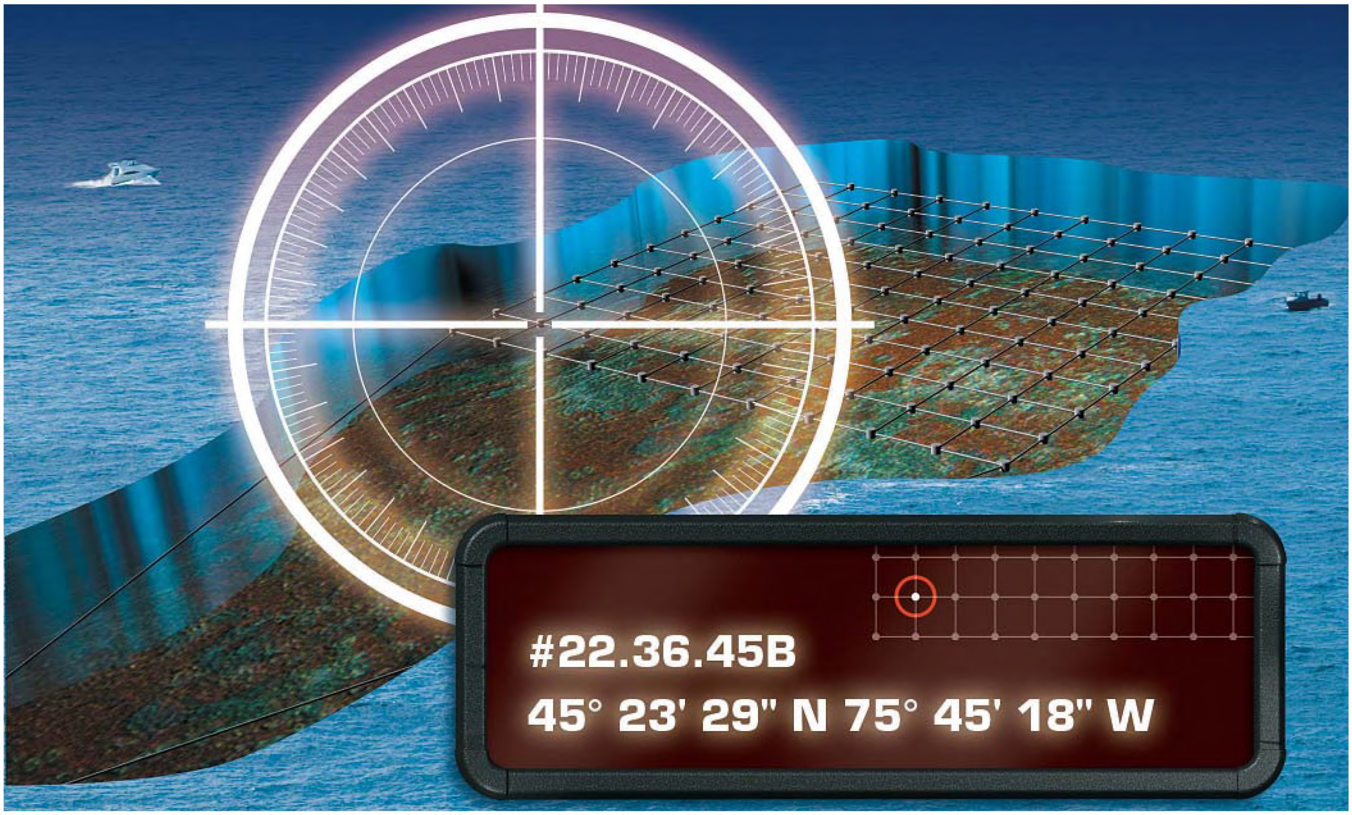
ISSN 0711-6659

canadian acoustics
acoustique canadienne

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

DECEMBER 2006
Volume 34 -- Number 4

DECEMBRE 2006
Volume 34 -- Numéro 4



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PRESIDENT'S MESSAGE / MESSAGE DU PRÉSIDENT

The highlight of the year for the Canadian Acoustical Association is our annual general conference "Acoustics Week in Canada." These meetings represent a great opportunity to hear/present the latest on acoustics work in Canada, meet friends and colleagues, and, over the years, visit many interesting Canadian cities.

In October, 2006, we enjoyed a very successful conference in Halifax, Nova Scotia, thanks to Nicole Collison, Francine Desharnais and their organizing committee, with over 100 attendees and 75 papers covering all aspects of acoustics. A number of special notes included: two fascinating plenary speakers, Denis Jones and Michael Kiefte, who spoke with contagious passion and humour on acoustic analysis of Nova Scotian residents (hermit thrush songs and local Maritimes dialects, respectively); excellent discussion and networking opportunities during 40-minute coffee breaks in the exhibit area with refreshments provided by generous sponsors; and a social night featuring unique "gypsy-swing" music. Particularly encouraging was the large student participation in the conference, with 24 student papers of consistently high quality (Alberto Behar oversaw the Student Paper Award judging—which turned out to be a considerable task).

In 2007 we look forward to meeting in the wonderful city of Montreal, Quebec. The conference theme will be Aeroacoustics, fitting to the reputation of Montreal as the "Areospace Capital of the World" (although all aspects of acoustics are encouraged, of course). I'm sure this will be a memorable conference—look for details in this and subsequent issues of Canadian Acoustics. Many thanks to Rama Bhat, Kamaran Siddiqui and their committee for taking this meeting on.

I'd also like to take this opportunity to thank the members of the CAA Board of Directors for their time and efforts, particularly Mark Cheng and Corjan Buma who completed their terms this year, and to welcome new Board members Tim Kelsall and Clair Wakefield. Finally, a great deal of the day-to-day operations of the CAA is capably overseen by our Editor, Ramani Ramakrishnan, Treasurer, Dalia Giusti, and Secretary, David Quirt, whose contributions are greatly appreciated.

Stan Dosso

Le point culminant de l'année pour l'association canadienne d'acoustique est notre congrès annuel « La semaine de l'acoustique canadienne ». Ces réunions sont d'excellentes opportunités d'entendre et de présenter les plus récentes études acoustiques au Canada, de retrouver amis et collègues, et, au cours des dix dernières années, de visiter plusieurs villes canadiennes fort intéressantes.

Le congrès à Halifax, Nouvelle-Écosse, en octobre 2006 a été un grand succès avec plus de 100 participants et 75 études présentés, couvrant tous les aspects de l'acoustique. Nous devons nos remerciements à Nicole Collison, Francine Desharnais, et à leur comité d'organisation. Quelques évènements à souligner étaient: les présentations de deux orateurs fascinants, Denis Jones et Michael Kiefte, qui ont parlé avec passion et humour contagieux de l'analyse acoustique des habitants de la Nouvelle-Écosse (respectivement de chansons grive d'ermite et de dialectes maritimes locaux); les excellentes discussions et les opportunités d'élargir son réseau de connaissances lors des pause cafés de 40 minutes dans la salle d'exposition, avec des rafraîchissements fournis par de commanditaires généreux; et une soirée sociale avec de la musique « swing-gypse ». La grande participation étudiante a été particulièrement encourageante, avec 24 exposés étudiants, constamment d'haute qualité (Alberto Behar a eu la tâche difficile de juger les exposés étudiants).

En 2007, nous attendons impatiemment le congrès dans la merveilleuse ville de Montréal, Québec. Le thème de la conférence sera l'aéroacoustique, un sujet approprié, puisque Montréal a la réputation de « Capitale Mondiale Aérospatiale » (les études acoustiques de tout aspect sont évidemment encouragées). Je suis certain que ce congrès sera mémorable – des détails sont fournis dans ce numéro de L'Acoustique Canadienne, ainsi que dans les numéros à venir. Merci à Rama Bhat, Kamaran Siddiqui, et à leur comité, pour avoir accepté la tâche d'organisation de cet évènement.

J'aimerais aussi prendre cette occasion pour remercier les membres du conseil d'administration de l'ACA, particulièrement Mark Cheng et Corjan Buma, qui ont complété leurs termes cette année, ainsi que les nouveaux membres du conseil Tim Kelsall et Clair Wakefield. Finalement, une grande partie des opérations quotidiennes de l'ACA est rendue possible par notre éditeur, Ramani Ramakrishnan, trésorier Dalia Giusti, et secrétaire David Quirt. Leurs contributions sont grandement appréciées.

Stan Dosso

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Research article / Article de recherche

ARRAY ELEMENT LOCALIZATION ACCURACY AND SURVEY DESIGN

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ABSTRACT

Accurate localization of the individual elements of an underwater acoustic receiver array is an important prerequisite to advanced array processing applications. Array element localization (AEL) methods are typically based on inverting acoustic arrival-time measurements from controlled sources at (approximately) known positions to the receivers to be localized. This paper presents and illustrates a general approach to AEL inversion and to AEL survey design based on quantifying the posterior receiver-location uncertainty, taking into account uncertainties in the data, source locations, sound speed, and water depth. The inversion is based on a fast ray-tracing algorithm that employs Newton's method and the method of images to determine eigenrays for direct and reflected arrivals. The efficiency of this approach allows computationally intensive analysis such as Monte-Carlo appraisal and nonlinear optimization for designing optimal source configurations. These algorithms provide a rigorous approach that can be applied to examine all aspects of AEL accuracy and survey design, illustrated here by several examples. It is shown that synchronized AEL surveys (in which source transmission times are known) provide only a minor improvement over non-synchronized surveys (often much simpler logistically), and the difference can be made up by using more sources in an optimal configuration or by including additional arrivals. Including multiple-reflected arrivals improves receiver depth estimates (provided water depth is well known), but provides little improvement in horizontal localization.

SOMMAIRE

La localisation précise d'éléments individuels d'un étalage de récepteurs acoustiques sous-marin est un facteur important qui peut fortement influencer la validité de la manipulation de données. Les methodes de Localisation des Eléments d'Etalage (AEL) sont typiquement basées sur l'inversion de temps d'arivée acoustiques mesurés, parvenant de sources contr ôlées à des positions connues (approximativement), relatives aux positions des récepteurs localiser. Cet article présente et illustre une approche gnérale à l'inversion de AEL et à la planifications d'études de AEL, basée sur la quantification de l'incertitude postérieure de la position des récepteurs, compte-tenue de l'incertitude des données, de la position des sources, de la vitesse sonore, et de la profondeur d'eau. L'inversion est basée sur un algorithme rapide de traage de rayon qui utilise la méthode Newton et la méthode d'images pour déterminer les rayons-eigen pour les arives directes et reflétées. L'efficacité de cette approche permet l'utilisation de méthodes calcul informatique intense, comme l'évaluation Monte-Carlo et l'optimisation non-linéaire, pour la planification de configuration de sources optimale. Ces algorithmes fournissent une approche qui peut étre applique pour examiner tout les aspects de la précision et de la planification d'études de AEL, illustré ici par plusieurs exemples. Il est démontr ici que les études de AEL harmonisés (pour qui les temps de transmission de source sont connues) fournissent seulement une amélioration mineure comparativement aux études non-harmonizés (qui ont souvent une logistique plus simple), et que la différence peut étre rcupre en utilisant plus de sources dans une configuration optimale ou en incluant des arivées additionnelles. En incluant les arivées à réflextion multiple, l'estimation de profondeur des récepteurs est améliore (à condition que la profondeur d'eau est bien connue), mais n'améliore que peu la localisation horizontale.

1. INTRODUCTION

Array processing methods in underwater acoustics require accurate knowledge of the locations of individual elements in a receiver array [1,2]. However, sufficiently accurate receiver locations are often not know after array deployment at sea, and array element localization (AEL) surveys are typically required. AEL is based on inverting acoustic arrival-time measurements from a series of controlled sources to the receivers to be localized. AEL methods usually use direct acoustic-path arrivals, but can also include surface- and/or bottom-reflected arrivals to provide more information, provided these arrivals can be identified. Synchronized AEL surveys (in which the source transmission instants are known and the data represent absolute travel times) are often more complicated logistically than non-synchronized surveys (which provide relative travel times), but produce more informative data. A third possibility is that of synchronized surveys which make use of cross-correlation or waveform envelope techniques to pick arrival times, and hence provide data consisting of absolute travel times but with an unknown offset that is common for all data.

Ideally, AEL inversion should address all (significant) sources of error in the acoustic survey, and incorporate physical prior information about the solution in addition to the measured data. Although the source positions are often treated as known parameters in AEL inversion, in reality, errors in these positions are often significant and represent the limiting factor [3]. This limitation can be addressed using the method of regularization to formulate an inversion that properly treats both source and receiver positions as unknown parameters with prior estimates and associated uncertainties [3–10]. An unknown bias to the measured sound-speed profile (commonly due to inexact calibration [11]) can also be included in the inversion. For arrays that are expected to be essentially straight, a regularization can be formulated for the smoothest array shape (i.e., the shape with minimum curvature or changes in direction) subject to fitting the acoustic data to a statistically appropriate level. Regularized inversion has been applied to diverse AEL problems involving fixed horizontal arrays [3–5], moored vertical arrays [5, 6], towed arrays [7, 8], and freely-drifting sonobuoy fields [9, 10].

The uncertainties of the recovered receiver positions can be estimated efficiently from a linearized approximation of the posterior covariance matrix, evaluated at the regularized solution. Alternatively, uncertainty estimates can be derived from a Monte Carlo appraisal procedure which calculates sensor-location error statistics from an ensemble of noisy synthetic inversion results [3]. Monte Carlo appraisal is computationally intensive, but represents a fully nonlinear solution, and also can be formulated to provide relative receiver position uncertainties by correcting each inversion result for optimal translation and rotation (linearized uncertainty estimates represent absolute uncertainties). Regularized AEL inversion and Monte Carlo appraisal, including the associated assumptions regarding data error statistics (described in Sec. 3), have been verified by comparing AEL results to a high-precision optical survey for a 2-D array, including both horizontal and vertical sub-arrays, deployed from shore-fast Arctic sea ice [5].

The geometric configuration of acoustic sources is an important factor controlling the accuracy of AEL inversion: a good configuration can provide much more accurate AEL results than a poor configuration [12]. The optimal source configuration can be determined for a particular array deployment by minimizing the mean receiver localization error over source positions. This represents a challenging numerical optimization problem, and, for efficiency, the localization error is based on the linearized estimate. Computing optimal source configurations also allows various aspects of AEL inversion, such as the effect of the number of sources, to be examined in a meaningful manner.

AEL inversion is based on inverting the acoustic ray-tracing equations. Hence, efficient AEL algorithms require an efficient ray-tracer; this is particularly important for the computationally-intensive Monte Carlo and optimization applications. The ray-tracer developed here is designed to determine eigenrays (rays that connect source and receiver) using Newton's method to iteratively improve an initial estimate. Since AEL surveys are based on simple, specific acoustic paths, this approach is much more efficient than than standard methods of shooting a large number of rays to bracket (trap) and subsequently refine eigenrays. Newton's method is applied to surface- and/or bottom-reflected rays using the method of images.

The remainder of this paper is organized as follows. The ray-tracing algorithm is described in Section 2. Section 3 develops the regularized AEL inversion and linearized uncertainty estimation. Section 4 describes the Monte Carlo appraisal for nonlinear uncertainty estimation. Section 5 considers design of optimal AEL source configurations. A synthetic example illustrating AEL inversion/uncertainty estimation and considering several factors affecting AEL accuracy and survey design runs through these sections. Finally, Section 6 summarizes and discusses this work. This paper is the result of a recent project to unify and extend previous disparate work in AEL [3–10, 12]. Hence, while portions of the theory in Sections 3–5 have been presented elsewhere, this paper is the first to provide a complete, systematic, and self-consistent approach to the various AEL applications (and also corrects several earlier errors). Further, the extension of the efficient ray-tracer and AEL inversion to reflected and turning ray paths and the applications to study AEL accuracy and survey design are novel.

2. RAY TRACING

Consider an ocean acoustic source and receiver at $(x_j,\, y_j,\, z_j)$ and $(x_i,\, y_i,\, z_i)$, respectively, with $z_j \le z_i$ (source above receiver is assumed here; for the opposite, a negative sign is required in the integrals below unless otherwise noted). The horizontal range between source and receiver is given by

$$r = \left[(x_i - x_j)^2 + (y_i - y_j)^2\right]^{1/2} . \tag{1}$$

Expressions for the range r and arrival-time t between source and receiver along a non-turning direct ray (i.e., a ray that does not change vertical direction as the result of reflection or refraction) are obtained by applying Snell's Law to an infinite stack of infinitesimal layers [13]

$$r = \int_{z_j}^{z_i} \frac{p\, c(z)\, dz}{\left[1 - p^2 c^2(z)\right]^{1/2}} , \tag{2}$$

$$t = t_0 + \int_{z_j}^{z_i} \frac{dz}{c(z)\left[1 - p^2 c^2(z)\right]^{1/2}} , \tag{3}$$

where t_0 represents the source transmission time. In Eqs. (2) and (3), the ray parameter $p = cos\theta(z)/c(z)$

(where $\theta(z)$ is the grazing angle) is invariant along a ray path, and defines the take-off angle at the source. The ray parameter for an eigenray connecting source and receiver is determined by searching for the value of p which produces the correct range (to a specified tolerance) using Eq. (2). The efficiency of this search is the key to an efficient ray-tracing algorithm.

For non-turning direct-path eigenrays, a highly efficient procedure of determining p is based on Newton's method. An initial estimate p_0 is based on straight-line propagation with a constant sound speed c_H representing the harmonic mean of the water-column sound-speed profile between source and receiver

$$c_H = (z_i - z_j) \Bigg/ \int_{z_j}^{z_i} \frac{dz}{c(z)} \tag{4}$$

(this equations also holds for $z_i \leq z_j$). An improved estimate p_1 is obtained by expanding $r(p)$ in a Taylor's series about p_0 and neglecting nonlinear terms leading to

$$p_1 = p_0 + \left[\frac{\partial r(p_0)}{\partial p}\right]^{-1} (r(p) - r(p_0)) \,. \tag{5}$$

In Eq. (5), $\partial r/\partial p$ is determined by differentiating (2) according to Leibnitz's rule to yield

$$\frac{\partial r}{\partial p} = \int_{z_j}^{z_i} \frac{c(z)\, dz}{[1 - p^2 c^2(z)]^{3/2}} \,. \tag{6}$$

If $r(p_1)$ computed from Eq. (2) is within the tolerance of the desired range according to Eq. (1), the procedure is complete. If not, the starting value is updated, $p_0 \leftarrow p_1$, and the procedure repeated iteratively until a satisfactory value is obtained. Since Newton's method converges quadratically near the solution, this is a highly efficient method of determining eigenrays to high precision, often requiring only one or two iterations. Once the ray parameter p is determined, the travel-time along the ray path is computed using Eq. (3).

In addition to computing travel times, AEL inversion (described in Section 3) requires partial derivatives of travel-time with respect to source and receiver coordinates, source instants, and sound-speed bias. Consider first the partial derivative with respect to horizontal coordinate x_i. Employing the chain rule

$$\frac{\partial t}{\partial x_i} = \frac{\partial t}{\partial p}\frac{\partial p}{\partial r}\frac{\partial r}{\partial x_i} = \frac{\partial t}{\partial p}\left[\frac{\partial r}{\partial p}\right]^{-1}\frac{\partial r}{\partial x_i} \,. \tag{7}$$

The three partials on the right side of Eq. (7) can be calculated from Eqs. (3), (2) and (1), respectively, yielding

$$\frac{\partial t}{\partial x_i} = p\,(x_i - x_j)/r \,. \tag{8}$$

Similarly, partial derivatives with respect to the other horizontal coordinates are

$$\frac{\partial t}{\partial x_j} = p\,(x_j - x_i)/r \,, \tag{9}$$

$$\frac{\partial t}{\partial y_i} = p\,(y_i - y_j)/r \,, \tag{10}$$

$$\frac{\partial t}{\partial y_j} = p\,(y_j - y_i)/r \,. \tag{11}$$

The partial derivative of t with respect to vertical coordinate z_i can be determined from Eq. (3)

$$\begin{aligned}\frac{\partial t}{\partial z_i} \;=\; & \int_{z_j}^{z_i} \frac{p\, c(z)\, dz}{[1 - p^2 c^2(z)]^{3/2}} \left(\frac{\partial p}{\partial z_i}\right) \\ & - \frac{1}{c(z_i)\left[1 - p^2 c^2(z_i)\right]^{1/2}} \,.\end{aligned} \tag{12}$$

An expression for $\partial p/\partial z_i$ can be obtained by noting that

$$\frac{\partial r}{\partial z_i} = 0 = \int_{z_j}^{z_i} \frac{c(z)\, dz}{[1 - p^2 c^2(z)]^{3/2}} \left(\frac{\partial p}{\partial z_i}\right) - \frac{p\, c(z_i)}{[1 - p^2 c^2(z_i)]^{1/2}} \,. \tag{13}$$

Solving for $\partial p/\partial z_i$ and substituting into Eq. (12) yields

$$\frac{\partial t}{\partial z_i} = \frac{1}{c(z_i)} \left[1 - p^2\, c^2(z_i)\right]^{1/2} \,. \tag{14}$$

Similarly,

$$\frac{\partial t}{\partial z_j} = -\frac{1}{c(z_j)} \left[1 - p^2 c^2(z_j)\right]^{1/2} \,. \tag{15}$$

The derivative of t with respect to the source instant t_0 in Eq. (3) is simply given by

$$\frac{\partial t}{\partial t_0} = 1. \tag{16}$$

However, for the purposes of AEL inversion, t_0 in Eq. (3) is replaced by $(\bar{c}t_0)/\bar{c}$, where $\bar{c}$ represents a representative sound speed. This allows the unknown source instant to be represented as $\bar{c}t_0$, which has the same physical units (distance) and similar uncertainty as the positional parameters (scaling parameters in this manner generally improves the numerical stability of inversion algorithms). In this case the partial derivative becomes

$$\frac{\partial t}{\partial(\bar{c}t_0)} = \frac{1}{\bar{c}}. \tag{17}$$

Measured sound-speed profiles are generally accurate in a relative sense, but frequently suffer from bias errors of up to 2 m/s due to inaccurate calibration [11]. To account for an unknown bias in the sound-speed profile, let $c(z) = c_t(z) + c_b$, where $c_t(z)$ is the true sound speed and c_b is the bias. Differentiating Eq. (3) with respect to c_b (and noting $\partial p/\partial c = -p/c$) leads to

$$\frac{\partial t}{\partial c_b} = -\int_{z_j}^{z_i} \frac{dz}{c^2(z)\left[1 - p^2 c^2(z)\right]^{1/2}} \,. \tag{18}$$

Sea surface and bottom reflections can be included in the above formulation for direct rays using the method of images, i.e., by representing the reflected ray path by

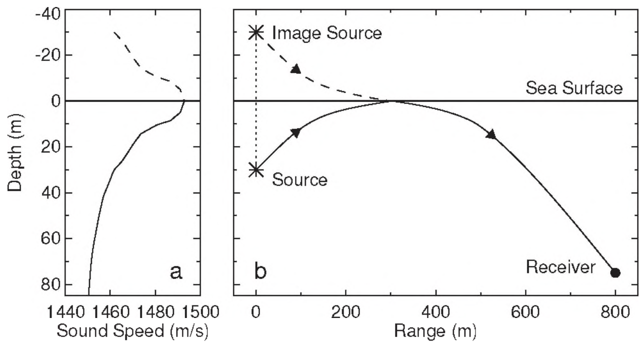

Figure 1: Example of tracing a surface-reflected ray using the method of images. Panel (a) shows the "image" sound-speed profile, with structure reflected about the sea surface. Panel (b) shows the equivalence of a reflected path and a direct path traced through the image sound-speed profile.

a direct path from an image source located above the surface or below the bottom, respectively. To apply the method of images, the sound-speed profile is reflected about the interface in the same manner as the source, and a direct ray is traced through the resulting "image" sound-speed profile. An example of this procedure is illustrated in Fig. 1 for a surface-reflected ray. Ray paths involving multiple reflections can be accommodated by applying the method of images recursively.

To implement the equations derived above, it is assumed that a discrete sound-speed profile can be represented by a series of layers with a (non-zero) linear gradient in each layer. In the following, let $\{(z_k, c_k), k = 1, N_z\}$ represent the piece-wise linear sound-speed profile (including any required profile reflections), and let $\{g_k\}$ be the corresponding sound speed gradients. The integrals in Eqs. (2), (3), (4), (6), and (18) can be evaluated analytically, yielding the following results, where $w_k \equiv (1 - p^2 c_k^2)^{1/2}$,

$$r = \sum_{k=j}^{i-1} \frac{w_k - w_{k+1}}{p\, g_k}, \tag{19}$$

$$t = t_0 + \sum_{k=j}^{i-1} \frac{1}{g_k} \left[\log_e \frac{c_{k+1}\,(1 + w_k)}{c_k\,(1 + w_{k+1})} \right], \tag{20}$$

$$c_H = (z_i - z_j) \Bigg/ \sum_{k=j}^{i-1} \frac{1}{g_k} \left[\log_e \frac{g_k(z_{k_1} - z_k) + c_k}{c_k} \right], \tag{21}$$

$$\frac{\partial r}{\partial p} = \sum_{k=j}^{i-1} \frac{w_k - w_{k+1}}{p^2\, g_k\, w_k\, w_{k+1}}, \tag{22}$$

$$\frac{\partial t}{\partial c_b} = \sum_{k=j}^{i-1} \frac{1}{g_k} \left[\frac{w_{k+1}}{c_{k+1}} - \frac{w_k}{c_k} \right]. \tag{23}$$

If a non-turning eigenray cannot be found for a particular source/receiver depth and range, a search over turning rays is required. An efficient strategy for this search uses the average sound-speed gradient between source and receiver as an indicator of the most likely take-off direction for a turning ray. Given $z_j < z_i$ (source above receiver), consider first the case of a negative (downward-refracting) average gradient. In this case, the first rays considered are those leaving the source upward to see if they turn back down to the receiver. This is accomplished efficiently by considering rays that turn at the top of each layer of the sound-speed profile above the source. If $g_k < 0$, the p value for an upward propagating ray turning at the top of the kth layer is given by

$$p = 1/c_k. \tag{24}$$

If tracing rays that turn at successive layer boundaries bracket the receiver, an eigenray is trapped and can be refined using the bisection method. If no such eigenrays exists, a secondary search can be carried out over downward-propagating rays that turn upward below the receiver (if such rays exist) using a similar strategy. Alternatively, if the average sound-speed gradient between source and receiver is positive (upward-refracting), the initial search is over rays that turn upward at layer boundaries below the receiver, followed by rays that turn downward above the source (if they exist). The above strategy is used for $z_j > z_i$ (receiver above source) by applying reciprocity.

Once the ray parameter p is determined for a turning ray, the integrals along the ray-path are evaluated. Consider, for example, the case of an initially downward propagating ray entering the lth layer with a positive sound-speed gradient g_l. The turning depth for this ray is given by

$$z_T = z_l + (1/p - c_l)/g_l. \tag{25}$$

If this depth is less than z_{l+1} (bottom of lth layer) the ray turns in this layer; if not, it proceeds into layer $l+1$. If the ray turns in layer l, then the integration involves four steps: (i) integrate from the source depth z_j down to z_l, (ii) integrate from z_l to z_T (where $w_T = 0$), (iii) integrate upward from z_T to z_l, and (iv) integrate from z_T to the receiver depth z_i. This leads to the following equations for turning rays:

$$r = \sum_{k=j}^{l-1} \frac{w_k - w_{k+1}}{p\, g_k} + \frac{2\, w_l}{p\, g_l} + \sum_{k=l}^{i} \frac{w_k - w_{k-1}}{p\, g_{k-1}}, \tag{26}$$

$$\begin{aligned} t \;&=\; t_0 + \sum_{k=j}^{l-1} \frac{1}{g_k} \left[\log_e \frac{c_{k+1}\,(1 + w_k)}{c_k\,(1 + w_{k+1})} \right] + \frac{2}{g_l} \log_e \frac{1 + w_l}{p\, c_l} \\ &\quad + \sum_{k=l}^{i} \frac{1}{g_{k-1}} \left[\log_e \frac{c_{k-1}\,(1 + w_k)}{c_k\,(1 + w_{k-1})} \right], \end{aligned} \tag{27}$$

$$\begin{aligned} \frac{\partial r}{\partial p} \;&=\; \sum_{k=j}^{l-1} \frac{w_k - w_{k+1}}{p^2\, g_k\, w_k\, w_{k+1}} - \frac{2}{g_l\, p^2\, w_l} \\ &\quad + \sum_{k=l}^{i} \frac{w_k - w_{k-1}}{p^2\, g_{k-1}\, w_k\, w_{k-1}}, \end{aligned} \tag{28}$$

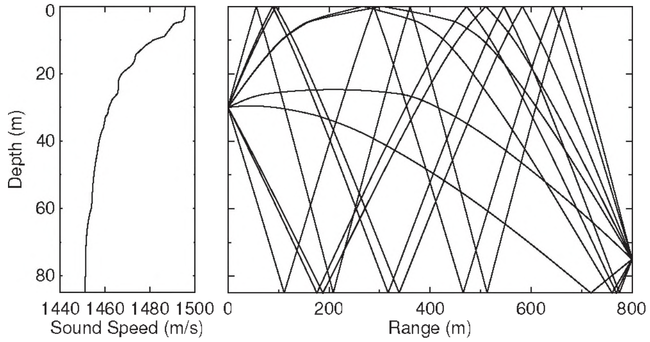

Figure 2: Ray-tracing example. Left panel shows downward-refracting sound-speed profile. Right panel shows ray paths for direct ray and all reflected rays with up to two bottom reflections (ten paths).

$$\begin{aligned}\frac{\partial t}{\partial c_b} &= \sum_{k=j}^{l-1} \frac{1}{g_k}\left[\frac{w_{k+1}}{c_{k+1}} - \frac{w_k}{c_k}\right] + \frac{2\,w_l}{c_l g_l} \\ &\quad + \sum_{k=l}^{i} \frac{1}{g_{k-1}}\left[\frac{w_{k-1}}{c_{k-1}} - \frac{w_k}{c_k}\right]. \qquad (29)\end{aligned}$$

Similar equations can be derived for an initially upward propagating ray that turns in a negative sound-speed gradient.

An example of the above ray-tracing algorithm is given in Fig. 2 for a challenging case involving a strongly downward refracting sound-speed profile with variable gradients and a near-surface mixed (near iso-speed) layer. The water depth is 85 m and the source and receiver depths are 30 and 75 m, respectively. Figure 2 shows all rays with up to three surface and two bottom reflections for a range of 800 m. The direct and bottom-reflected rays are turning rays which require the bisection search to determine the corresponding ray parameters. All other rays were determined using Newton's method. The surface- and surface-bottom reflected rays are close to turning near the ocean surface (i.e., go through small grazing angles); this represents a difficult ray-parameter search and required 8 iterations of Newton's method to converge to a range tolerance of 0.01 m. All other rays required only two iterations for convergence.

3. AEL INVERSE THEORY

The AEL inverse problem formulated here consists of estimating 3-D position variables (x, y, z) for the N_r receivers and N_s sources of an AEL survey, based on linearized inversion of travel-time data as represented by the acoustic ray theory developed in Section 2. The data can include direct and/or surface- and bottom-reflected arrivals, and can consist of absolute travel times (known source transmission instants), relative travel times (unknown source instants), or absolute travel times with an unknown offset. In the case of relative travel times, N_s source instants are included as explicit unknown parameters in the inversion. For travel-time data with an unknown transmission offset, the offset is included as a single parameter. Finally, the bias for the measured sound-speed profile is also considered as an unknown parameter in the inversion.

The acoustic arrival times $\mathbf{t}$ measured in an AEL survey can be written in general vector form as

$$\mathbf{t} = \mathbf{t}(\mathbf{m}) + \mathbf{n}. \qquad (30)$$

In Eq. (30), the model $\mathbf{m}$ represents the unknown parameters (discussed above). The forward mapping $\mathbf{t}(\mathbf{m})$ represents computation of acoustic arrival times along ray paths between sources and receivers. Finally, $\mathbf{n}$ represents additive errors (noise), with the assumption that the error n_i on datum t_i is due to an independent, Gaussian-distributed random process with zero mean and standard deviation σ_i.

The inverse problem of estimating $\mathbf{m}$ from $\mathbf{t}$ is functionally nonlinear. However, a local linearization can be obtained by expanding $\mathbf{t}(\mathbf{m}) = \mathbf{t}(\mathbf{m}_0 + \delta\mathbf{m})$ in a Taylor series to first order about an arbitrary starting model $\mathbf{m}_0$ leading to [3]

$$\mathbf{J}\,\mathbf{m} = \mathbf{t} - \mathbf{t}(\mathbf{m}_0) + \mathbf{J}\,\mathbf{m}_0 \equiv \mathbf{d}, \qquad (31)$$

where $\mathbf{J}$ is the Jacobian matrix of partial derivatives $J_{ij} = \partial t_i(\mathbf{m}_0)/\partial m_j$ (derived in Section 2), and $\mathbf{d}$ represents modified data defined in terms of known quantities. Equation (31) represents a linear inverse problem which can be solved for $\mathbf{m}$ as described below. Since nonlinear terms are neglected, the linearized inversion must be repeated iteratively until convergence.

Treating both source and receiver locations as unknown leads to an ill-conditioned inverse problem which cannot be solved using standard least-squares methods even in cases where the number of data exceed the number of unknowns. This ill-conditioning indicates that the data alone do not constrain the solution, and additional independent information (prior information) is required. The method of regularization [14–16] provides a powerful approach to include prior information in linear inversion. This is accomplished by minimizing an objective function ϕ that combines the data misfit with regularizing terms that impose the prior information. Two forms of prior information are typically available in AEL problems, and can be imposed by including two regularization terms:

$$\phi = |\mathbf{G}\,(\mathbf{J}\,\mathbf{m} - \mathbf{d})|^2 + \mu_1|\mathbf{H}_1\,(\mathbf{m} - \hat{\mathbf{m}}_1)|^2 + \mu_2|\mathbf{H}_2\,(\mathbf{m} - \hat{\mathbf{m}}_2)|^2. \qquad (32)$$

In (32), the first term represents the (linearized) χ^2 data misfit, and the remaining terms represent regularizations (described below) with trade-off parameters (Lagrange multipliers) μ_1 and μ_2 determining the relative importance of the three terms in the minimization.

The first regularization term in Eq. (32) applies prior parameter estimates for the source and receiver positions as available from knowledge of the deployment procedure. Hence, $\hat{\mathbf{m}}_1$ consists of the prior estimates for these parameters and the regularization matrix $\mathbf{H}_1$ is of the form

$$\mathbf{H}_1 = \mathrm{diag}[1/\delta_i], \qquad (33)$$

where δ_j represents the estimated standard deviation of an assumed Gaussian uncertainty distribution for the jth prior parameter estimate $\hat{m}_j$.

The second regularization term is optional, and can be used (when applicable) to apply the prior expectation that the array shape is expected to be a smooth function of position (x, y, z). This can be applied using $\hat{\mathbf{m}}_2 = \mathbf{0}$ and $\mathbf{H}_2$ consisting of a Toeplitz matrix with non-zero entries on jth row of the form

$$\mathbf{H}_{2j} = \left[0, \ldots, \frac{-1}{(u_{j+1}-u_j)^2}, \frac{u_{j+2}-u_j}{(u_{j+2}-u_{j+1})(u_{j+1}-u_j)^2}, \right.$$
$$\left. \frac{-1}{(u_{j+2}-u_{j+1})(u_{j+1}-u_j)}, \ldots, 0\right], \qquad (34)$$

applied to the x, y, and z receiver position variables, where u_j represents the distance along the array to the jth receiver. Each row of $\mathbf{H}_2$ in Eq. (34) represents a discrete approximation to the second derivative operator $\partial^2/\partial u^2$. Hence, $|\mathbf{H}_2\,\mathbf{m}|^2$ provides a measure of the total curvature of the array shape, and the regularization produces the simplest array shape that is consistent with the acoustic data and prior position estimates.

The regularized solution is obtained by setting $\partial\phi/\partial\mathbf{m} = 0$, leading to [3]

$$\begin{aligned} \mathbf{m} \;=\; & \hat{\mathbf{m}}_1 + \left[\mathbf{J}^T\mathbf{G}^T\mathbf{G}\,\mathbf{J} + \mu_1\,\mathbf{H}_1^T\mathbf{H}_1 + \mu_2\,\mathbf{H}_2^T\mathbf{H}_2\right]^{-1} \\ & \left[\mathbf{J}^T\,\mathbf{G}^T\mathbf{G}\,\mathbf{d} - \mathbf{J}\hat{\mathbf{m}}_1\right]. \qquad (35) \end{aligned}$$

AEL inversion consists of an iterative application of the regularized solution, typically initiated from a starting model coinciding with the prior parameter estimates. Convergence is based on achieving a statistically appropriate fit to the acoustic data (i.e., that the χ^2 misfit achieves its expected value of $\langle\chi^2\rangle = N$ for N data) and obtaining a stable solution such that the change in receiver locations between iterations is small compared to the desired accuracy. A practical aspect of implementing the inversion involves assigning values to the trade-off parameters, μ_1 and μ_2, which control the balance between the data misfit and the various forms of prior information; a straightforward procedure is described in [3].

An important component of any inverse problem is estimating the uncertainty of the solution. For linear problems with Gaussian-distributed data errors and prior estimates, the posterior model covariance matrix is given by

$$\mathbf{C} = [\mathbf{J}^T\mathbf{G}^T\mathbf{G}\,\mathbf{J} + \mathbf{H}_1^T\,\mathbf{H}_1]^{-1}, \qquad (36)$$

with the ith diagonal element of $\mathbf{C}$ representing the variance (standard deviation squared) of the ith recovered parameter. For nonlinear inverse problems solved via iterated linearized inversion, the covariance matrix can be approximated by Eq. (36) with $\mathbf{J}$ evaluated at the final model. The validity of this approach depends on the degree of nonlinearity of the inverse problem, but has been found to be a good approximation for AEL inversion [12] (considered further in the following section). Because of the computational efficiency of the linearized uncertainty estimates, they provide a convenient and effective way to characterize AEL inversion results, and can be applied in designing optimal AEL surveys (described in Section 5).

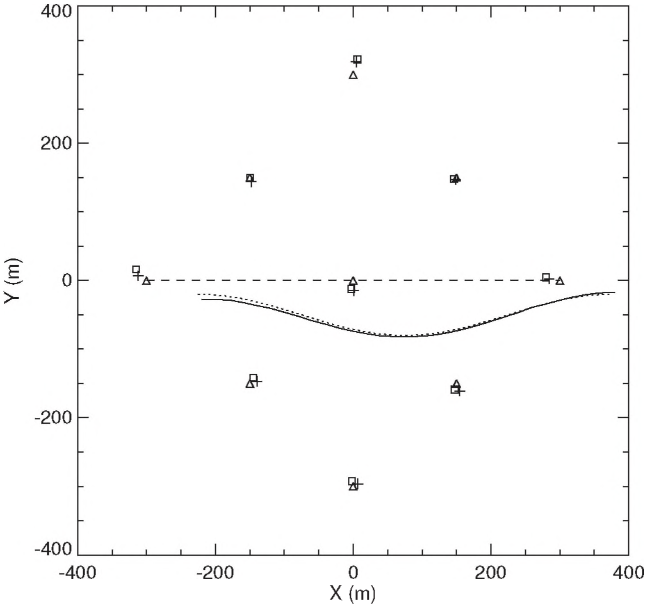

Figure 3: AEL inversion test case. The true position of the 31-element receiver array is indicated by the dotted line, the prior estimate by the dashed line, and the inversion result by the solid line. True positions, prior estimates, and inversion results for the source locations are indicated by the squares, triangles and crosses, respectively.

An example of the regularized AEL inversion is given in Fig. 3 for a synthetic test case based on a 600-m array of 31 equally spaced receivers (20-m separation) at approximately 75-m depth in a water-column with sound-speed profile shown in Fig. 2. As shown in Fig. 3, the starting model and prior estimate for the receiver locations consist of a straight array along the x axis from −300 to 300 m (dashed line), while the true array shape (dotted line) is curved and displaced by approximately 75 m in x and 50 m in y. The prior estimate for all receiver depths is 75 m, while the true depths include Gaussian-distributed random perturbations of 5-m standard deviation about this depth. The prior estimates for 9 source locations (triangles) are arranged symmetrically about the prior array estimate, with a 30-m source depth. The true source positions (squares) include random perturbations with standard deviations of 10 m in x and y and 3 m in z, corresponding to the assumed uncertainties of the prior estimates for these parameters (representative of measurements made at sea). Simulated AEL data (absolute travel times) were computed for direct-path arrivals and Gaussian errors of standard deviation 0.5 ms were added to produce the measured data set. AEL inversion was carried out for the smoothest array shape that fit the data and prior estimates to within their uncertainties. The inversion result for the receiver locations

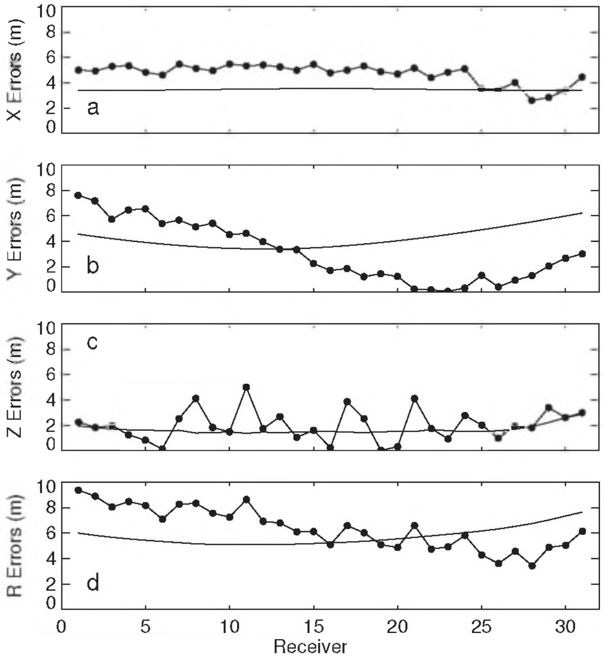

Figure 4: Localization errors for the AEL test case. Panels (a)–(d) show absolute errors (filled circles) and linearized uncertainty estimates (solid lines) for sensor locations in x, y, z, and R, respectively.

(solid line) is in close agreement with the true receiver locations, although a small translation (to positive x) and rotation (counter-clockwise) is evident. The inversion results for the source locations (crosses) are generally significantly closer to the true source positions than to the prior estimates, particularly in cases where the true and prior locations differ substantially (e.g., at $x = \pm300$ m and $y = +300$ m).

The AEL localization errors are examined in Fig. 4, which compares the absolute errors in x, y, z, and $R = [x^2 + y^2 + z^2]^{1/2}$ to the corresponding linearized posterior uncertainty estimates. The linearized uncertainties represent the actual errors reasonably well, although the results of the translation (in x) and rotation (in y) lead to some systematic differences (translations and rotations are specific to the particular data and prior errors, while the linearized estimates quantify expected uncertainties).

The effect of knowledge of source transmission instants is investigated in Fig. 5, in terms of linearized receiver position uncertainties in x, y, z, and R for the above AEL test case. The uncertainties for relative travel-time data (Fig. 5a), are slightly larger for all coordinates than the other two data types (Fig. 5b and c), with a total degradation of approximately 1 m in R. Figure 5(b) and (c) show virtually identical results for data consisting of absolute travel-times and absolute travel-times with an unknown offset.

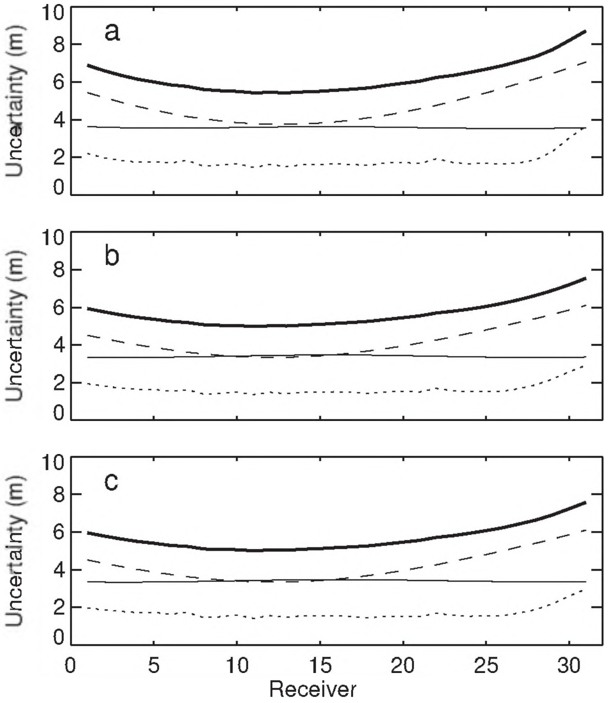

Figure 5: Linearized receiver-location uncertainties for relative travel-time data, absolute travel-time data, and absolute travel-time data with unknown offset shown in (a)–(c), respectively (uncertainties x, y, z, and R indicated by solid, dashed, dotted, and heavy solid lines).

The use of reflected arrivals in AEL is examined in Fig. 6, which compares the mean linearized receiver-location uncertainty in x, y, z, and R for five data sets consisting of different combinations of ray paths including: direct (d), surface-reflected (s), bottom-reflected (b), direct plus surface-reflected plus bottom-reflected (dsb), and all ray paths with up to one bottom reflection (all, six paths). The effect of water-depth uncertainty can be incorporated in the inversion by increasing the uncertainties of the bottom-reflected arrival-time data by an amount commensurate with propagation over the uncertainty in depth, as determined via ray-tracing. Water-depth uncertainties of 1, 3, and 8 m are considered in Fig. 6(a)–(c), respectively. Figure 6(a) shows that the receiver-location uncertainties in x and y are virtually unchanged by including reflected arrivals, as these follow identical radial paths and provide little new information regarding horizontal positioning. Compared to the direct-path inversion, the uncertainty in z is slightly improved for the surface-reflected path as it arrives at a steeper angle, but slightly degraded for the bottom-reflected path due the uncertainty in water depth. The localization uncertainty in z is significantly reduced by including multiple arrivals in the AEL inversion. Figure 6(a)–(c) show that the z localization uncertainties increase slightly with water-depth uncertainty for multiple-path inversions that include the bottom-reflected path, and increase significantly for the bottom-reflected only inversion. Figure 6(c) shows that inverting bottom-reflected data with large water-depth uncertainty leads to slightly degraded receiver-localization in x and y.

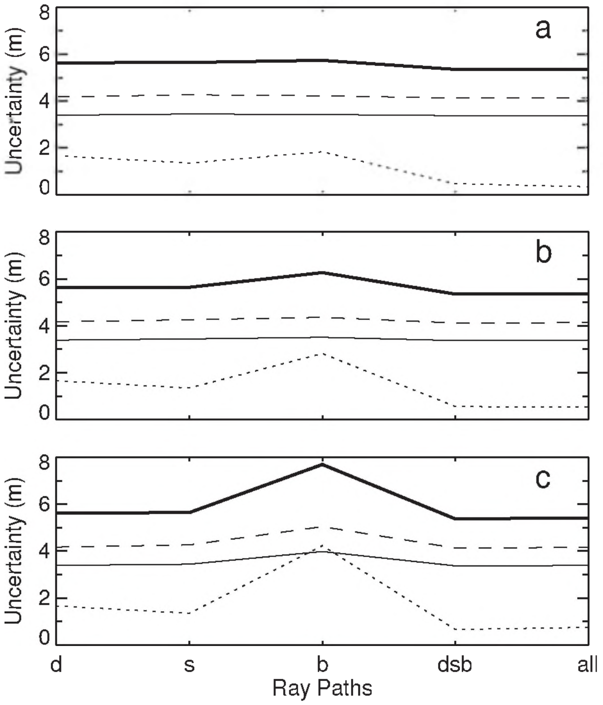

Figure 6: Mean linearized receiver-location uncertainties in x, y, z, and R (solid, dashed, dotted, and heavy solid lines, respectively) for different combinations of ray paths (defined in text). Panels (a)–(c) show results for water-depth uncertainties of 1, 3 and 8 m, respectively.

4. MONTE CARLO UNCERTAINTY ANALYSIS

The previous section described linearized uncertainty estimates which can be evaluated efficiently from the regularized solution. Monte Carlo appraisal provides an alternate approach which provides fully nonlinear uncertainty estimates, but is much more computationally intensive. In the Monte Carlo approach, the source and receiver positions determined via inversion of the measured data are assumed to define the true positions for a synthetic inverse problem, and acoustic arrival-time data are computed. A series of independent inversions are then carried out, each with different random errors applied to the computed data and to the prior position estimates and starting model (these errors are drawn from Gaussian distributions with standard deviations equivalent to the corresponding estimated uncertainties of the data and priors). Standard deviations about the true sensor positions can then be computed from the ensemble of inversion results.

An advantage of the Monte Carlo approach is that it can be used to estimate localization errors in both an absolute sense (relative to the fixed geographic coordinate system) and in a relative sense (in array-based coordinates), while linearized uncertainty estimates represent absolute errors. For some array processing applications, relative position errors provide a more relevant measure. This is because position errors common to all receivers are equivalent to a simple rigid-body translation and/or rotation of the receiver array. However, relative position errors introduce inter-receiver timing and phase errors which cannot be corrected by translation or rotation, and degrade applications such as matched-field localization.

To obtain relative error estimates from the Monte Carlo analysis, the effects of translations and rotations of the individual inversion estimates (relative to the true positions) are removed prior to computing the error statistics. Optimal estimates of these transformations are derived as follows. Let (x_i, y_i) represent N_r receiver-position estimates and (X_i, Y_i) represent the true positions. The optimal translation $(\delta x, \delta y)$ is found be minimizing the l_2 error norm (i.e., least-squares minimization)

$$E_1 = \sum_{i=1}^{N_r} \left\{ [x_i + \delta x - X_i]^2 + [y_i + \delta y - Y_i]^2 \right\}. \tag{37}$$

Setting $\partial E_1/\partial \delta x = \partial E_1/\partial \delta y = 0$ yields

$$\delta x = \frac{1}{N_r} \sum_{i=1}^{N_r} [X_i - x_i] = \bar{X} - \bar{x}, \tag{38}$$

$$\delta y = \frac{1}{N_r} \sum_{i=1}^{N_r} [Y_i - y_i] = \bar{Y} - \bar{y}, \tag{39}$$

where the over-bar represents the mean over all receivers. Equations (38) and (39) indicate that the optimal translation consists of a shift in x and y equal to the difference between the mean true and estimated positions. To determine the optimal rotation (after translation), define rotated estimated positions as

$$\tilde{x}_i = r_i \cos(\theta_i + \psi), \qquad \tilde{y}_i = r_i \sin(\theta_i + \psi) \tag{40}$$

where $r_i = [x_i^2 + y_i^2]^{1/2}$, $\theta_i = \tan^{-1}(y_i/x_i)$, and ψ is the rotation angle to be determined. The l_2 error norm between the rotated and reference positions is defined

$$E_2 = \sum_{i=1}^{N_r} \left\{ [r_i \cos(\theta_i + \psi) - X_i]^2 + [r_i \sin(\theta_i + \psi) - Y_i]^2 \right\}. \tag{41}$$

Setting $\partial E_2/\partial \psi = 0$ for a minimum leads (after some algebra) to

$$\psi = \tan^{-1} \frac{\sum_i r_i (Y_i \cos\theta_i - X_i \sin\theta_i)}{\sum_i r_i (X_i \cos\theta_i - Y_i \sin\theta_i)}. \tag{42}$$

As an example of the Monte Carlo appraisal, Fig. 7 compares both absolute and relative nonlinear receiver uncertainty estimates to the linearized uncertainty estimates derived in Section 3 for the AEL example considered previously. The regularized inversion and linearized uncertainty estimates required about 1–2 s computation time on a 2 GHz desktop computer running IDL (Interactive Data Language). The Monte Carlo uncertainties are based on 500 independent (randomized) inversions

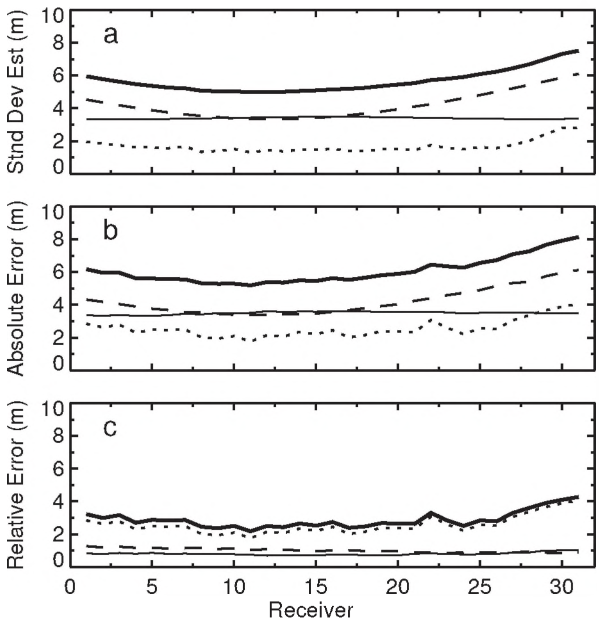

Figure 7: Receiver-location uncertainty estimates (uncertainties in x, y, z, and R indicated by solid, dotted, dashed, and heavy solid lines, respectively). Panel (a) shows the linearized uncertainty estimates (standard deviations), panels (b) and (c) show the absolute and relative uncertainties estimated by Monte Carlo appraisal.

which required about 15 minutes computation time. Figure 7(a) and (b) show that the linearized uncertainties and the Monte Carlo absolute uncertainties are in good agreement. Figure 7(c) shows that removing the effects of translation and rotation results in relative uncertainties that are substantially smaller in x, y, and R (not z). Finally, Fig. 8 shows that the relative errors from the AEL inversion (i.e., corrected for optimal translation and rotation) and the Monte Carlo relative uncertainty estimates are in excellent agreement.

5. OPTIMAL AEL SURVEY DESIGN

This section considers the problem of determining optimal AEL source configurations, i.e., the source configuration that produces the most accurate inversion for sensor positions. To this end, an AEL error measure is defined and the optimal survey configuration determined by minimizing this error with respect to the source positions [12]. Since this represents a difficult optimization problem which must be solved numerically, the AEL error must be computationally efficient, and hence is based on the linearized uncertainty estimates described in Section 3.

Let ξ_x, ξ_y, and ξ_z represent the standard deviations of the x, y, and z receiver-position coordinates as estimated by the square root of the diagonal elements of the linearized posterior covariance matrix given by Eq. (36).

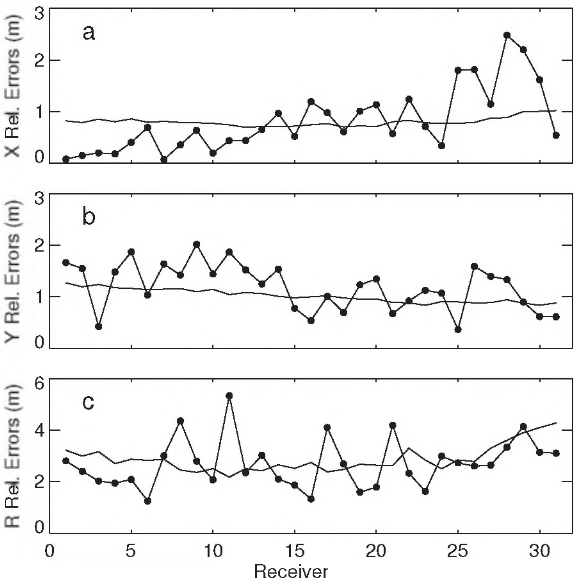

Figure 8: Relative receiver-location errors. Panels (a)–(c) show relative errors (filled circles) and Monte Carlo uncertainty estimates (solid lines) for sensor locations in x, y, and R, respectively.

The AEL error measure is then defined

$$E = \left[\frac{1}{N_s} \sum_{i=1}^{N_s} \xi_x^2 + \xi_y^2 + \xi_z^2 \right]^{1/2}. \tag{43}$$

This measure represents the root-mean-square (RMS) 3-D uncertainty of the receiver positions. The source configuration that minimizes E provides the receiver-position estimates that are the most accurate on average.

Minimizing E in Eq. (43) represents a strongly non-linear optimization problem that can have a degenerate global minimum (due to symmetries) and a large number of local minima, and hence is not amenable to linearized optimization methods. Here, an updated version of adaptive simplex simulated annealing (ASSA) is applied. ASSA represents an adaptive hybrid optimization that combines the local downhill simplex (DHS) method and very fast simulated annealing [17]. The version applied here included several advances over that described in [17]. First, the algorithm automatically determines an appropriate starting temperature based on the error functions associated with the models of the (randomly-chose) starting simplex. Second, multiple-contraction DHS steps are automatically applied in cases where the algorithm has difficulty finding improved solutions. Third, the adaptive component was modified to maintain a ratio of accepted to attempted perturbations of between 0.2–0.5 (the original version maintained a ratio of greater than 0.2). The modified version of ASSA appears to be significantly more efficient than the original.

To illustrate optimal AEL source configurations, consider first the configuration of 9 sources shown in Fig. 3: the expected RMS receiver error for this case is $E = 6.4$ m

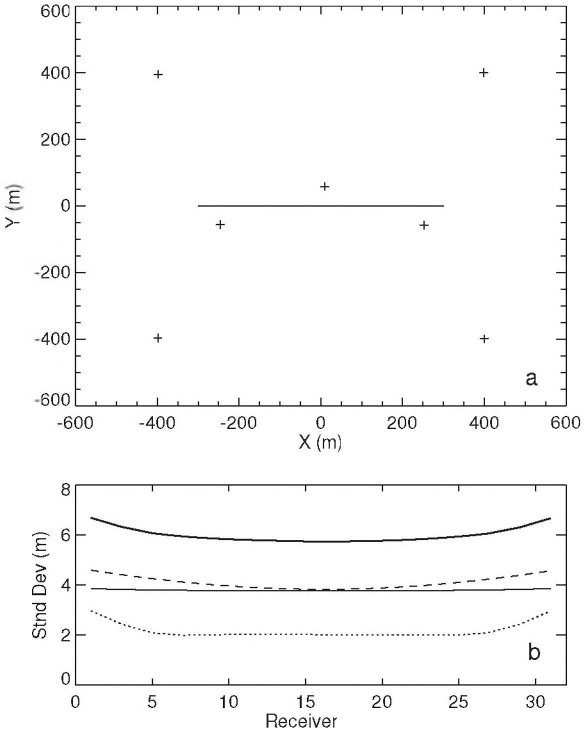

Figure 9: (a) Optimal configuration for 7 sources (crosses) to localize the receiver array (solid line). (b) Linearized standard deviation estimates for the optimal configuration (x, y, z, and R indicated by solid, dotted, dashed, and heavy solid lines, respectively)

(note that this applies for the prior straight-array estimate, since the true array shape is not known at the survey design stage). This error can be reduced significantly by using an optimal configuration for the AEL sources. In fact, the optimal configuration of just 7 sources (shown in Fig. 9), constrained within $-400 \leq x,\ y \leq 400$ m, leads to RMS error $E = 6.0$ m. The numerical optimization required approximately 15 minutes computation time.

The ability to compute optimal source configurations allows a variety of aspects of AEL survey design to be studied in an objective and meaningful manner. For instance, to examine the dependence of receiver localization error on the number of sources included in the AEL survey, it is only possible to separate the dependence on the number of sources from source-configuration effects by employing optimal source configurations. An example of such a study based on the the previously-described AEL test case (direct-arrival data) is given in Fig. 10. This figure shows the RMS receiver localization error as a function of the number of AEL sources (in optimal configurations) for the three types of data (absolute travel-times, relative travel-times, and absolute travel-times with unknown offset). The RMS localization uncertainties for data consisting of absolute travel-times with an unknown offset are virtually identical to those for absolute travel-times when more than three AEL sources are employed (for three sources, the difference is 0.3 m). This indicates that little localization information is lost in solving for the unknown offset time. RMS uncertainties are always larger for relative travel-time data than for absolute travel-times, although the difference decreases with increasing number of sources (from about 2.3 m for three sources to $\sim$0.5 m for 20 sources). Figure 10 shows that the advantages of using absolute travel-time data from synchronized surveys are relatively minor, and can be offset using relative travel times and an increased number of sources. For instance, Fig. 10 shows that using ten sources and relative travel-time data produces an RMS uncertainty equivalent to seven sources with absolute travel-time data.

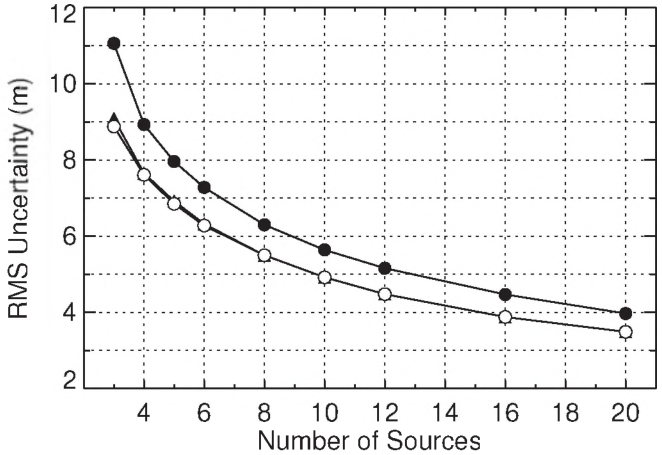

Figure 10: RMS receiver-location uncertainty versus number of sources for relative travel-time data (solid circles), absolute travel-time data (open circles), and absolute travel-time data with unknown offset (triangles, generally obscured by open circles). Data consist of direct arrival-times.

The difference between localization errors for relative and absolute travel-time data can be also reduced

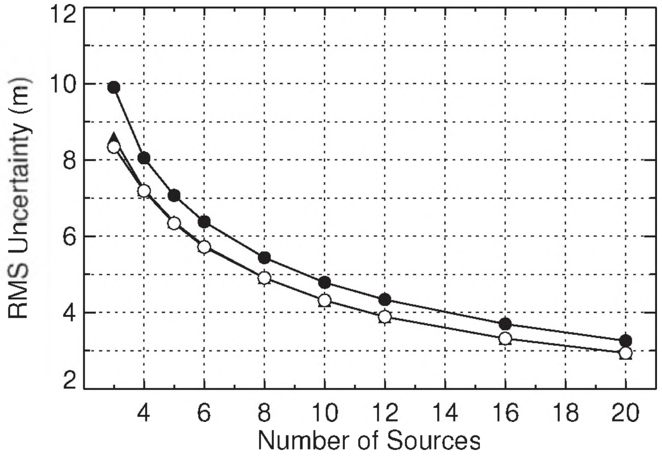

Figure 11: Same as Fig. 10, except data consist of direct and surface-reflected arrival-times.

by including reflected arrivals, since this provides additional data to constrain the same set of unknown source transmission instants. Figure 11 shows the RMS localization uncertainty for relative and absolute travel-time data including both direct and surface-reflected arrivals. This figure indicates that differences between the results for absolute and relative travel times are approximately half those in Fig. 10 for direct arrivals.

6. SUMMARY AND DISCUSSION

This paper presented the theory and implementation of a complete approach to AEL based on regularized inversion of the acoustic ray-tracing equations, which accounts for uncertainties in the data, source locations, sound speeds, and water depth. Posterior uncertainties in the recovered receiver locations are estimated efficiently from the linearized model covariance matrix, or from a fully nonlinear Monte Carlo appraisal at increased computational effort. The Monte Carlo analysis can also be applied to compute relative receiver-location uncertainties, which can be more relevant for some array-processing applications. The overall AEL error is quantified in terms of the RMS linearized receiver-location uncertainty, and optimal source configurations can be designed by minimizing this error measure over source positions via numerical optimization.

The ray-tracer developed here for AEL applications uses Newton's method to efficiently determine specific eigenrays to high precision without shooting a large number of rays to bracket the receiver. Surface and bottom reflections are included in this formulation using the method of images. Turning rays can also be included using a search based on rays that turn at sound-speed layer boundaries. The efficiency of the ray tracer and of the resulting AEL inversion algorithm allows computationally intensive analysis such as the Monte Carlo error estimation and nonlinear optimization for optimal source configurations.

The AEL algorithms developed here can be used to investigate factors affecting AEL accuracy and guide in designing AEL surveys. Several illustrations were given, including examining the relative advantages of synchronized versus non-synchronized AEL surveys and of including multi-path arrivals in AEL inversion. It is found that synchronized AEL surveys provide only a minor improvement over non-synchronized surveys, which can be made up by using more sources in an optimal configuration or by including reflected arrivals. AEL results based on absolute travel-time data with an unknown offset are virtually identical to absolute travel-time results. Including multiple-reflected arrivals can significantly improve receiver-depth estimation (if water depth is well known), but provides little improvement in horizontal localization as the rays follow identical radial paths.

ACKNOWLEDGEMENTS

The first author would like to thank several collaborators from earlier AEL projects in which many of the ideas described here originated, including Nicole Collison, Garry Heard, and Barbara Sotirin.

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MANDARIN LISTENERS' PERCEPTION OF ENGLISH VOWELS: PROBLEMS AND STRATEGIES

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ABSTRACT

Previous research suggests L2 vowel perception problems are often due to the assimilation of L2 sounds to L1 categories. However, there is also evidence for a universal strategy which states listeners will rely on duration cues whenever spectral cues are not sufficient for discriminating L2 vowel contrasts. This study examines Mandarin listeners' perceptual problems with English vowels. In a perception test, a group of adult Mandarin-English bilinguals residing in Canada identified synthesized English /i/-/ɪ/, /u/-/ʊ/, and /æ/-/ɛ/ continua that manipulated vowel spectral and duration cues. Compared with a native English group who responded exclusively to the spectral cues, the majority of native Mandarin listeners failed to show native-like perceptual patterns for the three vowel contrasts. However, they responded heavily and consistently to duration cues for the /i/-/ɪ/ but not for the /u/- /ʊ/ and /æ/-/ɛ/ contrasts. Both group and individual data suggest that native Mandarin listeners used different strategies in perceptual identification of L2 vowel contrasts. Most Mandarin listeners did not appear to have clear category distinctions for /u/-/ʊ/ and /æ/-/ɛ/ pairs and some established incorrect perceptual representation of the /i/-/ɪ/ contrast. The findings did not fully support the universal strategy of using duration cues when non-native vowel contrasts are difficult to perceive.

SOMMAIRE

Les recherches antérieures suggèrent que les problèmes liés à la perception de voyelles dans la langue seconde (L2) sont souvent dus à l'assimilation de sons L2 aux catégories de la langue maternelle (L1). Par contre, il y a également évidence d'une stratégie universelle selon laquelle les auditeurs utilisent les indices temporaux (durée) lorsque les indices spectraux ne sont pas suffisants pour distinguer les voyelles contrastes de L2. Cette étude explore les problèmes perceptuels pour des voyelles anglophones chez des auditeurs mandarins. Dans le cadre d'un test de perception, un groupe d'adultes bilingues mandarin-anglophone résidant au Canada ont identifié des voyelles anglophones synthétisées (/i/-/ɪ/, /u/-/ʊ/ et /æ/-/ɛ/) qui diffèrent selon leur spectre et leur durée. Alors que des auditeurs dont la langue maternelle est l'anglais ont répondu exclusivement aux indices spectraux, la majorité des auditeurs mandarins n'ont pas démontré ce même patron perceptuel pour les voyelles contrastes examinées. Ces derniers ont par contre répondu fortement et uniformément aux indices de durée pour le contraste /i/-/ɪ/, mais non pour les contrastes /u/- /ʊ/ et /æ/-/ɛ/. Les donnÿes individuelles et de groupe suggŸrent que les auditeurs mandarins utilisent des stratÿgies diffÿrentes lors de lùidentification perceptuelle de voyelles contrastes de L2. La majoritÿ dùentre eux ne semblaient pas possÿder de catÿgories distinctives claires pour les paires /u/-/ʊ/ et /æ/-/ɛ/, et certains avaient établi une représentation perceptuelle inexacte du contraste /i/-/ɪ/. Les résultats n'appuient pas l'existence d'une stratégie universelle d'utilisation d'indices de durée lorsque les voyelles contrastes de L2 sont difficiles à distinguer.

1. INTRODUCTION

It is well known that adult second language (L2) learners often have difficulties with the perception and production of non-native phonological segments that either do not occur or are realized differently in their first language (L1). Current L2 speech learning theories have hypothesized that such problems are due to the assimilation of L2 sounds to L1 phones. For example, the two most influential models, Best's Perceptual Assimilation Model (PAM) and Flege's Speech Learning Model (Best, 1994, 1995; Flege, 1995, Flege, Schirru, & MacKsy, 2003) both describe how the L1 segments are related to L2 categories in a systematic way.

The PAM Model (Best, 1994, 1995; Best, McRoberts, & Sithole, 1988; Best & Strange, 1992) predicts the levels of difficulty in differentiating L2 sounds on the basis of how a pair of L2 segments is assimilated to L1 sounds. For instance, two L2 sounds can be assimilated to two different L1 phones that are similar to the nonnative pair, the Two Categories type (TC). The non-native pair can also be assimilated to a single native sound equally well or poorly, the Single Category type

(SC), or to a single non-native sound with different phonetic match which will result in one better assimilated than the other, the Category Goodness type (CG).

Flegeùs (1995, 2003) Speech Learning Model (SLM) states that the success in the perception of L2 phones depends on whether a learner is able to establish phonetic categories for the segments that exist in L2 but not in L1. According to the SLM, a new category fails to be established as an L2 speech sound in spite of the audible differences between the L2 sound and the closest L1 sound or between two closest L2 sounds if the learner fails to perceive such differences. Therefore, L1 and L2 speech sounds interact through a öcategory assimilationõ mechanism (Flege et al. 2003). öBy hypothesis, category formation will be blocked if instances of an L2 speech category continue to be identified as instances of an L1 categoryõ (Flege et al. 2003, p. 469). The SLM also states that learnersù capacity for speech learning remains intact across the life span and L2 learners will gradually approximate L2 phonetic norms for certain L2 sounds more closely as their L2 experiences increases over time. Therefore, L2 experience plays an important part in the process of learning.

During the past few decades, L2 speakers' problems with L2 segments, mostly on consonants, have been well documented. Cross-linguistic vowel perception and production has received more attention since the last decade and there is increasing evidence that learners' perception of L2 vowels is strongly influenced by their first language experience. Non-native vowels that do not have clear L1 counterparts have been repeatedly shown to be difficult to learn (Bohn & Flege, 1990, 1992, Flege, Bohn, & Jung, 1997; Ingram & Park, 1997; Munro, 1993; Munro, Flege & Mackay, 1995; Strange, Yamada, Kubo, Trent, Nishi, & Jenkins, 1998; Wang, 1997, 2002; Wang & Munro, 1998, 1999, 2004). For example, Munro (1993) found that native Arabic speakers perceived and produced English tense and lax vowel distinctions in terms of long and short vowel category differences as found in Arabic, indicating strong influence of the speakers' L1 experience. Similarly, in L2 vowel production, Wang (1997) found that native Mandarin speakers produced English vowels without clear Mandarin counterparts significantly less intelligible than those with their L1 counterparts. In a most recent study, late Korean-English bilinguals showed evidence of unidirectional influence of the L1 on the L2 and produced English vowels that were heavily "colored" by acoustic properties of their Korean vowels (Baker & Trofimovich, 2005).

However, there is also evidence that first language experience influence alone cannot explain all L2 vowel perception problems. For example, Bohn (1995) reported that native Spanish and Mandarin speakers relied heavily on duration cues in their perceptual identification of the English /i/-/ɪ/ contrast although neither Mandarin nor Spanish contrasts long and short vowels in their vowel systems. Based on these findings, Bohn (1995) proposed the Linguistic Desensitization Hypothesis (LDH), which states that L2 listeners, regardless of their L1 experience, will rely on duration cues whenever spectral cues are not sufficient to signal non-native vowel contrasts. Therefore, the use of duration cues reflects a general speech perception strategy that takes over whenever spectral information is not sufficient to signal the non-native vowel contrasts. The model hypothesizes that there is a common strategy for L2 vowel perception that is independent of a speaker's first language experience.

It is important to note that the LDH is based on a study that involved only one pair of L2 vowels, the English /i/-/ɪ/contrast. Whether it applies to other vowel contrasts needs to be tested. In a preliminary study using synthesized English /i/-/ɪ/ and /u/-/ʊ/ contrasts that differed systematically in duration and spectral steps, Wang and Munro (1999) found that while native English speakers responded exclusively to vowel spectral cues for both vowel contrasts, native Mandarin speakers relied heavily on duration cues for the /i/-/ɪ/ but not for the /u/-/ʊ/ contrast. The results of the /i/-/ɪ/ contrast were in agreement with Bohn's findings in that the listeners who failed to perceive the vowel spectral differences all responded exclusively to the duration cues. However, the findings with the /u/-/ʊ/ contrast did not appear to support the LDH because the general speech perception strategy of using the duration cues did not kick in when the listeners failed to perceive the spectral differences for the /u/ and /ʊ/ contrast. It was not clear why the native Mandarin listeners made use of duration cues systematically for only the /i/-/ɪ/ pair but not the /u/ - /ʊ/ contrast as Mandarin has both /i/ and /u/ but lacks /ɪ/ and /ʊ/ categories in a symmetrical way and the synthesized test stimuli manipulated both spectral and duration properties in the same fashion. Obviously, studies with multiple non-native vowel contrasts are needed to test the Linguistic Desensitization Hypothesis as well as different assimilation patterns hypothesized in both the PAM and SLM models.

This study addresses L2 vowel perception problems through testing native Mandarin speakers' perception of three non-native vowel contrasts, the English /i/-/ɪ/, /u/-/ʊ/, and /æ/-/ɛ/ pairs which pose serious problems for native Mandarin speakers in both perception and production (Wang, 1997, Rogers, 1997). Synthesized vowel continua manipulating vowel spectral and temporal cues were used to assess the listeners' perceptual patterns. The goal is to explore the nature of Mandarin listeners' perceptual problems with these vowel contrasts and to identify strategies they implement to differentiate non-native vowel contrasts. With increased number of nonnative vowel contrasts than the previous studies, this study also explores whether native Mandarin listeners use different strategies to identify the three target vowel contrasts when they fail to show native-like perceptual patterns. The specific research questions to be addressed are: 1) Do native Mandarin listeners show native-like perceptual patterns when identifying English vowel contrasts? 2) If they fail to show native-like perception, do they show ability to distinguish the spectral end points for each of the three target

English vowel contrasts under investigation? 3). If the Mandarin listeners fail to respond to vowel spectral cues in a native-like way, will they automatically rely on duration cues to distinguish all three vowel contrasts? In other words, do Mandarin listeners apply the same strategy in perceptual identification of the three target English vowels that do not contrast in their L1?

1.1. Mandarin Vowels

Mandarin is generally described as having five vowel phonemes /i y u e a/ with about a dozen surface forms [i y i ɯ u e ə ɤ o ɛ a]. The exact number of surface forms varies according to different descriptions (Chao, 1968; Cheng, 1966; Howie, 1976; Li & Thompson, 1981; Svantesson, 1984; Wu, 1994). The mid vowel /e/ is realized as [ɛ] in rising diphthongs /jɛ/ and /ɥɛ/, and as [o] before /u/. The low vowel /a/ is centralized in quality and is phonetically different from the English /ɑ/. The Mandarin [u] is described as both higher and more posterior than the English counterpart (Norman, 1998). Although the [ɪ] and [ʊ] symbols sometimes appear in Mandarin diphthongs [eɪ], [aɪ] and [oʊ], [aʊ], they only indicate the direction of the movement and therefore function as glides [j] and [w] (Dow, 1972). Compared with the English [ɪ ɛ æ ʊ], which all occur as stressed monophthongs, Mandarin lacks such counterparts in its vowel system. Therefore, it can be viewed that Mandarin has categories comparable to the English [i eɪ u oʊ] but lacks the [ɪ ɛ ɔ æ ʊ ɑ ʌ] categories.

Table 1. Native Mandarin participants' background information

ID	Gender	Age	LOR	AOL	% Use English
M03	f	30	9	11	20
M04	f	33	12	15	50
M05	f	22	69	12	50
M07	f	22	10	11	80
M08	m	33	5	15	10
M09	f	24	44	13	50
M12	f	31	13	9	50
M13	m	18	48	12	60
M14	m	24	14	12	30
M15	f	26	13	13	25
M16	f	34	2	13	100
M17	m	30	6	9	50
M18	f	39	27	13	30
M19	m	38	60	12	90
M20	m	31	5	11	20
M23	f	42	12	23	98
M24	f	28	4	14	70
Mean		29.7	20.8	12.8	51.9

Age = reported in years
LOR = Length of residence in Canada (months)
AOL = Age at which learning English began in home country (years)
% Use English = Subject's estimated % daily use of English outside home.

2. METHOD

2.1. Participants

The participants were 17 Mandarin speakers (6 male and 11 female) recruited from the international student population from a western Canadian university in British Columbia. Fifteen of them were born and raised in Mainland China and the remaining two in Taiwan. They ranged in age from 18 - 42 years (mean = 30) at the time of the study. All were advanced Mandarin-English bilinguals and their mean length of residence in Canada was two years (range = 0.5-5.5 years). All participants had studied English in their country of origin, beginning at a mean age of 13 years. Their mean age of arrival in Canada was 28 years (range = 13-34 years). According to self-report, their estimated daily use of English ranged from 20%-100% (mean = 52%). The participants' background information is summarized in Table 1. Six native English speakers (4 male and 2 female, mean age = 29) from the student and faculty population in a university in California took the same test as control subjects. Although the native English speakers were not from the same region in which the L2 speakers resided, they were included because their perceptual patterns in terms of responding to the spectral and duration steps of the three vowel continua were virtually identical to six native Canadian English speakers who were tested on the same synthesized vowel continua during stimuli preparation. Both the Canadian and American English speakers responded exclusively to spectral cues for the target vowel contrasts. Only the American English listeners' data were analyzed as a control group as the Canadian English listeners' data were used for testing the stimuli.

2.2. Stimulus Preparation

The English /hid/-/hɪd/, /hud/-hʊd/, and /hæd/-/hɛd/ continua were generated using a Klatt (1980) synthesizer at 20-kHz sampling rate with 16-bit resolution in the cascade mode. All three continua were synthesized with six duration and six spectral steps producing 36 tokens per continuum. The F1-F3 formant frequency values are summarized in Table 2. For the duration steps, the six longest vowels (at step 1) were 250 ms and the six shortest were 125 ms (at step 6) with a 25 ms increment between two steps. A formant contour was incorporated by using different values of F1 and F2 at the beginning and end of the vowel portion for each spectral step. F0 was set at 125 Hz at the beginning and dropped gradually to 105Hz at about the mid point of the vowel and then to 100 Hz toward the end. During the stimulus synthesis phase, three native Canadian English listeners provided feedback in an open-set identification test. They were not told that the stimuli

Table 2. F1-F3 values of synthesized /hid/- /hɪd/, /hud/- hʊd/, and /hæd/-/hɛd/ vowel continua

/hid/- /hɪd/

	F1		F2		F3
Spectral Steps	Start	End	Start	End	
1	300	300	2020	2020	2960
2	316	320	1984	1972	2900
3	332	339	1948	1923	2840
4	348	363	1912	1862	2780
5	364	394	1876	1776	2720
6	380	440	1840	1640	2660

/hud/- hʊd/

	F1		F2		F3
Spectral Steps	Start	End	Start	End	
1	350	320	1250	1000	2300
2	370	355	1220	1035	2310
3	390	390	1190	1070	2320
4	410	425	1160	1105	2330
5	430	460	1130	1140	2340
6	450	500	1100	1180	2350

/hæd/-/hɛd/

	F1		F2		F3	
Spectral Steps	Start	End	Start	End	Start	End
1	640	690	1690	1520	2430	2470
2	610	670	1730	1560	2445	2485
3	580	650	1770	1600	2460	2500
4	550	630	1810	1640	2475	2515
5	520	600	1850	1680	2490	2530
6	490	580	1890	1720	2505	2545

presented to them were synthesized speech and were only told to write down the words they heard in English orthography. When the continua were completed, all endpoint stimuli (steps 1 & 2 and steps 5 & 6) were perfectly identified (as the target vowel) by another three native Canadian English speakers in an open-set identification test; this was observed regardless of the differences in duration. The stimuli were then normalized for peak amplitude using Sound Edit 16 software for playback.

2.3. Procedures

Individual perceptual test sessions were held in a sound-treated room using custom-designed software on a Macintosh computer. The 36 /hVd/ words per vowel continuum were repeated once generating 72 tokens for each vowel contrast. The test stimuli were presented in three separate blocks as two-way forced choice identification tasks. The keyword labels used for the tests were heed/hid, who'd/hood, and had/head respectively for each vowel contrast. The order each listener identified the three vowel blocks was counterbalanced. Each listener completed a trial session to learn the test procedure before taking the test. During the test, each stimulus was played only once through the headphones and the listener identified the word by pressing a labeled button on the computer screen. The listener had the control over the pace of the test by either immediately or delaying as much as they wanted in clicking the button each time after a stimulus was presented. As soon as the listener clicked the button, the next trial was played back. The test data were collected automatically by the computer and saved for subsequent analysis.

3. RESULTS

3.1. Overall Results

The Mandarin and English groups' mean percentage identification as the tense endpoint in the series (hereafter % ID) scores on "heed/hid," who'd/hood," and "had/head" vowel continua were calculated for each of the six spectral and six duration steps and are presented in Figure 1. The % ID scores on each spectral step were pooled over the six duration steps, and the scores on each duration step were pooled over the six spectral steps. To quantify listeners' responses to spectral cues, their % ID scores on "heed/hid", "who'd/hood", and "had/head series" at spectral steps 1 & 2 across all six duration steps (the most "heed", "who'd", and "had" like tokens) and at spectral steps 5 & 6 across the six duration steps, (the most "hid", "hood", and "head" like tokens) were calculated. If the listeners relied exclusively on the spectral cues to contrast the vowel pairs, they should identify the stimuli at spectral steps 1 & 2 (the unambiguous "heed", "who'd", and "had" stimuli) 100% as "heed", "who'd", and "had" respectively across the three vowel continua. Their % ID scores on "heed", "who'd", and "had" should decline along the continua and reach 0% at spectral steps 5 & 6 (the spectrally unambiguous "hid", "hood", and "head" stimuli). Similarly, if the listeners relied exclusively on duration cues to contrast these vowel pairs, they should identify all the longest tokens (at duration steps 1 & 2) 100% and shortest stimuli (at duration steps 5 & 6) 0% as "heed", "who'd", and "had".

Furthermore, listeners' degree of sensitivity to spectral cues to contrast these vowel pairs were assessed by subtracting their mean % ID scores of spectral steps 5 & 6 from the mean % ID scores of spectral steps 1 & 2. The higher the % difference between the two spectral end points, the more the listeners responded to the spectral cues for labeling the vowel contrasts. For example, the spectral end point difference score would be 100% if a listener identified all the spectral step 1 & 2 tokens as "heed" and step 5 & 6 tokens as "hid". Similarly, the higher the % difference scores between the duration end points, the more the listeners relied on duration cues for contrasting the vowel pairs.

For the native English group, the mean spectral end point difference scores were 95%, 99% and 97% for "heed", "who'd", and "head" respectively, indicating almost exclusive

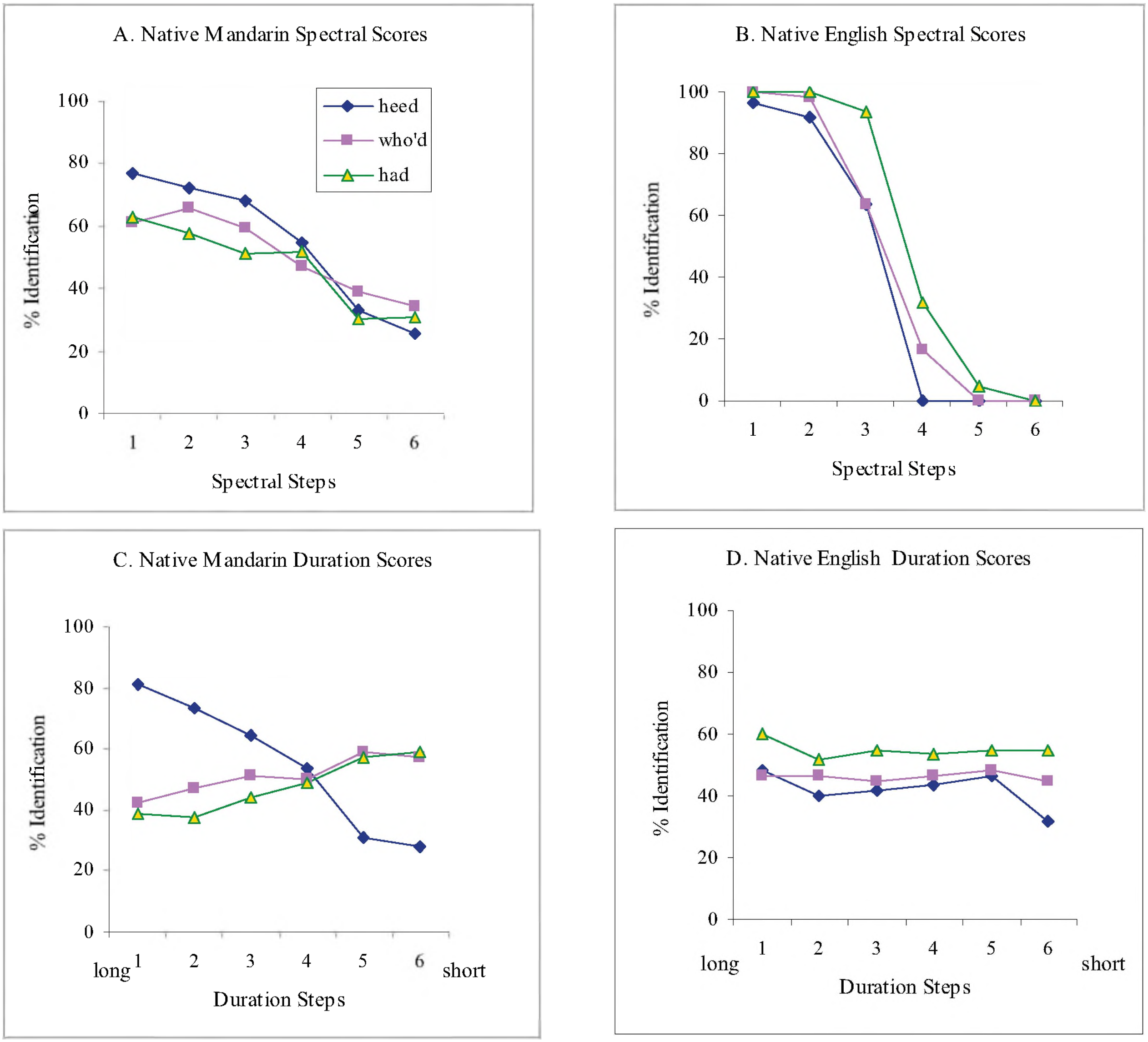

Figure 1. Native Mandarin (Panel A & C) and English (Panel B & D) listeners’ mean % ID scores on “heed,” who’d,” and “had” of the three vowel continua at six spectral steps (Panel A & B) and six duration steps (Panel C & D). The scores on each spectral step were pooled over the six duration steps, and the scores at each duration step were pooled over the six spectral steps.

use of spectral cues in perceptual identification of these three vowel pairs. In contrast, their % duration end point difference scores were 6%, 2%, and 4% respectively. For the native Mandarin group, the mean spectral end point difference scores were 35%, 26%, 29% and the mean duration end point difference scores were 47%, -13%, and -20% for “heed/hid”, “who’d/hood”, and “had/head series respectively.

Two ANOVAs were conducted to address question 1 raised in the introduction – do Mandarin listeners show native-like perception when identifying the 3 English vowel contrasts. First, spectral endpoint difference scores were analyzed in a two-way ANOVA with group (Mandarin & English) as between subject factor and vowel pair (heed/hid, who’d/hood, had/head) as within subject factor. This analysis established an effect of group [F(1,21) = 42.428, p = .000] but the factor of vowel pair [F(2,42) = .203, p = .817] and vowel pair × group interaction [F(2,42) = .421, p = .659] were not significant. Next, the same two-way ANOVA was conducted on the mean *duration* end point difference scores to assess whether Mandarin listeners responded to the duration cues like native English listeners. This analysis revealed no effect of group [F(1,21) = .001, p = .970]. However, both vowel pair [F(2,42) = 4.688, p = .015] and vowel pair × group interaction [F(2,42) = 3.900, p = .028] were significant. Follow up one-way ANOVAs established a significant difference between Mandarin and English groups on the “heed/hid vowel pair [F (1,21) = 8. 343, p = .009] only. English and Mandarin listeners did not differ in their response to duration end points for the who’d/hood pair [F (1,21) =

.597, p = .448] or the "had/head" pair [F (1,21) = 1.459, p = .240]. These results show that the native Mandarin listeners did not show sensitivity to spectral cues that is comparable to that of native English listeners for any of the three target vowel contrasts and they failed to show a native-like response pattern to duration cues when identifying the heed/hid contrast. However, for who'd/hood and the had/head contrasts the Mandarin listeners conformed to the pattern observed in native English listeners showing little sensitivity to the durations cues.

To further explore native Mandarin listeners' sensitivities to spectral and duration cues and to address questions 2 and 3 regarding perceptual strategy, two statistical analyses on the % ID scores were carried out for the Mandarin group only. First, a two-way ANOVA with vowel pair (heed/hid, who'd/hood, had/head) and spectral endpoint (mean steps 1 & 2 vs. mean steps 5 & 6) as within subject factors was conducted. This ANOVA established a significant effect for spectral end point [F(1,28) = 33. 097, p = .000] and for vowel pair [F(2,48)= 4.109, p = .023] but the vowel × spectral end point interaction was not significant F(2,48) = .906, p = .411]. These findings show that Mandarin listeners were able to reliably distinguish the spectral end points of each vowel pair although their perceptual pattern was not native-like. Pairwise comparisons on vowel pair show that overall % ID scores were higher for the heed/hid than for the had/head series.

Next, the same two-way ANOVA was conducted on % ID scores with *duration* end point (mean steps 1 & 2, mean steps 5 & 6) and vowel pair (heed/hid, who'd/hood, had/head) as within-subject factors. This ANOVA showed no effect of duration end point [F(1, 48) = .562, p = .457] or vowel pair [F(2, 48) = 1.836, p = .170]. However, the vowel pair× duration endpoint interaction was significant [F(1, 48) = 12.241, p = .000]. Three follow up t-tests were conducted to examine the simple effect of vowel duration endpoint for each vowel pair. The results statistically confirm the pattern plotted in Figure 1C, showing that percentage identification scores were significantly different for long vowel tokens (steps 1&2) compared to shirt vowel tokens (steps 5&6) for the heed/hid series [t(16) = 5.749, p = .000] but not for the who'd/hood series [t(16) = 1.153, p = .266] and had/head series [t(16) = 1.729, p = .103]

Table 3. Native English listeners' end point difference scores (mean % scores of steps 1&2–mean % scores of steps 5&6)

ID	Contrasts	Spectral*	Duration*	Absolute D*
E01	heed/hid	100	13	13
E02		96	0	0
E03		96	0	0
E04		88	17	17
E05		96	13	13
E06		96	-4	4
E01	who'd/hood	100	13	13
E02		100	-8	8
E03		96	8	8
E04		100	8	8
E05		100	-17	17
E06		100	8	8
E01	head/had	92	21	21
E02		100	8	8
E03		100	17	17
E04		92	-8	8
E05		100	-4	4
E06		96	-8	8
Mean/SD		97(3.7)	10 (5.7)	10 (5.7)
- 2 SD		90	-1.7	
+ 2 SD		104	21.1	

Spectral = Spectral end point difference scores
Duration = Duration end point difference scores
Absolute D = Absolute value of duration end point difference scores

Overall, the analyses show that while Mandarin listeners did not demonstrate native-like perceptual patterns in responding to vowel spectral cues across the target vowel contrasts, they did reliably distinguish the spectral end points for each vowel series indicating they had some sensitivity to vowel spectral cues. However, they differed in their response to the duration end points across the three vowel pairs, they reliably distinguished the duration cues for the heed/hid contrast but not for the other two vowel contrasts.

3.2. Individual Differences

Individual listener responses were also examined to address the same research questions. Individual data were evaluated in two ways: 1) to determine whether any native Mandarin listeners established native-like perceptual patterns in responding to spectral and duration cues to label the three target vowel pairs and 2) to assess how individual listeners responded to spectral and duration cues when perception was not native-like. For the first type of analysis, the mean and standard deviations of native English group's end point difference scores were used as references. A Mandarin listener would be considered to have established native-like perceptual pattern for contrasting each vowel pair if their spectral and duration end point difference scores fall within two plus and minus standard deviations of the native English mean scores, i.e. 90% or above for spectral cues and 21% or less for duration cues.

Individual native English listeners' spectral and duration end point difference scores with the group mean and standard deviations are presented in Table 3. The absolute values of native English listeners' end point difference scores were taken for computing the mean and standard deviations as one or two listeners had negative duration end point difference scores for each vowel pair (see Table 3). Individual Mandarin listener's % ID scores for heed/hid, who'd/hood and had/head at six spectral and six duration steps as well as the end point difference scores (mean % scores of steps 1 & 2 – mean % scores of steps 5 & 6) are presented in Table 4 through Table 6.

As seen from Tables 4-6, across the three vowel pairs, very few listeners' spectral end point scores fell within two standard deviations (highlighted in bold) of the native English mean score, which is 90% and above. Two out of the 17

Table 4. Mandarin listeners' % ID scores of "heed" at each spectral and duration step and the % end point difference scores (steps 1&2-steps 5&6). The numbers in bold indicate those fall within 2 standard deviations of the native English mean. Listeners whose end point difference scores meet the 70% criterion for "spectral" (S), or "duration" (D) cues , or neither (N) are presented in the last row.

Individual Listeners and % Perceptual Scores for "heed"																	
Steps	M03	M04	M05	M07	M08	M09	M12	M13	M14	M15	M16	M17	M18	M19	M20	M23	M24	Mean
Spectral 1	100	58	83	50	100	67	100	75	92	83	33	58	92	100	92	50	75	77
Spectral 2	100	58	92	67	100	50	83	58	83	92	50	58	50	83	100	58	42	72
Spectral 3	92	58	75	58	67	50	67	67	75	50	67	58	75	83	92	67	58	68
Spectral 4	75	50	25	50	58	50	67	58	50	25	75	58	58	75	42	58	50	54
Spectral 5	17	42	0	67	0	25	17	25	17	25	50	58	50	33	17	67	58	33
Spectral 6	0	50	0	58	0	33	8	0	33	17	67	42	33	0	0	50	42	25
1&2-5&6	**92**	12	88	-4	**100**	30	79	54	63	67	-17	8	30	75	88	-5	9	45
Steps	M03	M04	M05	M07	M08	M09	M12	M13	M14	M15	M16	M17	M18	M19	M20	M23	M24	Mean
Duration 1	75	100	58	100	58	100	58	67	92	67	83	100	100	75	67	92	83	81
Duration 2	67	67	58	92	50	92	58	67	67	42	67	100	92	75	58	100	92	73
Duration 3	58	67	50	83	50	42	75	50	67	42	92	92	83	67	50	58	67	64
Duration 4	67	67	42	50	67	42	75	58	58	50	50	33	42	42	50	67	50	53
Duration 5	58	8	42	17	58	0	50	17	33	42	33	8	25	42	42	17	33	31
Duration 6	58	8	25	8	42	0	25	25	33	50	17	0	17	75	75	17	0	28
1&2-5&6	**13**	76	**16**	84	**4**	96	**21**	46	47	**9**	50	96	75	**17**	**4**	79	71	48
70% S. D. N.	S	D	S	D	S	D	S	N	N	N	N	D	D	S	S	D	D	

Table 5. Mandarin listeners' % ID scores of "who'd" at each spectral and duration step and the % end point difference scores (steps 1&2-steps 5&6). The numbers in bold indicate those fall within 2 standard deviations of the native English mean. Listeners whose end point difference scores meet the 70% criterion for "spectral" (S), or "duration" (D) cues , or neither (N) are presented in the last row.

Individual Listeners and % Perceptual Scores for "who'd"																	
Steps	M03	M04	M05	M07	M08	M09	M12	M13	M14	M15	M16	M17	M18	M19	M20	M23	M24	Mean
Spectral 1	8	100	50	58	100	100	17	33	58	100	25	92	50	58	100	33	58	61
Spectral 2	25	100	33	42	92	100	33	42	58	92	42	92	67	92	100	58	50	66
Spectral 3	17	83	33	50	100	100	42	33	42	75	50	92	58	67	83	42	42	59
Spectral 4	33	58	50	42	50	50	58	67	33	42	50	42	58	33	25	58	50	47
Spectral 5	58	25	42	67	17	42	58	50	58	25	42	8	50	33	0	42	42	39
Spectral 6	83	0	58	58	0	0	100	67	33	0	33	0	33	0	0	42	75	34
1&2-5&6	-54	88	-9	-13	88	79	-54	-21	13	84	-4	88	17	59	**100**	4	-5	**27**
Steps	M03	M04	M05	M07	M08	M09	M12	M13	M14	M15	M16	M17	M18	M19	M20	M23	M24	Mean
Duration 1	25	58	100	92	58	58	33	17	25	58	17	50	0	42	58	25	0	42
Duration 2	58	50	75	92	50	67	42	42	33	58	25	58	8	33	42	42	25	47
Duration 3	42	58	42	83	58	50	42	67	42	67	0	58	58	58	58	58	33	51
Duration 4	25	50	33	50	58	75	42	33	50	58	25	67	67	50	50	50	67	50
Duration 5	50	75	17	0	67	67	67	67	67	58	83	50	83	42	58	58	92	59
Duration 6	25	75	0	0	67	75	83	67	67	33	92	42	100	58	42	42	100	57
1&2-5&6	**4**	**-21**	79	92	**-13**	**-9**	-38	-38	-38	**13**	-67	**8**	-88	**-13**	**0**	**-17**	-84	-13
70% S. D. N.	N	S	D	D	S	S	N	N	N	S	N	S	D	N	S	N	D	

Table 6. Mandarin listeners’ % ID scores of “who’d” at each spectral and duration step and the % end point difference scores (steps 1&2-steps 5&6). The numbers in bold indicate those fall within 2 standard deviations of the native English mean. Listeners whose end point difference scores meet the 70% criterion for “spectral” (S), or “duration” (D) cues , or neither (N) are presented in the last row.

Individual Listeners and % Perceptual Scores for “had”																	
Steps	M03	M04	M05	M07	M08	M09	M12	M13	M14	M15	M16	M17	M18	M19	M20	M23	M24	Mean
Spectral 1	100	58	83	58	33	75	25	83	83	58	58	58	42	50	58	50	100	100
Spectral 2	75	58	58	58	50	67	25	50	58	75	58	83	58	25	58	33	92	75
Spectral 3	50	42	42	67	58	50	33	50	50	33	75	58	58	25	33	50	92	50
Spectral 4	58	42	17	50	50	50	58	42	50	75	58	58	50	50	42	42	92	58
Spectral 5	0	42	8	42	50	8	25	25	17	25	67	42	17	33	58	50	8	0
Spectral 6	0	33	25	25	58	25	42	50	8	8	58	42	67	8	50	25	0	0
1&2-5&6	88	21	54	25	-13	55	-9	29	58	50	-5	29	8	17	4	4	**92**	30
Steps	M03	M04	M05	M07	M08	M09	M12	M13	M14	M15	M16	M17	M18	M19	M20	M23	M24	Mean
Duration 1	58	8	33	67	25	67	0	33	42	50	83	25	0	0	92	8	67	58
Duration 2	50	8	33	67	42	50	8	17	42	42	67	33	0	33	67	8	67	50
Duration 3	33	33	58	67	33	50	8	58	50	42	75	42	50	42	50	8	50	33
Duration 4	33	42	33	58	33	42	33	50	58	58	75	50	58	58	33	50	67	33
Duration 5	50	83	50	33	75	33	67	75	33	50	42	100	83	25	33	75	67	50
Duration 6	58	100	25	8	92	33	92	67	42	33	33	92	100	33	25	100	67	58
1&2-5&6	**0**	-84	**-5**	47	-50	26	-76	-46	**5**	**5**	38	-67	-92	**-13**	51	-80	**0**	-20
70% S. D. N.	S	D	N	N	N	N	D	N	N	N	N	N	D	N	N	D	S	

listeners (M03 and M08) met the criteria for the heed/hid contrast. Only one listener each met this standard for the who’d/hood (M20) and for the had/head contrast (M24). None of the Mandarin listeners demonstrated native-like perceptual patterns to identify all three target vowel contrasts.

A more complicated pattern was observed with individual Mandarin listeners’ duration end point difference scores across the three target vowel contrasts. First, while none of the listeners had negative duration end point difference score for the heed/hid pair, over half of the listeners had it for the who’d/hood and had/head pairs (see Tables 4-6). Second, several listeners had substantially high negative end point duration difference scores (ranging from -76% to -92%) suggesting that these listeners switched the labels in responding to duration cues as they consistently identified short stimuli as “who’d” and “had” and long stimuli as ‘‘hood’ and “head” respectively. Because of these negative scores, the absolute values of the spectral and duration end point scores were taken for judging whether each individual listener met the native-like criteria. However, the negative end point difference scores are still presented in their original value in Tables 4-6 to facilitate identification the label switching listeners.

Applying the 21% or less native-like standard for the duration end point difference scores, seven, nine, and six listeners (highlighted in bold in Tables 4-6) fell within the 2 standard deviation criterion for the heed/hid, who’d/hood and had/head pair respectively. These results show that while only one or two listeners met the native-like standard for responding to spectral cues, substantially more listeners met the native-like criterion for not using duration cues to contrast these target vowel pairs.

For the second type of analysis on individual data, a 70% or higher end point difference score was used as criterion to assess whether an individual listener showed some sensitivity to spectral or duration cues (even though most did not show native-like perceptual patterns). This criterion requires the listeners to identify each endpoint at least 20% above chance level. Applying this criterion, listeners whose spectral end point difference score was 70% or higher were categorized as +S for their sensitivity to the spectral cues. Similarly, those whose duration end point difference scores was 70% (absolute value) or higher were categorized as +D for their sensitivity to duration cues. Listeners whose spectral and duration endpoint difference scores both fell below the 70% criterion were classified as +N for using neither spectral nor duration cues. The classification of each individual listener into these three categories based on this standard is presented in the last row of Table 4 through Table 6 for the three vowel contrasts respectively.

The total number of listeners fell into each of the above three categories, +S, +D, and +N for each vowel contrast are summarized in Table 7. Applying this standard, as seen in Table 7, more listeners (7) responded to duration cues (+D) for the heed/hid pair than for the who’d/hood (4) and had/head

Table 7. Number of listeners classified as +S, +D, and +N for each target vowel pair

Classified	Heed/hid	Who'd/hood	Had/head
+S	6	6	2
+D	7	4	4
+N	4	7	11

pairs (4). Furthermore, substantially more number of listeners respond to neither spectral nor duration cues (+N) for the had/head (11) and who'd/hood (7) pairs than for the heed/hid (4) pair.

To summarize, only one or two out of the 17 Mandarin listeners met the native-like criteria to respond to spectral cues to identify each vowel contrast and none met the native-like criteria to identify all three vowel contrasts. The individual data also showed that listeners used different strategies in differentiating the three target vowel pairs when they failed to show native-like perceptual patterns. More listeners responded to duration cues for the heed/hid contrast than for the other two contrasts. Furthermore, the majority of individual listeners did not appear to respond to either spectral or duration cues to contrast the had/head and who'd/hood pairs. These listeners did not appear to have clear separate categories for these vowel pairs.

4. DISCUSSION

Revisiting the three research questions raised earlier, the current data provide negative answer to question 1 – do native Mandarin listeners show native-like perceptual patterns when identifying the English /i/-/ɪ/, /u/-/ʊ/, and /æ/-/ɛ/contrasts. The listeners were able to reliably distinguish the spectral end points of each vowel pair, indicating they were somewhat sensitive to vowel spectral differences. Therefore, the data provide positive answer to question 2 - if they fail to show native-like perception, do they show ability to distinguish the spectral end points for each of the three target English vowel contrasts under investigation? The data provide negative answer to question 3 – if the Mandarin listeners fail to respond to vowel spectral cues in a native-like way, will they automatically rely on duration cues to distinguish all three vowel contrasts? The results show that the listeners relied on duration cues to distinguish the /i/-/ɪ/ but not /u/-/ʊ/, and /æ/-/ɛ/contrasts. These differences suggest that Mandarin listeners applied different strategies in identifying the three vowel contrasts that had parallel acoustic/phonetic properties.

The analysis of individual listener data further supported the above findings. First, very few listeners met the native like criterion for relying on spectral cues to distinguish the target vowel pairs. Second, when the listeners failed to respond to spectral cues, the majority of them automatically relied on duration cues to contrast the heed/hid contrast but not who'd/hood or had/head contrasts. Third, the majority of the listeners responded to neither spectral nor duration cues systematically to distinguish the who'd/hood or had/head contrasts. The findings suggest that these listeners did not have clear two-category distinctions for the who'd/hood or had/head contrasts.

Although the acoustic structures of the three vowel pairs are parallel and the spectral and duration cues were presented in a systematic manner in the synthesized stimuli, the Mandarin listeners responded differently across the three vowel continua. Are such perceptual differences due to assimilation? What are some other factors that influence the use of different strategies in distinguishing these vowel pairs? To answer these questions, it is necessary to examine the nature of Mandarin speakersù perceptual problems from the perspective of current perceptual assimilation theories, in particular, Bestùs Perceptual Assimilation Model and Flegeùs Speech Learning Model and the Linguistic Desensitization Hypothesis.

The current data did not provide consistent support for the Linguistic Desensitization Hypothesis, which states that L2 speakers will rely on duration cues to differentiate the non-native vowel contrasts whenever vowel spectral differences are not sufficient to signal the contrasts (Bohn, 1995). Apparently, the majority of Mandarin speakers who had problems discriminating the three target vowel contrasts did not automatically and consistently respond to duration cues for the English /u/-/ʊ/ and /æ/-/ɛ/ contrasts, although they did for the /i/-/ɪ/ contrast. In fact, the majority of listeners did not respond to either spectral or duration cues to distinguish the /u/-/ʊ/ and /æ/-/ɛ/. Therefore, the use of the duration cues does not always take over as a general strategy whenever spectral cues are not sufficient to signal the non-native vowel contrasts. Obviously, Mandarin speakers used different strategies for different vowel contrasts in the current study and there is no such universal strategy for relying on duration cues for contrasting all three target vowel contrasts.

As discussed earlier in the introduction, Linguistic Desensitization Hypothesis was based on the L2 listenersù perception of the English /i/-/ɪ/ contrast only. It is interesting to note that both Bohnùs study (1995) and the current data show that speakers whose L1 does not contrast duration for its vowel system relied on duration cues to distinguish the English /i/-/ɪ/ contrast. Future studies need to test other L2 vowel contrasts that have parallel structures as the English /i/-/ɪ/, /u/-/ʊ/, and /æ/-/ɛ/pairs.

Applying the PAM Model, Mandarin listenersùperceptual problems with the English /u/-/ʊ/ and /ɛ/-/æ/ contrasts seem to fit the Single Category assimilation type, the assimilation of two L2 sounds to a single L1 category. However, the PAM model cannot explain the majority of the Mandarin listeners' use of the duration cues to perceptually distinguish the English /i/ - /ɪ/ contrast as the listeners did not simply "assimilate" the /ɪ/ sound to the L1 /i/, the single category in this area of the vowel space where English has /i/ and /ɪ/.

According to the Speech Learning Model, a new category fails to be established as an L2 speech sound in spite of the audible differences between the L2 sound and the closest L1 sound or between two closest L2 sounds if the learner fails to perceive such differences (Flege, 1995). Under this view, Mandarin speakers who had problems in perceiving the English /u/-/ʊ/ and /æ/-/ɛ/contrasts did not seem to have established phonetic categories for /ʊ/ and /æ/. Listeners who distinguished the /i/-/ɪ/ contrast based on temporal cues seemed to have established an *inaccurate* /ɪ/ category, because their perceptual representations of /ɪ/ were different from those of native English speakers. Therefore, at least some Mandarin speakersù perceptual problem with the /i/-/ɪ/ contrast suggests *modification* rather than assimilation.

Obviously, the PAM, the SLM and the LDH all partly explained some of Mandarin speakersù perceptual problem with English vowel contrast but none can fully account for the different strategies Mandarin speakers used in their perception of English vowels. What are some of the possible causes for such differences? In searching answers to this question, some possible factors are examined. First, Mandarin listenersù category representations of the target vowels might be influenced by L2 instruction. In China, the /i/-/ɪ/ contrast is commonly taught as two vowel categories that differ in length (Wang & Munro, 1999) while the /u/-/ʊ/, and /æ/-/ɛ/ pairs are not taught in the same manner. It is important that future studies examine learnersù L2 experience not only in terms of length of residence in the L1 environment but also in terms of formal pronunciation instruction in their country of origin.

Another possible explanation for the listenersù differences in perceptual patterns may be related to the difference in functional load each of the three target vowel contrasts bears. The /i/-/ɪ/ distinction bears more functional load and has more minimal pairs in English than does the /u/-/ʊ/ contrast (Brown, 1988). Hardly any commonly used vocabulary items are distinguished by the /u/-/ʊ/ contrast in English as minimal pairs (Brown, 1988; Kucera & Francis, 1967). Therefore, in real communication, the confusion caused by the substitution of /i/ for /ɪ/ would cause more problems than the substitution of /u/ for /ʊ/. The greater need to contrast /i/and /ɪ/ in communication probably results in more painstaking efforts from learners in finding the acoustic properties that signal the difference between the vowels in order to understand and to be understood. This might provide an explanation for the single category perception of the /u/-/ʊ/ but not for the i/-/ɪ/ pair.

However, the current data also showed that the majority of the listeners who had difficulties with the /æ/-/ɛ/ pair did not attend to the duration cues. This phenomenon cannot be explained by the functional load differences because, compared with the /u/-/ʊ/ pair, the /æ/-/ɛ/contrast actually has more minimal pairs and therefore bears a much greater functional load (Brown, 1988). The need to distinguish the /æ/-/ɛ/ contrast did not appear to help the learners (at least some listeners in the current study) to find strategies to distinguish this vowel pair. In fact, the /æ/-/ɛ/contrast appeared to be more resistant to perceptual learning as more Mandarin listeners were found to have perceptual difficulties with this pair (see also Wang, 2002).

One possible reason for the listenersù difficulties with the /æ/-/ɛ/ pair may be related to the high degree of spectral overlapping for the /æ/-/ɛ/ contrast. Evidence from L1 vowel perception tests suggests that the American English /æ/-/ɛ/contrast is intrinsically more spectrally confusing than the /i/-/ɪ/ and /u/- /ʊ/ contrasts. Hillenbrand & Clark (2000) reported that native American English speakersù identifications of English /i/-/ɪ/ and /u/-/ʊ/ contrasts were not affected by distorted duration (edited long and short vowels) differences because spectral differences were always sufficient for the differentiation of these vowel pairs. In contrast, their identifications of the /æ/-/ɛ/ contrast was affected by the distorted duration differences for the /æ/-/ɛ/ contrast. The authors speculated that the /æ/-/ɛ/ contrast showed a greater degree of spectral overlap than the /i/-/ɪ/ and /u/-/ʊ/ contrasts. Based on these previous findings on the English /æ/-/ɛ/ contrast, it might also be speculated that, although the physical steps of the synthesized vowel continua were controlled as equal, listeners might not *perceive* them as equal because the perceived duration differences might be affected by or interact with spectral properties differently across the three vowel pairs. Future studies need to test these differences with different L2 vowel contrasts.

Overall, the findings suggest that L2 vowel learning is a complex issue. A full understanding of the nature of the L2 vowel perception and production problems must consider not only the sound systems and assimilation patterns but factors such as learner characteristics, learning experience, and the influence of pronunciation teaching in foreign language classrooms. The current study took a step in this direction and future studies should take into consideration of these multiple factors when analyze non-native speakersù perception and production problems in learning L2 vowel contrasts. Future studies should include more vowel contrasts in different target languages, and different types of L2 learners.

ACKNOWLEDGEMENTS

The author appreciates many helpful comments from Linda Polka and two anonymous reviewers. The author also thanks all individuals for their participation.

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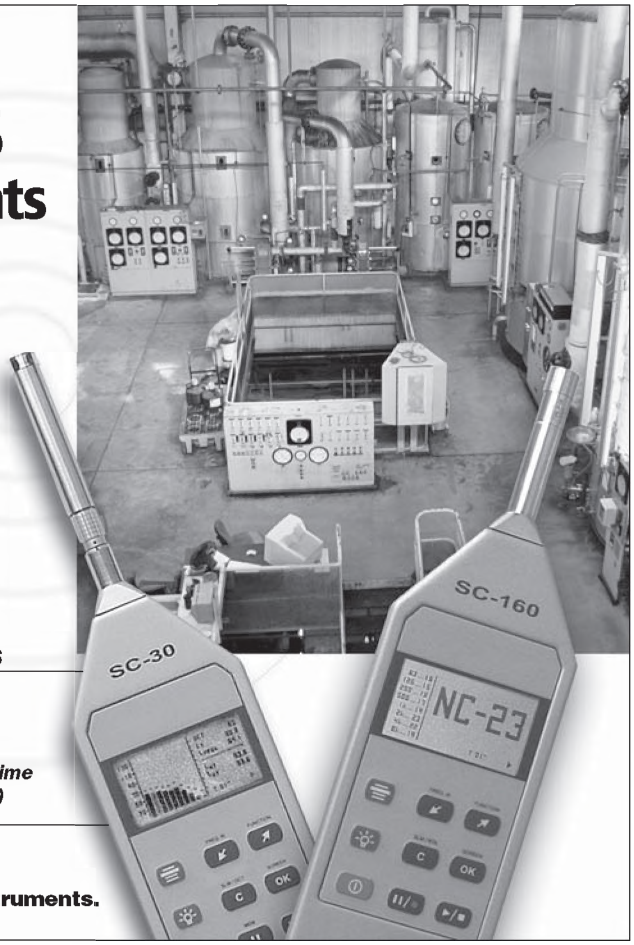

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TRANSMISSION LOSS OF ULTRA LIGHTWEIGHT CONCRETE BLOCK

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ABSTRACT

Transmission loss of ultra lightweight concrete block were measured in-situ and the FSTC (Field Sound Transmission Class) was established using the ASTM Standards.. Block wall constructions that were investigated include the untreated block, conditions with the block sealed and batt insulation installed on one side. The field STC performance was compared to earlier laboratory test results of Northwood and Monk [6] as well as predicted performance provided by National Concrete Masonry Association methods [2]. The field transmission loss of the ulta lightweight block showed that low field STC ratings are realized, due to the porous nature of the block, and that the block must be sealed to provide high field STC ratings. Further, the results showed that regression equation of Reference 2 is seen to provide an over-estimation of the STC rating for unsealed ultra lightweight block.

SOMMAIRE

Les pertes de transmission sonore d'un bloc de béton ultra léger ont été mesurées in situ et la classe de transmission sonore en conditions réelles (FSTC - Field Sound Transmission Class) a été établie en utilisant les normes ASTM. Les constructions de murs en blocs de béton qui ont été examinées comprennent un mur de blocs de béton sans traitement, un mur de blocs de béton scellés et un mur de blocs de béton avec de l'isolant en natte d'un côté. Les résultats des essais de classe de transmission sonore en conditions réelles ont été comparés à ceux d'essais en laboratoire effectués précédemment par Northwood and Monk [6] ainsi qu'à des prévisions de résultats fournies par des méthodes de la National Concrete Masonry Association methods [2]. Les pertes de transmission sonore en conditions réelles du bloc de béton ultra léger ont montré que des niveaux faibles de classe de transmission sonore en conditions réelles sont obtenus, en raison du caractère poreux du bloc de béton, et que le bloc de béton doit être scellé pour produire des niveaux élevés de classe de transmission sonore en conditions réelles. En outre, les résultats ont montré que l'équation de régression de la référence 2 se révèle produire une surestimation du niveau de classe de transmission sonore pour le bloc ultra léger non scellé.

1. INTRODUCTION

During the construction of a condominium project, the STC ratings of ultra lightweight block used between adjacent dwelling units were reviewed. These ultra lightweight blocks are being used by masonry contractors as their lighter weight reduces labour costs for the project.

For this project, the "ULTRA LITE Lightweight Concrete Block Masonry" by Richvale York Block Inc. was investigated [1]. Block weight comparisons are provided in Table 1. The ULTRA LITE Lightweight blocks are provided with nominal face dimensions of 190mm x 390mm, equivalent concrete thickness of 96.6mm, 1858 kg/m3 block density, and concrete type L2 20S. For this investigation the 15cm width, 60% solid, was used for the wall construction.

Metric Size (cm)	Block Weight Comparisons (kg)		
	Concrete	Lightweight	Ultra Lite
10	12.7	10	8.4
15	14	11.7	10.3
20	17.2	14	11.6
25	20.9	17.2	14.3
30	24.8	20.8	16.2

Table 1 Block Weight Comparison [Reference 1]

2. CALCULATED STC

Prior to testing, the calculated STC for the ULTRA LITE Block was provided by the manufacturer based on the empirical relationship shown by Equation 1.

$$STC = (0.18 \times density \times equivalent\ thickness) + 40$$

$$density = 115.9 \frac{lb}{ft^3}$$

$$equivalent\ thickness = 0.317\,ft$$

$$\therefore$$

$$STC = (0.18 \times 115.9 \times 0.317) + 40 = 46.613 \approx 47$$

Equation 1 from NCMA Tek 13-1A STC [References 2, 3]

The NCMA Tek 13-1A considers this equation to be applicable to uncoated fine- or medium-textured concrete masonry, and that coarse-textured units may require surface treatment (acrylic, alkyd latex, cement - based paint, plaster) to seal at least one side of the wall to achieve the calculated STC rating [4]. The sound ratings of concrete block walls noted in the National Building Code (Table A-9.10.3.1.A Note 3) also make reference to sealing the surfaces with at least two coats of paint or other surface finish to prevent sound leakage and achieve the stated STC ratings.

3. STC TESTING

The ULTRA LITE block was field tested in accordance with ASTM E-3365. The block wall was constructed between two reverberant rooms (concrete block construction, 2.6m wide x 4.9m long x 2.4m high, RT60 2s). Flanking paths through the doors to the rooms were sealed with batt insulation and duct tape. Sound measurements were conducted with a calibrated 2230 B&K sound level meter with 1/3rd octave band analyzer, with a white noise source. Three combinations of tests were conducted: 1) ULTRA LITE block, unsealed, 2) ULTRA LITE block with sealant on one side - Blocks were painted, but the paint was not able to provide an acceptable coating as the block soaked up the paint. As a result, Tremco Acrylic Fire Stopping Sealant was used - and 3) ULTRA LITE block with 88mm thick exposed pink batt insulation on one side. The field transmission loss data for each test is provided in Figures 1 thru' 3.

4. DISCUSSION

Table 2 summarizes the STC ratings for the three samples, which are compared to similar test results by Northwood and Monk [6], and the calculated STC from NCMA Tek 13-1A. [2]

Comparing the ULTRA LITE results with the Northwood/ Monk results shows a similarity between the two sets of tests. This provides some confidence in the field test results. Further, it shows that when left untreated, the 1 5cm 60% solid ULTRA LITE lightweight block will achieve FSTC-35, and requires sealant on one side to achieve an FSTC greater than 50 since the sealant provides significant transmission loss improvement (10-20 dB) across the frequency range of interest (160 – 4000Hz) (Please refer to Figure 2).

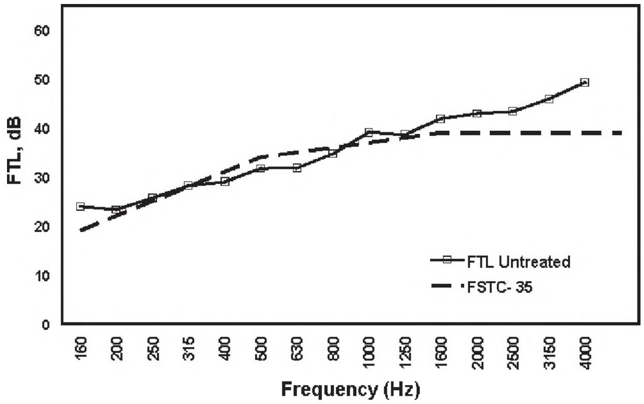

Figure 1. Ultra Lite Block, Untreated

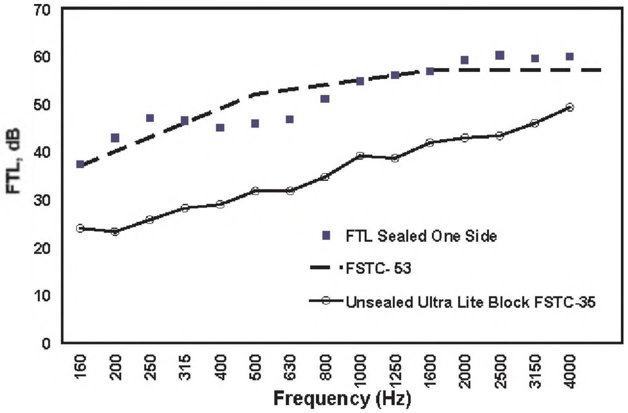

Figure 2. Ultra Lite Block, Sealed One Side

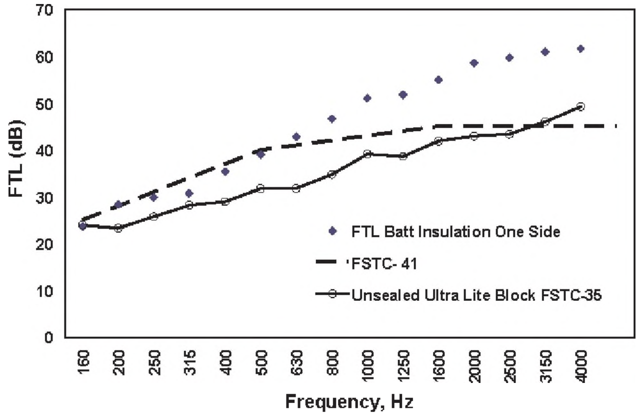

Figure 3. Ultra Lite Block, Batt Insulation One Side

The tested ULTRA LITE Block, when left untreated, significantly underperforms compared to the predicted Tek 13-1A rating (-12 STC points). However, with proper sealant on one side, significantly better performance (+6STC) than stated by the Tek 13-1A equation was achieved.

For normal weight concrete block walls, it is the mass per unit area and stiffness that typically governs the STC rating of the wall [7]. However, it is the porous nature, and hence low airflow resistance, of the ultra lightweight blocks that plays a significant role in determining its sound transmission loss8. With a porous material the sound waves that impinge on the wall continue their travel through the pore structure (though some of the energy is absorbed through friction). At the same time, the sound waves tend to move the wall as a whole, where this vibration is a parallel path for sound transmission (as determined by the mass and stiffness characteristics of the concrete). Both paths determine the overall transmission loss of a given wall [9].

Wall Type	No Treatment	Sealed, One Side	Batt Insulation, One Side
NCMA Tek 13-1A STC	46	46	46
ULTRA LITE Block, 15cm 60% solid	35	53	41
30cm Lightweight Block, NRC	39	51	-

Table 2. STC Comparison

With the porous ultra lightweight concrete, the transmission loss appears to be dominated by the low airflow resistance and is essentially independent of the weight or stiffness of the wall. However, once one side of the wall is sealed then the sound transmission takes place entirely by wall vibration, which then allows for higher STC ratings in the ultra lightweight block wall, as determined by the weight and stiffness [10]. Although not investigated here, research by Northwood and Monk showed that sealing both sides (versus one side) showed little improvement. Further, sealing both sides may produce reduced performance by enhancing the cavity-sealant resonance [6].

Of interest was the effect that batt insulation would have in improving the STC performance, as insulation is commonly used with block/drywall partition constructions. The results show that although the overall STC performance is improved (+6 dB) with batt insulation, this improvement is mainly in the higher frequencies, with little or no improvement below 400 Hz (Please refer to Figure 3). As sound waves pass through the porous structure of the block, some sound energy will be absorbed by the insulation after the waves pass through the block. The batt insulation is significantly better at absorbing higher frequencies than lower, and attenuates the sound energy accordingly, as is brought out in these field transmission loss results.

5. CONCLUSIONS

The following conclusions arise from the transmission loss test results presented in this paper.

a) Untreated ultra lightweight concrete block provides low FSTC ratings due to the porous nature, and hence low airflow resistance, of the block.

b) The ultra lightweight concrete block must be well sealed to provide FSTC ratings above 50.

c) The NCMA Tek 13-1A regression equation is suspect when applied to unsealed ultra lightweight concrete block, as it is significantly different than the field tested STC rating.

d) Sealing the ultra lightweight block with an acrylic sealant provides significant transmission loss improvement over the frequency range.

e) Application of batt insulation to the ultra lightweight block does improve mid to high frequency transmission loss performance, but does not provide significant benefit in the lower frequencies.

The following recommendations are based on the findings in this paper.

I. Block wall constructions utilizing the ultra lightweight concrete block must be well sealed on one side when used in critical noise applications (e.g. compliance with Building Codes)

II. Sealant should be acrylic, alkyd latex, cement - based paint, or plaster. This block is too porous for standard paint application, as the block will soak up the paint.

III. Sealant types with both one and two sides sealed can also be investigated, to determine if sealing both sides creates a cavity resonance effect with the ultra lightweight block and a specific sealant material (as was noted by Northwood and Monk for lightweight concrete).

IV. The NCMA Tek 13-1A regression equation should be revisited in light of the findings in this paper, as its use for determining STC ratings of unsealed ultra lightweight block types is suspect.

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10) H. Sabine (1960) Noise Control "Effect of Painting on Sound Transmission Loss of Lightweight Concrete Block Partitions"

ACKNOWLEDGEMENTS

I would like to thank the following: the Daniels Corporation for their cooperation with this investigation, and for providing the facilities for testing; Mr. John Swallow of Swallow Acoustic Consultants for his comments and suggestions; and Mr. Alf Warnock of NRC for his help with the reference ma-

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IN-CABIN NOISE LEVELS DURING COMMERCIAL AIRCRAFT FLIGHTS

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ABSTRACT

Air transport is one of the most commonly used mode of transportation and hence passenger comfort is highly desirable. Aircraft interior noise is important, especially in long-term flights, concerning the health, comfort, and psychological wellness of both passengers and flight crew. Noise levels, which changes according to different motions of aircraft, can be defined as the noise during takeoff and landing and during level flight (cruise). There are also non-aircraft-originating noise sources in the cabin. These can be classified into those caused by passenger activities such as conversations and luggage-related rearrangements as well as those caused by flight-crew such as flight attendant-related speaking activities, announcements from pilot and flight attendants, mechanical noises during food/beverage services and flight security demonstrations, and other announcement signals. In this study, in-cabin noise levels were measured during all flight activities in a commercial jet passenger plane. These noise levels consist of both continuous and discontinuous types. As a general tendency, continuous noise levels were seen to be 60-65 dB(A) prior to takeoff, and 80-85 dB(A) and 75-80 dB(A) during flight and landing, respectively. Discontinuous in-cabin noise levels were observed to reach levels as high as 81-88 dB(A) range. This study shows that it can be possible to control and reduce in-cabin noise levels, especially due to human activities and a few recommendations are suggested.

SOMMAIRE

La transportation aérienne est l'une des modalités de transportation la plus générale et de cela, le confort de passagers est hautement désirable. Le bruit intérieur de l'avion est important, particulièrement á des longues distances, concernant la santé, le confort et la vaccination psychologique de ces passagers et équipes de vole. Les aptitudes du bruit changes selon les motions différents de l'avion peuvent être définies comme le bruit durant le décollage et atterrissage et, durant le vole du niveau (excursion). Il y a aussi dans la cabine, des sources du bruit se produisant spontanément non pas par l'avion. Ces sources du bruit peuvent être classifiées dans celles-ci causées par des activités de passager telles que conversation et des réarrangements en relation avec bagage ainsi que celles-la causées par des équipes de vole telles que les activités d'expression en relation avec les gens attentant leur vole, les annonces faites par un pilot et les voles attendant á se réaliser, les bruits mécaniques durant les services de nourriture / breuvage et les démonstrations de sécurité au vole , et d'autres signales d'annonces. Dans cet étude, les niveaux du bruit ont été mesurés dans la cabine durant toutes les activités de vole réalisées dans une avion de passager commerciale. Ces niveaux du bruit consistent de tous ces types continues et discontinues. Comme une tendance générale, les niveaux du bruit continuels avaient été vus être 60 á 62 dB (A) avant le décollage et, respectivement 80 á 85 dB(A) et 75 á 80 dB(A) durant vole et atterrissage .Il a été observé que les nivéaux du bruit discontinues dans la cabine sont arrivées aux nivéaux aussi hauts que la gamme de 81 á 88 dB(A). Cet étude manifeste que il peut être possible de contrôler et réduire les niveaux du bruits dans cabine particulièrement due á des activités humaines et , quelques recommandations sont suggérées.

INTRODUCTION

Undesirable sound waves in an environment are defined as noise. The importance of noise pollution increases every day, due to its human-related hazards in modern world. Noise have both physiologically and psychologically negative effects on human health such as influencing temporary hearing losses like elevation of noise hearing threshold and continuous hearing losses like acoustic trauma (Karpuzcu, 1999). These problems can be influenced by both exposure time and/or level of noise. There are several effects of noise on human psychology such as fatigue, nervousness, stress, insomnia, decrease of concentration and labor yield, and changes in both memory and social behaviors (Ingle et al., 2005). Although personal and public differences exist, it is generally accepted that sleeping and other activities are seriously disturbed and humans become irritated from noise, when sound level is above 65 dB(A) (Karabiber, 1999).

Air transport is currently the most preferred mode of transportation.. Interior noise of a plane in operation affects health conditions of passengers and flight crew, as well as their comfort and psychological well-being. The active control of noise in aircraft and automobile interiors is a problem that has received considerable attention in the recent past (Bullmore et al., 1990; Tichy, 1991; Sun et al., 1996). Active strategies for aircraft interior noise suppression are generally applied at low frequencies (100-400 Hz), where passive techniques become ineffective (Jayachandran et al., 1999).

Noise levels change depending upon the different operations of aircraft, and they can be defined as the total noise during takeoff and landing and level flight (cruise). The main sources of aircraft interior noise are the power plant (propeller and engine-reciprocating or turbine) and the turbulent boundary layer.(Wilby, 1996) High speed turbulent flow over an aircraft fuselage is responsible for a substantial component of the interior noise, and is probably the most important source of cabin noise for jet powered passenger aircraft in steady cruise. (Wilbiy, 1996; Howe, 1998). The ground operations of aircraft include aircraft engine tests, takeoff preparation, and braking after landing (Large, 1981). If noise effect is related to its duration, then it can be seen that cruise flight of the aircraft tis the most important noise type, affecting health of passengers and flight crew. Minor noise sources are air conditioner humming and air friction.

There are also noise sources that are not aircraft-related. These are non-special noises, such as conversations and noises during placing of hand-luggage into overhead compartments. Noise sources due to flight crew are flight attendant conversations, loudspeaker announcements by pilots and attendants, mechanical noises during food and beverage service and flight safety demonstrations, and announcements.

Although noise is a factor which can generally cause hearing losses, both commercial and business jet airplanes are manufactured under international standards, producing noise levels below hearing threshold limits. However, during flights at night, noise can really be a disturbing factor affecting passengers' sleep. This can cause physiological and psychological problems. The threshold level of a noise which will cause arousal from sleep depends on sleep stage and the age of the subject, among other things. Noise levels which can cause sleep disturbance cover a wide range. For sleeping environments, the maximum acceptable intrusive level is 55 dB(A) (U.S. Department of Commerce, 1985). This factor must be taken into account while investigating in-cabin noise levels.

THE EXPERIMENT

In-cabin noise measurements were performed in two Airbus A321 commercial passenger planes. A Testo 816 sound level meter (defined as Type 2 as per IEC standards) was used in noise measurements, and noises were expressed as dB(A) units. Noise values were obtained as continuous and instantaneous signatures. Noise measurements were continuously performed and significant noise changes manually recorded.

Noise measurements were conducted in the cabins of two similar single-aisle Airbus A321 jet passenger aircrafts. Figure 1 shows the measurement point at passenger seat and general layout of the cabin. Noises during parking, taxiing, takeoff, climbing, cruise, approach, landing, and parking again, were measured at this point. During cruise (straight flight), indicative noise measurements were done at different passenger seats, in the corridor, and front and rear sides of the aircraft. The measurements included two different domestic line flights about 1,000 km long along the same flight route, over a 1 hour and 45 minutes flight duration. There are two jet engines mounted on the wings of Airbus A321. The salient aircraft details are shown in Table 1 (Onurair Transport Co., 2005). There were 219 passengers in the first (Flight No. 1) and 212 in the second (Flight No. 2) flight, and both flights used 2 pilots and 5 flight attendants. Cruise altitude in both flights was about 9,000 m.

RESULTS

A total of 103 noise measurements were made, 54 in the first and 49 in the second flight. In these measurements, it was observed that aircraft interior noise levels were in the range of 58 to 85.5 dB(A). A summary of the measurement results are presented in Table 2.

Table 2 shows that average values for continuous noises in a 1,000-km flight are 64.0 dB(A), 64.0 dB(A), 78.4 dB(A), 78.7 dB(A), 76.0 dB(A), 63.6 dB(A), and 58.5 dB(A) during parking, taxiing, takeoff and climbing, cruise, approach and landing, taxiing, and parking, respectively.

In the ground measurements prior to takeoff, it was seen that continuous aircraft interior noise levels were 60.9 dB(A), 63.0 dB(A), and 64.7 dB(A) for before passenger entry, during passenger entry (with no music broadcast), and during passenger entry (with short-time music broadcast), respectively. Music broadcast was intentionally maintained for one minute and all other measurements were collected without music broadcast in the cabin.

In both flights, demonstration announcements were performed by flight attendants while parked. Demonstrations

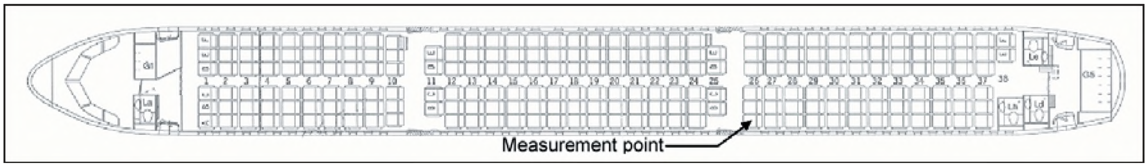

Figure 1. Airbus A321 cabin layout

Manufacturer	Airbus
Wing span	34.09 m
Overall Length	44.51 m
Cabin Length	34.44 m
Max. cabin width	3.70 m
Height	12.09 m
Fuselage diameter	3.96 m
Total volume (LD3+Bulk)	41.85m^3
Max. Operating Mach n° (Mmo)	0.82 Mc
Max. flight height	11900 m
Power plant (wing mounted)	Two PWD JT V2530-A5
Passenger capacity	220

Table 1. Some technical details of Airbus A321 commercial aircraft.

were repeated two times in native language (live) and in English (tape). In the demonstrations, continuous noise levels were 68 dB(A) and 56.3 dB(A) during live and taped announcements, respectively

Instantaneous aircraft interior noises and noise sources are shown in Table 3. Time histories of continuous and instantaneous noise values are presented in Figures 2 and 3, respectively. It can be seen from Figures 2 and 3 that noise levels show significant differences in takeoff and landing. Instantaneous noise levels were found to be concentrated before takeoff and after landing. The principal causes of instantaneous noises, before takeoff and after landing, were found to be generated by in-cabin announcements and passengers (Please refer to Table 3).

Figure 4 was generated to determine the general tendency of flight-time-noises, by merging the takeoff moments of the two flights into one graph. Figure 4 shows, in general, there is similarity in the two flights. This similarity can then be summarized for continuous noise levels to be 60-65 dB(A) before takeoff, 80-85 dB(A) during takeoff, 75-80 dB(A) in cruise, and slightly lower than these during landing. In Flight No. 2, there was a slight turbulence at 22:16 during cruise, and this caused the continuous noise levels to be 79-80 dB(A)

Flight stage	No. of measurements		Max. dB(A)		Min. dB(A)		Avg. dB(A)	
Flight no.	1	2	1	2	1	2	1	2
Parking	12	7	68	68	58	56.3	65	63.1
Taxiing	6	4	68	67	60	62	64.3	63.8
Takeoff and climb	6	4	85.5	83	77	69	79.4	77.4
Cruise	10	16	82	82	74	75	79.4	78.1
Approach and landing	14	11	85	82	73	70	76.1	76
Taxiing	2	3	67	64	63	60	65	62.3
Parking	4	4	60	60	57	58	58.4	58.7

Table 2. Continuous noise data of aircraft interior environment

Flight No. 1			**Flight No. 2**		
Flight stage	**Instant noise dB(A)**	**Noise source**	**Flight stage**	**Instant noise dB(A)**	**Noise source**
Parking	70 62, 62, 68 80, 81, 83	Overhead stowage cover Passenger conversation Announcement	**Parking**	75	Overhead stowage cover
Taxiing	69	Mechanic	**Taxiing**	82	Announcement
Takeoff and Climb	-	-	**Takeoff and Climb**	89	Mechanic
Cruise	-	-	**Cruise**	88 82	Warning signal Pilot's Announcement
Approach and Landing	81, 85	Announcement	**Approach and Landing**	85, 88 87	Announcement Brakes
Taxiing	-	-	**Taxiing**	88	Announcement
Parking	-	-	**Parking**	81	Announcement

Table 3. Instantaneous noise data and noise sources of cabin interior environment

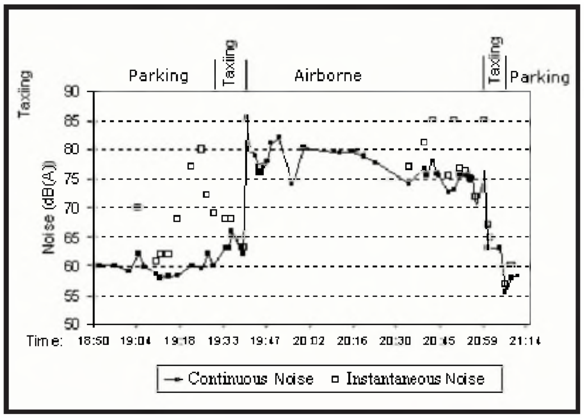

Figure 2. Changes of continuous and instantaneous noise measurements for Flight No. 1

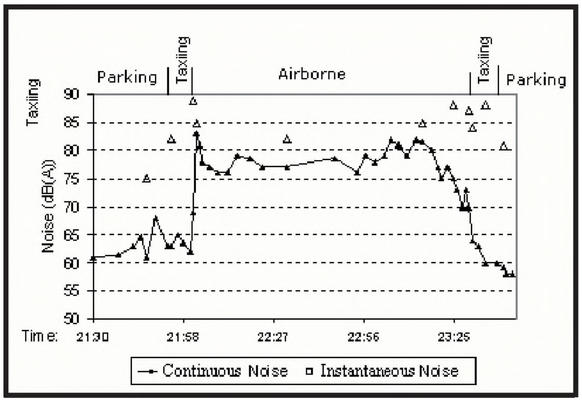

Figure 3. Changes of continuous and instantaneous noise measurements for Flight No. 2

for around four minutes. The continuous noise level before turbulence was 76 dB(A).

Noise exposure times, in both flights, 5 to 8 minutes for takeoff and climb, 45 to 63 minutes for cruise, and 20 to 25 minutes for approach and landing. Takeoff and landing times were each shorter than 1 minute. For operations on ground, total noise exposure times were 30-35 minutes for parking, and 15-16 minutes for taxiing. Flight crews were on board for at least 10 minutes more than the passengers.

In addition to the measurements at seat 26A, which included the continuous noise measurements during flight, short-timed-measurements over one-minute periods were collected at several places in the cabin. Continuous noise values obtained at these places were - 76 dB(A) in the front section, 75 dB(A) in the middle part, and 78,5 dB(A) in the rear section. Continuous noise values at passenger seats were - 82 dB(A) for window side, 78 dB(A) for middle seats, and 78 dB(A) for aisle side.

DISCUSSION

Aircraft interior noise levels in two domestic flights were measured for 1,000 km-long cruise in a commercial jet passenger aircraft. In both flights, averaged noise levels were 77.4-79.4 dB(A) for takeoff and climb, 78.1-79.4 dB(A) for cruise (level flight), and 76.0-76.1 dB(A) for approach and landing. These values were higher than the hazardous threshold limit for human health of 65 dB(A). In addition, for operations on ground, average noise levels were measured to be 58.4-65 dB(A) for parking, and 62.3-65 dB(A) for taxiing.

In-cabin noise levels were in the range of 81 to 88 dB(A), including mechanical noises for takeoff and climb, cruise, approach and landing, and miscellaneous noises during warning signal, announcements from pilot and flight attendants, and brakes. In ground stages (parking and taxiing), instantaneous noises ranging from 62 to 83 dB(A) were due to closing of overhead luggage compartments, passenger conversations, and to announcements. It was foundd that during flight, instantaneous noises were mainly of flight crew-origin, while noises on the ground were mainly passenger-generated.

During level flight, continuous in-cabin noise levels did not vary too much. Continuous noise levels, within the same minute, were75 dB(A), 76 dB(A) and 78.5 dB(A) in the middle part of cabin, front and rear sides respectively. The position of passenger seats was important regarding the aircraft interior noise levels during flight. Window-side-seats showed 4 dB(A) more noise exposure than the middle and aisle-side seats. This shows that the real sources for continuous noise are airborne friction on aircraft fuselage and engine noises, and that it is necessary to develop the isolation of the cabin with better noise-absorbing materials to lower the continuous noise levels inside the cabin. Noise isolation must be far more efficient in the rear side, and the auxilary power unit must be operated more quietly.

It was seen that the effective instantaneous in-cabin noise source was primarily the live announcements by flight crew. Such public announcements, therefore, can be substituted by taped ones and the noise levels can be reduce by 12 dB(A) to 56 dB(A) or less. The 56 dBA level is near the waking threshold of 55 dB(A). Moreover, live announcements can be less controlled and high-pitched, and hence during cruise,

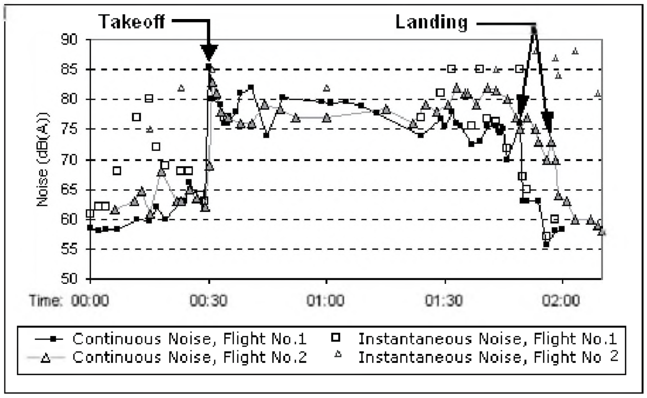

Figure 4. Fitted presentation of noise levels for both flights, referenced to takeoff stage

more disturbing. If they can be provided as taped substitutes, these announcements will more controlled and less disturbing. Therefore, it is be possible to minimize the human-originating portion of aircraft interior noise. This rearrangement about announcements will be useful in reducing both continuous noise levels during demonstrations as well during food and beverage services by the flight crew.

During ground operations, there are principally mechanical noises. The "mild" (low volume) music broadcast will increase the continuous noise level by 1.7 dB(A), however, this broadcast is still useful, since it masks both continuous and instantaneous noises. Mild music broadcast was observed to have a positive effect in masking noises of passenger conversations and overhead compartment arrangements, and thus providing a relaxed ambience.

ACKNOWLEDGEMENTS

The authors are grateful to Onurair Transport Co. for noise level measurements permission in aircraft cabin environment.

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ACOUSTICS STANDARDS ACTIVITY IN CANADA

2006 UPDATE AND INVITATION TO PARTICIPATE

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ABSTRACT

This article is an update for 2006 of Acoustics Standards activities in Canada, especially those of the Canadian Standards Association. CSA currently has 10 Acoustics Standards and three more with significant acoustics content. Over five times that number of international acoustics standards have been reviewed and endorsed in a new Canadian Standard, Z107.10. This innovative standard streamlines the process whereby CSA endorses standards from other organisations, such as ANSI and ISO, which have been found suitable for use in Canada. Canadian acousticians are invited to contact the author to become more involved with the many acoustics standards activities currently underway in Canada and on behalf of Canada around the world.

SOMMAIRE

Cet article est une mise à jour des activités de normalisation en acoustique au Canada pour 2006, spécialement celles de l'Association canadienne de normalisation (ACNOR). L'ACNOR a présentement dix normes acoustiques et 3 autres comportant un contenu acoustique important. Plus de cinq fois ce nombre de normes acoustiques internationales ont été revues et sont endossées dans une nouvelle Norme Canadienne, Z107.10. Cette norme innovatrice améliore le processus par lequel CSA approuve des normes des autres organisations (par exemple ANSI ou ISO) comme étant acceptable pour une utilisation au Canada. Les acousticiens canadiens sont invités à contacter l'auteur pour s'impliquer dans les nombreuses activités en rapport avec les normes acoustiques actuellement en cours au Canada et au nom du Canada partout dans le monde.

1. INTRODUCTION

The major goals of this article are to inform Canadian acousticians of progress in Canadian Standards activities and to invite those who are interested to become more involved with these activities. Participation is one of the best ways to stay in touch with this fast moving field and an excellent way to meet those who are leading it in many fields. Any acoustician interested in becoming involved with Acoustics standards in Canada is invited to contact the author or any of the subcommittee chairs. Most chairs welcome newcomers willing to work and the work need not involve a lot of time. The following will give an overview of the areas involved.

Canadian Standards Association (CSA) Technical Committee Z107 – Acoustics and Noise Control and its subcommittees look after all but one of the 10 Canadian Acoustics Standards (the exception is Z94.2 Hearing Protection Devices, which has its own technical committee). Z107 also coordinates all Canadian acoustics standards activity, with representatives from Z94.2 and from Canada's international standards advisory committees providing liaison to their activities. It also reviews international standards and endorses those found relevant and useful for Canada

2. Z107.10 OMNIBUS STANDARD

The most important progress made by Z107 in 2006 is the publication of Z107.10, Guide for the Use of Acoustical Standards in Canada, a new omnibus standard by Cameron Sherry and his Editorial Subcommittee. The standard summarises all acoustics standards for which Z107 has an interest, including CSA standards, and those ISO, ASTM, ANSI and IEC standards that Z107 considers of importance to Canada. This gives the reader a single source for information relating to Acoustics standards of interest to Canada, including those referred to by regulations and guidelines within Canada. Given the speed with which ISO and other groups are changing standards, this new approach is not only convenient, it is essential and the intent is to issue revisions annually.

Z107.10 is an important innovation in standards review in Canada. For many applications there is no need to write a Canadian Acoustics Standard. Many international standards are well written by highly qualified technical committees and their use here helps simplify communication with international acousticians and acoustics done in Canada by global organisations.

Until now, standards from outside Canada were either endorsed or adopted singly, a time consuming process whereby each standard was reviewed and balloted and in some cases published with small changes required for the Canadian context. The new standard streamlines this process considerably and is the first of its kind in Canada, addressing an important need in allowing Canadian users more ready access to Acoustics standards around the world.

An example will give an idea of what the standard contains:

> ASTM E492, Test Method for Laboratory Measurement of Impact Sound Transmission Through Floor-Ceiling Assemblies Using the Tapping Machine
>
> This test method covers the procedures for laboratory measurement of impact sound transmission of floor-ceiling assemblies, using a standardized tapping machine. It is assumed that the test specimen constitutes the primary sound transmission path into a receiving room located directly below. Measurements may be conducted on floor-ceiling assemblies of all kinds, including those with floating-floor or suspended ceiling elements, or both, and floor-ceiling assemblies surfaced with any type of floor-surfacing or floor-covering material. The corresponding single-figure rating is the impact insulation class (IIC), which is determined according to ASTM E989.
>
> Architects, builders, and code authorities can use the IIC rating for acoustical design purposes, to specify the attenuation of sound from impacts due to footsteps for specific building constructions. The use of IIC to define the required impact sound insulation is recommended in the National Building Code of Canada, but is not mandatory.

This example shows an entry for an ASTM standard endorsed for use in Canada. It describes the standard, its results and the relevance in a Canadian context.

3. COMMITTEE ACTIVITIES

3.1 Z107 Acoustics and Noise Control

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

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

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

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

In 2005, the most active subcommittee, **Industrial Noise**, was split into two separate subcommittees, Occupational Noise and Environmental Noise, splitting up the workload and allowing each to focus on different issues. The latter subcommittee is also incorporating the Transportation and Powered Machinery subcommittees and their standards.

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

- **Z107.52-M1983** (R1994) Recommended Practice for the Prediction of Sound Pressure Levels in Large Rooms Containing Sound Sources. This standard is in need of major updating and a chair is being sought to do this work. The intent is to provide guidance to Canadian industry on how to design quiet plants. It is seen as building upon Z107.58, which provides advice on buying quiet equipment.
  Z107.56-06 Procedures for the Measurement of Occupational Noise Exposure. A new version was publisahed in 2006. It is referenced in Federal and some provincial regulations and has been updated by a working group chaired by Alberto Behar. The new version strongly recommends use of the 3 dB exchange rate, but equations for a 5 dB exchange rate are still provided to be useful to Ontario and Quebec, although their use is discouraged.
- **Z107.58-2002** Noise Emission Declarations for Machinery was written by a group chaired by Stephen Bly and was published3 in 2002. It became a National Standard of Canada in 2003 It is a voluntary guide on noise emission declarations for machinery to be used in Canada and is compatible with European regulations to allow Canadian machinery to be sold into that market. It is intended to help Canadian companies to purchase quieter machinery and plan noise control strategies. It does so by enabling manufacturers to formally provide sound-level data in an agreed format.
  A Noise Emission Declaration is a statement of sound levels produced by equipment, which would usually be included with the instruction or maintenance manual and in technical sales literature. Measurements are made according to ISO standards and include estimates of the likely variability of the measurements. Canada recommends use of either a declaration stating the level and uncertainty as two numbers, or adding them together into a single number.

In addition, the Occupational Noise subcommittee undertakes reviews of proposed federal and provincial regulations, often at the request of the regulators, and other activities affecting industrial noise. Recently a group from the subcommittee met with Ontario regulators considering a new occupational noise regulation. They strongly agreed with the proposal to use a 3 dB exchange rate and suggested Ontario follow the lead of Z107.56 in not having a separate limit for impulse noise. For a more detailed discussion of this issue, see Reference 4, by the author.

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

- **Z107.53-M1982** (R1994) Procedure for Performing a Survey of Sound Due to Industrial, Institutional, or Commercial Activities. This standard is in the process of being replaced with the new ISO1996 series, which were the last ISO Acoustics standards endorsed separately, before Z107.10 took over that role. A group centred on the Ontario MOE have been looking at using ISO 1996 to assess community noise[1, 2].
- **CAN3-Z107.54-M85** (R1993) Procedure for Measurement of Sound and Vibration Due to Blasting Operations. A working group, chaired by Vic Schroter, is revising this standard.
- **CAN/CSA-Z107.55-M86** Recommended Practice for the Prediction of Sound Levels Received at a Distance from an Industrial Plant. A joint CSA/ANSI working group co-chaired by Rich Peppin and Tim Kelsall is looking at ISO9613. This standard was originally written by an ISO working group chaired by Joe Piercy of NRC. It may ultimately replace or become the basis for a revised version of Z107.55, however the group has identified a number of shortcomings which need to be addressed.
- **CAN/CSA-Z107.9-00:** Standard for Certification of Noise Barriers. This standard is an adaptation of the Ontario MTO Highway Noise Barrier specification. It provides municipalities, developers, road and highway departments, railways and industry with a standard specification which can be used to define the construction of barriers intended to be durable enough for long term use in Canadian conditions.
- The US Department of Transportation, Federal Highway Administration, "Highway Noise Barrier Design Handbook" is already harmonized with the CSA standard, as is the Ontario Provincial Standard, and numerous US state transportation agencies, making this the de-facto standard for barriers across North America.

The subcommittee incorporates the Transportation and Powered Machinery subcommittees and their standards and is looking toward adopting the ISO Standard for the measurement of noise emitted by Wind Turbines.

Editorial, chaired by Cameron Sherry, (which reviews all proposed standards) and is responsible for reviewing and endorsing ANSI S1.1-1994 Acoustical Terminology. They recently reviewed the latest revision to Z107.56. In addition, they will have ongoing responsibility for updating the omnibus standard Z107.10 using input form each subcommittee. Cameron is actively looking for new members to assist in this work and can be contacted directly or through the author.

Z107 also has subcommittees providing liaison with international standards activities, specifically steering committees in Building Acoustics, Instrumentation and Acoustics and Noise. These Steering committees are run by the Standards Council of Canada and are harmonised with the Z107 committee to which they report regularly on progress. Draft international standards are provided on a private website to which steering committee members have access in order to review them and recommend Canada's position.

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

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

Liaison with the Canadian Steering Committee for ISO TC43 (Acoustics) and TC43(1)(Noise), chaired by Stephen Keith who provides Canadian comments, votes on ISO standards and coordinates the work of Canadian representatives on several ISO working groups. This group deals with ISO Standards on measurement and assessment of sound and hearing, such as WG 17: Hearing protectors WG28: Machinery noise emission standards (referenced in CSA Z107.58) WG 40: Impulsive sound propagation for environmental noise assessment, WG 45: Acquisition of data pertinent to land use, and WG 53: Occupational Noise Exposure. All of the above international Working Groups have Canadian members.

All these groups are always interested in new members willing to work.

3.2 Z94 – Hearing Protection

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

4.0 CANADIAN ACOUSTICS STANDARDS

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

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

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

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

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

Z107.10 Guide for the Use of Acoustical Standards in Canada.

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

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

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

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

Z107.56-06 Procedures for the Measurement of Occupational Noise Exposure / Méthode de mesure de l'exposition au bruit en milieux de travail

Z107.58-2002 Noise Emission Declarations for Machinery

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

Standards with Acoustics Component:

Z62.1-95 Chain Saws

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

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

Endorsed Standards

53 standards are listed in Z107.10.

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HIGH FREQUENCY ACOUSTIC CHANNEL ESTIMATION ERROR ANALYSIS DURING THE UNET06 DEMONSTRATIONS

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1. INTRODUCTION

We are interested in assessing the adversity of a shallow water acoustic channel to coherent communications. The shallow water channel presents a particularly difficult environment for high rate acoustic communications as channel conditions can change dramatically both spatially from site to site and temporally over durations as short as hours. Shallow water coastal environments can range from very calm with relatively coherent acoustic response functions to severely doubly spread environments where multi-path delay is coupled with path dependent Doppler. Doppler spreading is imparted by the temporal dynamics of the water column along with wind driven surface wave motion. Platform motion imparts severe temporal variations for paths that interact with a rough bottom. Each of these processes impact each acoustic path, with its individual launching and arrival angle, differently. The net effect of this delay spread and rapid temporal variation is that communication receivers must model the acoustic channel accurately in order to efficiently decode the sent data. It is the goal of this work to develop a computationally efficient estimator of the channel response function that includes the innovation variance associated with the temporal fluctuations of the channel and apply these to data collected in St. Margaret's Bay, the site of the 2006 underwater networking demonstrations (Unet06).

1.1 Experiment design

During Unet06, DRDC-Atlantic with the Naval Research Laboratory, conducted high frequency broadband channel probe experiments to characterize the underwater acoustic channel's adversity to communications. Figure 1 depicts the experiment layout. The DRDC multimode pipe projector (MMPP) provided a 185 dB // 1μPa@1m source level at 44 kHz center frequency and was allowed to drift approximately 2 meters from the bottom in 70m of water at ranges between 300 m and 1 km from the NRL ACDS 8-element vertical receiver array. The receiver array was placed approximately mid water column and was sampled at 160 ksps. The doubly spread acoustic channel is estimated from the recorded data sets by an augmented Kalman recursion to be described.

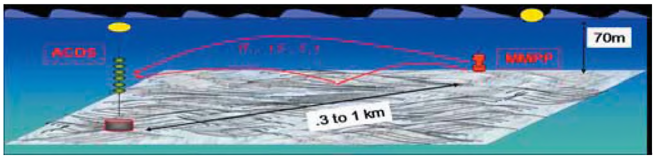

Figure 1, High frequency channel probe experiment. Source is a DRDC multimode pipe projector (MMPP) drifting 2 meters from the bottom. Receiver is an NRL ACDS unit with 2 meters of vertical aperture.

1.2 Model of Acoustic Response Dynamics

The posterior covariance of the acoustic channel is a function of the data and the innovation variance of the Gauss Markov response process. To compute the channel estimate and covariance function this latent innovation variance must be estimated. We augment, by an empirical Bayes approach [1], the Kalman recursion with a point estimate of the innovation variance to improve estimation of the acoustic response function. The underwater acoustic response function h_t is modeled as Gauss-Markov on the interval of observation, that is $h_t | h_{t-\Delta}, q, a \sim N_h(a_t h_{t-\Delta}, q_t I)$, where $N_x(\mu,\Sigma) = |2\pi\Sigma|^{1/2} \exp[(x-\mu)'\Sigma^{1}(x-\mu)/2]$ and $x | y \sim p_x(y)$ denotes that density of x given y. By the form of the innovation covariance we have assumed that the innovation process is uncorrelated and invariant to path delay. The background noise at the k^{th} receive element is assumed to be spatially uncorrelated, stationary, but with temporal covariance Σ_k. We model the noise covariance as an autoregressive process and choose the model order using the BIC principle. The received data segment at the k^{th} hydrophone, over the t^{th} time interval is $r_{k,t}$, and distributed as $r_{k,t} | h_t, s_t, t'(t) \sim N_r(S_{t'} h_t, \Sigma_k)$. Here $S_{t'}$ is the convolution matrix formed from the source signal vector s_t, the t^{th} segment of the source signal, dilated according to $s_{t'} = \sqrt{dt'/dt} \times s(t'(t))$, where $t'(t)$ represents an estimate among all paths and receive elements of the time varying, dilated time index.

1.3. Source signal dilation estimation

The dilation process is dominated by source-receiver platform motion in scenarios where either or both are not rigidly fixed and decoupled from the surface [2,3]. For a fixed receiver array under downward refracting conditions with source drifting near the bottom source motion is the greatest cause of imparted dilation. Estimates of the dilation process by the method described in [1] are presented in Figure 2. The source held from a cable to a surface vessel imparts a noticeable time varying dilation. The accelerations are over 1m/sec^2 as depicted.

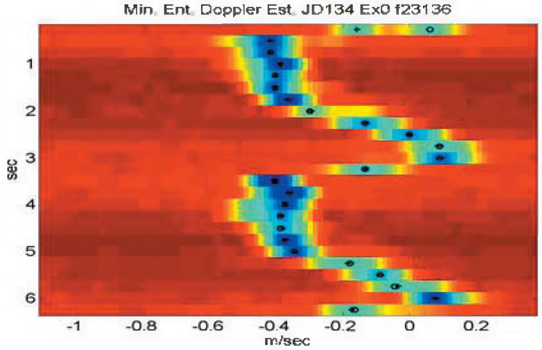

Figure 2: Dilation estimate over signaling packet duration of 6.25 seconds from drifting source. Center frequency is 44 kHz bandwidth is 5 kHz.

2. ESTIMATION

Under the Gauss-Markov assumption on the acoustic Green's function with known Markov transition gain a, and innovation variance q, it follows that $h_t \mid a_t, q_t, r_{\leq t} \sim N(\hat{h}_t, P_t)$ where $r_{\leq t}$ represents all data preceding the time of estimation, $\hat{h}_t = (I - G_t S_{t'}) A \hat{h}_{t-\Delta} + G r_t$, $P_t = (I - G_t S_{t'}) R_t$, $R_t = A P_{t-\Delta} A' + q_t I$ and G_t is the Kalman gain. Since for any other estimator of the response function, for instance $\hat{h}_t^* = \hat{h}_t(q^* \neq q)$, $E[(h_t - \hat{h}_t^*)'(h_t - \hat{h}_t^*)] > tr[P_t(q)]$, when the innovation variance (or transition gain) is not known exactly, a good estimator of it improves channel response estimation. To estimate these consider the marginal density $p(a,q \mid r_{\leq t}) \propto \int p(r_t \mid h_t, a, q, r_{<t}) p(h_t \mid a, q, r_{<t}) dh_t \times p(a,q \mid r_{<t})$ leading to a MAP estimate of a and q given $r_{\leq t}$ as

$$\hat{a}_{\leq t}, \hat{q}_{\leq t} = \arg\max_{a,q} \log\left[N_{r_t}(a_t S_{t'} \hat{h}_{t-\Delta}, a_t^2 P_{t-\Delta} + q_t I + \Sigma) \times p(a,q \mid r_{<t})\right]$$

. Estimates based on approximations to this criteria can be used to augment a Kalman recursion for improved estimation of the response h_t. Figure 3 presents estimates based on the MAP principle above for $q_{\leq t}$ for the 8 phone array displayed relative to phone 4.

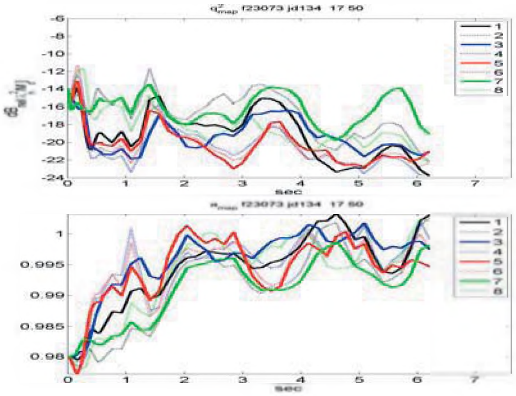

Figure 3. Approximate MAP estimates: Above, innovation variance relative to instantaneous channel energy. Below Markov transition gain.

3. RESULTS

Figure 4 displays the magnitude of the channel response function and a histogram of $tr[S_{t'} R_t S_{t'}'] / tr[\Sigma]$ which measures adversity of response estimation uncertainty relative to ambient noise variance. The probing interval is of duration 6.25 seconds at a range of approximately 500m. The channel uncertainty is two times as adverse to communications than the noise variance.

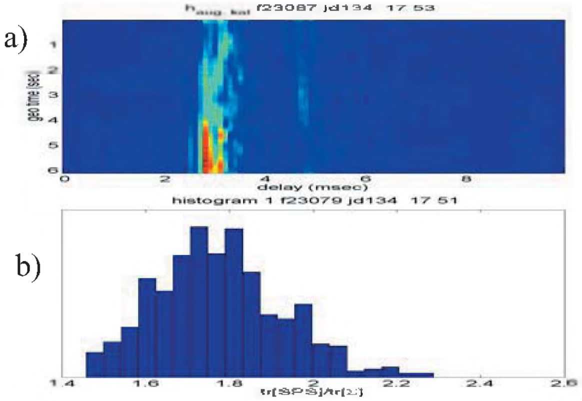

Figure 4 a) Magnitude of estimated acoustic response function. b) Histogram of ratios of channel estimation error power $tr[S_t R_t S_t']$ to ambient noise power $tr[\Sigma_t]$.

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ACKNOWLEDGEMENT

This work supported by the Office of Naval Research.

From Acoustics Week in Canada 2006/De l'acte semaine candienne d'acoustique 2006

CSA Z107.10 GUIDELINE TO ACOUSTICAL STANDARDS IN CANADA

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1. INTRODUCTION

Why did the CSA Z107 committee decide that there should be a Canadian acoustical standard, Z107.10? There are many acoustical standards available within the world but which ones should be used and which should not? If we use an acoustical standard are there any limitations? What terms should we use when talking or writing about acoustics and how are they defined? The answers to some of these questions should be apparent in this paper.

2. COMMENTARY

The field of acoustics is very broad it includes speech, music, hearing, sound transmission, sound absorption, sound generation, ultra sound, transportation, instruments, etc. the list seems endless. The truth is that it just about all activities we humans participate in involve sound. Either we wish to generate sound or we wish to reduce it. Sometimes we get pleasure from sound sometimes we are in agony or somewhere in between.

If we are to control sound we must be able to measure it. This requires the definition of terms and of course there must be agreement that the terms have been defined appropriately. Canadians have been active on many acoustical committees and thus collectively have a very broad experience. Canadians are members of the following acoustical standards writing committees ANSI, ASTM, ISO, IEC, CSA, SAE and several others I have not listed. Each of these committees then breaks down into subcommittees and then into working groups.

How can acousticians help the public or our fellow acousticians in understanding and choosing acoustical standards that cover all the fields of acoustics? The Z107 committee of CSA had a vision of a Canadian acoustical standard that would provide Canadians with an answer. Canadians do not have enough resources to write the required acoustical standards in all fields and in fact we sometimes are hard pressed to write an acoustical standard in any field. The Z107 committee has for many years been reviewing and endorsing acoustical standards that may be used by the Canadian public. However, the public is at lost sometimes when it realizes there are several standards with somewhat identical objectives. Now what?

The vision of the Z107 committee was the acoustical standard CSA Z107.10. This standard lists by topics the standards endorsed or written by CSA that are recommended for use in Canada. This standard is intended to be a living one, in that each year it is expected that additional material will be added to it. The Z107 committee would like you to contribute to this standard. It is the standard; we hope you will refer to when you want to choose an appropriate acoustical one. It is available for purchase from CSA.

Following is the present list of headings; hopefully more will be added in the future.

- BUILDING ACOUSTICS
- CALIBRATION OF ACOUSTICAL MEASURING EQUIPMENT
- ENVIRONMENTAL NOISE
- HEARING MEASUREMENT
- HUMAN EXPOSURE TO VIBRATION
- INDUSTRIAL NOISE
- POWERED MACHINES
- TRANSPORTATION NOISE
- TERMINILOGY

In the field of building acoustics we have an on going discussion about the use of ASTM acoustical standards and ISO acoustical standards. The building practices of Europe and North America are not the same thus the reason why the laboratories have been built to different standards. Canada in its normal position gets stuck in the middle of the sandwich. We have Canadians who head or have headed working groups, subcommittees or main committees in both ASTM and ISO. The standard Z107 provides you with information on fourteen endorsed ASTM building standards and indicates which ones are referenced in the National Building Code of Canada. It is anticipated that some ISO standards will be endorsed in the future. When this is done an explanation will be provided about the advantages or disadvantages of the equivalent ASTM standard.

The calibration of acoustical equipment must be performed on a regular basis otherwise the data obtained may lead us to make some false assumptions. The instruments themselves must be carefully assembled and must meet certain criteria. Some serious problems exist in this area as not everyone agrees on what should be the certain criteria. Just ask Dr. George Wong and he will provide a detailed explanation. It is well known that anyone attempting an acoustic measurement is going to affect the sound field they are measuring to some degree. There are no standards listed in this section. It anticipated that standards will be endorsed by the subcommittee for inclusion in the very near future.

The standards in the Environmental section of the standard are covered in a paper given by Bill Gastmeier. See the Canadian Acoustic Proceedings, September 2006, page 48.

In the section on hearing measurement there are three Canadian standards. One deals with hearing protection, one with audiometers and one with audiometry. These three are rather unique in that are not endorsed standards but ones you can purchase from CSA. The latter two are the responsibility of Z107, the parent of this standard. The other is the responsibility of committee Z94.

In the section on Human Exposure to Vibration there are two endorsed standards. Both standards deal with exposure to hand vibration. They are ISO standards and one of the world's foremost experts is a home grown Canadian, Dr. Tony Brammer, who has made a major contribution to both standards. It is anticipated that more ISO standards in this field will be considered for endorsation.

In the section on Industrial Noise there are 3 CSA standards and 18 endorsed ISO standards. The standards have a wide range of subjects. There is one CSA standard on noise prediction (at a receiver position inside a building), one CSA standard on noise emission declarations and one CSA standard on measuring personal noise exposure using dosimeters or sound level meters. This latter standard was a first in the world and has acted as the base document for several other standard writing bodies. The endorsed ISO standards cover sound power measurements, sound intensity measurements and noise emissions from machinery. It is anticipated that more standards will be added to this section.

In the section on Powered Machines there are 6 endorsed standards of which four are from ISO and two are from SAE. There use to be CSA standards that partially covered the subject areas of these six standards but they since have been withdrawn. The replacements are superior. The machines described in the standards may be used in construction or in agriculture. They cover stationary conditions as well as dynamic ones. One of the standards indicates how to properly measure sounds at the operator's position.

In the section on Transportation Noise there are 5 measurement standards, one of which is a CSA standard for the Certification of Noise barriers. Originally there were CSA standards for the other subject areas but as there were no Canadians wishing to support them so they were withdrawn. The subject areas are covered by ISO standards for the measurement of noise from vessels in inland waterways, stationary road vehicles, passenger cars in an urban setting and powered recreational craft.

The final section is on Terminology and presently there is only one endorsed ANSI standard. There are other acoustic terminology standards such as one from IEC but it has yet to receive broad recognition by Canadian acousticians. The IEC standard has some definition conflicts with the ANSI document that need to be sorted out.

ACNOWLEDGEMENTS

The development of this guideline standard is due to the work of the CSA Z107 main committee, subcommittees and working group members.

AUTHOR NOTES

This standard will remain a well referenced document if the Canadian Acoustical Community continues to contribute if information about standards it wishes to be recognized in Canada. You are invited to contact the author or Dave Shanahan of CSA if you have a standard for consideration.

CAA - Web Master

The Canadian Acoustical Association is seeking a volunteer to take on the duties of webmaster for the CAA website at http://caa-aca.ca/. The main responsibilities of the webmaster are to keep the site up to date, in response to information provided by the CAA secretary, awards coordinator and other members of the CAA board of directors, and to maintain a "Job Advertisement and Job Wanted" page. Recently a system was created for submission of CAA conference abstracts and papers using an on-line MySQL database and PHP programming. This is an ideal opportunity for someone to improve their knowledge and skills for online database programming and to apply these skills to automation of other aspects of the CAA website. For further information please contact Dave Stredulinsky, email: webmaster@caa-aca.ca. ph. (902) 426-3100 ext 352.

From Acoustics Week in Canada 2006/De l'acte semaine candienne d'acoustique 2006

COMPARING CRICKET EARS

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1. INTRODUCTION

Cricket calls are cheerfully musical in contrast to broadband sounds made by many other insects. This musicality is due to their ubiquitous use of single-frequency carrier pulses to form the male calling song,broadcast to attract a female mate. Most crickets worldwide -- >3000 described spp. (Otte & Naskrecki 1997) -- call at a carrier near 4 kHz (Otte 1992), the wavelength of which is about 7 cm -- far longer than any cricket's body dimensions. Thus a distant cricket female, localizing a male's call to guide her approach, has a body too small to create useful side-to-side amplitude differences by body diffraction. Yet substantial binaural differences in response activity between right and left tympana (located on the forelegs) do occur (Michelsen et al. 1994) and females are well able to localize singing males. The mechanism apparently relies upon binaural differences in phase (Michelsen et al. 1994).

1.1 *Gryllus* cricket ear anatomy

Tracheae are branching, interconnected tubes reinforced by spiralled exoskeleton (taenidia). They conduct respiratory gases throughout the insect body and as such are preadapted to also conduct sound. From behind each eardrum in *Gryllus* spp. a trachea runs bodyward along the leg to the prothoracic segment (Fig. 1). Here, near the body wall of its side, it joins the anterior face a of larger-diameter transverse trachea. This transverse trachea connects right and left prothoracic spiracles. This cross-body trachea, together with the two leg tracheae, comprise an acoustic waveguide system with four entry points for sound: the two spiracles (capable of being closed or open) and the two eardrums.

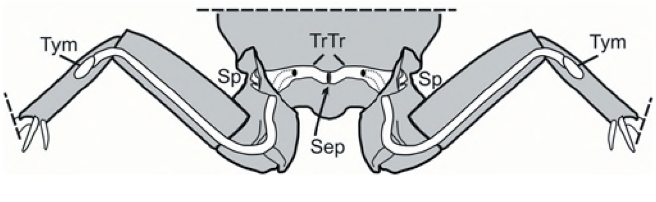

Fig. 1. There are four sound inputs to the internal sound system of *Gryllus*. A leg trachea runs from behind each tibial tympanum (Tym) and enters the large transverse trachea (TrTr) anteriorly (see right and left solid-black [small] ovals); the transverse trachea crosses the body between right and left prothoracic spiracles (Sp), with the phase-shifting septum (Sep) at the body midline. The upper portion of the cricket's body and leg tarsi are removed.

1.2 *Gryllus* ear function

Consider a field cricket facing forward (0º) and a sound source aimed directly at its right ear, at 60º to the cricket's longitudinal axis (Fig. 1). External incidental sound interacts with that entering via two other ports:1) contralateral spiracle, and 2) ipsilateral spiracle [input via the contralateral ear is feeble and can be disregarded (Michelsen et al. 1994)]. The sum of these two internal sounds as vectors (taking into account transmission gain in the tracheae, and phase at the rear of the eardrum) will interact with the incident sound to determine a resultant pressure change moving the ipsilateral ear. At the same time as the ipsilateral ear is very active in tracking the sound of the speaker at 60º, the contralateral eardrum at 300º is made comparatively inactive by the interaction of the same mirror-image vectors. Phase difference effected by cross-body transmission from the contralateral spiracle thus creates what body diffraction cannot: substantial binural differences in perceived sound that vary with changes in the orientation of the cricket toward the source. The greatest difference in left-right eardrum response occurs when the source faces the ipsilateral tympanum at either 30 or 330 degrees.

1.3 Mechanical phase shifter

This localization mechanism relies on an internal phase shift of no less than 313º at the 4.5-kHz carrier of the cricket *Gryllus bimaculatus*. And the carrier wavelength is an important aspect of the adaptiveness of this shift, i.e., only at the carrier wavelength is the shift of appropriate dynamic range for creating usable binaural differences. But path length differences to the rear of the right and left ears for an eccentric species-specific carrier source, cannot alone account for the phase change. Somehow a mid-body septum in the transverse trachea adds a phase delay of as much as 259º. When this septum is perforated, the phase delay is lost (Michelsen & Löhe 1995).

2. Acoustic tracheae in a nemobiine

Allonemobius fasciatus, the striped ground cricket, is a member of the subfamily Nemobiinae and is distributed across temperate North America. (For more information about this cricket see Singing Insects of North America [http://buzz.ifas.ufl.edu/]). The calling carrier of *A. fasciatus* is about 7.2 kHz, nearly 3 kHz higher than that of a field cricket. It is a relatively small species with a body length near 10 mm, about half the body length of *Gryllus* spp.

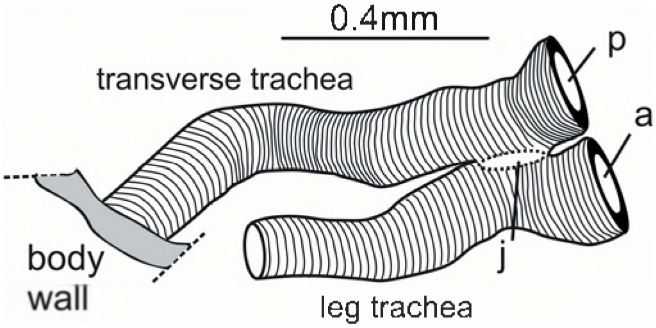

Fig. 2. Dorsal view of left half of prothoracic acoustic tracheal system of *A. fasciatus*. The left leg trachea connects to the transverse trachea via the junction j close to the midline and joins also to the leg trachea of the right side via a second midline septum anteriorly (a).

Situated low in the prothorax, just above the prothoracic ganglion, the transverse trachea of *A. fasciatus* (Fig. 2) traverses the body from left to right between the prothoracic spiracles. As with *Gryllus* there is a midline septum (**p**, Fig. 2). The leg trachea of the left side (shown truncate in Fig. 2) runs from behind the left tympanum inside the foreleg and joins with the left half of the transverse trachea at a location (**j**, Fig. 2) very close to the midline. But in contrast to *Gryllus* spp. the left leg trachea of the nemobiine links with its right-side equivalent at a second septum (**a**, Fig. 2).

The two septa are circular and, at a gross level, appear identical. In a newly killed insect, dissected under Ringers, there is a central circular region, opaquely white, surrounded by a narrow periphery that is semitransparent. (The solid black of Fig. 2 indicates the relative extent of this semitransparent periphery.) Each septum completely blocks its tracheal passage. Aside from being smaller, in keeping with the size disparity of *A. fasciatus* and *Gryllus* spp., these septa do not differ between the two cricket species.

3. DISCUSSION

It is reasonable to suppose that the purpose of these transverse tracheae is to transmit sound across the body, i.e., there is no respiratory function consistent with the blocking of these passages with a septum. The tracheae seem also overly large for a purely respiratory role. So it is reasonable to regard these air tubes as acoustically adapted.

Michelsen et al. (1994) established that the input to the contralateral spiracle of *G. bimaculatus* was dominant in the localization process, sound from both the ipsilateral spiracle and the contralateral tympanum being of little importance. The morphology of this nemobiine system suggests a much greater role for tympanal access in producing phase changes. The right and left leg tracheae, by being confluent in the midline at an anterior septum, have created an additional sound route: sound entering at a contralateral tympanum can reach and perhaps influence the ipsilateral tympanum more directly than in *Gryllus*.

Crickets globally call with carriers between 3 and 5 kHz (Otte 1992). Though some species, as does *A. fasciatus*, sing with slightly shorter wavelengths, most species are also smaller than field crickets, so the problem of ineffective body diffraction for localization should remain acute.

There are so many kinds of cricket, and to date no comparative anatomical examination of their acoustic tracheae. So it is quite probable that many diverse acoustic tracheal morphologies remain to be discovered among these insects. As for this single example of a distinct nemobiine acoustic tracheal morphology: how dual septa might function by altering phase is unknown.

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5. ACKNOWLEDGEMENTS

The author acknowledges support from the Natural Sciences and Engineering Research Council of Canada (Discovery Grant 4946, Acoustic designs of orthopteran insects).

From Acoustics Week in Canada 2006/De l'acte semaine candienne d'acoustique 2006

HIGH FREQUENCY ACOUSTIC OBSERVATIONS OF EPISODIC MIXING EVENTS IN LUNENBURG BAY

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1. INTRODUCTION

High frequency (0.6-5 MHz) acoustic backscatter data has been collected during the past four years (2002-2006) at Dalhousie's coastal ocean observing system at Lunenburg Bay (www.cmep.ca). Severe storm events, including hurricanes, produce high wave (Hs > 2m) and wind (U10 > 10 m/s) conditions in the area for sustained periods (T > 1 day) during late summer and autumn. Coincident with periods of high waves or high winds or both, enhanced acoustic backscatter is observed to occur throughout the water column.

The acoustical backscatter observations recorded via acoustic current profilers and velocimeters at three locations within the bay are shown in Figure 1. The subplots labeled BN1-3 correspond to locations around the bay (buoy node 1 is at the head of the bay while BN2 and 3 are at the south and north shores of the mouth of the bay). Six periods of enhanced surface-intensified backscatter (at days 267, 272, 277, 280, 287, 289) and 3 periods of enhanced scattering near the bottom (days 267, 272 and 289) occur between yearday 260 to 290 (September 17 to October 17). To varying degrees, local sheltering of wind and waves resulted in distinct data sets from each location for any given period of enhanced scattering.

2. SAMPLING PROTOCOL

During 2003 the acoustic profiler located at BN3 was an internally recording ADCP which was set to measure the velocity at 1Hz for two minutes and record the averaged ensemble. The real-time ADPs at BN1, 2 sampled at 1 Hz and recorded the ensemble average every 10 s, while the ADVs sampled and recorded at 4Hz with no averaging. The real-time instruments collected data for 10 minutes every half-hour. Wave height estimates were made using the data from the internally recording ADCP which was equipped with a waves measurement package, and calculated a spectrum every half hour using 20 minutes of data sampled at 2 Hz. Wind speed measurements were made using a shore based anemometer mounted on a 10m tower and were reported every hour. Additional wind speed estimates were made by buoy mounted anemometers (at 3m height above the sea-surface) at 1 minute intervals.

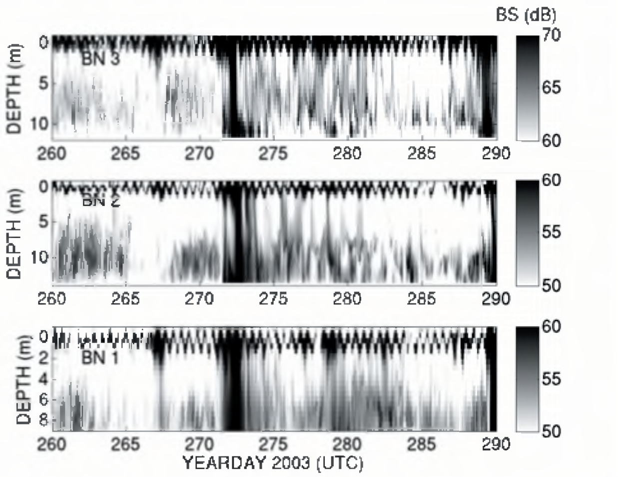

Fig. 1. Acoustic backscatter intensity (high backscatter in black) recorded at each of the three buoys during 2003.

3. RESULTS

The event at day 272 corresponds to the arrival of Hurricane Juan at Halifax NS. With Hs reaching 9 m outside Lunenburg Bay, and measuring 4 m at the mouth of the bay this event has been the focus of the preliminary investigation of these episodic events.

Figure 2 shows the acoustic backscatter intensity differences from BN2 recorded during Juan. The black dashed line is the depth at which the difference in measured backscatter at one vertical cell with the cell directly above is less than or equal to zero (positive number means that the cell above has a larger BS intensity). The black solid line is the depth to the bottom of the transition layer predicted by Terray et al. The depth to this layer is related to wind speed and significant wave height and directly related to the dissipation of kinetic energy from the surface to water column. The depth at which the backscatter intensity becomes uniform is related to the predicted depth of the transition layer.

The acoustic backscatter measured in the first bin (1.65m from the bottom) of the ADP and the acoustic backscatter measured by the ADV (25 cm from bottom) are well correlated over this event, as shown by the dashed and dash-dotted line in Figure 3. Both are related to the sum of the power spectral density of the vertical velocity over the frequency range $0.2 < f < 0.8$ (shown by the solid line).

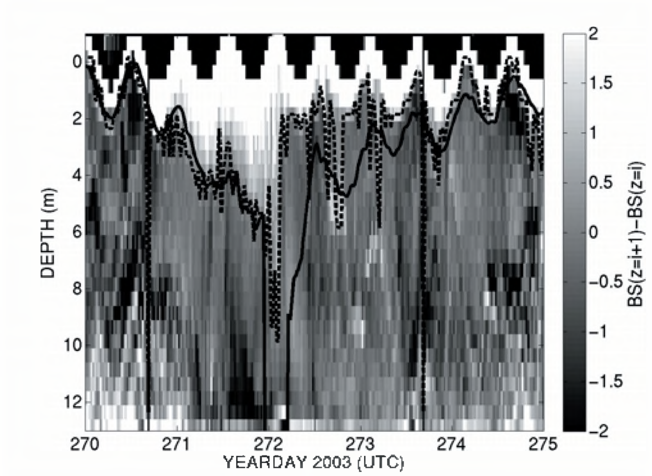

Fig. 2. The difference (BS(z(i+1))-BS(z(i))) in averaged backscatter ensembles averaged over the 10 minute sampling period, measured by the ADP at BN2. The dashed black line is the depth to a BS intensity difference of zero, while the solid black line is the depth to the transition layer predicted by Hs and wind speed. A white value indicates the backscatter in a bin above is greater than the backscatter in the adjacent bin below.

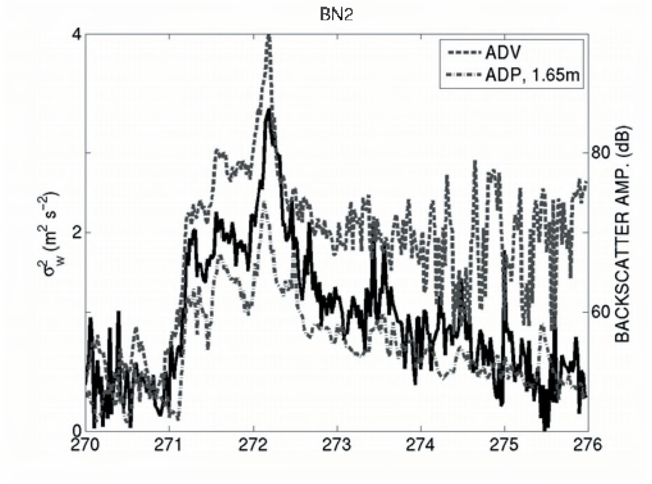

Fig. 3. Vertical velocity variance in the 0.2 < f < 0.8 band is shown by the solid line. The acoustic backscatter measured in the first bin (near-bottom) of the ADP (dash) and the backscatter measured by the ADV (dash-dot) are also shown.

4. DISCUSSION

There are several interesting features which are prominent in this data but not presented in this summary. These include:

- Near-surface backscatter intensity is directly related to wind speed at time scales of one minute
- Near-surface backscatter is dependent only on wind speed, with little or no dependence on fetch
- During periods of resuspension of bottom sediments, the power spectra of near-bed vertical velocity exhibit a slope of -5/3, indicating turbulence is responsible for the upward flux of sediment.
- The backscatter measured by the ADV (at 25-cm height) remains elevated much longer than that by the ADP (at 1.65-m height).

A supplemental experiment which included the deployment of in-situ laser measurements of sediment size has yet to be analyzed. In addition, sediment samples take from each of the site have been taken and measured but have not yet been incorporated into this discussion.

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ACKNOWLEDGEMENTS

We wish to thank Walter Judge and Stephane Kirchhoff for their help in deploying the instruments. We would also like to acknowledge the Captain of the UStar, Bryan Schofield, whose help on the water is invaluable. This research was funded by grants from the Canadian Foundation for Climate and Atmospheric Sciences, and the Canadian Foundation for Innovation.

MAGNETIC RESONANCE IMAGING OF ACOUSTIC STREAMING IN GASES

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1. INTRODUCTION

Acoustic streaming is the motion of a fluid caused by the presence of a sound field. In the form first explained in detail by Lord Rayleigh [1], which occurs when a standing sound wave is established in an enclosure, a pattern of circulation from node to antinode is developed (Figure 1).

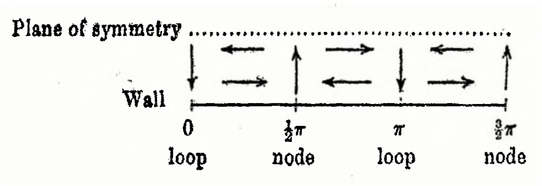

Figure 1. Illustration from Rayleigh's 1884 paper on acoustic streaming. The plane of symmetry is the centre line of an enclosing vessel.

The phenomenon of acoustic streaming has found application in cleaning, in mixing for microfluidics, and in cooling. In thermoacoustic engines, acoustic streaming is usually a parasitic effect, responsible for a reduction in efficiency. AS flows in gases are particularly delicate and quite difficult to measure, without disturbing the flow. Thus there is a need for non-invasive measurement methods in order to study important applications of AS. Laser doppler anemometry (LDA) is one possibility, but LDA cannot operate in optically opaque systems. In this paper, we demonstrate the utility of magnetic resonance imaging (MRI) as another possible measurement method for the study of AS in gases. Clinical magnetic resonance imaging (MRI) has developed at an astonishing pace in the thirty years since its inception. MRI outside the clinic is plagued by the short signal lifetimes (~ 10-4 s) of most materials, and has developed more slowly. Materials MRI has a generally lower signal-to-noise per unit time than most other imaging modalities (*e.g.* microscopies, X-ray tomography), but benefits from an extremely diverse array of possible image contrasts, which are manipulated through careful control of the spin physics during image acquisition. MR images can reflect many physical parameters including velocity and diffusivity.

2. METHOD

Both position and velocity sensitization are accomplished through the use of magnetic field gradients. The pulse sequence timing diagram of Figure 2 schematizes the history of sample manipulation during our measurement. This approach is termed the pulsed-field-gradient (PFG) spin echo [2].

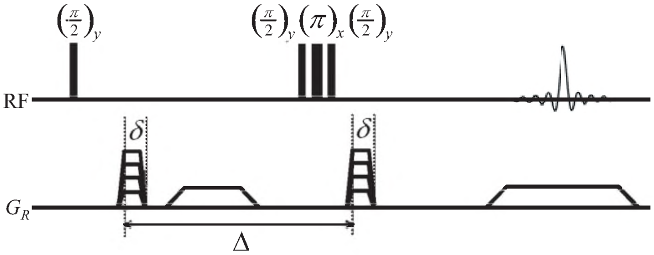

Figure 2. Pulse sequence timing diagram. On the RF axis are an excitation of the sample, an inversion of the magnetization and detection of the signal. On the G_R axis are applications of motion-sensitizing magnetic field gradient (two pulses, each of duration δ) and imaging gradient (longer, lower amplitude pulses).

3. RESULTS

The imaging sequence of figure 2 was applied at 2.4 T to a 2m-long 20-cm-diamter cylindrical tube filled with propane gas. The MRI signal from propane is long-lived for a gas (~ 10^{-2} s). One-dimensional images (profiles) of a 12-cm section near the centre of the tube are shown in the upper half of figure 3. The first data set (labeled "silent") shows 15 profiles, each acquired with a different amplitude of motion-sensitizing PFG (figure 2). The amplitude of PFG increases in the direction of the arrow. The upper row of data shows most attenuation and is most sensitized to motion. These 15 measurements were repeated five times, at roughly 15-minute intervals, before during and after the establishment of an acoustic standing wave at 835 Hz in the tube. The pattern of attenuation clearly changes in the presence of the sound field (indicating a change in the motion of the propane) and returns to its quiescent state when the sound is turned off. For quantification of this change, the 15 profiles are Fourier transformed along the dimension defined by the PFG amplitude. The resulting 5 images (lower half of figure 3) are collections of velocity spectra. Consider again the first ("silent") data set: the majority of propane appears in the central row and, therefore, has a velocity of 0 cm/s. The width of the spectrum represents the diffusivity (random motion) of the propane. The wider the velocity spectrum, the greater the coefficient of diffusivity at that location. Before the sound field is applied, the velocity spectra along the length of the tube are identical. In the presence of the sound field ("835 Hz"), that uniformity is lost. The peak in the velocity spectrum clearly shifts towards negative velocities in the first part of the tube section, and towards positive velocities in the second part. Figure 4 shows velocity spectra extracted from figure 3 at the positions along the tube section which show the greatest difference from their quiescent counterparts. These positions are 7.27 cm apart. λ/4 calculated from literature data for the speed of sound in propane [3] is 7.25 cm (see figure 1).

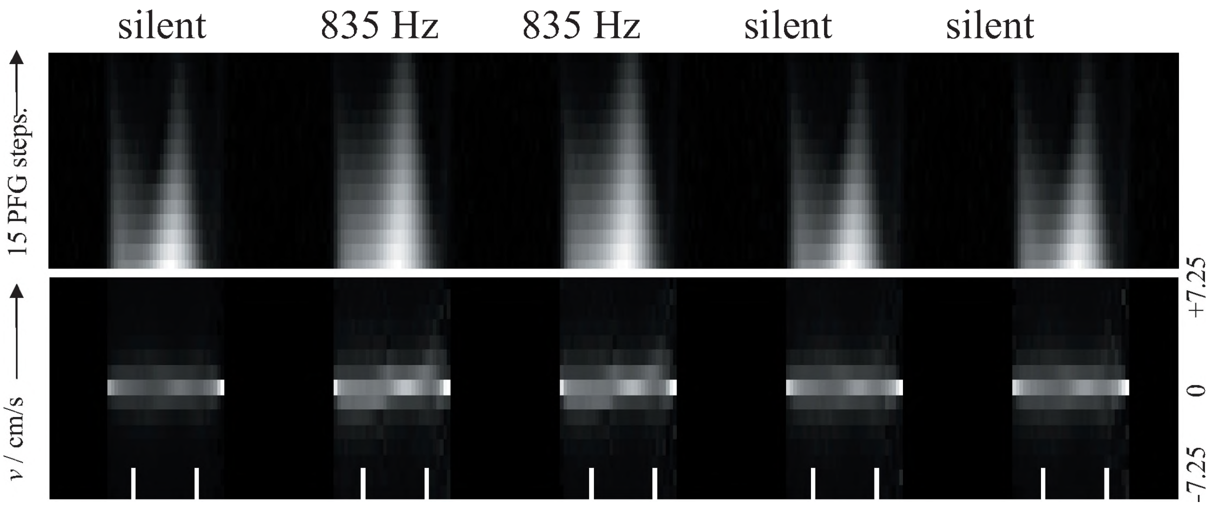

Figure 3. (Top) Five sets of profiles acquired before, during and after establishment of a standing sound wave in the tube. The section of the tube imaged is 12 cm long. Each profile is motion sensitized and 15 different profiles were acquired at each time, with increasing motion sensitization in the direction of the arrow, Fourier transformation along that dimension gives velocity spectra (Bottom), in which the horizontal axis is position along the tube, the vertical axis velocity (from –7.25 to +7.25 cm/s) and the brightness of each pixel is representative of the mass fraction of propane moving with that particular velocity at that position along the tube. Positive velocities are left to right along the tube section. The white vertical lines in each collection of velocity spectra, mark the positions of the spectra in figure 4.

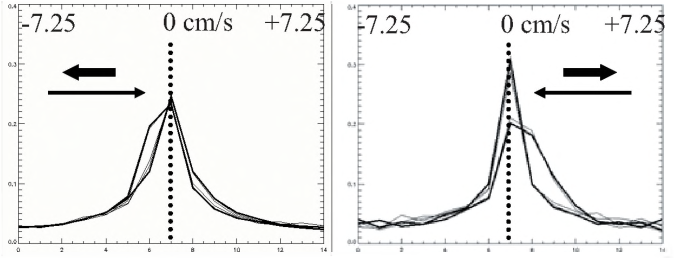

Figure 4. Velocity spectra selected from figure 3 at the positions indicated. Spectra from all 5 timepoints (before, during and after sound application) are overlaid. The profiles indicate a smaller mass fraction of faster counter flow (at the tube walls) as expected for developed Rayleigh streaming.

4. CONCLUSIONS

Magnetic resonance imaging is a completely non-invasive measurement method for the study of acoustic streaming in gases. MRI measurements will promote understanding in a variety of thermoacoustic applications.

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From Acoustics Week in Canada 2006/De l'acte semaine candienne d'acoustique 2006

A PRELIMINARY STUDY OF THE GEOACOUSTIC PARAMETERS OF GASSY SEDIMENT IN ST. MARGARET'S BAY, NOVA SCOTIA.

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1. INTRODUCTION

In recent years, St. Margaret's Bay, Nova Scotia, has become an important experimental site for Defence R&D Canada. It is well sheltered, has low maritime traffic, and is relatively close to the city of Halifax. Consequently, there is a growing need for oceanographic models for the bay, including geoacoustic models to predict sound propagation. The deep central basin of St. Margaret's Bay is an interesting region for geoacoustic studies because of the gas bubbles embedded in the surficial layer of sediment. This gas can be seen on sub-bottom profiles as a reflection horizon at depths of 2 to 4 m below the seafloor.

The geoacoustic parameters of gassy sediment are complicated to measure since they vary with frequency. The sound speed and attenuation of a surficial gassy layer have been measured by some, like Gardner [1], for frequencies between 3 and 100 kHz. However, very few have documented the values of these parameters for frequencies below 1 kHz. This work aims at estimating the values of these parameters at frequencies below 500 Hz.

2. METHOD

In this paper, measured and modeled Transmission Loss (TL) as a function of range were compared to estimate the values of geoacoustic parameters in gassy sediment. The method consists of modeling the acoustic propagation of a simulated signal for different seabed models to calculate the TL *vs.* range. These curves are then compared to the measured TL from real underwater sources. A good match of the peaks, troughs and the general slope between the measured and modeled TL *vs.* range should correspond to a good estimate of the seabed parameters. The preliminary results presented here were obtained by visually matching the measured and modeled TL of low-frequency sources in the deep central basin of St. Margaret's Bay.

2.1 Experimental and Simulated Data

Data from two similar experiments were used to measure *in situ* TL as a function of range. In each case, a low-frequency underwater source was towed along a straight transit and recorded on a vertical line array of hydrophones at ranges varying between 40 m and 800 m. Each of the two sources emitted a narrowband signal of four frequencies ranging between 72 Hz and 451 Hz. TL as a function of range was measured for all eight frequencies and for each hydrophone of the vertical array. A similar set of curves was then produced for simulated signals propagated over several seabed models using a parabolic equation model [2].

2.2 Seabed models

Two seabed models were generated as a starting point for the analysis. The compressional sound speed and attenuation estimates of the first model followed the theory developed by Anderson and Hampton [3, 4]. According to this theory, at frequencies below the resonance frequency of the gas bubbles embedded in the sediment, the sound speed of the compressional sound wave can be over ten times slower than in gas-free sediment. The theory describes how a small quantity of gas can significantly increase the attenuation of the compressional sound wave, while it has little effect on the sound speed.

Properties of the sediment and the embedded gas have to be known with great accuracy to evaluate compressional sound speed (c_p) and attenuation (α_p) using the Anderson and Hampton formulas, however, little is known about the gas found in St Margaret's Bay. Consequently, our first seabed model used values of sound speed and attenuation that were calculated by comparing the characteristic of St Margaret's Bay to the similar and well studied environment of Eckernförde Bay, in the Baltic Sea [5]. These calculations led to a very low sound speed of 75 m/s, and an attenuation of 1.0 dB/λ, for frequencies between 72 and 451 Hz.

The second seabed model was developed by following a study published in 1977 by Kepkay [6]. In his thesis, Kepkay reported *in situ* measurements of sound speed in the deep central basin of St. Margaret's Bay. According to these measurements, the average sound speed was 1364 m/s in the top 2 m of sediment, for frequencies presumed lower than the resonance frequency of the gas bubbles. This number is lower than the estimated sound speed in saturated gas-free sediment, 1440 m/s [6], but much higher than predicted by the Anderson and Hampton formula. Since Kepkay did not measure the attenuation in the sediment, this second model included the same attenuation value as in the previous model.

In both seabed models, the geoacoustic parameters other than the c_p and α_p of the gassy sediment layer, including the shear sound speed (c_s), attenuation (α_s), and density (ρ), were estimated from Piper and Keen [7], and Osler [8].

After comparing the TL produced using the two seabed models with the measured TL *vs.* range, each parameter characterizing the gassy layer was modified individually to analyze its influence on the TL of the signal. A range of seabed models were then produced and preliminary results of geoacoustic parameters for the deep central basin were obtained by retaining the seabed model producing the best visual match of measured and modeled TL *vs.* range.

3. RESULTS

Table 1 presents the geoacoustic parameters corresponding to the seabed models presented in the previous section. Models are produced by using one of the three Gassy Lahave clay layers overlying the other sediment layers. These gassy layers correspond to: (a) the Anderson and Hampton theory, (b) the measurements from Kepkay, and (c) the final model producing the best TL match.

Table 1. Geoacoustic parameters used to construct three seabed models, corresponding to (a) the Anderson and Hampton theory, (b) the measurements from Kepkay, and (c) the final model producing the best TL match.

Sediment		Thickness [m]	ρ [g/cm^3]	C_p [m/s]	α_p [dB/λ]	c_s [m/s]	α_s [dB/λ]
Gassy Lahave clay	a	2	1.25	75	1.00	0	1.6
	b	2	1.14	1364	1.00	50	0.5
	c	3	1.14	1100	15.00	50	0.0
Saturated Lahave clay		2	1.27	1440	0.05	75	0.0
Lahave clay		10	1.56	1480	0.03	125	1.0
Till, Gravel		∞	2.00	1900	0.48	450	3.0

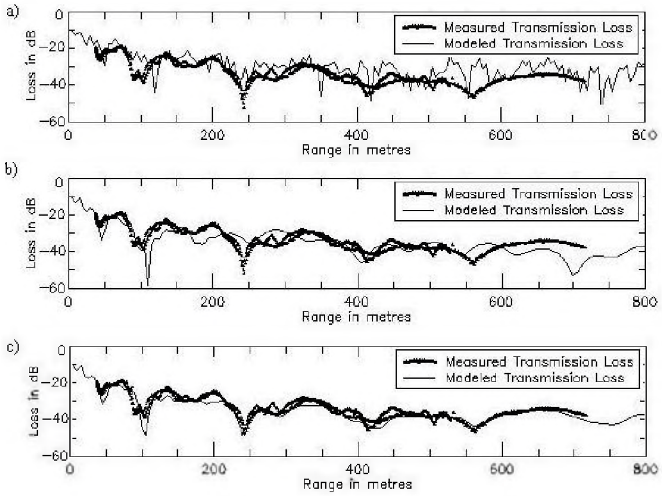

Fig. 1. Comparison of TL vs. range for simulated and measured signal at 117 Hz, seabed from a) Anderson & Hampton theory, b) Kepkay's measurements, and c) best visual match of data.

Figure 1 presents the comparison between the real and modeled TL *vs.* range using the three seabed models presented in Table 1. Here, the black dots represent the measured TL *vs.* range, and the black lines represent the modeled TL *vs.* range at a frequency of 117 Hz and a hydrophone depth of 29 m. The double line formed by the black dots is caused by the duplication of ranges from the symmetrical source transiting towards and past the array.

4. DISCUSSION

The preliminary results presented here introduce a geoacoustic model for St Margaret's Bay that produce reasonable TL match at frequencies below 500 Hz. In future work an inversion algorithm will be used to refine our model and evaluate the changes in compressional sound speed and attenuation with frequency. A better comprehension of the very-low frequency acoustic response in gassy sediment will help localize more accurately targets in coastal environments like bays and harbours. This inversion analysis will allow calculations of uncertainties associated with the different geoacoustic parameters, which will provide valuable insight for further improvements to target localization algorithms.

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AN ENVIRONMENTAL NOISE IMPACT ASSESSMENT AND FORECASTING TOOL FOR MILITARY TRAINING ACTIVITIES

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1. INTRODUCTION

The Impulse Noise Propagation Model (INPM) was developed by JASCO Research Ltd for the Canadian Department of National Defence as an environmental impact assessment and forecasting tool for airborne noise from military training activities. Progressing beyond its defence environment roots the INPM is currently being expanded to encompass a wide range of industrial noise sources both impulsive and continuous. This paper describes some of the features and capabilities of the airborne noise modelling core software, focusing on its benchmarking, validation against measurements, and special handling of propagation conditions such as atmospheric turbulence.

2. ALGORITHMIC MODULES

2.1 Acoustic Source Levels Modelling or Retrieval

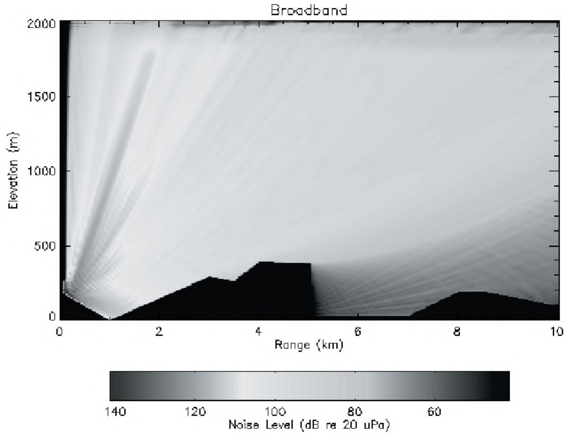
Sound propagation modelling requires as input the source levels in individual frequency bands, expressed in dB re $20\mu Pa^2$ at 1m distance. Depending on the modelling accuracy requirements, the range of spectral levels to be modelled is resolved into octave or one-third octave bands. Finer spectral resolution allows more accurate modelling of the frequency-specific sound propagation structure, which may have an impact on the spatial distribution of received noise even after the results are combined into broadband levels. The software incorporates two alternative approaches to the generation of spectral source levels: numerical estimation of the acoustic output for source types that are amenable to a modelled description (such as detonations of explosive), or retrieval and possibly interpolation of stored levels from a database compiled from measurement results.

2.2. Sound propagation modelling

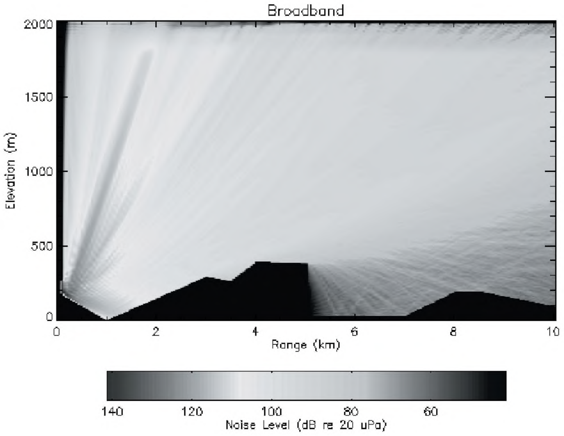
The computational core of the INPM is the sound propagation module, which is based on the widely adopted Parabolic Equation (PE) model. The software uses a two-dimensional implementation of the PE method that takes into account diffraction, air turbulence and sound interaction with the terrain; it also incorporates a faster Ray Tracing algorithm that can be automatically invoked in place of PE for higher frequencies at which ray methods approximate well the propagation of sound in air.

The PE modelling algorithm in the INPM is based on the split-step Padé method introduced by Collins (1993) of the US Naval Research Lab for use in underwater acoustic propagation problems. Collins' code, known as RAM, was extensively modified at JASCO Research to adapt it for atmospheric use. Substantial alterations to the existing routines and development of entirely new algorithms were required to include in the propagation model the effects of terrain cover (variable complex ground impedance) and atmospheric turbulence, among others. An example of a requirement specific to airborne propagation modelling is the need to introduce an artificial absorbing layer to extinguish the field before it reaches the upper edge of the computational grid, adjusted for each frequency so as not to affect those transmission paths that could potentially be refracted back towards the ground.

The INPM acoustic propagation module can output the complete sound level field in range and height along a radial from the source. This can be rendered as a grey scale image plot as in the figure below, which presents an example of noise propagation in a slightly upwind condition (noise tends to bend upward in this case) in non-turbulent air.



The case just shown provides a baseline against which the handling of atmospheric turbulence by the model can be demonstrated. It is easy to see that in the region beyond the cliff side at 5km range very little sound energy can be found since in an upwind propagation regime the terrain drop creates an effective shadow. If turbulence is introduced, on the other hand, the sound field shown below results. Now higher noise levels can be found in the zone beyond the cliff side as sound is scattered into this zone.

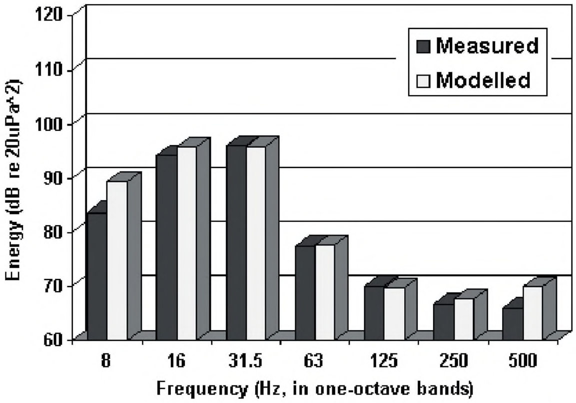


Turbulence in the INPM was implemented using a method developed by Gilbert et al. (1990) in which a 2-dimensional perturbation function is applied to the normal refractive index. The zero-mean perturbation function is characterized by maxima and minima that are semi-randomly separated according to a specified coherence length. Desktop validation of the PE model was carried out using benchmark results from Attenborough et al. (1995). Validation of the turbulence component was performed by comparing noise level predictions under turbulent conditions with data from an experiment by Wiener and Keast (1959).

3. EXPERIMENTAL VALIDATION

The model has been subjected to a thorough experimental verification. Noise from military detonations was accurately measured to provide data for validating the source level modelling and propagation components of the INPM. Measurements were performed at distances from the source ranging from about 100m to 3.5km along radials that spanned dry grassy fields, forested areas, vegetated hills as well as a stretch of water across an inlet. These experimental results were then used in the validation of the model. The acoustic recordings were resolved into one-octave band levels that could be directly compared to the output from the INPM. The only inputs provided to the model were the properties of the explosive charge and the propagation parameters along the source-receiver traverse: elevation, acoustic impedance for different types of ground cover, and air column profiles (temperature, humidity, wind speed and direction) from meteorological probe launches.

The bar graph below shows the result of the comparison between measured and modelled noise levels in individual octave bands for a detonation of C4 high explosive in a 30cm deep ground pit, at a range of 1.6km from the source. It can be seen from this example, which is typical of many others, that the propagation model in the INPM is able to replicate quite closely the transmission loss at all modelled frequencies (both model and measurement, for example, show a marked attenuation starting at the 63Hz band) and that the source model provides realistic starting levels.



4. THE INPM IN PRACTICAL USE

The INPM is an effective noise forecasting tool because of its integrated architecture. A comprehensive run manager module coordinates a range of tasks that include:

- Extraction from geographic grid files of the terrain elevation and ground cover data along an automatically-defined set of modelling segments;
- Importing of atmospheric data, usually in the form of encoded forecasts from meteorological agencies, for the period of applicability of a model run;
- Repeated execution of the sound propagation model to generate noise levels along the modelling segments for each frequency band;
- Additive merging of output sound level data over all computed frequency bands and multiple sources to generate either noise contour maps or time-location noise level reports.

The INPM has significant potential to make a contribution to the lowering of noise impact on the environment by enabling more informed planning and decision making.

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From Acoustics Week in Canada 2006/De l'acte semaine candienne d'acoustique 2006

A REMOTELY-PILOTED ACOUSTIC ARRAY FOR STUDYING SPERM WHALE VOCAL BEHAVIOUR

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1. INTRODUCTION

Although acoustic research on groups of sperm whales (*Physeter macrocephalus*) has revealed much concerning the way that codas (short stereotyped click sequences) are shared and produced at the group level (e.g. Rendell and Whitehead 2003), the difficulty in determining which individual in a group of marine mammals is vocalizing has inhibited the investigation of the existence of individual repertoires, syntax or other complex phenomena in the communication system of this species. While recent advances in the use of passive acoustic localization have provided important tools for studying the movement, foraging behaviour, and communication patterns of marine mammals, previously described systems do not easily permit the discrimination of vocalizations made by pelagic cetaceans in very close proximity to one another. In an effort to address this problem, we developed an acoustic array consisting of small remotely-piloted vessels (RPVs) to record and localize the vocalizations of individual sperm whales in social clusters at the water's surface.

2. METHOD

2.1 Equipment

Each RPV, as well as a larger research platform (a 12-m auxiliary sailboat), is equipped with a hydrophone (Vemco VHLF; frequency response: 200 Hz-20 kHz ± 3dB; midband sensitivity: 147 dB re 1 V/μPascal) that is suspended approximately 80 cm below the water's surface. On each RPV, acoustic signals from the hydrophone are amplified, high-pass filtered at 1 kHz, and broadcast by a FM transmitter (NRG Kits PLL PRO III). Signals are then received by digital AM/FM PLL synthesized radios (SONY ICF-M260) onboard the research platform and recorded on a multi-track recorder (FOSTEX VF-160; sampling rate: 44.1 kHz). The acoustic signals from the hydrophone onboard the primary research platform are also high-pass filtered at 1 kHz and recorded on the multi-track recorder.

On each recording platform, a GPS unit (Garmin GPS25-HVS) logs position each second and saves the data to a flashcard for later retrieval. A frequency shift keying (FSK) modulator transforms the stream of ASCII sentences from the GPS unit onboard the primary research platform to an amplitude-modulated tonal signal (see Møhl et al. 2001), which is recorded as an acoustic track on the multi-track recorder in synchrony with the hydrophone signals. Thus, subsequent demodulation of the FSK timestamp during analysis allows for synchronization of the acoustic and positional data (see Møhl et al. 2001). Each RPV is 1 m in length and built of durable fiberglass. The motor and rudder of each RPV is powered by two 12-V batteries and controlled by a radio transmitter onboard the primary research platform.

2.2 Deployment / Calibration

During deployment, RPVs can be piloted to establish and maintain favorable array geometry around a group of whales, provided that they are not moving too rapidly (up to approximately 1 knot). The maximum array size possible with this system is limited by the range of the FM transmitters, which is approximately several hundred meters. The maximum duration of a recording session is limited by the life of the 12-V batteries that power the RPV payloads and is approximately 3 hours. During deployment, estimates of sea surface temperature and salinity are obtained with a thermometer and refractometer respectively.

A series of calibration tests were conducted to determine the accuracy of this acoustic array. Three RPVs were deployed from a stationary 12-m sailboat and positioned so as to form a diamond approximately 25-50 m per side. Two metal pipes were suspended from a wood plank with a distance of 1.5 m between them and hung over the sides of a dinghy. The dinghy was then rowed through the array while a hammer was used to strike the pipes in an alternating manner, thereby generating two loud and impulsive sound sources of audibly different frequencies a known distance apart. Pipes were then struck in a repetitive manner at the periphery of the array as well as in an end-fire position outside of the array (i.e. directly in line with two receivers).

2.3 Analysis

During analysis, the binary GPS files containing the phase data were downloaded from the flashcards, converted to a RINEX file, and submitted to an online Precise Point Positioning processor (Canadian Geodetic Service CSRS–PPP online processor) to improve positional accuracy. Erroneous noise in GPS positions was also reduced by discarding fixes obtained by less than 7 satellites and by independently smoothing the x- and y- coordinates for each GPS receiver by fitting quadratic equations to time segments spanning several seconds before and after each epoch in the record (see Christal and Whitehead 2001).

Acoustic analysis was conducted in a standard sound-editing program (Cool Edit, Syntrillium) and a dedicated software package (Rainbow Click, IFAW). The speed of sound in water was derived from the LeRoy equation using sea surface temperature and salinity. We used routines custom-written in MATLAB® version 6.1.450, release 12.1 to calculate the time differences in which sounds first arrived at different hydrophones (see Wahlberg et al. 2001).

Using these time-of-arrival-differences (TOADs) between the four hydrophones, the positions of GPS receivers, the speed of sound in water, and the assumption that sound sources and receivers were all on the same plane, the location of a detected sound was calculated as the average over the 12 MINNA (minimum number of receivers array) solutions (see Wahlberg et al. 2001). Because a triad of receivers results in three hyperbolae and three hyperbolic intersections rather than one (a result of error in the estimation of TOADs, speed of sound, and hydrophone positions), the use of four hydrophone receivers results in four possible hydrophone triads and thus a total of 12 hyperbolic intersections, which when averaged provide the best estimate of the sound source's location while accounting for measurement error. All GPS and localization analysis used custom-written MATLAB® routines.

3. RESULTS

Inside the array, the estimated mean distance between the localized sound sources was 1.97 ± 0.3 m ($n = 22$), giving an overall mean absolute error of 0.48 m from the true distance of 1.5 m (Fig. 1). At the periphery of the array, this mean error increased to 0.83 ± 0.5 m ($n = 7$). The mean error for repeated bangs in the end-fire area (in line with two receivers) increased to 9.42 ± 7.0 m ($n = 11$).

4. DISCUSSION

The accuracy of this system to 0.5 m within the array is more than acceptable for differentiating the coda vocalizations exchanged between sperm whales that are approximately 6.5 m apart within a social cluster (Whitehead 2003). However, assuming errors similar to those reported for the calibration of a similarly-sized array (Watkins and Schevill 1972), the localization error at even 80 m from the array (approximately 20 m), while small enough to permit the differentiation of clicks made by different social groups, is too large to allow the confident assignment of vocalizations to individual whales found at that range. Similarly, the error estimated here of 9 m for sounds in an end-fire position prohibits the differentiation of whales vocalizing in close proximity to one another in these regions.

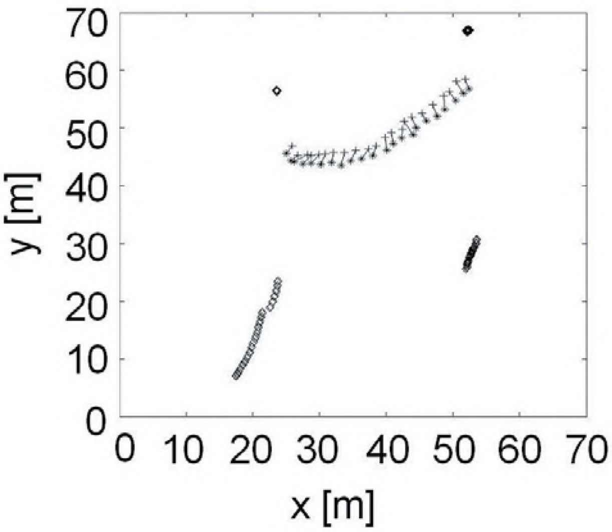

FIG. 1. The GPS receiver positions of recording platforms throughout the described calibration are represented in the figure by diamonds. The estimated source locations of the banged pipes are represented by ✕ and ✳. The mean distance between the pipes as determined by acoustic localization (see text) was 1.97 ± 0.3 m (represented by solid lines connecting the symbols representing the estimated source locations). See text for description of calibration.

The dynamic array described here was designed with the intention of maintaining preferable array geometry around a group of slow-moving pelagic cetaceans, a configuration that is clearly important in the assignment of localized vocalizations to sperm whales in close proximity to one another. This system is currently being used by the authors to study the way that codas are sequenced and exchanged by individual sperm whales as well as the spatial arrangement of vocalizing animals, thereby permitting a more thorough examination of the function of coda communication in this species.

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SPATIALLY RESOLVED NMR RELAXATION OF GAS IN CAVITATING LIQUID

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1. INTRODUCTION

Gaseous cavitation in water begins via formation of gaseous bubbles in the body of liquid from the previously dissolved gas due to an external pressure drop. An interaction between the liquid and the gaseous phases is quite complex in case of acoustic cavitation where an external sound pressure makes the appearing bubbles oscillate, leading either to their growth and coalescence, or to their collapse and fragmentation. Gas inside the bubbles is the subject to high pressures and temperatures resulting in chemical reactions and emission of light from cavitating liquids.

Quantitative information on the behaviour of gas in multibubble cavitation is difficult to obtain with optical and acoustical methods since bubbles are excellent sound absorbers and light reflectors. Nuclear Magnetic Resonance is a promising modality for cavitation studies as its signal can be modulated by molecular environment of nuclei under study. However, a drawback of gas NMR and MRI is its inherent low sensitivity: NMR signal is proportional to the number of spins which in gaseous samples is three orders of magnitude lower than in liquid. Therefore, when doing NMR of gas in cavitating liquid, one must employ a nuclear spin different than that of hydrogen, otherwise the useful signal from gas will be swamped by the signal from water. Non-hydrogen based gases should also be soluble in water to be able to participate in formation of bubbles.

Chlorodifluoromethane, also known as Freon-22, is very soluble in water (0.78 volume/volume at 25 C). It has two atoms of fluorine that can be engaged in NMR experiments with the NMR signal distinctly different from that of water. Its NMR relaxation parameters T1 and T2 depend very dramatically on the state of this compound. When Freon-22 is in a gaseous state, it has T1 of 2.5 and T2 of 1.4 ms at 2.35 T, while for the Freon completely dissolved in water, its T1 and T2 are 2 and 1.4 s correspondingly. Thus, with NMR measurements, it will be possible to distinguish between the two states of Freon-22.

2. METHOD

All experiments were performed on 2.35 T MRI scanner (Nalorac, TX) with 20 kHz Langevin type transducer (Sensor-Tech,ON) at standing wave conditions inside the water-filled cuvette (see Fig.1). Two sets of experiments were performed: CPMG without spatial resolution and SPRITE MRI with resolution along the length of the cuvette. CPMG sequences with saturation-recovery to measure T2 at various recovery delays were designed to provide information about the amount of Freon in dissolved and free states before, during, and after cavitation. The signal intensity of the dissolved Freon was additionally saturated by a short recovery delay (1s) so that it was attenuated down to only 32% of its initial intensity. At the same time, the signal from a free gas would have no attenuation. Echo decays were fitted as bi-exponential, and the short and long components of the decays were attributed to free and dissolved states of Freon. Echo time was 300 us, with 1024 echoes and 64 scans. The saturation delay was incremented in 8 steps, from 10 ms to 1s. The total acquisition time for each series was 9 min.

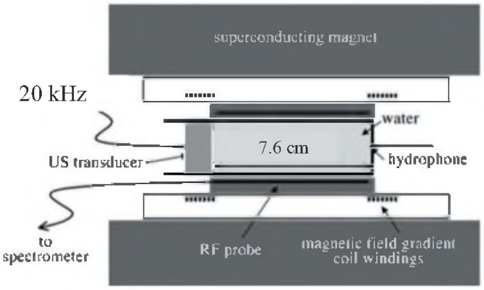

Figure 1. Experimental setup

SPRITE MRI (Single Point Ramped Imaging with T1-Enhancement, Balcom) was chosen for its insensitivity to presence of metal (the transducer) and its ability to detect NMR signal at short encoding times t_p. Signal intensity in SPRITE depends on the sample's T1, RF flip angle θ and repetition time TR:

$$S \propto e^{-t_p/T_2^*} \frac{1-e^{-TR/T_1}}{1-\cos\theta e^{-TR/T}} \sin\theta \, .$$

The imaging parameters were chosen so that the signal from the dissolved freon would be attenuated by a factor of 4 whereas the gaseous Freon would have no attenuation. With encoding time t_p of 380 μs, TR of 2 ms and 64 gradient steps, 4096 scans were accumulated with the total acquisition time for each series of 8 min.

3. RESULTS AND DISCUSSION

Before the cavitation onset, an amount of observable free gas in the cuvette was slightly above the noise level (0.86% of the total gas concentration). As soon as cavitation began, the amount of free gas increased, reaching 2.1%. After the transducer was turned off, the amount of free gas increased again and reached 5.9(3)% of the total gas concentration in the cuvette (see Fig.2). It should be pointed out that we do not necessarily detect NMR signal from all

Freon molecules that are present in the cuvette. Nuclear magnetization is sensitive to a temperature increase and local magnetic fields. If some portion of Freon is inside the cavitating bubbles, extreme conditions during the bubble collapse might destroy the freon's nuclear magnetization, thus masking the total amount of gas participating in the cavitation.

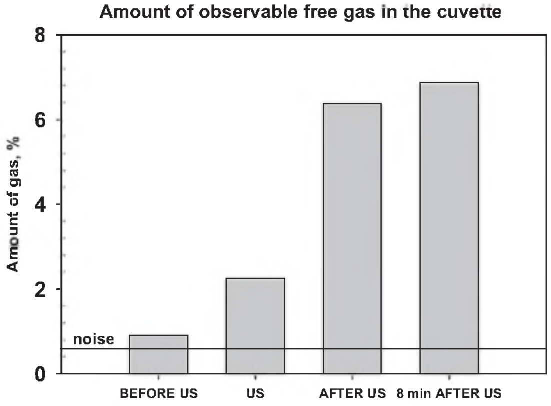

Figure 2. Amount of free gas before, during, and after cavitation.

The observed increase in the amount of free gas after the cavitation can be either due to the previously undetectable gas that has been released (which would give us information on total amount of gas inside the cavitating cloud) or due to some degassing mechanism taking place after the sound field has been switched off. Degassing power of cavitation is well-known; however, it is usually associated with the release of bubbles trapped by the sound field.

More information can extracted from a spatially-resolved data (Fig.3). Here we see a prominent increase in intensity near the centre of the cuvette, and two intensity drops on either side corresponding to a pressure node of the standing wave (the centre) and two pressure antinodes. In a standing wave, bubbles of a larger than a resonant size accumulate in a pressure node, whereas bubbles of a smaller than a resonant size accumulate in a pressure antinode (Leighton).(A resonant size radius for air bubbles in water at 20 kHz is about 0.15 mm).The signal increase in the centre indicates a presence of larger bubbles, its detection facilitated by an NMR T1 contrast mechanism that amplifies a signal from gaseous Freon by a factor of 4.

The signal decrease might mean a destruction of the nuclear magnetization by violent cavitation taking place in the antinodes: it has been argued that it is the smaller bubbles that are most chemically active, and it is from the antinodes the sonoluminescence is usually emitted in the standing wave (Leighton, Young). It is more likely, however, that smaller bubbles will cause local perturbations of the magnetic field due to a difference between magnetic permeabilities of water and gas, effectively dephasing, but not destroying, the freon's magnetization. That can be tested by repeating measurements at much shorter encoding times (50 μs vs. present 380 μs), with the subsequent conversion of the dephasing information into the bubble size distribution. We plan to perform such measurements in the near future.

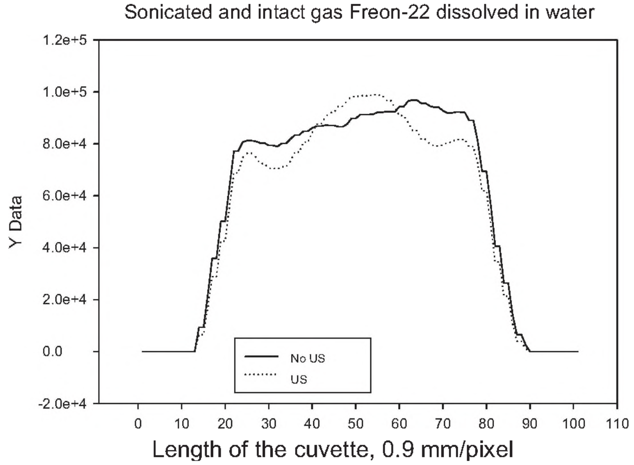

Figure 3. SPRITE profiles of Freon before and during cavitation

4. CONCLUSION

We have demonstrated, for the first time, a possibility of Magnetic Resonance Imaging of gas in cavitating fluid. MRI can provide us with unique information on the conditions inside cavitating cloud and states of both dissolved and free gas, showing great promise for a future research.

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ACKNOWLEDGEMENTS

The authors thank the Natural Sciences&Engineering Research Council of Canada for financial support. The UNB MRI Centre is supported by an NSERC Major Facilities Access Award.

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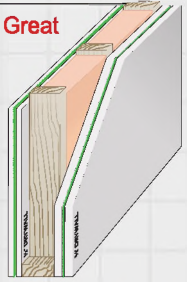
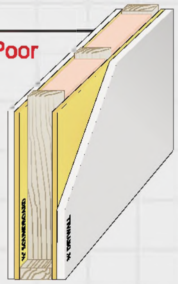


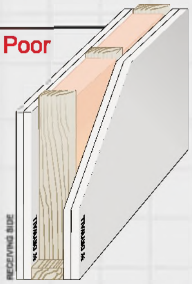
Soundboard

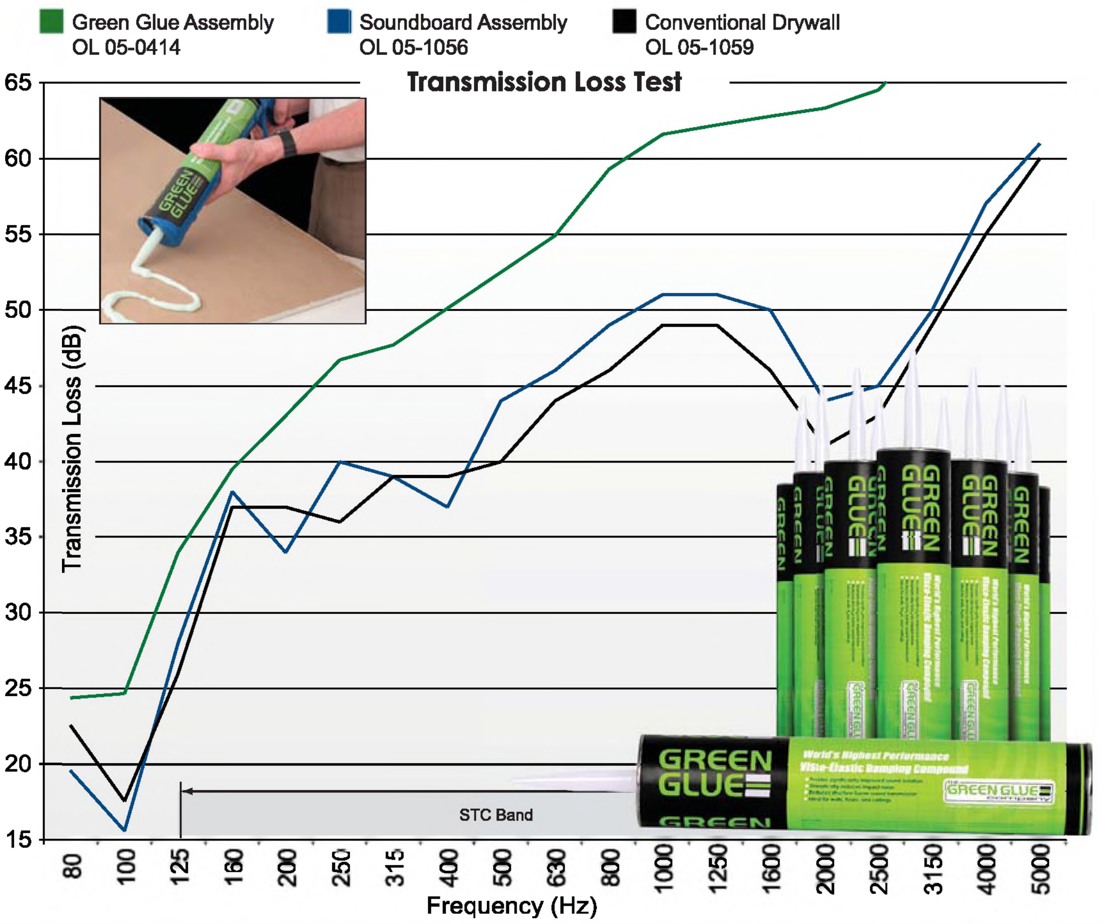
Low Frequency: Poor
46 STC Rating
32 OITC



Conventional Drywall

Low Frequency: Poor
44 STC Rating
33 OITC





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CANADA WIDE SCIENCE FAIR

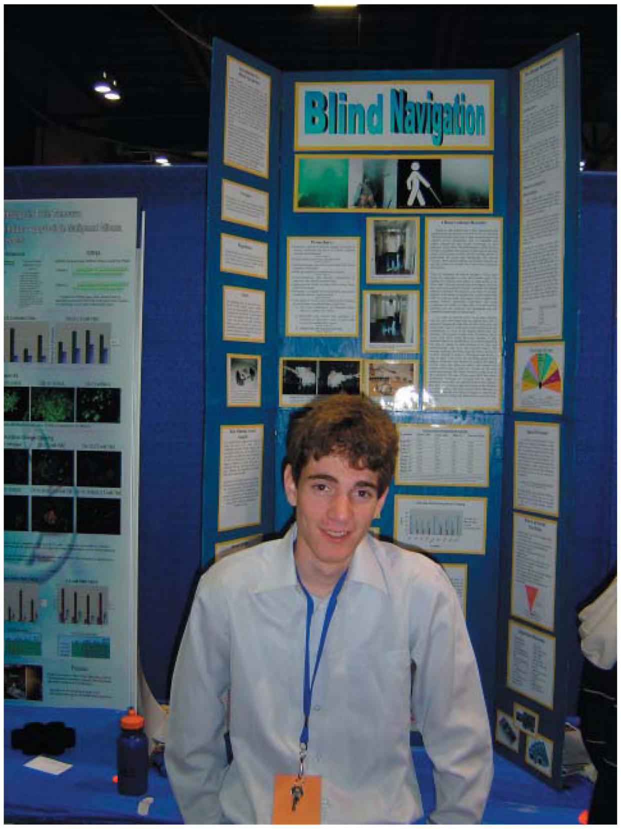
From File Reports

Steven Gasior is the winner of this year's Special Award from the Canadian Acoustics Association for his project - Blind Navigation.

Steven Gasior, 16 yrs old, is now attending St. Joseph Secondary School in Mississauga Ontario as a grade 11 student. He has competed in science fairs every year beginning in Grade 7 and has received medals or special awards for every project submitted. In addition to the Canadian Acoustical Association Award for his work on Blind Navigatio, Gasior also won the S.M Blair Family Foundation Award, and lastly a Bronze Medal in the engineering division at CWSF.

In his spare time, Steven enjoys building and designing new and innovative creations that mainly make science fiction a reality. His creations range from a robotic submarine to new flying vehicles. He designs robots and writes various computers programs that mainly pertain to the robotics club. He enjoys converging multiple devices together and making all-in-one devices. He has a strong fascination with aviation and power sports (ATV, Dirt Bike, sea-doo) and hopes to get his recreational aircraft license by the time he is 20. In his spare time, Steven enjoys making movies and creating his own dance tracks by combining old lyrics and modern beats.

Steven is an active member in the robotics club and is working towards completing his qualification to become a lifeguard along with being a swimming instructor.



Steven Gasior's full article is reproduced below.

BLIND NAVIGATION*

Steven Gasior
St. Joseph Secondary School, Mississauga, Ontario, Canada

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

INTRODUCTION

Blind navigation is a project dedicated to assist people or professions that are faced with vision impairment. Blind navigation will help people who are physically blind or visually impaired due to aging or disease by providing information of what exists in the space around them, allowing them greater freedom and mobility. Firefighters in dense smoke filled buildings and divers in muddy waters face similar difficulties in navigating their surroundings due to having their vision impaired by environmental factors. This could save lives in rescue situations where locating or navigating an area without vision is critical.

Humans use their hearing to pinpoint the source or location of sounds by analyzing time delays, amplitude and frequency variations. Each ear detects a different sound intensity and frequency, which ultimately leads to the location of the source of sound. Blind navigation uses this ability and interfaces it with wearable proximity sensors. Using audible frequencies based on the location of stationary objects, tones are created by using the same principal of sound directional comprehension. Thus people with vision impairment can quickly, accurately and safely navigate their surroundings.

URNS

URNS stand for ultrasonic range navigation system. It was designed to assist those individuals who have impaired vision or work in environments that make navigation, by means of sight, difficult (firefighter, diver). The URNS invention is an engineering feat primarily because it converges natural brain operative habits with proximity sensors that take advantage of natural brain phenomenon. As mentioned before humans have the capability to pinpoint location/origin of sound based on the difference of frequency and time delays. Because sound is a wave, the wavelength gets greater as distance increases and there is a brief sound delay as the sound hits the right ear before the left and vice versa. Human brains take advantage of this difference to identify the speaker's location. URNS takes this phenomenon to the next level. Using proximity sensors, a 180 degree array is formed around ones head. Based on the location of stationary objects the sensors can pinpoint that location in relation to the other sensors. Then based on the location of the object the computer program plays a tone supposedly generated from that exact location. These tones provide a sense of the environment. The program could also be written to play sounds depending on the context. This is common in the programming, as tones are played based on comparisons between all 10 sensors. Basically URNS is similar to the surround sound system that many entrainment systems have. The sounds are infinitely changing based on the environment one is in but still provides a general location much like the same as a television.

URNS is still in development. The programming language used is Pbasic, which is a weak language and hence all the sensors need to be pulsed sequentially rather than simultaneously resulting in a sampling rate of 2 seconds rather than 200 milliseconds. Also the size of URNS is rather big, however it has much potential to be sized down to fit in a normal pair of glasses. Because of limitations to URNS only frequency can be regulated and amplitude cannot. With modifications to URNS internal circuitry it is hoped to be able to change the amplitude and frequency as well as play many frequencies at one time much like a symphony. Only difference is the symphony changes as you walk and rarely plays together. A prototype of URNS is shown in Figure 1.


Figure 1. URNS for Blind Navigation

GOALS

The engineering goals of the project are to provide visually impaired persons a portable, easy to use, and inexpensive device to assist in navigating their surroundings, using URNS technology. The device should be able to extrapolate data from an array of sensors and provide non-visual information about an objects location.

INSTRUMENTATION

A list of materilas required to produce the necessary device is shown in Table 1 below.

-Breadboard x2
-Ping ultrasonic sensors x10
-Stereo headphones and female headphone jack
-Bs2e microprocessor
-Switch x2
-LED x2
-5v regulator and 9v battery x2
-10uf capacitors x4
-8Ω resistor x2

-Stamp holder
-Data cable
-5mm acrylic sheet
-Plastic glasses
-3mm foam
-Battery holder x2
-Electric solder and Hot glue
-Adhesive spray and Crazy glue
-20pieces of 4x28 screws
-μMp3 module

Table 1. Required Materials

EXPERIMENT

The experimental process is briefly described below in point format.

- Research methods of distance ranging and types of sensors. Determine the needs of visually impaired people and professions
- Develop computer model and use of criteria such as priority, distance calculation, velocity calculation, sampling rate and audible output.
- Sensor array and main electronic components were bread boarded.
- Sensor location was tested for optimal functionality, ease of use and cosmetic appeal. Positions include foot, waist, torso, head, arms or hand.
- Computer program was tested and confirm functionality of all components.
- Main prototype was constructed and all electronics were mounted to frame
- Master program was written and tested with components mounted on the prototype frame. Sensor functionality was tested by placing objects in front of sensors and determining how the output/tone changes.
- Once prototype bench testing is complete experimentation with humans commenced to determine the optimal programming and interface that is most understandable, accurate in terms of spatial perception, and easy to use. A person is seated while objects are placed around them and told where there are located in order for the person to become familiar with its use. The person while seated is then blindfolded and asked to identify where objects were placed to determine the accuracy of the prototype.
- The subject wore the prototype and had to determine moving objects in front of sensors. Human subjects then identified the motion of the object to determine

understanding of object movement and describe their surroundings.

- In this experiment the subject would be timed while walking a controlled course under a number of conditions given below:
  - No visual impairment to determine ideal times to complete the course.
  - Blindfolded and without the prototype to determine if other cues could be used to complete the course. If the subject strayed too far from the laid out course the test would be stopped. Subject is asked to continually describe their location in the laid out course.
  - Blindfolded and using a cane. If the subject strayed too far from the laid out course the test would be stopped. Subject is asked to continually describe their location in the laid out course.
  - Blindfolded and using the prototype. If the subject strayed too far from the laid out course the test would be stopped. Subject is asked to continually describe their location in the laid out course.

RESULTS

The experimental results show that using frequencies between 350-700 Hz for no less than 200 millisecond works best in data comprehension and comport. Lower frequencies may be inaudible and higher frequencies can become annoying.

A trend in the way humans perceive tones was observed. A tone sequence of less than 200 milliseconds is difficult for a human to interpret. The amount a data sent at one time needs to be limited to allow for the average person to understand the tones and extrapolate the objects location. However many of these factors can be compensated for in the master program to allow for optimal understanding on the subjects behalf. With greater training and practice with the system people can interpret the tones more accurately and quickly.

Due to limitations of the speed of the microprocessor and the type of sensor, the sample rate is two seconds to scan a 180 degree array. Thus a slow walk of roughly 2 feet per second is the fastest speed of travel with full scanning. It is anticipated a faster processor could conduct a greater number of calculations as to velocity change and direction of motion to alert the subject of impending collisions even while the subject is running. Greater memory storage would allow storing the location of all objects scanned and predicting collisions based on the direction of travel.

Table 2 presents the data that illustrates time taken by four subjects to navigate a 118 ft course using the apparatus, a cane, and normal sight. The sighted test subjects were asked to walk slowly at no faster than 2 feet per second since the subject could run the course and complete it within 5 seconds. At 2 feet per second it would take 59 seconds to complete the course. All sighted subjects completed the course in less than 59 seconds. Subjects were asked to navigate the course blindfolded with no external aides, but none completed the course without significant redirection and none completed the course on their own.

The chart shows how the apparatus compares to a cane, or sight. The sight test resulted in the lowest time. All tests with the cane took longer than the sighted trail. This is primarily because the data flow is slow since only one sensor (the cane) is used and it must traverse the arc continuously in front of the subject. All subjects would have hit objects above shoulder level using the cane because it only identifies objects at ground level unlike the apparatus, which senses objects at eye level. All subjects described the cane as easiest to learn, this is primarily because of its slow and understandable data flow that allows for ease. The URNS (Ultrasonic Ranging Navigation System) uses a more complicated means of interpretation but can scan 180 degrees at one time and contains an upward ranging detector to locate objects at eye level. Due to the complexity of five tones for left and right ear amateur subjects initially find it more difficult to interpret but there is much room for improvement as the subject uses and relies on the apparatus more and more to navigate. The average sampling rate using the cane is about two to three seconds to make a 180-degree scan before a step is taken. This limits the traveling speed of the subject. Where no objects were located by the cane the subject moved faster but when more than object was located the subject often took at least two sweeps of the cane before walking. However the URNS has the capability to sample at 200ms or 20 times faster than a cane leaving much room for improvement.

Subject	Time to navigate with sight.	Navigate blindfolded using cane	Navigate blindfolded using apparatus 1st time	Navigate blindfolded using apparatus 5th trial
Subject 1	17 sec	102 sec	150 sec	86 sec
Subject 2	24 sec	107 sec – subject strayed off course and was redirected	187 sec	130 sec
Subject 3	33 sec	119 sec	243 sec	98 sec
Subject 4	29 sec	148 sec	322 sec	156 sec

Table 2. Effect of Blind Navigation

However the prototype unit completes the 180-degree scan in 2 seconds due to chipset limitations and sensor type. The URNS program sets a priority that a tone is emitted if an object is less than one metre from the subject. This allows the subject to walk quickly when hearing no tones, since the subject knows that no objects are in their path.

CONCLUSIONS

The current investigation showed that it is possible to use an array of sensors to assist visually impaired persons navigate their surroundings. However training and practice in use of the device is necessary to obtain maximum benefit. As well, the speed at which most humans can comprehend information and the maximum frequency at which people find comfortable can be incorporated to assist the visually impaired navigate.

ACKNOWLEDGEMENTS

I would like to thank St. Joseph secondary school for providing an adult sponsor and member of the IRB board. I'd like to acknowledge Edward Gasior (my Dad) for making all the late night trips to the electronic store and Julian Smith for volunteering to be the adult sponsor. I also thank Sandra Carvalho for providing insight into physiology and being apart of the IRB board and my family members for volunteering to be the test subjects.

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Pictures

Picture of basic stamp- <http://www.parallax.com/images/prod_jpg/bs2e-ic.jpg>

Picture of mp3 player- <http://www.roguerobotics.com/store/images/roguerobotics/UMP3.jpg>

Picture of Ping)) sensors - <http://www.parallax.com/images/prod_jpg/28015-5pack.jpg>

Picture of blind individual- <http://www.deafvision.net/mdba/whtcne.jpg>

Picture of firefighter- <http://www.southboroughfire.org/70_Newton_2-5-05_07.jpg>

Picture of diver- <http://www.triton-ast.co.yu/EKSPEDICIJE/MLAVA/z11.JPG>

Picture of fog pathway- <http://digicam.co.za/gallery/details.php?image_id=2744>

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Noise of Polyphase Electric Motors
J. F. Gieras, C. Wang, J. C. Lai, Pages 372
Taylor and Francis 2006 - ISBN 13 978-0-8247-2381-1; US$199.00

Noise of Polyphase Electric Motors focuses on one special aspect of industrial machinery. The book is divided into 11 chapters and the contents are: 1) Generation and Radiation of Noise in Electrical Machines; 2) Magnetic Fields and Radial Forces in Polyphase Motors fed with Sinusoidal Currents; 3) Inverter-Fed Motors; 4) Torque Pulsations; 5) Stator System Vibration Analysis; 6) Acoustic Calculations; 7) Noise and Vibration of Mechanical and Aerodynamic Origins; 8) Acoustic and Vibration Instrumentation; 9) Numerical Analysis; 10) Statistical Energy Analysis; and 11) Noise Control. The book also includes four appendices with information on fundamental topics.

Chapter 1 begins with a cursory overview of basic acoustics with a quick jump into describing the various sources of sound in electrical rotating machinery. Each section of the chapter is very brief and there seems to be no planning in the ordering of these sections. For example, Section 1.8 deals with economical aspects. It was difficult to fathom the rationale for the inclusion of a section like 1.8. The brief paragraph quickly concludes that the more expensive a motor is, due to the higher flux density, the noisier the machine is. Another oversight is the mere listing of the acoustic levels of different motors from field measurements. One would have hoped that the book would slowly lead you into the determination of sound power radiation and not within the first 10 pages of a 372-page-long treatise on the "Noise of Motors." This reviewer wished more thought had gone into the preparation of the introductory chapter.

Chapter 2 discusses the magnetic fields and radial forces in polyphase motors. Considerable effort and space have been spent on describing, in detail, the mechanical and electromagnetic aspects of motors. For someone who is not an electrical engineer, Chapter 2 was tough and a rough slog. There was no immediate correlation to noise. One needs to reach the end of the chapter where the noise and vibration frequencies resulting from these forces are dealt with. Section 2.8 deals with other noise and vibration source of electromagnetic in nature. One would have hoped that this chapter would deal with noise and vibration concerns resulting from these electromagnetic forces. One doesn't actually need the intricate details of the force calculations to understand the basics of noise generation.

Chapter 3 is similar to Chapter 2 except that Chapter 3 discusses the details of inverter-fed motors and the focus is non-sinusoidal currents. Considerable details are presented as to the evaluation of the various forces. There is no direct link to noise generation except a brief line in the begining of the chapter, and we quote, "The increase in the noise of an induction motor fed from a pulse width modulation (PWM) inverter with switching frequency up to 7 kHz is from 7 to 15 dBA." An immediate question is why was it necessary to know this information even before one gets an idea of the sources of noise generation. The second question is, "What is this increase and over what datum condition?" The reader needs to read till Section 3.5 to get an understanding of the above quoted statement. The chapter ends with a brief description of the noise reduction potential of these motors. A set of strategies is given in point format without any idea of the actual techniques to achieve the strategy. This chapter definitely could use proper planning and a good edit. Chapter 4 is in the same vein as Chapters 2 and 3 and presents details of the evaluation of torque pulsations without a direct link to noise generation. The only salient feature of this chapter is the description in Section 4.9 where some ideas on reducing the torque pulsations are enunciated.

Chapter 5 presents the forced vibration analysis as they apply to electric motors and their sub-systems. Most of the materials discussed in this chapter is available from any standard text book on vibrations. However the material is presented from the point of view of motors and the focus is on establishing the natural frequencies of the entire motor and its salient components. One of the main weaknesses of this chapter is the lack of connection to the noise generation.

Chapter 6 is supposedly the raison d'etre of this book, where acoustic calculations are discussed. This chapter is supposed to provide the link between vibratory forces and the radiated noise through a vibro-acoustic modeling. The first four sections deal with basic evaluation procedures for calculating the radiation efficiency of a standard plane radiator and a typical cylindrical radiator. Once again, these details are available from other books (some more than 25 years old) in the literature. Only Section 6.5, albeit within 5 short pages, presents information of value. One wished for more details in Section 6.5 with important parameters properly explained and sourced. Similarly, Chapter 7 in 9 short pages presents valuable information on noise sources of mechanical and aerodynamic origin.

Chapter 8 discusses measurement techniques to obtain sound levels of motors. The first 8 sections contain information that is already known. Only if electrical engineers who design motors are the main readership, one can understand the merit of including this basic information. If the book is aimed at a broader acoustical community, the need for the first 8 sections is questionable. Section 8.5 presents a testing method for motors with a few sets of results.

Chapter 9 provides numerical methods to evaluate the forces as well as the acoustic field. Standard FEM (Finite Element Method) and BEM (Boundary Element Method) techniques are highlighted in this chapter. This is one of the few chapters that contain information of importance with salient application to noise levels of motors.

Chapter 10 describes SEA (Statistical Energy Analysis), and suffers from the same misguided aim of providing enormous information on the basics of SEA with very little salient application. Only cursory treatment of the application of SEA methods to acoustical evaluation of motors is shown.

The final chapter presents a very brief treatment of noise control. Standard methods are highlighted. One hoped, for a book with a narrow focus, for some standard case studies that show the results of the application of control methodologies. The above book, to be useful to general acousticians and noise control engineers, need considerable improvement. It needs a complete refocus of its stated aim as a Noise book.

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The Science and Applications of Acoustics – 2nd Edition - Daniel R. Raichel, Pages 660
Springer 2006 - ISBN 13 978-0387-26062-4; US$89.95

The Science and Applications of Acoustics is a broad based textbook to be used in different applications oriented to undergraduate and/or graduate level courses. The book is divided into 21 chapters and the contents are: 1) A capsule history of acoustics; 2) Fundamentals of acoustics; 3) Sound wave propagation and characteristics; 4) Vibrating strings; 5) Vibrating bars; 6) Membranes and plates; 7) Pipes, waveguides and resonators; 8) Acoustics analogs, ducts and filters; 9) Sound-measuring instrumentation; 10) Physiology of hearing and psychoacoustics; 11) Acoustics of enclosed spaces: Architectural acoustics; 12) Walls, enclosures and barriers; 13) Criteria and regulations for noise control; 14) Machinery noise control; 15) Underwater acoustics; 16) Ultrasonics; 17) Commercial and medical ultrasound applications; 18) Music and musical instruments; 19) Sound reproduction; 20) Vibration and vibration control and 21) Nonlinear acoustics.

Unlike conventional books on acoustics, the book under review begins with a short history of acoustical applications as Chapter 1. One must commend Prof. Raichel for his bravery since any short history omits, not intentionally of course, names of scientists who have contributed to the field. A field day is to be had in acoustical society meetings arguing about the omissions. But the chapter is a good read from a historical perspective. The book begins in earnest with Chapter 2, where the wave theory of sound is discussed and the fundamental continuity equations are derived to produce the general wave equation. Simple and straightforward analysis is presented. However, the same cannot be said for Chapter 3. It is titled “Sound wave propagation and characteristics,” and covers a large canvas, and the sections flow rather hurriedly from one to another. Even the treatment in each section is perfunctory and cursory. Too many diverse topics are presented in too short a space. To cite an example. After providing a brief introduction to Reflection, Refraction, and Diffraction in Sections 3.7, 3.8 and 3.9 respectively, Section 3.10 discusses octave and third octave bands. One would think that band frequencies are usually introduced after looking at narrow band spectrum, and the order in Chapter 3 is out of sync.

Chapters 4, 5 and 6 are the customary chapters that discuss vibrations in strings, bars and membranes, with one or two application in musical acoustics. Chapter 7 presents a summary of wave propagation in closed and open pipes with the evaluations of natural frequencies and standing waves with salient examples. The simple pipe theory is extended to three dimensional propagation cases in rigid rectangular and circular waveguides with higher order modes inside the waveguides. The chapter concludes with a basic treatment of the Helmholz resonator. Chapter 8 continues the low frequency, i.e., plane wave approximation to develop the basic analysis of ducts and fileters. The lumped parameter acoustic analogy is applied to calculate the natural frequencies and transmission loss of simple ducts and filters such as expansion chambers, orifices and side-branch resonators.

Chapter 9 is not only comprehensive in its scope, but also complete. It discusses sound measuring instrumentation. After describing the necessary characteristics of the required instrumentation, the salient features of a microphone, sound level meter, integrating sound level meters, dosimeters, and sound intensity probes were presented. With a complete introduction to measurement concepts in band frequencies, the chapter discusses both real time analysis and fast Fourier transform techniques. It also highlights the sources of measurement error. Considerable space has been allotted to the measurement of sound power and the different methods that are applied to measure sound power. The chapter includes applicable standards for measurement of sound. Finally, the chapter presents a brief description of the use of personal computers as a measurement platform, which this reviewer found to be very useful.

Chapter 10 presents the physiology of hearing. After discussing the hearing mechanism in detail, a brief description of hearing loss is given. A brief summary of sensitivity, loudness, pitch, as well as methods to evaluate articulation index and speech interference level are presented. The chapter concludes with the methods to correct hearing loss such as hearing aids and cochlear implants. Standard treatment of room acoustics is presented in Chapter 11 with a few case studies of auditoria shown as examples of room acoustical design considerations.
Acoustics of walls, enclosures and barriers are presented in Chapter 12. Transmission loss is described completely with

the required elements for single panel and double panels. The transmission loss through small and large enclosures is discussed and the limitations are highlighted. Diffraction by barriers and the calculation of insertion loss of barriers are given a complete treatment in Chapter 12.

Chapter 13 turns its attention to criteria and noise regulations. Since its main focus is the USA market, only the salient features of American laws, such as the 1969 National Environmental Policy Act, Occupational Safety and Health Act of 1970 and the 1972 Noise Control Act are highlighted. Once again, this chapter is organized haphazardly. One wishes that more thought had gone into the flow of this chapter. The material is handled cursorily. For example, the noise dose, as per the 1970 OSHA Act, is discussed without any analysis of the 5 dB and 3 dB exchange rate controversy. Many of the noise descriptors used for applying the regulatory guidelines, such as loudness index, noise rating curves, Leq, NEF are discussed. Traffic noise, its evaluation and its assessment are dealt with in detail. Criteria and regulations in other jurisdictions, such as Canada and Europe, are touched upon. Chapter 14 describes noise control for machinery such as fans, motors, transformers, pumps, gears, gas flows and such. Estimation of noise levels and control methodology are presented. Examples are give for a few of the general noise control techniques. The recent active noise control is given short shrift in only four short paragraphs.

Underwater acoustics is described in Chapter 15. With a brief introduction to sound in water, the chapter provides short descriptions of sound speed, water velocity profiles, propagation through underwater layers (channels), transmission loss in underwater, sound absorption, refraction, and propagation in mixed layers. Sound measurement through active and passive sonar, including arrays, sonar equation, echoes and pulses is also discussed in this chapter.

Chapter 16 and 17 discuss ultrasonics and its application. Sound phenomena in frequencies greater than 20 kHz are the main focus of these two chapters. After a detailed introduction to ultrasonics (both low and high intensity), salient components such as relaxation, cavitations and phonons are presented Considerable details of ultrasonic transducers, arrays and scanning methods are introduced in Chapter 16. Chapter 17 discusses the commercial and medical applications of ultrasonics. Some of the highlighted details are: ultrasonic cleaning, flaw detection, propagation velocity determination, measurement of mechanical stress, flow meters, motion sensing, and ultrasonic imaging. The chapter concludes with some of the important medical uses.

Music and musical instruments are the main focus of Chapter 18. A wide array of information is covered in a perfunctory manner in this chapter. Basic components of music such as musical notation, duration of notes, time signatures, loudness notation, harmony and musical instruments are described. The latter portion of the chapter presents highlights of various instruments that produce sound. Most of the occidental musical instruments are covered. However, no acoustic analysis is presented of the mechanism of sound generation with one exception. Detailed analysis of sound produced by wind instruments is shown in Chapter 18. The chapter concludes with a brief description of electronic instruments and the composition of an orchestra.

Chapters 19 through 21 are the briefest chapters of this textbook. Sound reproduction is presented in Chapter 19. Basic information of technologies available is highlighted which also includes the current field of 'wave field synthesis (WFS)' that has revolutionized the sound listening field with audio equipment such as MP3 players and iPod. Chapter 20 discusses vibration and its control, but is limited to single degree of freedom systems. Typical control methods are highlighted. Non-linear acoustics is described in the final chapter. Wave distortion and the formation of N waves are described. Standard ray theory as well as the formation of shock waves are briefly presented.

This book is elementary for graduate level and is advanced for undergraduate level. The book also covers a wide canvas of acoustical subjects and this could be one of the main weaknesses of the book. Many of the chapters provide only basic information in a cursory fashion. The book, however, provides enough material to a knowledgeable professor and/or an acoustical engineer who can then build on the basic materials.

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

NEWS / INFORMATIONS

CONFERENCES

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

2006

28 November – 2 December: 152nd meeting, 4th Joint Meeting of the Acoustical Society of America and the Acoustical Society of Japan, Honolulu, Hawaii. Contact: Acoustical Society of America, Suite 1NO1, 2 Huntington Quadrangle, Melville, NY 11747-4502; Tel: 516-576-2360; Fax: 516-576-2377; E-mail: asa@aip.org; Web: asa.aip.org
3 - 6 December: INTER-NOISE 2006, Honolulu HA, USA (Same Hotel at ASA meeting the week preceeding. Web: www.inceusa.org

2007

13-17 March. Spring Meeting of the Acoustical Society of Japan., Tokyo, Japan. Web: www.asj.gr.jp/index-en.html

15-17 March. AES 30th International Conference on Intelligent Audio Environments. Saariselka, Finland. Web: www.aes.fi/aes30

19-22 March. Meeting of the German Acoustical Society (DAGA2007). Stuttgart, Germany. Web: www.daga2007.de
09-12 April. International Congress of Ultrasonics (2007 ICU). Vienna, Austria. Web: www.icultrasonics.org

10-12 April. 4th International Conference on Bio-Acoustics. Loughboro, UK. Web: www.ioa.org.uk

17-20 April. IEEE International Congress on Acoustics, Speech, and Signal Processing (IEEE ICASSP 2007). Honolulu, HI, USA. Web: http://www.icassp2007.org

24-25 April. Institute of Acoustics (UK) Spring Conference. Cambridge, UK. Web: www.iap.org.uk/viewupcoming.asp
16-20 May: IEEE International Conference on Acoustics, Speech, and Signal Processing (IEEE ICASSP 2007). Honolulu, HI, USA. Web: www.icassp2007.org

01-03 June. 2nd International Symposium on Advanced Technology of Vibration and Sound (VS Tech 2007). Lanzhou, China. Web: www.jsme.or.jp/dmc/meeting/vstech2007.pdf

03-07 June. 11th International Conference on Hand-Arm Vibration. Bologna, Italy. Web: www.associazioneitalianadiacustica.it/HAV2007/index.htm

04-06 June. Japan-China Joint Conference on Acoustics 2007. Sendai, Japan. Web: www.asj.gr.jp/eng/index.html

04-08 June: 153rd Meeting of the Acoustical Society of America. Salt Lake City, Utah, USA. Web: www.asa.aip.org
18-21 June. Oceans07 Conference. Aberdeen, Scotland. Web: www.oceans07ieeeaberdeen.org

25-29 June. 2nd International Conference on Underwater Acoustic Measurements: Technologies and Results. Heraklion, Crete, Greece. Web: www.uam2007.gr

CONFÉRENCES

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

2006

28 novembre – 2 decembre: 152e rencontre, 4e Rencontre acoustique jointe de l'Acoustical Society of America, et l'Acoustical Society of Japan, Honalulu, Hawaii. Info: Acoustical Society of America, Suite 1NO1, 2 Huntington Quadrangle, Melville, NY 11747-4502; Tél.: 516-576-2360; Fax: 516-576-2377; Courriel: asa@aip.org; Web: asa.aip.org
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18-21 juin. Oceans07 Conference. Aberdeen, Scotland. Web: www.oceans07ieeeaberdeen.org

25-29 juin. 2nd International Conference on Underwater Acoustic Measurements: Technologies and Results. Heraklion, Crete, Greece. Web: www.uam2007.gr

02-06 July. 8th International Conference on Theoretical and Computational Acoustics. Heraklion, Crete, Greece. Web: www.iacm.forth.gr/~ictca07

03-07 July. 1st European Forum on Effective Solutions for Managing Occupational Noise Risks. Lille, France. Web: www.noiseatwork.eu

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

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

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

2-7 September 19th International Congress on Acoustics (ICA2007), Madrid Spain. (SEA, Serrano 144, 28006 Madrid, Spain; Web:www.ica2007madrid.org

9-12 September: ICA2007 Satellite Symposium on Musical Acoustics (ISMA2007). Barcelona, Spain. Web: www.isma2007.org

9-12 September: ICA2007 Satellite Symposium on Room Acoustics (ISMA2007). Sevilla, Spain. Web: www,isra2007.org

17-19 September. 3rd International Symposium on Fan Noise. Lyon, France. Web: www.fannoise2007.org

19-21 September. Autumn Meeting of the Acoustical Society of Japan. Kofu, Japan. Web: www.asj.gr.jp/index-en.html

24-28 September. XIX Session of the Russian Acoustical Society. Nizhny Novgorod, Russia. Web: www.akin.ru

22-24 October. Noise-Con 2007. Reno, Nevada, USA. Web: www.inceusa.org/nc07/index.asp

November 27 - December 02: 154th Meeting of the Acoustical Society of America. New Orleans, LA, USA. Web: www.asa.aip.org

2008

29 June - 04 July: Joint Meeting of European Acoustical Association, Acoustical Society of America, and Acoustical Society of France. Paris, France. Web: www.sfa.asso.fr/en/index.htm

7-10 July: 18th International Symposium on Nonlinear Acoustics (ISNA18). Stockholm, Sweden. E-mail: benflo@mech.kth.se

27-30 July. Noise-Con 2008. Dearborn, MI, USA.

28 July - 1 August: 9th International Congress on Noise as a Public Health Problem. Mashantucket, Pequot Tribal Nation, (CT, USA). Web: www.icben.org

22-26 September: Interspeech 2008 - 10th ICSLP, Brisbane, Austrailia. Web: wwwinterspeech2008.org

01-05 November. IEEE International Ultrasonic Symposium. Beijing, China. Web: www.ieee-uffa.org/ulmain.asp?page=symposia

2010

23-27 August: International Confress on Acoustics 2010. Sydney, Australia. Web: www.acoustics.asn.au

02-06 juillet. 8th International Conference on Theoretical and Computational Acoustics. Heraklion, Crete, Greece. Web: www.iacm.forth.gr/~ictca07

03-07 juillet. 1st European Forum on Effective Solutions for Managing Occupational Noise Risks. Lille, France. Web: www.noiseatwork.eu

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

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9-12 septembre: ICA2007 Satellite Symposium sur Musical Acoustics (ISMA2007). Barcelona, Spain. Web: www.isma2007.org

9-12 septembre: ICA2007 Satellite Symposium sur Room Acoustics (ISMA2007). Sevilla, Spain. Web: www,isra2007.org

17-19 septembre. 3rd International Symposium on Fan Noise. Lyon, France. Web: www.fannoise2007.org

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01-05 novembre. IEEE International Ultrasonic Symposium. Beijing, China. Web: www.ieee-uffa.org/ulmain.asp?page=symposia

2010

23-27 août: International Confress sur Acoustics 2010. Sydney, Australia. Web: www.acoustics.asn.au

NEWS

We want to hear from you! If you have any news items related to the Canadian Acoustical Association, please send them. Job promotions, recognition of service, interesting projects, recent research, etc. are what make this section interesting.

EXCERPTS FROM "*WE HEAR THAT*", IN *ECHOS*, ASA

Neville Fletcher received the first award for Outstanding Contribution to Acoustics from the Australian Acoustical Society (AAS). The award was made at the AAS conference in Busselton. Neville was especially recognized for his contributions to musical acoustics and biological acoustics. He has also served as editor of the journal Acoustics Australia. Neville is a Fellow of ASA, and received the Silver Medal in Musical Acoustics in 1998.

The President's Prize, for the best technical paper at a conference of the Australian Acoustical Society was presented to **Laura Brooks, Rick Morgans,** and **Colin Hansen** for their paper "Learning Acoustics Through the Boundary Element Method: An Inexpensive Graphical Interface and Associated Tutorials." This paper is reprinted in the December issue of Acoustics Australia.

EXCERPTS FROM "*SCANNING THE JOURNALS*", IN *ECHOS*, ASA

"Virtual Acoustic Prototypes: Listening to Machines that Don't Exist" is the title of a paper in the December issue of Acoustics Australia. A virtual acoustic prototype (VAP) is a computer representation of a machine such that it can be heard without having to exist as a physical assembly. Whereas visualization tools are well developed in the field of visual design, the analogous tools for auralization are still in their infancy. In order to construct a VAP, a method is needed to represent the excitation and transmission mechanisms. Airborne sound, fluid-borne sound, and structure-borne sound must be considered. This paper was adapted from the keynote lecture at Acoustics 2005.

Physicists have developed a mathematical model to explain the breathing patterns of **canaries when they sing**, according to a paper in the 10 February issue of Physical Review Letters. By treating both a bird's vocal organ and neurons as nonlinear systems, researchers have found that complex songs, involving notes of many frequencies and lengths, might be produced by surprisingly simple neurological structures and processes. The new model shows that birdsong is produced from the interplay between the air sac and the neural system in contrast to the long-held view in which a nervous system sends instructions to a passive body. This suggests that subharmonic behavior can play an important role in providing a complex variety of responses with minimal neural substrate.

"Sound ideas" is the title of a feature article on **phononic crystals** in the December issue of Physics World. When a wave passes through a periodic structure, interference leads to the formation of "band gaps" that prevent waves with certain frequencies from traveling through the structure. Band gaps are observed for electron waves in semiconductors, electromagnetic waves in photonic crystals, and sound waves in phononic crystals. The periodic variation in the density and speed of sound that is needed to make a phononic crystal can be achieved by making air holes in an otherwise solid structure. Negative refraction in phononic crystals is possible due to multiple scattering of sound waves at the solid-air interfaces. Phononic crystals could provide researchers in acoustics and ultrasonics with new components that offer the same level of control over sound that mirrors and lenses provide over light. [Phononic crystals were reported in Phys. Rev. Letts. **93**, 024301 (July 9, 2004); see Fall 2004 issue of ECHOES].

The **spiral shape of the cochlea** increases sensitivity to low frequency sound, according to a paper in the March 3 issue of Physical Review Letters. Although calculations show that curvature has little effect on the average vibrational energy traveling along the tube, energy increasingly accumulates near the outside edge of the spiral rather than remaining evenly spread across it. Low frequencies travel the furthest into the spiral, so the effect is strongest for them. Concentration of sound intensity translates into higher sensitivity. The researchers liken the sound propagation to the "whispering gallery modes" found in domes such as London's St. Paul's Cathedral.

The complex **songs of humpback whales** have their own syntax or grammar, according to an article in the 23 March issue of New Scientist. Male humpback whales produce songs that last anywhere from six to thirty minutes, and these vocalizations vary across the seasons. During breeding periods they are thought to help attract female partners. Now computer programs have been used to analyze complete songs and to demonstrate their hierarchical syntax. Shorter whale songs appear more complex than longer ones. The investigators admit that we are still a long way from understanding the meaning of whale songs, however. Some of the whale songs can be heard at www.newscientist.com/channel/life/dn8886.html.

The **acoustics of the singing voice** is the topic of a review article in the April issue of Physics World. Scientists are now able to record spectra of the human voice using relatively simple equipment, and this is having a major impact on the way singing is learned, performed, and recorded. Displaying the spectral signature of the voice in real time on a computer screen, for example, provides an effective teaching aid. It is possible to detect piracy in commercial recordings and even to synthesize the human voice to recreate lost sounds. Almost all songs recorded nowadays have undergone some degree of pitch shifting, the article claims, to disguise the fact that many pop stars cannot sing very well.

The use of **ultrasonic communication** by the concaveeared torrent frog is reported in the 16 March issue of Nature, Males of this species emit birdlike melodic calls with pronounced frequency modulations that often contain spectral energy in the ultrasonic range. This extraordinary upward extension into the ultrasonic range is likely to have evolved in response to the low-frequency ambient noise near streams.

Regular **didgeridoo** playing has been found to be an effective treatment for patients with obstructive sleep apnea, according to a report in the 23 December issue of the British Medicine Journal. Participants practiced an average of 5.9 days a week for 25.3 minutes.

New digital video technology can reveal **shock waves** as never before according to an article in the January- February issue of American Scientist. Shock waves, like sound waves, are usually as invisible as the air through which they travel. However, schlieren and shadowgraph techniques have been used for flow visualization for at least 100 years. Now high-speed digital cameras with retroreflective screens can record shock position over time and use this information to determine post-shock fluid properties.

“Drowning in Sound” is the title of an article in the April issue of IEEE Spectrum that discusses the **sonar vs. whales** story. In January 2005 dozens of pilot whales began to run themselves onto the sand beach along North Carolina’s Outer Banks. The U. S. Navy had been conducting a training exercise in the area around the time of the event, and an initial report by the National Marine Fisheries Service listed sonar as a possible cause for the incident. The Navy stated that the exercise took place about 100 kilometers from where the whales beached, too far to have had any effect. More than a year after the stranding, doubts still linger. The sonar controversy has also focused attention on a broader issue: oceans everywhere are getting noisier because of commercial shipping, underwater oil and gas exploration, and other human activity, and scientists have no clear idea what harm these noises have on whales and other sea creatures.

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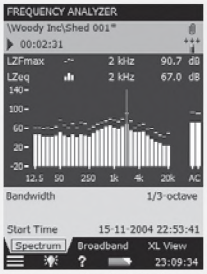

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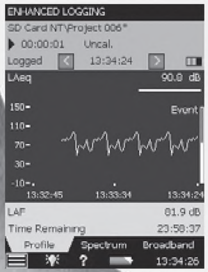

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Canadian Acoustical Association

Minutes of the Board of Directors Meeting
10 October 2006

Halifax, Nova Scotia

Present: Stan Dosso (chair), Dave Stredulinsky, David Quirt, Alberto Behar, Rich Peppin,
Corjan Buma, Christian Giguère, Ramani Ramakrishnan, Nicole Collison
Regrets: Dalila Giusti, Anita Lewis, Vijay Parsa, John Bradley

The meeting was called to order at 5:10 p.m. After a brief review of progress on action items, the minutes of Board of Directors meeting on 22 April 2006 were approved as published in Canadian Acoustics (June 2006 issue). *(moved A. Behar, seconded R. Ramakrishnan, carried).*

President's Report

Stan Dosso reported that there have been no major changes or problems in the affairs of the Association. He credits this to sustained efforts by Board members, who have kept all the major activities of the Association proceeding steadily. He also noted the sustained high level of papers both at the annual conference and in *Canadian Acoustics* .

Secretary's Report

David Quirt reported that the surge of new memberships associated with the Ottawa meeting seems to have passed, so membership declined by 15 to 380 as of 4 October. However, total renewals and new members were the same as last year, about half the new members from the 2005 meetings have renewed, and the number of Sustaining Subscribers continues to rise.

Mailing list (4 October)	**Canada**	**USA**	**Other**	**Change**
Member	198	20	6	**-22**
Emeritus	2		1	**0**
Student	70	2	6	**+5**
Sustaining	42	4	1	**+5**
Direct	5	2	0	**–2**
Indirect	9	7	5	**-1**
		Total = 380		**-15**

To ease membership renewal, the Secretary and Treasurer have continued the option of payments by VISA, and 40% used this method. To strengthen CAA communication via e-mail, and to reduce errors in mailing *Canadian Acoustics*, systematic updating of membership address data including e-mail was continued in the renewal process.

Issues of Noise News International were mailed as they arrived, to the 47 members who requested this option, but shipment from the publisher in the USA is consistently 4-6 months late.

Secretarial operating costs for FY2005/06 were $1468 (slightly higher than last year), mainly for mailing costs and postal box rentals. A budget of $1500 for 2006/07 was approved. *(Moved by R.Peppin, second R. Ramakrishnan, carried.)*

Overall, the routine process of the Corporation is proceeding without major problems. Report was accepted. *(Moved R. Peppin, second R. Ramakrishnan, carried.)*

Treasurer's Report

The Treasurer, Dalila Giusti, submitted a report and a preliminary financial statement, but was unable to attend the meeting. It is a quite typical year financially. Interest on our capital fund in 2005/06 was $5293, which almost covered the $5750 expense for prizes in 2005/06, but there would be a shortfall of more than $3000 if all prizes were awarded. (Note that steps to increase income from the capital fund were authorized at the Board meeting in April 2006.) Most expenses were essentially as budgeted, and the conference in London made a significant profit. Total assets increased again this year, to $287,333 at fiscal year end (31 August 2006).

The Treasurer's report presented a proposed fee structure, and this was discussed. The basic principle of small changes every few years to avoid major changes was reconfirmed. The Secretary was asked to review the fee history; this showed that rates for Sustaining Subscribers have been steady for 5 years, but those for Members and Students changed just 3 years ago. A new fee structure ($50 more for Sustaining Subscribers, other rates constant until next year) was accepted for presentation at the Annual General Meeting.
(Moved C. Buma, second A. Behar, carried.)

The Board accepted the Treasurer's report, subject to submission of the Auditor's report.
(Moved R. Peppin, second N. Collison, carried.)

Editor's Report

The Editor, Ramani Ramakrishnan, presented a brief report on issues related to content, appearance, and publication process for *Canadian Acoustics.* Some highlights:

- A special issue in June 2006 featured papers from a conference on wind turbine noise; other conferences will be featured in 2007 and 2008.
- An issue emphasizing articles in French is planned for March 2007.
- The backlog of invoices for advertising has been handled.

At the previous Board meeting, the Editor was asked to cost options and create a proposal for increasing the number of issues per year to five or six. Although the supply of technical content would permit this, it appears this would increase the annual cost by more than $10,000, so the Board accepted the Editor's suggestion to remain at 4 (larger) issues/year. It was noted that the Editor plans a sabbatical in 2008 or 2009, but expects to be able to handle most editorial duties via e-mail. It was agreed we should find an associate/understudy to support the Editor during this period.

The Board accepted the Editor's report.
(moved D. Quirt, second A. Behar, carried.)

CAA Conferences – Past, Present & Future

2005 (London): Vijay Parsa presented the final report on the London Ontario conference at the preceding meeting (See June 2006 issue of *Canadian Acoustics.*) The conference was a success financially and the program was excellent; the Board repeated thanks to the London team.

2006 (Halifax): Nicole Collison reported on current status of the Halifax meeting. Many special sessions were organized, and 75 papers were accepted including two plenaries. Attendance of about 100 is expected. Nine exhibits have been booked, which uses all the space available for exhibitors, and there are many sponsors for social parts of the meeting. In addition to the banquet on Thursday night, Wednesday evening will feature an "Icebreaker" event with entertainment by local group *Gypsophilia.* Another new feature is a questionnaire to get feedback for planning future meetings. The Board thanked the organizers for their excellent preparations, and congratulated them on the many new and appealing features of this conference.

2007 (Montreal): Rama Bhat of Concordia University reported on arrangements for the Montreal conference on 9-12 October 2007. They anticipate about 200 papers, with strong emphasis on aerospace – Montreal's aerospace community is heavily involved. Sessions will be in the new Engineering and Visual Arts Building at Concordia, with exhibits in the building across the road. This arrangement caused some concern, and it was agreed that long breaks or some other way to encourage attendance at exhibits (perhaps poster sessions?) should be devised. This meeting will deviate from our usual pattern by not having catered lunches included in the conference fee, and blocks of rooms are booked at several nearby hotels. Dr. Bhat was thanked for the work to date, as the Board expressed eager anticipation for a meeting in Montreal.

Awards

Christian Giguère presented a detailed report. There are applications for all awards except the Shaw Prize. Winners will be announced at the CAA banquet on Thursday (except for student presentation awards to be given at the final lunch on Friday) and also reported in Canadian Acoustics. Alberto Behar has assumed responsibility for judging the student presentations, and he recruited judges and initiated a discussion of how to improve the judging process.

Some further updates of the web pages to clarify rules for specific prizes are planned, but good progress has already been made on this. A master list of award winners in past years is also being prepared, and should be posted on the website soon. The Board thanked Christian and his Coordinators.

CAA Website

This report began with discussion of Dave Stredulinsky's request for replacement as Webmaster. The Board expressed thanks to Dave, who has maintained this activity for years and has agreed to continue as Webmaster until a replacement is found. It was agreed that an advertisement for Webmaster should be included in the December issue of *Canadian Acoustics,* and Board members were asked to support this search.

There was enthusiastic praise for the steadily improving site, especially the implementation of database capability to facilitate abstract and paper submission for the Halifax Conference. The Jobs Wanted & Available page seems to be a huge success, due to Dave's continuing screening and updating of content. Creation of an online archive of Canadian Acoustics was discussed. Some progress has been made in preparing back issues – the Board decided previously that the archive should include all issues more than 2 years old, and be freely available online. Dave noted that there has been no further progress in researching our options for online payment.

The Board thanked Dave for his report, and his huge contribution to this facet of CAA.

Other Business

(InterNoise-09 in Ottawa): Organization for the InterNoise-09 conference in collaboration with INCE-USA was presented briefly to the Board. The organizers (Nightingale and Gover) expect final approval at the InterNoise Conference in December. Merits of merging the CAA meeting in 2009 into this (as was done for ICA in 1985 and InterNoise in1990) were briefly debated.

Nominations for open positions on the Board were discussed. Mark Cheng has resigned from the Board due to a change in his job, and Corjan Buma is coming to the end of his term. The Board thanked these Directors for their contributions to our Association. Stan has recruited Dave Chapman (a Past President) to manage the nomination process in the AGM; he committed to coordinate final preparations to confirm the slate to be presented at the AGM on 12 October.

New options for membership grades and fees were discussed, including Lifetime Memberships, and fees for retired and Emeritus Members. The Secretary was assigned to investigate options and procedures and to prepare a proposal.
(Moved R. Peppin, second A. Behar, carried.)

Adjournment

Ramani Ramakrishnan moved to adjourn the meeting, seconded by Nicole Collison, carried. Meeting adjourned at 9:15 p.m.

Action Items Arising from the Meeting:

S. Dosso: (1) With Dave Chapman, organize nomination process for AGM. (2) Discuss with the organizers in Ottawa, the potential for merging CAA into InterNoise in Ottawa in 2009

D. Quirt: (1) Assemble and send a set of back issues of *Canadian Acoustics* to be converted to pdf files for the archive. (2) Prepare proposal for new forms of membership.

D. Giusti: (1) Prepare proposal for new investment, of $40k from Capital Fund. (2) Deal with Auditor's report for 2005/06 and present to the Board.

R. Ramakrishnan: (1) With Dave Stredulinsky, prepare an advertisement for a new Webmaster. (2) Recruit an associate to support production of the journal during upcoming sabatical.

C. Giguère: (1) Proceed with website list of past winners and clarification of prize rules.


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ACOUSTICS LABORATORY

Canadian Acoustical Association

Minutes of Annual General Meeting

Citadel Hotel, Halifax NS
12 October 2006

Call to Order

President Stan Dosso called the meeting to order at 5:15 p.m. Minutes of the previous Annual General Meeting on 13 October 2005 in London were approved as printed in the December 2005 issue of Canadian Acoustics. *(Moved by Cameron Sherry, seconded by Nicole Collison, carried)*

President's Report

Stan Dosso briefly summarized the report he presented at the Board meeting on 10 October. He emphasized that the society is in good condition, and he thanked all those who have made major contributions to our activities.

Secretary's Report

David Quirt presented a brief overview of membership and operational activity. CAA membership and subscriptions have dropped marginally, to 385 at the end of September. This followed the usual pattern after a surge of new memberships at a conference; many of those who joined at the Ottawa meeting did not renew. The administrative budget of $1468 covered mailing and database expenses in the last fiscal year; an itemized account was presented to the Board of Directors. An increase to $1500 has been approved for next year. All activities are proceeding smoothly. Details are in the report from the Board of Directors meeting on 11 October. *(Acceptance of the report was moved by Alberto Behar, seconded by Ramani Ramakrishnan, carried.)*

Treasurer's Report

In the absence of Dalila Giusti, David Quirt presented an overview of her report to the Board on CAA finances. We are in good shape, with total assets of $287,333 at fiscal year end. There has been steady expansion of financial assets for several years, supported by financially successful meetings and income from advertising and special issues of *Canadian Acoustics.* Our capital fund includes a variety of securities that provided $5122 in interest last year. A change to increase the yield has been authorized (but not yet implemented) with the goal of fully covering the cost of awards. *(Acceptance of the Treasurer's report was moved by Werner Richarz, seconded by Dalton Prince, carried.)*

This year, the budget predicts a small deficit if the conference in Halifax breaks even and other income and expenses remain the same as in 2005-06. The Board therefore proposed an increase in fees for Sustaining Subscribers this year (to $300 after 5 years at the current $250) with other rates remaining unchanged. There were several suggestions about desirability of new categories such as Retired Members. The Secretary reported that the Board has started development of a proposed new Membership and Fee structure incorporating such changes, for consideration by the membership next year. *(Acceptance of the proposed fee structure was moved by Ramani Ramakrishnan, seconded by Cameron Sherry, carried.)*

Editor's Report

Ramani Ramakrishnan gave the Editor's report. *Canadian Acoustics* production has proceeded smoothly throughout the year, with all issues printed on schedule. A special conference proceedings issue on wind turbine noise was published in June 2006. Content and the submission/review/publication process are generally satisfactory. The option of increasing to 5 or 6 issues per year has been analyzed – available content would permit this, but the financial cost (>$20/member) is too high with the current publishing model. This raised questions about feasibility of publishing an online or CD version of the journal, which the Editor agreed to evaluate

Award Coordinator's Report

Christian Giguère acknowledged the continuing hard work of our awards coordinators, and reported the awards to be presented this year.

CAA is not awarding the Shaw Prize, but all our other prizes have been awarded. In addition, there are the student paper presentation awards. (See separate announcement in this issue for names of recipients.)

Past and Future Meetings

Brief reports were presented on meeting status:

London (October 2005): Vijay Parsa presented the final report on the London Ontario conference to the Board in the spring (See June 2006 issue of *Canadian Acoustics*.) Stan Dosso gave an overview of the highlights: the conference was a success financially and the program was excellent. Stan repeated thanks to the London team.

Halifax (October 2006): Nicole Collison reported for the Halifax team. The organized sessions covered a wide range of topics, with 2 plenary talks and 75 papers, of which about 1/3 are student papers. Online submission of abstracts and papers was tested successfully at this meeting. The attendance should exceed 100, and a financial surplus is expected.

Montreal (October 2007): Rama Bhat presented an overview of plans for the 2007 conference, which will be 9-12 October, at Concordia University. A strong focus on acoustics in aerospace is planned. Details will be on the website and in upcoming issues of *Canadian Acoustics*.

There was a round of applause to express our thanks to all organizers.

CAA Website

Stan Dosso reported that David Stredulinsky is seeking a successor as Webmaster. Stan also noted the excellent quality of the CAA site and the steady improvements such as the online submission system for papers at this conference. There were many comments supportive of various features of the website (and the most sustained applause of the meeting to recognize this contribution to CAA).

Nominations and Election

CAA corporate rules require that we elect the Executive and Directors each year.

This year two directors will leave the Board. Mark Cheng has resigned from the Board due to a change in his job, and Corjan Buma is coming to the end of his extended term. The meeting recognized their contributions.

The Past Past President, David Chapman, presented the nominations and managed the election process. In each case, he read the name of the nominee, and then asked twice if there were other nominees from the floor.

- First he presented names of the proposed (continuing) Directors who have agreed to serve for another year: Nicole Collison, Christian Giguère, Alberto Behar, Rich Peppin, Anita Lewis, Vijay Parsa.
- Second, he presented the names of two proposed new Directors: Tim Kelsall and Clair Wakefield.
- Finally, he presented names of proposed (continuing) members of the Executive: Stan Dosso as President, David Quirt as Secretary, Dalila Giusti as Treasurer, and Ramani Ramakrishnan as Editor.

In each case, there were no other nominations from the floor, so these nominees were declared elected by acclamation.

Adjournment

Alberto Behar moved and Dave Quirt seconded, that the meeting be adjourned. Carried. Meeting adjourned at 6:35 p.m.

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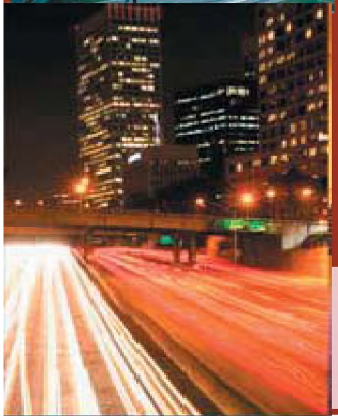

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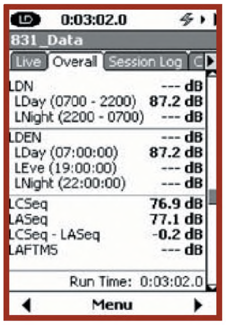

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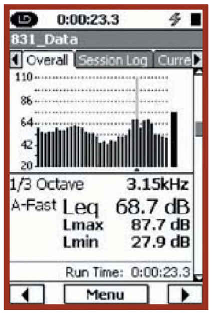

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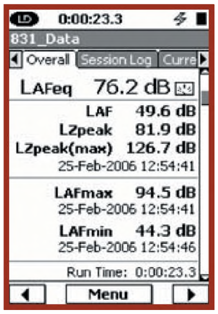

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LAFmax 94.5 dB
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LAFmin 44.3 dB
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The Canadian Acoustical Association
L'Association Canadienne d'Acoustique

PRIZE ANNOUNCEMENT • ANNONCE DE PRIX

A number of prizes and subsidies are offered annually by The Canadian Acoustical Association. Applicants can obtain full eligibility conditions, deadlines, application forms, past recipients, and the names of the individual prize coordinators on the CAA Website (http://www.caa-aca.ca). • Plusieurs prix et subventions sont décernés à chaque année par l'Association Canadienne d'Acoustique. Les candidats peuvent se procurer de plus amples renseignements sur les conditions d'éligibilités, les échéances, les formulaires de demande, les récipiendaires des années passées ainsi que le nom des coordonnateurs des prix en consultant le site Internet de l'ACA (http://www.caa-aca.ca).

Deadline for Underwater Acoustic and/or Signal Processing Student Travel Subsidy: **31 March 2007**
Échéance Subvention de Voyage pour Étudiants en Acoustique Sous-marine ou Traitement du Signal: **31 Mars 2007**

EDGAR AND MILLICENT SHAW POSTDOCTORAL PRIZE IN ACOUSTICS • PRIX POST-DOCTORAL EDGAR AND MILLICENT SHAW EN ACOUSTIQUE

$3,000 for full-time postdoctoral research training in an established setting other than the one in which the Ph.D. was earned. The research topic must be related to some area of acoustics, psychoacoustics, speech communication or noise. • $3,000 pour une formation recherche à temps complet au niveau postdoctoral dans un établissement reconnu autre que celui où le candidat a reçu son doctorat. Le thème de recherche doit être relié à un domaine de l'acoustique, de la psycho-acoustique, de la communication verbale ou du bruit.

ALEXANDER GRAHAM BELL GRADUATE STUDENT PRIZE IN SPEECH COMMUNICATION AND BEHAVIOURAL ACOUSTICS • PRIX ÉTUDIANT ALEXANDRE GRAHAM BELL EN COMMUNICATION VERBALE ET ACOUSTIQUE COMPORTEMENTALE

$800 for a graduate student enrolled at a Canadian academic institution and conducting research in the field of speech communication or behavioural acoustics. • $800 à un(e) étudiant(e) inscrit(e) au 2e ou 3e cycle dans une institution académique canadienne et menant un projet de recherche en communication verbale ou acoustique comportementale.

FESSENDEN GRADUATE STUDENT PRIZE IN UNDERWATER ACOUSTICS • PRIX ÉTUDIANT FESSENDEN EN ACOUSTIQUE SOUS-MARINE

$500 for a graduate student enrolled at a Canadian academic institution and conducting research in underwater acoustics or in a branch of science closely connected to underwater acoustics. • $500 à un(e) étudiant(e) inscrit(e) au 2e ou 3e cycle dans une institution académique canadienne et menant un projet de recherche en acoustique sous-marine ou dans une discipline reliée à l'acoustique sous-marine.

ECKEL GRADUATE STUDENT PRIZE IN NOISE CONTROL • PRIX ÉTUDIANT ECKEL EN CONTRÔLE DU BRUIT

$500 for a graduate student enrolled at a Canadian academic institution and conducting research related to the advancement of the practice of noise control. • $500 à un(e) étudiant(e) inscrit(e) au 2e ou 3e cycle dans une institution académique canadienne et menant un projet de recherche relié à l'avancement de la pratique du contrôle du bruit.

RAYMOND HÉTU UNDERGRADUATE PRIZE IN ACOUSTICS • PRIX ÉTUDIANT RAYMOND HÉTU EN ACOUSTIQUE

One book in acoustics of a maximum value of $100 and a one-year subscription to *Canadian Acoustics* for an undergraduate student enrolled at a Canadian academic institution and having completed, during the year of application, a project in any field of acoustics or vibration. • Un livre sur l'acoustique et un abonnement d'un an à la revue *Acoustique Canadienne* à un(e) étudiant(e) inscrit(e) dans un programme de 1er cycle dans une institution académique canadienne et qui a réalisé, durant l'année de la demande, un projet dans le domaine de l'acoustique ou des vibrations.

CANADA-WIDE SCIENCE FAIR AWARD • PRIX EXPO-SCIENCES PANCANADIENNE

$400 and a one-year subscription to *Canadian Acoustics* for the best project related to acoustics at the Fair by a high-school student • $400 et un abonnement d'un an à la revue *Acoustique Canadienne* pour le meilleur projet relié à l'acoustique à l'Expo-sciences par un(e) étudiant(e) du secondaire.

DIRECTORS' AWARDS • PRIX DES DIRECTEURS

One $500 award for the best refereed research, review or tutorial paper published in *Canadian Acoustics* by a student member and one $500 award for the best paper by an individual member • $500 pour le meilleur article de recherche, de recensement des travaux ou d'exposé didactique arbitré publié dans l'*Acoustique Canadienne* par un membre étudiant et $500 pour le meilleur article par un membre individuel.

STUDENT PRESENTATION AWARDS • PRIX POUR COMMUNICATIONS ÉTUDIANTES

Three $500 awards for the best student oral presentations at the Annual Symposium of The Canadian Acoustical Association. • Trois prix de $500 pour les meilleures communications orales étudiant(e)s au Symposium Annuel de l'Association Canadienne d'Acoustique.

STUDENT TRAVEL SUBSIDIES • SUBVENTIONS POUR FRAIS DE DÉPLACEMENT POUR ÉTUDIANTS

Travel subsidies are available to assist student members who are presenting a paper during the Annual Symposium of The Canadian Acoustical Association if they live at least 150 km from the conference venue. • Des subventions pour frais de déplacement sont disponibles pour aider les membres étudiants à venir présenter leurs travaux lors du Symposium Annuel de l'Association Canadienne d'Acoustique, s'ils demeurent à au moins 150 km du lieu du congrès.

UNDERWATER ACOUSTICS AND SIGNAL PROCESSING STUDENT TRAVEL SUBSIDIES • SUBVENTIONS POUR FRAIS DE DÉPLACEMENT POUR ÉTUDIANTS EN ACOUSTIQUE SOUS-MARINE ET TRAITEMENT DU SIGNAL

One $500 or two $250 awards to assist students traveling to national or international conferences to give oral or poster presentations on underwater acoustics and/or signal processing. • Une bourse de $500 ou deux de $250 pour aider les étudiant(e)s à se rendre à un congrès national ou international pour y présenter une communication orale ou une affiche dans le domaine de l'acoustique sous-marine ou du traitement du signal.

Canadian Acoustical Association
Association canadienne d'acoustique

2006 PRIZE WINNERS / RÉCIPIENDAIRES 2006

BELL GRADUATE STUDENT PRIZE IN SPEECH COMMUNICATION AND HEARING / PRIX ÉTUDIANT BELL EN COMMUNICATION ORALE ET AUDITION

Amy McKinnon, Dalhousie University
"*Pitch Perception in Young Cochlear Implant Listeners*"

FESSENDEN GRADUATE STUDENT PRIZE IN UNDERWATER ACOUSTICS / PRIX ÉTUDIANT FESSENDEN EN ACOUSTIQUE SOUS-MARINE

Xavier Mouy, Institut des sciences de la mer de Rimouski (UQTR)
"*Développement d'un détecteur intelligent des baleines*"

ECKEL GRADUATE STUDENT PRIZE IN NOISE CONTROL / PRIX ÉTUDIANT ECKEL EN CONTRÔLE DU BRUIT

Gary Chan, University of British Columbia
"Prediction and Active Noise Control in Fitted Industrial Rooms"

RAYMOND HÉTU UNDERGRADUATE PRIZE IN ACOUSTICS / PRIX ÉTUDIANT RAYMOND HÉTU EN ACOUSTIQUE

Shazia Ahmed, Sina Fallah, Brenda Garrido, Andrew Gross, Matthew King,
Timothy Morrish, Desiree Pereira, Shaun Sharma, Ewelina Zaszewska
University of Toronto Mississauga
"Portable Audio Devices and their Effects on Hearing"

CANADA-WIDE SCIENCE FAIR AWARD / PRIX EXPO-SCIENCES PANCANADIENNE

Steven Gasior, Mississauga (Ontario)
"Blind Navigation"

DIRECTORS' AWARDS / PRIX DES DIRECTEURS

Student Member / Membre Étudiant:

Youssef Atalla, Université de Sherbrooke

"Inverse Acoustical Characterization of Open Cell Porous Media using Impedance Tube Measurements"
Canadian Acoustics 33(1):11-24

Individual Member / Membre Individuel:

Murray Hodgson, University of British Columbia

"Empirical Prediction of the Effect of Classroom Design on Verbal Communication Quality"
Canadian Acoustics 33(4): 5-12

STUDENT PRESENTATION AWARDS / PRIX POUR COMMUNICATIONS ÉTUDIANTES
CITADEL HALIFAX HOTEL, HALIFAX (NS), OCTOBER 11-13, 2006

Rida Al Osman, University of Ottawa

"AlarmLocator: A Software Tool to Facilitate the Installation of Acoustic Warning Devices in Noisy Work Plants"

Jeff Defoe, University of Windsor

"Computational Aeroacoustics for Electronics Coolers"

Matt Nantais, University of Windsor

"Graphics Processing Unit Cooling Solutions: Acoustic Characteristics"

Ewen MacDonald, University of Toronto

"Making Young Ears Old (and old ears even older)"

CONGRATULATIONS / FÉLICITATIONS

Congrès annuel de l'Association canadienne d'acoustique
9 – 12 octobre 2007
Université Concordia, Montréal (Québec)

Nous vous invitons à assister à trois journées de formation et de perfectionnement sur différents domaines de l'acoustique dans le cadre du congrès annuel de l'Association canadienne d'acoustique (ACA). Comme le congrès se déroulera à Montréal, « capitale mondiale de l'aérospatiale », le thème de la conférence principale sera l'**AÉROACOUSTIQUE**. Vous pourrez également assister à des communications qui seront données simultanément durant deux jours et demi sur l'acoustique et la perception auditive, notamment des séances spéciales et des expositions de produits acoustiques. Vous êtes en outre conviés aux expositions, à l'assemblée générale annuelle ainsi qu'au banquet de clôture.

Séances plénières

Il y aura deux séances plénières : l'une sur l'aéroacoustique et l'autre, sur l'acoustique des bâtiments.

Séances spéciales

Plusieurs séances spéciales donneront lieu à des communications sollicitées par le comité d'organisation ou proposées par les membres. Parmi les thèmes traités : aéroacoustique, thermoacoustique, électroacoustique, acoustique musicale, acoustique des bâtiments, photoacoustique, audiologie/bioacoustique, contrôle acoustique, communication verbale, instrumentation et traitement des signaux en acoustique, normes acoustiques, acoustique environnementale. Si vous souhaitez organiser une session spéciale, veuillez contacter M. Kamran Siddiqui, président du Comité technique (technical-chair@caa-aca.ca).

Expositions et commanditaires

Du matériel aéroacoustique et d'autres produits seront exposés en face des salles de conférence. Les pauses se tiendront également dans l'espace d'exposition. Veuillez contacter M. Muthukumaran Packirisamy, président du Comité des expositions (exhibits@caa-aca.ca), pour tout renseignement sur les exposants et sur les possibilités de commanditer diverses activités du congrès.

Participation étudiante

Les membres étudiants qui font une communication bénéficient d'une subvention de déplacement, à condition de retourner le formulaire prévu à cet effet avant le 15 septembre 2007. Celles et ceux qui sont inscrits à une université canadienne peuvent également entrer en lice pour le Prix de la meilleure communication étudiante.

Résumés

Prière d'adresser les résumés de 2 pages par courrier électronique au plus tard le 22 mai 2007 pour parution dans la revue *L'Acoustique canadienne*, dans le numéro consacré au congrès (publié en septembre 2007). Ce numéro spécial est devenu le véhicule annuel du compte rendu des avancées en recherche acoustique au Canada. Vous trouverez des renseignements sur les modalités de soumission des résumés ainsi qu'un résumé-type à l'adresse suivante : http://users.encs.concordia.ca/~caa-2007. L'avis d'acceptation ainsi que les suggestions de modifications des examinateurs seront transmis d'ici au 3 juillet 2007. La version finale des résumés révisés doit parvenir au plus tard le 6 juillet 2007 pour publication dans les Actes du congrès.

Numéro spécial de la revue *L'Acoustique canadienne*

Après l'étape de la révision, on invitera certains auteurs à soumettre une version intégrale de leur article pour parution dans le numéro spécial de *L'Acoustique canadienne.* Les articles complets et les renseignements sur les modalités de soumission seront affichés à l'adresse http://users.encs.concordia.ca/~caa-2007. La version finale des articles sollicités doit parveni aux organisateurs au plus tard le 6 août 2007 pour fin de publication.

Inscription

Les formulaires d'inscription se trouvent sur le site Web du congrès. Tous les participants doivent s'inscrire. La préinsciption prend fin le 15 septembre 2007. Un comptoir d'inscriptio sera ouvert tout au long de l'activité.

Lieu et hébergement

Le congrès se déroulera au centre-ville de Montréal, dans le très beau pavillon intégré Génie informatique et arts visuels de l'Université Concordia, à 22 km à l'est de l'aéroport internationa P.-E.-Trudeau (desservi par les principales lignes aériennes). Plusieurs hôtels se trouvent à quelques pas du pavillon. L'Université s'est associée avec certains d'entre eux pour y loger les congressistes à un tarif spécial; les autres hôtels offrent des tarifs d'entreprises.

Accueil

Le congrès annuel de l'ACA est une occasion de retrouver de vieux amis ou de se faire de nouvelles connaissances autour d'un café pendant ou après les séances de travail. De nombreux bars et restaurants accueillent les congressistes dans les environs. Au cours du banquet, qui se déroulera au sommet du Mont-Royal, les participants pourront profiter d'une agréable soirée aux couleurs automnales avec pour toile de fond Montréal tout en lumières.

Contacts

Président du congrès	Rama Bhat	conference@caa-aca.ca
Président – Comité technique	Kamaran Siddiqui	technical-chair@caa-aca.ca
Président – Comité des expositions	Muthukumaran Packirisamy	exhibits@caa-aca.ca
Président – Comité du site Web	Sivakumar Narayanswamy	webmaster@caa-aca.ca
Présidente – Comité logistique	Wenfang Xie	logistics-technical@caa-aca.ca

Dates à retenir

Date limite de réception des résumés de 2 pages (par voie électronique)	22 mai 2007
Avis d'acceptation et invitation à soumettre les articles complet par courriel	3 juillet 2007
Date limite de réception des articles complets (par voie électronique)	6 août 2007
Date limite pour obtenir le tarif de préinscription	15 sept. 2007
Colloque annuel de l'ACA – Université Concordia, Montréal	9 – 12 octobre

Acoustics Week in Canada 2007
October 9-12
Concordia University, Montreal, Quebec

Please join us to participate in three days of papers on diverse areas of acoustics. The main conference theme will be on **AEROACOUSTICS** fitting to the reputation of Montreal as the “Aerospace Capital of the World”. There will be two and a half days of parallel sessions of papers on all areas of acoustics and auditory perception, including some planned special sessions as well as an interesting array of exhibits detailing acoustical products. In addition to the technical sessions, you are invited to attend the exhibits, annual general meeting, and banquet.

Plenary Sessions

There will be two plenary sessions one in Aeroacoustics and one in Building Acoustics.

Special Sessions

Several special sessions will be offered that will include invited and contributed papers. Sessions include Aeroacoustics, Thermoacoustics, Electroacoustics, Musical Acoustics Building Acoustics, Photo Acoustics, Audiology/Bioacoustics, Noise Control, Speech communication, Instrumentation & Signal Processing in Acoustics, Acoustic Standards and Environmental Acoustics. . If you are interested in organizing a special session, please contact Kamran Siddiqui, the Technical Chair (technical-chair@caa-aca.ca)).

Exhibits & Sponsors

An exhibit hall of equipment related to aeroacoustics and other acoustical products will be located across from the meeting rooms. The exhibit area will also be the central coffee break area. Please contact Muthukumaran Packirisamy, the exhibit coordinator (exhibits@caa-aca.ca) for exhibitor information and sponsorship of various aspects of this meeting.

Student Participation

For student members who are presenting papers, there is a travel subsidy that is available upon application. In addition, student members enrolled in Canadian universities may also enter a competition for the best student presentation award. Students are encouraged to submit the request for travel subsidy before 15th September 2007.

Abstract submissions

Submission of 2 page abstracts may be made electronically on or before May 22, 2007 for inclusion in the conference issue of Canadian Acoustics (September 2007). This conference issue has become the archival record of new acoustical research activities in Canada each year. Abstract submission information and a sample abstract would be available on the CAA Montreal 2007 website (http://users.encs.concordia.ca/~caa-2007). Notification of acceptance together with reviewer suggestions for modifications will be sent out by July 03. Final submissions of the revised abstracts must be received by August 6, 2007 in order to facilitate publication in the conference proceedings.

Special Edition of the Canadian Acoustics Journal

After review, authors of some selected papers will be invited to submit the extended version of their paper for publication in a special edition of the Canadian Acoustics Journal. Full paper and the complete submission information will be available on the CAA Montreal 2007 website (http://users.encs.concordia.ca/~caa-2007). Final submissions of the invited papers must be received by August 6, 2007 in order to facilitate publication

Registration

Registration forms are available on the conference website. Early registration closes on September 15, 2007. All conference participants must register for the conference. A registration desk will be open throughout the conference.

Venue and Accommodation

The conference will be held in the attractive new Engineering and Visual Arts Complex of the Concordia University in downtown Montreal which is 22kms east of P E Trudeau Airport served by all major airlines. There are several hotels within walking distance. There are few hotels with whom the university has agreements to house its guests at special rates. There are other hotels of all levels, where the corporate rates will hold.

Hospitality

CAA conferences are always an opportunity to meet old friends and to make new ones over a coffee during the conference, or over a drink after the sessions. Many bars and restaurants are nearby and there will be a banquet as part of the conference which will be held on top of Mount Royal. The participants can enjoy an evening filled with colors of Fall on the backdrop of a splendid Montreal Skyline.

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Important Dates

Deadline for receipt of 2 page summary paper (Electronic submission)	22nd May 2007
Notice of acceptance and invitation for full paper submission by email	3rd July 2007
Deadline for receipt of full paper (Electronic submission)	6th Aug 2007
Deadline for early registration rates	15th Sep 2007
CAA annual conference – Concordia University, Montreal	9th – 12th Oct

The Canadian Acoustical Association / l'Association Canadienne d'Acoustique

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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 / Electro-acoustics	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

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