ISSN 0711-6659

canadian acoustics
acoustique canadienne

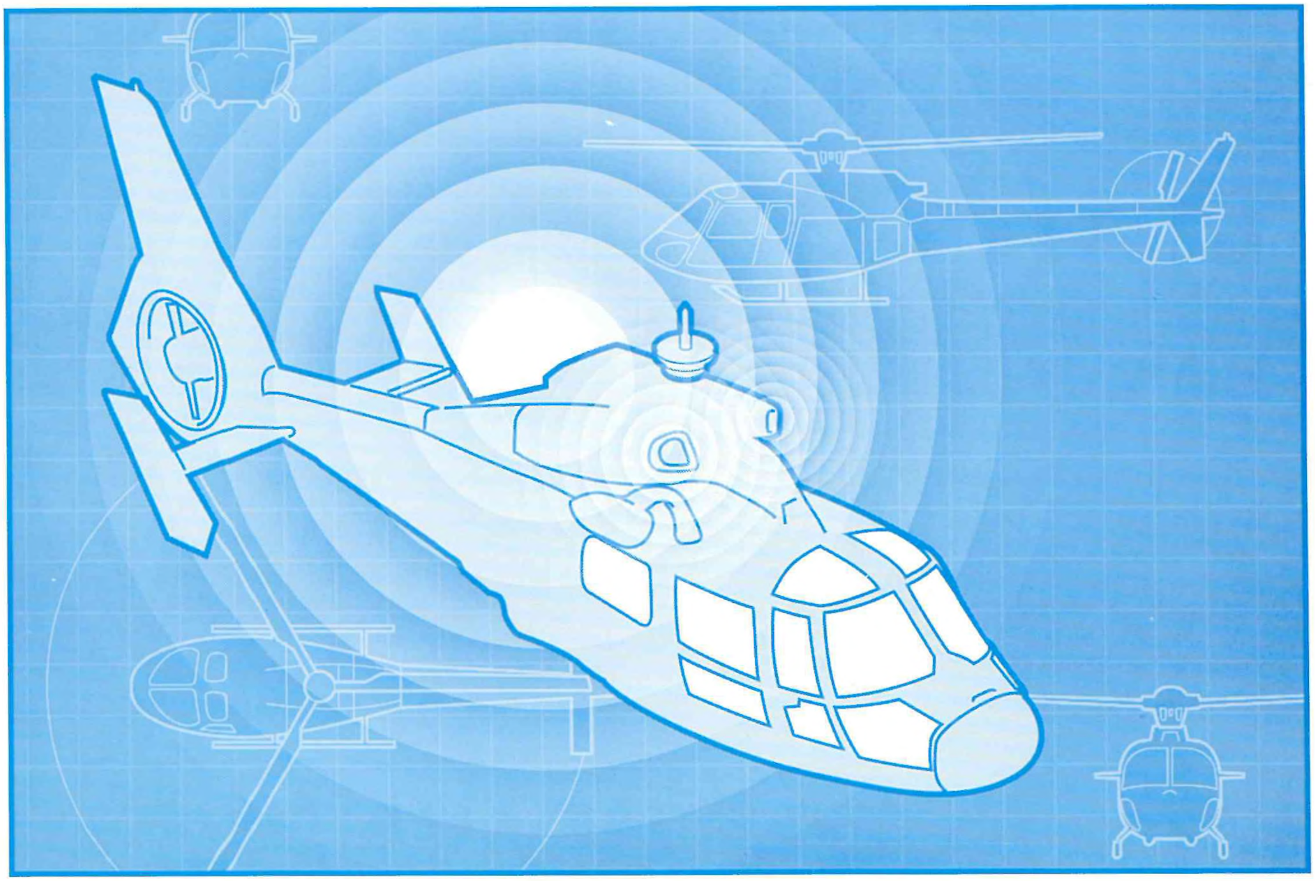
DECEMBER 1998 DECEMBRE 1998
Volume 26 — Number 4 Volume 26 — Numéro 4

Jérémie Voix

TECHNICAL ARTICLES AND NOTES / ARTICLES ET NOTES TECHNIQUES

PROCEEDINGS OF ACOUSTICS WEEK IN CANADA 1998 /
ACTES DE LA SEMAINE CANADIENNE D'ACOUSTIQUE 1998

OTHER FEATURES / AUTRES RUBRIQUES



canadian acoustics

acoustique canadienne

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: $10 (student); $50 (individual, institution); $150 (sustaining - see back cover). Back issues (when available) may be obtained from the CAA Secretary - price $10 including postage. Advertisement prices: $400 (centre spread); $200 (full page); $120 (half page); $80 (quarter page). Contact the Associate Editor (advertising) to place advertisements. Canadian Publication Mail Product Sales Agreement No. 0557188.

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: $10 (étudiant); $50 (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: $400 (page double); $200 (page pleine); $120 (demi page); $80 (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.

EDITOR-IN-CHIEF / RÉDACTEUR EN CHEF

Ramani Ramakrishnan
Aiolos Engineering Inc.
51 Constellation Court
Suite 200
Toronto, Ontario M9W 1K4
Tel: (416) 674-3017
Fax: (416) 674-7055
E-mail: ramani@aiolos.com

Advertising / Publicité

Chris Hugh
Hatch Associates Ltd.
2800 Speakman Drive
Mississauga, Ontario L5K 2R7
Tel: (905) 403-3908
Fax: (905) 824-4615
E-mail: chugh@hatch.ca

EDITOR / RÉDACTEUR

Chantai Laroche
Dépt. d'orthophonie et d'audiologie
Université d'Ottawa
545 King Edward
Ottawa, Ontario K1N 6N5
Tél: (613) 562-5800 ext$^{\underline{\text{n}}}$/poste 3066
Fax: (613) 562-5256
E-mail: claroche@aix1.uottawa.ca

News / Informations

Francine Desharnais
DREA - Ocean Acoustics
P. O. Box 1012
Dartmouth, NS B2Y 3Z7
Tel: (902) 426-3100
Fax: (902) 426-9654
E-mail: desharnais@drea.dnd.ca

EDITORIAL / ÉDITORIAL

"Uneasy Lies the Head that Wears a Crown" King Henry IV, Part II

Let me hope that the Bard's pithy statement doesn't hold true in this instance and that *uneasiness* doesn't go with this position, now that I have the unenviable task of filling the shoes of my predecessor, Murray Hodgson. I'd like to begin by thanking Murray for steering the *Canadian Acoustics* on an even keel for all these years. Against all obstacles, Murray performed a yeoman's job and I believe Murray deserves collective kudos from all of us.

I am sure, now that a new captain has taken over, all of you must wonder about the journey the journal has embarked on and the directions the journal is expected to take. I am thankful that the old guard, Chantal Laroche, Chris Hugh and Francine Desharnais, have graciously agreed to continue to work with me. One of my colleagues at Aiolos Engineering, Dr. Sid-Ali Meslioui, has offered to assist me with French translations. So we begin with a strong team and the beginning portends well.

The journal will continue as it is for sometime. However, I am cognizant of the results of our President, John Bradley's, recent survey, that the membership expects the journal to have a strong presence within the Canadian Acoustical Association. I shall truly endeavour to make the journal evolve into something midway between a trade magazine such as *Sound and Vibration*, and an academic journal such as the *Journal of the Acoustical Society of America*. My main hope is to have the focus of *Canadian Acoustics* on the acoustical activities across Canada. I strongly believe that it is possible to have a journal that caters to a wide professional audience across Canada. Join me to make this happen!

"Mensonges incommodes la tête qui porte une couronne " le Roi Henry IV, partie II

Laissez-moi espérer que le rapport vigoureux de Bard ne juge pas vrai dans ce cas, et que l'incommodité n'est pas assortie à cette position, maintenant que j'ai la tâche détestable d'enfiler les pantoufles de mon prédécesseur, Murray Hodgson. Je voudrais commencer par remercier Murray pour avoir orienter l'*Acoustique Canadienne* sur une voie solide durant toutes ces années. Murray a exécuté son travail avec beaucoup de perséverence et de tenacité malgré tous les obstacles. Je crois donc que Murray mérite les plus vives félicitations de la part de chacun d'entre nous.

Je suis sûr, maintenant qu'un nouveau capitaine a succédé, vous tous devrez vous demandez sur quelle voie le journal s'est embarqué et dans quelles directions il sera orienter. Je suis reconnaissant que la vieille garde, Chantal Laroche, Chris Hugh et Francine Desharnais, aient gracieusement accepté de continuer à travailler avec moi. Un de mes collègues à Aiolos Engineering, Dr. Sid-Ali Meslioui, a offert de m'aider avec les traductions françaises. Ainsi nous commençons par une équipe forte et les débuts s'annonçent déjà très prometteurs.

Le journal va continuer comme il est pendant encore quelques temps. Cependant, je suis conscient des résultats du dernier sondage, de notre président John Bradley, que les membres s'attendent à ce que le journal ait une présence forte dans l'Association Canadienne d'Acoustique. J'essayerai vraiment de transformer le journal en quelque chose à mi-chemin entre un magazine commercial tel que " Sound and Vibration", et un journal typiquement académique tel que "Journal of the Acoustical Society of America." Mon principal espoir est d'orienté l'*Acoustique Canadienne* envers toutes les activités d'acoustique à travers le Canada. Je crois sincèrement qu'il est possible d'avoir un journal qui répond non seulement aux besoins des membres de l'association mais aussi à celui des professionnels à travers le pays. Joignez-moi donc pour réaliser ceci.

WHAT'S NEW ??

Promotions
Deaths
New jobs
Moves
Retirements
Degrees awarded
Distinctions
Other news

Do you have any news that you would like to share with *Canadian Acoustics* readers? If so, send it to:

QUOI DE NEUF ??

Promotions
Décès
Offre d'emploi
Déménagements
Retraites
Obtention de diplômes
Distinctions
Autres nouvelles

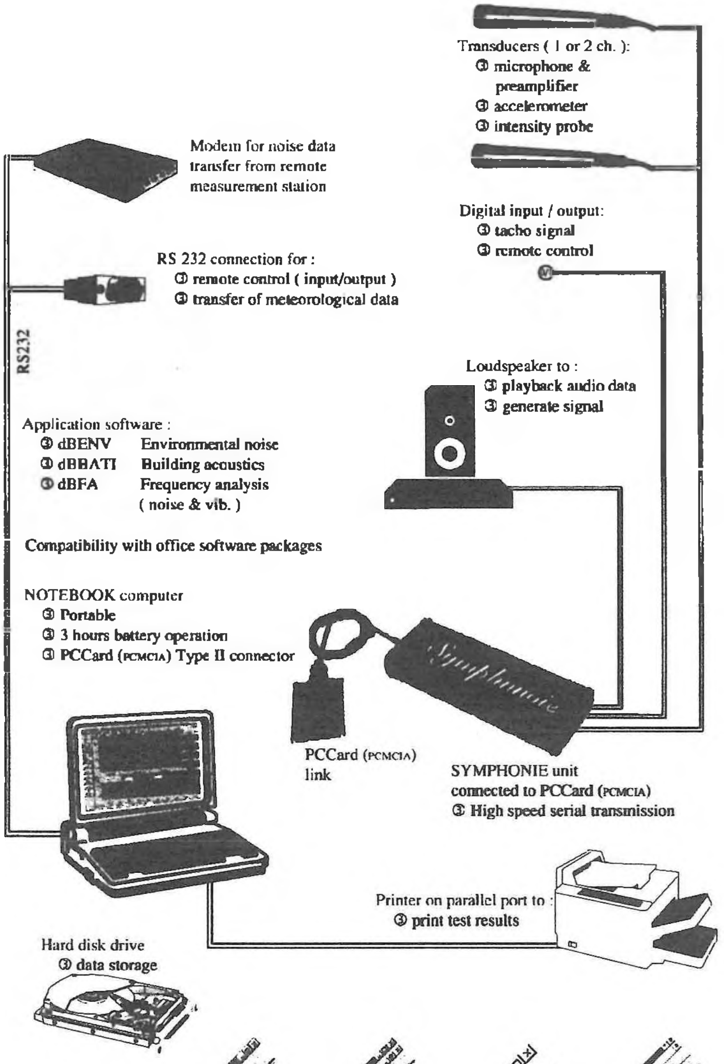
Avez-vous des nouvelles que vous aimeriez partager avec les lecteurs de l'*Acoustique Canadienne*? Si oui, écrivez-les et envoyer à:

Francine Deshamais, DREA Ocean Acoustics, P.O. Box 1012, Dartmouth NS, Email: desharnais@drea.dnd.ca

01dB Inc.

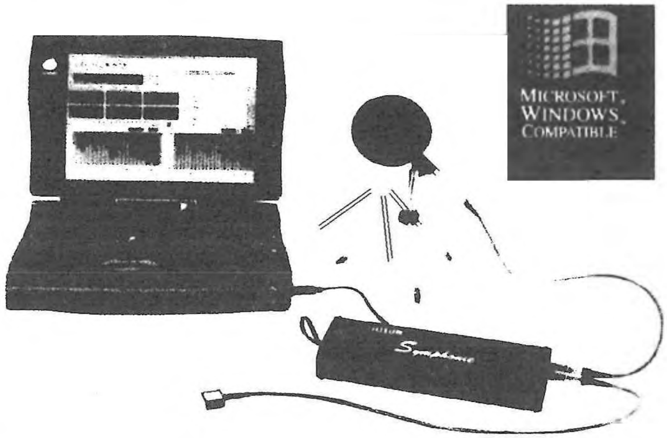
Symphonie

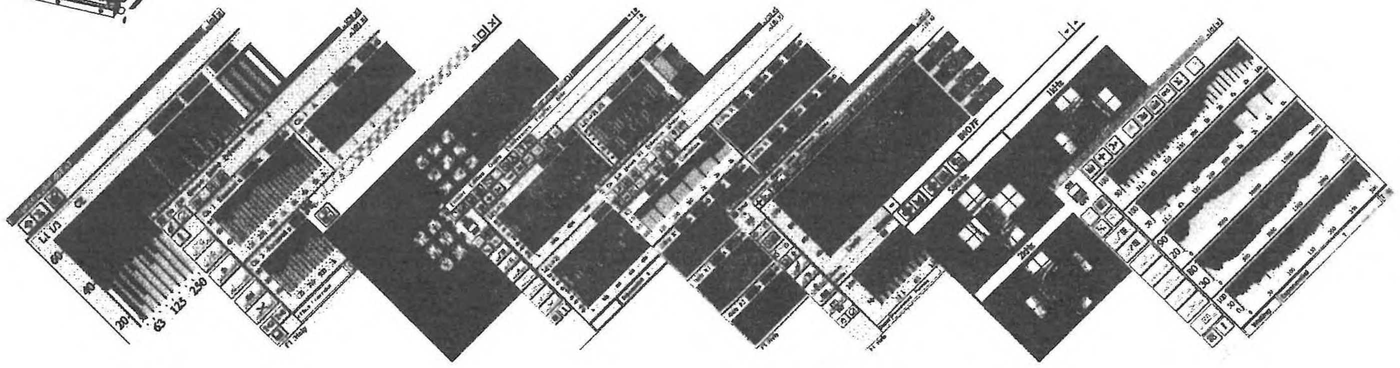
Dual Channel
Real Time
Measurement System

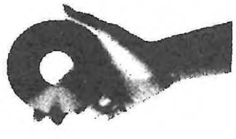


- ✓ Dual Channel Real Time Frequency Analyser
- ✓ Enviromental Noise Analyser
- ✓ Building Acoustics Analyser
- ✓ Vibration Analyser
- ✓ Sound Intensity Analyser
- ✓ Sound Power ISO 9614
- ✓ Digital recorder
- ✓ Octave Analyser
- ✓ Psycho-Acoustics/Sound Quality
- ✓ Type 1 ANSI 1.4
- ✓ Digital Filtering Type 0-IEC 1260, ANSI 51.11
- ✓ Windows 95/98 NT Based Real-time Acquisition
- ✓ Real-time Loudness

MICROSOFT. WINDOWS. COMPATIBLE







Mediaacoustic CD-ROM
Teaching Acoustics by Computer

NOVEL DYNAMICS INC.

Dynamic Test and Analysis Systems

Toronto 519-853-4495 Fax 519-853-3366
Ottawa 613-599-6275 Fax 613-599-6274

Canadian Acoustics / Acoustique Canadienne 26(4) 3-13 (1998) ***Research article / Article de recherche***

ANALYTICAL FORMULATION OF THE RADIATION OF SOUND FROM A RECTANGULAR LINED DUCT

Sid-Ali Meslioui
Aiolos Engineering Corporation
51 Constellation Court, Toronto, Ontario, M9W 1K4, Canada.

Jérémie Voix

SUMMARY

This paper deals with the radiation of sound from the open-end of a flanged rectangular lined duct. The duct model consists of a semi-infinite rectangular duct with a lined section of length L. The efficiency of the acoustic treatment for the radiated sound is evaluated by comparing the total power radiated from a duct with and without the lined section. This procedure also allows evaluation of the directivity patterns. The transmitted modal coefficients at the impedance discontinuity junction for a propagating mode (plane wave or higher order mode), incident from the rigid duct, are calculated. Simple analytical tools to predict the radiation of sound have been developed by using the "baffled membrane" approximation method. This model cannot handle reflections from the end, nor radiation to the back, nor an eventual outside flow. However, it is well adapted to the case of a lined duct treated with an arbitrary acoustic impedance, where an exact solution for even a two-dimensional duct is difficult. This method can be applied to turbofan noise and to HVAC systems for possible altering of the radiation pattern by either modifying the radiation field or the types of propagating modes.

SOMMAIRE

Nous présentons ici un modèle simplifié du rayonnement acoustique par l'extrémité d'un conduit droit à section rectangulaire dont seule la partie terminale est traitée par un revêtement absorbant sur une longueur donnée L. Lorsqu'une onde acoustique incidente, constituée d'un mode de propagation donné, arrive sur la portion traitée, il se forme une onde transmise et une onde réfléchie, toutes deux combinaisons de modes de propagation. Les modes de l'onde transmise sont atténués puisque les nombres d'ondes associés sont complexes. S'ils atteignent l'extrémité du conduit en conservant une amplitude suffisante, ils rayonnent à l'extérieur. Dans un premier temps, on calcule les coefficients modaux des modes transmis, puis le rayonnement acoustique par l'extrémité. Cependant, le modèle proposé ne prend en compte ni les réflexions, ni le rayonnement vers l'arrière, ni un éventuel écoulement du milieu extérieur. En revanche, il fournit des résultats simples à exploiter et se prête donc parfaitement à une étude paramétrique. De plus, il est parfaitement adapté au cas d'un conduit avec parois absorbantes, alors que la prise en compte d'une impédance de paroi induit des complications considérables dans la solution analytique exacte, même en configuration bidimensionnelle. Finalement, ce modèle a l'avantage de fournir un outil de calcul prévisionel du rayonnement acoustique par l'extrémité d'un conduit bafflé.

1. INTRODUCTION

In general, a propagating acoustic mode in a duct (plane wave or higher order mode) suffers diffraction at the exit plane of the duct. This phenomena results in both reflected and incident waves in the duct, as well as the radiation of the sound to the outside. The description of the phenomena in the near field is quite complicated, and in general, greater interest is given to the radiated sound in the far field.

The initial studies on the radiation of sound from an infinite rectangular flanged duct were conducted by Rayleigh [1]. The radiated sound was calculated from the known end section acoustic velocity by using the so-called "Rayleigh Integral." This approximation is also known as "baffled membrane method." Many later studies are based on this model.

The exact solution of the radiation problem, for the fundamental mode, from the end of a semi-infinite circular duct was developed by Levine and Schwinger [2], who applied the Wiener-Hopf technique [3] to solve the integral equation. The study showed that the plane wave reflection coefficient tends to zero at high frequencies which means that an approximate solution can thus be obtained by neglecting the reflection from the end at high frequencies. Later, Tyler and Sofrin [4] proposed a similar solution for the case of a rectangular or an annular duct for any incident mode. They found out that, in the case of higher order modes, the reflection coefficients need to be considered only near the cut-off frequencies of the modes while it tends to zero quickly above these frequencies (Morfey [5] and Homicz et al. [6]). The case of a lined duct with a known acoustic impedance was solved by Zorumski [7]. Later, Lansing et al. [8] studied the effect of the impedance of the duct walls on the transmission-reflection coefficients and on the radiation from the end of a baffled duct.

Koch [9] used the Wiener-Hopf technique to study the effect of a finite layer of an acoustic material, in a two dimensional semi-infinite duct, on the propagation and radiation of modes. He showed that the attenuation for a given mode is effective only around its cut-off frequency. However, the acoustic field has considerably changed because of the conversion of the modes due to the presence of the liner. Johnston and Ogimoto [10] also used the Wiener-Hopf technique to study the radiation of sound from the end of a finite cylinder containing uniform flow. Their method had to resort to many numerical approximations due to complicated analytical developments. Finally, Candel [11] developed analytical expression to calculate the radiation of acoustic modes from the end of a duct with uniform mean flow. He applied Fraunhofer approximation to the Kirchhoff formulation (formulation similar to that of the baffled membrane). The results were similar those obtained by Wiener-Hopf techniques.

The above studies mainly dealt with semi-infinite duct with simple geometry. The difficulties arise when the geometry or the shape of the duct is no longer straight, where only numerical methods (Finite Element or Boundary Element Methods) seem to be useful. These numerical methods, Kagawa et al. [12], and Wu and Lee [13], can be used to solve for ducts of arbitrary cross-sections and with finite length. However, these methods are frequency dependent and require a long computational time. Finally, Hamdi [14, 15] developed a method to predict the noise radiated from finite length ducts with arbitrary shape. The computation of the internal and external acoustic field is based upon a new variational formulation of the integral equations.

It is seen that the exact solution for the radiation of sound from an open duct of arbitrary shape or for a lined duct is not possible. This paper presents a simple method to predict the radiation of sound from a semi-infinite rectangular lined duct. The acoustic treatment is over length L, near the open end. This model, even though complicated due to the presence of the lined section, seems to provide more realistic results compared to the cases of fully lined and unlined ducts to determine the attenuation provided by the liner. Furthermore, this model will be of great use because of its simple formulation in turbofan noise and HVAC systems design.

The efficiency of the acoustic treatment for the radiated sound is evaluated by comparing the total power radiated from a duct with and without the lined section. This procedure can also be used to study the directivity patterns. However, this model is not suitable to evaluate end reflections or ducts with mean flow.

The presence of a lined section induces a discontinuity problem which is solved in the first part. The modal coefficients of the transmitted modes are calculated from a matrix system which depends on the eigenvalues of the duct modes.

The second part deals with the radiation problem. A comparison between an exact solution obtained by using Wiener-Hopf techniques, Candel [11,18], and the approximate solution based on the baffled membrane method for the radiation of sound from a two semi-infinite parallel plates, is also discussed This comparison provides a validitation of the model elaborated in the last section. Furthermore, analytical expressions are also given to calculate the radiation of sound from the end of the duct.

2. SOUND PROPAGATION IN DUCT WITH DISCONTINUITY OF IMPEDANCE

Sound propagation in a flanged rectangular duct treated with acoustic lining over a length L near the flanged end is analyzed in this section. The duct and the coordinate system are shown in Figure 1. The first section of the duct (section I) has rigid walls; the second section (section II) has its all four walls treated with an acoustic liners with known normal acoustic impedance. Let us now consider an acoustic mode (m_0, n_0) incident from the rigid section I with an amplitude $A_{m_0n_0}$. The acoustic mode, at the junction between the lined and unlined sections of the duct, is partly transmitted into the lined section as a series of modes with complex amplitudes $\hat{A}_{qp}$ and partly reflected back into the rigid section I with complex modal amplitudes $\hat{B}_{mn}$. The acoustic energy in the incident mode is thus partially transmitted into the lined section and partially reflected back. The determination of the amplitudes of the transmitted modes is described in section 2.2.

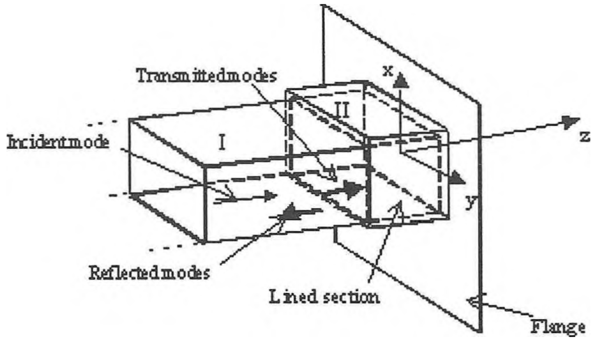


Figure 1-a: Flanged rectangular duct with an acoustically lined end section

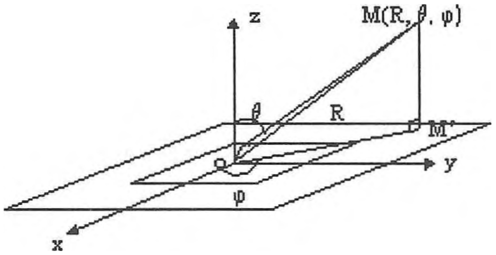


Figure 1-b: Radiation system coordinates

2.1 Basic Equations

The acoustic field inside the duct is determined by the Helmholtz equation

$$\Delta P + k^2 P = 0 \tag{1}$$

where P is the acoustic pressure, $k = \omega / c_0$ is the wave number, ω the angular frequency and ρ, c_0 are the ambient density and speed of sound respectively. The sidewall boundary conditions are

- In section I: $\dfrac{\partial P}{\partial \tilde{\mathbf{n}}} = 0$

  at $x = \pm l_x/2\,;\ y = \pm l_y/2$ (2)
- In section II: $\dfrac{\partial P}{\partial \tilde{\mathbf{n}}} = i\,k\,A\,P$

  at $x = \pm l_x/2\,;\ y = \pm l_y/2$ (3)

where A is the normalized wall admittance of a “locally reacting” boundary and $\tilde{\mathbf{n}}$ is the outward normal.

The general solution for the pressure field in section I of the duct is given by, (the term $e^{i\omega t}$ is implicit throughout the paper)

$$\begin{aligned} P_I(x,y,z) &= A_{m_0 n_0}\,\Psi\left(K_{m_0} x\right)\Psi\left(K_{n_0} y\right) e^{-iK_{m_0 n_0} z} \\ &\quad + \sum_{m=1}^{\infty}\sum_{n=1}^{\infty} \hat{B}_{mn}\,\Psi(K_m x)\Psi(K_n y)\, e^{iK_{mn} z} \end{aligned} \tag{4}$$

where,

$$\begin{cases} \Psi(K_m x) = {}^{\cos}_{\sin}(K_m x) \\ \Psi(K_n y) = {}^{\cos}_{\sin}(K_n y) \end{cases} \tag{5}$$

are the eigenfunctions. A cosine function is used for the even modes and a sine function for the odd modes. The transverse wave numbers K_m and K_n are determined by the boundary condition (2) and are

$$\begin{cases} K_m = (m-1)\pi / l_x \\ K_n = (n-1)\pi / l_y \end{cases} \tag{6}$$

where l_x and l_y are the cross-sectional dimensions of the duct in the x and y direction respectively. ‘m’ and ‘n’ are integers different from zero.

The axial wave number is given by the following dispersion equation

$$K_{mn}^2 = k^2 - \left(K_m^2 + K_n^2\right) \tag{7}$$

The propagation of the waves in the axial direction is possible as long as the axial wave number $K_{mn}^2 > 0$. According to equation (7), this is true for

$$\omega > c_0 \sqrt{K_m^2 + K_n^2} = \omega_{mn}^c \tag{8}$$

Below this “cut-off” frequency ω_{mn}^c, the axial wave number K_{mn} becomes a purely imaginary number, and the propagation factors in equation (4) turn into $e^{-\left|K_{mn} z\right|}$; which means the amplitudes of these modes decay exponentially with axial distance from the source: they are “cut-off”. Notice that the mode (m_0, n_0) is just one particular mode over all possible (m, n) modes.

Now, let us consider the case of a treated duct: the general solution for the pressure field in Section II of the duct is (assuming that reflections from the end of the duct are neglected)

$$P_{II}(x,y,z)=\sum_{q=1}^{\infty}\sum_{p=1}^{\infty}\hat{A}_{qp}\,\hat{\Psi}(\hat{K}_q\,x)\,\hat{\Psi}(\hat{K}_p\,y)\,e^{-i\hat{K}_{qp}z} \tag{9}$$

where,

$$\begin{cases}\hat{\Psi}(\hat{K}_q\,x)=\begin{smallmatrix}\cos\\ \sin\end{smallmatrix}(\hat{K}_q\,x)\\ \hat{\Psi}(\hat{K}_p\,y)=\begin{smallmatrix}\cos\\ \sin\end{smallmatrix}(\hat{K}_p\,y)\end{cases} \tag{10}$$

are the complexes eigenfunctions. The transverse wave numbers are determined by the boundary condition (3),

$$\begin{cases}\hat{K}_q=\hat{\mu}_q\,\pi\,/\,l_x\\ \hat{K}_p=\hat{\mu}_p\,\pi\,/\,l_y\end{cases} \tag{11}$$

and the axial wave number by the following dispersion equation

$$\hat{K}_{qp}^2=k^2-\left(\hat{K}_q^2+\hat{K}_p^2\right) \tag{12}$$

where $\hat{\mu}_q$ and $\hat{\mu}_p$ are complex numbers. Note, in this case, the "cut-off notion" has no physical meaning. Assuming $\hat{K}_{qp}=(\alpha\pm i\,\beta)k$, α is the non-dimensional axial wave number and β is the damping factor of the mode. β should be positive for a mode propagating in z > 0 direction. This means that we should look for a solution to equation (12) that gives attenuation.

Solving equation (9) by the method of separation of variables and imposing the boundary conditions (3) leads to the following characteristic equations

$$\left(\hat{K}_e\,l_j/2\right)\begin{smallmatrix}\tan\\ \cot\end{smallmatrix}\left(\hat{K}_e\,l_j/2\right)=\pm i\,k\,A\,l_j/2 \tag{13}$$

where the term in tangent is used for even modes and the one with cotangent for odd modes. Indices 'e' and 'j' represent q or p and x or y respectively depending on the propagation direction.

The axial and transverse wave numbers were computed using a numerical scheme developed by Eversman [16, 17], where the characteristic equation is transformed into a first order non-linear differential equation. The differential equation is integrated by using a Runge-Kutta algorithm with appropriate initial values. The transverse wave numbers are then used to compute the axial wave number using equation (12).

2.2 Calculation of Transmitted Modal Coefficients

The pressure and acoustic velocity are related by the momentum equation

$$\nabla\,\overline{\mathrm{P}}=-i\,k\,\rho\,c_0\,\overline{\mathrm{V}} \tag{14}$$

Using equations (4) and (9), the axial velocity in both sections (I and II) can be written as

$$\begin{cases}V_I(x,y,z)=(1/k\,\rho\,c_0)\left\{A_{m_0n_0}\,K_{m_0n_0}\,e^{-iK_{m_0n_0}z}\,\Psi(K_{m_0}\,x)\,\Psi(K_{n_0}\,y)-\sum\limits_{m=1}^{\infty}\sum\limits_{n=1}^{\infty}\hat{B}_{mn}\,K_{mn}\,e^{iK_{mn}z}\,\Psi(K_m\,x)\Psi(K_n\,y)\right\}\\ V_{II}(x,y,z)=(1/k\,\rho\,c_0)\sum\limits_{q=1}^{\infty}\sum\limits_{p=1}^{\infty}\hat{A}_{qp}\,\hat{K}_{qp}\,\hat{\Psi}(\hat{K}_q\,x)\,\hat{\Psi}(\hat{K}_p\,y)\,e^{-i\hat{K}_{qp}z}\end{cases} \tag{15}$$

The unknown amplitudes $\hat{A}_{qp}$ and $\hat{B}_{mn}$ in equations (4), (9) and (15) are determined from a system of linear equations obtained by applying continuity conditions: the pressures and axial velocities in the two sections of the duct must be equal at the junction (z = 0) of the lined and unlined sections.

$$\begin{cases}P_I(x,y,0)=P_{II}(x,y,0)\\ V_I(x,y,0)=V_{II}(x,y,0)\end{cases} \tag{16}$$

Thus, by substituting equations (4), (9) and (15) into (16) and using the orthogonality properties of the eigenfunctions, the following system for the transmitted modal coefficients is obtained

$$\sum_{q=1}^{\infty}\sum_{p=1}^{\infty} \hat{A}_{qp}\,\hat{I}_{m'q}\,\hat{J}_{n'p}\left(\hat{K}_{qp}+K_{m'n'}\right)=A_{m_0n_0}\frac{\left(1+\delta_{m_01}\right)}{2}\frac{\left(1+\delta_{n_01}\right)}{2}\delta_{m_0m'}\,\delta_{n_0n'}\left(K_{m'n'}+K_{m_0n_0}\right) \tag{17}$$

where δ is the Kronecker delta and

$$\hat{I}_{ij}=\frac{1}{l_x}\int_{-l_x/2}^{l_x/2}\Psi(K_i\,x)\,\hat{\Psi}\left(\hat{K}_j\,x\right)dx \tag{18}$$

$$\hat{J}_{ij}=\frac{1}{l_y}\int_{-l_y/2}^{l_y/2}\Psi(K_i\,y)\,\hat{\Psi}\left(\hat{K}_j\,y\right)dy \tag{19}$$

Equations (18) and (19) are solved analytically. The same process as described above leads to a system of equation, as in (17) for the reflected modal coefficients. The reflected modal coefficients are not discussed here, since the aim is to calculate the radiated sound field.

The system indices, m and n, vary from 1 to $\mathbf{M_m}$ and 1 to $\mathbf{N_n}$ respectively; while q, p vary from 1 to $\mathbf{Q_q}$ and 1 to $\mathbf{P_p}$ respectively after truncation. $\mathbf{M_m}$ and $\mathbf{N_n}$ are the total possible propagating modes along 'x' and 'y' in Section I. Therefore, we have **[Q$_q$*P$_p$]** complex equations and **[Q$_q$*P$_p$]** complex unknown which are the transmitted modal coefficients. The final linear system (17) could be re-written as,

$$[a].[X]=[b] \tag{20}$$

where,

$[a]$ complex vector which contains the modal transmitted coefficients to be determined,

$[X]$ complex matrix which depends on the modes (m, n) and on the eigenvalues of the system,

$[b]$ known vector which depends on the incident mode (m_0,n_0) and its amplitude $A_{m_0n_0}$.

The final matrix [X] is square and the dimension of the system is multiplied by 2 to account for the complex numbers, therefor the final matrix dimension are [2*$\mathbf{Q_q}$*$\mathbf{P_p}$, 2*$\mathbf{Q_q}$*$\mathbf{P_p}$]. Further, The truncation is performed at $\mathbf{Q_q}$=$\mathbf{M_m}$+2 and $\mathbf{P_p}$=$\mathbf{N_n}$+2, and has been checked when calculating all possible transmitted and reflected coefficients at the discontinuity junction for any incident mode (m_0,n_0). It has been found that it's worthless and time consuming to consider a number of modes (generated in section II) greater than the limit chosen above. Finally, a numerical scheme, using LU decomposition algorithm with a matrix inversion, has been used to solve the final matrix system.

3. RADIATION FROM THE END OF THE DUCT

The radiated acoustic power from the duct is evaluated using

$$W=\int_{\varphi=0}^{2\pi}\int_{\theta=0}^{\pi/2}\frac{|P(M)|^2}{2\,\rho\,c_0}R^2\sin\theta\;d\theta\;d\varphi \tag{21}$$

where P(M) is the complex acoustic pressure at a location M in space expressed in spherical coordinates, $M=(R,\theta,\varphi)$.
The acoustic pressure in equation (21) can be written in terms of surface velocity using the Rayleigh integral,

$$P(M)=\frac{i\omega\,\rho}{2\pi}\int_S V\left(x_0,y_0\right)\Big|_{z=L}\;\frac{e^{-ikh}}{h}\;dS \tag{22}$$

where h is the distance between the source location $M_0(x_0,y_0)$ and the receiver location M. The acoustic far-field hypothesis leads to the following approximations

$\frac{1}{h}\approx\frac{1}{R}$ for the amplitude, and

$k\,h\approx k\,R-D_x\,x_0-D_y\,y_0$ for the phase

where,

$$D_x=k\;\sin\theta\;\cos\varphi \tag{23}$$

$$D_y=k\;\sin\theta\;\sin\varphi \tag{24}$$

3.1 Rigid Duct

Equation (22) can be calculated analytically for each incident mode of a rigid duct. For a given mode (m_0,n_0) the fluctuation of the pressure can be written as, for an even-even mode excluding the fundamental mode $(m,n)=(1,1)$:

$$|P(M)|=\frac{1}{2\pi\,R}\left|A_{m_0n_0}\right|4\,K_{m_0n_0}\,|D_x|\,|D_y|\;\left|\frac{\sin(D_x\,l_x/2)}{K^2_{m_0}-D^2_x}\right|\left|\frac{\sin(D_y\,l_y/2)}{K^2_{n_0}-D^2_y}\right| \tag{25}$$

The term $\sin(D_x\, l_x/2)$ is replaced by $\cos(D_x\, l_x/2)$ in the case of an odd mode (same thing for the y direction). In the particular case of the fundamental mode $(m,n)=(1,1)$, the expression (25) becomes:

$$|P(M)| = \frac{|A_{11}|}{2\pi\, R}\, k\, l_x\, l_y \left| \frac{\sin(D_x\, l_x/2)}{(D_x\, l_x/2)} \right| \left| \frac{\sin(D_y\, l_y/2)}{(D_y\, l_y/2)} \right| \tag{26}$$

3.2 Lined Duct

The axial velocity component in integral (22) is complex with acoustic treatment and is given by,

$$V(x_0, y_0) = (1/k\, \rho\, c_0) \sum_{q=1}^{Q_q} \sum_{p=1}^{P_p} \hat{A}_{qp}\, \hat{K}_{qp}\, \hat{\Psi}(\hat{K}_q\, x_0)\, \hat{\Psi}(\hat{K}_p\, y_0)\, e^{-i\hat{K}_{qp} L} \tag{27}$$

By replacing (27) into (22) and calculating the integral analytically, we obtain the following expression for the fluctuating pressure:

$$\begin{aligned} |\hat{P}(M)| = {} & \frac{1}{2\pi\, R} \sum_{q=1}^{Q_q} \sum_{p=1}^{P_p} |\hat{A}_{qp}|\, \mathrm{Re}\{\hat{K}_{qp}\}\, e^{-2\,\mathrm{Im}\{\hat{K}_{qp}\}L} \\ & x \left| \frac{D_x\, \sin(D_x\, l_x/2)\cos(\hat{K}_q\, l_x/2) - \hat{K}_q\, \cos(D_x\, l_x/2)\sin(\hat{K}_q\, l_x/2)}{\hat{K}_q^2 - D_x^2} \right| \\ & x \left| \frac{D_y\, \sin(D_y\, l_y/2)\cos(\hat{K}_p\, l_y/2) - \hat{K}_p\, \cos(D_y\, l_y/2)\sin(\hat{K}_p\, l_y/2)}{\hat{K}_p^2 - D_y^2} \right| \end{aligned} \tag{28}$$

Similar expressions can be obtained for the other cases by replacing the term $D_x \sin(D_x\, l_x/2)\cos(\hat{K}_q\, l_x/2)$ with $D_x \cos(D_x\, l_x/2)\sin(\hat{K}_q\, l_x/2)$ of equation (28), and $\hat{K}_q\, \cos(D_x\, l_x/2)\sin(\hat{K}_q\, l_x/2)$ with $\hat{K}_q \sin(D_x\, l_x/2)\cos(\hat{K}_q\, l_x/2)$ in the case of an odd mode (same thing apply for the modes in the y direction).

4. RESULTS

In the existing literature, the possibility of changing the radiation pattern by modifying the aperture field has received a little attention. While, the attenuation properties of acoustical lining have been extensively studied, its effect on the radiation pattern has been overlooked.

The validity of the present formulation for the radiated field is first discussed. For this, we have compared the present approximate radiated field from a simple duct contained within two parallel semi-infinite rigid plates with the exact Wiener-Hopf solution of Candel [18].

4.1 Validation

Consider now the duct, shown in Figure 2, formed by two semi-infinite parallel plates. The acoustic pressure in the far-field is given by the Rayleigh Integral which is written as follows for the 2D case,

$$P(M) = i\omega\, \rho \int_l V(x_0)\big|_{z=0}\, \frac{e^{-ikr}}{\sqrt{2\pi\, r}}\, dl \tag{29}$$

Following the same process as described above, the expressions of the acoustic pressure in the far field are given below

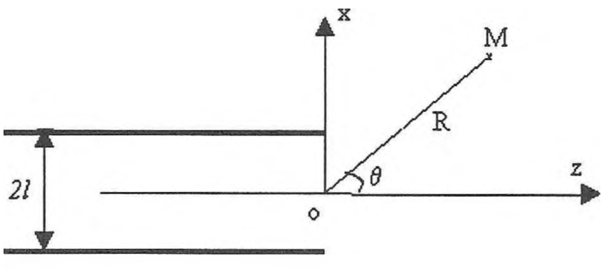


Figure 2. Geometry of the radiated problem for a duct formed by two semi-infinite rigid plates.

- Even modes (different from zero):

$$P(M)=\sqrt{\frac{2}{\pi r}}\left|A_{m_0}\right|\sqrt{1-\left(K_{m_0}/k\right)^2}\left|\frac{\sin\theta\,\sin(k\,l\sin\theta)}{\left(K_{m_0}/k\right)^2-\sin^2\theta}\right| \qquad (30)$$

- Odd modes:

$$P(M)=\sqrt{\frac{2}{\pi r}}\left|A_{m_0}\right|\sqrt{1-\left(K_{m_0}/k\right)^2}\left|\frac{\sin\theta\,\cos(k\,l\sin\theta)}{\left(K_{m_0}/k\right)^2-\sin^2\theta}\right| \qquad (31)$$

- Fundamental mode:

$$P(M)=\sqrt{\frac{2}{\pi r}}\left|A_{m_0}\right|k\,l\left|\frac{\sin(k\,l\sin\theta)}{(k\,l\sin\theta)}\right| \qquad (32)$$

where,

$\left|A_{m_0}\right|$ is the amplitude of the incident mode m_0 and K_{m_0} is its transverse wave number. The radiation fieled for multiple values of $k*l$ (reduced frequency) was calculated with the same mode number $m_0=2$ (incident mode) of Candel [18].

The radiation patterns for a duct formed by two semi-infinite parallel rigid plates are shown in Figure 3. The radiation pattern shows a larger number of lobes, a greater peak pressure, and angular distribution displaced towards the duct axis with increasing frequency. Most importantly, the approximate solution, represented on the right, agrees well with the exact solution, represented on the left, by the Wiener-Hopf technique. Even at high frequency, the agreement is good even though there is less radiation behind the duct aperture. Moreover, the direction of the main lobe remains unchanged in both cases and with the same sound pressure level.

4.2 Examples

The method described in section 3 leads to a simple relation to calculate the radiated far field from any rectangular duct. It also provides a useful tool for analytical study of the influence of lined duct wall on the radiation pattern.

The liners considered in this example are absorbers made of fibrous materials backed by a hard surface. The liners are assumed to be locally reacting. For a given flow resistivity σ, liner thickness d and frequency f, the impedance of the liner is determined by the empirical formulae given by Delany and Bazley [19]. The principal formula is:

$$Z=-i\,Z_c\cot(K_c\,d) \qquad (33)$$

where,

$$Z_c=\rho\,c_0\left[1+0.0571\,X^{-.754}-i\,0.087\,X^{-.732}\right] \qquad (34)$$

$$K_c=k\left[1+0.0978\,X^{-.700}-i\,0.189\,X^{-.595}\right] \qquad (35)$$

Z_c is the characteristic impedance of the material, K_c its wave number and $X=\rho f/\sigma$ a non-dimensional parameter. The admittance of the liner is $A=\rho\,c_0/Z$

4.3 Discussion

Directivity patterns for lined ducts are shown in Figures 4 through 10, for liner thickness of 100 mm and fill density of 25 kg/m^3. The treatment length, L, is 1 m and the acoustic far field pressure is calculated at a distance (R) of 10 m from the opening.

In Figures 4(a), 5(a), 6(a) and 7(a) the radiation patterns of the fundamental mode (1,1) are shown for the case of a rectangular rigid duct at different frequencies given in Table 1. The figures show one main lobe presenting a maximum along the duct axis which is a characteristic for that mode, and two or several side lobes depending on the frequency parameters. The same observation as described in section 4.1 can be made here about the lateral lobes: when the frequency increase, the radiation pattern shows a larger number of lobes, a greater peak pressure, and an angular distribution is displaced towards the duct axis.

Figures 4(b), 5(b), 6(b) and 7(b) show the effect of the liner on the directivity patterns in the case of a lined duct. It is seen that the radiation to the lateral sides is strongly reduced while the main lobe is becomes more wider.

The results for a higher order incident mode (2,2), are shown in Figure 8 for $k\,l_x/2\approx 5.5;\ k\,l_y/2\approx 3.5$ and in Figure 9 for $k\,l_x/2\approx 22;\ k\,l_y/2\approx 14$. The rigid duct case is represented in Figures 8(a), 9(a) and the lined case in Figures 8(b), 9(b). In the rigid case, the sound pressure level at the duct axis is zero and the directivity is stronger in the lateral sides with 4 main lobes. The effects of the acoustic treatment on the radiation remain as described above with a weak radiation in the lateral sides.

Finally, the incident mode (4,3) is shown in Figures 10(a) and 10(b) for the rigid case and the lined case respectively at frequency $\left(k\,l_x/2\approx 22;\ k\,l_y/2\approx 14\right)$. The same observations are evident.

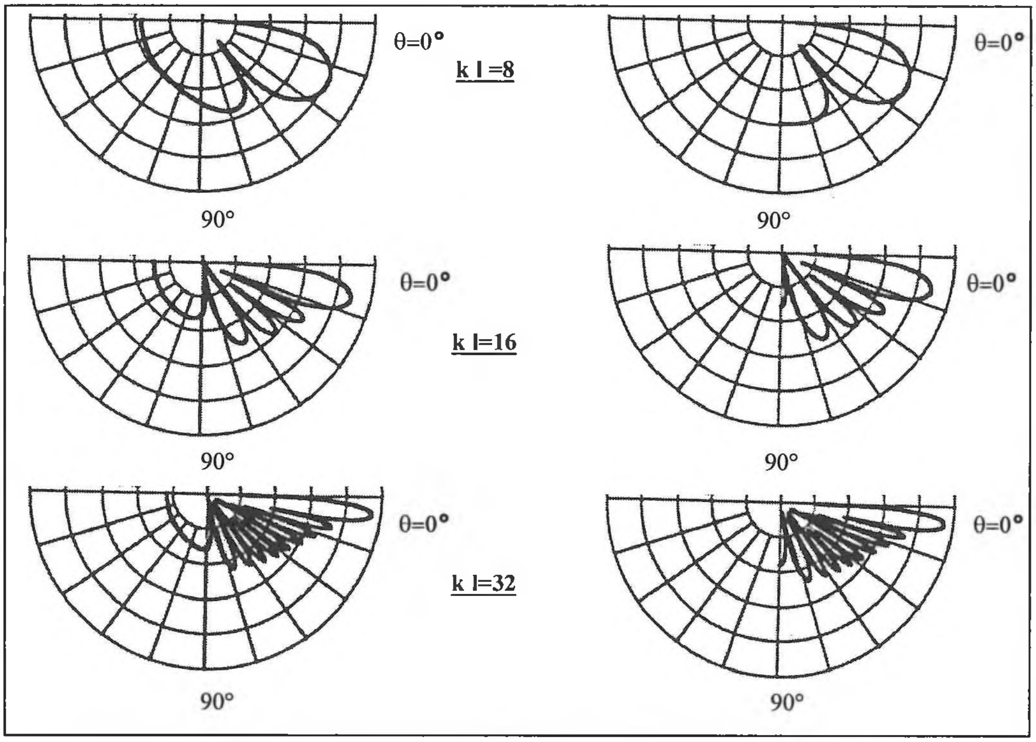


Figure 3. Radiation patterns for a duct formed by two semi-infinite parallel rigid plates. The exact Wiener-Hopf solution (by Candel [18]) is on the left; the approximate solution is on the right for different k l and mode $m_0 = 2$ (scale: 10 dB per graduation).

Figure no.	Incident mode	Adimensional frequency parameter $(k l_x / 2; k l_y / 2)$	Normalized Admittance	Total possible modes	Possible modes in X direction	Possible modes in Y direction
4	(1,1)	(5.5; 3.5)	(1.15-i 0.53)	10	4	3
5	(1,1)	(11; 7)	(1.48-i 0.3)	31	7	5
6	(1,1)	(22; 14)	(1.1-i 0.25)	114	14	10
7	(1,1)	(55; 36)	(1.09-i 0.15)	668	35	24
8	(2,2)	(11; 7)	(1.48-i 0.3)	31	7	5
9	(2,2)	(22; 14)	(1.1-i 0.25)	114	14	10
10	(4,3)	(22; 14)	(1.1-i 0.25)	114	14	10

Table 1. Description of the parameters of Figures 4 to 10.

5. CONCLUSIONS

The radiation from a lined duct with finite length treatment was evaluated using analytical/numerical schemes. It was seen that the presence of an acoustic liner inside a duct significantly reduces the side radiation from the open end of the duct. The absorbing walls focus the acoustic energy towards the center axis of the duct. While, near the walls, the energy is absorbed and hence the pressure oscillations are small. The amplitude of the pressure field in the aperture is decreased towards the edges. Such a decrease is equivalent to a reduction of the aperture area and would result in a broader main lobe in the radiation pattern and thus a lower directionality. However, the decreases in the amplitude of the pressure also produce a large reduction in the side lobe amplitudes. For the fundamental mode, the maximum of the radiated sound is reached at the duct axis as expected.

Finally, the analytical expressions developed here provide a useful tool to study the influence of a lined duct wall on the radiation pattern. It also allows the possibility of changing the radiation pattern by modifying the aperture field.

6. REFERENCES

[1] J.S. Rayleigh, "The Theory of Sound"
Dover Publication Inc. (1945).

[2] H. Levine and J. Schwinger, "On the radiation of sound from an unflanged circular pipe", Physical Revue (1948), Vol. 73(4), pp 383-406.

[3] B. Noble, "Methods based on the Wiener-Hopf technique", Pergamon Press, Oxford (1958).

[4] J.M. Tyler & T.G. Sofrin, "Axial flow compressor noise studies", SAE Trans. (1962), vol. 70, pp 309-332.

[5] C.L. Morfey, "A note on the radiation efficiency of acoustic duct modes", J. Sound and Vibration (1969), Vol. 9(3), pp. 367-372.

[6] G.F. Homicz and J.A. Lordi, "A note on the radiative directivity patterns of duct acoustic modes", J. Sound and Vibration (1975), Vol. 41(3), pp. 283-290.

[7] W.E. Zorumski, "Generalized radiation impedance and reflection coefficients of circular and annular ducts", J. Acoust. Society of America (1973), Vol. 54(6).

[8] D.L. Lansing and W.E. Zorumski, "Effects of wall admittance changes on duct transmission and radiation of sound", J. Sound and Vib. (1973), Vol. 27(1), pp. 85-100.

[9] W. Koch, "Radiation of sound from a two-dimensional acoustically lined duct", J. Sound and Vibration (1977), Vol. 55(2), pp. 255-274.

[10] G.W Johnston and K. Ogimoto, "Sound radiation from a finite length unflanged circular duct with uniform axial flow", J. Acoust. Society of America (1980), Vol. 68(6).

[11] S.M. Candel, "Acoustic radiation from the end of a two-dimensional duct, effects of uniform flow and duct lining", J. Sound and Vibration (1973), Vol. 28(1), pp. 1-13.

[12] Y. Kagawa et al., "Finite element approach to acoustic transmission-radiation systems and application to horn and silencer design", J. Sound and Vibration (1980), Vol. 69(2), pp. 207-228.

[13] T.L. Wu and L. Lee, "A direct boundary integral formulation for acoustic radiation in a subsonic uniform flow", J. Sound and Vibration (1994), Vol. 175(1), pp. 51-63.

[14] M.A. Hamdi, "Formulation variationnelle par équations intégrales pour le calcul de champ linéaires proches et lointains", Thèse de Doctorat d'état (1982), Université Technologique de compiègne - France.

[15] M.A. Hamdi and J.M. Ville, "Sound radiation from ducts: theory and experiment", J. Sound and Vibration (1986), Vol. 107(2), pp. 231-242.

[16] W. Eversman, "Computation of axial and transverse waves numbers for uniform two-dimensional ducts with flow using a numerical integration scheme", J. Sound and Vibration (1975), vol. 41(2), pp. 252-255.

[17] W. Eversman, "Initial values for the integration scheme to compute the eigenvalues for propagation in ducts", J. Sound and Vibration (1977), Vol. 50(1), pp. 159-162.

[18] S.M. Candel, "Acoustic radiation from a two dimensional duct. Effects of uniform flow and duct lining", Ph.D dissertation (1972), Chapter V, California Institute of Technology.

[19] M.E. Delany and E.N. Bazley, "Acoustical properties of fibrous absorbent materials", Applied Acoustics (1970), Vol. 3, pp. 105-116.

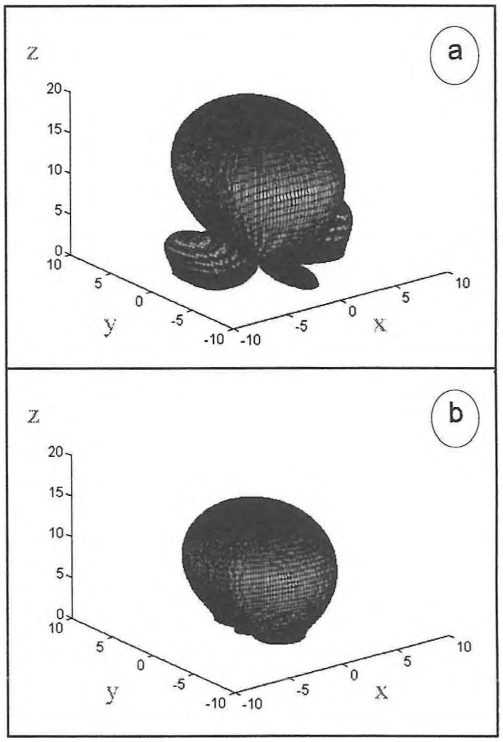


Figure 4. Directivity Patterns for mode incident (1,1), Adimensional frequency parameter (k lx/2; k ly/2)=(5.5; 3.5). (a) rigid case, (b) treated case. Normalized acoustic admittance=(1.15 - i .53).

x axis scale is $|P(M)| \sin\theta \cos\varphi$ *; y axis scale is* $|P(M)| \sin\theta \sin\varphi$ *and z axis scale is* $|P(M)| \cos\theta$

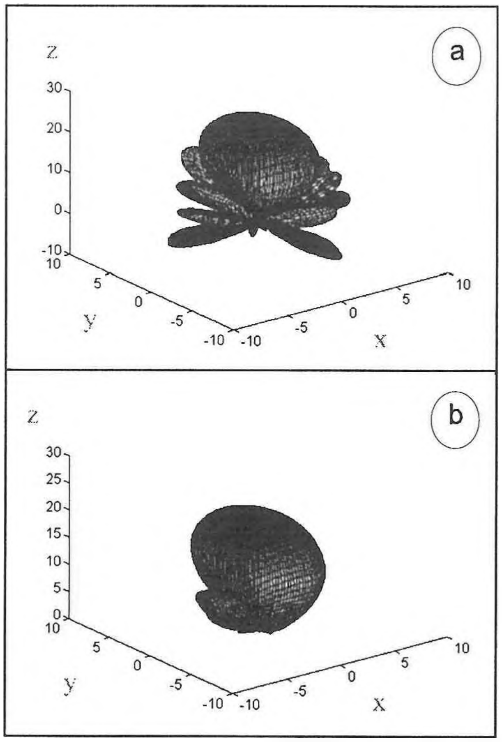


Figure 5. Directivity Patterns for mode incident (1,1), Adimensional frequency parameter (k lx/2; k ly/2)=(11; 7). (a) rigid case, (b) treated case. Normalized acoustic admittance=(1.48 - i .3).

x axis scale is $|P(M)| \sin\theta \cos\varphi$ *; y axis scale is* $|P(M)| \sin\theta \sin\varphi$ *and z axis scale is* $|P(M)| \cos\theta$

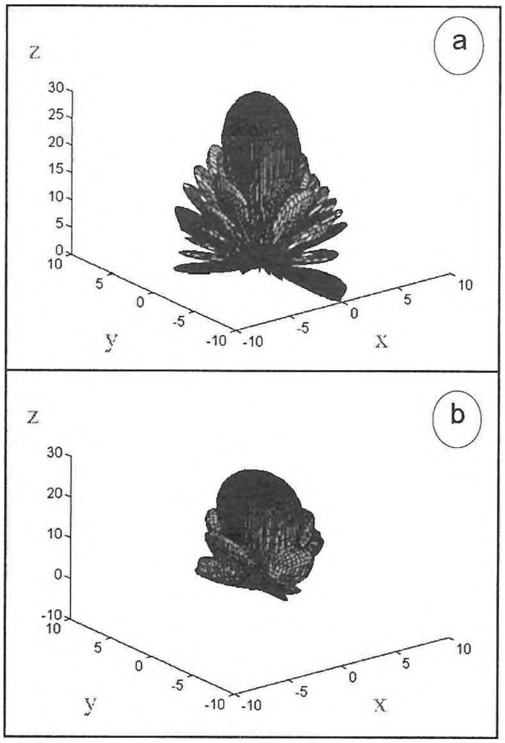


Figure 6. Directivity Patterns for mode incident (1,1), Adimensional frequency parameter (k lx/2; k ly/2)=(22; 14). (a) rigid case, (b) treated case. Normalized acoustic admittance=(1.1 - i .25).

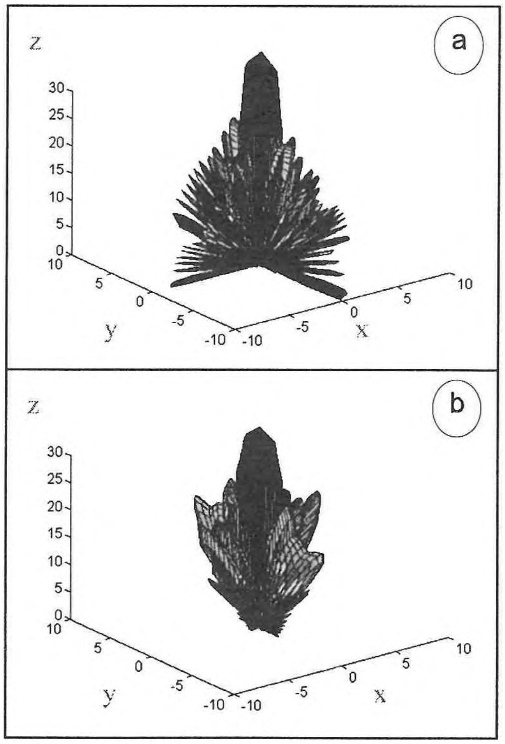


Figure 7. Directivity Patterns for mode incident (1,1), Adimensional frequency parameter (k lx/2; k ly/2)=(55; 36). (a) rigid case, (b) treated case. Normalized acoustic admittance=(1.09 - i .15).

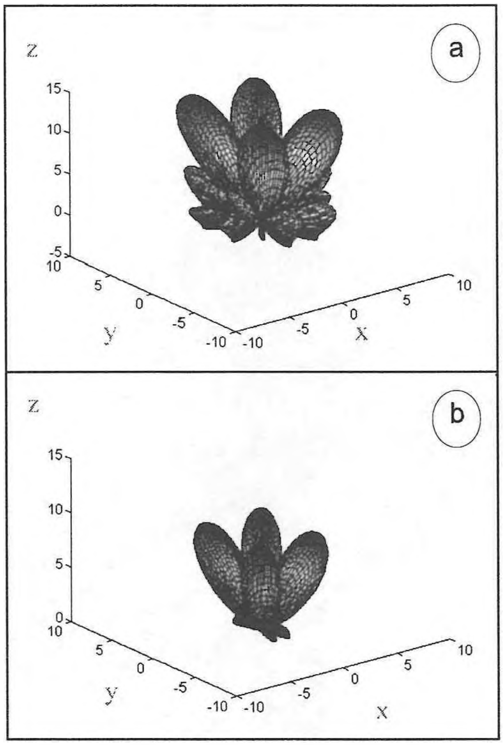


Figure 8. Directivity Patterns for mode incident (2,2), Adimensional frequency parameter (k lx/2; k ly/2)=(11; 7). (a) rigid case, (b) treated case. Normalized acoustic admittance=(1.48 - i .3).

x axis scale is $|P(M)| \sin\theta \cos\varphi$ *; y axis scale is* $|P(M)| \sin\theta \sin\varphi$ *and z axis scale is* $|P(M)| \cos\theta$

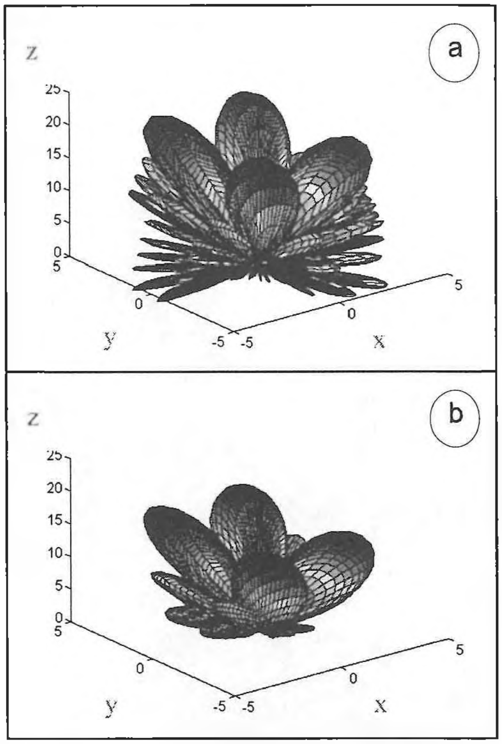


Figure 9. Directivity Patterns for mode incident (2,2), Adimensional frequency parameter (k lx/2; k ly/2)=(22; 14). (a) rigid case, (b) treated case. Normalized acoustic admittance=(1.1 - i .25).

x axis scale is $|P(M)| \sin\theta \cos\varphi$ *; y axis scale is* $|P(M)| \sin\theta \sin\varphi$ *and z axis scale is* $|P(M)| \cos\theta$

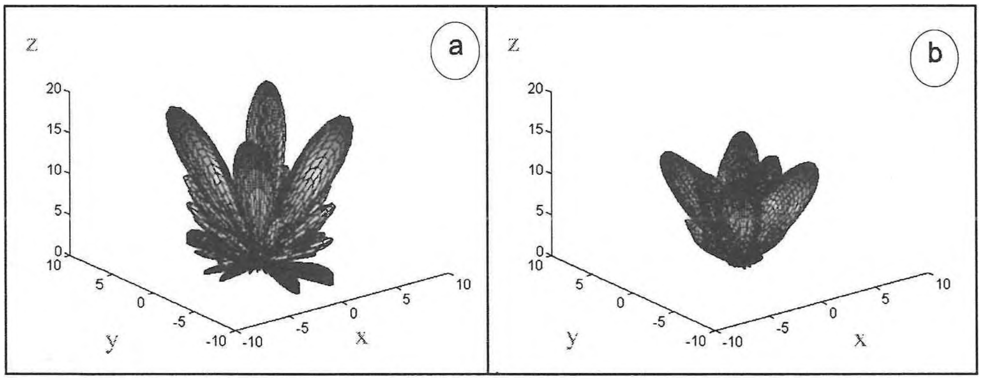
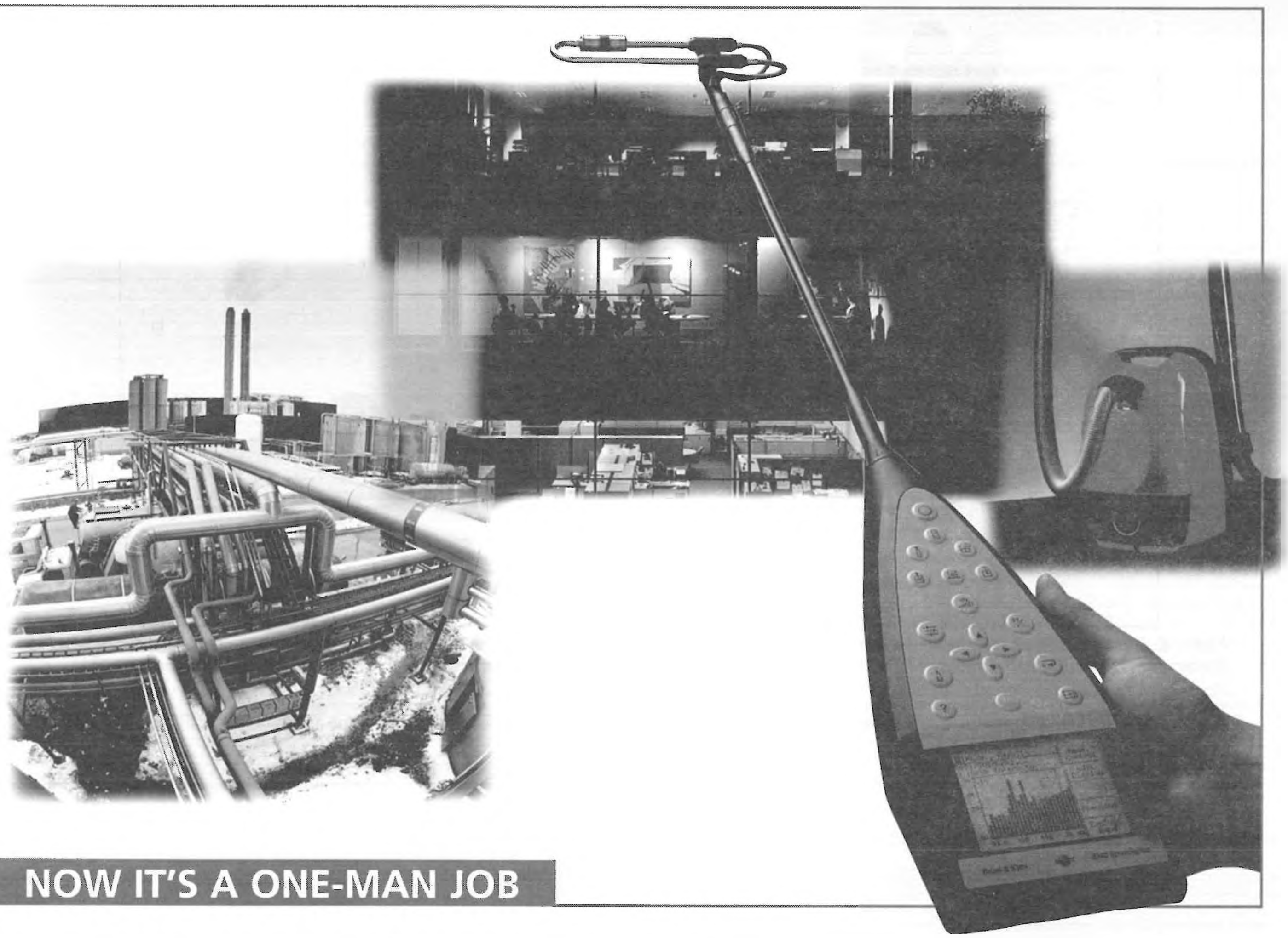


Figure 10. Directivity Patterns for mode incident (4,3), Adimensional frequency parameter (k lx/2; k ly/2)=(22; 14). (a) rigid case, (b) treated case. Normalized acoustic admittance=(1.1 - i .25).

x axis scale is $|P(M)| \sin\theta \cos\varphi$ *; y axis scale is* $|P(M)| \sin\theta \sin\varphi$ *and z axis scale is* $|P(M)| \cos\theta$

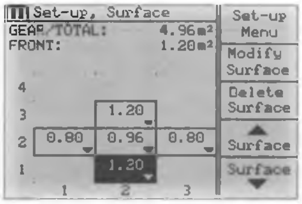
SOUND INTENSITY MADE EASY



NOW IT'S A ONE-MAN JOB

Sound intensity in the palm of your hand. With the Hand-held Sound Intensity System it's easy for one person in the field to make a sound intensity measurement from initial scanning to final, on-the-spot results.

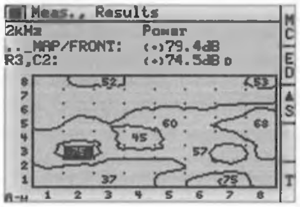
- ***ISO/ANSI sound power***
- ***Noise source location***
- ***Sound field analysis***
- ***Building acoustics***
- ***Automatic guidance and aural feedback***



Set-up, Surface

GEAR/TOTAL: 4.96m²

FRONT: 1.20m²



Meas., Results

2kHz Power

.._MAP/FRONT: (+)79.4dB

R3,C2: (+)74.5dB

Everything you need to make a measurement, from a sound intensity analyzer to chalk for marking are included in the Hand-held Sound Intensity System, all neatly packed in a handy and robust carrying case.

Want to know more? Contact your local Brüel & Kjær sales representative today

98010

2260 INVESTIGATOR

Brüel & Kjær
2815 Colonnades Court • Norcross, GA 30071
TOLL FREE: (888) 788-1138 · Fax: (770) 447-2327 · *FAX-ON-DEMAND: (800) 511-8602*
e-mail: Bkinfo@SpectrisTech.com · *Worldwide Web: www.BKhome.com*

Brüel & Kjær

Canadian Acoustics / Acoustique Canadienne 26(4) 15-21 (1998) **Research article / Article de recherche**

Optimizing Classroom Acoustics Using Computer Model Studies

Rebecca Reich and John Bradley,
Institute for Research in Construction, National Research Council, Montreal Road Ottawa, K1A 0R6.

Abstract

Speech intelligibility in rooms is determined by both room acoustics characteristics as well as speech-to-noise ratios. These two types of effects are combined in measures such as useful-to-detrimental sound ratios which are directly related to speech intelligibility. This paper reports investigations of optimum acoustical conditions for classrooms using the ODEON room acoustics computer model. By determining conditions that relate to maximum useful-to-detrimental sound ratios, optimum conditions for speech are determined. The results show that an optimum mid-frequency reverberation time for a classroom is approximately 0.5 s, but speech intelligibility is not very sensitive to small deviations from this optimum. Speech intelligibility is influenced more strongly by ambient noise levels. The optimum location of sound absorbing material was found to be on the upper parts of the walls.

Résumé

L'intelligibilité de la parole dans une chambre est déterminée par les caractérsitiques acoustiques et aussi par les rapports parole-bruit. Ces deux types d'effets sont combinés dans des mesures comme des rapports son-utile/son-nuisible, qui sont reliés directement à l'intelligibilité de la parole. Cet article présente les investigations des conditions acoustiques optimums pour des classes en utilisant le modèle généré par la programme acoustique ODEON. En déterminant les conditions reliées aux rapports son-utile/son-nuisible maximums, il est possible de trouver des conditions optimums pour la parole. Les résultats montrent qu'un temps de réverberation mi-fréquence optimum pour une classe est environ 0.5 s, mais l'intélligibilité de la parole n'est pas très susceptible aux petites déviations de cet optimum. L'intélligibilité de la parole est influencée plus fortement par les niveaux de bruit ambiant. On trouve que la location optimum de matériel absorbant est sur la partie supérieure des murs.

1.0 Introduction

The intelligibility of speech in a classroom must be critical to the learning process. When the words of the teacher or of other students are not completely intelligible, students cannot learn efficiently. Speech intelligibility (SI) can be measured as the percentage of test words heard correctly by groups of listeners. Intelligibility can also be related to various acoustical quantities, which can then be used to assess conditions for speech in rooms without having to perform cumbersome speech intelligibility tests.

The intelligibility of speech in rooms is related to the levels of the speech sounds and ambient noises as well as to the room acoustics characteristics of the space. The higher the level of the speech sounds relative to the ambient noise, the greater the intelligibility of the speech. Thus, the effects of speech and noise levels are usually considered in terms of speech-to noise ratios (S/N), (i.e. a signal-to-noise ratio where the signal is the speech). Speech intelligibility increases with increasing speech-to-noise ratio until an S/N of approximately +15 dB is reached which typically corresponds to 100% SI [1,2].

Speech intelligibility is also influenced by room acoustics. This was originally assessed in terms of the reverberation time (RT) of the room. Various optimum reverberation times have been recommended to maximize speech intelligibility in rooms and these optimum values usually increase with increasing room volume [3]. The effect of room acoustics on speech intelligibility is now thought to be better related to measures that more correctly assess the benefits of both the direct sound and reflections arriving within about 50 ms after the direct sound [1,4,5]. Because our hearing system effectively integrates these early reflections together with the direct sound, they contribute to increasing intelligibility. However, later arriving reflections degrade intelligibility by causing one word to blur into the next. Thus, early-to-late arriving sound ratios are now thought to be better indicators of the effect of room acoustics on speech intelligibility. For example, C_{50} is the ratio of the early-arriving speech energy in the first 50 ms after the direct sound to the later-arriving speech energy.

Three different acoustical measures are available that combine both the room acoustics and speech/noise aspects into a single quantity. The speech transmission index (*STI*) (or its simplification *RASTI*) is perhaps the best known [6]. It is derived from modulation transfer functions that are influenced by both ambient noise and room acoustics. The useful-to-detrimental sound ratio concept was first proposed by Lochner and Burger [5] and a simplification was later evaluated by Bradley [1,4]. In this ratio, the useful energy is the early arriving speech sound. The detrimental energy is the sum of the late arriving speech energy and the ambient noise. The third measure, *%Alcons,* is derived from the direct sound level, the ambient noise level and the reverberation time [7]. All three measures have recently been compared and shown to be strongly correlated with each other [12].

The current paper reports on investigations to determine how to obtain optimum acoustical conditions in a typical classroom. The classroom was modeled using the ODEON room acoustics ray tracing program. Acoustical conditions were assessed in terms of both early-to-late arriving sound ratios (C_{50}) and useful-to-detrimental sound ratios (U_{50}). It was possible to determine optimum reverberation times for a typical classroom and also the optimum placement of sound absorbing material to maximize speech intelligibility.

2.0 The ODEON Model Classroom

The ODEON room acoustics ray-tracing program (version 2.6 for DOS) was used to model a typical classroom. The geometry of the classroom is illustrated in Figure 1. The room was 11 m long by 9 m wide and 3.4 m high with a volume of 336.6 m^3. The students were simulated by an absorbing block 1.8 m from the rear wall 3 m from the front wall and centered between the side walls. As shown in Figure 1, one source position was used and 9 receiver positions. Four different sources were used alternatively at the same location. One source was omni-directional and the others had the directionality of a human talker. One of the 3 directional sources was directed down the centre line of the classroom towards the rear wall. The other two were directed at ±45 degrees from this.

Material	α	δ
Concrete (floor)	0.02	0.1
Gypsum Board (walls)	0.04	0.5
Students	0.69	0.7
Ceiling tile	0.95	0.1
Ceiling tile (half absorption)	0.47	0.1

Table 1. Material properties, absorption coefficient α *and diffusion coefficients* δ .

For simplicity, in this paper only 1000 Hz results will be presented. The 1000 Hz absorption coefficients of the various surfaces are given in Table 1. The table also shows the diffusion coefficients for each surface used in the ODEON calculations. The floor was assumed to be a smooth hard concrete surface and the walls gypsum board. The block representing the students was given the absorption coefficients of people sitting on wooden chairs. In the initial experiments the absorption of the ceiling was varied but in the final experiments absorption representative of highly absorbing ceiling tiles (shown in Table 1) was used.

3.0 Acoustical Measures

The ODEON program directly calculates values of the reverberation time (*RT*) and the early decay time (*EDT*). It also calculates expected sound pressure levels (*SPL*) based on the source having a sound power representative of speech. Although ODEON does not provide C_{50} values, it does provide values of Deutlikeit (*D*) which is usually referred to as 'definition' or 'distinctness' in English. Deutlikeit measures the ratio of early-arriving to total speech energy and can be related to C_{50} as follows,

$$C_{50}(ODEON) = 10\ log[D/(1-D)],\ dB \qquad (1)$$

Using this equation, C_{50} values were calculated from the ODEON output of *D* values.

For an ideal exponential decay, one can calculate C_{50} values from decay times. From the ratio of the integrals of the early (0 to 50 ms) and the late (50 ms to ∞) intervals of an ideal exponential decay one obtains,

$$C_{50}(RT) = 10\ \log[e^{(13.815*0.05/RT)} - 1],\ dB \qquad (2)$$

in terms of reverberation time (*RT*) or,

$$C_{50}(EDT) = 10\ log[e^{(13.815*0.05/EDT)} - 1],\ dB \qquad (3)$$

in terms of the early decay time (*EDT*).

Equations (2) and (3) provide simple techniques for estimating C_{50} values when only the decay times are

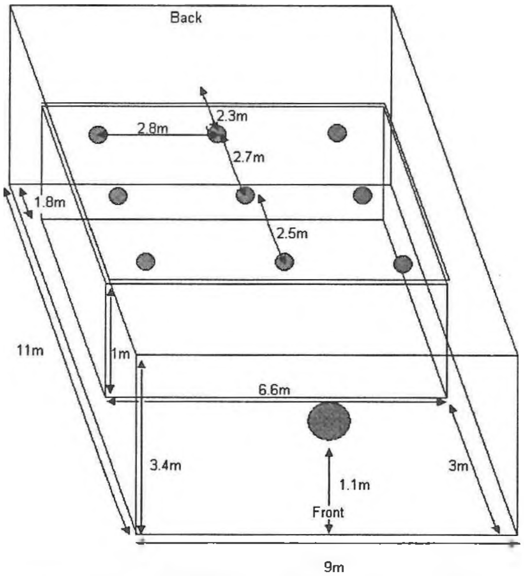


Figure 1. ODEON model of the classroom showing source position (large filled circle) and receiver positions (small filled circles).

known. Because they are based on the assumption of ideal exponential decays, they will give different C_{50} values than those calculated from the actual impulse responses but may be satisfactory approximations in small rooms.

Useful-to-detrimental ratios are the ratio of the early arriving speech energy to the sum of the late arriving speech energy and the ambient noise. They relate directly to speech intelligibility and can also be derived from C_{50} values combined with speech and noise levels as follows,

$$U_{50} = 10\log\{c_{50}/[1+(c_{50}+1)10^{(Noise-SPL)/10}]\}, \text{ dB} \quad (4)$$

where c_{50} are the linear and not the logarithmic early-to-late ratios.

4.0 Comparisons with Predictions from Sabine and Eyring Equations

The ODEON calculations were first validated by comparing calculated *RT* values with those obtained from the Sabine and Eyring reverberation time equations. Because it is not obvious what values of diffusion coefficients should be assigned to each surface, these comparisons give a check that the results appear to be reasonable. In these tests the 1000 Hz absorption coefficient of the ceiling was varied from 0.1 to 0.9 in steps of 0.2. This gave a realistic range of acoustical conditions in the classroom for comparisons of the calculated reverberation times.

Figure 2 compares the resulting reverberation times from ODEON ray tracing results and from the Sabine and Eyring reverberation time equations. All 3 results show decreasing reverberation times with increased ceiling absorption as would be expected. The ODEON calculations of *RT* agree very closely with those obtained using the Sabine equation. *RT* values obtained using the Eyring equation are a little lower. The results suggest that the ODEON model is a reasonable representation of a typical classroom.

C_{50} values obtained from ODEON ray tracing results ($C_{50}(ODEON)$) were compared to estimates using equations (2) and (3) above to test the accuracy of these approximate estimates of C_{50} values. These are compared in Figure 3 for the same variations of ceiling absorption. Increased ceiling absorption leads to less later arriving sound energy and to increased C_{50} values. For these cases, both estimates of C_{50} values agree reasonably well with the ODEON calculations. However, C_{50} values estimated from *EDT* values agree best with the C_{50} values calculated directly from ODEON impulse responses. *EDT* values are more influenced by the details of early reflections and hence can be used to better estimate C_{50} values. $C_{50}(RT)$ values were least satisfactory for the $\alpha = 0.9$ case where the *RT* was most different to the *EDT*.

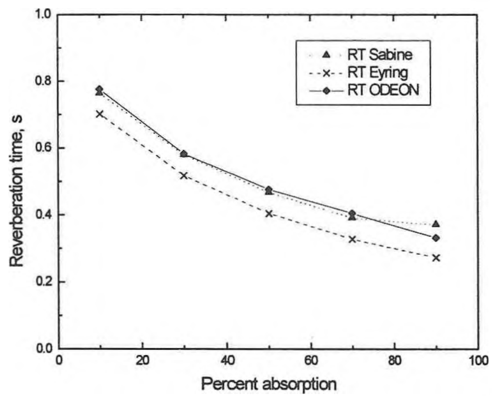


Figure 2. Reverberation time versus ceiling absorption for average of 9 receivers and OMNI source at 1000 Hz.

5.0 Estimating the Optimum Reverberation Time

For the results in the previous section, adding more absorption to the ceiling systematically decreased the reverberation time. At the same time C_{50} values increased, indicating better conditions for speech. However, the addition of absorption to the ceiling also caused a decrease of calculated speech sound levels in the classroom. For a particular ambient noise level, this would lead to decreased speech-to-noise ratios and hence decreased speech intelligibility. Thus, adding absorption has both beneficial and detrimental effects. Increased absorption leads to both increased C_{50} values and decreased speech-to-noise ratios. There must be some intermediate amount of absorption that would lead to an optimum compromise corresponding to the maximum speech intelligibility. This optimum amount of sound absorbing material will relate to a particular reverberation time, which will be the optimum reverberation time for maximum speech intelligibility in the classroom.

This optimum reverberation time can be determined from the condition that leads to the maximum useful-to-detrimental sound ratio (U_{50}). U_{50} is directly related to

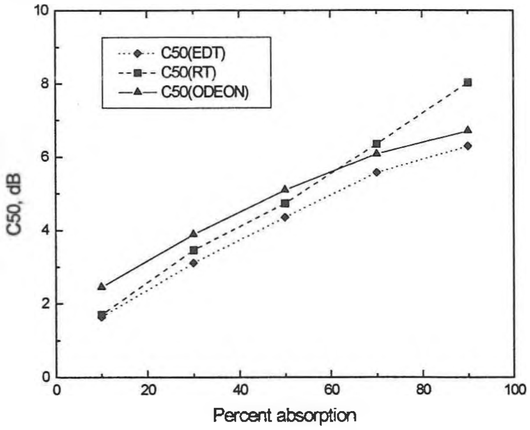


Figure 3. C_{50} versus ceiling absorption for average of 4 sources and 9 receivers, 1000 Hz.

speech intelligibility and combines both the influence of room acoustics (C_{50}) and speech-to-noise ratio. Thus, the condition that leads to the maximum U_{50} value will correspond to the maximum speech intelligibility and to the optimum combination of C_{50} and speech-to-noise ratio. The reverberation time corresponding to this optimum condition is the required optimum reverberation time for speech in the classroom.

The same 5 different absorption coefficients for the ceiling were used as in the previous section, varying from 0.1 to 0.9 in steps of 0.2. These led to 1000 Hz reverberation times of from approximately 0.3 to 0.8 s and the range of C_{50} values shown in Figure 3. Using the speech levels calculated by the ODEON program and background noise levels of 35, 40, 45, and 50 dBA, U_{50} values were calculated. This gave a wide but realistic range of both room acoustics and speech-to-noise conditions. The resulting U_{50} values are plotted in Figure 4. For the 'reasonably good' case of a 40 dBA ambient noise level, the maximum U_{50} value corresponds to a 0.48 s reverberation time. However, the optimum reverberation time varies somewhat with the ambient noise level. For noisier conditions more reverberant conditions help increase speech levels and hence improve speech-to-noise ratios. For quieter ambient noise situations, less reverberant conditions lead to maximum U_{50} values because they correspond to improved room acoustics conditions (i.e. increased C_{50}).

One can estimate speech intelligibility scores from U_{50} values [8] using the following equation,

$$SI = 98.24 + 0.861\,(U_{50}) - 0.0863\,(U_{50})^2,\ \% \quad (5)$$

This gives the expected intelligibility on a simple rhyme test where 97% or higher corresponds to excellent conditions for speech. For the 40 dBA ambient noise level case, speech intelligibility scores were estimated from the U_{50} values and are plotted in Figure 5. Although the optimum speech intelligibility corresponds to the case of approximately 0.5 s reverberation time, a wide range of reverberation times lead to speech intelligibility scores within 0.5% of the maximum. Thus, obtaining exactly the optimum reverberation time is not very critical to achieving near optimum conditions for speech. This is partly because intelligibility is directly related to C_{50} but only indirectly related to RT.

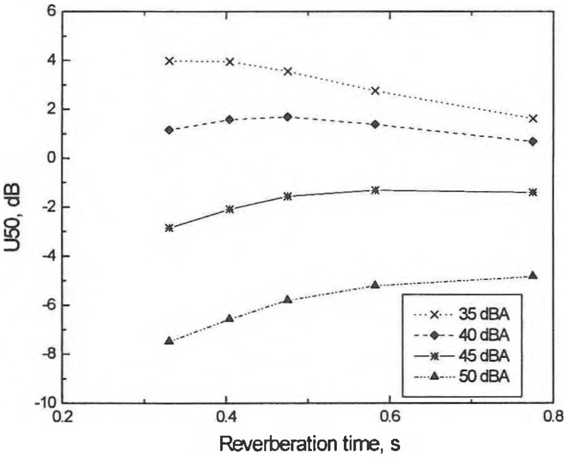


Figure 4. U_{50} versus ceiling absorption, OMNI source, 1000 Hz.

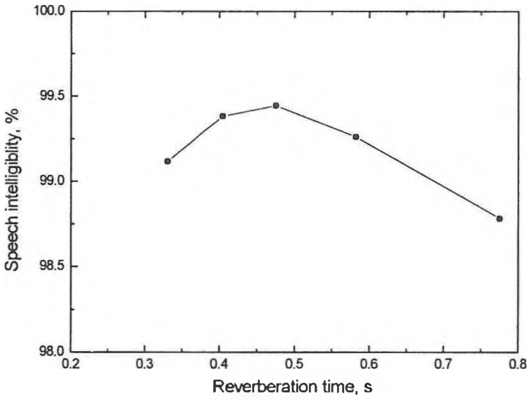


Figure 5. Variation of speech intelligibility with reverberation time for 40 dBA ambient noise.

6.0 Optimum Placement of Sound Absorbing Material

Although the reverberation time is only influenced by the average sound absorption in the room, C_{50} values can be affected by the location of the absorbing material. Thus it may be possible to improve conditions for speech by more optimally locating the available sound absorbing material and without changing the reverberation time. Previous recommendations include: putting absorption on the ceiling and rear wall [9], and avoiding treating the centre of the ceiling with sound absorbing material [10]. In fact a German standard [11] recommends this latter approach for rooms such as classrooms.

While it is difficult to change the location of absorption in a real room, it can be done quite conveniently in a computer model such as ODEON. Nine different configurations of added sound absorbing material were tested. In all cases the total sound absorption was kept constant. A highly absorbing ceiling material was assumed to have an absorption coefficient of 0.95. The base case consisted of completely covering the ceiling with material having half this absorption coefficient (i.e. α=0.47). (This is essentially the same as the optimum reverberation time case for which the ceiling was 50% absorptive). Other cases consisted of covering an area equal to half the area of the ceiling with material with an absorption coefficient of α=0.95. The 9 absorption configurations are described in Table 3. The surface diffusion coefficients were as described in Table 1. All untreated areas of the walls and ceiling were gypsum board with properties described in Table 1.

#	Description
1	Full ceiling, $\alpha = 0.47$
2	Front half ceiling, $\alpha = 0.95$
3	Rear half ceiling, $\alpha = 0.95$
4	Rear part ceiling and back wall, $\alpha = 0.95$
5	Ring on ceiling and upper walls, $\alpha = 0.95$
6	Ring on ceiling, $\alpha = 0.95$
7	Ring on upper walls, $\alpha = 0.95$
8	Upper side and rear walls, $\alpha = 0.95$
9	Upper side walls, $\alpha = 0.95$

Table 3. Description of 9 absorption configurations.

The location of the absorbing material was expected to influence conditions for speech by changing C_{50} values. The C_{50} values obtained at the nine receiver positions illustrated in Figure 1 were averaged and these mean values are plotted for each of the nine absorption configurations in Figure 6. Mean C_{50} values are given for each of the 4 different sound sources described in section 2 above. The results in Figure 6 indicate small differences between the different sources but the same variations occur among the 9 absorption configurations for all sources. For example, the omni-directional source tends to produce C_{50} values that are a fraction of a decibel lower than the other sources but there are variations of up to 4 dB among the various absorption configurations.

The clarity in the room is maximum when there is an absorptive material on the upper parts of the side and rear walls (condition # 8), and results are almost identical when the absorptive treatment is continued to the upper part of the front wall. The most inferior treatment is when the absorption is limited to the front half of the ceiling (i.e. over the source). Treating the rear part of the ceiling and the rear wall (condition 4) was not optimum as recommended by one previous study [9].

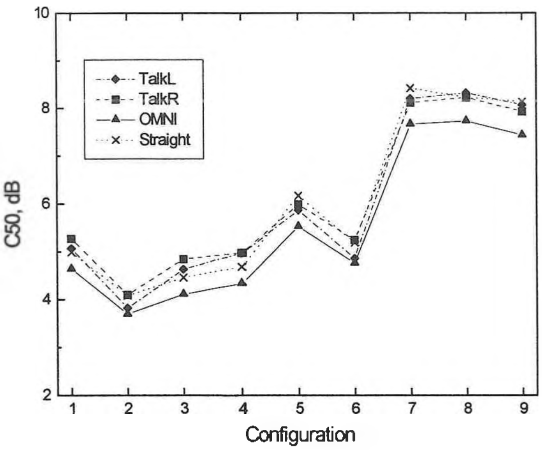


Figure 6. Mean C_{50} for each absorption configuration and source type, 1000 Hz.

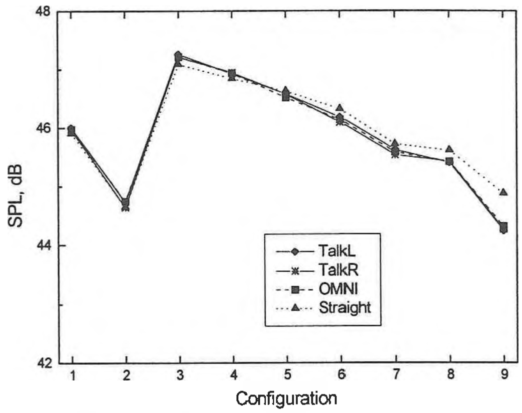


Figure 7. Mean speech sound pressure level (SPL) for each absorption configuration and source type, 1000 Hz.

Although conditions # 7 and # 8 lead to maximum C_{50} values, they did not optimise speech sound levels. The corresponding 1000 Hz mean speech sound levels are shown in Figure 7 for the 9 configurations and for all 4 sources. The source type has less effect on sound levels than the small effects on C_{50} values. Varying the location of the sound absorbing material has a maximum effect on speech sound levels of just under 3 dB. Treating only the rear half of the ceiling (condition # 3) leads to the maximum speech sound level. Conditions # 7 and # 8 that corresponded to maximum C_{50} values have sound levels about 1.5 dB lower than the maximum found for condition # 3. Thus, again there is a trade-off between increasing clarity (C_{50}) and increasing speech levels.

The condition that optimizes both C_{50} and speech-to-noise ratios can be determined by finding the configuration that corresponds to the maximum useful-to-detrimental ratio (U_{50}). Using an ambient noise level of 40 dBA, U_{50} values

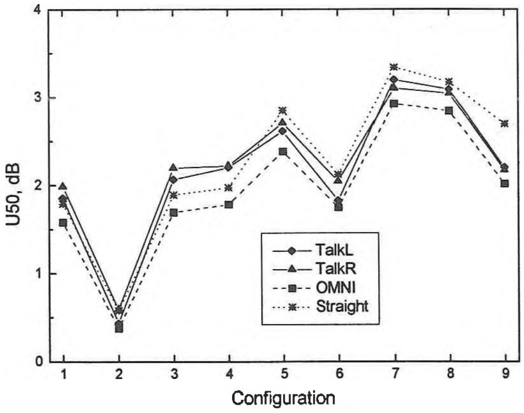


Figure 8. Mean U_{50} for each absorption configuration and source type, 40 dBA ambient noise level, 1000 Hz.

were calculated for each configuration and for each source type. These U_{50} values are shown in Figure 8. Again source type has only a small effect but U_{50} values increase by about 1.3 dB from configuration # 1 (full ceiling treated) to configuration # 7 (upper part of walls treated).

7.0 Conclusions

By varying the absorption coefficient of the classroom ceiling, it was possible to derive an optimum reverberation time of approximately 0.5 s. This corresponds to the maximum useful-to-detrimental sound ratio (U_{50}) and hence to the maximum speech intelligibility. Although this corresponds to the maximum speech intelligibility, a range of reverberation times lead to almost the same speech intelligibility. Speech intelligibility is within 0.5% of maximum within the range from at least 0.3 to 0.6 s reverberation tme. Thus it is not important to achieve exactly the optimum 0.5 s reverberation time. The results in Figure 4 show that ambient noise level is a much more important determinant of U_{50} values and hence speech intelligibility in a classroom. Further, the optimum reverberation time also depends on the ambient noise level and a little more reverberant conditions are helpful in higher noise levels.

The location of added sound absorbing material has different effects on speech clarity (C_{50}) and speech sound level. Maximum speech clarity (C_{50}) was obtained with the absorptive treatment on the upper parts of the side and rear walls. Conditions with improved speech clarity (C_{50}) tended to have reduced speech sound levels. However, when considering the combined effects in terms of useful-to-detrimental sound ratios (U_{50}), the configuration with the upper parts of the walls treated produced optimum results. Thus the most effective location of sound absorbing material is to add it to the upper parts of the walls and to add an amount sufficient to produce an occupied 1000 Hz reverberation time of approximately 0.5 s.

The determination of optimum reverberation time and the optimum location of the added sound absorbing material is also influenced by the ambient noise level. However, the location of the absorbing material on the upper parts of the walls would still be appropriate in noisier conditions and so can be more generally recommended. Because these treatments all involved the same total amount of sound absorbing material, there should be little difference in the cost of the various configurations. Thus, the optimum configuration represents an acoustical improvement with no extra cost.

This is an initial exploratory study that demonstrates that there are possible modest improvements to classroom acoustics. These would correspond to quite small improvements in speech intelligibility but their subjective importance is not known. Further work is required to assess the subjective importance of these changes and to explore the effects of other parameters. Further studies should include the effects of other room shapes and other possible configurations of absorptive treatments. One could also consider different amounts of added sound absorbing material and include results for a range of frequencies. Future studies should also consider the effect of added absorption on ambient noise levels. The present studies are based on the useful-to-detrimental sound ratio concept and hence incorporate the trade-off between room acoustics and speech-to-noise ratios included in that measure. New studies could repeat this process in terms of speech transmission index (*STI*) values to verify that the same conditions are found to be optimum. Finally, the process should be validated by measurements in actual rooms with varied absorption configurations.

The use of computer models such as ODEON is seen to be a convenient method for determining the importance of parameters influencing speech intelligibility in rooms. The combination of such computer model studies and a limited number of validation measurements in real rooms is a cost-effective approach for developing better information for designing better classrooms. The resulting improvements in speech intelligibility could translate to more relaxed and accurate communication between students and teachers.

References

1. Bradley, J.S. "Speech Intelligibility Studies in Classrooms", J. Acoust. Soc. Am., vol. 80, pp. 846-854 (1986).
2. Houtgast, T., "The Effect of Ambient Noise on Speech Intelligiblity in Classrooms", App. Acoustics, vol. 14, pp. 15-25 (1981).
3. Knudsen V.O. and Harris, C.M., "Acoustical Design in Architecture", John Wiley, New York (1950).
4. Bradley, J.S., " Predictors of Speech Intelligibility in Rooms", J. Acoust. Soc. Am., Vol. 80, pp. 837-845, (1986).
5. Lochner, J.P.A. and Burger, J.F., " The Influence of Reflections on Auditorium Acoustics", J. Sound Vib., Vol. 1, pp. 426-454, (1964).
6. Houtgast, T., and Steeneken, J.M., " A Review of the MTF Concept in Room Acoustics and Its Use for Estimating Speech Intelligibility in Auditoria", J. Acoust. Soc. Am., Vol. 77, pp. 1069-1077, (1985).
7. Peutz, V.M.A., " Articulation Loss of Consonants as a Criterion for Speech Transmission in Room", J. Aud. Eng. Soc., Vol. 19, No. 11, pp. 915-919, (1971).
8. Bradley. J.S., "Uniform Derivation of Optimum Conditions for Speech in Rooms", National Research Council, Institute for Research in Construction Building Research Note, NRN 239, (November 1985).

9. Sala, E. And Viljanen, V., “Improvement of Acoustic Conditions for Speech Communication in Classrooms”, App. Acoustics, vol. 45, pp. 81-91 (1995).

10. Essman, H., “Der Einfluss raumakustischer Verhältnisse in Unterrichtsräumen auf den Leistungserfolg bei Schülern”, Wissenschaftliche Zeitschrift der Technischen Universität Dresden, vol. 22, pp. 201-209 (1973).

11. “Hörsamkeit in kleinen bis mittlegrosen Räumen”, German standard DIN 18041 (1968).

12. Bradley, J.S., “Relationships Among Measures of Speech Intelligibility in Rooms”, J, Aud. Eng. Soc, vol. 46, pp. 396-405 (1998).

SOUND
VIBRATION
READINGS!

Scantek has all the latest in high quality sound and vibration instrumentation. For sale. Or rent. We also offer experienced technical support, including instrument calibration. For more information or to place an order, call the number below, right now. You'll get good vibrations from our service, too.

New from Rion:

Vibration Meter VM-82 - Easy to use vibration meter for acceleration, velocity and displacement measurements.

Sound Level Meter NA-27 - New generation of precision integrating sound level meter with 1/3-octave band real-time analyzer.

Integrating Sound Level Meter NL-06 - For environmental measurements. Easy to read display covers 100dB dynamic range. Memory card slot allows efficient data management.

Vibration Level Meter VM-52/VM-52A - Low frequency vibration measurements for floors, ground and vehicles. The VM-52A features data storage by memory card.

Vibration Analyzer VA-11 - Sophisticated vibration analyzer with FFT capability. Simple operation.

1/3-Octave Band Real-time Analyzer SA-29/SA-30 - Simultaneous analysis of 1/1 and1/3-octave bands are possible for 1-ch input. 1-ch (SA-29), 2-ch (SA-30) models and ATA type memory card available. Built-in printer for hard copy display.

Scantek
Sound and vibration instrumentation and engineering

Call: 301.495.7738

Fax: 301.495.7739 • E-mail:scantek@erols.com
Home page: http://www.rion.co.jp

FIELD SOUND TRANSMISSION LOSS TESTS IN LOW RISE CONSTRUCTION

James L. Feilders
Jade Acoustics Inc., 545 North Rivermede Road, Concord, Ontario, L4K 4H1

Introduction

Sound transmission loss tests following ASTM E336-84 procedures were conducted in a three storey multifamily residential dwelling prior to occupancy. Tests were conducted on two wall types - a block firewall and a double wood stud wall - separating equal sized small bedrooms on the third floor. The field test results were compared to lab tests for the same construction. Comments on flanking were made.

Wall Configuration

The building construction consisted of wood framing with exterior brick veneer and aluminum siding. A block firewall separated every two units. The firewall consisted of 190 mm normal weight hollow block covered on each side by 38 mm batt insulation and wood strapping with 16 mm gypsum board.

The wall between pairs of units was double wood stud construction from basement floor slab to underside of roof. In the ceiling space, double roof trusses formed the partition. The construction below the ceiling was two wythes of 16 mm gypsum board on 89 mm wood studs with mineral wool insulation separated by a 25 mm air space. A metal firestop was used at each floor.

The rooms had equal size and layout on each side of the common wall but the rooms for the wood stud wall had carpet while the rooms for the block wall did not.

Reverberation time was measured using decays of the pink noise. The STC value was automatically calculated by the LD 2800 Real Time Analyzer.

Block Wall Test Results

The measured Field Sound Transmission Class (FSTC) was FSTC 58. The laboratory results from NRC were STC 60. Figure 1 shows the comparison.

Wood Wall Results

The measured Field Sound Transmission Class (FSTC) was FSTC 52. The laboratory results from NRC were STC 57. Figure 2 shows the comparison. The poorer field performance is possibly due to the metal firestop used at the floor level. Other flanking paths may also be causing the loss of high frequency performance. The tests done by NRC in their flankage test facility showed less high frequency performance than in the reverberation room facility. This is consistent with what was found here.

FIGURE 1
BLOCK WALL

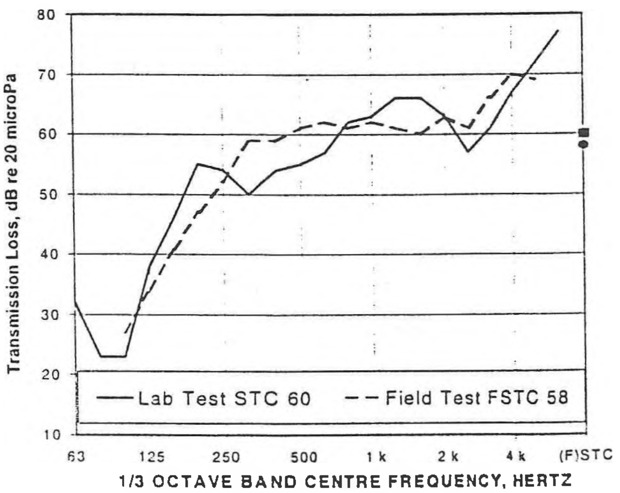
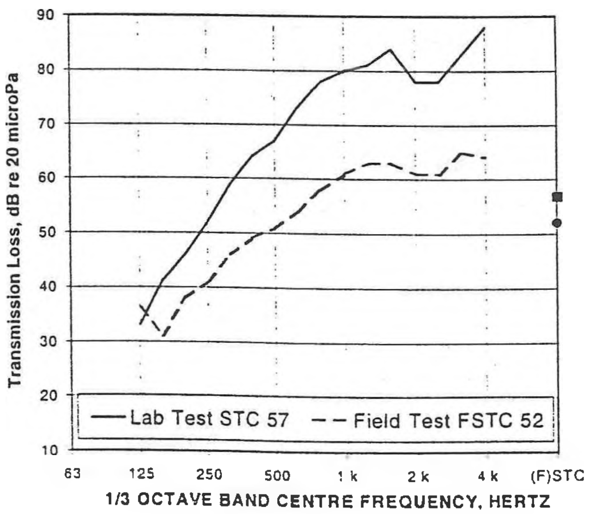


FIGURE 2
WOOD WALL



SPEECH RECOGNITION: CURRENT STATUS AND PROSPECTS

Li Deng
Department of Electrical and Computer Engineering, University of Waterloo, Waterloo, Ontario, Canada N2L 3G1

INTRODUCTION

Speech recognition technology has been significantly advanced over the past two decades. The advances can be attributed to the breakthrough use of a consistent statistical paradigm empowered by increasing quantities of speech data corpus, as well as by powerful algorithms developed for model learning from the data. Up until now, the technology has been primarily founded on the principle of statistical "ignorance" modeling, where generally unstructured speech models (mainly the hidden Markov model or HMM) learn their gigantic number of parameters from massive amounts of directly observable speech data.

In this plenary talk, I will first provide a critical review of the state-of-the-art automatic speech recognition technology. This review will include: 1) Analyzing the "Fundamental Equation" of statistical speech recognition; 2) Fundamental architecture of the modern speech recognition systems dissected into their common, basic phonetic and phonological components; and 3) Critical review of the backbone of modern speech recognition technology — HMMs. In this review, I will try to analyze why the current speech recognition technology is successful in certain areas of applications and not successful in other areas. Following such a review, I will address a number of key research issues which are aiming to overcome several fundamental deficiencies in the current speech recognition technology. A potentially fruitful approach will be outlined. This approach replaces the "bead-on-the-string" notion in the linear phonological model (uniformly used in the current speech recognition technology) by a version of nonlinear phonology in which the atomic speech units are constructed from multi-dimensional features overlapping in time. This approach further interfaces such units to phonetic models of speech dynamics, which has a statistical structure generalizing from the conventional HMM.

SPEECH RECOGNITION: FUNDAMENTAL EQN.

First, Let me give a brief description of the statistical framework that underlies much of modern speech recognition research and system development. Let $O = O_1, O_2, ..., O_T$ be a sequence of observable acoustic data of speech, which can either be speech waveforms, or continuous-valued acoustic vectors (or any other type of general acoustic measurements), and let $W = w_1, w_2, ..., w_n$ be the sequence of words intended by the speaker who produces the acoustic record O above. The goal of a speech recognizer is to "guess" the most likely word sequence $\hat{W}$ given the acoustic data O. Bayesian decision theory provides a minimum Bayes-risk solution to the above "guessing game", and the minimum Bayes risk can be made equivalent to minimum probability of error if the risk is assigned values of one or zero for incorrect and correct guesses, respectively. According to Bayesian decision theory, speech recognition is formulated as a top-down search problem over the allowable word sequences W based on the posterior probability $P(W|\mathrm{O})$:

$$\hat{W} = argmax_W P(W|\mathrm{O}) = argmax_W P(\mathrm{O}|W)P(W), \qquad (1)$$

where $P(W)$ is the prior probability that the speaker utters W, which is independent of the acoustic data and is determined by the language model, and $P(\mathrm{O}|W)$ is the probability that the speaker produces (or the microphone of the speech recognizer receives) the acoustic data O if W is the intended word sequence by the speaker. Disregarding the issue of language modeling, the above formulation, or fundamental eqn. (1), of the speech recognition problem can be reduced to two issues: 1) speech generation or production from word sequence to acoustic streams — how to accurately compute the probability $P(\mathrm{O}|W)$? and 2) a search for the word sequence W (the operation $\arg\max_W$ in Eqn. 1) that provides the optimal value of the posterior probability.

CRITICAL REVIEW OF HMMs

There is no doubt that HMMs are currently the most successful technology in many (heavily) constrained speech recognition applications. This success is not so much due to the mathematical formulation of the HMM itself as due to its conformity to the probabilistic analysis-by-synthesis formulation epitomized in Eqn.(1). Implicit in Eqn.(1) are the need to efficiently compute a production probability $P(\mathrm{O}|W)$ and the need to learn "production model" parameters so as to achieve high accuracy in evaluating $P(\mathrm{O}|W)$. HMMs are amenable to efficient computation and parameter learning thanks to Baum's work, and thus would fit naturally into the probabilistic analysis-by-synthesis framework of Eqn.(1). This is entirely consistent with the qualification of an HMM as a speech generator or production model, because embedded in the HMM there is a mechanism for converting a word sequence W directly into acoustic data O.

The theoretical treatment of the HMM as a production model is one thing; how reasonably and effectively it behaves as a production model is another thing. To examine this latter issue, let us first examine the production probability $P(\mathrm{O}|W)$ which appeared in Eqn.(1) into two factors:

$$P(\mathrm{O}|W) = \sum_{\mathcal{P}} P(\mathrm{O}|\mathcal{P})P(\mathcal{P}|W) \approx max_{\mathcal{P}} P(\mathrm{O}|\mathcal{P})P(\mathcal{P}|W), \qquad (2)$$

where $\mathcal{P}$ is a discrete-valued *phonological model* and specifies, according to probability $P(\mathcal{P}|W)$, how words and word sequences W can be expressed in terms of a particular organization of a small set of "atomic" phonological units; $P(\mathrm{O}|\mathcal{P})$ is the probability that a particular organization $\mathcal{P}$ of phonological units produces the acoustic data for the given word sequence W. We shall call this latter mapping device from phonological organization to speech acoustics *phonetic model*.

In view of the factorization in Eqn.(2), state-of-the-art speech recognizers using phone-based HMMs can be analyzed as follows. The phonological model $\mathcal{P}$ is essentially a linearly-organized multiple-state phone sequence governed by a left-to-right Markov chain, and the phonetic model is simply a temporally independent random sampling from a set of (trainable) acoustic distributions associated with the states in the Markov chain. Both of these model components are highly simplistic descriptions of the true speech process, and such simplicity limits the success of the current technology in free-constrained speech recognition applications. Nevertheless, such simplicity permits efficient model learning (training) from data, which is responsible for its success in strongly-constrained speech recognition applications that contain only a sparse space of phonetic confusion.

FEATURE-BASED PHONOLOGICAL MODEL

One approach to revolutionizing the phonological model $\mathcal{P}$ in speech recognition is to adopt speech units which are based on overlapping phonological features. The features are common across languages. They exploit relations and similarities of feature components across languages, thereby offering opportunities to share observation data across languages and to generalize the observations from a source language(s) to a different, target language. One key element in constructing the feature system for use in speech recognition is to appropriately represent the possible feature sequences with their temporal evolution or statistical feature-overlapping pattern responsible for producing the speech utterances corresponding to word sequences (for any arbitrary language). For American English, the rules are based on the syllabic structure as we have implemented them. The feature overlap pattern within consonant clusters pertaining to onset and coda are rather regular, as are the overlap patterns between onset and nucleus and those between nucleus and coda. Our current rule set disallows spreads in Tongue features between onset and coda (i.e., cross nucleus) within a syllable. For Velum and Labial features, the cross-nucleus feature spread patterns are constrained to be from coda to onset only and not from onset to coda. Feature spreads are permitted, with constraints determined by the prosodic constituent boundaries, between adjacent syllables. Once a syllable is broken down into its constituents, the size of these constituents becomes countably small and hence they are easily enumerated.

The feature-overlapping pattern can be described computationally as a finite-state automaton, where each state in the automaton corresponds to a feature bundle with no precise timing information specified. Within this framework, the mathematical operations permitted in computational phonology can be successfully applied. In particular, if a sufficient amount of data is available with detailed annotation on such information as syntactic, prosodic, morphological, lexical-stress levels, syllabic, phonemic, allophonic, and articulatory events, then a probabilistic parsing strategy can be developed to automatically construct the feature-bundle based finite-state automaton. This strategy enables optimal use of a comprehensive set of linguistic constraints imposed at multiple levels of the general hierarchical structure of speech.

PHONETIC MODELS OF SPEECH DYNAMICS

The symbolic nature of the feature-based phonological model by itself does not permit an accurate description of the observed dynamic behavior in speech patterns. An integration mechanism between the discrete valued phonological model and continuous valued phonetic model must be developed. There is a general consensus that, in human speech production, the phonological component acts in a discrete fashion to control the running of the phonetic (physiological and physical) production "machinery" which, in turn, ensures correct implementation of the phonologically defined speech production goals. This phonetic machinery has a number of distinct components including motor controller (neuromotor command generator), articulatory system (smooth motion of several articulatory organs driven largely by separate neuromotor commands), vocal tract (VT) acoustic system (speech signal generator), and the auditory system (speech signal transformation). Needless to say, these components in human speech communication need to be drastically simplified at the current stage in any functional, computational model, but the key dynamic character of the process must be faithfully preserved and the dynamic model's parameters must be carefully and accurately learned from observable data in as much a physically meaningful way as possible.

Our research group at Univ. of Waterloo have been guided by this general principle during the past several years in pursuing research on various forms of the dynamic phonetic-interface model. The three main forms, differing with respect to the distinct levels at which the object of dynamic modeling is posited, have been developed. First, the acoustic-dynamic model based on trended HMM attempts to condition the properties of the dynamics directly on specific feature-coded speech production mechanisms. In that model, the underlying articulatory-feature based phonological units are used to determine either a dynamic or a static trajectory (via the differing orders of polynomial used as the trended function) that describes the acoustic correlates of the phonological units, and substantial phonetic recognition performance improvements have been demonstrated. Second, the articulatory-dynamic or stochastic target model aims at accounting for detailed movement behavior of biomechanical articulators guided by the multi-dimensional target distributions defined in the biomechanical articulator coordinate space. Third, the statistical task-dynamic model posits the object of dynamic modeling in the space of the "task" variable which is functionally significant for phonetic implementation of phonologically defined speech production goals.

The statistical task-dynamic model we have developed is based on the use of either VT constriction or VT resonance as the "hidden" dynamic variable. The dynamic process can be written as a second-order, target-directed state equation, with the continuous valued state providing the input to a static nonlinear function that results in observation speech acoustics. This statistical nonlinear dynamic system model is employed to describe aspects of the physical process of spontaneous speech production, where a large amount of speech knowledge about the VT constriction or resonance dynamic behavior in speech production is naturally incorporated into the model design, training, and decoding/scoring. The statistical nature of model design allows the computation of the probability for acoustic observations of speech, in a more accurate fashion than the conventional HMM has provided. Such a model consists of two separate components which accommodate separate sources of speech variabilities. The first component is a smooth dynamic one, linear by nonstationary. The nonstationarity is described by left-to-right regimes corresponding to phonological units. This way of handling nonstationarity is very close to that by conventional HMMs, but for each state (discrete as in HMM), rather than having an i.i.d. process, we have a phonetic-goal-directed linear dynamic process with physical entity of the state variable (continuous). Equipped with the physical meaning of the state variable, variabilities due to phonetic contexts and to speaking styles are naturally represented in the model by varying model parameters. (This contrasts with the conventional HMM approach where the variabilities are handled by expanding the total number of model parameters.) The second component is static and nonlinear. This component handles other types of variabilities including VT anatomical differences across speakers and channel/microphone variations. The two components combined form a nonstationary, nonlinear dynamic system whose structure and properties are well understood in terms of the general process of human speech production. The learning algorithms include ones from system theory, neural-network theory, and statistical optimization theory. The VT-resonance version of the model has been successfully used by my student Jeff Ma and myself in the six-week 1998 summer workshop at Johns Hopkins University where we demonstrated the effectiveness of this model in reducing word error rate for unconstrained, spontaneous, telephone-line speech recognition task defined from the Switchboard corpora.

SUMMARY AND PROSPECTS

The current state of speech recognition technology based on HMMs can be characterized as being successful in highly constrained tasks while experiencing greater and greater hardship as the tasks are becoming less and less constrained. For example, for conversational speech recorded in telephone lines for which human listeners typically have no difficulty in comprehension, the best recognizers in the world still produce over one third errors in the recognized words. The new paradigm of speech recognition outlined in this paper aims to overcome some fundamental difficulties of the current speech recognition technology. This paradigm is founded on a statistical learning strategy driven by linguistic (phonological) and physical (phonetic) principles of speech-pattern formation, as well as by functional and computational modeling of such speech patterns. It stands in contrast to the prevailing technology characterized by blind, data-driven and "ignorance" modeling where phonetic and linguistic knowledge sources are used, at best, as external constraints, rather than as intrinsic elements of the model for speech patterning. The proposed stochastic model of speech contains a compactly parameterized structure which jointly represents contextual and speaking-style variations manifested in the speech acoustics, and it provides a natural mechanism for omni-lingual speech recognition.

The research program described here emphasizes the notion of structural learning of speech-data generation mechanisms for use in designing statistically based speech recognition systems. This notion breaks away from the blind, data-driven approach currently dominating the speech recognition technology. Our current research efforts are devoted to demonstrating the potential success of integrating structural knowledge from speech science with the statistical models used in speech technology. The research is pursued both at the theoretical and algorithmic development levels and at a practical level aiming at advancing core speech recognition technology.

RECOGNIZING DISFLUENCIES IN SPONTANEOUS SPEECH

Douglas O'Shaughnessy
INRS-Telecommunications, 16 Place du Commerce
Nuns Island, Quebec, Canada H3E 1H6

1. INTRODUCTION

Most previous acoustic analysis of speech has examined data from speakers who carefully pronounce their speech, usually by reading prepared texts. Natural spontaneous or conversational speech differs from that of careful or read speech in several ways, the most obvious difference concerning hesitation phenomena. In spontaneous speech, people often start talking and then think along the way. This causes spontaneous speech to have interruptions; the specific interruption phenomena studied in this paper are pauses and restarts. Pauses can be either unfilled (silence) or filled with a speech sound (usually "uhh" or "umm" in North American English). Restarts (or false starts) are interruptions in the flow of speech, where the speaker (usually after a brief pause) reiterates a portion of the speech immediately preceding, with or without a change. The repetition can range from a portion of a syllable up to several words. In the case of a change, the modification may be either a substitution of a new word (in the place of a fully- or partially-spoken previous word) or an insertion of a word in a word sequence (with the sequence containing the new word being uttered again).

This paper concerns the acoustic analysis of pauses and restarts in spontaneous speech, from the point of view of their automatic location via acoustical analysis. A large database of spontaneous speech was analyzed in terms of duration and fundamental frequency measurements, as well as spectral analysis. For recognition purposes, a simple spectral analyzer was used to identify repeated words.

The pauses and restarts are described acoustically, with a view toward automatic recognition, to ensure their proper elimination from consideration in speech recognition systems. A primary application of this study lies in improving the performance of automatic speech recognizers, for applications that must accept an input of spontaneous speech (e.g., verbal conversations with computer databases). For such purposes, we wish to eliminate filled pauses and one version of any repeated words (or parts of words), and in the case of changed words, we wish to suppress the original unwanted words, so that the recognizer will operate on only a sequence of desired words. Thus, we examine here the relationship of pauses and restarts to intonation, and do so in a fashion that should allow direct exploitation in automatic recognition systems accepting spontaneous, continuous speech.

Speech researchers have often expressed interest in exploiting the intonation of spoken utterances in automatic recognition algorithms, but have been deterred by the complex nature of how intonation relates to the text of an utterance. Various aspects of the intonation employed in a restart allow it to be identified as a restart, and furthermore allow suppression of the undesired words in many cases. Pauses are more simple to locate, but unfilled pauses can be confused with phonemic stop closures, and filled pauses can be confused with monosyllabic words.

Within-utterance hesitations can cause significant difficulties for automatic speech recognizers, which usually make no provision for pauses at random locations or for repeated words or parts of words. Automatically determining which words (or parts of words) are being replaced in a speech repair and locating filled pauses could help automatic recognizers avoid textual errors in the output. In virtually all current recognition systems, words repeated in a false start are either simply fed as word hypotheses to the textual component of the recognizer or cause difficulties in having a proper interpretation in the language-model component (since the language model is invariably trained only on fluent text). Similarly filled pauses appear as actual words in the textual output.

2. PREVIOUS STUDIES

Acoustical analyses of disfluencies with a view toward speech recognizers are rare [2]. Previous work on restarts has dwelled almost exclusively on the length of the word-repeat sequences (and occasionally on the pause duration). Most of the work on restarts that has been reported in the literature has treated the phenomena in a general qualitative or overly simple quantitative fashion. As far as we know, no reports have previously linked the intonational cues of both F0 (fundamental frequency) and duration to restarts in a way that could be useful to automatic speech recognition. Indeed, very few recognition systems use intonational cues, especially F0, at all. In this paper, we examine how these latter parameters could be exploited directly.

Recently an attempt was made to automatically detect and correct restarts in spontaneous speech [2]. Looking at an enlarged version of our own database, the authors examined 10 000 utterances, of which 607 were found to have restarts. In utterances longer than nine words, a significantly high 10% had restarts. 59% of the restarts involved only one word (whose deletion would render the sentence fluent); 24% involved two words (or word fragments); 8% involved three words, etc. Of the one-word restarts, the majority (61%) involved a word fragment, 16% involved the repetition of a word, 7% involved inserted words, and 9% concerned replacement words. The majority of the two-word restarts were either a straight repeat of two words or a replacement of the second word, while 19% involved inserted words, and 10% involved a replacement of the first of the two words.

3. SPEECH DATABASE

In this paper, we examine disfluencies in a standard speech database (used by several speech recognition research groups in North America), ranging from pauses to simple restarts (involving only the repetition of 1–2 words) to complex restarts (where, instead of simply repeating words, one substitutes a new word for an unwanted one).

In the context of our investigation into voice dialog access to databases, we are currently examining an application involving a simulated travel agent. A naive user (the speaker) is given the task of arranging a trip involving air travel via commerical airlines, by verbally interacting with a "computer travel agent." Thus, the user formulates verbal questions and commands in a spontaneous fashion, as if in conversation with a travel agent. (The current system does not reply verbally, but rather outputs information from a database onto a computer screen.) The spoken data consists of 42 adult male and female speakers, each speaking about 30 different utterances, each ranging in length from a few words to several dozen words (median length of about 12 words).

In the approximately 1000 utterances examined (from many different speakers, each containing an average of about thirteen words), there were 60 occasions where the speaker simply repeated words or portions of words, 30 cases of inserted words, and 25 occurrences of new words substituted for prior spoken words (or word parts). Thus, approximately

10% of the utterances (a percentage consistent with the parallel study of [2]) had a restart.

4. ANALYSIS METHOD

Hardcopy displays were made of all utterances containing restarts (as determined by listening and transcribing each utterance), in sections of 3-5 seconds at a time. Each display contained a waveform (amplitude vs. time) and a narrow-band spectrogram (showing 0-2 kHz). Time resolution in these displays ranged from 44 to 78 mm/s; the frequency axis showed 39 mm/kHz. These displays were manually segmented into words and syllables, and F0 contours were obtained by tracing strong harmonics in the middle of the first or second formant.

5. ACOUSTICAL ANALYSIS RESULTS

Actual unfilled pauses (as distinct from silence in stop closures) were as short as 40 ms and as long as several seconds. The 149 unfilled pauses examined at syntactic boundaries averaged 760 ms (median = 490 ms), whereas the 92 pauses within major syntactic units averaged 490 ms (median = 270 ms).

Filled pauses resemble short words in continuous, spontaneous speech. Filled pauses at major syntactic boundaries had durations in the range of 200-500 ms; those within syntactic units were shorter on average (170-320 ms). The syntactic nature of the filled pause could be distinguished by analyzing the silence periods adjacent to the filled pause: for the ungrammatical filled pause, a preceding unfilled pause (if any) was very brief (less than 350 ms), as was any ensuing silence (less than 500 ms). Each grammatical filled pause was preceded by a silence exceeding 275 ms; a long prior silence (more than 700 ms) led to a relatively short filled pause (less than 300 ms), whereas a short prior silence correlated with a long filled pause (more than 300 ms).

The spectral pattern of a filled pause was a uniform vowel during its duration (e.g., a steady schwa), sometimes followed by the steady nasal /m/. Filled pauses all had falling (5-20 Hz) or flat F0 patterns, at relatively low F0 levels. Ones at syntactic boundaries tended to start higher in F0 and then fall, whereas filled pauses internal to a syntactic unit had lower F0 patterns. All had F0 ending in the bottom 15% of the speaker's F0 range.

As for false starts, when a word was simply repeated (as is) in a restart, it had virtually the same prosodics (i.e., same duration and pitch) in both its instances in most cases, but there were a number of times where the repeated word had less stress (i.e., shorter duration and lower pitch). When a word was changed (i.e., a substitution or insertion) in the restart, on the other hand, its second instance was virtually always more stressed (i.e., longer duration and higher pitch).

In the case of restarts where the speaker stopped in the middle of a word and simply "backed up" and resumed speaking with no changed or inserted words, the pause lasted 100–400 ms in 85% of the examples (with most of the remaining examples having a pause of about 1 second in duration). About three-fourths of the interrupted words did not have a completion of the vowel in the intended word's first syllable (e.g., the speaker usually stopped after uttering the first consonant). In virtually all examples, the speaker completed at least 100 ms of the word, however, before pausing for at least 100 ms. When the pause occurred at a word boundary, the words repeated after the pause were characterized by two situations: either a straight repetition with little prosodic change (this happened especially when a lengthy pause intervened), or a repetition where the repeated words shortened up to 50%.

In the case of a word being substituted or inserted into the word sequence in the restart, the substituted/inserted word received a large stress (relatively long duration and rise in F0) in examples where the new word added significant semantic information, but did not in examples where the new word was redundant in terms of the prior context (e.g., if the new word was a synonym of an immediately previous word). As for the repeated words (after the pause) prior to the inserted word, function words showed little or no shortening, but usually had lower F0; on the other hand, content words here exhibited significant shortening and lower F0 (the shortening here was about 50% for short words less than 300 ms, and about 100-200 ms for longer words). Such prosodic change only applied to non-prepausal words, because words immediately prior to a pause were often subject to significant prepausal lengthening.

6. RECOGNIZING RESTARTS

Since pauses involved in restarts were generally shorter than other pauses [1], we could suggest a simple rule of "pause < 400 ms –> restart." For our database, such a rule will correctly identify 70% of restarts, but will give 35% false alarms (i.e., incorrectly claiming as restarts those grammatical pauses which are shorter than 400 ms). While this performance is well above chance, it is clear that pause duration alone is not a reliable cue to a simple restart. Also, restart pauses at the very start of utterances were quite variable in duration (the 400 ms rule is more reliable when applied to pauses found after 3 syllables of an utterance). Obviously, the spectral-time detail on either side of a pause must be examined to verify whether a restart is present.

Since most restarts are simple repetitions, looking for identical spectral-time patterns (of up to 3 syllables in length) on either side of a short pause will greatly increase the restart recognition accuracy. For simple repetitions, the scope of spectral analysis is very limited: one need only look at about 2–3 syllables before and after each candidate pause. Very few simple repetitions repeated more than three syllables (a significant portion of complex restarts, on the other hand, involve more than three syllables). If a close spectral match is found and the pause exceeds a low threshold (e.g., 120 ms – to avoid confusion with stop closures), we declare that the pause is a simple restart, and that one version (usually the first) of the matching syllables should be excluded from consideration in any ensuing recognition process. We were very successful in automatically recognizing such simple restarts.

Recognizing restarts with changed words appears to be much more difficult than identifying simple restarts. We look for a short pause (again < 400 ms), followed by a spectral-time pattern containing 1–2 syllables corresponding to a portion of the speech immediately prior to the pause. However, there are many possibilities here and many of them have spectral and prosodic patterns that resemble fluent speech (i.e., speech without repeated or substituted words, but having pauses). For example, after the pause in such a restart, the immediately ensuing word(s) may be the added/substituted ones, or there may be one or two repeated words (from before the pause). The added/substituted words may be as short as one or as long as six syllables.

ACKNOWLEDGMENTS

This work was supported in part by grants from the Natural Sciences and Engineering Research Council of Canada.

REFERENCES

[1] O'Shaughnessy, D.: "Recognition of hesitations in spontaneous speech," ICASSP-92, pp. 593–596, March 1992.

[2] Bear, J.; Dowling, J.; Shriberg, E.: "Integrating Multiple Knowledge Sources for Detection and Correction of Repairs in Human-Computer Dialog." Proc. Assoc. Computational Lingusitics, pp. 56–63, 1992.

[3] Shriberg, E., "Intonation of clause-internal filled pauses," Proc. ICSLP-92, pp. 991–994, Oct. 1992.

NEWS / INFORMATIONS

CONFERENCES

The following list of conferences was mainly provided by the Acoustical Society of America. 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 desharnais@drea.dnd.ca

1998

9-11 December: National Symposium on Acoustics – 1998, Calcutta, India. Contact: Acoustical Society of India, c/o S.S. Agrawal, Central Electronics Engr. Res. Inst., CSIR Complex, Hillside Road, New Delhi-110 012, India; Fax: +91 33 471 4371.

15-16 December: Sonar Signal Processing, Loughborough, UK. Contact: Institute of Acoustics, Agriculture House, 5 Holywell Hill, St. Albans, Herts AL1 1EU, UK; Fax: +44 1727 850 533; Email: acoustics@clus1.ulcc.ac.uk

1999

15-19 March: Joint Meeting of Acoustical Society of America/European Acoustics Association, Berlin, Germany. Contact: ASA, 500 Sunnyside Blvd., Woodbury, NY 11797; Tel: 516-576-2360; Fax: 516-576-2377; Email: asa@aip.org; WWW: asa.aip.org

27-29 April: International Conference on Vibration, Noise and Structural Dynamics, Venice, Italy. Contact: D. Hill, Staffordshire University, P.O. Box 333, Beaconside, Stafford ST18 0DF, UK; Fax: +44 1785 353552.

10-14 May: 4th International Conference on Theoretical and Computational Acoustics, Trieste, Italy. Contact: A. Marchetto, ICTCA,99, Osservatorio Geofisico Sperimentale, P.O. Box 2011-Opicina, 34016 Trieste, Italy; Fax: +39 40 327040; Email: ictca99@ogs.trieste.it

17-20 May: Society of Automotive Engineers (SAE) and Noise and Vibration Conference & Exposition meeting, Traverse City, MI. Contact: M.J. Asensio, SAE/Troy, 3001 W Big Beaver Rd, Troy, MI, USA. Tel: 248-649-4920, ext. 3106.

24-26 May: 2nd International Conference on Emerging Technologies in NDT, Athens, Greece. Contact: A. Anastassopoulos, Envirocoustics S.A., Eleftheriou Venizelou 7 & Delfon, 14452 Athens, Greece; Fax: +30 1 28 46 805; Email: envac@acci.gr

27-30 June: ASME Mechanics and Materials Conference, Blacksburg, VA. Contact: Mrs. Norma Guynn, Dept. of Engineering Science and Mechanics, Virginia Tech, Blacksburg, VA 24061-0219; Fax: 540-231-4574; Email: nguynn@vt.edu; WWW: http://www.esm.vt.edu/mmconf/

28-30 June: 1st International Congress of the East European Acoustical Association, St. Petersburg, Russia. Contact: EEAA, Moskovskoe Shosse 44, St. Petersburg 196158, Russia; Fax: +7 812 127 9323; Email: krylspb @sovam.com

28 June - 1 July: Joint Conference of Ultrasonics International '99 and World Congress on Ultrasonics '99 (UI99/WCU99), Lyngby, Denmark. Contact: L. Bjorno, Department of Industrial Physics, Technical University, Building 425, 2800 Lyngby, Denmark; Fax: +45 45 93 01 90; E-mail: lb@ipt.dtu.dk; WWW: www.msc.cornell.edu/~ui99/

CONFÉRENCES

La liste de conférences ci-jointe a été offerte en majeure partie par l'Acoustical Society of America. 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 courrier électronique à desharnais @drea.dnd.ca

1998

9-11 décembre: Symposium national d'acoustique – 1998, Calcutta, Inde. Info: Acoustical Society of India, c/o S.S. Agrawal, Central Electronics Engr. Res. Inst., CSIR Complex, Hillside Road, New Delhi-110 012, India; Fax: +91 33 471 4371.

15-16 décembre: Traitement de signal sonar, Loughborough, Royaume-Uni. Info: Institute of Acoustics, Agriculture House, 5 Holywell Hill, St. Albans, Herts AL1 1EU, UK; Fax: +44 1727 850 533; Email: acoustics@clus1.ulcc.ac.uk

1999

15-19 mars: Rencontre conjointe de l'Acoustical Society of America et de l'Association d'acoustique européenne, Berlin, Allemagne. Info: ASA, 500 Sunnyside Blvd., Woodbury, NY 11797; Tél: 516-576-2360; Fax: 516-576-2377; Email: asa@aip.org; WWW: asa.aip.org

27-29 avril: Conférence internationale sur les vibrations, le bruit, et la dynamique des structures, Venise, Italie. Info: D. Hill, Staffordshire University, P.O. Box 333, Beaconside, Stafford ST18 0DF, UK; Fax: +44 1785 353552.

10-14 mai: 4e conférence internationale sur l'acoustique théorique et informatisée, Trieste, Italie. Info: A. Marchetto, ICTCA,99, Osservatorio Geofisico Sperimentale, P.O. Box 2011-Opicina, 34016 Trieste, Italy; Fax: +39 40 327040; Email: ictca99@ogs.trieste.it

17-20 mai: Conférence et exposition de la Société des Ingénieurs d'autos (SAE) et conférence Bruit et Vibrations, Traverse City, MI. Info: M.J. Asensio, SAE/Troy, 3001 W Big Beaver Rd, Troy, MI, USA. Tél: 248-649-4920, poste 3106.

24-26 mai: 2e conférence internationale sur les nouvelles technologies de NDT, Athènes, Grèce. Info: A. Anastassopoulos, Envirocoustics S.A., Eleftheriou Venizelou 7 & Delfon, 14452 Athens, Greece; Fax: +30 1 28 46 805; Email: envac@acci.gr

27-30 juin: Conférence ASME sur la mécanique et les matériaux, Blacksburg, VA. Info: Mrs. Norma Guynn, Dept. of Engineering Science and Mechanics, Virginia Tech, Blacksburg, VA 24061-0219; Fax: 540-231-4574; Email: nguynn@vt.edu; WWW: http://www.esm.vt.edu/mmconf/

28-30 juin: 1er Congrès international de l'Association d'acoustique de l'Europe de l'Est, St. Petersburg, Russie. Info: EEAA, Moskovskoe Shosse 44, St. Petersburg 196158, Russia; Fax: +7 812 127 9323; Email: krylspb @sovam.com

28 juin - 1 juillet: Conférence conjointe de "Ultrason International '99" et "Congrès mondial '99 sur les ultrasons" (UI99/WCU99), Lyngby, Danemark. Info: L. Bjorno, Department of Industrial Physics, Technical University, Building 425, 2800 Lyngby, Denmark; Fax: +45 45 93 01 90; E-mail: lb@ipt.dtu.dk; WWW: www.msc.cornell.edu/~ui99/

4-9 July: 10th British Academic Conference in Otolaryngology, London, UK. Contact: BOA-HNS, The Royal College of Surgeons, 35-43 Lincoln's Inn Field, London WC2A 3PN, UK; Fax: +44 171 404 4200.

5-8 July: 6th International Congress on Sound and Vibrations, Copenhagen, Denmark. Contact: F. Jacobsen, Department of Acoustic Technology, Building 352, Technical University of Denmark, 2800 Lyngby, Denmark; Fax: +45 45 880577; Email: fjac@dat.dtu.dk; Web: www.dat.dtu.dk

1-4 September: 15th International Symposium on Nonlinear Acoustics (ISNA-15), Gottingen, Germany. Contact: W. Lauterborn, Drittes Physikalisches Institut, Universitat Gottingen, Burgerstr. 42-44, 37073 Gottingen, Germany; Fax: +49 551 39 7720; Email: lb@physik3.gwdg.de

15-17 September: British Society of Audiology Annual Conference, Buxton, UK. Contact: BSA, 80 Brighton Road, Reading RG6 1PS, UK; Fax: +44 0118 935 1915; Email: bsa@b-s-a.demon.co.uk; Web: www.b-s-a.demon.co.uk

2000

20-24 March: Meeting of the German Acoustical Society (DAGA), Oldenburg, Germany. Contact: DEGA, FB Physik, Universität Oldenburg, 26111 Oldenburg, Germany; Fax: +49 441 798 3698; Email: dega@aku.physik.uni-oldenburg.de

3-5 October: WESPRAC VII, Kumamoto, Japan. Contact: Computer Science Dept., Kumamoto Univ., 2-39-1 Kurokami, Kumamoto, Japan 860-0862; Fax: +81 96 342 3630; Email: wesprac7@cogni.eecs.kumamoto-u.ac.jp

16-20 October: 6th International Conference on Spoken Language Processing, Beijing, China. Contact: ICSLP 2000 Secretariat, Institute of Acoustics, PO Box 2712, 17 Zhong Guan Cun Road, 100 080 Beijing, China; Fax: +86 10 6256 9079; Email: mchu@plum.ioa.ac.cn

4-9 juillet: 10e Conférence académique britannique sur l'otolaryngologie, Londres, Royaume-Uni. Info: BOA-HNS, The Royal College of Surgeons, 35-43 Lincoln's Inn Field, London WC2A 3PN, UK; Fax: +44 171 404 4200.

5-8 juillet: 6e congrès international sur le son et les vibrations, Copenhague, Danemark. Info: F. Jacobsen, Department of Acoustic Technology, Building 352, Technical University of Denmark, 2800 Lyngby, Denmark; Fax: +45 45 880577; Email: fjac@dat.dtu.dk; Web: www.dat.dtu.dk

1-4 septembre: 15e Symposium international sur l'acoustique non-linéaire (ISNA-15), Gottingen, Allemagne. Info: W. Lauterborn, Drittes Physikalisches Institut, Universitat Gottingen, Burgerstr. 42-44, 37073 Gottingen, Germany; Fax: +49 551 39 7720; Email: lb@physik3.gwdg.de

15-17 septembre: Conférence annuelle de la Société britannique d'audiologie, Buxton, Royaume-Uni. Info: BSA, 80 Brighton Road, Reading RG6 1PS, UK; Fax: +44 0118 935 1915; Email: bsa@b-s-a.demon.co.uk; Web: www.b-s-a.demon.co.uk

2000

20-24 mars: Rencontre de la Société allemande d'acoustique (DAGA), Oldenburg, Allemagne. Info: DEGA, FB Physik, Universität Oldenburg, 26111 Oldenburg, Germany; Fax: +49 441 798 3698; Email: dega@aku.physik.uni-oldenburg.de

3-5 octobre: WESPRAC VII, Kumamoto, Japon. Info: Computer Science Dept., Kumamoto Univ., 2-39-1 Kurokami, Kumamoto, Japan 860-0862; Fax: +81 96 342 3630; Email: wesprac7@cogni.eecs.kumamoto-u.ac.jp

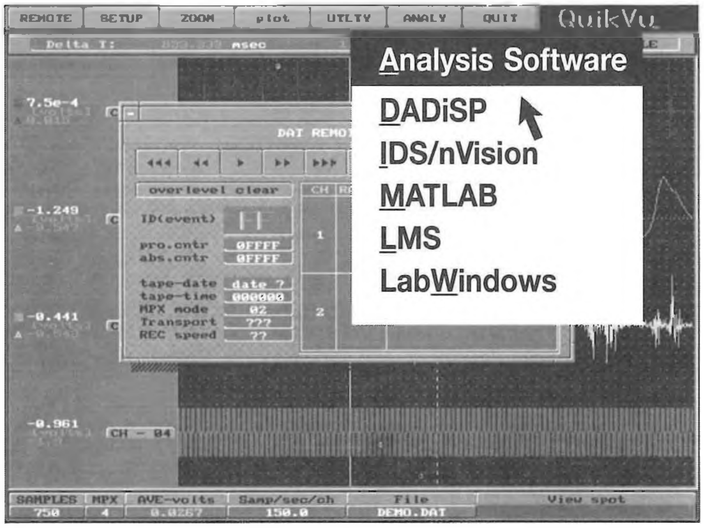
16-20 octobre: 6e conférence internationale sur le traitement de la langue parlée, Beijing, Chine. Info: ICSLP 2000 Secretariat, Institute of Acoustics, PO Box 2712, 17 Zhong Guan Cun Road, 100 080 Beijing, China; Fax: +86 10 6256 9079; Email: mchu@plum.ioa.ac.cn

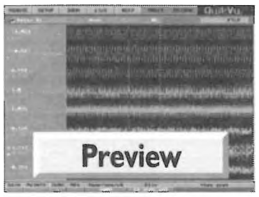
Ontario Student Wins the Science Fair Award

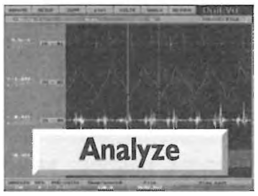
John Hayden of Coburg, Ontario wins the special award of the Canadian Acoustical Association at the Canada Wide Youth Science Fair.

The title of his project was, "Psychoacoustics – A Detailed Study of Human Perception."

Congratulations and Good Luck John Hayden.


REMOTE
SETUP
ZOOM
plot
UTLTY
ANALY
QUIT
QuikVu
Delta T:
msec
7.5e-4
-1.249
-0.441
-0.961
DAT REMOTE
overlevel clear
ID(event)
pro.cntr
abs.cntr
0FFFF
tape-date
tape-time
MPX mode
Transport
REC speed
date ?
000000
02
???
CH - 04
Analysis Software
DADiSP
IDS/nVision
MATLAB
LMS
LabWindows
SAMPLES
MPX
AVE-volts
Samp/sec/ch
File
View spot
750
4
150.0
DEMO.DAT


Preview


Analyze


Download

SYSTEM 824

SLM/RTA

Five sophisticated acoustical instruments in One!

1 **Integrating Sound Level Meter** meeting Type 1 Standards with simultaneous measurement of sound pressure levels using fast, slow, and impulse detector, and simultaneous A, C, and flat weighting. It measures 48 sound pressure parameters at once! All this with a 105 dB linearity range!

Simple Sound Analyzer with simultaneous sound pressure level measurement and real-time 1/3 octave frequency analysis.

Logging Sound Level Meter permits data gathering of broadband sound pressure levels and frequency spectra over user-defined time intervals.

Real Time Frequency Analyzer with 1/1 and 1/3 octave analysis over a 20kHz frequency range and optimized for characterizing steady-state or high speed transient events.

5 **Fast Fourier Transform Analyzer** with 100, 200, and 400 lines resolution and 20kHz range for specific frequency investigations.

Listen with Larson•Davis

For use in a wide variety of applications

Research and Development

- Building Acoustics
- Sound Power Determination
- Vibration measurements
- Statistics
- Simple Point Shoot
- Transient Capture

Environmental

- Aircraft Noise
- Industrial Noise
- General Surveys
- Transportation Noise
- Community Noise

Worker Safety

- Noise Exposure Measurements
- Work Place Surveys
- Machinery Noise
- Audiometric Calibration
- Simultaneous C minus A Measurements

Dalimar Instruments Inc.

At your service since 1986

193, Joseph Carrier, Vaudreuil-Dorion, Quebec, Canada J7V 5V5 Tel.: (450) 424-0033 Fax: (450) 424-0030
90 "C" Centurian Drive, Suite 206, Markham, Ontario, Canada L3R 8C5 Tel.: (905) 948-8345 Fax: (905) 948-8344
E-mail: info@dalimar.ca Website: www.dalimar.ca

Canadian Acoustical Association
l'Association Canadienne d'Acoustique

Minutes of the CAA Board of Director's Meeting

27 October 1998, London, Ontario

Present:	John Bradley	John Hemingway	Trevor Nightingale
	Ramani Ramakrishnan	Don Jamieson	David Quirt
	Annabel Cohen	Dalila Giusti	
Regrets:	Jean Nicolas	Li Cheng	Stan Dosso
	W. Sydenborgh	D. DeGagne	

Meeting called to order at 7.35 p.m..

Minutes of the last Board of Director's meeting approved as written. (Moved by D. Quirt, seconded by D. Giusti, carried).

President's Report (John Bradley)

J. Bradley acted as interim editor for the September issue of the journal. Ramani Ramakrishnan will take over as the permanent editor beginning with the December 1998 issue. J. Bradley created an Operations Manual that combined several CAA documents. This would be discussed as a separate item later in the meeting.

Secretary's Report

The number of paid members, 339, remained constant relative to last year at this time, although the break-down by category changed somewhat. The number of student members was up by 12 over while the number of professional members was down. The membership is still down by about 10% relative to FY96/97. Final meeting report, accounting and cheque were received from the Windsor 97 conference. Secretarial operating costs for the period October 97 to October 98 were $857.04, comparable to the same period last year. The Secretary's report was accepted. (Moved R. Ramakrishnan, seconded by D. Quirt, carried).

Treasurer's Report

The finances are stable with revenues (from membership fees, journal advertising, and conferences) exceeding expenses by approximately $13k. This had lead to a very large operating fund; minimum balance in 1998 was over $39k. Low interest rates have reduced the yield from the Capital fund to under $7k which would have been inadequate to support all the prizes. Due to some prizes having no applicants, a little over $4k was spent on prizes this year. The Treasurer recommended transferring $20k from the operations account to the capital account where is can earn more interest. (Moved by D. Giusti and seconded by R. Ramakrishnan, carried). The Treasurer's report was accepted. (Moved by A. Cohen, seconded by D. Quirt, carried).

Membership Chair Report

The CAA web page is continues to provide a source of information about the organization and the annual conference. Maintenance and updates are on going. Various ideas for attracting and retaining new members were discussed at some length. Ideas included making presentations at universities targeted at students, and for existing members to encourage new people. It was agreed that each member must take an active role in promoting the organization.

Editor's Report

R. Ramakrishnan reported that he has begun soliciting papers for future issues of the journal and has received numerous commitments. It is hoped that the scope of the journal can be broadened to include more than just research papers, thereby increasing the appeal. The effectiveness of the editorial board was discussed and it seemed that there was room for improvement.

Awards Coordinator

There were no applicants for the Eckel, Fesenden or the Shaw postdoctoral prize. The Bell Prize would be awarded to M. Begatto. A book prize in memory of Raymond Hetu will be added to the list of CAA prizes. The Board accepted the recommendations of M. Hodgson and his committee on how the prize should be administered with the exception of one point. It was suggested that each person named as an author on the winning report receive a book. (Moved by D. Giusti seconded by A. Cohen, carried). The Director's award in the student category will be awarded to Jeff Jones. In the category of professional over thirty there was a tie. The award and prize money will be shared by S. Abel and M. Cheesman. There were no candidates in the category of professional under thirty. It was suggested that the Director's Award (student category) and the Student Presentation Awards be made open to both graduate and undergraduate students. (Moved by D. Quirt, seconded by Don Jamieson, carried). D. Giusti agreed to take over as Director's award coordinator for D. Quirt whose term as director has ended.

Nomination Committee

The nomination committee prepared a slate of candidates to replace retiring directors; D. Quirt, and S. Dosso. With regret, the resignation of Jean Nicolas was accepted. He felt that his increased responsibilities at U. Sherbrooke have kept him from devoting time as a BoD member. The Executive agreed to stand for reelection. The slate would be tabled at the Annual General Meeting for a vote by the membership.

CAA Conference Meetings

Windsor 1997: Final report issued and a $2000 profit realized after all expenses.

London 1998: Conference Chair, Don Jamieson, thanked the organizing committee for their efforts. Early numbers indicated about 90 persons would attend. 11 exhibit tables were sold to eight companies.

Victoria 1999: Written report of S. Dosso was read to the board. It appears that the Victoria conference is proceeding well with the hotel selected and the conference dates set for October 18 and 19.

Sherbrooke 2000: Noureddine Atalla agreed to chair the conference.

There was considerable discussion regarding conference announcements and schedules. D. Jamieson and A. Cohen agreed to provide a list of acoustics publications to which the Secretary can send CAA Conference announcements. Announcements in Canadian Acoustics should be automatic. It was also suggested that when a written summary paper is not available for publication in the September issue the 200 word abstract will be published.

CAA Operations Manual

The manual provides a listing of milestones, the by-laws, a brief description of the duties of the officers, organizational time lines for the annual CAA conference, recommendations complied from past CAA conference chair reports, a listing of the CAA prizes and applications forms.

The manual evoked considerable discussion. Comments centered around the lack of a CAA mission statement, the number of directors required to achieve quorum, and the poor attendance of many of the Directors. It was suggested that each person review the document and make suggestions and forward them to J. Bradley well before the next board meeting.

Meeting adjourned at 11:05 p.m. (moved by J. Hemingway and seconded by R. Ramakrishnan, carried).

Canadian Acoustical Association
l'Association Canadienne d'Acoustique

Minutes of the CAA Annula General Meeting

30 October 1998, London, Ontario

Present: 19 voting members

Meeting called to order at 2:01 p.m.

Minutes of the last Annual General Meeting approved as written. (Moved by C. Sherry, seconded by A. Warnock).

President's Report (John Bradley)

J. Bradley reported that he had acted as interim editor for the September issue of the Journal and that Ramani Ramakrishnan will take over as the permanent editor beginning with the December 1998 issue. J. Bradley also reported that he had created an Operations Manual that listed CAA milestones, the by-laws, brief description of the duties of the officers, organizational time lines for the annual CAA conference, recommendations complied from past CAA conference chair reports, listing of the CAA prizes and applications forms.

Secretary's Report

T. Nightingale reported that the number of paid members, 339, remains constant although the number in each category has changed. The number of student members was up by 12 over while the number of professional members was down. Overall the membership is still down by about 10% relative to FY96/97. Secretarial operating costs for the period October 97 to October 98 were $857.04, comparable to the same period last year. The Secretary's report was accepted. (Moved R. Ramakrishnan, seconded by J. O'Keefe, carried).

Treasurer's Report

J. Hemingway reported that the finances are stable with revenues exceeding expenses by approximately $13k for this fiscal year. This surplus has lead to a very large operating fund; minimum balance in 1998 was over $39k. The Treasurer reported that his recommendation to transfer $20k from the operations account to the capital account (where is can earn more interest) had been approved by the Board. The Treasurer's report was accepted. (Moved by H. Williamson, seconded by A. Warnock, carried).

Membership Chair Report

D. Jamieson reported his efforts to maintain the CAA web page. There was considerable discussion about improving "links" to other sites to increase the number of "hits". It was recognized by the membership at the meeting that each individual must do his/her part in promoting the organization and attracting members.

Editor's Report

R. Ramakrishnan provided a report indicating his intention to broaden the scope and appeal of Canadian Acoustics. He reported a fair amount of success in soliciting papers for the coming year.

Awards Coordinator

A Cohen summarized each of the prizes: Shaw Postdoctoral: No applicants, Bell : M. Bagatto, Eckel: No applicants, Fesenden: No Applicants, Directors' Award Student Category: Jeff Jones, Professional Under Thirty: No Applicants, Professional Over Thirty: Tie, prize shared by S. Abel and M Cheesman. Recipients of the Student Presentation Award: S. Boucher, J. Scarsellone, B. Grover, and M. Lantz.

A book prize in memory of Raymond Hetu was announced. It will be awarded for the best undergraduate project in the area of acoustics.

Past President Nomination Report

J. Hemingway announced the Committee's slate of candidates to replace directors D. Quirt, and S. Dosso who retired and Jean Nicolas who resigned. Forwarded were Douglas Whicker, Tim Kelsall and Noureddine Atalla. Nominations from the floor were invited. Kathy Fuller was nominated by A. Cohen. A vote was held for all eight board positions. The complete slate was nine persons (five existing members that had not retired or resigned, three forwarded by the Nominations Committee, and one from the floor). The following were elected members of the Board for FY98/99: N. Atalla, A. Cohen, D. DeGagne, K. Fuller, D. Giusti, T. Kelsall, W. Sydenborgh, D. Whicker. Regrets were extended to L. Cheng who was not reelected.

J. Hemingway moved to destroy the ballots. Motion seconded by C. Sherry and carried.

CAA Conference Meetings

Windsor 1997: Final report issued and a $2000 profit realized after all expenses.

London 1998: Conference Chair, Don Jamieson, thanked the organizing committee for their efforts. Early numbers indicated about 90 persons attended making it a very successful conference.

Victoria 1999: A written report from S. Dosso was read to the membership. Organization of the Victoria conference is well underway with the hotel selected and the conference dates set for October 18 and 19.

Sherbrooke 2000: It as reported that the conference in 2000 would be in Sherbrooke with Noureddine Atalla acting as conference chair.

Other Business

C. Sherry moved that the membership fees and subscription rates remain unchanged for FY98/99. The motion was seconded by H. Williamson and carried.

There was considerable discussion regarding posting consultant's names at the CAA web site. It was finally agreed to post all sustaining subscribers at the web site.

Meeting adjourned at 3:05 p.m. (Moved by R. Ramakrishnan seconded by A. Warnock).

The Canadian Acoustical Association
l'Association Canadienne d'Acoustique

PRIZE ANNOUNCEMENT

A number of prizes, whose general objectives are described below, are offered by the Canadian Acoustical Association. As to the first four prizes, applicants must submit an application form and supporting documentation to the prize coordinator before the end of February of the year the award is to be made. Applications are reviewed by subcommittees named by the President and Board of Directors of the Association. Decisions are final and cannot be appealed. The Association reserves the right not to make the awards in any given year. Applicants must be members of the Canadian Acoustical Association. Preference will be given to citizens and permanent residents of Canada. Potential applicants can obtain full details, eligibility conditions and application forms from the appropriate prize coordinator.

EDGAR AND MILLICENT SHAW POSTDOCTORAL PRIZE IN ACOUSTICS

This prize is made to a highly qualified candidate holding a Ph.D. degree or the equivalent, who has completed all formal academic and research training and who wishes to acquire up to two years supervised research training in an established setting. The proposed research must be related to some area of acoustics, psychoacoustics, speech communication or noise. The research must be carried out in a setting other than the one in which the Ph.D. degree was earned. The prize is for $3000 for full-time research for twelve months, and may be renewed for a second year. Coordinator: Sharon Abel, Mount Sinai Hospital, 600 University Avenue, Toronto, ON M5G 1X6. Past recipients are:

1990	*Li Cheng*	*Université de Sherbrooke*	*1995*	*Jing-Fang Li*	*University of British Columbia*
1993	*Roland Woodcock*	*University of British Columbia*	*1996*	*Vijay Parsa*	*University of Western Ontario*
1994	*John Osler*	*Defense Research Estab. Atlantic*			

ALEXANDER GRAHAM BELL GRADUATE STUDENT PRIZE IN SPEECH COMMUNICATION AND BEHAVIOURAL ACOUSTICS

The prize is made to a graduate student enrolled at a Canadian academic institution and conducting research in the field of speech communication or behavioural acoustics. It consists of an $800 cash prize to be awarded annually. Coordinator: Don Jamieson, Department of Communicative Disorders, University of Western Ontario, London, ON N6G 1H1. Past recipients are:

1990	*Bradley Frankland*	*Dalhousie University*	*1994*	*Michael Lantz*	*Queen's University*
1991	*Steven D. Turnbull*	*University of New Brunswick*	*1995*	*Kristina Greenwood*	*University of Western Ontario*
	Fangxin Chen	*University of Alberta*	*1996*	*Mark Pell*	*McGill University*
	Leonard E. Cornelisse	*University of Western Ontario*	*1997*	*Monica Rohlfs*	*University of Alberta*
1993	*Aloknath De*	*McGill University*	*1998*	*Marlene Bagatto*	*University of Western Ontario*

FESSENDEN STUDENT PRIZE IN UNDERWATER ACOUSTICS

The prize is made to a graduate student enrolled at a Canadian university and conducting research in underwater acoustics or in a branch of science closely connected to underwater acoustics. It consists of $500 cash prize to be awarded annually. Coordinator: David Chapman, DREA, PO Box 1012, Dartmouth, NS B2Y 3Z7.

1992	*Daniela Dilorio*	*University of Victoria*	*1994*	*Craig L. McNeil*	*University of Victoria*
1993	*Douglas J. Wilson*	*Memorial University*	*1996*	*Dean Addison*	*University of Victoria*

ECKEL STUDENT PRIZE IN NOISE CONTROL

The prize is made to a graduate student enrolled at a Canadian academic institution pursuing studies in any discipline of acoustics and conducting research related to the advancement of the practice of noise control. It consists of a $500 cash prize to be awarded annually. The prize was inaugurated in 1991. Coordinator: Murray Hodgson, Occupational Hygiene Programme, University of British Columbia, 2206 East Mall, Vancouver, BC V6T 1Z3.

1994	*Todd Busch*	*University of British Columbia*	*1996*	*Nelson Heerema*	*University of British Columbia*
1995	*Raymond Panneton*	*Université de Sherbrooke*	*1997*	*Andrew Wareing*	*University of British Columbia*

DIRECTORS' AWARDS

Three awards are made annually to the authors of the best papers published in *Canadian Acoustics.* All papers reporting new results as well as review and tutorial papers are eligible; technical notes are not. The first award, for $500, is made to a graduate student author. The second and third awards, each for $250, are made to professional authors under 30 years of age and 30 years of age or older, respectively. Coordinator: Delila Giusti, Jade Acoustics, Concord, ON L4K 4H1.

STUDENT PRESENTATION AWARDS

Three awards of $500 each are made annually to the undergraduate or graduate students making the best presentations during the technical sessions of Acoustics Week in Canada. Application must be made at the time of submission of the abstract. Coordinator: Ramani Ramakrishnan, Aiolos Engineering, Toronto ON M9W 1K4, Tel: (416) 674-3017.

The Canadian Acoustical Association
l'Association Canadienne d'Acoustique

ANNONCE DE PRIX

Plusieurs prix, dont les objectifs généraux sont décrits ci-dessous, sont décernés par l'Association Canadienne d'Acoustique. Pour les quatre premiers prix, les candidats doivent soumettre un formulaire de demande ainsi que la documentation associée au coordonnateur de prix avant le dernier jour de février de l'année durant laquelle le prix sera décerné. Toutes les demandes seront analysées par des sous-comités nommés par le président et la chambre des directeurs de l'Association. Les décisions seront finales et sans appel. L'Association se réserve le droit de ne pas décerner les prix une année donnée. Les candidats doivent être membres de l'Association. La préférence sera donnée aux citoyens et aux résidents permanents du Canada. Les candidats potentiels peuvent se procurer de plus amples détails sur les prix, leurs conditions d'éligibilité, ainsi que des formulaires de demande auprès du coordonnateur de prix.

PRIX POST-DOCTORAL EDGAR ET MILLICENT SHAW EN ACOUSTIQUE

Ce prix est attribué à un(e) candidat(e) hautement qualifié(e) et détenteur(rice) d'un doctorat ou l'équivalent, qui a complété(e) ses études et sa formation de chercheur, et qui désire acquérir jusqu'à deux années de formation supervisée de recherche dans un établissement reconnu. Le thème de recherche proposée doit être relié à un domaine de l'acoustique, de la psycho-acoustique, de la communication verbale ou du bruit. La recherche doit être menée dans un autre milieu que celui où le candidat a obtenu son doctorat. Le prix est de $3000 pour une recherche plein temps de 12 mois avec possibilité de renouvellement pour une deuxième année. Coordonnatrice: Sharon Abel, Mount Sinai Hospital, 600 University Avenue, Toronto, ON M5G 1X6. Les récipiendaires antérieur(e)s sont:

1990	*Li Cheng*	*Université de Sherbrooke*	*1995*	*Jing-Fang Li*	*University of British Columbia*
1993	*Roland Woodcock*	*University of British Columbia*	*1996*	*Vijay Parsa*	*University of Western Ontario*
1994	*John Osler*	*Defense Research Estab. Atlantic*			

PRIX ÉTUDIANT ALEXANDER GRAHAM BELL EN COMMUNICATION VERBALE ET ACOUSTIQUE COMPORTEMENTALE

Ce prix sera décerné à un(e) étudiant(e) inscrit(e) dans une institution académique canadienne et menant un projet de recherche en communication verbale ou acoustique comportementale. Il consiste en un montant en argent de $800 qui sera décerné annuellement. Coordonnateur: Don Jamieson, Department of Communicative Disorders, University of Western Ontario, London, ON N6G 1H1. Les récipiendaires antérieur(e)s sont:

1990	*Bradley Frankland*	*Dalhousie University*	*1994*	*Michael Lantz*	*Queen's University*
1991	*Steven D. Turnbull*	*University of New Brunswick*	*1995*	*Kristina Greenwood*	*University of Western Ontario*
	Fangxin Chen	*University of Alberta*	*1996*	*Mark Pell*	*McGill University*
	Leonard E. Cornelisse	*University of Western Ontario*	*1997*	*Monica Rohlfs*	*University of Alberta*
1993	*Aloknath De*	*McGill University*	*1998*	*Marlene Bagatto*	*University of Western Ontario*

PRIX ÉTUDIANT FESSENDEN EN ACOUSTIQUE SOUS-MARINE

Ce prix sera décerné à un(e) étudiant(e) inscrit(e) dans une institution académique canadienne et menant un projet de recherche en acoustique sous-marine ou dans une discipline scientifique reliée à l'acoustique sous-marine. Il consiste en un montant en argent de $500 qui sera décerné annuellement. Coordonnateur: David Chapman, DREA, PO Box 1012, Dartmouth, NS B2Y 3Z7.

1992	*Daniela Dilorio*	*University of Victoria*	*1994*	*Craig L. McNeil*	*University of Victoria*
1993	*Douglas J. Wilson*	*Memorial University*	*1996*	*Dean Addison*	*University of Victoria*

PRIX ÉTUDIANT ECKEL EN CONTRÔLE DU BRUIT

Ce prix sera décerné à un(e) étudiant(e) inscrit(e) dans une institution académique canadienne dans n'importe quelle discipline de l'acoustique et menant un projet de recherche relié à l'avancement de la pratique en contrôle du bruit. Il consiste en un montant en argent de $500 qui sera décerné annuellement. Ce prix a été inauguré en 1991. Coordonnateur: Murray Hodgson, Occupational Hygiene Programme, University of British Columbia, 2206 East Mall, Vancouver, BC V6T 1Z3.

1994	*Todd Busch*	*University of British Columbia*	*1996*	*Nelson Heerema*	*University of British Columbia*
1995	*Raymond Panneton*	*Université de Sherbrooke*	*1997*	*Andrew Wareing*	*University of British Columbia*

PRIX DES DIRECTEURS

Trois prix sont décernés, à tous les ans, aux auteurs des trois meilleurs articles publiés dans l'*Acoustique Canadienne.* Tout manuscrit rapportant des résultats originaux ou faisant le point sur l'état des connaissances dans un domaine particulier sont éligibles; les notes techniques ne le sont pas. Le premier prix, de $500, est décerné à un(e) étudiant(e) gradué(e). Le deuxième et le troisième prix, de $250 chacun, sont décernés à des auteurs professionnels âgés de moins de 30 ans et de 30 ans et plus, respectivement. Coordonnateur: Delila Giusti, Jade Acoustics, Concord, ON L4K 4H1.

PRIX DE PRÉSENTATION ÉTUDIANT

Trois prix, de $500 chacun, sont décernés annuellement aux étudiant(e)s sous-gradué(e)s ou gradué(e)s présentant les meilleures communications lors de la Semaine de l'Acoustique Canadienne. La demande doit se faire lors de la soumission du résumé. Coordonnateur: Ramani Ramakrishnan, Aiolos Engineering, Toronto ON M9W 1K4, Tel: (416) 674-3017.

Canadian Acoustical Association
l'Association Canadienne d'Acoustique

1998 PRIZE WINNERS / RÉCIPIENDAIRES 1998

ALEXANDER GRAHAM BELL PRIZE IN SPEECH COMMUNICATION AND BEHAVIOURAL ACOUSTICS
PRIZ ALEXANDER GRAHAM BELL EN COMMUNICATION VERBALE ET ACOUSTIQUE COMPORTEMENTALE

Marlene Bagatto, University of Western Ontario

"Acoustic cues to children's speech production errors "

DIRECTORS' AWARDS / PRIX DES DIRECTEURS

Professional ≥30 years / Professionel ≥30 ans:

Sharon Abel, Mount Sinai Hospital

"Accuracy in sound localization: interactive effects of stimulus bandwidth, duration and rise decay"

Margaret F. Cheesman, University of Western Ontario

"Accuracy in sound localization: interactive effects of stimulus bandwidth, duration and rise decay"

Student / Étudiant(e):

Jeffery A. Jones, Queen's University

"The effects of separating auditory and visual sources on audiovisual integration of speech "

STUDENT AWARDS / PRIX ÉTUDIANT

Jana M. Scarsellone, University of Alberta

"Denture Influence on Resonance Balance in Speech"

Bradford Gover, **University of Waterloo**

"Least-squares Inverse Filtering of Speech"

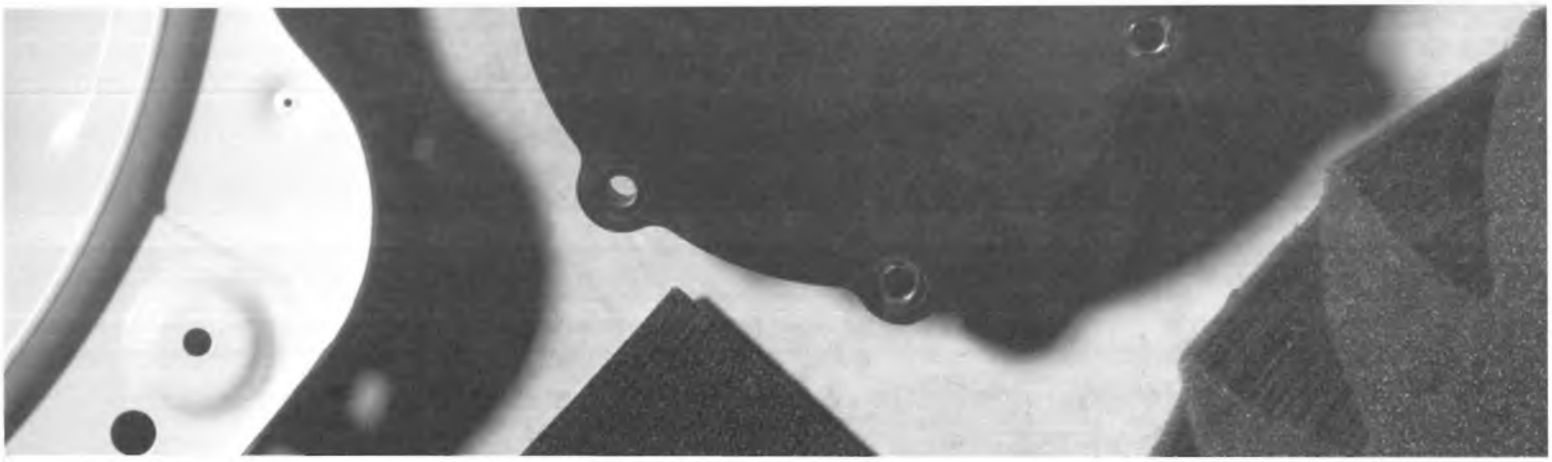
Michael E. Lantz, **Queen's University**

"Total and Relative Duration as cues to surface structure in music"

Stéphane Boucher, **Université de Sherbrooke**

"A new concept for active control of transformer noise (Part 2)"

CONGRATULATIONS / FÉLICITATIONS



The ABC's of Noise Control

Comprehensive Noise Control Solutions

H.L. Blachford Ltd.'s Comprehensive Material Choices Noise treatments can be categorized into three basic elements: Vibration Dampers, Sound Absorbers and Sound Barriers.

Vibration Dampers

It is well known that noise is emitted from vibrating structures or substrates. The amount of noise can be drastically reduced by the application of a layer of a vibration damping compound to the surface. The damping compound causes the vibrational energy to be converted into heat energy. Blachford's superior damping material is called ANTIVIBE and is available in either a liquid or a sheet form.

Antivibe® DL is a liquid damping material that can be applied with conventional spray equipment or troweled for smaller or thicker applications.

It is water-based, non-toxic, and provides economical and highly effective noise reduction from vibration.

Antivibe DS is an effective form of damping material provided in sheet form with a pressure sensitive adhesive for direct application to your product.

Sound Barriers

Sound barriers are uniquely designed for insulating and blocking airborne noise. The reduction in the transmission of sound (transmission loss or "TL") is accomplished by the use of a material possessing such characteristics as high mass, limpness, and impermeability to air flow. Sound barrier can be a very effective and economical method of noise reduction.

Barymat® is a sound barrier that is limp, has high specific gravity, and comes in plastic sheets or die cut parts. It can be layered with other materials such as acoustical foam, protective and decorative facings or pressure sensitive adhesives to achieve the desired TL for individual applications.

Sound Absorbers

Blachford's **Conasorb®** materials provide a maximum reduction of airborne noise through absorption in the frequency ranges associated with most products that produce objectionable noise. Examples: Engine compartments, computer and printer casings, construction, forestry and agriculture equipment, buses and locomotives.

Available with a wide variety of surface treatments for protection or esthetics. Materials are available in sheets, rolls and die-cut parts – designed to meet your specific application.

Suggest Specific Materials or Design

Working with data supplied by you, H.L. Blachford Ltd. will recommend treatment methods which may include specific material proposals, design ideas, or modifications to components.

ISO 9001 REGISTERED A Quality Supplier

The complete integration of:

- Experience of over forty years
- Quality-oriented manufacturing
- Extensive research and development
- Problem solving approach to noise control

MISSISSAUGA
(905) 823-3200

MONTREAL
(514) 938-9775

VANCOUVER
(604) 263-1561

Blachford
www.blachford.ca

The Canadian Acoustical Association
l'Association Canadienne d'Acoustique

MEMBERSHIP DIRECTORY 1997 / ANNUAIRE DES MEMBRES 1997

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.M. Abdou
King Fahd University of Petroleum &
Minerais
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 1,2,10

Dr. Sharon M. Abel
Mount Sinai Hospital
600 University Ave., Suite 843
Toronto, ON
Canada M5G 1X5
(416) 586-8278
FAX: (416) 586-8588
abel@mshri.on.ca
Member 5,6,8

ACO Pacific Inc.
2604 Read Ave.
Belmont, CA
USA 94002
(650) 595-8588
FAX: (650) 591-2891
Sustaining Member
acopac@acopacific.com

Acoutherm Insulation Ltd.
743 Garyray Drive
Weston, ON
Canada M9L 1R2
(416) 744-0151
FAX: (416) 744-6189
Member 1,5,7

Acquisitions Section/Inspec.
Institute of Electrical Engineers
Michael Faraday House
Six Hills Way, Stevenage
Herts SG1 2AY, England
Indirect Subscriber

Acquisitions Unit (DSC-AO)
British Library
Boston Spa, Wetherby
W Yorks LS23 7BQ, England
Indirect Subscriber

Aercoustics Engineering Limited
Barman & Associates
50 Ronson Drive, Suite 127
Rexdale, ON
Canada M9W 1B3
(416) 249-3361
FAX: (416) 249-3613
Sustaining Member 1,2,3,4,6,10

Steve Aiken
251 Platts Lane, Apt. 520
London, ON
Canada N6H 4P4
(519) 661-3901
FAX: (519) 661-3805
aiken@audio.hhrcru.uwo.ca
Student 5,7,8

Jean-Luc Allard
SNC/Lavalin Environment Inc.
Noise and Vibration Control
2271 Fernand-Lafontaine Blvd.
Longueuil, QC
Canada J4G 2R7
(514) 651-6710
FAX: (514) 651-0885
allaj@snc-lavalin.com
Sustaining Member

Dr. D.L. Allen
Vibron Limited
1720 Meyerside Dr.
Mississauga, ON
Canada L5T 1A3
(416) 670-4922
FAX: (416) 670-1698
Member 1,5,7

Mr. Maurice Amram
Ecole Polytech. de Montréal
Dép. de génie physique
CP 6079, Succursale A
Montréal, QC
Canada H3C 3A7
(514) 340-4572
FAX: (514) 340-3218
Member 1,5,7

Mr. Chris Andrew
City Works Services, Coordinator
Noise Section, Environmental Division
20th Floor, East Tower, City Hall
Toronto, ON
Canada M5H 2N2
(416) 392-0792
FAX: (416) 392-1456
Member 1,5

Graham T. Andrews
440 Waterloo St. S.
Cambridge, ON
Canada N3H 1N9
(519) 650-2056
Member 2,6,10

James R. Angerer
105 Florentia St.
Seattle, WA
USA 98109
(206) 655-0975
james.r.angerer@boeing.com
Member 1,6,8

Mr. Horst Arndt
Unitron Industries Ltd.
20 Beasley Drive
P.O. Box 9017
Kitchener, ON
Canada N2G 4X1
(519) 895-0100
FAX: (519) 895-0108
Member 2,6,8

G. Robert Arrabito
18 Alladin Avenue
North York, ON
Canada M6L 1S5
(416) 635-2033
FAX: (416) 635-2104
robbie@dciem.dnd.ca
Member 5,9

ASFETM
3565 rue Jarry Est
Bureau 202
Montréal, QC
Canada H1Z 4K6
(514) 729-6961; 888-lasfetm
FAX: (514) 729-8628
Member

Marc Asselineau
Peutz & Associes
103 boul. Magenta
F-75010 Paris, France
+33 1 42858485
FAX: +33 1 42821057
asselino@worldnet.fr
Sustaining Member 1,4,5

Noureddine Atalla
G.A.U.S.
Dept. of Mechanical Eng.
Université de Sherbrooke
Sherbrooke, QC
Canada 1K 2R1
(819) 821-7102
Member 5,7,9

Youssef Atalla
4408 rue Moreau
Sherbrooke, QC
Canada J1L 1V2
(819) 821-8000ext3106
yatalla@linus.gme.usherb.ca
Student 2,8,9

Atlantic Acoustical Associates
P.O. Box 96, Station M
Halifax, NS
Canada B3J 2L4
(902) 425-3096
FAX: (902) 425-0044
peteraaa@istar.ca
Sustaining Member 1,2,5

Yiu Nam Au-Yeung
22 Edinburgh Dr.
Richmond Hill, ON
Canada L4B 1W3
(905) 764-8465
FAX: (905) 764-8465
Member 1,5,7

Mr. Frank Babic
Environmental Acoustics Inc.
Unit 13, 5155 Spectrum Way
Mississauga, ON
Canada L4W 5A1
(905) 238-1077
FAX: (905) 238-9079
enviraco@idirect.com
Sustaining Member 10

Marlene Bagatto
Apt. 906, 585 Proudfoot Lane
London, ON
Canada N6H 4R6
(519) 471-4459
FAX: (519) 661-3805
bagatto@audio.hhcru.uwo.ca
Student 5,7,8

Jeffery S. Bamford
1196 McCraney Street East
Oakville, ON
Canada L6H 4S5
(416) 691-3839
FAX: (416) 691-9013
jBamford@EngineeringHarmonics.com
Member 2,10,11

Michel Barrette
Université de Sherbrooke
Dép. de génie mécanique
2500 boul. Université
Sherbrooke, QC
Canada J1K 2R1
(819) 821-8000ext3179
FAX: (819) 821-7163
mbarrett@gaus.gme.usherb.ca
Student 2,3,10

Bradley Basnett
157 King St.
Carleton Place, ON
Canada K7C 1G5
(613) 253-8843
FAX: (613) 763-3293
Member 1,2

Byron C. Becker
Apt. 404, 3520 - 31st Street N.W.
Calgary, AB
Canada T2L 2A4
(403) 284-9597
FAX: (403) 282-8249
bcbecker@acs.ucalgary.ca
Student 2,4,5

Mr. Alberto Behar
45 Meadowcliffe Dr.
Scarborough, ON
Canada M1M 2X8
(416) 265-1816
FAX: (416) 265-1816
albehar@orbonline.net
Member 1,5,8

Mr. S. Benner
Ministry of the Environment
3rd Fl., 250 Davisville Ave.
Toronto, ON
Canada M4S 1H2
(416) 440-3549
FAX: (416) 440-6973
bennersh@ene.gov.on.ca
Member 1,5

Stephen W. Bennett
4317 Cliffmont Rd.
North Vancouver, BC
Canada V7G 1J6
(604) 929-6942
Member 1,5

Elliott H. Berger
Cabot Safety Corp.
7911 Zionsville Rd.
Indianapolis, IN
USA 46268
Member

Mr. John Binek
SPL Control Inc.
1400 Bishop St.
Cambridge, ON
Canada N1R 6W8
(519) 623-6100
FAX: (519) 623-7500
jbinek@splcontrol.com
Member 5

Mr. J. Blachford
H.L. Blachford Ltd.
977 Lucien l'Allier
Montréal, QC
Canada H3G 2C3
(514) 938-9775
FAX: (514) 938-8595
jblach@blachford.ca
Member 5

Denis Blanchet
Université de Sherbrooke
Dép. de génie mécanique
2500 boul. Université
Sherbrooke, QC
Canada J1K 2R1
(819) 821-8000ext3179
denis.blanchet@gaus.gme.usherb.ca
Student 2,6,7,8,9,10

Mr. Christopher T. Blaney
MTO, Planning & Env. Office
Atrium Tower, 3rd Floor
1201 Wilson Ave.
Downsview, ON
Canada M3M 1J8
(416) 235-5561
FAX: (416) 235-4940
blaney@mto.gov.on.ca
Member 5

Stephen Bly
Radiation Protection Bureau
Room 228A, 775 Brookfield Rd.
Ottawa, ON
Canada   K1A 1C1
(613) 954-0308
FAX: (613) 941-1734
sbiy@hpb.hwc.ca
Member   3,5

The Boeing Company
62-LF / Renton Technical Library
P.O. Box 3707
Seattle, WA
USA   98124
Indirect Subscriber

Eugene H. Bolstad
5903 - 109B Ave.
Edmonton, AB
Canada   T6A 1S7
(403) 468-1872
FAX: (403) 468-1872
Courtesy Subscription   1,5

Stephane Boucher
52 London
Sherbrooke, QC
Canada   J1H 3M3
(819) 562-9152
stephane.boucher@gel.usherb.ca
Student   2,4,10

Alex Boudreau
1136 rue Auray, App. #13
Sherbrooke, QC
Canada   J1K 2C4
(819) 821-7000 (3371)
FAX: (819) 821-7163
alex.boudreau@gme.usherb.ca
Student   2,4

Stephen Bourke
202 - 1875 West 7th Avenue
Vancouver, BC
Canada   V6J 1S9
(604) 730-7162
FAX: (604) 730-7162
bourke@bc.sympatico.ca
Member   1,2,5

Mr. J.W. Boutilier
1143 Upper Paradise Road
Hamilton, ON
Canada   L9B 2N3
Member   1,2,5

Mr. P.G. Bowman
Union Gas Ltd.
50 Keil Dr.
Chatham, ON
Canada   N7M 5M1
(519) 352-3100
FAX: (519) 436 5210
Member   5

Jeff Boyczuk
McGill University
School of Communication Sciences and Disorders
1266 Pine Avenue West
Montreal, QC
Canada   H3G 1A8
(514) 398-4135
FAX: (514) 398-8123
bwhe@musicb.mcgill.ca
Student   5,7,8

Kim Braaten
4507 Argyle St.
Regina, SK
Canada   S4S 3M3
(306) 585-3174
Student

Marc Bracken
Aercoustics Engineering
Suite 127, 50 Ronson Dr.
Toronto, ON
Canada   M9W 1B3
(416) 249-3361
FAX: (416) 249-3613
Member   1,2,4,6

J.S. Bradley
National Research Council Canada
Institute for Research in Construction
Acoustics Lab., Building M-27
Ottawa, ON
Canada   K1A 0R6
(613) 993-9747
FAX: (613) 954-1495
john.bradley@nrc.ca
Member   1,2,4

Dr. A.J. Brammer
National Research Council Canada
Institute for Microstructural Science
Bldg. M-36
Ottawa, ON
Canada   K1A 0R6
(613) 993-6160
FAX: (613) 952-3670
Member   5,6,7

Mr. David W. Brown
Brown Strachan Assoc.
Two Yaletown Sq.
1290 Homer St.
Vancouver, BC
Canada   V6B 2Y5
(604) 689-0514
FAX: (604) 689-2703
Member   1,5,7

Mr. Claudio Bulfone
531 - 55A St.
Delta, BC
Canada   V4M 3M2
(604) 943-8224
FAX: (604) 666-3982
bulfonc@tc.gc.ca
Member   1,5,7

Corjan Buma
10408 - 36 Ave.
Edmonton, AB
Canada   T6J 2H4
(403) 435-9172
FAX: (403) 435-9172
bumacj@superiway.net
Member   1,4,5

Todd Busch
Acentech Incorporated
1429E Thousand Oaks Blvd., Suite 200
Thousand Oaks, CA
USA   91362
(805) 379-4778
FAX: (805) 379-1797
beowulf0@earthlink.net
Member

Mr. Richard Cabot
1980 Twin Points Dr.
Lake Oswego, OR
USA   97034
(503) 627-0832
FAX: (503) 641-8906
rcc@ap.com
Member   2,4,6

Mr. Angelo J. Campanella
Campanelia Assoc.
3201 Ridgewood Drive
Columbus, OH
USA   43026-2453
(614) 876-5108
FAX: (614) 771-8740
acampane@postbox.acs.ohio-state.edu
Member   1,3,5

William J. Cavanaugh
Cavanaugh Tocci Assoc Inc.
3 Merifield Lane
Natick, MA
USA   01760
(978) 443-7871
FAX: (978) 443-7873
cta@cavtocci.com
Member   1,5,6

Mr. Yvan Champoux
Université de Sherbrooke
Dép. de génie mécanique
Faculté des sciences appliquées
Sherbrooke, QC
Canada   J1K 2R1
(819) 821-8000ext2146
FAX: (819) 821-7163
yvan.champoux@gme.usherb.ca
Member   1,2,5

Mr. David M.F. Chapman
Defence Research Establishment Atlantic
P.O. Box 1012
Dartmouth, NS
Canada   B2Y 3Z7
(902) 426-3100
FAX: (902) 426-9654
dave.chapman@drea.dnd.ca
Member   9,4

N. Ross Chapman
University of Victoria
School of Earth & Ocean Sciences
P.O. Box 3055
Victoria, BC
Canada V8W 3P6
Member 9

Brian Chapnik
HGC Engineering
Plaza One, Suite 203
2000 Argentia Rd.
Mississauga, ON
Canada L5N 1P7
(905) 826-4044
FAX: (905) 826-4940
chapnik@me.me.utoronto.ca
Member 2,5,7

Mr. Marshall Chasin
34 Bankstock Dr.
North York, ON
Canada M2K 2H6
(416) 733-4342
Member 2,5,6

M. Cheesman
University of Western Ontario
Dept. of Communication Sciences and Disorders
Faculty of Health Sciences, Elborn College
London, ON
Canada N6G 1H1
(519) 279-2111, ext. 8283
FAX: (519) 661-3805
cheesman@audio.hhcru.uwo.ca
Member 5,7,8

Mr. Li Cheng
Université Laval
Dept. de génie mécanique
Fac. des sciences et de génie
Québec, QC
Canada G1K 7P4
(418) 656-2199
FAX: (418) 656-7415
li.cheng@gmc.ulaval.ca
Member 5,7

Chief Editor
Acoustics Australia
Acoustics Australia Lib.
Australian Def. Force Academy
Canberra, ACT 2600, Australia
Courtesy Subscription

Dr. W.T. Chu
National Research Council Canada
Institute for Reserach in Construction
Acoustics Lab., Building M-27
Ottawa, ON
Canada K1A 0R6
(613) 993-9742
FAX: (613) 954-1495
wing.chu@nrc.ca
Member 1,5,7

CISTI M-20 Bldg. Branch
National Research Council Canada
Ottawa, ON
Canada K1A 0S2
Indirect Subscriber

CISTI, Serials Acquisition
National Research Council Canada
Ottawa, ON
Canada K1A 0S2
Indirect Subscriber

Mr. John B. Codrington
Acres International Ltd.
4342 Queen Street
Niagara Falls, ON
Canada L2E 6W1
(905) 374-5200
FAX: (905) 374-1157
jcodring@niagarafalls.acres.com
Member 5,7

Dr. Annabel J. Cohen
University of Prince Edward Island
Dept. of Psychology
Charlottetown, PE
Canada C1A 4P3
(902) 628-4331
FAX: (902) 628-4359
annabel@ernie.psyc.upei.ca
Member 4,6,8

Mr. Joseph L. Corcoran
Matrix Projects Limited
4622 Caulfield Dr.
West Vancouver, BC
Canada V7W 1E8
(604) 926-7241
Member 1,5,7

J.E. Coulter Associates Ltd.
Suite 211, 1210 Sheppard Ave. E
Toronto, ON
Canada M2K 1E3
(416) 502-8598
FAX: (416) 502-3473
jcoulter@idirect.com
Sustaining Member 1,5,7

I - 20DAW, C S I
Direction Mediatheque – Phys
B.P. 30
F 75927 Paris Cedex 19
France
Indirect Subscriber

CSST, Centre de Doc.
1199 rue de Bleury, 4e
C.P. 6067, Succ. Centre-Ville
Montréal, QC
Canada H3C 4E2
Direct Subscriber

I - 20DAW, C.S.T.B, Grenoble
Service Documentation
24 rue Joseph Fourier
F 38401 St. Martin d'Heres
France
Indirect Subscriber

Dr. Lola Cuddy
Queen's University
Dept. of Psychology
Kingston, ON
Canada K7L 3N6
(613) 545-6013
FAX: (613) 545-2499
cuddyl@psyc.queensu.ca
Member 4,5,7

Nathalie Dabin
Université de Sherbrooke
Dép. de génie mécanique
2500 boul. Université
Sherbrooke, QC
Canada J1K 2R1
(819) 821-8000ext3166
ndabin@gme.usherb.ca
Student 9,11

Dr. Gilles Daigle
National Research Council Canada
Inst. for Microstructural Science
Bldg. M-36
Ottawa, ON
Canada K1A 0R6
(613) 993-6188
FAX: (613) 952-3670
Member 3,5

Dalimar Instruments Inc.
193, Joseph Carrier
Vaudreuil-Dorion, QC
Canada J7V 5V5
(514) 424-0033
FAX: (514) 424-0030
dalimar@mlink.net
Sustaining Member 1,4,5

Davidson & Associates Inc.
94, de la Gare, Bureau #102
St-Sauveur-des-Monts, QC
Canada J0R 1R6
(514) 227-4248
FAX: (514) 227-1613
Direct Subscriber 1,5,7

Dr. Huw G. Davies
University of New Brunswick
Dept. of Mechanical Engineering
P.O. Box 4400
Fredricton, NB
Canada E3B 5A3
(506) 453-4513
FAX: (506) 453-5025
davies@unb.ca
Member

Jack L. Davis
Nova Gas Transmission Ltd.
P.O. Box 2535, Station M
Calgary, AB
Canada T2P 2N6
(403) 290-7365
FAX: (403) 290-7227
Member 2,7

David DeGagne
Alberta Energy and Utilities Board
640 - 5th Ave. SW
Calgary, AB
Canada T2P 3G4
(403) 297-3200
FAX: (403) 297-3520
degagd@mail.eub.gov.ab.ca
Member 10

Professeur J. Dendal
Univ. de Liège, Serv. d'Ac. App.
Bulletin d'Acoustique
SartTilman (B.28)
Liege, B 4000, Belgique
Courtesy Subscription

Mark Christopher Derrick
41 Shawfield Way SW
Calgary, AB
Canada T2Y 2X9
(403) 259-3600
FAX: (403) 259-4190
hfpcalgary@aol.com
Member 2,6

Francine Desharnais
DREA
P.O. Box 1012
Dartmouth, NS
Canada B2Y 3Z7
(902) 426-3100x219
FAX: (902) 426-9654
desharnais@drea.dnd.ca
Member 9

Renée N. Desjardins
McMaster University
Dept. of Psychology
1280 Main St. W.
Hamilton, ON
Canada L8S 4K1
(905) 525-9140ext23215
FAX: (905) 529-6225
rdesjard@mcmaster.ca
Member 7,8

Mr. J. Desormeaux
Ontario Hydro
Health & Safety Division
1549 Victoria St. E.
Whitby, ON
Canada L1N 9E3
(905) 430-2215
FAX: (905) 430-8583
picc/mck1/desormji
Member 1,5,6

B. Craig Dickson
Speech Technology Research
1623 McKenzie Ave., Suite B
Victoria, BC
Canada V8N 1A6
(250) 477-0544
FAX: (250) 477-2540
craig@speechtech.com
Member 7,12

Trent S. Dinn
HFP Acoustical Consultants Ltd.
#1140, 10201 Southport Road SW
Calgary, AB
Canada T2W 4X9
(403) 259-3600
FAX: (403) 259-4190
trent@hfpacoustical.dom
Member 2,6,10

Stan Dosso
University of Victoria
School of Earth and Ocean Sciences
Victoria, BC
Canada V8W 3P6
(250) 472-4341
FAX: (250) 721-6200
sdosso@uvic.ca
Member 9,10,11

The Library
DREA
P.O. Box 1012
Dartmouth, NS
Canada B2Y 3Z7
Direct Subscriber

Jean-Claude Dubé
Aluminerie Lauralco inc.
1, boul. des Sources
Deschambault, QC
Canada G0A 1S0
(418) 286-5283
FAX: (418) 286-5411
dube.jean-claude@lauralco.com
Member 2,3

Jan Eckstein
Industrial Health Foundation Inc.
34 Penn Circle West
Pittsburgh, PA
USA 15206
Courtesy Subscription

Mr. A.T. Edwards
328 Gloucester Ave.
Oakville, ON
Canada L6J 3X1
(416) 845-1840
Courtesy Subscription

Prof. M. David Egan
P.O. Box 365
Anderson, SC
USA 29622-0365
(864) 226-3832
Member 1,2,5

Dr. Jos J. Eggermont
University of Calgary
Dept. of Psychology
2500 University Drive NW
Calgary, AB
Canada T2N 1N4
(403) 220-5214
FAX: (403) 282-8249
eggermon@acs.ucalgary.ca
Member 6,8

001ACF5829
Milton S. Eisenhower Library
Serials Dept.
Johns Hopkins University
Baltimore, MD
USA 21218
Indirect Subscriber

Gilles Elhadad
5715 Kincourt
Cote St Luc, QC
Canada H4W 1Y7
(514) 487-7159
FAX: (514) 487-9525
Member 1,5

Dr. Dale D. Ellis
Defence Research Establishment Atlantic
P.O. Box 1012
Dartmouth, NS
Canada B2Y 3Z7
(902) 426-3100ext104
FAX: (902) 426-9654
ellis@drea.dnd.ca
Member 3,9

Energy Utilities Board
Library, 2nd Level
640 - 5 Avenue S.W.
Calgary, AB
Canada T2P 3G4
indirect Subscriber

Fabra Wall Ltd.
P.O. Box 5117, Station E
Edmonton, AB
Canada T5P 4C5
fabrawall@fabra-wall.ab.ca
(403) 987-4444
FAX: (403) 987-2282
Direct Subscriber 1,5,10

Mark Ryan Fallat
University of Victoria
School of Earth and Ocean Sciences
Box 3055
Victoria, BC
Canada V8W 3P6
(250) 472-4342
FAX: (250) 472-4620
mfallat@uvic.ca
Student 9,10

Dr. M.G. Faulkner
University of Alberta
Dept. of Mechanical Engineering
Edmonton, AB
Canada T6G 2G8
(403) 492-3446
FAX: (403) 492-2200
Member 1,5,7

Mr. James L. Feilders
Jade Acoustics Inc.
545 N Rivermede Rd., Suite 203
Concord, ON
Canada L4K 4H1
(905) 660-2444
FAX: (905) 660-4110
jade_acoustics@compuserve.com
Member 1,5,7

Raymond Fischer
10 Kirk Rd.
Billerica, MA
USA 01821
(978) 670-5339
FAX: (978) 667-7047
noise@tiac.net
Member

Fisheries and Oceans, Library
Pacific Biological Station
Nanaimo, BC
Canada V9R 5K6
Indirect Subscriber

Rick Fleming
7 Goodwill Avenue, Apt. 8
Charlottetown, PE
Canada C1A 3C5
(902) 894-4986
rfleming@upei.ca
Student 1,4,9

Peter J. Flipsen
Apt. 4, 404 Chamberlain Ave.
Madison, WI
USA 53705
(608) 263-9674
FAX: (608) 263-0529
flipsen@waisman.wisc.edu
Member 8

Olivier Foin
Université de Sherbrooke
Dép. de génie mécanique
Sherbrooke, QC
Canada J1K 2R1
(819) 821-8000ext3161
FAX: (819) 821-7163
olivier.foin@gme.usherb.ca
Student 2,10

Harold Forester
1434 Franklin Dr.
Laval, QC
Canada H7W 1K6
(450) 681-2333
FAX: (450) 681-2354
forester@ican.net
Member 1,5,7

Mr. Stanley Forshaw
3958 Sherwood Rd.
Victoria, BC
Canada V8N 4E6
(250) 721-4075
Member 8

Pauline Fortier
955 Beaugrand
Beloeil, QC
Canada J3G 5T3
(514) 928-6777ext5440
FAX: (514) 928-6781
pauline fortier/rrsss016/ssss/gouv.qc.pssss
Member 5,6,7

Dr. Claude R. Fortier
State of the Art Acoustik Inc.
Suite 43, 1010 Polytek St.
Ottawa, ON
Canada K1J 9J3
(613) 745-2003
FAX: (613) 745-9687
Member 1,2,5

Martin Fortin
1690 Francois H. Prévost
Montréal, QC
Canada H2M 2N3
(514) 343-7301
FAX: (514) 343-5740
fortm@ere.umontreal.ca
Student 2,7,8

Ronald Fox
Fox Audio
42 Emily Manor Drive
R.R. #2 Omemee, ON
Canada K0L 2W0
(705) 789-7339
FAX: (705) 799-1112
foxaudio@pipcom.com
Member 11

Mr. Leslie Frank
HFP Acoustical Cons. Ltd.
10201 Southport Rd. SW, #1140
Calgary, AB
Canada T2W 4X9
(403) 259-3600
FAX: (403) 259-4190
les@hfpacoustical.com
Member 1,5,6

Ron Freiheit
Wenger Corp.
555 Park Dr.
Owatonna, MN
USA 55060
(507) 455-4100
FAX: (507) 455-4258
rwenger@pan.com
Member 1,4,5

M.K. Fuller
University of British Columbia
Audiology & Speech Sciences
5804 Fairview Ave.
Vancouver, BC
Canada V6T 1Z3
(604) 822-4716
FAX: (604) 822-6569
kpf@audiospeech.ubc.ca
Member 6,8

W. Robert J. Funnell
McGill University
Dept. of BioMedical Engineering
3775 rue University
Montréal, QC
Canada H3A 2B4
(514) 398-6739
FAX: (514) 398-7461
r.funnel@med.mcgill.ca
Member

Ken Fyfe
University of Alberta
4-9 Mechanical Engineering
Edmonton, AB
Canada T6G 2G8
(403) 492-7031
FAX: (403) 492-2200
ken.fyfe@ualberta.ca
Member 1,2,3,6,10

Mr. V. Gambino
Aercoustics Eng. Ltd.
50 Ronson Dr., Suite 127
Rexdale, ON
Canada M9W 1B3
(416) 249-3361
vgambino@aercoustics.com
Member 1,2,5

Dr. Robert Gaspar
Spaarg Engineering Limited
Noise and Vibration Analysis
822 Lounsborough Street
Windsor, ON
Canada N9G 1G3
(519) 972-0677
FAX: (519) 972-1811
gasparr@engn.uwindsor.ca
Member 1,5,7

Mr. Wm. Gastmeier
HGC Engineering Ltd.
Plaza One, Suite 203
2000 Argentia Rd.
Mississauga, ON
Canada L5N 1P7
(905) 826-4044
FAX: (905) 826-4940
bgastmeier@hcgengineering.com
Member 1,5,7

Dr. R.W. Gatehouse
University of Guelph
Dept. of Psychology
50 Stone Road East
Guelph, ON
Canada N1G 2W1
(519) 824-4120
FAX: (519) 837-8629
Member 5,6,8

Jean-Sébastien Genot
Université de Sherbrooke
GAUS, Dép. de génie mécanique
Casier étudiants gradués
Sherbrooke, QC
Canada J1K 2R1
(819) 821-7812
Fax: (819) 821-7163
jgenot@sofia.gme.usherb.ca
Student 2,6,10

Pierre Germain
208 - 1547 Comox St.
Vancouver, BC
Canada V6G 1P3
(604) 899-3306
Student 1,4,5

Mr. Hazem Gidamy
S.S. Wilson & Assoc.
9011 Leslie Street, Suite 307
Richmond Hill, ON
Canada L4B 3B6
(905) 707-5800
Member 1,5,7

Mr. Philip Giddings
Engineering Harmonics
61 Dixon Avenue
Toronto, ON
Canada M4L 1N5
(416) 691-3839
FAX: (416) 691-9013
engineeringharmonics.com
Member 1,2,6

Christian Giguere
Jan Naardingstraat 8
9402KL Assen, Nederland
+31 592 343047
FAX: +31 30 2541922
c.giguere@med.ruu.nl
Member 5,7,8

Fred Gilpin
2323 Sentinel Dr.
Abbotsford, BC
Canada V2S 5C9
(604) 859-8078
FAX: (604) 859-3068
fred_gilpin@mindlink.bc.ca
Member 1,4

Daiila Giusti
Jade Acoustics Inc.
545 N Rivermede Rd., Suite 203
Concord, ON
Canada L4K 4H1
(905) 660-2444
FAX: (905) 660-4110
jade_acoustics@compuserve.com
Member 1,5,7

Jean-Marc Gladu
Suite 200, 1111 Prince of Wales Dr.
Ottawa, ON
Canada K2C 3T2
(613) 727-2820
FAX: (613) 727-2901
gladuje@epo.gov.on.ca
Member 1,2,6

Izzy Gliener
Western Noise Control
10112 - 105 Avenue
Edmonton, AB
Canada T5H 0K2
(403) 423-2119
FAX: (403) 426-0352
Member 1,5,7

Blaise Gosselin
Hydro-Quebec
Ligne, Cable et environnement
800 de Maisonneuve est, 21e etage
Montréal, QC
Canada H2L 4M8
(514) 840-3000ext5134
FAX: (514) 840-3137
gosselin.blaise@hydro.qc.ca
Sustaining Member

Mr. Manfred W. Grote
ARCOS Acoustical Cons. Ltd.
101 - 1400 Kensington Rd. NW
Calgary, AB
Canada T2N 3P9
(403) 283-1191
FAX: (403) 283-1125
arcos@oanet.com
Member 1,2,5

Bradford Grover
University of Waterloo
Dept. of Physics
Waterloo, ON
Canada N2L 3G1
(613) 991-2616
FAX: (613) 952-3670
brad.grover@nrc.ca
Student 1,2,10

Roberto Guadagno
Brampton Audiology
Suite 106, 36 Vodden St. E
Brampton, ON
Canada L6V 4H4
(905) 874-1170
FAX: (905) 874-4785
Member 5,7,8

Mr. J.M. Guevremont
Specmont Inc.
1490, de Coulomb
Boucherville, QC
Canada J4B 7K2
(514) 449-2545
FAX: (514) 449-0322
Member 5

Dr. Jingnan Guo
University of British Columbia
Occup. Hyg. Prog. & Dept. of Mech. Eng.
3rd Floor, 2206 East Mall
Vancouver, BC
Canada V6T 1Z3
(604) 822-9575
FAX: (604) 822-9588
jingnan@mech.ubc.ca
Member 1,2,10

Dr. R.W. Guy
Concordia University, C.B.S.
1455 de Maisonneuve W.
Montréal, QC
Canada H3G 1M8
(514) 848-3191
FAX: (514) 848-7965
guy@cbs.engr.concordia.ca
Member 1,5

E. Haboly
Vancouver International Airport Authority
P.O. Box 23750, APO
Richmond, BC
Canada V7B 1Y7
Indirect Subscriber

Dr. A.T. Haines
McMaster Univ, 3H50 HSC
Occupational Health Program
Hamilton, ON
Canada L8N 3Z5
(416) 525-9140ext22333
FAX: (905) 528-8860
hainest@fhs.csu.mcmaster.ca
Member

Linda Hall Library
Serials Department
5109 Cherry Street
Kansas City, MO
USA 64110
Direct Subscriber

Sue Haske
University of Alberta
Speech Pathology & Audiology
Rm. 2-70, Corbett Hall
Edmonton, AB
Canada T6G 2G4
Courtesy Subscription

Dr. David I. Havelock
National Research Council Canada
IMS, Acoustics & Sig. Proc. Grp.
Bldg. M-36, Montreal Road
Ottawa, ON
Canada K1A 0R6
(613) 993-7661
FAX: (613) 952-3670
david.havelock@nrc.ca
Member 10

Lynn Marie Heap
1033 Verdier Avenue
Brentwood, BC
Canada V8M 1H8
(250) 721-7421
FAX: (250) 721-7423
lmheap@uvric.ca
Student 4,7,8

Mr. John Hemingway
2410 Old Pheasant Rd.
Mississauga, ON
Canada L5A 2S1
(905) 949-0915
FAX: (905) 949-0915
jrh@mail.globalserve.net
Member 1,5,7

M. Salem Hertil
Marshall Macklin Monaghan
Acoustics, Noise and Vibration
80 Commerce Valley Dr. East
Thornhill, ON
Canada L3T 7N4
(905) 880-4211x360
FAX: (905) 882-7277
hertils@mmm.ca
Member 1,2,6

Bernard Hétu
3215, av. Ellendale, App. 2
Montréal, QC
Canada H3S 1W7
(514) 735-8476
Member 1,2,6

HGC Engineering
Howe Gastmeier Chapnik Ltd.
Plaza One, Suite 203
2000 Argentia Rd.
Mississauga, ON
Canada L5N 1P7
Sustaining Member

Mr. Ralph K. Hillquist
RKH Consults Inc.
P.O. Box 38
Benzonia, MI
USA 49616
(616) 882-0234
FAX: (616) 882-0234
hillquis@benzie.com
Member 1,5,6

Ms. Angela Hitti
Cambridge Scientific, Abstracts
7200 Wisconsin Ave.
Bethesda, MD
USA 20814
Courtesy Subscription

Megan Hodge, Ph.D.
University of Alberta
Speech Pathology & Audiology
Rm 2-70 Corbett Hall
Edmonton, AB
Canada T6G 2G4
(403) 492-5898
FAX: (403) 492-1626
megan.hodge@ualberta.ca
Member 8

Dr. Murray Hodgson
University of British Columbia
Occupational Hygiene Programme
2206 East Mall, 3rd Fl.
Vancouver, BC
Canada V6T 1Z3
(604) 822-3073
FAX: (604) 822-9588
hodgson@mech.ubc.ca
Member 1,5

Mr. J.T. Hogan
University of Alberta
Dept. of Linguistics
4 20 Assiniboia Hail
Edmonton, AB
Canada T6G 2E6
(403) 492-3480
FAX:: (403) 492-0806
Member 4,8

Dr. David Holger, Editor
Noise Control Engineering Journal
Iowa State University, College of Engineering
104 Marston Hall
Ames, IO
USA 50011-2151
Courtesy Subscription

Mr. Brian Howe
HGC Engineering
Plaza One, Suite 203
2000 Argentia Rd.
Mississauga, ON
Canada L5N 1P7
(905) 826-4044
FAX: (905) 826-4940
bhowe@hgcengineering.com
Member 1,5,7

Lin Hu
Forintek Canada Corp.
319 rue Franquet
Ste-Foy, QC
Canada G1P 4R4
(418) 659-2647
Member 1,2,3

Daniel Hutt
DREA
P.O. Box 1012
Dartmouth, NS
Canada B2Y 3Z7
(902) 426-3100ext218
FAX: (902) 426-9654
daniel.hutt@drea.dnd.ca
Member 9,10

IAPA, Information Centre
250 Yonge St., 28th Fl.
Toronto, ON
Canada M5B 2L7
(416) 506-8888
FAX: (416) 506-8880
Direct Subscriber

Integral DX Engineering Ltd.
907 Admiral Ave.
Ottawa, ON
Canada K1Z 6L6
(613) 761-1565
FAX: (613) 729-4337
Sustaining Member 1,5,7

I.R.S.S.T.
Informathèque
505 Maisonneuve O., 11e étage
Montréal, QC
Canada H3A 3C2
Indirect Subscriber

Jade Acoustics Inc.
545 N Rivermede Rd., Suite 203
Concord, ON
Canada L4K 4H1
(905) 660-2444
FAX: (905) 660-4110
Sustaining Member

Dr. Donald G. Jamieson
University of Western Ontario
Hearing Health Care Res. Unit
Elborn College
London, ON
Canada N6G 1H1
(519) 661-3901
FAX: (519) 661-3805
jamieson@audio.hhcru.uwo.ca
Member 2,6,8

Jean-Marc Janin
Université de Sherbrooke
Dép. de génie mécanique
2500 boul. Université
Sherbrooke, QC
Canada J1K 2R1
(819) 821-8000ext3166
jmjanin@gme.usherb.ca
Student 1,2,10

Mr. R.B. Johnston
International Hearing Aids Ltd.
349 Davis Road
Oakville, ON
Canada L6J 5E8
(905) 845-8892
FAX: (905) 845-7380
Member 2,6,8

Dr. H.W. Jones
374 Viewmount Drive
Allen Heights
Tantallon, NS
Canada B0J 3J0
(902) 826-7922
FAX: (902) 826-7602
hw.jones@ns.sympatico.ca
Member 1,3,5

Doug Jones
Silex Inc.
7850 Tranmere Dr.
Mississauga, ON
Canada L5S 1L9
(800) 387-7818
FAX: (905) 612-8999
Sustaining Member 2,6

Jeffrey A. Jones
Queen's University
Dept. of Psychology
Kingston, ON
Canada K7L 3N6
(613) 545-2499
jones@psyc.queensu.ca
Student 5,7,8

J.P. Environment Prod. Inc.
P.O. Box 816, Station C
Kitchener, ON
Canada N2G 4C5
(519) 662-3220
FAX: (519) 662-3223
jpenviro@golden.net
Direct Subscriber 1,5,7

Jose A. Karivelil
Alcan
Box 1500
Jonquiere, QC
Canada G7S 4L2
(418) 699-2111ext6664
FAX: (418) 699-2993
jose_karivelil@alcan.com
Member 5,7

Leah Kaufan
Engineering Information Inc.
1 Castle Point Terrace
Hoboken, NJ
USA 07030-5996
(210) 216-8500(679)
Member

Allan Kaufman
4735 - 48 Street
Clyde, AB
Canada T0G 0P0
Courtesy Subscription

Stephen E. Keith
Radiation Protection Bureau, Health Canada
Acoustics Unit, Non-ionizing Radiation Section
Rm 228, 775 Brookfield Rd., 6301B
Ottawa, ON
Canada K1A 1C1
(613) 941-8942
FAX: (613) 941-1734
skeith@hpb.hwc.ca
Member 1,2,5,7,10

Mr. Thomas Kelly
185 Clearview Avenue
Apartment 1007
Ottawa, ON
Canada K1Z 6R9
(613) 563-5576
FAX: (613) 563-3357
kellyj@navcanada.ca
Member 5,6,10

Tim Kelsall
Hatch Associates Ltd.
2800 Speakman Dr.
Mississauga, ON
Canada L5K 2R7
(905) 855-7600
FAX: (905) 855-8270
tkelsall@hatch.ca
Sustaining Member 1,5

Mr. Leslie G. Kende
105 Clifton Road
Toronto, ON
Canada M4T 2G3
(416) 489-3193
FAX: (416) 440-6973
Member 1,5,7

Mr. Archie Kerr
Bayer Inc.
P.O. Box 3001
Sarnia, ON
Canada N7T 7M2
(519) 337-8251ext5484
FAX: (519) 339-7752
akerr@ibm.net
Member 1,5

Gerald Kiss
University of Alberta
Acoustics & Noise Unit, Dept. of Mech. Eng.
6720 - 30 Street, NW
Edmonton, AB
Canada T6P 1J6
(403) 466-6465
FAX: (403) 466-6465
Sustaining Member 1,2,6

Mr. John W. Kopec
Riverbank Acoustical Labs
IIT Research Institute
1512 S Batavia Avenue
Geneva, IL
USA 60134
(630) 232-0104
FAX: (630) 232-0138
k.kopec@iitri.com
Member 1,5

Mr. John J. Kowalewski
Ontario Hydro Technologies
800 Kipling Avenue, KB 214
Toronto, ON
Canada M8Z 5S4
(416) 207-6178
FAX: (416) 231-5862
kowalewj@ont.hydro.on.ca
Member 1,2,6

Dr. Steven Kraemer
T.U.V. Rheinland
344 Sheppard Ave. E., Suite 1
North York, ON
Canada M2N 3B4
(416) 733-3677
FAX: (416) 733-7781
kraemer@tuv.com
Member 1,2,5

Mr. C.A. Krajewski
95 Southill Drive
Don Mills, ON
Canada M3C 2H9
(416) 440-3590
FAX: (416) 440-6973
Member 1,5,7

Mr. Verne Kucy
The Corporation of Delta
4500 Clarence Taylor Cr.
Delta, BC
Canada V4K 3E2
(604) 946-3281
FAX: (604) 946-3240
Member 1,5,6

Laboratoire Central
Prefecture de Police
39 bis, rue de Dantzig
75015 Paris, France
Indirect Subscriber

Denis Lamonde
Mecart Inc.
Parc Ind. Metropolitain
110 rue de Rotterdam
Saint-Augustin-de-Desmaures, QC
Canada G3A 1T3
(418) 878-3584
FAX: (418) 878-4877
mecart@quebectel.com
Direct Subscriber 1,4,5

Michael E. Lantz
Queen's Universit
Kingston, ON
Canada K7L 3N6
(613) 634-2062
lantzm@pavlov.psyc.queensu.ca
Student 4,5

Dr. Chantal Laroche
Universite d'Ottawa
Audiologie/Orthophonie
545 King Edward
Ottawa, ON
Canada K1N 7N5
(613) 562-5800ext3066
FAX: (613) 562-5256
claroche@uottawa.ca
Member 5,6,8

Dr. Charles A. Laszlo
University of British Columbia
Inst. for Hearing Accessibility Research
2356 Main Mall
Vancouver, BC
Canada V6T 1Z4
(604) 822-3956
FAX: (604) 822-5949
laszlo@ee.ubc.ca
Member 5,7

André Leblond
Hydro Québec
Direction principale Recherche et Développement – IREQ
1800, boul. Lionel-Boulet
Varennes, QC
Canada J3X 1S1
(514) 652-8410
FAX: (514) 652-8309
leblond.andre@ireq.ca
Member 6

Estelle Leboucher
Université de Sherbrooke
Dép. de génie mécanique
2500 boul. Université
Sherbrooke, QC
Canada J1K 2R1
(819) 821-8000ext3106
FAX: (819) 821-7163
elebouch@gaus.gme.usherb.ca
Student 2,3,6

Dominique Leclerc
1220 boul Lebourg neuf, bureau 200
Québec, QC
Canada G2K 2G4
(418) 626-1688
FAX: (418) 626-5464
leclercd@soprin.com
Member 1,2,6

Dr. Hie K. Lee
14 Beaufort Drive
Kanata, ON
Canada K2L 1Z4
(613) 957-8460
FAX: (613) 954-5822
hie_lee@hc-sc.gc.ca
Member 5,6,7

Tony Leroux
Université d'Ottawa
Audiologie/Orthophonie
545 King Edward
Ottawa, ON
Canada K1N 6N5
(613) 564-7537
FAX: (613) 564-9919
Member 5,6,8

Jing-Fang Li
51, rue d'Alger
72000 Le Mans, France
+(33) 2-43282966
jingfang@cybercable.tm.fr
Member 2,9,10

Mr. A.D. Lightstone
Valcoustics Canada Ltd.
30 Wertheim Court, Unit 25
Richmond Hill, ON
Canada L4B 1B9
(905) 764-5223
FAX: (905) 764-6813
Member 1,5,7

Dr. Stanley P. Lipshitz
University of Waterloo
Dept. of Applied Mathematics
Waterloo, ON
Canada N2L 3G1
(519) 885-1211ext3755
FAX: (519) 746-4319
spl@audiolab.uwaterloo.ca
Member 2,3,6

Alexander P. Lorimer
7 Bent Oak Circle
Mississauga, ON
Canada L5N 4J2
(905) 542-2796
Member 1,5,7

Reginald W. Low
Sound Concepts Canada Inc.
599 Henry Avenue
Winnipeg, MB
Canada R3A 0V1
(204) 783-6297
FAX: (204) 783-7806
Member 1,2,7

Mr. David Lubman
14301 Middletown Lane
Westminster, CA
USA 92683
(714) 898 9099
FAX: (714) 373-3050
Compuserve: 711703306
Member 1,4,5

Anthony Mak
810 East 18th Avenue
Vancouver, BC
Canada V5V 1G8
Member 1,2,4

Mr. G.C. Maling (Jr.), Editor
Noise/News
Arlington Br., P.O. Box 2469
Poughkeepsie, NY
USA 12603
Courtesy Subscription

Pierre Marcotte
Université de Sherbrooke
Dép. de génie mécanique
2500 boul. Université
Sherbrooke, QC
Canada J1K 2R1
pierre.marcotte@gme.usherb.ca
Student 2,6

David Marion
Phillips & Temro Industries Ltd.
100 Paquin Road
Winnipeg, MB
Canada R2J 3V4
(204) 667-2260
FAX: (204) 667-2041
Direct Subscriber 5,7,10

Christian Martel
Octave Acoustique Inc.
277 boul. Jacques Cartier
Shannon, QC
Canada G0A 4N0
(418) 844-3338
FAX: (418) 844-3338
Direct Subscriber 1,2,4

Patrice Masson
12 D'Auteuil
St. Julie de Vercheres, QC
Canada J0L 2S0
(819) 821-8000ext3106
FAX: (819) 821-7163
patrice.masson@mge.usherb.ca
Member 2,3,6,10

Mr. Nigel Maybee
12 Woodmont Pl. SW
Calgary, AB
Canada T2W 4N3
(403) 238-5199
FAX: (403) 259-4190
nigel@hfpacoustical.com
Member 5

Dr. W.G. Mayer
Georgetown University
Physics Department, JASA
Washington, DC
USA 20057
Courtesy Subscription

Wendy McCracken
Headwaters Health Authority
P.O. Box 758
Okotoks, AB
Canada T0L 1T3
(403) 938-4911
FAX: (403) 938-2783
Member 1,3,5

Dr. Wm. P.S. McKay
903-430 5th Ave. N
Saskatoon, SK
Canada S7K 6Z2
(306) 664-3176(h); (306) 655-1183 (o)
FAX: (306) 655-1279
wmckay@the.link.ca
Member 6,7

Mr. Andrew C. McKee
Vibrason Instruments
430 Halford Road
Beaconsfield, QC
Canada H9W 3L6
(514) 426-1035
FAX: (514) 426-1035
103671.3331@compuserve.com
Member 2,6,10

Zita McRobbie
Simon Fraser University
Linguistics Dept.
Burnaby, BC
Canada V5A 1S6
(604) 291-5782
FAX: (604) 291-5659
zita_mcrobbie@sfu.ca
Member 7,8

Mr. T. Medwedyk
Group One Acoustics Inc.
1538 Sherway Dr.
Mississauga, ON
Canada L4X 1C4
(416) 896-0988
FAX: (416) 897-7794
goa@interlog.com
Direct Subscriber 1,4,7

Andy Metelka
Novel Dynamics Test Inc.
R.R. #2, 13652 Fourth Line, Halton Hills
Acton, ON
Canada L7J 2L8
(519) 853-4495
FAX: (519) 853-3366
metelka@aztec-net.com
Sustaining Member 2,6,10

Dr. J.G. Migneron
Acoustec Inc.
1381 rue Galilée, Suite 103
Québec, QC
Canada G1P 4G4
(418) 682-2331
FAX: (418) 682-1472
Sustaining Member 1,2,6

Mr. C.A. Mihalj
Marshall Macklin Monaghan
80 Commerce Valley Dr. E
Thornhill, ON
Canada L3T 7N4
(905) 882-1100ext275
FAX: (905) 882-0055
mihalja@mmm.ca
Member 1,2,6

Jeri Miller
McGill University, c/o Royal Victoria
Hospital Ob/Gyn,
Women's Pavilion, Rm F5131
687 Pine Ave. West
Montréal, QC
Canada H3A 1A1
(514) 842-1231x4590
Student

Ministère des Transports
Centre Documentation
35 Port-Royal est, 3e étage
Montréal, QC
Canada H3L 3T1
Indirect Subscriber

Dr. Thomas Moore
Queen's University
Dept. of Mechanical Engineering
Kingston, ON
Canada K7L 3N6
(613) 545 2582
FAX: (613) 545-6489
moore@me.queensu.ca
Member 5,7

Buck Moore
Mood-Swing Sound
53 Niagara St.
Toronto, ON
Canada M5V 1C3
(416) 504-1571
FAX: (416) 504-1571
Member 1,2,4,5

M. Michel Morin
MJM Conseillers en Acoustique Inc.
6555 Cote des Neiges, Suite 440
Montréal, QC
Canada H3S 2A6
(514) 737-9811
FAX: (514) 737-9816
mjm@videotron.ca
Sustaining Member 1,2,4

Mrs. Deirdre A. Morison
Health Canada, Medical Devices Bureau
Room 1605, Stats. Can. - Main Building
Tunney's Pasture, A.L. 0301H1
Ottawa, ON
Canada K1A 0L2
(613) 957-7910
FAX: (613) 957-7318
deirdre_morison@hc-sc.gc.ca
Member 3,5,10

National Library of Canada
Canadiana Acquisitions Division
and Legal Deposit Office
Ottawa, ON
Canada K1A 0N4
Courtesy Subscription

Nelson Industries Inc.
Corporate Research Dept.
P.O. Box 600
Stoughton, WI
USA 53589-0600
(608) 873-4370
Sustaining Member 2,5,7

Mr. Phat Nguyen
Produits Acoustiques PN Inc.
10858 St-Vital
Montreal-Nord, QC
Canada H1H 4T4
(514) 946-6299
FAX: (514) 328-0887
pnguyen@colba.net
Member 1,5,7

M. Jean Nicolas
G.A.U.S., Université de Sherbrooke
Dép. de génie mécanique
Sherbrooke, QC
Canada J1K 2R1
(819) 821-6905
FAX: (819) 821-7163
jean.nicolas@gme.usherb.ca
Member 5,10

Dr. T.R.T. Nightingale
National Research Council Canada
Institute for Research in Construction
Bldg. M-27
Ottawa, ON
Canada K1A 0R6
(613) 993-0102
FAX: (613) 954-1495
trevor.nightingale@nrc.ca
Member

Mr. Blake Noon
Eckel Industries of Canada Ltd.
P.O. Box 776
Morrisburg, ON
Canada K0C 1X0
(613) 543-2967
FAX: (613) 543-4173
eckel@eckel.ca
Sustaining Member 1,5

Scott Norcross
National Research Council Canada
Institute for Research in Construction
Bldg. M-27
Ottawa, ON
Canada K1A 0R6
(613) 993-9748
FAX: (613) 954-1495
Scott.norcross@nrc.ca
Member 1,2,4

Norhammer Ltd.
Box 443
Gravenhurst, ON
Canada P1P 1T8
(705) 689-2374
FAX: (705) 689-6968
Direct Subscriber 5

Northern Illinois University
Periodicals Department
University Libraries
Dekalb, IL
USA 60115
Indirect Subscriber

Colin Novak
1518 Bruce Ave.
Windsor, ON
Canada N8X 1X9
(519) 253-7193
novakl@uwindsor.ca
Student 1,2,6

Mr. John O'Keefe
Aercoustics Engineering Ltd.
Suite 127, 50 Ronson Drive
Rexdale, ON
Canada M9W 1B3
(416) 249-3361
FAX: (416) 249-3613
jokeefe@aercoustics.com
Member 1

Mr. Donald Olynyk
Consulting Acoustical Eng.
8403 - 87 Street, #201
Edmonton, AB
Canada T6C 3G8
(403) 465-4125
Member 1,2,5

Donald M. Onysko
1019 Buckskin Way
Gloucester, ON
Canada K1C 2Y8
(613) 824-2371
FAX: (613) 824-8070
onysko@istar.ca
Member 6

Dr. John C. Osler
Saclant Undersea Research Centre
APO AE 09613-5000, USA
+(39) 187 540 298
FAX: +(39) 187 540 331
osler@saclantc.nato.int
Member 9

M. Pierre M. Ouimet
Société Radio-Canada
Service national - Environnement et
sécurité, Ingénierie national
1400 boul. René-Lévesque est, Local A10-8
Montréal, QC
Canada H2L 2M2
(514) 597-3807
FAX: (514) 597-3838
pierre_ouimet@src.ca
Member 1

Russell Ovans
Jason Sound Industries Ltd.
1709 Welch St.
North Vancouver, BC
Canada V7P 3G9
(604) 986-2367
FAX: (604) 988-1036
ovans@cs.sfu.ca
Direct Subscriber 1,4,6

OZA Inspections Ltd.
P.O. Box 271
Grimsby, ON
Canada L3M 4G5
(416) 945-5471; (800) 667-8263
FAX: (416) 945-3942
oza@the-oza-group.com
Sustaining Member 7,10

Mr. Thomas Paige
Vibron Ltd.
1720 Meyerside Drive
Mississauga, ON
Canada L5T 1A3
(905) 677-4922
FAX: (905) 670-1698
vibron@myna.com
Member 1,2,5

George J. Pan
National Research Council Canada
Building M-36, Room 1022
Ottawa, ON
Canada K1A 0R6
(613) 991-2601
FAX: (613) 952-3670
george.pan@nrc.ca
Member 2,7,8,10

Raymond Panneton
Université de Sherbrooke
G.A.U.S.
Dép de génie mécanique
Sherbrooke, QC
Canada J1K 2R1
Member

Louise Paré
966 Neufchatel
Repentigny, QC
Canada J5Y 2A5
(514) 759-9900
FAX: (514) 759-5149
Member 5,6

Yann Pasco
Université de Sherbrooke
G.A.U.S.
2500 boul. de l'université
Sherbrooke, QC
Canada J1H 5S8
(819) 821-8000ext3106
yann.pasco@gaus.usherb.ca
Student 1,2,6

Mr. Richard Patching
Patching Associates Acoustical
Engineering
6815 - 8th St. NE, Suite 105
Calgary, AB
Canada T2E 7H7
(403) 274-5882
FAX: (403) 295-0732
patching@internode.net
Member 1,5,7

Mr. R. Pemberton
16 Pineglen Cres.
Nepean, ON
Canada K2E 6X9
(613) 727-8116
FAX: (613) 727-8318
pemberp@aigonquinc.on.ca
Member 1,5,7

Mr. Richard J. Peppin
Larson Davis, Inc.
5012 Macon Rd.
Rockville, MD
USA 20852
(301) 770-3863
FAX: (301) 770-3979
peppinR@asme.org
Member 1,5,7

Dr. P. Phillips
71 LeBreton Street North
Ottawa, ON
Canada K1R 7H3
(613) 567-8533
Student 4,6

Claire Piché
9663 Basile-Routhier
Montréal, QC
Canada H2C 2C1
(514) 388-1009
FAX: (514) 388-2179
mobili-son@sympatico.ca
Student 1,2,4

Dr. J.E. Piercy
National Research Council Canada
Inst. for Microstructural Sciences
Bldg. M-36
Ottawa, ON
Canada K1A 0R6
(613) 749-8929
FAX: (613) 952-3670
jepiercy@cyberus.ca
Member 3,5,6

Claude D. Pigeon
8396 av. du Mail
Anjou, QC
Canada H1K 1Z8
(514) 990-0459
claude.d.pigeon@sympatico.ca
Student 1,2

Linda Polka
McGill University
Sch of Communication Sciences and
Disorders
1266 Pine Ave. West
Montréal, QC
Canada H3G 1A8
(514) 398-7235
FAX: (514) 398-8123
cztg@musica.mcgill.ca
Member 7

Dr. S.E. Prasad
Sensor Technology Ltd.
P.O. Box 97, 20 Stewart Road
Collingwood, ON
Canada L9Y 3Z4
(705) 444-1440
FAX: (705) 444-6787
eprasad@sensortech.ca
Member 2,3,9

Moneca Price
708-251 Platts Lane
London, ON
Canada N6H 4P4
(519) 661-2111ext8199
price@audio_hhcru.uwo.ca
Student 5,7,8

Dalton Prince
H.L. Blachford Ltd.
2323 Royal Windsor Dr.
Mississauga, ON
Canada L5J 1K5
(905) 823-3200
FAX: (905) 823-9290
amsales@blachford.ca
Member 1,2,6

Daniel P. Prusinowski
745 Warren Drive
East Aurora, NY
USA 14052-1913
(716) 652-9979
FAX: (716) 652-7227
Member 1,2,5

Dr. J.D. Quirt
National Research Council Canada
Institute for Research in Construction
Bldg. M-20
Ottawa, ON
Canada K1A 0R6
(613) 993-9746
FAX: (613) 954-1495
dave.quirt@nrc.ca
Member 1,2,5

Dr. Ramani Ramakrishnan
41 Watson Avenue
Toronto, ON
Canada M6S 4C9
(416) 762-6093
FAX: (416) 604-4194
jal@sympatico.ca
Member 1,5,7

Alain Ratle
Université de Sherbrooke
Dép. de génie mécanique
Sherbrooke, QC
Canada J1K 2R1
(819) 821-8000ext3106
alain.ratle@gme.usherb.ca
Student 2,6,10

Dr. L.A. Read
Dean, Arts & Science
Wilfrid Laurier University
75 University Ave. W
Waterloo, ON
Canada N2L 3C5
(519) 884-1970ext2220
Member 1,4

Rebecca Reich
4708 Roslyn Avenue
Montreal, QC
Canada H3W 2L2
Student 4,5,8

Mr. Hans J. Rerup
H.J. Rerup Consulting Inc.
95 Frid St.
Hamilton, ON
Canada L8P 4M3
(416) 521-0999
FAX: (416) 525-8658
Direct Subscriber 1,5

Fernando Ribas
J.L. Richards & Associates Limited
864 Lady Ellen Place
Ottawa, ON
Canada K1Z 5M2
(613) 728-3571
FAX: (613) 728-6012
mail@jlrichards.ca
Sustaining Member 1,2,7

Max Richer
Université de Sherbrooke
Dép. de génie mécanique
2500, boul. de l'Université
Sherbrooke, QC
Canada J1K 2R1
(819) 821-7000ext3166
FAX: (819) 821-7163
max.richer@gme.usherb.ca
Student 2,4,6

Mr. Matias Ringheim
Kilde Akustikk A/S
P.O. Box 229
N 5701 Voss, Norway
+(47) 5652-0460
FAX: +(47) 5652-0479
matias.ringheim@kilde-akustikk.no
Member 1,5,6

Dr. R.J. Rogers
University of New Brunswick
Dept. of Mechanical Engineering
P.O. Box 4400
Fredericton, NB
Canada E3B 5A3
(506) 447-3106
FAX: (506) 453-5025
rjr@unb.ca
Member 5,7

Monica Rohlfs
9836 - 84th Ave.
Edmonton, AB
Canada T6E 2G2
(403) 433-3497
davmon@planet.eon.net
Member 5,8

Dr. M. Roland Mieszkowski
Digital Recordings
5959 Spring Garden Rd., Suite 1103
Halifax, NS
Canada B3H 1Y5
(902) 429-9622
FAX: (902) 429-9622
roland@tuns.ca
Member 2,6,8

Tom Rose
Rose Associates
117 Red Oak
Flower Mound, TX
USA 75028
(972) 539-7000
FAX: (972) 539-6139
Member 1,5,7

Andrea Rowe
226 Cameron Avenue
Windsor, ON
Canada N9B 1Y6
rowe4@server.uwindsor.ca
Student

Joey Ruch-Borris
North east 28-61-23 west of the 4th
(Tawatinaw), Westlock, AB
Canada T0G 2L0
Courtesy Subscription

Frank A. Russo
Queen's University
Acoustics Lab., Department of Psychology
Kingston, ON
Canada K7L 3N6
(613) 545-2490
FAX: (613) 545-2499
russof@pavlov.psyc.queensu.ca
Student 4,5,7,8

Mr. Wm. D. Ruth
HEARing MEasurements Co. Ltd.
27 Strathearn Ave., Unit 2
Bramalea, ON
Canada L6T 4V5
FAX: (905) 791-3055
bruth@netcom.ca
Member 5

Dr. Susan Rvachew
Alberta Children's Hospital
Speech-Language Section
1820 Richmond Rd. S.W.
Calgary, AB
Canada T2T 5C7
(403) 229-7054
FAX: (403) 228-5695
susan.rvachew@crha-health.ab.ca
Member

James G. Ryan
National Research Council Canada
Inst. for Microstructural Sciences
Building M-36
Ottawa, ON
Canada K1A 0R6
(613) 993-2300
FAX: (613) 952-3670
Member 4,7,11

Dr. M.P. Sacks
Tacet Engineering Ltd.
111 Ava Road
Toronto, ON
Canada M6C 1W2
(416) 782-0298
FAX: (416) 785-9880
Sustaining Member 1,5,7

Michael Sanderson
Chalmers University of Technology
Dept. of Applied Acoustics
S-41296 Gothenburg, Sweden
+46 31 72-2203
FAX: +46 31 72-2212
mike@ta.chalmers.se
Member 1,5,7

Santé travail / environnement
Centre Documentation – HMR
75 rue Port-Royal est, Bureau 240
Montréal, QC
Canada H3L 3T1
Indirect Subscriber

Claude Sauvageau
Centre de recherche industrielle du Québec
8475, ave. Christophe-Colomb
Montréal, QC
Canada H2M 2N9
(514) 383-1550
FAX: (514) 383-3234
csauvag@mtl.criq.qc.ca
Member 2,6,10

Jacques Savard
6398 boul. De Gaspe
Montréal, QC
Canada H2S 2X7
(514) 279-0258
jacques.savard@admtl.com
Member 2,6,11

Mr. Miron Savic
58 Hirshhorn Avenue
Elliot Lake, ON
Canada P5A 1N9
(705) 848-3263
Member 5,7,8

Scantek Inc.
916 Gist Ave.
Silver Spring, MD
USA 20910
(301) 495-7738
FAX: (301) 495-7739
scantek@erols.com
Sustaining Member 1,2,5

Jana Scarsellone
520 Carse Lane
Edmonton, AB
Canada T6R 2L7
(403) 435-7457
FAX: (403) 430-0374
janas@compuserve.com
Student 8

Nicolae Schiopu
1201 - 17 Lascelles Blvd.
Toronto, ON
Canada M4V 2B6
(416) 978-6170
FAX: (416) 978-4317
nicolae.schiopu@utoronto.ca
Student 2,5,7

Bruce Schneider
University of Toronto
Dept. of Psychology
Erindale Campus
Mississauga, ON
Canada L5L 1C6
(905) 828-3963
FAX: (905) 569-4326
schneid@psych.utoronto.ca
Member 5,7,8

Mr. Henri Scory
IRSST
505 Maisonneuve Ouest
Montréal, QC
Canada H3A 3C2
(514) 288-1551
FAX: (514) 288-9399
scory.henri@irsst.qc.ca
Member 3,5,7

Dr. Richard C. Seewald
University of Western Ontario
Elborn College
Communicative Disorders
London, ON
Canada N6G 1H1
(519) 661-3901
FAX: (519) 661-3805
Member 2,6,8

Hooshang Sepehri
Gilan University
Faculty of Science
P.O. Box 1914
Rasht, Iran
Member 2,3,6

Service Documentation
DCN/Ingenierie Centre Sud
Dept. Lutte Sous-Marine
Boite Postale 30
83800 Toulon Naval, France
Indirect Subscriber

Dr. Kimary N. Shahin
University of British Columbia
Dept. of Linguistics
Buchanan C369, 1866 Main Mall
Vancouver, BC
Canada V6T 1Z1
(604) 822-4256
FAX: (604) 822-9687
kimary@unixg.ubc.ca
Member 5,7,8

Dr. Edgar A.G. Shaw
Researcher Emeritus
National Research Council Canada
IMS, Room 1014, M-36
Ottawa, ON
Canada K1A 0R6
(613) 993-6157
FAX: (613) 952-3670
Member 2,5,6

Mr. Neil A. Shaw
Ozone Sound Eng. Ltd.
P.O. Box 619
Topanga, CA
USA 90290-0619
(310) 455-2221
FAX: (310) 455-0923
menlo@compuserve.com
Member 1,2,4

Cameron W. Sherry
Enviro Risque Inc.
78 Lucerne
Pointe Claire, QC
Canada H9R 2V2
(514) 426-8720
FAX: (514) 426-8719
cwsherry@aol
Member 1,5

Davor Sikic
Jade Acoustics Inc.
Suite 203, 545 North Rivermede Dr.
Concord, ON
Canada L4K 4H1
(905) 660-2444
FAX: (905) 660-4110
jade_acoustics@compuserve.com
Member 1,5,7

Adam Skiba
726 du Limosin
Sainte-Foy, QC
Canada G1X 2S7
(418) 658-6214
FAX: (418) 658-6214
askiba@globetrotter.qc.ca
Student

Ms. Elzbieta B. Slawinski
University of Calgary
Dept. of Psychology
2500 University Drive NW
Calgary, AB
Canada T2N 1N4
(403) 220-5205
FAX: (403) 282-8249
eslawins@acs.ucalgary.ca
Member 6,8

Nicholas A. Smith
48 Sudbury Hall Dr.
Scarborough, ON
Canada M1B 3H6
(416) 281-7979
FAX: (416) 287-7642
nicholas@psych.utoronto.ca
Student 4,5,7

Ranil Sonnadara
McMaster University
Dept. of Psychology
1280 Main St. W.
Hamilton, ON
Canada L8S 4K1
(905) 525-9140ext24797
FAX: (905) 529-6225
ranil@mcmaster.ca
Student 4,5

Steve Sorenson
Lear Corporation
Masland Division
39650 Orchard Hill Place
Novi, MI
USA 48375
(734) 207-0270
FAX: (734) 207-2212
srsorenson@compuserve.com
Member

Spaarg Engineering Limited
Noise and Vibration Analysis
822 Lounsborough St.
Windsor, ON
Canada N9G 1G3
(519) 972-0677
FAX: (519) 972-0677
gasparr@engn.uwindsor.ca
Sustaining Member 1,5,7

Spectris Technologies Inc.
90 Chemin Leacock Road
Pointe Claire, QC
Canada H9R 1H1
(514) 695-8225
FAX: (514) 695-4808
Sustaining Member 2,6,9

State of the Art Acoustik Inc.
43 - 1010 Polytek Street
Ottawa, ON
Canada K1J 9J3
(613) 745-2003
FAX: (613) 745-9687
Sustaining Member

Daniel St. Georges
1815 - 58th Avenue
Montréal, QC
Canada H1A 2P8
(514) 642-1622
FAX: (514) 642-1622
dstgeorg@mlink.net
Member 1,5,10

David R. Stapells
University of British Columbia
School of Audiology & Speech Sciences
5804 Fairview Ave.
Vancouver, BC
Canada V6T 1Z3
(604) 822-5795
FAX: (604) 822-6569
stapells@audiospeech.ubc.ca
Member 5,7,8

Robert D. Stevens
HGC Engineering
Plaza One, Suite 203
2000 Argentia Rd.
Mississauga, ON
Canada L5N 1P7
(905) 826-4044
FAX: (905) 826-4940
rstevens@hgcengineering.com
Member 1,4,5

Mr. John Stevenson
WCB of BC, Prev. Div.
8100 Granville St.
Richmond, BC
Canada V6Y 3T6
(614) 276-3100
FAX: (604) 276-3247
a1a38024@bc.sympatico.ca
Member 1,2,5

Dr. Michael R. Stinson
National Research Council Canada
Inst. for Microstructural Sciences
Building M-36
Ottawa, ON
Canada K1A 0R6
(613) 993-3729
FAX: (613) 952-3670
mike.stinson@nrc.ca
Member 3,5,6

Mr. Robert A. Strachan
Brown Strachan Assoc.
Two Yaletown Sq.
1290 Homer St.
Vancouver, BC
Canada V6B 2Y5
(604) 689-0514
FAX: (604) 689-2703
Member 1,5,7

Mr. D.C. Stredulinsky
32 John Cross Dr.
Dartmouth, NS
Canada B2W 1X3
(902) 426-3100
FAX: (902) 426-9654
stredulinsky@drea.dnd.ca
Member 1,5,7

Megha Sundara
McGill University
School of Communication Sciences &
Disorders
1266 Pine Avenue West
Montreal, QC
Canada H3G 1A8
(514) 398-8496
FAX: (514) 398-8123
msunda@po-boxmcgill.ca
Student 5,7,8

John C. Swallow
John Swallow Associates
250 Galaxy Boulevard
Etobicoke, ON
Canada M9W 5R8
(416) 798-0522
FAX: (416) 213-1079
Sustaining Member

Mr. Winston V. Sydenborgh
2355 Headon Road, Unit 13
Burlington, ON
Canada L7M 4H3
(905) 332-1034
FAX: (905) 823-9290
amsales@blachford.ca
Member 1,5,7

Dr. John M. Terhune
University of New Brunswick
Dept. of Biology
P.O. Box 5050
Saint John, NB
Canada E2L 4L5
(506) 648-5633
FAX: (506) 648-5650
terhune@unbsj.ca
Member 6,8,9

Mr. Peter Terroux
Atlantic Acoustical Associates
P.O. Box 96, Stn M
Halifax, NS
Canada B3J 2L4
(902) 425-3096
FAX: (902) 425-0044
peteraaa@istar.ca
Member 1,2,5

George H. Thackray
Greater Toronto Airports Authority
Lester B Pearson Int Airport
P.O. Box 6031
Toronto AMF, ON
Canada L5P 1B2
(905) 676-5417
FAX: (905) 676-3483
Member 1,5

Brandon Tinianow
Johns Manville T.C.
10100 West Ute Ave.
Littleton, CO
USA 80127
(303) 978-6737
FAX: (303) 978-3123
tinianow@jm.com
Member 1,2,4

Michel Tournour
Université de Sherbrooke
Dép. de génie mécanique
2500, boul. de l'Université
Sherbrooke, QC
Canada J1K 2R1
(819) 821-7000ext3152
FAX: (819) 821-7163
michel.tournour@gme.usherb.ca
Student 2,3,6

Dr. Laurel Trainor
McMaster University
Dept. of Psychology
1280 Main St. W.
Hamilton, ON
Canada L8S 4K1
(905) 525-9140ext23007
FAX: (905) 529-6225
ljt@mcmaster.ca
Member 4,5,8

B.A. Trenholm
P.O. Box 494
Dartmouth, NS
Canada B2Y 3Y8
(902) 461-3100ext249
Member 2,8,9

Mr. Robert Trepanier
Bruel & Kjaer, a division of
Spectris Technologies Inc.
90 Leacock Road
Pointe Claire, QC
Canada H9R 1H1
(514) 695-8225
FAX: (514) 695-4808
robert.trepanier@spectristech.com
Member 2,5,7

Prof. B. Truax
Simon Fraser University
School of Communication
Burnaby, BC
Canada V5A 1S6
(604) 291-4261
FAX: (604) 291-4024
truax@sfu.ca
Member 2,4,5

J. Ulicki
Bruel & Kjaer
140 - 6815 8th Street NE
Calgary, AB
Canada T2E 7H7
(403) 274-7577
FAX: (403) 274-7694
jim.ulicki@specristech.com
Member 1,5,7

Universitaetsbibliothek
& Techn. Informations-Bibliothek/TIB
Welfengarten 1 B
30167 Hannover, Germany
Indirect Subscriber

Universitaetsbibliothek Muenster
Postfach 8029
48043 Muenster, Germany
Indirect Subscriber

Université de Montréal
Bibliothèque Acquisitions Periodiques
C.P. 6128, Succ. A.
Montréal, QC
Canada H3C 3J7
Indirect Subscriber

Université de Tunis III Inst.
Sup. de Gestion – Bibliotheque
45, rue de la liberté
2000 Le Bardo-Cite Bouchoucha, Tunisie
Indirect Subscriber

University of New Brunswick
Harriet Irving Library
P.O. Box 7500
Fredericton, NB
Canada E3B 5H5
Indirect Subscriber

University of Prince Edward Island
Robertson Library
550 University Ave.
Charlottetown, PE
Canada C1A 4P3
Direct Subscriber

University of Toronto Library
Serials Department
Toronto, ON
Canada M5S 1A5
(416) 978-3076
Direct Subscriber

University of Windsor
Leddy Library, Serials Section
Windsor, ON
Canada N9B 3P4
Indirect Subscriber

Valcoustics Canada Ltd.
30 Wertheim Court, Unit 25
Richmond Hill, ON
Canada L4B 1B9
(905) 764-5223
FAX: (905) 764-6813
Sustaining Member 1,5,7

Vancouver Health Board
Library
1060 West 8th Ave.
Vancouver, BC
Canada V6H 1C4
Indirect Subscriber

Mr. Frank Van Oirschot
Industrial Metal Fabricators (Chatham) Ltd.
Industrial Noise Control
P.O. Box 834, 288 Inshes Ave.
Chatham, ON
Canada N7M 5L1
(519) 354-4270
FAX: (519) 354-4193
Sustaining Member 5,7,10

Mr. W. Varvara
361 Union Avenue
Westbury, NY
USA 11590
Indirect Subscriber

Jeremie Voix
Université de Sherbrooke
Dép. de génie mécanique
2500, boul. de l'Université
Sherbrooke, QC
Canada J1K 2R1
(819) 821-8000ext3179
FAX: (819) 821-7163
jeremie.voix@gme.usherb.ca
Student 2,4,6

Clair Wakefield
Wakefield Acoustics Ltd.
1818 Belmont Avenue
Victoria, BC
Canada V8R 3Z2
(250) 270-9302
FAX: (250) 370-9309
noise@islandnet.com
Member 1,2,6

A.D. Wallis
Cirrus Research PLC
Acoustic House
Bridlington Rd., Hunmanby
N Yorks Y014 0PH, England
(723) 863723
FAX: (723) 891742
Member 5

Dr. A.C.C. Warnock
National Research Council Canada
Institute for Research in Construction
Acoustics Laboratory, Bldg. M-27
Ottawa, ON
Canada K1A 0R6
(613) 993-9370
FAX: (613) 954-1495
alf.warnock@nrc.ca
Member 1,5,7

Mr. D.E. Watson
H.L. Blachford Ltd.
2323 Royal Windsor Dr.
Mississauga, ON
Canada L5J 1K5
(905) 823-3200
FAX: (905) 823-9290
dewatson@hlb.blachford.ca
Sustaining Member 5

1ABU5946
Wayne State University
Science & Engineering Library
5048 Gullen Mall
Detroit, MI
USA 48202-3918
Indirect Subscriber

Mr. Frank Westaway
Chief Noise Control Officer
Dept. of Public Works
71 Main St. W, 4th Fl.
Hamilton, ON
Canada L8N 3T4
(416) 523-5670
FAX: (416) 513-0899
Member 5,8

Mr. Ewart A. Wetherill
28 Cove Road
Alameda, CA
USA 94502
(415) 391-7610
FAX: (415) 391-0171
paoletti@compuserve.com
Member 1,2,5

Douglas J. Whicker
BKL Consultants Ltd.
145 W 17th St., Suite 250
North Vancouver, BC
Canada V7M 3G4
(604) 988-2508
FAX: (604) 988-7457
whicker@bkla.com
Member 1,2,5

Mr. Ronald G. White
7 Amberglen Court
Holland Landing, ON
Canada L9N 1J6
(416) 675-3983
FAX: (416) 675-5546
Member 1,4,5

Michelle Wiley
1108 - 80 Avenue
Edmonton, AB
Canada T6G 0R5
(403) 439-9473
FAX: (403) 491-6031
mwiley@grhosp.ab.ca
Student 5,7,8

Terence Williams
The Wade Williams Corp.
914 Gordon St.
Victoria, BC
Canada V8W 1Z8
(604) 384-0504
FAX: (604) 384-6811
Member
Hugh Williamson
Hugh Williamson Assoc. Inc.
12 Maple Lane
Ottawa, ON
Canada K1M 1G7
(613) 747-0983
FAX: (613) 747-4514
hugh_williamson@msn.com
Member 1,6

Wilrep Ltd.
1515 Matheson Blvd. E, Unit C 10
Mississauga, ON
Canada L4W 2P5
(905) 625-8944
FAX: (905) 625-7142
Sustaining Member

Mr. Keith Wilson
Owens-Corning Canada Inc.
2255 Lakeshore Road E, R.R. #1
Hawkestone, ON
Canada L0L 1T0
(416) 730-7939
FAX: (416) 733-8613
Member 1,3,5

James W. Wiskin
University of Utah
Dept. Bio-engineering, MEB 2480
50 S Central Campus Dr.
Salt Lake City, UT
USA 84112
(801) 585-3407
FAX: (801) 585-5361
wiskin@ee.utah.edu
Member 3,9,10

Mr. Chris N. Wolfe
Vibra-Sonic Control
& Materials Handling Ltd.
4004 Gravely Street
Burnaby, BC
Canada V5C 3T6
(604) 294-9495
FAX: (604) 294-8033
cwolfe@vibra-sonic.bc.ca
Member 1,5,7

Dr. G.S.K. Wong
National Research Council Canada
Inst. for Nat. Meas. Stds.
Building M-36
Ottawa, ON
Canada K1A 0R6
(613) 993-6159
FAX: (613) 990-8765
george.wong@nrc.ca
Member 2,3,5

Richard G. Wright
HFP Acoustical Consultants Ltd.
10201 Southport Road, S.W., #1140
Calgary, AB
Canada T2W 4X9
(403) 259-3600
FAX: (403) 259-4190
richardw@hfpacoustical.com
Member 2,11

Weixiong Wu
Université Laval
C.R.A.D.
Pavillon Félix-Antoine-Savard, bureau 1636
Ste-Foy, QC
Canada G1K 7P4
Student 1,2,11

Karen Yu
11 Virginia Cres.
London, ON
Canada N5X 3E4
Student 7

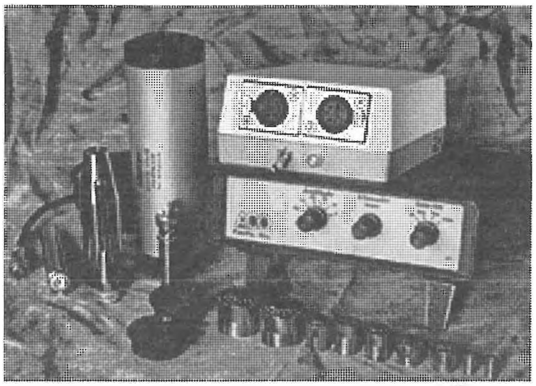
Pearlie Yung
#1108 - 1850 Rathburn Road East
Mississauga, ON
Canada L4W 2X9
(905) 602-6848
Member 1,2,5

PRECISION MICROPHONES and MICROPHONE SYSTEMS

ACO Pacific, Inc.

2604 Read Ave.
Belmont, CA 94002 U.S.A.
Tel:650-595-8588 FAX:650-591-2891
e-mail: acopac@acopacific.com

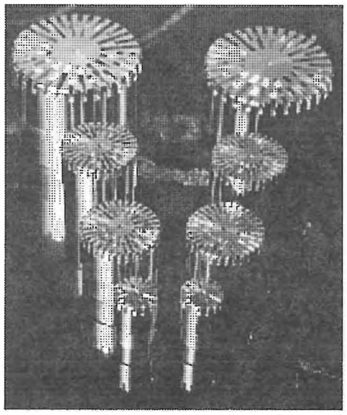
Established in 1978 ACO Pacific, Inc. is chartered to serve the needs of both End-users and Equipment Manufacturers. Headquartered in the San Francisco Bay Area, ACO Pacific, Inc. has manufacturing facilities and suppliers both in California and internationally.



Our OEM relationships include Hewlett Packard, Audio Precision, SPS, DRA Labs and many other large and small instrumentation and process control manufacturers. Our End-user customers include: manufacturers of loudspeakers; computers and peripherals; heavy equipment; automobiles and automotive parts - tires, brakes, engines; universities; aerospace; and an alphabet soup of government agencies US and foreign.

ACO Pacific's Product Family

Measurement Microphones
Microphone Preamplifiers
Microphone Power Supplies
SPL Calibrators
Simple Intensity™ Sound Intensity Systems
Very Random™ Noise Generators



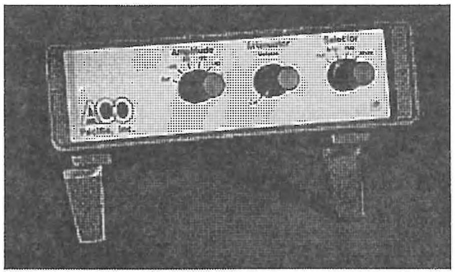
The "Alternative"

Type 1 Measurement Microphones
1, 1/2 and 1/4 Inch Models
Stainless Steel
and
Titanium Diaphragms
Quartz Insulators
Frequency Responses to 120 kHz
Noise Floors below 10 dBA
Meets or Exceeds IEC and ANSI Standards

Model 3024

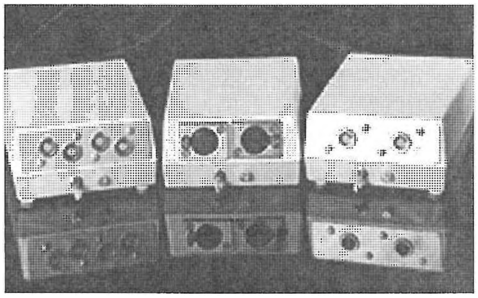
Very Random™Noise Generator

Pink and White Noise, 1kHz Sine Outputs
1.6 Hz to 39 kHz (-3dB)
Portable - Battery and AC Power



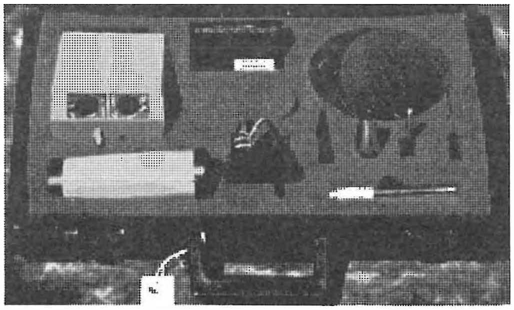
ACOustical Interface™

Precision Microphone Power Supplies
2 and 4 Channels - Gain Available
XLR and Lemo™ Connectors



PS9200KIT

Includes: PS9200 (XLR) Power Supply
AC Adaptor
4012 Preamplifier w/CA4012-5 Cable
Selection of 1/2 Inch Type 1 Microphone
WS1 - 3 inch Windscreen
SC1 Die Cut Storage Case (SC2 optional)
Options: 511E SPL Calibrator (shown)
"G" Gain Stage



ACOustics Begins With ACO™

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.

Photographs: Submit original glossy, black and white photograph.

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.

Photographies: Soumettre la photographie originale sur papier glacé, noir et blanc.

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

SUBSCRIPTION INVOICE

FACTURE D'ABONNEMENT

Subscription for the current calendar year is due January 31. New subscriptions received before July 1 will be applied to the current year and include that year's back issues of *Canadian Acoustics*, if available. Subscriptions received from July 1 will be applied to the next year.

L'abonnement pour la présente année est dû le 31 janvier. Les nouveaux abonnements reçus avant le 1 juillet s'appliquent à l'année courante et incluent les anciens numéros (non-épuisés) de *l'Acoustique Canadienne* de cette année. Les abonnements reçus après le 1 juillet s'appliquent à l'année suivante.

Check ONE Item Only: / Cocher la case appropriée :

CAA Membership	___	$ 50	___	Membre individuel
CAA Student membership	___	$ 10	___	Membre étudiant(e)
Institutional Subscription	___	$ 50	___	Membre institutionnel
Sustaining Subscription	___	$ 150	___	Abonnement de soutien
Total Remitted		$_______		Versement total

INFORMATION FOR MEMBERSHIP DIRECTORY

RENSEIGNEMENT POUR L'ANNUAIRE DES MEMBRES

Check areas of interest (max 3): / Cocher vos champs d'intérêt (max. 3):

Architectural Acoustics	1.	_____	1.	Acoustique architecturale
Engineering Acoustics / Noise Control	2.	_____	2.	Génie acoustique / Contrôle du bruit
Physical Acoustics / Ultrasound	3.	_____	3.	Acoustique physique / Ultrasons
Musical Acoustics / Electroacoustics	4.	_____	4.	Acoustique musicale / Electroacoustique
Psychological / Physiological Acoustics	5.	_____	5.	Physio/psycho-acoustique
Shock and Vibration	6.	_____	6.	Chocs et vibrations
Hearing Sciences	7.	_____	7.	Audition
Speech Sciences	8.	_____	8.	Parole
Underwater Acoustics	9.	_____	9.	Acoustique sous-marine
Signal Processing / Numerical Methods	10.	_____	10.	Traitement des signaux / Méthodes numériques
Other	11.	_____	11.	Autre

Business telephone number (_____) ______________ Numéro de téléphone au bureau
Business facsimile number (_____) ______________ Numéro de télécopieur au bureau
Business E-Mail number ________________________________ Numéro de courier électronique au bureau

PLEASE TYPE NAME AND ADDRESS BELOW:

VEUILLEZ ECRIRE VOTRE NOM ET VOTRE ADRESSE CI-DESSOUS:

Faites parvenir ce formulaire à l'adresse suivante en prenant soin d'y joindre un chèque fait au nom de L'ASSOCIATION CANADIENNE D'ACOUSTIQUE:

Make cheques payable to THE CANADIAN ACOUSTICAL ASSOCIATION. Mail this form with payment to:

Trevor Nightingale
Secretary, Canadian Acoustical Association
P. O. Box 74068
Ottawa, Ontario K1M 2H9

The Canadian Acoustical Association
l'Association Canadienne d'Acoustique

SUSTAINING SUBSCRIBERS / ABONNES DE SOUTIEN

The Canadian Acoustical Association gratefully acknowledges the financial assistance of the Sustaining Subscribers listed below. Annual donations (of $150.00 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 $150.00 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.

ACO Pacific
2604 Read Ave.
Belmont, CA, USA 94002
(650) 595-8588 FAX: (650) 591-2891

Acoustec Inc.
Attn: Dr. J.G. Migneron
1381 rue Galilée, Suite 103
Québec, Québec G1P 4G4
(418) 682-2331 FAX: (418) 682-1472

Aercoustics Engineering Limited
Barman & Associates
50 Ronson Drive, Suite 127
Rexdale, Ontario M9W 1B3
(416) 249-3361 FAX: (416) 249-3613

Atlantic Acoustical Associates
P.O. Box 96, Station M
Halifax, Nova Scotia B3J 2L4
(902) 425-3096

H. L. Blachford Ltd.
Annt: Mr. D.E. Watson
2323 Royal Windsor Dr.
Mississauga, Ontario L5J 1K5
(905) 823-3200 FAX: (905) 823-9290

Bruel & Kjaer Canada Ltd.
90 Leacock Road
Pointe Claire, Québec H9R 1H1
(514) 695-8225 FAX: (514) 695-4808

J. E. Coulter Associates Ltd.
Suite 507
1200 Sheppard Ave. E
Willowdale, Ontario M2K 2S5
(416) 502-8598 FAX: (416) 502-3473

Dalimar Instruments Inc.
193, Joseph Carrier
Vaudreuil-Dorion, Québec J7V 5V5
(514) 424-0033 FAX: (514) 424-0030

Eckel Industries of Canada Ltd.
Attn: Mr. Blake Noon
P.O. Box 776
Morrisburg, Ontario K0C 1X0
(613) 543-2967 FAX: (613) 543-4173

Environmental Acoustics Inc.
Attn: Mr. H.J. Doedens
#13 - 5155 Spectrum Way
Mississauga, Ontario L4W 5A1
(905) 238-1077 FAX: (905) 238-9079

Hatch Associates Ltd.
Attn: Tim Kelsall
2800 Speakman Dr.
Mississauga, Ontario L5K 2R7
(905) 855-7600 FAX: (905) 855-8270

HGC Engineering
Plaza One, Suite 203
2000 Argentia Road
Mississauga, Ontario L5N 1P7
(905) 826-4044 FAX: (905) 826-4940

Hydro-Quebec
Vice-presidence Environnement
75 Rene Levesque ouest, 16e etage
Montreal, Québec H2Z 1A4

Industrial metal Fabricators (Chatham) Ltd.
Industrial Noise Control
Attn: Mr. Frank Van Oirschot
P.O. Box 834, 288 Inshes Ave.
Chatham, Ontario N7M 5L1
(519) 354-4270 FAX: (519) 354-4193

Integral DX Engineering Ltd.
907 Admiral Ave.
Ottawa, Ontario K1Z 6L6
(613) 761-1565 FAX: (613) 729-4337

Jade Acoustics Inc.
545 North Rivermede Road, Suite 203
Concord, Ontario L4K 4H1
(905) 660-2444 FAX: (905) 660-4110

John Swallow Associates
Attn: John C. Swallow
250 Galaxy Boulevard
Etobicoke, Ontario M9W 5R8
(416) 798-0522

Larson Davis Laboratories
1681 West 820 North
Provo, Utah, USA 84601
(801) 375-0177

MJM Conseillers en Acoustique Inc.
Attn: M. Michel Morin
6555 Cote des Neiges, Suite 400
Montréal, Québec H3S 2A6
(514) 737-9811 FAX: (514) 737-9816

Nelson Industries Inc.
Corporate Research Dept.
P.O. Box 600
Stoughton, WI, USA 53589-0600
(608) 873-4370

OZA Inspections Ltd.
P.O. Box 271
Grimsby, Ontario L3M 4G5
(416) 945-5471 FAX: (416) 945-3942

Peutz & Associes
Attn: Marc Asselineau
103 boul. Magenta
F-75010 Paris, France
+33 1 42858485 FAX: +33 1 42821057

J. L. Richards & Assoc. Ltd.
Attn: Fernando Ribas
864 Lady Ellen Place
Ottawa, Ontario K1Z 5M2
(613) 728-3571 FAX: (613) 728-6012

Scantek Inc.
916 Gist Ave.
Silver Spring, MD, USA 20910
(301) 495-7738 FAX: (301) 495-7739

SNC/Lavalin Environment Inc.
2 Felix Martin Place
Montréal, Québec H2Z 1Z3
(514) 393-1000

Spaarg Engineering Limited
Noise and Vibration Analysis
822 Lounsborough St.
Windsor, Ontario N9G 1G3
(519) 972-0677 FAX: (519) 972-0677

State of the Art Acoustik Inc.
Attn. Dr. C. Fortier
Unit 43, 1010 Polytek St.
Ottawa, Ontario, K1J 9J3

Tacet Engineering Ltd.
Attn: Dr. M.P. Sacks
111 Ava Road
Toronto, Ontario M6C 1W2
(416) 782-0298 FAX: (416) 785-9880

University of Alberta
MEANU, Dept. of Mech. Eng.
6720 - 30 St.
Edmonton, Alberta T6P 1J6
(403) 466-6465 FAX: (403) 466-6465

Valcoustics Canada Ltd.
30 Wertheim Court, Unit 25
Richmond Hill, Ontario L4B 1B9
(905) 764-5223 FAX: (905) 764-6813

Wilrep Ltd.
1515 Matheson Blvd. E, Unit C 10
Mississauga, Ontario L4W 2P5
(905) 625-8944 FAX: (905) 625-7142