention Div.
PO Box 5350, Stn Terminal
Vanccouver, BC, V6B 5L5, Canada
(604) 276-3210, FAX:(604) 279-7407
seaton@wcb.bc.ca
Member, Interest:1,2,3

Eckel Industries of Canada Ltd.
Mr. Blake Noon
P.O. Box 776
Morrisburg, ON, K0C 1X0, Canada
(613) 543-2967, FAX:(613) 543-4173
eckel@eckel.ca
Sustaining Subscriber, Interest:1,2

Prof. M. David Egan
P.O. Box 365
Anderson, SC, 29622-0365, USA
(864) 226-3832
Member, Interest:1,2,4

Dr. Jos J. Eggermont
University of Calgary
Dept. of Psychology
2500 University Drive NW
Calgary, AB, T2N 1N4, Canada
(403) 220-5214, FAX:(403) 282-8249
eggermon@acs.ucalgary.ca
Member, Interest:5,7,8

Gilles Elhadad
Acoustik GE Inc
5715 Kincourt
Cote St Luc, QC, H4W 1Y7, Canada
(514) 487-7159, FAX:(514) 487-9525
ge@acoustikge.com
Member, Interest:1,2

Dr. Dale D. Ellis
DRDC Atlantic
P.O. Box 1012
Dartmouth, NS, B2Y 3Z7, Canada
(902) 426-3100x104, FAX:(902) 426-9654
dale.ellis@drdc-rddc.gc.ca
Member, Interest:3,9

Maha Elsabrouty
University of Ottawa
800 King Edward
Ottawa, ON, K1N 6N5, Canada
(613) 562-5800x6140
melsabro@site.uottawa.ca
Student Member

Engineering Elsevier
PO Box 830470
Birmingham, AL, 35283, USA
Indirect Subscriber

Fabra Wall Ltd.
P.O. Box 5117, Station E
Edmonton, AB, T5P 4C5, Canada
(403) 987-4444, FAX:(403) 987-2282
fabrawall@fabra-wall.ab.ca
Direct Subscriber, Interest:1,5,10

Fakultet Elektrotehnike I Racunarstva
Knjiznica
Unska 3
Zagreb, 10,000, CROATIA
, FAX:+385-1-2335-956
Sonja.bijelic@algoritam.hr
indirect subscriber

Omar Falou
Ryerson University
Dept. of Computer Science
350 Victoria Street
Toronto, ON, M5B 2K3, Canada
ofalou@ryerson.ca
Student Member, Interest:3,9,11

James Farquharson
Faszer Farquharson & Associates Ltd.
Suite 304
605 - 1st Street S.W.
Calgary, AB, T2P 3S9, Canada
(403) 508-4996, FAX:(403) 508-4998
ffa@telusplanet.net
Member, Interest:1,2,4

Clifford Faszer
Faszer Farquharson & Associates Ltd.
Suite 304
605 - 1st Street S.W.
Calgary, AB, T2P 3S9, Canada
(403) 508-4996, FAX:(403) 508-4998
ffa@telusplanet.net
Member, Interest:1,2,6

Andrew Faszer
Flat 41 Churchill College
Storey's Way
Cambridge, CB3 005, United Kingdom
44 1223 742311, FAX:+44 1223 337596
acf40@cam.ac.uk
Student Member, Interest:1,2

Dr. G. Faulkner
University of Alberta
Dept. of Mechanical Engineering
Edmonton, AB, T6G 2G8, Canada
(403) 492-3446, FAX:(403) 492-2200
gary.faulkner@ualberta.ca
Member, Interest:1,2,6

Mr. James L. Feilders
Jade Acoustics Inc.
545 N Rivermede Rd., Suite 203
Concord, ON, L4K 4H1, Canada
(905) 660-2444, FAX:(905) 660-4110
jim@jadeacoustics.com
Member, Interest:1,2,6

Vincent Ferraro
Daley Ferraro Associates
2720 Queensview Drive
Ottawa, ON, K2B 1A5, Canada
(613) 726-2939
vincent .ferraro@dfa-hovey.com
Member

Raymond Fischer
Noise Control Eng. Inc.
799 Middlesex Turnpike
Billerica, MA, 01821, USA
(978) 670-5339, FAX:(978) 667-7047
nonoise@noise-control.com
Member, Interest:1,2,9

Fisheries and Oceans Canada
Library, Pacific Biological Station
3190 Hammond Bay Rd.
Nanaimo, BC, V9T 6N7, Canada
Indirect Subscriber

John E.K. Foreman
1717 Phillbrook Cresc.
London, ON, N5X 2Z5, Canada
(519) 672-3689, FAX:(519) 672-3689
jekf0222@aol.com
Member Emeritus, Interest:2,5

Harold Forester
1434 Franklin Dr.
Laval, QC, H7W 1K6, Canada
(450) 681-2333, FAX:(450) 681-2354
forester@videotron.ca
Member, Interest:1,2,6

Chris Forrester
Research in Motion
305 Phillip St.
Waterloo, ON, N2L 3W8, Canada
(519) 888-7465
cforrester@rim.com
Member

Mr. Stanley Forshaw
3958 Sherwood Rd.
Victoria, BC, V8N 4E6, Canada
(250) 721-4075
Member, Interest:8

Dr. Claude R. Fortier
State of the Art Acoustik Inc
Suite 43
1010 Polytek St.
Ottawa, ON, K1J 9J3, Canada
(613) 745-2003, FAX:(613) 745-9687
Member, Interest:1,2,5

Dany Francoeur
2019 Galt Ouest, #4
Sherbrooke, QC, J1K 1J9, Canada
(819) 565-2918
dany.francoeur@usherbooke.ca
Student Member, Interest:2,6

Mr. Leslie Frank
HFP Acoustical Consultants Corp.
1140, 10201 Southport Rd. SW
Calgary, AB, T2W 4X9, Canada
(403) 259-3600, FAX:(403) 259-4190
les@hfpacoustical.com
Member, Interest:1,5,6

Karen Fraser
City of Brampton
2 Wellington St. West, 5th Floor
Brampton, ON, L6Y 4R2, Canada
(905) 874-2489, FAX:(905) 874-2599
karen.fraser@brampton.ca
Member

Ron Freiheit
Wenger Corp.
555 Park Dr.
Owatonna, MN, 55060, USA
(507) 455-4100x139, FAX:(507) 455-4258
ron.freiheit@wengercorp.co,
Member, Interest:1,4,5

Anthony E. Frost
18 Marcot Road
Solihull, West Midlands, B927PP, United Kingdom
+44 7963 639731
anthony.frost1@hotmail.com
Member, Interest:1,4

Kathy Fuller
University of Toronto at Mississauga
Dept. of Psychology
3359 Mississauga Rd.
Mississauga, ON, L5L 1C6, Canada
(905) 828-3865, FAX:(905) 569-4326
kpfuller@utm.utoronto.ca
Member, Interest:5,7,8

W. Robert J. Funnell
McGill University
Biomedical Engineering & Otolaryngology
3777, rue University
Montréal, QC, H3A 2B4, Canada
(514)-398-6739, FAX:(514) 398-7461
robert.funnell@mcgill.ca
Member, Interest:5

Mr. V. Gambino
Aercoustics Engineering Ltd
Suite 165
50 Ronson Dr.
Rexdale, ON, M9W 1B3, Canada
(416) 249-3361
vince.gambino@aercoustics.com
Member, Interest:1,2,4,6

Dr. Robert Gaspar
Spaarg Engineering Limited
Noise and Vibration Analysis
822 Lounsborough Street
Windsor, ON, N9G 1G3, Canada
(519) 972-0677, FAX:(519) 972-1811
gasparr@engn.uwindsor.ca
Member, Interest:1,2,6

Mr. Wm. Gastmeier
HGC Engineering Ltd.
Plaza One, Suite 203
2000 Argentia Rd.
Mississauga, ON, L5N 1P7, Canada
(905) 826-4044, FAX:(905) 826-4940
bgastmeier@hcgengineering.com
Member, Interest:1,2,6

Philippe-Aubert Gauthier
51 8e avenue sud
Sherbrooke, Québec, J1G 2P6, Canada
(819) 347-1127
philippe_aubert_gauthier@hotmail.com
Student Member, Interest:2,4,6

Dr. David B. Gerhard
University of Regina
Department of Computer Science
3737 Wascana Parkway
Regina, SK, S4S 0A2, Canada
(306)-585-5227, FAX:(306) 585-4745
david.gerhard@uregina.ca
Member, Interest:4,5,8

Sebastien Ghinet
Université de Sherbrooke
Dép. génie mécanique
2500 boul. Université
Sherbrooke, QC, J1K 2R1, Canada
(819) 821-8000x3152, FAX:(819) 821-7163
Sebastien.Ghinet@usherbrooke.ca
Student Member, Interest:1,2,10

Bryan Gick
University of British Columbia
Dept. of Linguistics
E270 - 1866 Main Mall
Vancouver, BC, V6T 1Z1, Canada
(604) 822-4817, FAX:(604) 822-9687
gick@interchange.ubc.ca
Member, Interest:8

Mr. Hazem Gidamy
S.S. Wilson & Assoc.
15 Wertheim Court, Suite 211
Richmond Hill, ON, L4B 3H7, Canada
(905) 707-5800, FAX:(905) 707-5801
admin@sswilsonassociates.com
Member, Interest:1,5,7

Mr. Philip Giddings
Engineering Harmonics
29A Leslie Street
Toronto, ON, M4M 3C3, Canada
(416) 465-3378, FAX:(416) 465-9037
pgiddings@engineeringharmonics.com
Member, Interest:1,4,5

Christian Giguere
Université d'Ottawa
Programme d'audiologie et d'orthophonie
451 chemin Smyth
Ottawa, ON, K1H 8M5, Canada
(613) 562-5800x4649, FAX:(613) 562-5428
cgiguere@uottawa.ca
Member, Interest:5,7,8

Annie Gilbert
7633 10e avenue, app.02
Montreal, QC, H2A 3B3, Canada
(514) 374-7721
annie.gilbert@umontreal.ca
Student Member, Interest:5,7,8

Pat Giles
MAXXON Corporation
920 Hamel Rd P.O. Box 253
Hamel, MN, 55340, USA
(763) 478-9600, FAX:(763) 478-2431
monica@maxxon.com
Member

Dalila Giusti
Jade Acoustics Inc.
545 N Rivermede Rd., Suite 203
Concord, ON, L4K 4H1, Canada
(905) 660-2444, FAX:(905) 660-4110
dalila@jadeacoustics.com
Member, Interest:1,2,6

Carrie Gotzke
University of Alberta
Speech Pathology & Audiology
2-70 Corbett Hall
Edmonton, AB, T6G 2G4, Canada
Student Member

Bradford N. Gover
National Research Council Canada
Institute for Research in Construction
Ottawa, ON, K1A 0R6, Canada
(613) 993-7985, FAX:(613) 954-1495
brad.gover@nrc-cnrc.gc.ca
Member, Interest:1,2,10

David Grainger
University of Western Ontario
National Centre for Audiology
Elborn College - 2262, 1201 Western Road
London, ON, N6G 1H1, Canada
(519) 661-2111x86054, FAX:(519) 661-3805
dgrainge@nca.uwo.ca
Member, Interest:2,7

David Green
NRC / IIT
Building M-50, 1200 Montreal Rd.
Ottawa, ON, K1A 0R6, Canada
(613) 993-6572, FAX:(613) 952-0215
dave.green@nrc-cnrc.gc.ca
Member, Interest:10

Emmanuelle Gros
463 Galt Ouest
Sherbrooke, QC, J1H 1Y5, Canada
(819) 346-6842, FAX:(819) 821-7163
emmanuelle.gros@Usherbrooke.ca
Student Member, Interest:1,2,5

Mr. Manfred W. Grote
ARCOS Acoustical Cons. Ltd.
101 - 1400 Kensington Rd. NW
Calgary, AB, T2N 3P9, Canada
(403) 283-1191, FAX:(403) 283-1125
arcos@oanet.com
Member, Interest:1,2,5

Roberto Guadagno
Brampton Audiology
Suite 106
36 Vodden St. E
Brampton, ON, L6V 4H4, Canada
(905) 874-1170, FAX:(905) 874-4785
rob@bramptonaudiology.com
Member, Interest:5,7,8

J. Michel Guevremont
Specmont Inc.
625 Rue du Parc-industriel
Longueuil, PQ, J4H 3V7, Canada
(450) 449-2545, FAX:(450) 449-0322
specmont@specmont.com
Member

Dr. Jingnan Guo
Worksafe Western Australia
Dept. Consumer & Employment Protection
Westcentre 1260 Hay St.,
West Perth, WA 6005, Australia
081 93278777
jing@mech.uwa.edu.au
Member, Interest:1,2,10

Claire Gurski
509-880 Kipps Lane
London, ON, N5Y 5K4, Canada
mchough@uwo.ca
Student member

H.L. Blachford Ltd.
Mr. Dalton Prince
2323 Royal Windsor Dr.
Mississauga, ON, L5J 1K5, Canada
(905) 823-3200, FAX:(905) 823-9290
amsales@blachford.ca
Sustaining Subscriber, Interest:1,2,6

Sean Farzin Hadavand
5 Concorde Place, Apt 1903
Toronto, ON, M3C 3M8, Canada
(416) 441-0884, FAX:(416) 444-2822
sean.hadavand@bksv.com
Member, Interest:2,4,6

Peter Hanes
National Research Council Canada
INMS
Bldg M-36
Ottawa, ON, K1A 0R6, Canada
(613) 998-1282, FAX:(613) 998-5396
peter.hanes@nrc-cnrc.gc.ca
Member, Interest:4,6,11

Jean-Francois Hardy
780 de Rougemont, #6
Sainte-Foy, QC, G1X 2M2, Canada
(418) 659-2385
jean-francois.hardy.1@ulaval.com
Student Member, Interest:1,4

Harriet Irving Library
University of New Brunswick
P.O. Box 7500
Fredericton, NB, E3B 5H5, Canada
Indirect Subscriber

Hatch Associates Ltd.
Mr. Tim Kelsall
Sheridan Science & Technology Park
2800 Speakman Dr.
Mississauga, ON, L5K 2R7, Canada
(905) 403-3932, FAX:(905) 855-8270
tkelsall@hatch.ca
Sustaining Subscriber, Interest:1,2

Jennifer Hatton
7346 112th Street
Delta, BC, V4C 4V7, Canada
(778) 837-9944
jhatton@interchange.ubc.ca
Student Member, Interest:5,7

Dr. David I. Havelock
National Research Council Canada
IMS, Acoustics & Sig. Proc. Grp.
Bldg. M-36, Montreal Road
Ottawa, ON, K1A 0R6, Canada
(613) 993-7661, FAX:(613) 952-3670
david.havelock@nrc.ca
Member, Interest:10

Richard Hedges, P.Eng
13 Pioneer Way
Cambridge, ON, N1R 5S7, Canada
(519) 622-9453
rhedges@netscape.ca
Member, Interest:2,6,11

Antje Heinrich
University of Toronto at Mississauga
Dept. of Psychology
3359 Mississauga Road
Mississauga, ON, L5L 1C6, Canada
(905) 828-5433
aheinric@utm.utoronto.ca
Student Member

HGC Engineering Ltd.
Mr. Bill Gastmeier
Plaza One, Suite 203
2000 Argentia Rd.
Mississauga, ON, L5N 1P7, Canada
(905) 826-4044, FAX:(905) 826-4940
info@hgcengineering.com
Sustaining Subscriber

Gaston L.M. Hilkhuysen
Audiology, Dept. Otolaryngology
VU University Medical Center
De Boelelaan 1117
Amsterdam, 1081HV, The NETHERLANDS
+3120444 0963
G.Hilkhuysen@VUMC.nl
Student Member

Mr. Ralph K. Hillquist
The Viking Consultancy
P.O. Box 38
Benzonia, MI, 49616, USA
(231) 882-0234, FAX:(231) 882-0234
rkhillquist@chartermi.net
Member, Interest:1,2,6

Dr. Megan Hodge
University of Alberta
Speech Pathology & Audiology
Rm 2-70 Corbett Hall
Edmonton, AB, T6G 2G4, Canada
(780) 492-5898, FAX:(780) 492-9333
megan.hodge@ualberta.ca
Member, Interest:8

Dr. Murray Hodgson
University of British Columbia
School of Occ. & Env. Hygiene
2206 East Mall, 3rd Fl.
Vancouver, BC, V6T 1Z3, Canada
(604) 822-3073, FAX:(604) 822-9588
hodgson@mech.ubc.ca
Member, Interest:1,2,7

Joe Hood
Macdonald Detwiler
Ste. 60, 1000 Windmill Road
Halifax, NS, B3B 1L7, Canada
(902) 481-3560
jhood@halifax.mda.ca
Member

Dr. Kirill V. Horoshenkov
University of Bradford
Great Horton Road
Bradford, BD7 1DP, UK
+44(0)1274 233867
K.Horoshenkov@bradford.ae.uk
Member

Mr. Brian Howe
HGC Engineering Ltd.
Plaza One, Suite 203
2000 Argentia Rd.
Mississauga, ON, L5N 1P7, Canada
(905) 826-4044, FAX:(905) 826-4940
bhowe@hgcengineering.com
Member, Interest:1,2,6

Lin Hu
Forintek Canada Corp.
319 rue Franquet
Ste-Foy, QC, G1P 4R4, Canada
(418) 659-2647, FAX:(418) 659-2922
lin.hu@qc.forintek.ca
Member, Interest:1,2,3

Christopher Hugh
Hatch Associates
2800 Speakman drive
Mississauga, ON, L5K 2R7, Canada
(905) 403-3706, FAX:(905) 855-8270
CHUGH@hatch.ca
Member, Interest:1,2,6

Daniel Hutt
Defence Research Establishment Atlantic
P.O. Box 1012
Dartmouth, NS, B2Y 3Z7, Canada
(902) 426-3100x218, FAX:(902) 426-9654
daniel.hutt@drdc-rddc.gc.ca
Member, Interest:9,10

Hydro-Quebec
M. Blaise Gosselin
Ligne, Cable et environnement
800 de Maisonneuve est, 21e etage
Montréal, QC, H2L 4M8, Canada
(514) 840-3000x5134, FAX:(514) 840-3137
gosselin.blaise@hydro.qc.ca
Sustaining Subscriber, Interest:1,2,6

I 894
EBSCO FRANCE
(BNF/LIBRES-A/PARIS / 22392823)
SCE GROUPAGE
91763 Palaiseau Cedex, FRANCE
Indirect Subscriber

INSPEC- Inst.of Electrical Engineers
Acquisitions - Michael Faraday House
Six Hills Way
Stevenage, SG1 2AY, ENGLAND
Indirect Subscriber

Integral DX Engineering Ltd.
Mr. Greg Clunis
907 Admiral Ave.
Ottawa, ON, K1Z 6L6, Canada
(613) 761-1565
au741@ncf.ca
Sustaining Subscriber, Interest:1,5,7

J.E. Coulter Associates Ltd.
Mr. John Coulter
1210 Sheppard Ave. E, Suite 211
Toronto, ON, M2K 1E3, Canada
(416) 502-8598, FAX:(416) 502-3473
jcoulter@on.aibn.com
Sustaining Subscriber, Interest:1,2,6

J.L.Richards & Assoc. Ltd.
Mr. Fernando Ribas
864 Lady Ellen Place
Ottawa, ON, K1Z 5M2, Canada
(613) 728-3571, FAX:(613) 728-6012
mail@jlrichards.ca
Sustaining Subscriber, Interest:1,2,7

Jade Acoustics Inc.
Ms. Dalila Giusti
545 N Rivermede Rd., Suite 203
Concord, ON, L4K 4H1, Canada
(905) 660-2444, FAX:(905) 660-4110
dalila@jadeacoustics.com
Sustaining Subscriber, Interest:1,2,6

JASCO Research Ltd.
Mr. Scott Carr
Suite 2001, 1969 Upper Water St.
Halifax, NS, B3J 3R7, Canada
(902) 491-4489, FAX:(902) 542-5250
scott@jasco.com
Sustaining Subscriber

Mary Beth Jennings
University of Western Ontario
NCA, Elborn College
London, ON, N6G 1H1, Canada
jennings@nca.uwo.ca
Student member

Dr. Yan Jia
Vienna International Centre
c/o CTBTO
P.O. Box 1250
A-1400 Vienna, Austria
0043-1-947 4858, FAX:0043-1-947 4858
yan.jia@ctbto.org
Member, Interest:3,6,9

John Swallow Associates Ltd.
Mr. John Swallow
366 Revus Ave., Unit 23
Mississauga, ON, L5G 4S5, Canada
(905) 271-7888, FAX:(905) 271-1846
jswallow@jsal.ca
Sustaining Subscriber, Interest:1,2,4

Johns Hopkins University
Milton S. Eisenhower Library
001ACF5829
Serials Dept.
Baltimore, MD, 21218, USA
Indirect Subscriber

Dr. H.W. Jones
18 Eastland Close
Swansea
Wales, SA3 5NU, United Kingdom
Member Emeritus, Interest:1,2,3

Jose A. Karivelil
Alcan
Box 1500
Jonquiere, QC, G7S 4L2, Canada
(418) 699-2111x6664, FAX:(418) 699-2993
jose.karivelil@alcan.com
Member, Interest:2,6

Stephen E. Keith
Radiation Protection Bureau, Health Canada
Acoustics, Non-ionizing Radiation Section
Rm 228, 775 Brookfield Rd., 6301B
Ottawa, ON, K1A 1C1, Canada
(613) 941-8942, FAX:(613) 941-1734
Member, Interest:1,2,5,7,10

Tim Kelsall
Hatch Associates Ltd.
Sheridan Science & Technology Park
2800 Speakman Dr.
Mississauga, ON, L5K 2R7, Canada
(905) 403-3932, FAX:(905) 855-8270
tkelsall@hatch.ca
Member, Interest:1,2

Douglas S. Kennedy
BKL Consultants Ltd.
#308-1200 Lynn Valley Rd
North Vancouver, BC, V7J 2A2, Canada
(604) 988-2508, FAX:(604) 988-7457
dkennedy@bkla.com
Member, Interest:1,2,6

Mehrdad Kermani
University of Western Ontario
Electrical & Computer Engineering Dept
London, ON, N6A 5B9, Canada
mkermani@uwo.ca
Student member

Andrew Khoury
Bruel & Kjaer North America Inc.
6600 Trans Canada Highway, Suite 620
Pointe-Claire, QC, H9R 4S2, Canada
(514) 695-8225, FAX:(514) 695-4808
andrew.khoury@bksv.com
Member

Sungyoung Kim
5525 Trent Ave., #606
Cote St-Luc, QC, H4W 2B8, Canada
(514) 486-9470
Student Member

Frances King
National Research Council Canada
IRC, Acoustics, M-27
Ottawa, ON, K1A 0R6, Canada
(613) 993-9742, FAX:(613) 954-1495
frances.king@nrc-cnrc.gc.ca
Member, Interest:1,2,10

Andrew Klassen
HTS Engineering
889 Lady Ellen Pl.
Ottawa, ON, K1Z 5L3, Canada
(613) 728-7400
andrewk@HTSENG.com
Member

Mr. John J. Kowalewski
44 East Humber Dr
King City, ON, L7B 1B6, Canada
Member, Interest:1,2,6

Dr. Steven Kraemer
T.U.V. Rheinland
344 Sheppard Ave. E., Suite 1
North York, ON, M2N 3B4, Canada
(416) 733-3677, FAX:(416) 733-7781
skraemer@us.tuv.com
Member, Interest:1,2,4

Mr. C.A. Krajewski
95 Southill Drive
Don Mills, ON, M3C 2H9, Canada
(416) 440-3590, FAX:(416) 440-6973
Member, Interest:1,2,6

Kelly Kruger
Alberta Infrastructure Building
Property Development
6950 - 113 Street, 3rd Floor
Edmonton, AB, T6H 5V7, Canada
Member, Interest:1,2,6

Mr. Verne Kucy
The Corporation of Delta
4500 Clarence Taylor Cr.
Delta, BC, V4K 3E2, Canada
(604) 946-3281, FAX:(604) 946-3240
Member, Interest:2

Perry Kuypers
2323 Royal Windsor Dr.
Mississauga, ON, L5J 1V5, Canada
(905) 823-3200, FAX:(905) 823-9290
pkuypers@blachford.com
Member, Interest:1,2,3

Hanif Ladak
University of Western Ontario
Medical Biophysics, Medical Sciences Building
London, ON, N6A 5C1, Canada
hladak@uwo.ca
Member

Michael Ladouceur
NVC - Olsonfab Ltd.
355 Balmoral Ave.
Cornwall, ON, Canada
(613) 932-1033, FAX:(613) 932-9500
mladouceur@nvcolsonfab.com
Member, Interest:2,6,10

Sylvain Lalonde, ing
Acoustifab Inc.
763 Haute-Rive
Bois-des-Filion, Québec, J6Z 4T8, Canada
(450) 621-8392, FAX:(450) 621-0473
acoustifab@sympatico.ca
Member, Interest:1, 2, 6

Stephen Lamming
Stephen Lamming Associates
4391 Harvester Road, Unit 9
Burlington, ON, L7L 4X1, Canada
(905) 681-6215, FAX:(905) 632-8330
slamming@sla-env.ca
Member, Interest:2,6

Dr. Chantal Laroche
U. d'Ottawa,.Sciences de la réadaptation
Prog. d'audiologie et d'orthophonie
Pavillon Guindon, 451 chemin Smyth, 3062
Ottawa, ON, K1H 8M5, Canada
(613) 562-5800x3066, FAX:(613) 562-5428
claroche@uottawa.ca
Member, Interest:5,6,,7,8

M. Christian Laurier
Les Conceptions Christian Laurier
3-10480 St-Denis
Montréal, QC, H3L 2J1, Canada
(514) 817-1629
LCCL@Sympatico.ca
Member, Interest:4,7

David Lawrence
CAN-CELL Industries Inc.
14715-114 Avenue
Edmonton, AB, T5M 2Y8, Canada
(780) 447-1419x337, FAX:(780) 447-1034
david.lawrence@can-cell.com
Member, Interest:1

Cécile Le Cocq
7426 Avenue de L'Epée
Montréal, Québec, H3N 2E5, Canada
(514) 277-7645
cecilelecocq@yahoo.ca
Student Member, Interest:7,8,10

Gaétan Lecours
Bombardier Produits Récréatifs Inc.
555, rue de la Montagne
Valcourt, QC, J0E 2L0, Canada
(450) 532-2211x5324, FAX:(450) 532-5109
gaetan.lecours@brp.com
Member

Gilles Leroux
Decibel Consultants Inc.
265 boul. Hymus, Suite 2500
Pointe-Claire, QC, H9R 1G8, Canada
(514) 630-4855, FAX:(514) 630-4595
gLeroux@decibel-consultants.com
Member

Anita Lewis
Alberta Energy & Utilities Board
Operations and Compliance Branch
640- 5 Avenue SW
Calgary, AB, T2P 3G4, Canada
(403)-297-3793
anita.lewis@gov.ab.ca
Member

Mr. Justin Lewis
Avar Environmental Inc.
33 King St. E., Suite 12
Dundas, ON, L9H 5R1, Canada
(905) 628-0031, FAX:(905) 627 8226
Member

Marcus Li
35 Compton Crescent
London, On, N6C 4E9, Canada
(519) 681-2443
mtwli@hotmail.com
Member, Interest:2,4,6

Chi-Nin Li
8720 Delaware Road
Richmond, BC, V7C 4Y3, Canada
(604) 722-8013
clia@sfu.ca
Student Member, Interest:8

QI LI
2-401, #1 Building, #1 Garden, LIHAI garden
LISHAN DONG Road
LAOSHAN District, Qingdao, Shandong,
Post 266061, P.R. CHINA
QiLi@SITE.uottawa.ca
Student Member

:attn: Library/Journals
USAE Engineer R&D Center
P.O. Box 9005
Champaign, IL, 61826, USA
(217) 373-7217, FAX:(217) 373-7222
Indirect Subscriber, Interest:2,5,6

Mr. A.D. Lightstone
Valcoustics Canada Ltd.
30 Wertheim Court, Unit 25
Richmond Hill, ON, L4B 1B9, Canada
(905) 764-5223, FAX:(905) 764-6813
Member, Interest:1,2,6

Linda Hall Library
Serials Department
5109 Cherry Street
Kansas City, MO, 64110, USA
Direct Subscriber

Dr. Stanley P. Lipshitz
University of Waterloo
Dept. of Applied Mathematics
Waterloo, ON, N2L 3G1, Canada
(519) 885-1211x3755, FAX:(519) 746-4319
spl@audiolab.uwaterloo.ca
Member, Interest:2,3,4,6

Alexander P. Lorimer
7 Bent Oak Circle
Mississauga, ON, L5N 4J2, Canada
(905) 542-2796
Member, Interest:1,2,6

Reginald W. Low
Sound Concepts Canada Inc.
599 Henry Avenue
Winnipeg, MB, R3A 0V1, Canada
(204) 783-6297, FAX:(204) 783-7806
customerservice@soundconceptscan.com
Member, Interest:1,2,7

Mr. David Lubman
14301 Middletown Lane
Westminster, CA, 92683, USA
(714) 898 9099, FAX:(714) 373-3050
dlubman@ix.netcom.com
Member, Interest:1,4,5

Sergio Luzzi
Ordine degli Ingegneri
della Provincia di Firenze
Via Stibbert n. 1
50134 Florence, Italy
+39 055 473887, FAX:+39 055 416835
sergio.luzzi@tin.it
Student Member

Ning MA
University of Ottawa
800 King Edward
Ottawa, ON, K1N 6N5, Canada
(613) 562-5800x6140
NMA@site.uottawa.ca
Student Member

Vahid Madani
Downing College
Regent Street
Cambridge, CB2 1DQ, UK
+44 1223 332709, FAX:+44 1223 332662
VM247@cam.ac.uk
Student Member, Interest:2,10,6

Denise Mallette
I.R.S.S.T. - Informathèque
11e étage
505 boul de Maisonneuve O
Montréal, QC, H3A 3C2, Canada
(514) 288-1551, FAX:(514) 288-6097
mallette.denise@irsst.qc.ca
Member

Pierre Marcotte
IRSST
505, boul de Maisonneuve Ouest
Montréal, Qc, H3A 3C2, Canada
(514) 288-1551x251
Marcotte.Pierre@IRSST.qc.ca
Member

Christian Martel
Octave Acoustique Inc.
963, chemin Royal
Saint-Laurent-de-l'Ile-d'Orleans, QC, G0A 3Z0, Canada
(418) 828-0001, FAX:(418) 828-0002
octave@videotron.ca
Member, Interest:1,2,4

Patrice Masson
3755 Impériale
Rock Forest, QC, J1N 3W4, Canada
(819) 821-8000x3106, FAX:(819) 821-7163
patrice.masson@mge.usherb.ca
Member, Interest:2,3,6,10

Igor Mastikhin
University of New Brunswick
Physics, 8 Bailey Drive
Fredericton, NB, E3B 5A3, Canada
mast@unb.ca
Member

Eric Matheson-Jones
7132 85 St.
Edmonton, AB, T6C 3A7, Canada
(780) 469-8877
mathesonjones@yahoo.com
Member, Interest:1,2,6

Sébastien Matte
2450 Lemieux
Québec, QC, G1P 2V5, Canada
(418) 933-5181
bas-matte@hotmail.com
Student Member, Interest:1,2,4

Karen Mattock
McGill University
1266 Pine Ave West
Montreal, QC, H3G 1A8, Canada
karen.mattock@mail.mcgill.ca
Student member

Mr. Nigel Maybee
12 Woodmont Pl. SW
Calgary, AB, T2W 4N3, Canada
(403) 238-5199, FAX:(403) 259-4190
nigel@hfpacoustical.com
Member, Interest:2

Andreas Mayr
Hans-Gluck-Strasse 21
Peissenberg, D-82380, Germany
0049-170-9611976
andreas_ma21@hotmail.com
Student Member, Interest:1,2,10

Angie Mayrand
2554 Champlain Road, RR2
Penetanguishene, ON, L9M 1R2, Canada
(705) 549-3057
amayrand@uwo.ca
Student Member, Interest:4,5,7

Mc SQUARED System Design Group
Mr. Wade McGregor
Suite 102-145 West 15th Street
North Vancouver, BC, V7M 1R9, Canada
(604) 986-8181, FAX:(604) 929-0642
info@mcsquared.com
Sustaining Subscriber

Jason McCrank
HFP Acoustical Consultants Corp.
1140, 10201 Southport Rd. SW
Calgary, AB, T2W 4X9, Canada
(403) 259-6600, FAX:(403) 259-6611
jason@hfpacoustical.com
Member, Interest:1,2,5

Donald McGaughey
Royal Military College of Canada
Box 17000, Station Forces
Kingston, ON, K7K 7B4, Canada
(613) 541-6000x6033
mcgaughey-d@rmc.ca
Member

Trevor McGregor
370 Hansen Rd. N.
Brampton, ON, L6V 3P7, Canada
(905) 337-5044, FAX:(905) 337-5070
t.mcgregor@cgcinc.com
Member, Interest:1

James McKay
University of Western Ontario
Faculty of Music
Talbot College
London, ON, N6A 3K7, Canada
(519) 661-2111x84326, FAX:(519) 661-3531
jrmckay@uwo.ca
Member

Zita McRobbie
Simon Fraser University
Linguistics Department
Burnaby, BC, V5A 1S6, Canada
(604) 291-5782, FAX:(604) 291-5659
zita_mcrobbie@sfu.ca
Member, Interest:7,8

Mr. T. Medwedyk
Group One Acoustics Inc.
1538 Sherway Dr.
Mississauga, ON, L4X 1C4, Canada
(416) 896-0988, FAX:(416) 897-7794
goainc@bellnet.ca
Member, Interest:1,2,4,7

Jim Mellard
100 Woodthrush Court
Toronto, ON, M2K 2R1, Canada
(416) 222-6955
jjmellard@sympatico.ca
Member, Interest:1,6,10

Garfield Mellema
Defence Research Establishment Atlantic
P.O. Box 1012
Dartmouth, NS, B2Y 3Z7, Canada
(902) 426-3100x252
garfield.mellema@drdc-rddc.gc.ca
Member

Paul Melvin
633 Gibb Street
Oshawa, ON, L1J 1Z6, Canada
(905) 579-7555
gmelvin606@rogers.com
Student Member, Interest:2,6,10

Julie R. Mendelson
TRI
2528 Bayview Ave., P.O.Box 35514
North York, ON, M2L1A0, Canada
(416) 597-3422x3852
j.mendelson@rogers.com
Member, Interest:5,7

Sid-Ali Meslioui
Pratt & Whitney Canada Corp
1000 Marie-Victorin (01PA4)
Longueuil, QC, J4G 1A1, Canada
(450) 647-7339
sid-ali.meslioui@pwc.ca
Member, Interest:1,2,10

Dr. David Michaud
Health Canada
775 Brookfield Road
Ottawa, ON, K1A 1C1, Canada
dmichaud@hc-sc.gc.ca
Member

Mr. C.A. Mihalj
Marshall Macklin Monaghan
80 Commerce Valley Dr. E
Thornhill, ON, L3T 7N4, Canada
(905) 882-1100x275, FAX:(905) 882-0055
mihalja@mmm.ca
Member, Interest:1,2,6

Ministère DDE&P
Dir Polit. de l'AIR SUV
Qualité Atmosphere BTE 30
675 Rene-Levesque Est 6E
Quebec, QC, G1R 5V7, Canada
Indirect Subscriber

Ministère des Transports
Centre Documentation
35 Port-Royal est, 4e étage
Montréal, QC, H3L 3T1, Canada
Indirect Subscriber

MJM Conseillers en Acoustique Inc.
MJM Acoustical Consultants Inc.
M. Michel Morin
6555 Cote des Neiges, Suite 440
Montréal, QC, H3S 2A6, Canada
(514) 737-9811, FAX:(514) 737-9816
mmorin@mjm.qc.ca
Sustaining Subscriber, Interest:1,2,4

Julien Monet-Descombey
2145 rue Galt Ouest, Apt. 504
Sherbrooke, QC, J1K 1K3, Canada
(819) 563-3202, FAX:(819) 821-7163
julien.monet.descombey@usherbrooke.ca
Student Member, Interest:6

Dr. Thomas Moore
Queen's University
Dept. of Mechanical Engineering
Kingston, ON, K7L 3N6, Canada
(613) 533-2055, FAX:(613) 533-6500
mooretn@post.queensu.ca
Member, Interest:2,6

Mrs. Deirdre A. Morison
57 Bainbridge Ave
Nepean, ON, K2G 3T1, Canada
(613) 829-1938
d.morison@rogers.com
Member, Interest:3,5,10

Michael Morley
420-900 Tolmie Ave.
Victoria, BC, V8X 3W6, Canada
(250) 382-4363
mmorley@uvic.ca
Student Member, Interest:9

Geoff Morrison
University of Alberta
Linguistics Department
Edmonton, AB, T6G 2E7, Canada
(780) 433-7084
gsm2@ualberta.ca
Student Member, Interest:8

Xavier MOUY
19, rue Saint Joseph Est
Rimouski, PQ, G5L 2A8, Canada
(418) 725-5470
xavier_mouy@hotmail.com
Student Member, Interest:8,9,10

Mr. David L Moyer
Riverbank Acoustical Labs
Alion Science & Technology
1512 S Batavia Avenue
Geneva, IL, 60134, USA
(630) 232-0104, FAX:(630) 232-0138
dmoyer@alionscience.com
Member, Interest:1,2

Ann Nakashima
DRDC Toronto
Human Factors Research & Engineering
POBox 2000, 1133 Shepperd Ave. W.
Toronto, ON, M3M 3B9, Canada
(416) 635-2000x3064, FAX:(416) 635-2013
ann.nakashima@drdc-rddc.gc.ca
Member, Interest:2,6,10

National Marine Mammal Laboratory
Library, attn:Sonja Kromann
7600 Sand Point Way, NE, Bldg. 4
Seattle, WA, 98115-6349, USA
(206) 526-4013, FAX:(206) 526-6615
Sonja.Kromann@noaa.gov
Indirect Subscriber

Hugues Nelisse
IRSST
505 Boul de Maissonneuve Ouest
Montréal, QC, H3A 3C2, Canada
(514) 288-1551x221
nelisse.hugues@irsst.qc.ca
Member

Mr. Phat Nguyen
Produits Acoustiques PN Inc.
9210 Place Picasso
St-Léonard, QC, H1P 3J8, Canada
(514) 946-6299, FAX:(514) 993-6299
pn@acoustiquepn.ca
Member, Interest:1,2,6

Dr. T.R.T. Nightingale
National Research Council Canada
Institute for Research in Construction
Bldg. M-27
Ottawa, ON, K1A 0R6, Canada
(613) 993-0102, FAX:(613) 954-1495
trevor.nightingale@nrc-cnrc.gc.ca
Member, Interest:1,2

Michael Noble
BKL Consultants Ltd.
308-1200 Lynn Valley Road
North Vancouver, BC, V7J 2A2, Canada
(604) 988-2508, FAX:(604) 988-7457
noble@bkla.com
Member, Interest:1,2,4

Scott Norcross
CRC
3701 Carling Ave.,
P.O.Box 11490, Station H
Ottawa, ON, K2H 8S2, Canada
(613) 998-2762
scott.norcross@crc.ca
Member

Northern Illinois University
Periodicals Dept., University Libraries
1425 West Lincoln Highway
Dekalb, IL, 60115-2868, USA
Indirect Subscriber

Eva-Marie Nosal
University of Hawaii at Manoa
Geology & Geophysics
1680 East-West Road POST 813
Honolulu, HI, 96822, USA
(808) 956-4776, FAX:(808) 956-5154
nosal@hawaii.edu
Student Member, Interest:1,9,10

Colin Novak
1518 Bruce Ave.
Windsor, ON, N8X 1X9, Canada
(519) 253-7193, FAX:(800) 241-9149
novak1@uwindsor.ca
Member, Interest:1,5,6,2

Novel Dynamics Test Inc.
Mr. Andy Metelka
R.R. #2
13652 Fourth Line, Halton Hills
Acton, ON, L7J 2L8, Canada
(519) 853-4495, FAX:(519) 853-3366
metelka@aztec-net.com
Sustaining Subscriber, Interest:2,6,10

Edmund Obasi
RWDI Air Inc.
1800-840 7th Ave. SW
Calgary, AB, T2P 3G2, Canada
(403) 232-6771x243, FAX:(403) 232-6762
EEO@RWDI.com
Member, Interest:1,2,6

Wonsuk Ohm
National Research Council
Building M-36
Ottawa, ON, K1A 0R6, Canada
(613) 993-1003
wonsuk.ohm@nrc-cnrc.gc.ca
Member

Mr. John O'Keefe
Aercoustics Engineering Ltd
Suite 127
50 Ronson Drive
Rexdale, ON, M9W 1B3, Canada
(416) 249-3361, FAX:(416) 249-3613
jokeefe@aercoustics.com
Member, Interest:1

Donald Olynyk
Acoustical Engineer
9224-90 Street
Edmonton, AB, T6C 3M1, Canada
(780) 465-4125, FAX:(780) 465-4169
don.olynyk@shaw.ca
Member, Interest:1,2,4

Dr. John C. Osler
DRDC Atlantic
P.O. Box 1012
9 Grove Street
Dartmouth, NS, B2Y 3Z7, Canada
(902) 426-3100x119, FAX:(902) 426-9654
john.osler@drdc-rddc.gc.ca
Member, Interest:9

Owens-Corning Canada Inc.
Mr. Keith Wilson
390 West St., P.O. Box 72
Milton, NS, B0T 1P0, Canada
(800) 988-5269, FAX:(800) 989-8298
keith.wilson@owenscorning.com
Sustaining Subscriber, Interest:1,2

OZA Inspections Ltd.
Mr. Frank Westaway
P.O. Box 271
Grimsby, ON, L3M 4G5, Canada
(800) 667-8263x28, FAX:(905) 945-3942
oza@ozagroup.com
Sustaining Subscriber, Interest:7,10

Kevin Packer
Faszer Farquharson & Associates Ltd.
Suite 304
605 - 1st Street S.W.
Calgary, AB, T2P 3S9, Canada
(403) 508-4996, FAX:(403) 508-4998
ffa@telusplanet.net
Member, Interest:1,2,4,6

Mr. Thomas Paige
Kinetics Noise Control Inc.
Vibron products Group
1720 Meyerside Drive
Mississauga, ON, L5T 1A3, Canada
(905) 677-4922, FAX:(905) 670-1698
tpaige@vibron.com
Member, Interest:1,2,4

Raymond Panneton
Université de Sherbrooke
G.A.U.S.
Dép de génie mécanique
Sherbrooke, QC, J1K 2R1, Canada
Member

Jerome Parkinson
HFP Acoustical Consultants Corp
1140-10201 Southport Rd. SW
Calgary, AB, T2W 4X9, Canada
(403) 259-6600, FAX:(403) 259-6611
jerome@hfpacoustical.com
Member, Interest:1,2,4

Dr. Vijay Parsa
University of Western Ontario
National Centre for Audiology
London, ON, N6G 1H1, Canada
(519)-661-2111x88947, FAX:(519) 661-3805
parsa@nca.uwo.ca
Member, Interest:7,10

Mr. Richard Patching
Patching Associates Acoustical Eng.
Suite 100
7777 - 10 St. NE
Calgary, AB, T2E 8x2, Canada
(403) 274-5882, FAX:(403) 516-0544
rpatching@patchingassociates.com
Member, Interest:1,2,6

Matthew Penner
MCW Consultants Ltd.
210-1821 Wellington Ave
Winnipeg, MB, R3H 0G4, Canada
(204) 779-7900, FAX:(204) 779-1119
mpenner@mcw-ers.com
Member, Interest:1,4,2

Scott Penton
RWDI
650 Woodlawn Road
Guelph, On, N1K 1B8, Canada
(519)-823-2275, FAX:(519) 823-1316
slp@rwdi.com
Member, Interest:1,2,6

Mr. Richard J. Peppin
Scantek, Inc.
7060 #L Oakland Mills Rd.
Columbia, MD, 21046, USA
(410) 290-7726, FAX:(410) 290-9167
peppinr@scantekinc.com
Member, Interest:1,2,5,7

Haran Periyathamby, P.Eng.
2766 H Mull Avenue
Copley, OH, 44321, USA
(419) 887-3394
haran.periyathamby@dana.com
Member

Camille Perrot
Université de Sherbrooke
Département de Génie Mécanique
2502 boul. De l'Université
Sherbrooke, QC, J1K 2R1, Canada
camille.perrot@usherbrooke.ca
Student Member, Interest:2,3

Peutz & Associés
M. Marc Asselineau
34 rue de Paradis
Paris, F-75010, FRANCE
+33 1 45230500, FAX:+33 1 45230504
marc.asselineau@club-internet.fr
Sustaining Subscriber, Interest:1,2,4

Jessica Phillips-Silver
155 Market Street, Apt. 1405
Hamilton, ON, L8R 3H5, Canada
(905) 308-7796, FAX:(905) 529-6225
phillij@mcmaster.ca
Student Member, Interest:4,5

Michel Picard
7495 Thibault
Brossard, QC, J4W 2P2, Canada
(514) 343-7617, FAX:(514) 343-2115
michel.picard@umontreal.ca
Sustaining Subscriber, Interest:1,5,7

Claire Piché
9663 Basile-Routhier
Montréal, QC, H2C 2C1, Canada
(514) 388-1009, FAX:(514) 388-2179
mobili-son@sympatico.ca
Student Member, Interest:1,2,4

Dr. J.E. Piercy
14 Kaymar Dr.
Ottawa, ON, K1J 7C9, Canada
(613) 749-8929, FAX:(613) 749-8929
jepiercy@cyberus.ca
Member, Interest:2,3,5

Claude D. Pigeon
Suite 110
5800 boul Métropolitain E
Montréal, QC, H1S 1A7, Canada
(514) 990-0459
claude.d.pigeon@sympatico.ca
Student Member, Interest:1,2

Pinchin Environmental
Mr. Weidong Li
Air and Noise
5749 Coopers Avenue
Mississauga, ON, L4Z 1R9, Canada
(905) 507-4855, FAX:(905) 507-9151
wli@pinchin.com
Sustaining Subscriber

Dr. S.E. Prasad
Sensor Technology Ltd.
P.O. Box 97
20 Stewart Road
Collingwood, ON, L9Y 3Z4, Canada
(705) 444-1440, FAX:(705) 444-6787
eprasad@sensortech.ca
Member, Interest:2,3,4,9

Daniel P. Prusinowski
745 Warren Drive
East Aurora, NY, 14052-1913, USA
(716) 652-9979, FAX:(716) 652-7227
Member, Interest:1,2,5

Dr. Christopher J Pye
Integral Acoustics
490 MacLaren St
Ottawa, ON, K1R 5K6, Canada
(613) 567-6698, FAX:(613) 761-0317
chrispye@integralacoustics.ca
Member, Interest:1,2,4

Pyrok Inc.
Mr. Howard Podolsky
121 Sunset Rd.
Mamaroneck, NY, 10543, USA
(914) 777-7770, FAX:(914) 777-7103
info@pyrokinc.com
Sustaining Subscriber, Interest:1,2

Dr. J. David Quirt
National Research Council Canada
Institute for Research in Construction
Acoustics Lab., Bldg. M-27
Ottawa, ON, K1A 0R6, Canada
(613) 993-9746, FAX:(613) 954-1495
dave.quirt@nrc-cnrc.gc.ca
Member, Interest:1,2

Dr. Ramani Ramakrishnan
27 Ashmount Crescent
Toronto, ON, M9R 1C8, Canada
(416) 248-9896, FAX:(416) 979-5353
rramakri@ryerson.ca
Member, Interest:1,2,6

Zohreh Razavi
3075 Paisley Road
North Vancouver, BC, V7R 1C7, Canada
(604) 988-2204, FAX:(604) 822-9588
razaviz@mech.ubc.ca
Student Member, Interest:1,2,8

Hans J. Rerup
H.J. Rerup Consulting Inc.
67 Frid Street
Hamilton, ON, L8P 4M3, Canada
(905) 521-0999, FAX:(905) 521-8658
Member, Interest:1,2

Gordon Reusing
Conestoga-Rovers & Associates
651 Colby Drive
Waterloo, ON, N2V 1C2, Canada
greusing@craworld.com
Member

Werner Richarz
70 Roxborough Lane
Thornhill, ON, L4J 4S9, Canada
(416) 249-3361, FAX:(416) 249-3613
wricharz@aercoustics.com
Member, Interest:2,3

Mr. Matias Ringheim
Kilde Akustikk A/S
Tvildesvegen 16D
N 5700 Voss, Norway
(47) 5652-0460, FAX:(47) 5652-0479
matias.ringheim@kilde-akustikk.no
Member, Interest:1,2,5

Ranga Rodrigo
University of Western Ontario
Electrical & Computer Engineering Dept
London, ON, N6A 5B9, Canada
brodrigo@uwo.ca
Student member

Dr. R.J. Rogers
University of New Brunswick
Dept. of Mechanical Engineering
P.O. Box 4400
Fredericton, NB, E3B 5A3, Canada
(506) 447-3106, FAX:(506) 453-5025
rjr@unb.ca
Member, Interest:2,6

Jens Rohlfing
Haupstr. 20
67167 Erpolzheim, Rheinland Pfalz,
GERMANY
+49-6353-915009, FAX:+49-6353-915120
Rohlfing.Jens@gmx.de
Student Member

Tom Rose
Rose Associates
10409 Countryside Dr.
Denton, TX, 76207, USA
(972) 539-7000, FAX:(972) 539-6139
tom@tomrose.org
Member, Interest:1,2,6

Annie Ross
Dép. génie mécanique
Ecole Polytechnique
Montréal, Québec, H3C 3A7, Canada
(514) 340-4711x4591, FAX:(514) 340-4176
annie.ross@polymtl.ca
Member

Frank A. Russo
Univ. of Toronto at Mississauga
Dept. of Psychology
3359 Mississauga Rd. N
Mississauga, ON, L5L 1C6, Canada
(905) 828-3843, FAX:(905) 569-4326
frusso@utm.utoronto.ca
Member, Interest:4,5,7,8

RWDI West Inc.
#1800, 840-7th Avenue SW
Calgary, Alberta, T2P 3G2, Canada
(403)-232-6771, FAX:(403) 232-6762
info@rwdiwest.com
Direct subscriber

Jim Ryan
Gennum Corp.
232 Herzberg Rd.
Ottawa, ON, K2A 2A1, Canada
(613) 270-0458x2772
jim-r@gennum.com
Member

Claude Sauvageau
Centre de recherche industrielle du Québec
8475, ave. Christophe-Colomb
Montréal, QC, H2M 2N9, Canada
(514) 383-1550, FAX:(514) 383-3234
csauvag@mtl.criq.qc.ca
Member, Interest:2,6,10

Scantek Inc.
Mr. Richard J. Peppin
7060 #L Oakland Mills Rd.
Columbia, MD, 21046, USA
(410)-290-7726, FAX:(410) 290-9167
peppinr@scantekinc.com
Sustaining Subscriber, Interest:1,2,5

Katrina Scherebnyj
Apt. 108, 3520 W. Broadway
Vancouver, B.C., V6R 2B6, Canada
(604) 531-8375
katrina@mech.ubc.ca
Student Member, Interest:2,3,7

Bruce Schneider
CCIT Room 4073
3359 Mississauga Rd. North
Mississauga, ON, L5L 1C6, Canada
(905) 828-3963, FAX:(905) 569-4850
bschneid@utm.utoronto.ca
Member, Interest:5,7,8

Stefan Schoenwald
Frenkenweg 69
Nettetal,, 41334, Germany
+43 02157 128604
stefan.schoenwald@gmx.de
Student Member, Interest:1,2,6

Mr. Henri Scory
IRSST
505 Maisonneuve Ouest
Montréal, QC, H3A 3C2, Canada
(514) 288-1551, FAX:(514) 288-9399
scory.henri@irsst.qc.ca
Member, Interest:2,3,6

Mr. Robert Sculthorpe
Arxx Building Products
800 Division St.
Coburg, ON, K9A 5V2, Canada
Member

Dr. Kimary Shahin
Effat College
P.O. Box 34689
Jeddah, 21478, Saudi Arabia
966-2-230-0012, FAX:+966-2-637-7447
knshahin@hotmail.com
Member, Interest:8,7,2

Navid Shahnaz
University of British Columbia
Audiology and Speech Sciences
5804 Fairview Ave., J.Mather Building
Vancouver, BC, V6T 1Z3, Canada
(604) 822-5953, FAX:(604) 822-6569
nshahnaz@audiospeech.ubc.ca
Member, Interest:5,7,11

Mr. Neil A. Shaw
Menlo Scientific Acoustics Inc.
P.O. Box 1610
Topanga, CA, 90290-1610, USA
(310) 455-2221, FAX:(310) 455-0923
menlo@ieee.org
Member, Interest:1,2,4

Cameron W. Sherry
Enviro Risque Inc.
PO Box 190
Howick, QC, J0S 1G0, Canada
(450) 825-2322, FAX:(450) 825-1355
cwsherry@aol.com
Member, Interest:1,2,7

Wenxia Shi
University of Western Ontario
Electrical & Computer Engineering Dept
London, ON, N6A 5B9, Canada
wshi7@uwo.ca
Student member

Davor Sikic
Jade Acoustics Inc.
Suite 203
545 North Rivermede Dr.
Concord, ON, L4K 4H1, Canada
(905) 660-2444, FAX:(905) 660-4110
davor@jadeacoustics.com
Member, Interest:1,2,6

SILEX Innovations Inc.
Mr. Mehmood Ahmed
6659 Ordan Dr.
Mississauga, ON, L5T 1K6, Canada
(905) 612-4000, FAX:(905) 612-8999
mehmooda@silex.com
Sustaining Subscriber, Interest:2,6,7

Chris Sims
15 Attwood Drive
St. Albert, AB, T8N 2T4, Canada
(780) 504-8260
sims.chris@gmail.com
Student Member, Interest:1,2,4

Moninderjit Singh
P.O. Box 92487
Dubai, U.A.E.
+971-50-4883106
moninder@hotmail.com
Member, Interest:1,2,6

Ms. Elzbieta B. Slawinski
University of Calgary
Dept. of Psychology
2500 University Drive NW
Calgary, AB, T2N 1N4, Canada
(403) 220-5205, FAX:(403) 282-8249
eslawins@acs.ucalgary.ca
Member, Interest:5,7,8

Susan A. Small
University of BC
Audiology and Speech Sciences
5804 Fairview Ave.
Vancouver, BC, V6T 1Z3, Canada
(604) 822-7424, FAX:(604) 822-6569
ssmall@audiospeech.ubc.ca
Student Member, Interest:5,7,8

Elliot Smith
8-469A Bloor St. W.
Toronto, ON, M5S 1X9, Canada
(416) 920-5929
e2smith@engmail.uwaterloo.ca
Student Member, Interest:3,5,10

Nicholas A. Smith
McMasterUniversity
Dept. of Psychology
1280 Main St. W.
Hamilton, ON, L85 4K1, Canada
905-525-9140x24811, FAX:(905) 529-6225
nsmith@mcmaster.ca
Student Member, Interest:4,5,7

SNC/Lavalin Environment Inc.
M. Jean-Luc Allard
Noise and Vibration Control
2271 Fernand-Lafontaine Blvd.
Longueuil, QC, J4G 2R7, Canada
(514) 651-6710, FAX:(514) 651-0885
jeanluc.allard@snclavalin.com
Sustaining Subscriber, Interest:1,2,6

Connie So
5184 Sherbrooke St.
Vancouver, BC, V5W 3M4, Canada
so_connie@hotmail.com
Student Member, Interest:8

Soft dB Inc.
M. André L'Espérance
1040, avenue Belvédère, suite 215
Sillery, Québec, G1S 3G3, Canada
(418) 686-0993, FAX:(418) 686-2043
contact@softdb.com
Sustaining Subscriber

Dmitry Solodovnikov
348 Piccadilly Street
London, ON, N6A 1S7, Canada
dsolodov@uwo.ca
Student member

Solutions Acoustiques Inc.
Sylvain Larivière
3182 av. Francis-Hugues
Laval, Québec, H8T 2N5, Canada
(514) 793-3767, FAX:(450) 682-0644
sylvainlariviere@solutionsacoustiques.com
Sustaining Subscriber

Gilbert Soulodre
Communications Research Centre
6 Witherspoon Cr.
Ottawa, ON, K2K 3L6, Canada
(613) 998-2765
gilbert.soulodre@crc.gc.ca
Member

Don J. South
R.E.T. National Sales Manager
ATCO Noise Management
1243 McKnight Blvd. NE
Calgary, AB, T2E 5T1, Canada
(403) 292-7850, FAX:(403) 292-7816
Don.South@atconoise.com
Member, Interest:2,5,1

Ibrahima Sow
Université de Sherbrooke
Génie mécanique
2500 boul. Université
Sherbrooke, QC, J1K 2R1, Canada
(819) 821-7144, FAX:(819) 821-7163
toi41@yahoo.com
Student Member, Interest:2,6,10

Spaarg Engineering Ltd.
Dr. Robert Gaspar
Noise and Vibration Analysis
822 Lounsborough St.
Windsor, ON, N9G 1G3, Canada
(519) 972-0677, FAX:(519) 972-1811
gasparr@kelcom.igs.net
Sustaining Subscriber, Interest:1,2,6

Tiberiu Spulber
2935 Capilano Road
North Vancouver, BC, V7R 4H4, Canada
tspulber@BKLA.com
Member, Interest:1,2,6

V. Srikrishnan
53 Happy Avenue East
Singapore, 369855, Singapore
65-6747-7264, FAX:+65-6367-9367
sri@northernlaboratories.com
Member, Interest:2,6,10

State of the Art Acoustik Inc.
Dr. C. Fortier
43 - 1010 Polytek Street
Ottawa, ON, K1J 9J3, Canada
(613) 745-2003, FAX:(613) 745-9687
sota@sota.ca
Sustaining Subscriber

Robert D. Stevens
HGC Engineering Ltd.
Plaza One, Suite 203
2000 Argentia Rd.
Mississauga, ON, L5N 1P7, Canada
(905) 826-4044, FAX:(905) 826-4940
rstevens@hgcengineering.com
Member, Interest:1,2,4

John Stevenson
WCB of BC, Prev Div
#450-6450 Roberts St.
Burnaby, BC, V5G 4E1, Canada
(604) 276-3100, FAX:(604) 232-5950
a1a38024@telus.net
Member, Interest:1,2,4

Dr. Michael R. Stinson
National Research Council Canada
Inst. for Microstructural Sciences
Building M-36
Ottawa, ON, K1A 0R6, Canada
(613) 993-3729, FAX:(613) 952-3670
mike.stinson@nrc-cnrc.gc.ca
Member, Interest:2,3,5,10

Mr. Robert A. Strachan
Brown Strachan Assoc.
Two Yaletown Sq.
1290 Homer St.
Vancouver, BC, V6B 2Y5, Canada
(604) 689-0514, FAX:(604) 689-2703
Member, Interest:1,2,6

Dr. D.C. Stredulinsky
32 John Cross Dr.
Dartmouth, NS, B2W 1X3, Canada
(902) 426-3100, FAX:(902) 426-9654
Dave.Stredulinsky@drdc-rddc.gc.ca
Member, Interest:1,2,9

Tacet Engineering Ltd.
Dr. M.P. Sacks
45 Denver Cr
Toronto, ON, M2J 1G6, Canada
(416) 782-0298, FAX:(416) 785-9880
mal.sacks@tacet.ca
Sustaining Subscriber, Interest:1,2,6

Teknisk Akustik LTH
attn: Per Hammer
Box 118
221 00 LUND, Sweden
per.hammer@acoustics.lth.se
Direct Subscriber

Julianne Tenhaaf
RR 1, LCD 2
St. Catharines, ON, L2R 6P7, Canada
(905) 562-5425
jt0aml@brocku.ca
Student Member

Dr. John M. Terhune
University of New Brunswick
Dept. of Biology
P.O. Box 5050
Saint John, NB, E2L 4L5, Canada
(506) 648-5633, FAX:(506) 648-5650
terhune@unbsj.ca
Member, Interest:5,7,8,9

Mr. Peter Terroux
Atlantic Acoustical Associates
P.O. Box 96, Station Central
Halifax, NS, B3J 2L4, Canada
(902) 425-3096, FAX:(902) 425-0044
peteraaa@ns.sympatico.ca
Member, Interest:1,2,5

Frederic M. Tewfik
Vancouver International Airport Authority
P.O. Box 23750, Airport PO
Richmond, BC, V7B 1Y7, Canada
(604) 276-6396, FAX:(604) 276-6699
fred_tewfik@yvr.ca
Member, Interest:1,2,5

George H. Thackray
Greater Toronto Airports Authority
Lester B Pearson Int Airport
P.O. Box 6031
Toronto AMF, ON, L5P 1B2, Canada
(905) 676-5417, FAX:(905) 676-3483
george.thackray@gtaa.com
Member, Interest:1,2

Stan Thompson
200-440 Laurier Ave. W.
Ottawa, ON, Canada
(613)-598-0026, FAX:(613) 598-0019
STAN@NOVELDYNAMICS.COM
Member, Interest:1,2,6,10

Caroline Traube
6804 rue Fabre
Montreal, QC, H2G 2Z6, Canada
(514) 725-5544
caroline.traube@umontreal.ca
Student Member, Interest:1,4,7

Prof. B. Truax
Simon Fraser University
School of Communication
Burnaby, BC, V5A 1S6, Canada
(604) 291-4261, FAX:(604) 291-4024
truax@sfu.ca
Member, Interest:2,4,5

Miroslav Ubovic, CET
Earth Tech. Canada Inc.
105 Commerce Valley Dr. W., 7th Floor
Markham, ON, L3T 7W3, Canada
(905) 886-7022, FAX:(905) 886-9494
miroslav.ubovic@earthtech.ca
Member, Interest:1,2,6

Helen J Ule
1258 Aubin Rd
Windsor, ON, N8Y 4E5, Canada
(519) 948-7302, FAX:(800) 241-9149
ule@uwindsor.ca
Student Member, Interest:2,5

J. Ulicki
Xscala Sound & Vibration
Suite 516
234 - 5149 Country Hills Blvd. NW
Calgary, AB, T3A 5K8, Canada
(403) 274-7577, FAX:(403) 274-7694
mail05@xscala.com
Member, Interest:1,2,6

Karthikeyan Umapathy
2418-565 Sherbourne Street
Toronto, ON, M4X 1W7, Canada
(416) 979-5000x4152, FAX:(416) 979-5280
kumapath@uwo.ca
Student Member, Interest:2,4,10

Université de Montréal
Bibliothèque Acquisitions Periodiques
C.P. 6128, Succ. A.
Montréal, QC, H3C 3J7, Canada
Indirect Subscriber

University of PEI
Robertson Library
550 University Ave.
Charlottetown, PE, C1A 4P3, Canada
Indirect Subscriber

University of Toronto Library
Serials Department
Toronto, ON, M5S 1A5, Canada
(416) 978-3076, FAX:(416)-978-8827
Direct Subscriber

Svein Vagle
Institute of Ocean Sciences
PO Box 6000
9860 West Saanich Road
Sidney, BC, V8L 4B2, Canada
(250) 363-6339, FAX:(250) 363-6798
vagles@pac.dfo-mpo.gc.ca
Member, Interest:9,10

Valcoustics Canada Ltd.
Dr. Al Lightstone
30 Wertheim Court, Unit 25
Richmond Hill, ON, L4B 1B9, Canada
(905) 764-5223, FAX:(905) 764-6813
solutions@valcoustics.com
Sustaining Subscriber, Interest:1,2,6

Peter Van Delden
RWDI West Inc.
650 Woodlawn Road
Guelph, ON, N1K 1B8, Canada
(515) 823-1311
pv@rwdi.com
Member

Elisabeth van Stam
291 Windermere Road
London, ON, N6G 2J9, Canada
ekvansta@uwo.ca
Student member

Craig Vatcher
RWDI Air Inc.
1800-840 7th Ave. SW
Calgary, AB, T2P 3G2, Canada
(403) 232-6771x243, FAX:(403) 232-6762
CMWV@RWDI.com
Member, Interest:1,2,6

Vibro-Acoustics
Mr. Tim Charlton
727 Tapscott Rd
Scarborough, ON, M1X 1A2, Canada
(800) 565-8401, FAX:(888)-811-2264
tcharlton@vibro-acoustics.com
Sustaining Subscriber

Jérémie Voix
Ecole de technologie supérieure
Dép génie mécanique
1100 Notre-Dame Ouest
Montréal, QC, H3C 1K3, Canada
(514) 396-8800x7692, FAX:(514) 396-8530
jvoix@mec.etsmtl.ca
Student Member, Interest:2,7,10

Alexander von Stetten
Faszer Farquharson & Associates Ltd.
Suite 304
605 - 1st Street S.W.
Calgary, AB, T2P 3S9, Canada
(403) 508-4996, FAX:(403) 508-4998
ffa@telusplanet.net
Member, Interest:2,4,5

Tara Vongpaisal
3359 Mississauga Rd. N
Mississauga, ON, L5L 1C6, Canada
Student Member, Interest:4,5,7

Thien-An VU
NRC
Building M-36
Ottawa, ON, K1A 0R6, Canada
(613) 993-2300
Thien-An.Vu@nrc-cnrc.gc.ca
Student Member

Wakefield Acoustics Ltd.
Mr. Clair Wakefield
301-2250 Oak Bay Avenue
Victoria, BC, V8R 1G5, Canada
(250) 370-9302, FAX:(250) 370-9309
nonoise@shaw.ca
Sustaining Subscriber

Kent Walker
Apt. 14, 6735 Sherbrooke Ouest
Montreal, QC, H4B 1P3, Canada
(514) 485-6568
Kent.Walker@mail.mcgill.ca
Student Member

Dr. A.C.C. Warnock
National Research Council Canada
Institute for Research in Construction
Acoustics Laboratory, Bldg. M-27
Ottawa, ON, K1A 0R6, Canada
(613) 993-9370, FAX:(613) 954-1495
alf.warnock@nrc-crnc.gc.ca
Member, Interest:1,2,4,6

Wayne State University
Science & Engineering Library
5048 Gullen Mall
Detroit, MI, 48202-3918, USA
Indirect Subscriber

West Caldwell Calibration Labs
Mr. Stanley Christopher
5200 Dixie Road, Suite 118
Mississauga, ON, L4W 1E4, Canada
(905) 624-3919, FAX:(905) 624-3926
info@wccl.com
Sustaining Subscriber

Mr. Ewart A. Wetherill
28 Cove Road
Alameda, CA, 94502, USA
(510) 769-7040, FAX:(510) 769-7040
redwetherill@sbcglobal.net
Member, Interest:1,2,4

Douglas J. Whicker
PH3 - 410 Carnarvon Street
New Westminster, BC, V3L 5N9, Canada
(604) 525-5528
whicker@bkla.com
Member, Interest:1,2,4,6

Mr. Ronald G. White
7 Amber Glen Court
Holland Landing, ON, L9N 1J6, Canada
(416) 675-3983, FAX:(416) 675-5546
Member, Interest:1,2,4

Tim Wiens
Conestoga-Rovers & Associates
651 Colby Drive
Waterloo, ON, N2V 1C2, Canada
(519) 884-0510x2352
twiens@craworld.com
Member

Paul Wierzba
1116 Lake Placid Dr. S.E.
Calgary, AB, T2J 5H1, Canada
(403)-278-8052, FAX:(403) 278-8098
pwierzba@telusplanet.net
Member, Interest:2,6,10

Terence Williams
Terrence Williams Architect Inc.
#102 - 2957 Jutland Road
Victoria, BC, V8T 5J9, Canada
(250) 384-7878, FAX:(250) 384-7872
info@twarchitects.ca
Member

Hugh Williamson
Hugh Williamson Assoc. Inc.
12 Maple Lane
Ottawa, ON, K1M 1G7, Canada
(613) 747-0983, FAX:(613) 747-4514
hughwilliamson@sympatico.ca
Member, Interest:1,2,6

Wilrep Ltd.
Mr. Don Wilkinson
1515 Matheson Blvd. E, Unit C 10
Mississauga, ON, L4W 2P5, Canada
(905) 625-8944, FAX:(905) 625-7142
www.wilrep.com
Sustaining Subscriber

Ian Wilson
5638 Crown St
Vancouver, BC, V6N 2B5, Canada
(604) 267-2552
ilwilson@interchange.ubc.ca
Student Member, Interest:8

Doug Wilson
3621 Evergreen Street
Port Coquitlam, BC, V3B 4X2, Canada
(604) 468-9406
dougww3@netscape.net
Member, Interest:2,9,10

Mr. Chris N. Wolfe
Vibra-Sonic Control
& Materials Handling Ltd.
4004 Gravely Street
Burnaby, BC, V5C 3T6, Canada
(604) 294-9495, FAX:(604) 294-8033
cwolfe@vibra-sonic.bc.ca
Member, Interest:1,2,6

Dr. G.S.K. Wong
National Research Council Canada
Inst. for Nat. Meas. Stds.
Building M-36
Ottawa, ON, K1A 0R6, Canada
(613) 993-6159, FAX:(613) 990-8765
george.wong@nrc.ca
Member, Interest:2,3,4

Kar See Wong
6860 Tisserand
Brossard, QC, J4W 2M9, Canada
(514) 808-2377
karsee.wong@yahoo.ca
Student Member

Willy Wong
University of Toronto
Electrical & Computer Engineering
10 King's College Road
Toronto, ON, M5S 3G4, Canada
(416) 978-8734
willy@eecg.utoronto.ca
Member

Galen Wong
1328 East 27th Ave.
Vancouver, BC, V5V 2L8, Canada
(604) 873-8885
galenw@interchange.ubc.ca
Student Member, Interest:1,2,4

Geoff Woods
Canadian National Railway
1 Administration Road
Concord, ON, L4K 1B9, Canada
(905) 760-5007, FAX:(905) 760-5010
geoff.woods@cn.ca
Member

Richard G. Wright
HFP Acoustical Consultants Corp.
10201 Southport Road, S.W.
1140, 10201 Southport Rd. SW
Calgary, AB, T2W 4X9, Canada
(403) 259-3600, FAX:(403) 259-4190
richardw@hfpacoustical.com
Member, Interest:2,11

Lixue Wu
National Research Council
Rm 14, M-36, 1200 Montreal Road
Ottawa, ON, K1A 0R6, Canada
(613) 993-6966, FAX:(613) 998-5396
lixue.wu@nrc-cnrc.gc.ca
Member, Interest:2,6,9

Jiming Yang
130 Milliken Meadows Drive
Markham, ON, L3R 0V6, Canada
(905) 948-8375
jyang@ee.ryerson.ca
Student Member, Interest:2,7,10

Natalie York
2070 Ida Ave.
Shawinigan Lake, BC, V0R 2W0, Canada
(604) 318-4864
NLYORK@interchange.ubc.ca
Student Member, Interest:1,2,4

William Victor Young
6423 Vienna Street
Halifax, NS, B3L 1S7, Canada
(902) 453-4424
victor.young@drdc-rddc.gc.ca
Student Member, Interest:7, 9, 10

Luke Young
PO Box 1729
Pictou, NS, B0K 1H0, Canada
902-485-3435, FAX:(902) 485-4690
luke.young@lucastech.ca
Member

Pearlie Yung
Unit 44
5055 Heatherleigh Ave.
Mississauga, ON, L5V 2R7, Canada
(905) 507-6398
pearlie_yung@yahoo.com
Member, Interest:1,2,5

Xubao Zhang
60 Rush Meadow Street
Kitchener, ON, N2R 1S9, Canada
(519) 584-2418
xbzwdt@kw.igs.net
Member, Interest:7, 8, 10

Libo Zhang
NRC
IMS
Building M-36
Ottawa, ON, K1A 0R6, Canada
(613) 991-2616
libo@ee.ryerson.ca
Student Member

Yun Zheng
#1501, 52 Bayswater Avenue
Ottawa, ON, K1Y 4K3, Canada
(613)-761-6326
zyun98@yahoo.com
Student Member, Interest:5,7

Dejan Zivkovic
1208-1285 Richmond Road
Ottawa, ON, K2B 7Z4, Canada
dnzivkov@hotmail.com
Member, Interest:2,3,6

ZO 1935
TIB und Universitaetsbibliothek Hannover
DE/5100/G1/0001
ZO 1935, Welfengarten 1 B
30167 HANNOVER, GERMANY
Indirect Subscriber

INSTRUCTIONS TO AUTHORS FOR THE PREPARATION OF MANUSCRIPTS

Submissions: The original manuscript and two copies should be sent to the Editor-in-Chief.

General Presentation: Papers should be submitted in camera-ready format. Paper size 8.5” x 11”. If you have access to a word processor, copy as closely as possible the format of the articles in Canadian Acoustics 18(4) 1990. All text in Times-Roman 10 pt font, with single (12 pt) spacing. Main body of text in two columns separated by 0.25”. One line space between paragraphs.

Margins: Top - title page: 1.25”; other pages, 0.75”; bottom, 1” minimum; sides, 0.75”.

Title: Bold, 14 pt with 14 pt spacing, upper case, centered.

Authors/addresses: Names and full mailing addresses, 10 pt with single (12 pt) spacing, upper and lower case, centered. Names in bold text.

Abstracts: English and French versions. Headings, 12 pt bold, upper case, centered. Indent text 0.5” on both sides.

Headings: Headings to be in 12 pt bold, Times-Roman font. Number at the left margin and indent text 0.5”. Main headings, numbered as 1, 2, 3, ... to be in upper case. Sub-headings numbered as 1.1, 1.2, 1.3, ... in upper and lower case. Sub-sub-headings not numbered, in upper and lower case, underlined.

Equations: Minimize. Place in text if short. Numbered.

Figures/Tables: Keep small. Insert in text at top or bottom of page. Name as “Figure 1, 2, ...” Caption in 9 pt with single (12 pt) spacing. Leave 0.5” between text.

Line Widths: Line widths in techincal drawings, figures and tables should be a minimum of 0.5 pt.

Photographs: Submit original glossy, black and white photograph.

Scans: Should be between 225 dpi and 300 dpi. Scan: Line art as bitmap tiffs; Black and white as grayscale tiffs and colour as CMYK tiffs;

References: Cite in text and list at end in any consistent format, 9 pt with single (12 pt) spacing.

Page numbers: In light pencil at the bottom of each page.

Reprints: Can be ordered at time of acceptance of paper.

DIRECTIVES A L’INTENTION DES AUTEURS PREPARATION DES MANUSCRITS

Soumissions: Le manuscrit original ainsi que deux copies doivent être soumis au rédacteur-en-chef.

Présentation générale: Le manuscript doit comprendre le collage. Dimensions des pages, 8.5” x 11”. Si vous avez accès à un système de traitement de texte, dans la mesure du possible, suivre le format des articles dans l’Acoustique Canadienne 18(4) 1990. Tout le texte doit être en caractères Times-Roman, 10 pt et à simple (12 pt) interligne. Le texte principal doit être en deux colonnes séparées d’un espace de 0.25”. Les paragraphes sont séparés d’un espace d’une ligne.

Marges: Dans le haut - page titre, 1.25”; autres pages, 0.75”; dans le bas, 1” minimum; latérales, 0.75”.

Titre du manuscrit: 14 pt à 14 pt interligne, lettres majuscules, caractères gras. Centré.

Auteurs/adresses: Noms et adresses postales. Lettres majuscules et minuscules, 10 pt à simple (12 pt) interligne. Centré. Les noms doivent être en caractères gras.

Sommaire: En versions anglaise et française. Titre en 12 pt, lettres majuscules, caractères gras, centré. Paragraphe 0.5” en alinéa de la marge, des 2 cotés.

Titres des sections: Tous en caractères gras, 12 pt, Times-Roman. Premiers titres: numéroter 1, 2, 3, ..., en lettres majuscules; sous-titres: numéroter 1.1, 1.2, 1.3, ..., en lettres majuscules et minuscules; sous-sous-titres: ne pas numéroter, en lettres majuscules et minuscules et soulignés.

Equations: Les minimiser. Les insérer dans le texte si elles sont courtes. Les numéroter.

Figures/Tableaux: De petites tailles. Les insérer dans le texte dans le haut ou dans le bas de la page. Les nommer “Figure 1, 2, 3,...” Légende en 9 pt à simple (12 pt) interligne. Laisser un espace de 0.5” entre le texte.

Largeur Des Traits: La largeur des traits sur les schémas technique doivent être au minimum de 0.5 pt pour permettre une bonne reproduction.

Photographies: Soumettre la photographie originale sur papier glacé, noir et blanc.

Figures Scanées: Doivent être au minimum de 225 dpi et au maximum de 300 dpi. Les schémas doivent être scannés en bitmaps tif format. Les photos noir et blanc doivent être scannées en échelle de gris tifs et toutes les phoots couleurs doivent être scannées en CMYK tifs.

Références: Les citer dans le texte et en faire la liste à la fin du document, en format uniforme, 9 pt à simple (12 pt) interligne.

Pagination: Au crayon pâle, au bas de chaque page.

Tirés-à-part: Ils peuvent être commandés au moment de l’acceptation du manuscrit.

The Canadian Acoustical Association
l'Association Canadienne d'Acoustique

Application for Membership

CAA membership is open to all individuals who have an interest in acoustics. Annual dues total $60.00 for individual members and $20.00 for Student members. This includes a subscription to ***Canadian Acoustics***, the Association's journal, which is published 4 times/year. New membership applications received before August 31 will be applied to the current year and include that year's back issues of ***Canadian Acoustics***, if available. New membership applications received after August 31 will be applied to the next year.

Subscriptions to *Canadian Acoustics* *or* Sustaining Subscriptions

Subscriptions to ***Canadian Acoustics*** are available to companies and institutions at the institutional subscription price of $60.00. Many companies and institutions prefer to be a Sustaining Subscriber, paying $250.00 per year, in order to assist CAA financially. A list of Sustaining Subscribers is published in each issue of ***Canadian Acoustics***. Subscriptions for the current calendar year are due by January 31. New subscriptions received before August 31 will be applied to the current year and include that year's back issues of ***Canadian Acoustics***, if available.

Please note that electronic forms can be downloaded from the CAA Website at **caa-aca.ca**

Address for subscription / membership correspondence:

Name / Organization ______________________________
Address ______________________________
City/Province ______________ Postal Code ________ Country ______________
Phone ____________ Fax ____________ E-mail ____________

Address for mailing Canadian Acoustics, if different from above:

Name / Organization ______________________________
Address ______________________________
City/Province ______________ Postal Code ________ Country ______________

Areas of Interest: (Please mark 3 maximum)

1. Architectural Acoustics
2. Engineering Acoustics / Noise Control
3. Physical Acoustics / Ultrasound
4. Musical Acoustics / Electro-acoustics
5. Psychological / Physiological Acoustic
6. Shock and Vibration
7. Hearing Sciences
8. Speech Sciences
9. Underwater Acoustics
10. Signal Processing / Numerical Methods
11. Other

For student membership, please also provide:

____________	____________	____________	____________
(University)	*(Faculty Member)*	*(Signature of Faculty Member)*	*(Date)*

I have enclosed the indicated payment for:
[ ] CAA Membership $ 60.00
[ ] CAA Student Membership $ 20.00
[ ] Institutional Subscription $ 60.00
[ ] Sustaining Subscriber $ 250.00
includes subscription (4 issues /year)
to ***Canadian Acoustics.***

Payment by: [ ] Cheque
[ ] Money Order
[ ] VISA credit card *(Only VISA accepted)*

For payment by VISA credit card:

Card number ______________________________
Name of cardholder ______________________________
Expiry date ______________________________

____
(Signature) (Date)

Mail application and attached payment to:

D. Quirt, Secretary, Canadian Acoustical Association, PO Box 74068, Ottawa, Ontario, K1M 2H9, Canada

l'Association Canadienne d'Acoustique
The Canadian Acoustical Association

Formulaire d'adhésion

L'adhésion à l'ACA est ouverte à tous ceux qui s'intéressent à l'acoustique. La cotisation annuelle est de 60.00$ pour les membres individuels, et de 20.00$ pour les étudiants. Tous les membres reçoivent ***l'Acoustique Canadienne***, la revue de l'association. Les nouveaux abonnements reçus avant le 31 août s'appliquent à l'année courante et incluent les anciens numéros (non-épuisés) de ***l'Acoustique Canadienne*** de cette année. Les nouveaux abonnements reçus après le 31 août s'appliquent à l'année suivante.

Abonnement pour la revue *Acoustique Canadienne* et abonnement de soutien

Les abonnements pour la revue ***Acoustique Canadienne*** sont disponibles pour les compagnies et autres établissements au coût annuel de 60.00$. Des compagnies et établissements préfèrent souvent la cotisation de membre bienfaiteur, de 250.00$ par année, pour assister financièrement l'ACA. La liste des membres bienfaiteurs est publiée dans chaque issue de la revue ***Acoustique Canadienne***. Les nouveaux abonnements reçus avant le 31 août s'appliquent à l'année courante et incluent les anciens numéros (non-épuisés) de ***l'Acoustique Canadienne*** de cette année. Les nouveaux abonnements reçus après le 31 août s'appliquent à l'année suivante.

Pour obtenir des formulaires electroniques, visitez le site Web: **caa-aca.ca**

Pour correspondence administative et financière:

Nom / Organisation ____

Adresse ____

Ville/Province ____________________ Code postal __________ Pays ____________________

Téléphone ______________ Téléc. ____________ Courriel ________________________

Adresse postale pour la revue Acoustique Canadienne

Nom / Organisation ____

Adresse ____

Ville/Province ____________________ Code postal __________ Pays ____________________

Cocher vos champs d'intérêt: (maximum 3)

1. Acoustique architecturale
2. Génie acoustique / Contrôle du bruit
3. Acoustique physique / Ultrasons
4. Acoustique musicale / Electro-acoustique
5. Physio / Psycho-acoustique
6. Chocs et vibrations
7. Audition
8. Parole
9. Acoustique sous-marine
10. Traitement des signaux /Méthodes numériques
11. Autre

Prière de remplir pour les étudiants et étudiantes:

____________ ____________________ ________________________ ____________

(Université) (Nom d'un membre du corps professoral) (Signature du membre du corps professoral) (Date)

Cocher la case appropriée:
[ ] Membre individuel $ 60.00
[ ] Membre étudiant(e) $ 20.00
[ ] Abonnement institutionnel $ 60.00
[ ] Abonnement de soutien $ 250.00
(comprend l'abonnement à
L'acoustique Canadienne)

Méthode de paiement:
[ ] Chèque au nom de l'Association Canadienne d'Acoustique
[ ] Mandat postal
[ ] VISA *(Seulement VISA)*

Pour carte VISA: Carte n° ________________________

Nom ________________________

Date d'expiration ________________________

____

(Signature) (Date)

Prière d'attacher votre paiement au formulaire d'adhésion. Envoyer à :

Secrétaire exécutif, Association Canadienne d'Acoustique, Casier Postal 74068, Ottawa, K1M 2H9, Canada

The Canadian Acoustical Association
l'Association Canadienne d'Acoustique

PRESIDENT
PRÉSIDENT

Stan Dosso
University of Victoria
Victoria, British Columbia
V8W 3P6
(250) 472-4341
sdosso@uvic.ca

PAST PRESIDENT
PRÉSIDENT SORTANT

John Bradley
IRC, NRCC
Ottawa, Ontario
K1A 0R6
(613) 993-9747
john.bradley@nrc-cnrc.gc.ca

SECRETARY
SECRÉTAIRE

David Quirt
P. O. Box 74068
Ottawa, Ontario
K1M 2H9
(613) 993-9746
dave.quirt@nrc-cnrc.gc.ca

TREASURER
TRÉSORIER

Dalila Giusti
Jade Acoustics
545 North Rivermede Road, Suite 203
Concord, Ontario
L4K 4H1
(905) 660-2444
dalila@jadeacoustics.com

EDITOR-IN-CHIEF
RÉDACTEUR EN CHEF

Ramani Ramakrishnan
Dept. of Architectural Science
Ryerson University
350 Victoria Street
Toronto, Ontario
M5B 2K3
(416) 979-5000 #6508
rramakri@ryerson.ca
ramani@aiolos.com

WORLD WIDE WEB HOME
PAGE: http://www.caa-aca.ca

Dave Stredulinsky
(902) 426-3100

ASSISTANT EDITOR
RÉDACTEUR ADJOINT

Ralph Baddour
Department of Medical Biophysics
University of Toronto
rbaddour@uhnres.utoronto.ca

DIRECTORS
DIRECTEURS

Alberto Behar
(416) 265-1816
behar@sympatico.ca

Nicole Collison
(902) 426-3100, Ext. 94
nicole.collison@drdc-rddc-gc.ca

Vijay Parsa
(519) 661-2111 Ex. 88947
parsa@nca.uwo.ca

Corjan Buma
(780) 435-9172
bunacj@superiway.net

Christian Giguère
613-562-5800 Ext. 3071
cgigure@UOTTAWA.CA

Richard Peppin
(410) 290-7726
peppinr@scantekinc.com

Mark Cheng
(604) 276-6366
mark_cheng@yvr.ca

Anita Lewis
(403) 297-3793
anita.lewis@gov.ab.ca

SUSTAINING SUBSCRIBERS / ABONNES DE SOUTIEN

The Canadian Acoustical Association gratefully acknowledges the financial assistance of the Sustaining Subscribers listed below. Annual donations (of $250.00 or more) enable the journal to be distributed to all at a reasonable cost. Sustaining Subscribers receive the journal free of charge. Please address donation (made payable to the Canadian Acoustical Association) to the Secretary of the Association.

L'Association Canadienne d'Acoustique tient à témoigner sa reconnaissance à l'égard de ses Abonnés de Soutien en publiant ci-dessous leur nom et leur adresse. En amortissant les coûts de publication et de distribution, les dons annuels (de $250.00 et plus) rendent le journal accessible à tous nos membres. Les Abonnés de Soutien reçoivent le journal gratuitement. Pour devenir un Abonné de Soutien, faites parvenir vos dons (chèque ou mandat-poste fait au nom de l'Association Canadienne d'Acoustique) au secrétaire de l'Association.

ACI Acoustical Consultants Inc.
Mr. Steven Bilawchuk - (780) 414-6373
stevenb@aciacoustical.com - Edmonton, AB

Acoustik GE Inc.
M. Gilles Elhadad - (514) 487 7159
ge@acoustikge.com - Cote St Luc, QC

Dalimar Instruments Inc.
Mr. Daniel Larose - (514) 424-0033
daniel@dalimar.ca - Vaudreuil-Dorion, QC

Eckel Industries of Canada Ltd.
Mr. Blake Noon - (613) 543-2967
eckel@eckel.ca - Morrisburg, ON

HGC Engineering Ltd.
Mr. Bill Gastmeier - (905) 826-4044
info@hgcengineering.com - Mississauga, ON

J.E. Coulter Associates Ltd.
Mr. John Coulter - (416) 502-8598
jcoulter@on.aibn.com - Toronto, ON

JASCO Research Ltd.
Mr. Scott Carr - (902) 491-4489
scott@jasco.com - Halifax, NS

MJM Conseillers en Acoustique Inc.
MJM Acoustical Consultants Inc.
M. Michel Morin- (514) 737-9811
mmorin@mjm.qc.ca - Montréal, QC

OZA Inspections Ltd.
Mr. Frank Westaway - (800) 667-8263x28
oza@ozagroup.com - Grimsby, ON

Pinchin Environmental
Mr. Weidong Li
(905) 507-4855
wli@pinchin.com - Mississauga, ON

SILEX Innovations Inc.
Mr. Mehmood Ahmed - (905) 612-4000
mehmooda@silex.com - Mississauga, ON

Solutions Acoustiques Inc.
Sylvain Larivière - (514) 793-3767
sylvainlariviere@solutionsacoustiques.com -
Laval, Québec

Tacet Engineering Ltd.
Dr. M.P. Sacks - (416) 782-0298
mal.sacks@tacet.ca - Toronto, ON

Wakefield Acoustics Ltd.
Mr. Clair Wakefield - (250) 370-9302
nonoise@shaw.ca - Victoria, BC

ACO Pacific Inc.
Mr. Noland Lewis - (650) 595-8588
acopac@acopacific.com - Belmont, CA

Aercoustics Engineering Ltd
Mr. John O'Keefe - (416) 249-3361
aercoustics@aercoustics.com - Rexdale, ON

Dodge-Regupol
Mr. Paul Downey - (416) 440-1094
pcd@regupol.com - Toronto, ON

H.L. Blachford Ltd.
Mr. Dalton Prince - (905) 823-3200
amsales@blachford.ca - Mississauga, ON

Hydro-Quebec
M. Blaise Gosselin - (514) 840-3000x5134
gosselin.blaise@hydro.qc.ca - Montréal, QC

J.L.Richards & Assoc. Ltd.
Mr. Fernando Ribas - (613) 728-3571
mail@jlrichards.ca - Ottawa, ON

John Swallow Associates Ltd.
Mr. John Swallow - (905) 271-7888
jswallow@jsal.ca - Mississauga, ON

Novel Dynamics Test Inc.
Mr. Andy Metelka - (519) 853-4495
metelka@aztec-net.com - Acton, ON

Peutz & Associés
M. Marc Asselineau - +33 1 45230500
marc.asselineau@club-internet.fr
Paris, FRANCE

Pyrok Inc.
Mr. Howard Podolsky - (914) 777-7770
info@pyrokinc.com - Mamaroneck, NY

SNC/Lavalin Environment Inc.
M. Jean-Luc Allard - (514) 651-6710
jeanluc.allard@snclavalin.com - Longueuil, QC

Spaarg Engineering Ltd.
Dr. Robert Gaspar - (519) 972-0677
gasparr@kelcom.igs.net - Windsor, ON

Valcoustics Canada Ltd.
Dr. Al Lightstone - (905) 764-5223
solutions@valcoustics.com
Richmond Hill, ON

West Caldwell Calibration Labs
Mr. Stanley Christopher - (905) 624-3919
info@wccl.com - Mississauga, ON

Acoustec Inc.
Dr. J.G. Migneron - (418) 682-2331
courrier@acoustec.qc.ca - Québec, QC

Bruel & Kjaer North America Inc.
Mr. Andrew Khoury - (514) 695-8225
- Pointe-Claire, QC

Earth Tech Canada Inc.
Ms. Deborah Olsen - (905) 886-7022x2209
noisevibration@earthtech.ca - Markham, ON

Hatch Associates Ltd.
Mr. Tim Kelsall - (905) 403-3932
tkelsall@hatch.ca - Mississauga, ON

Integral DX Engineering Ltd.
Mr. Greg Clunis - (613) 761-1565
au741@ncf.ca - Ottawa, ON

Jade Acoustics Inc.
Ms. Dalila Giusti - (905) 660-2444
dalila@jadeacoustics.com - Concord, ON

Mc SQUARED System Design Group
Mr. Wade McGregor - (604) 986-8181
info@mcsquared.com - North Vancouver, BC

Owens-Corning Canada Inc.
Mr. Keith Wilson - (800) 988-5269
keith.wilson@owenscorning.com - Milton, NS

Michel Picard
(514) 343-7617; FAX: (514) 343-2115
michel.picard@umontreal.ca - Brossard, QC

Scantek Inc.
Mr. Richard J. Peppin - (410)-290-7726
peppinr@scantekinc.com - Columbia, MD

Soft dB Inc.
M. André L'Espérance - (418) 686-0993
contact@softdb.com - Sillery, Québec

State of the Art Acoustik Inc.
Dr. C. Fortier - (613) 745-2003
sota@sota.ca - Ottawa, ON

Vibro-Acoustics
Mr. Tim Charlton - (800) 565-8401
tcharlton@vibro-acoustics.com
Scarborough, ON

Wilrep Ltd.
Mr. Don Wilkinson - (905) 625-8944
www.wilrep.com - Mississauga, ON