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THE CANADIAN ACOUSTICAL ASSOCIATION
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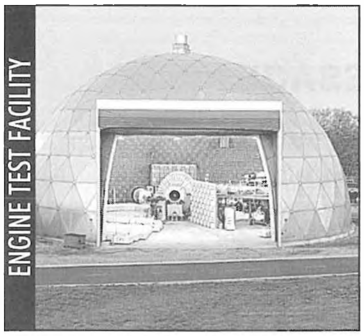
MESSAGE DU PRESIDENT / PRESIDENT'S MESSAGE

Accepter la présidence de notre association constitue un défi. Un défi, principalement en cette période, puisque le développement et la croissance de l'ACA semblent avoir stagnés. Je crois qu'il est temps de susciter de nouvelles idées, une nouvelle bouffée d'enthousiasme, du sang neuf. Je ne peux prétendre être du sang neuf mais j'aimerais faire ma part pour le développement de notre association. Je pense personnellement que notre journal, *l'Acoustique Canadienne*, et notre conférence annuelle doivent être au centre de nos préoccupations. Si ces deux éléments de base se développent et croissent, il y a de forte chance que l'adhésion à l'association et son succès suivent ce courant. Cependant, ils doivent se développer pour répondre à vos intérêts comme membres. Afin de prendre le pouls de la préférence des membres, j'ai envoyé un questionnaire à un échantillon de 85 de nos membres. Les réponses préliminaires confirment, de façon marquée, mon impression de l'importance qu'ont le journal et les conférences annuelles. Il y a aussi des indications sur les éléments de notre association que les membres jugent les plus importants ainsi que des suggestions pour initier des changements et des améliorations. J'apprécierais grandement recevoir vos commentaires et vos suggestions. Comment pourrions-nous améliorer notre journal et notre rencontre annuelle? Qui pourriez-vous suggérer comme personnes dynamiques qui mettraient en application les suggestions proposées? Ou peut-être aimeriez-vous répondre au questionnaire? Je vous invite à m'écrire, en anglais ou en français, par courrier électronique, télécopieur ou par courrier normal.

To accept the presidency of our association is to accept a challenge. A challenge, especially now, because the development and growth of CAA seems to have stagnated. I think it is time: for some new ideas, for a new burst of enthusiasm, for some new blood. I cant claim to be new blood but I would like to do my part in the continuing development of our association.

I personally think that our journal, *Canadian Acoustics*, and our annual conference must be the focus of our new efforts. As these two basic elements develop and grow, so will our membership and the success of our association. However, they must develop to suit the interests of you the members. To get an indication of members preferences, I have sent out a questionnaire to a sample of 85 members. Initial responses strongly confirm my impression of the importance of our journal and of our annual meeting. There are also many indications of what members find to be the most important features of our association as well as suggestions for changes and improvements.

I would really like to hear your comments and suggestions. How do you think we would improve our journal or our annual meeting? Who could you suggest as energetic people to help carry out your suggestions? Or perhaps you would like to respond to my questionnaire? Please write, in English or in French, by Email or FAX, or even by regular mail.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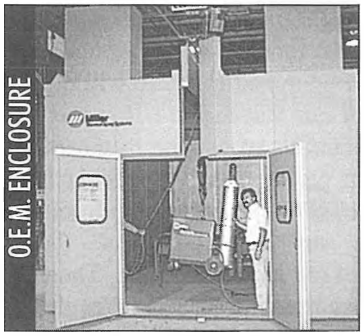
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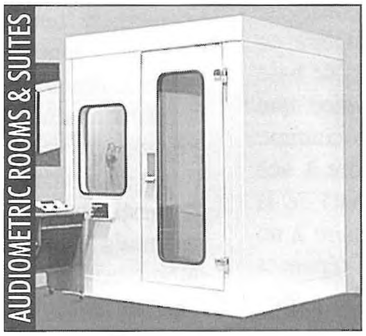
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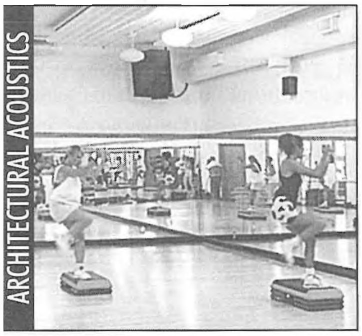
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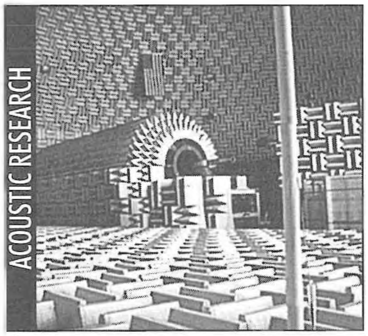
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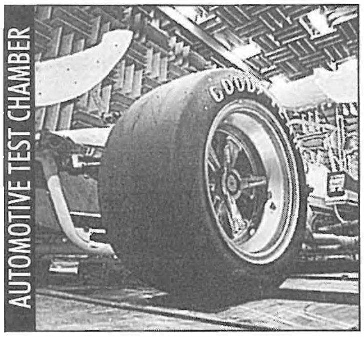
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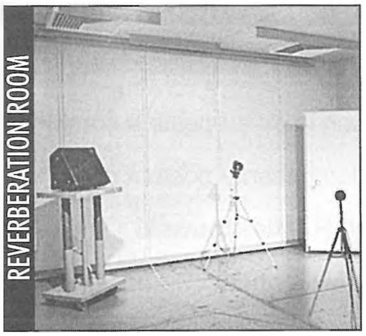
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Canadian Acoustics / Acoustique Canadienne 25(4) 3-11 (1997) ***Research article / Article de recherche***

COMPARISON OF SOME METHODS USED FOR PREDICTION OF ATMOSPHERIC SOUND PROPAGATION

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ABSTRACT

The sound field in inhomogeneous atmospheric conditions above an impedance plane is computed using three different numerical procedures, to assess their advantages and disadvantages. Two implementations of the parabolic equation are considered, the Green's function method and a Crank-Nicolson method; these are contrasted with a version of the fast field program. As test cases, both upward and downward refracting conditions are considered, with and without turbulence. Calculations made using the Green's function implementation are considerably faster, making it the method of choice when large numbers of calculations (as when many realizations of turbulence are required) are necessary. However, considerable care is required in setting computational parameters and parallel calculations with one of the other techniques for validation is advisable.

SOMMAIRE

Le champ sonore en présence d'un plan d'impédance est calculé à partir de trois méthodes numériques différentes afin d'évaluer leurs avantages et désavantages. On compare deux applications de l'équation parabolique; une méthode basée sur la fonction de Green et une méthode Crank-Nicolson. Ces deux méthodes sont aussi comparées avec une version du Fast Field Program. On traite les cas de la propagation en présence d'un gradient de célérité négatif et d'un gradient de célérité positif, en présence de turbulence et sans turbulence. La méthode basées sur la fonction de Green s'avère la plus rapide, ce qui lui donne une avantage lorsque le nombre de calcul est grand (en présence de turbulence, le calcul doit être effectué pour un nombre important de réalisation du champ turbulent). Cependant, un soin particulier doit être apporté au choix des paramètres de calcul et des calculs parallèles en utilisant une des autres méthodes sont souhaitables pour valider les resultats.

1. INTRODUCTION

With the ever-increasing speed of computers and the development of more efficient numerical algorithms, it is becoming possible to obtain quite realistic predictions of sound fields in the atmosphere.[1,2] The important physical mechanisms that control propagation, e.g., turbulence, refraction and terrain, can be examined directly and modelled more rigorously.[3,4] Ultimately, the knowledge generated will find its way into standards and regulatory prediction schemes. Three current approaches for the numerical computation of atmospheric sound propagation will be discussed and contrasted in this paper.

Many physical factors influence sound propagation.[5,6] The ground over which propagation occurs is rarely flat and interacts with the sound field through its ground impedance. The atmosphere is neither homogeneous nor static. The average sound speed generally varies with height above ground, giving rise to upward or downward refrac-

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*On a work term from the Danish Technical University

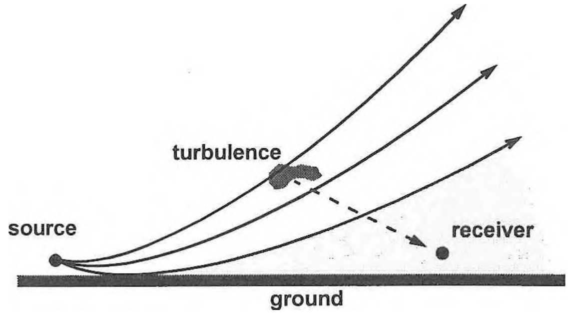

Figure 1. Sketch showing upward refraction conditions. The sound speed decreases with height, causing sound rays to curve upwards. In the acoustic shadow, the sound field is dominated by scattering from atmospheric turbulence.

tion conditions. Local inhomogeneities of wind speed or temperature or humidity, i.e., turbulence, will scatter sound energy. A typical situation found on warm summer afternoons is shown in Fig. 1. Because of solar heating, the air nearer the ground is warmer and the sound speed is greater there than higher up. Sound rays will tend to curve up, forming an acoustic shadow. Within the shadow, measured sound pressure levels are much higher[7] than would be predicted on the basis of simple theory. It is generally accepted that scattering of sound by turbulence is the dominant source of acoustic energy within such a shadow.

A useful survey of models currently being used for sound field computation may be found in the Benchmark paper[4]: ray-based methods, parabolic equation techniques and "fast field program" implementations are discussed. The latter two classes of methods are particularly useful, giving comparable accuracy and handling a wide range of sound speed profiles. Of these two classes, only those based on a solution of the parabolic equation have been proven able to handle turbulence in a realistic fashion. Two implementations of the parabolic equation, one based on a Crank-Nicolson finite-difference scheme[8] and the other, the "Green's function" parabolic equation, on a split-step Fourier implementation that explicitly treats the ground impedance condition,[9,10] are discussed in this paper. These typify the two main approaches to solution of the parabolic equation. The fast field program, although not able to treat turbulence directly, is a robust and accurate procedure[11,12] and provides a useful verification of the parabolic equation approaches.

Gilbert and Di have found that the Crank-Nicolson and Green's function approaches give comparable results for the no-turbulence case[9] and qualitatively similar results with turbulence.[10] This comparison will be explored further here.

Other implementations of the parabolic equation have been discussed, particularly in the underwater acoustics forum.[13,14] Many of these approaches, however, have been tailored for the underwater environment, where the bottom is treated differently than an impedance condition and turbulence is not generally important. A recent development, the split-step Padé approximation[15] could prove to be quite useful in atmospheric acoustics and an initial implementation by Juvé *et al.*[2] is promising.

2. THEORY

The relevant theory does appear elsewhere and so will only be covered briefly here.

Consider a point acoustical source located a height z_s above an impedance plane. For a harmonic time dependence $\exp(-i\omega t)$, the complex sound pressure p is given by the wave equation

$$[\nabla^2 + k^2]p(x, y, z) = -4\pi\delta(x, y, z - z_s) \tag{1}$$

where $k = \omega/c$ is the wavenumber. Because of turbulence in the atmosphere and the formation of refractive profiles, the sound speed varies with spatial position and, hence, so does the wavenumber. We restrict our attention to a vertical plane containing source and receiver, so only the horizontal range r and height z above the ground need be considered. It is convenient, then, to separate the wavenumber into two components,[1] a deterministic component $k_d(z)$ due to the static refractive profile, and a stochastic component $k_o\mu(r, z)$, through

$$k(r, z) = k_d(z) + k_o\mu(r, z) \ , \tag{2}$$

where k_o is a reference value. The impedance boundary condition for a specific surface impedance Z, is

$$\left(\frac{\partial p}{\partial z} + ik\beta p\right)_{z=0} = 0 \ , \tag{3}$$

with $\beta = \rho c/Z$ being the complex surface admittance.

Expressing Eq. (1) in cylindrical coordinates and assuming symmetry about the vertical axis passing through the source, we obtain

$$\frac{\partial^2 p}{\partial r^2} + \frac{1}{r}\frac{\partial p}{\partial r} + \frac{\partial^2 p}{\partial z^2} + k^2 p = -\frac{2}{r}\delta(r)\delta(z - z_s) \ , \tag{4}$$

where r is the horizontal distance from source. This is the point of departure for the fast field program (FFP) and the parabolic equation (PE) approaches.

2.1. Fast Field Program

In the fast field program (FFP), the atmosphere is treated as horizontal layers and turbulence is explicitly omitted, so $\mu = 0$ in Eq. (2). The range dependence is removed from Eq. (4) by applying the Hankel transform to give

$$\frac{d^2P}{dz^2} + [k^2(z) - K^2]P = -2\delta(z - z_s) \tag{5}$$

where the transform P is

$$P(K, z) = \int_0^\infty p(r, z)J_0(Kr)rdr\,. \tag{6}$$

Equation (5) presents a one-dimensional problem. Solutions are relatively straightforward[4,16,17] although details of implementation (e.g., whether sound speed is assumed constant or linearly-varying within each layer) lead to different versions of the fast field program. Given a solution $P(K, z)$ for each horizontal wavenumber K, the range dependence of the sound field is obtained by applying the inverse Hankel transform,

$$p(r, z) = \int_0^\infty P(K, z)J_0(Kr)KdK\,. \tag{7}$$

The integral can be replaced by a finite sum of N terms (discretizing both range r and wavenumber K) more suitable for computation, making use of the asymptotic form for the Bessel function,[16]

$$p(r_m) = 2e^{i\pi/4}\sqrt{\frac{\pi}{r_m}}\,\Delta K \sum_{n=0}^{N-1} P(K_n)\sqrt{K_n}\,e^{i2\pi mn/N}, \tag{8}$$

at each height z. This form is able to take advantage of fast Fourier transform techniques.

2.2. Crank-Nicolson PE

To obtain the parabolic equation, the substitution $U = pr^{1/2}$ and the far-field assumption $kr \gg 1$ are made in Eq. (4), giving

$$\frac{\partial^2 U}{\partial r^2} + \frac{\partial^2 U}{\partial z^2} + k^2 U = 0\,. \tag{9}$$

An operator $Q = k^2 + \partial^2/\partial z^2$ is introduced and Eq. (9) is factored into

$$\left(\frac{\partial}{\partial r} + i\sqrt{Q}\right)\left(\frac{\partial}{\partial r} - i\sqrt{Q}\right)U = 0\ ; \tag{10}$$

the two factors correspond to outgoing and incoming waves. (Strictly, this factorization is an approximation and holds exactly only when the operator Q is range-independent.) In many cases backscattering can be ignored so only the outgoing wave is retained, i.e.,

$$\frac{\partial U}{\partial r} = i\sqrt{Q}U\,. \tag{11}$$

For the Crank-Nicolson approach, this *one-way equation* is numerically solved using a finite difference approach. In our implementation,[8] the operator $\sqrt{Q}$ is approximated using Claerbout's rational Padé expansion[18]

$$\sqrt{Q} \equiv k_o\sqrt{1+q} \approx k_o\frac{1 + 3q/4}{1 + q/4}\ , \tag{12}$$

where for a reference wavenumber k_o and an index of refraction $n = k/k_o$,

$$q = (n^2 - 1) + \frac{1}{k_o^2}\frac{\partial^2}{\partial z^2}. \tag{13}$$

From Eq. (2), the index of refraction contains deterministic and stochastic components according to

$$n(r, z) = n_d(r, z) + \mu(r, z)\,. \tag{14}$$

Assuming weak turbulence, $\mu^2 \ll 1$, the operator q can be written as[19]

$$q = q_d + 2\mu n_d, \tag{15}$$

where

$$q_d = n_d^2 + \frac{1}{k_o^2}\frac{\partial^2}{\partial z^2} - 1, \tag{16}$$

so a separation of deterministic and stochastic components has been effected. The range dependence is treated through a finite difference approach and the vertical dependence, through a linear finite element approach[20], leading to a matrix equation: With the $U(r, z_n)$ at heights z_n being the elements of the vector $V(r)$, the resulting system of equations have the form

$$\mathrm{M}^- V(r + \Delta r) = \mathrm{M}^+ V(r), \tag{17}$$

where the matrices M^- and M^+ are tridiagonal. Given $V(r)$ at one range step, the field $V(r + \Delta r)$ at the next range step is obtained using a Gaussian decomposition procedure. The boundary condition, also discretized, is applied as a constraint on the lowest z_n above the ground. The recalculation of the stochastic matrix at each range step increases computation time significantly over the simply deterministic case. It is not possible to use a *split-step Fourier* technique (discussed next section) which would reduce computation time.

2.3. Green's Function PE

A faster implementation of the parabolic equation is the Green's function PE, developed by Gilbert and Di[9,10] for atmospheric propagation. This work is based on the *split-step Fourier* technique developed for underwater acoustics[13] but directly incorporates the impedance boundary condition. The approximations that go into this approach have been discussed by Havelock *et al.*[21] Equation (11) is integrated formally to give

$$U(r+\Delta r, z) = e^{i\sqrt{Q}\Delta r}U(r,z) \ . \tag{18}$$

In applying the *split step* approximation, the operator Q is first written as

$$Q = Q_o + \delta k^2 + 2k_o k_d \mu \tag{19}$$

where $Q_o = k_o^2 + \partial^2/\partial z^2$, $\delta k^2 = k_d^2 - k_o^2$, k_o is a reference wavenumber and a term in μ^2 has been ignored. With these, it is found that Eq. (18) can be written

$$U(r+\Delta r, z) \approx e^{i\Phi} e^{i\delta k^2 \Delta r/2k_o} e^{i\sqrt{Q_o}\Delta r} U(r,z) \ . \tag{20}$$

Now, terms involving deterministic and stochastic, range-dependent and range independent have been separated. The effects due to turbulence are entirely within the first *phase screen* term, with the change in acoustic phase across Δr being given by

$$\Phi(z) = k_o \int_{\Delta r} \mu(r,z)\, dr \ . \tag{21}$$

The effects due to the sound speed profile are contained within the second term of Eq. (20). Both these terms are simple multiplicative factors. The third term is evaluated further using a spectral decomposition approach, leading to a Fourier transform formulation that directly accounts for the ground impedance. FFT techniques may be used to permit rapid evaluation of this term.

As with the Crank-Nicolson approach, a marching solution is implemented. However, the range step can be much larger with the Green's function PE, leading directly to more rapid computation.

3. COMPARISON PROCEDURE

3.1. Test cases

The three techniques discussed above will be compared using four specific scenarios, upward and downward refraction conditions, with and without turbulence. All three techniques treat propagation for a single frequency component; a sound frequency of 500 Hz was selected because of its importance in many noise propagation situations. Flat grassland, with a ground impedance of $Z/\rho c = (5.57, 6.1)$, was considered. The source is 1.5 m above the ground and the receiver is 2 m above the ground.

A logarithmic sound speed profile[1]

$$c_d(z) = \begin{cases} c_o + a\ln(z/d)\ , & z \geq z_o \\ c_o + a\ln(z_o/d)\ , & z < z_o \end{cases} \tag{22}$$

is used, with values of c_o=340 m/s, d=0.006 m, and z_o=0.05 m. For downward refraction, a value of a=2 m/s is used and for upward refraction, a=-2 m/s. The two profiles are shown in Fig. 2.

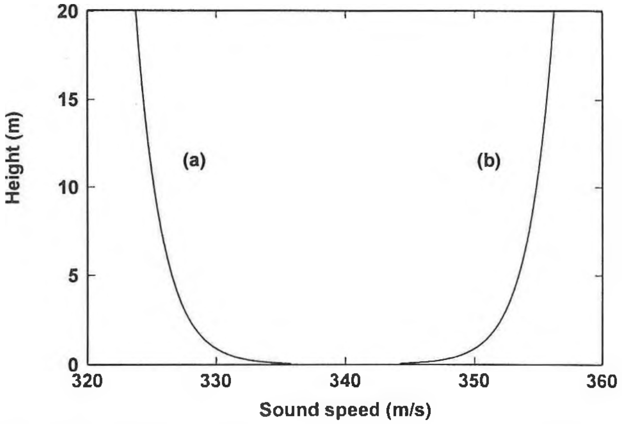

Figure 2. The sound speed profiles that will be used in the following comparisons showing (a) an upwardly refracting profile and (b) a downwardly refracting profile.

Each realization of a turbulent structure $\mu(r,z)$ in the atmosphere is generated using a Fourier approach.[1] For turbulence wavenumbers κ_r and κ_z corresponding to variations of μ in the r and z directions, respectively, we take

$$\mu(r,z) = \sum_{\kappa_r, \kappa_z} G(\kappa_r, \kappa_z) e^{-i\kappa_r r} e^{-i\kappa_r z} \ . \tag{23}$$

The μ are specified on a grid of points in the r-z plane, as $r = m\delta r$ and $z = n\delta z$, where $m=0,1,\ldots(M-1)$ and $n=0,1,\ldots(N-1)$. Correspondingly, the wavenumbers κ_r and κ_z have spacings of $\delta\kappa_r = 2\pi/M\delta r$ and $\delta\kappa_z = 2\pi/N\delta z$. The simulations used a grid spacing of $\delta r = \delta z = 0.05$ m (this choice is discussed further in the next section).

Each set of the complex Fourier coefficients $G(\kappa_r,\kappa_z)$ corresponds to a different realization or "snapshot" of a turbulent atmosphere. The phase angles of these coefficients are assigned randomly. The magnitudes, though, are assigned according to the spectral model being assumed. Consider the spatial correlation function defined as

$$C(s_r, s_z) = \langle \mu(r,z)\, \mu(r+s_r, z+s_z) \rangle, \tag{24}$$

where the triangular braces indicate spatial averaging over the displacement (s_r, s_z). It can be shown that the magnitude of $G(\kappa_r,\kappa_z)$ is related to the Fourier transform of $C(s_r, s_z)$ according to[1]

$$|G(\kappa_r, \kappa_z)|^2 = \frac{1}{MN}\sum_{r,z} C(s_r, s_z) e^{i\kappa_r r} e^{i\kappa_z z}. \tag{25}$$

Chernov[22] suggested that the measured correlation function is given approximately by

$$C(s_r, s_z) = \langle\mu^2\rangle e^{-(s_r^2+s_z^2)/L^2}, \tag{26}$$

where $\langle\mu^2\rangle$ is the mean square strength of the fluctuations and L is a measured spatial correlation length. Daigle[23] found that measured spectra were approximately of this form. Substituting this function into Eq. (25) and evaluating the sums, we obtain to a very good approximation the Gaussian power spectrum

$$|G(\kappa_r,\kappa_z)|^2 = \frac{\langle\mu^2\rangle \pi L^2}{MN\delta r\delta z} e^{-(\kappa_r^2+\kappa_z^2)L^2/4}. \tag{27}$$

For the simulations, a correlation length of 1.1 m and a mean square fluctuation of $\langle\mu^2\rangle = 2\times 10^{-6}$, consistent with typical measurements, were assumed. Because of memory constraints in the code of the Crank-Nicolson PE approach, we were limited to $M=N=512$. The final turbulence structure (25.6 m a side) was then repeated throughout the r-z plane. For the Green's function PE, phase screens were computed using Eq. (21) over range steps of $\Delta r = 6.4$ m.

3.2. Implementation issues

All three techniques require some care in their implementation.

We are using the CERL version[11,12] of the fast field program. Only the number and distribution of sound speed layers and the number of integration points were varied. Default values for other parameters ($K_{\max}$, extra loss) were used while the number of points per FFT was usually 2048. It is important to have sufficient layering to represent the sound speed profile and sufficient number of sampling points to represent the integrand of Eq. (7). The position of the layers was calculated using a simple power law of the form $z = 10^{-1.4+n\Delta x}$ (with n=0,1,...) and convergence was achieved for $\Delta x \sim 0.01$.

The parabolic equation approaches require that the vertical grid size be small compared to a wavelength. A step of $\delta z = 0.05$ m was used (generally, a step of 1/5 wavelength is acceptable). The Green's function approach, using a total vertical height of 819.2 m, thus contained 16384 grid points and a FFT (and inverse FFT) of that size was required at each range step. The Crank-Nicolson approach used 12000 grid points.

The horizontal range step, for the Crank-Nicolson approach, must also be small; a step of $\delta r = 0.05$ m was used in these calculations to be consistent with the specification of the turbulence (ordinarily, a step of 1/5 wavelength would be used). The Green's function approach permits a much larger range step and, in the calculations to follow, a step of 6.4 m was used. In fact, using too small of a range step with this technique leads to numerical difficulties[24] (due to an increased importance of evanescent contributions to the sound field) and the smaller range step must be compensated by both a reduced δz and an increased vertical range.

The two PE approaches require specification of the vertical sound pressure distribution at the first range step; the best starting field available in the current codes was used for each. The Green's function PE approach used a Gaussian starting field[9]. The Crank-Nicolson implementation made use of a "Back PE" technique[19,25] to generate its starting field. The truncation of the vertical grid at the desired upper height leads to a false reflection of sound energy back toward the ground. To reduce this reflection and restore the radiation boundary condition, an artificial absorbing layer is introduced. In this layer, an imaginary part is added to the index of refraction function n^2, increasing gradually from a zero value at the start of the absorbing layer.[9] The absorbing layer was introduced at a height of about 250 m above ground for both approaches.

For the Green's function PE, the reference sound speed must be chosen carefully to get agreement with the other techniques. A value of 330 m/s was used for the upward refraction case and a value of 352 m/s, for the downward refraction case.

4. RESULTS

The calculated sound pressure level, for each case, will be presented as a function of horizontal range for a single receiver height of 2 m. The curves are normalized by the free field levels that would be obtained in the absence of ground, refractive profiles and turbulence, i.e., they are relative to free field.

4.1. Downward refraction, no turbulence

The relative sound pressure level as a function of range is shown in Figure 3, for the case of downward refraction with no turbulence. The three curves correspond to calculations using the Crank-Nicolson PE, the Green's function PE and the fast field program. Very good agreement is obtained between the three methods. On average, the relative levels are about constant with range, indicating that the additional energy refracted toward the ground is tending to compensate for attenuation by the ground. The various dips show the regions of constructive and destructive interference typical of downward refraction. The Green's function PE prediction is approximately 1 dB higher than the other two predictions, in part because of the choice of a Gaussian starter field[19].

Considerable differences between methods are found in speed of computation and ease of implementation. The times required to generate the curves of Fig. 3 on a 486-class computer using the Green's function PE, the fast field program, and the Crank-Nicolson PE were approximately 2 min., 5 min., and 20 min., respectively. It should be noted, though, that this comparison is appropriate only if the sound pressure level is required at just a single height. If the sound field is required over a two-dimensional region of the *r-z* plane (not an unusual situation), then the fast field program (i.e., our implementation) must be rerun for each height desired. The two PE methods, by virtue of the marching technique of the algorithms, actually generate solutions at all heights simultaneously so no additional computation time is required. For example, if the sound field was to be determined at 50 or more vertical positions over the same horizontal range as shown in Fig. 3, then the computation time using the fast field program would increase to something like 4 hours, considerably more than the Crank-Nicolson PE approach. It is noted, though, that there are SAFARI implementations[29] of the fast field program that are able to handle multiple receiver positions without an undue increase in computation time.

On the other, the Green's function PE required considerably more care in implementation than the other techniques. Calculations were repeated using different values of the key parameters (e.g., $k_o.\delta r$, δz and maximum z) to ensure that stable and convergent solutions had been obtained. The Crank-Nicolson PE approach tended to require the least "tuning".

4.2. Downward refraction, with turbulence

In Fig. 4, the two parabolic equation approaches are compared for the case of downward refraction with a superimposed turbulence structure. The fast field program is unable to handle atmospheric turbulence. It is important to note that the inclusion of turbulence does *not* significantly slow down the calculation using the Green's function approach. However, calculations made using the Crank-Nicolson PE method require much more computation time when turbulence is included (more than 12 hours using a 486-class computer were required to compute the curve in

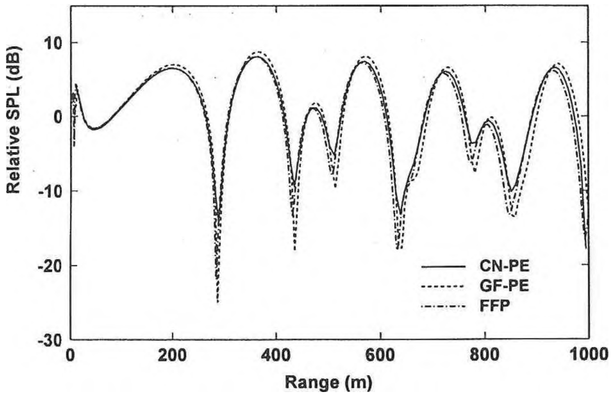

Figure 3. Downward refraction, no turbulence. The three curves are obtained using the Crank-Nicolson (CN-PE) and Green's Function (GF-PE) implementations of the parabolic equation and the fast field program (FFP).

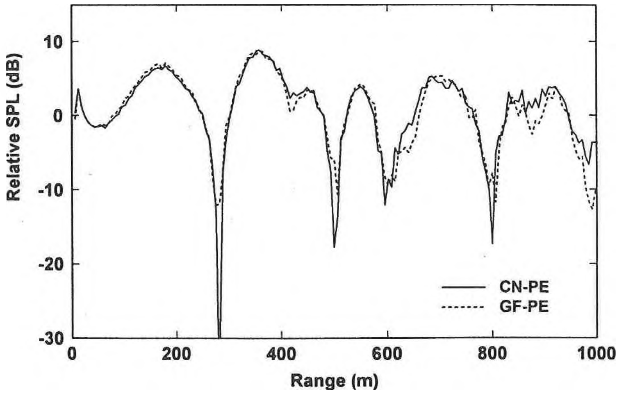

Figure 4. Downward refraction, with turbulence present. Predictions of the Crank-Nicolson (CN-PE) and Green's function (GF-PE) versions of the parabolic equation are shown.

Fig. 4). This slowdown is a result of having to recalculate the stochastic matrix at each range step.

The effect of including turbulence, seen by comparing Figs. 3 and 4, is evident but is relatively small in the downward refracting condition because this is "line-of-sight" propagation. The two methods of calculation are in reasonable agreement in that they modify the corresponding curves of Fig. 3 in a similar fashion.

It should be noted the calculations shown here correspond to a single "snapshot" of turbulence in the atmosphere. For a comparison to real measurements, many such realizations of a turbulent atmosphere would have to be generated and energy-averaged to give the equivalent rms levels that would be obtained experimentally.

4.3. Upward refraction, no turbulence

The results for an upwardly-refracting sound speed profile, i.e., the profile in Fig. 2(a), with no turbulence, are shown in Fig. 5. All three computational techniques are included. The relative levels drop rapidly with range (this is the acoustic shadow), falling to -50 dB for a range of 150 m. For ranges greater than 150 m or so, for this scenario, numerical noise was found to limit the calculations for all three techniques.

There are no significant differences between the predictions of the three approaches. The computational times are the same for upward refraction as for the downward refraction case.

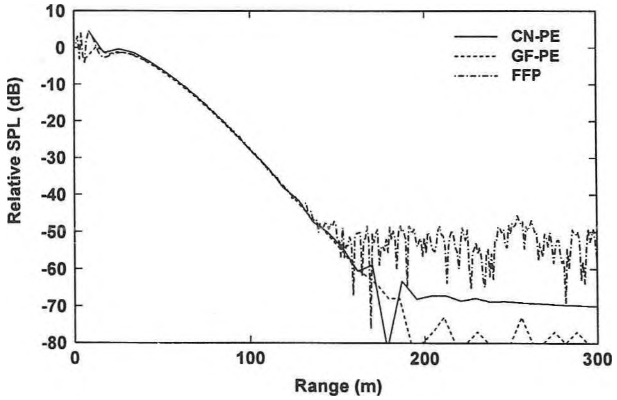

Figure 5. Upward refraction, no turbulence. The same three numerical approaches used in Figure 3 are applied here.

4.4. Upward refraction, with turbulence

In Fig. 6, the predictions for the two implementations of the parabolic equation are shown for an upwardly refracting atmosphere with turbulence. The importance of turbulent scattering is immediately apparent when this figure is compared to Fig. 5 which did not include turbulence. The relative sound pressure level does not decrease rapidly with range but levels off at about -30 dB, consistent with observations.[7]

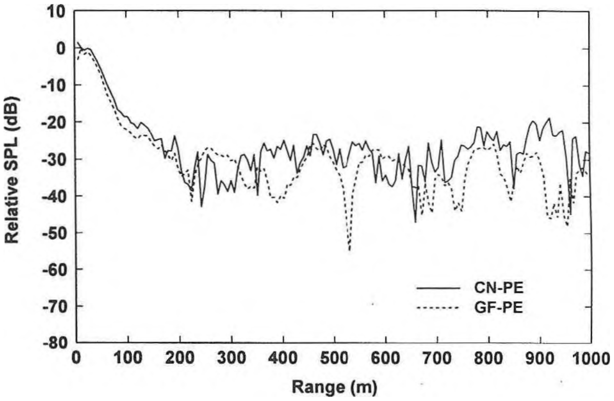

Figure 6. Upward refraction with a single realization of turbulence, showing the Crank-Nicolson and Green's function implementations of the parabolic equation.

The two predictions are qualitatively similar, levelling off to about the same value at large ranges. The curve for the Green's function PE prediction is smoother, as would be expected since it uses a larger range step. There are significant differences in the fine structure of the curves, though. The Crank-Nicolson PE used here employs a "wider-angle" approximation for the propagation operator $\sqrt{Q}$ than does the Green's function PE implementation,[9] so larger-angle scattering by turbulence may be treated more accurately. The correlation length of 1.1 m that has been assumed for the Gaussian turbulence spectrum means that there will be significant spatial variations of sound speed over distances as small as a meter or so. Additonal calculations are required to determine how well the Green's function PE accommodates structures of a size less than the range step.

These calculations correspond to a single realization of the turbulence, i.e., propagation through a frozen turbulent structure. The actual atmosphere is not static but constantly evolving in time and measured sound pressure levels are rms averages. To calculate corresponding levels, it is necessary to repeat the calculations many times, using a different turbulence realization with each. For enough realizations, the energy-average of the predictions will correspond to the rms level that would be measured.[26,27] Using the Green's function PE, with the same refractive profile and statistical description of turbulence as for Fig. 6, the mean relative sound pressure level as a function of range is found to be as shown in Fig. 7. A total of 200 realizations were used in this averaging, giving an uncertainty of less than 0.5 dB.

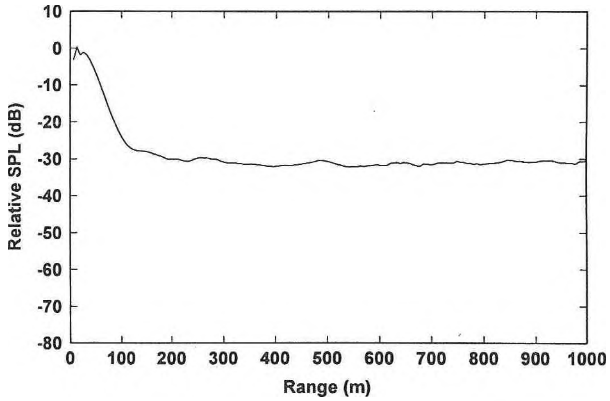

Figure 7. Upward refraction, with turbulence. Calculations for 200 different realizations of a turbulent atmosphere have been energy-averaged. The Green's function PE method has been used.

5. DISCUSSION

Overall, the different methods of calculation are in quite good agreement. Without turbulence, the fast field program and the two parabolic equation approaches gave very similar predictions. With turbulence present, there are differences in detail between the two parabolic equation predictions (i.e., the Crank-Nicolson and the Green's function PE) but the agreement is still reasonble and the key features are produced by both.

Computational speed is an important issue when realistic predictions of sound fields in the atmosphere, with turbulence included, are desired. Typically, 100-200 such realizations are required for each frequency or geometry chosen.

The fast field program works very well, in the absence of turbulence. It serves as a benchmark technique by which others can be tested for accuracy. The main drawback of this technique is its inability to handle turbulence which, as seen in comparing Figs. 5 and 6, is a very important factor in atmospheric propagation. Raspet[28] has done some work on incorporating turbulence into the fast field program, but the approach is somewhat indirect. The other disadvantage of this technique is the slow calculation speed, particularly when sound fields at many heights are required.

The Crank-Nicolson version of the parabolic equation method is straightforward to operate, requiring relatively little adjustment. It can handle turbulence and refractive profiles. However, the need for small range steps (typically $\lambda/5$) significantly limits its speed, particularly when turbulence is included in the description of the atmosphere.

The Green's function version of the parabolic equation is much faster[10], by a factor of 50-100. Its speed is a result of the relatively large range steps permitted (many wavelengths per step) and is achieved whether or not turbulence is included in the computation. However, this technique requires considerable care[24] in setting parameter values to ensure an accurate solution. For a selected range step, the vertical resolution must be sufficiently small and the number of vertical steps sufficiently large. Calculations are quite sensitive to the selection of reference sound speed c_o. As a result of its formulation, the technique has more difficulty with what would be considered simple cases (e.g., propagation above a rigid surface, in a homogenous atmosphere).

6. CONCLUSIONS

Three current methods for the calculation of sound fields above an impedance plane are discussed, the fast field program and the parabolic equation, with Crank-Nicolson and Green's function implementations. All are capable of generating accurate solutions. Only the parabolic equation methods have been shown to produce reliable predictions when turbulence is present in the atmosphere.

The Green's function PE is much faster computationally and, for this reason, is probably favoured when turbulence is included and a large number of realizations are required. However, this technique does require more care and fiddling to ensure accurate calculations. Rough guidelines for the selection of calculation parameters do exist.[9,24] It seems advisable, though, to use the Greens's function PE method in conjunction with one of the other approaches to verify that solutions are accurate.

Recent work using the split-step Padé approximation[15,2] suggests that a compromise been speed and ease of operation may be possible.

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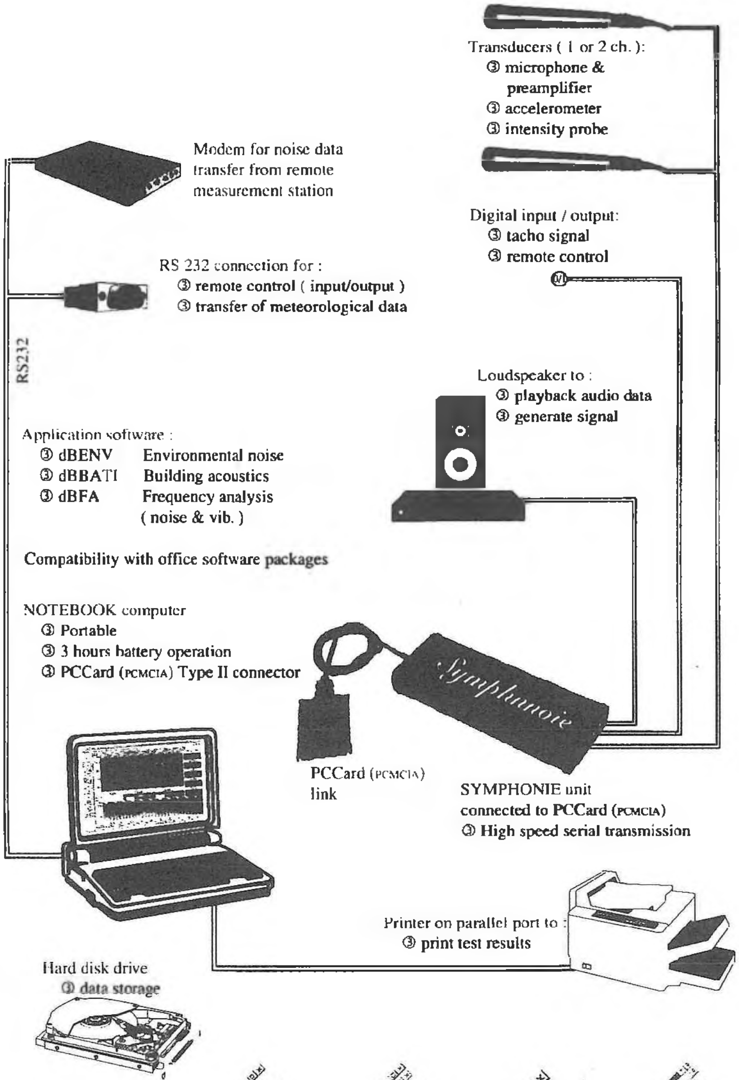

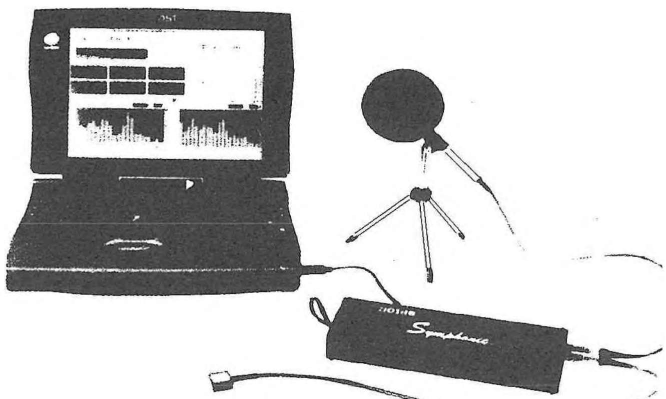

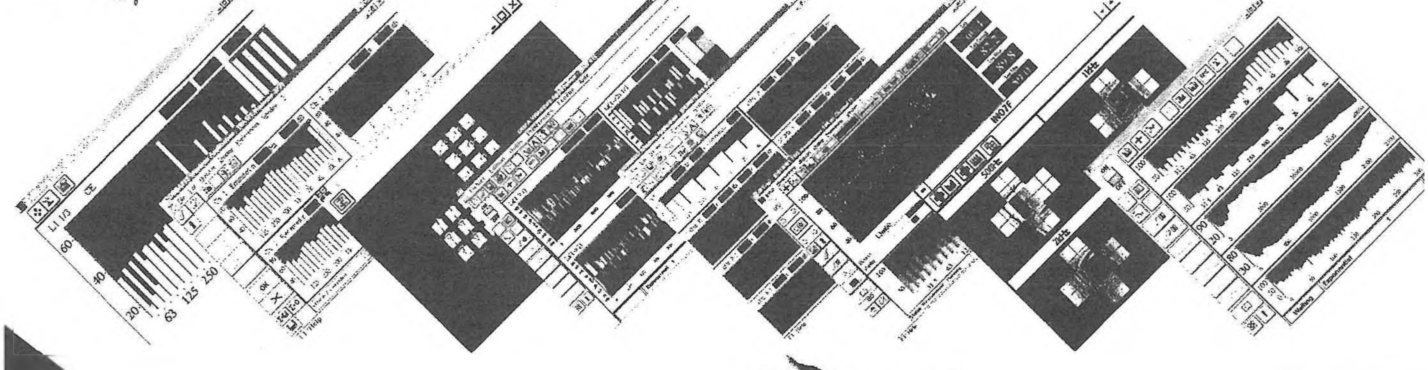

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THE EFFECTS OF SEPARATING AUDITORY AND VISUAL SOURCES ON AUDIOVISUAL INTEGRATION OF SPEECH

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ABSTRACT

When the image of a speaker saying the bisyllable /aga/ is presented in synchrony with the sound of a speaker saying /aba/, subjects tend to report hearing the sound /ada/. The present experiment explores the effects of spatial separation on this class of perceptual illusion known as the McGurk effect. Synchronous auditory and visual speech signals were presented from different locations. The auditory signal was presented from positions 0°, 30°, 60° and 90° in azimuth away from the visual signal source. The results show that spatial incongruencies do not substantially influence the multimodal integration of speech signals.

SOMMAIRE

Lorsqu'on présente simultanément l'image d'une personne prononçant la bisyllabe /aga/ et le son /aba/, les participants ont tendance à dire qu'ils ont entendu /ada/. Cette illusion est connue sous le nom d'effet McGurk. La présente étude explore les conséquences perceptives de la séparation spatiale entre les sources visuelle et sonore sur l'effet McGurk. Un signal auditif était presenté a 0, 30, 60, et 90 degrés en azimuth par rapport au signal visuel. Les resultats demontrent que les paramètres spatiaux n'ont que peu d'influence sur l'intégration visuo-auditive des signaux.

1. INTRODUCTION

One of the most elegant demonstrations of multisensory integration in humans is observed in speech perception. It is well known that watching a speaker's mouth movements while listening to speech in noisy environments enhances intelligibility (Miller, Heise & Lichten, 1951; Sumby & Pollack, 1954; Walden, Prosek, Montgomery, Scherr & Jones, 1977). McGurk and MacDonald (1976) demonstrated that visual information also affects the perception of speech in situations with perfectly audible acoustic signals. When speech sounds such as /ba/ were presented in synchrony with an image of a speaker saying /ga/, subjects reported hearing a different syllable, /da/. Other combinations of auditory and visual stimuli similarly yield "blended" percepts (e.g. auditory /ba/ and visual /da/ produce the perception of a /va/ syllable). In addition, certain manipulations cause participants to perceive both the auditory and visually presented syllables. For example, showing observers a visual /ba/ while they hear a /ga/ causes them to report hearing /bga/. This class of perceptual illusions has been labeled the "McGurk effect" and is a well established phenomenon (e.g., Green & Kuhl, 1989, 1991; MacDonald & McGurk, 1978; Manuel, Repp, Studdert-Kennedy, & Liberman, 1983; Massaro, 1987; Massaro & Cohen, 1983; Munhall, Gribble, Sacco, & Ward, 1996; Summerfield & McGrath, 1984). However, the particular conditions that affect the audiovisual integration of speech, as well as how the integration occurs, remain unidentified. In this study, we address the boundary conditions governing integration by studying the influence of spatial location on the McGurk effect.

Recently, Radeau (1994) and others have suggested that the audiovisual processing of speech represents an example of modular perceptual processing. In Radeau's view, speech is not subject to the same constraints as other types of audiovisual perception. Cross-modal information regarding nonspeech events seems to be integrated based on similar rules proposed by Gestalt psychologists for visual grouping; namely common fate and proximity (e.g., Bermant & Welch, 1976; Bertelson, 1993; Bertelson & Radeau, 1981; Jack & Thurlow, 1973; Radeau & Bertelson, 1977,1978; Welch & Warren, 1980). However, audiovisual speech integration persists when the rules are violated in the temporal domain (Massaro, Cohen & Smeele, 1996; Munhall et al., 1996. Very little work has been done on the effects of spatial separations between auditory and visual sources on the McGurk effect. Fisher and Pylyshyn (1994) report that spatial separations do not reduce the effectiveness of audiovisual stimuli in producing the McGurk effect. Bertelson, Vroomen, Wiegeraad and de Gelder (1994) confirmed this finding, however, both studies used relatively small spatial separations not exceeding 24° (B. D. Fisher, personal communication, November 22, 1995) and 37.5° (Bertelson et al. , 1994) to the right and left of the visual stimulus. Sharma (1989) did use larger spatial separations of 60° to the left and right of the visual stimulus and his experiment showed a small effect of spatial separation on the McGurk effect. However, the results were difficult to interpret because the effect was not consistent for the left and right side of the visual stimulus.

Our experiment was designed to determine whether the strength of the McGurk effect would be influenced by extreme spatial conflicts between the source of the auditory and visual stimuli. It may be that the failure of studies to find a consistent reduction in the audiovisual integration of speech signals has occurred because too small spatial discrepancies have been used. The auditory signal was presented from positions 0°, 30°, 60° and 90° in azimuth away from the visual signal source. It was predicted that if the processing that results in the McGurk effect relies on spatial congruency, then the size of the McGurk effect should decrease as the angular separation between the auditory and visual stimuli sources increases.

2. METHOD

2.1 Subjects

Thirty-six undergraduates at Queen's University, Canada, participated either for credit in an introductory psychology course or were paid volunteers. All subjects were native speakers of Canadian English who reported having either normal or corrected to normal vision and no previous history of hearing or speech disorders. The age of the subjects ranged from 18 to 63 years (M=21.9 years) .

2.2 Apparatus

Stimulus materials and equipment.

The stimuli were selected from a videodisc database created at Queen's University containing Canadian English talkers producing various vowel-consonant-vowel (VCV) bisyllables. Five talkers from the database, 3 females and 2 males between 20 and 30 years of age were used for the experiment. The visual stimuli were the bisyllables /igi/, /IgI/ and /ægæ/ and the auditory stimuli consisted of the bisyllables /ibi/, /IbI/ and /æbæ/ produced by the same talkers. The individual VCV stimuli were not counterbalanced across the five talkers because only stimuli that elicited strong McGurk effects were chosen for the experiment. As a result, 12 stimuli were used in the experiment; five /æbæ/-/ægæ/, four /ibi/-/igi/ and three /IbI/-/IgI/ audiovisual combinations. The audio stimuli were digitized from the sound track of the videodisc at a 22 kHz sampling rate using a 12-bit a/d board (DataTranslation, dt2820).

Stimulus display: Equipment and setup

Seven loudspeakers (Realistic Minumus 7's) were positioned along an arc at 30° intervals starting 2 m to the left of the subject (at 0° in azimuth) and ending 2 m to their right (at 180°). The seven loudspeakers were hidden from the subject by a white curtain hanging in a semicircle in front of the loudspeaker array. Figure 1 shows an overview of the experimental setup. The auditory stimuli were filtered with a 10 kHz cutoff using Frequency Devices (Model 901) analog filters and then amplified before playing at an average of 70 dB (SPL) through the selected loudspeaker. The visual tokens stored on the videodisc were presented by a Pioneer (Model LD-V8000) videodisc player connected to a 20 inch video monitor (Sony Model-PVM 1910).

Consonant identification responses were entered into a keyboard. The same software controlled the videodisc player, and synchronously played the auditory tokens

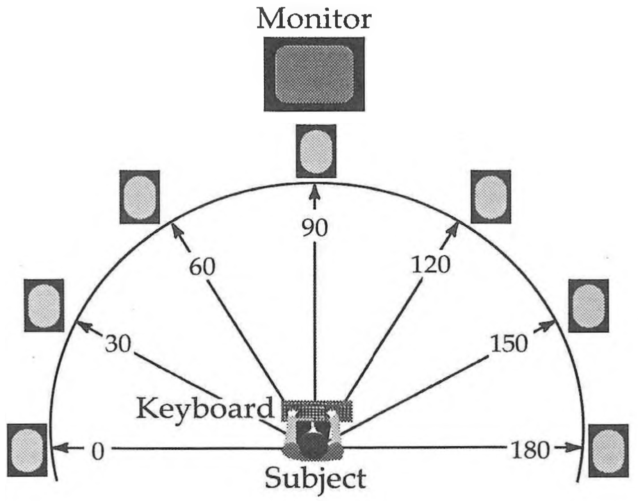

Figure 1: An overview of the experimental setup. Subjects sat facing the video monitor located directly in front of them. Consonant identification responses were made by pressing a key on a keyboard located in front of them. The seven loudspeakers were hidden behind a curtain and located at 0°, 30°, 60°, 90°, 120°, 150° and 180° in azimuth.

through the appropriate loudspeaker. The auditory and visual tokens were synchronized such that the timing of the acoustic burst onset of the /g/ on the videodisc soundtrack for the visual token was aligned with the burst onset of the /b/ of the digitized auditory token. The synchronization allowed the consonant burst alignments to be reliably reproduced (±1 ms).

2.3 Procedure

Subjects were seated 2 m from the video monitor in a 7 by 6.1m room. To minimize trial to trial differences in head position, a subject's head was held firmly in a concave head rest with a forehead strap.

Subjects were asked to report what consonant they heard within the nonsense bisyllables by pressing one of the labeled keys on the keyboard in front of them. They were given the forced-choice option of responding that they heard /b/, /g/, /d/, or some "other" consonant by pressing the B, G, D, or O labeled keys. The key order was counterbalanced across subjects. Subjects were told that they might or might not hear a particular nonsense syllable more than once during the session.

The experiment consisted of five practice and 252 experimental trials. Each auditory stimulus was presented three times from each of the seven loudspeaker locations (12 stimuli x 3 presentations x 7 loudspeakers). The auditory stimulus and the position from which it was presented was randomly selected by the computer on each trial. Following each response, the screen of the video monitor went black for two seconds before the next trial was initiated.

Design

There were three between-subject conditions in the experiment. Twelve subjects were presented with the audiovisual stimuli and required to identify the consonants[1]. Another 12 subjects were required to identify the consonants in the auditory tokens without seeing the visual stimuli. For these subjects, the video monitor was not turned on. The remaining 12 subjects were asked to identify the consonant using the visual information alone. The sound system was not activated for these subjects. To summarize, three independent conditions existed; an *Audiovisual*, *Auditory Only*, and a *Visual Only* condition.

3. RESULTS AND DISCUSSION

The percentage of /b/s that a subject reported hearing was the primary dependent measure for analysis[2]. A clear overall McGurk effect was found in the experiment. The Auditory Only group reported hearing 95.5% /b/s. In comparison, the Audiovisual Group reported hearing only 5.2% /b/s. Subjects in the Visual Only group reported seeing very few /b/s produced on the video monitor (3.4%). Although there was not a difference in percentage of /b/ responses between the Audiovisual and Visual Only conditions [F(1,33)=0.227, p>0.05], the Audiovisual group reported an entirely different response pattern across all of the possible responses than the Visual group. The overall means and standard errors of the /b/, /g/, /d/ and "other" responses for the three groups are presented in Figure 2. As can be seen in the figure, the Audiovisual group reported hearing many more /d/s than the Visual group [F(1,33)=121.1, p<0. 0001] while the Visual group reported more /g/s than the Audiovisual group [F(1,33)=44.99, p<0. 0001]. Thus, the observed McGurk effect was not due to a substitution of visual information for auditory information but presumably reflected influences from both auditory and visual modalities.

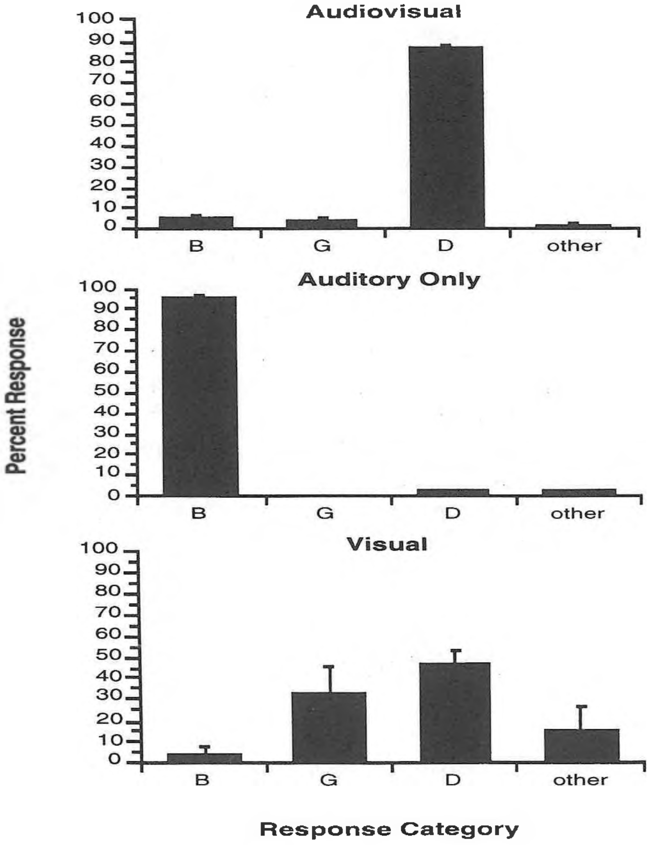

Figure 2: Means and standard errors of the consonant identification responses for the Audiovisual and Auditory Only conditions.

3.1 Analysis by Loudspeaker Location

An analysis of loudspeaker location was performed using only the Audiovisual and Auditory Only groups since the Visual Only group did not receive auditory stimulus presentations. The mean number of /b/ responses that occurred for each loudspeaker location is presented in Figure 3. As noted before, the Auditory Only group reported more /b/s overall than did the Audiovisual group. In addition, a significant location effect was found [F(6,132)=3. 686, p<0.01]. There was no interaction between group and loudspeaker location [F(6,132)=0. 59, p>0.5]. As can be seen in Figure 3, it appears that slightly more /b/ responses were given when the auditory tokens emanated from the right side of the subject versus the left in the Audiovisual group. However, when the mean of the responses for the three speakers on the left was compared with the mean of the three speakers on the right, this right versus left difference was not significant in either the Audiovisual group [F(1,11)=4.71, p>0.05] or the Auditory Only group [F(1,11)=3.94, p>0.05].

While no interaction between loudspeaker location and condition was observed, an examination of the means in Figure 3 reveals a small tendency in the Audiovisual condition for the more central speakers to produce a smaller number of /b/ responses. However this difference is extremely small with the difference between the smallest (the central location) and largest /b/ responses being only 1.17%. When the center location is contrasted with the means reported for the other loudspeaker locations, no difference is found [F(1,11)=2.36; p>0.1].

It appears that the McGurk effect is not greatly influenced by the magnitude of the spatial discrepancy between auditory and visual events. The results show a large McGurk effect even when the angular separation between the auditory and visual sources increases to as much as 90°. As such, these results replicate the findings both of Bertelson et al. (1994) and Fisher and Pylyshyn (1994) but with much larger spatial discrepancies.

4. CONCLUSION

The results of our experiment show that increasing the spatial separation between the auditory and visual stimulus sources has little effect on the McGurk effect. The visual influences on speech perception occur regardless of whether or not the bimodal signals are physically or merely perceptually coincident in space. This finding replicates and extends that of Fisher and Pylyshyn (1994) and Bertelson et al. (1994) by demonstrating McGurk effects for much larger spatial discrepancies. There were small influences of the spatial incongruity but the size of these influences suggests that spatial aspects of the stimuli are not the primary basis of audiovisual integration in speech.

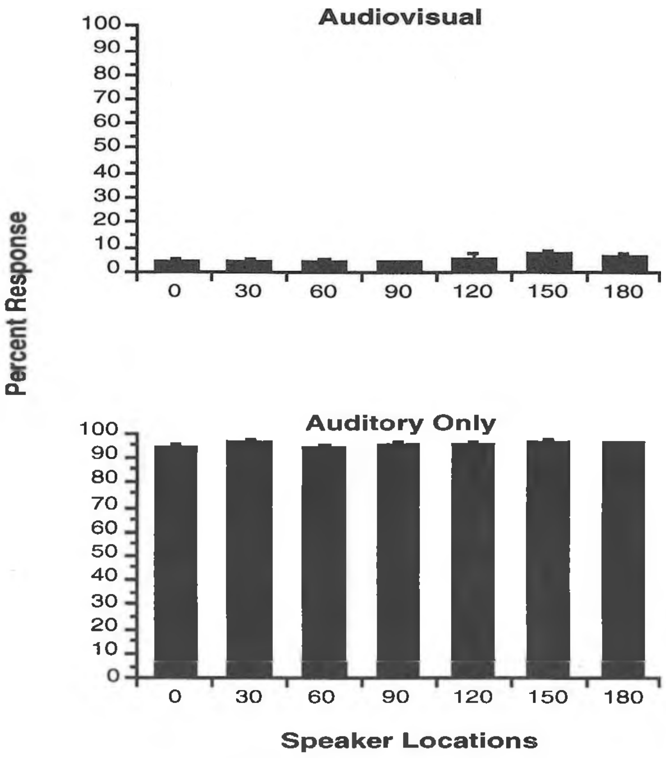

Figure 3: Mean and standard errors of /b/ responses for the Audiovisual and Auditory Only groups that occurred for each loudspeaker location.

The question arises, on what basis does audiovisual integration take place? Originally it had been our working assumption that information from the two modalities is "glued" together perceptually on the basis of shared amodal properties: The cross-modal equivalent of Gestalt grouping principles (common fate and proximity) might account for audiovisual integration in speech (Radeau, 1994). In this and a previous set of experiments (Munhall et al., 1996; cf., Massaro et al., 1996) we have manipulated coincidence in space and coincidence in time with the expectation that our measure of audiovisual speech integration, the McGurk effect, would be influenced. To our surprise, both sets of studies revealed a remarkable tolerance for incongruity. We are left with two major classes of explanations for our findings:

1. The overall redundancy of audiovisual leaves many bases on which the information from the two modalities could be linked. As Mendelson (1979) noted there is a hierarchy of amodal properties that are available to perceivers for any single object or event. Events are patterned in space and time along a number of dimensions and these patterns can provide many optical and acoustical cues (Gibson, 1966). Speech utterances are complex events that involve

multidimensional visual and auditory patterns. Syllables have onset and offset times and locations in space but they also have durations, rhythms, rates of change, et cetera. In the experiments in Munhall et al. (1996) and the present experiment we have manipulated only the most basic shared amodal properties, one at a time. In the absence of any perceptual competition, presenting the subject with a conflict situation for one property may not seriously stress audiovisual integration. This suggests that multiple property conflict experiments (e.g., manipulating temporal and spatial incongruity simultaneously) may yield more dramatic changes in the McGurk effect than observed in our experiment .

2. The second explanation is that fusion in speech occurs only following independent information processing within a modality (e.g., Kuhl, 1991; Massaro, 1987; Miller, Connine, Schermer & Kluender, 1983; Samuel, 1982; Summerfield, 1987). In this view integration would not be constrained by Gestalt grouping principles applied to the general sensory characteristics of signals. Rather, domain specific information would determine the degree of integration of signals from different modalities. For example, it has been suggested that the time-varying characteristics of speech are used for perceptual grouping and phonetic perception (Remez & Rubin, 1994; Summerfield, 1987). In this view, listeners would extract information about the rate of change of vocal tract shape from both the auditory and visual stimuli and may not be reliant on other information usually thought to be necessary for perceptual grouping.

This suggestion would account for a number of findings about the McGurk effect that indicate that a sense of perceptual unity is not necessary for vision to influence auditory speech perception. Green and Kuhl (1991), for example, have shown that the McGurk effect is present even when subjects know the voice and face don't match in gender. The knowledge that the auditory and visual signals cannot be derived from the same source does not affect the integration of speech. Similarly, Rosenblum and Saldaña (1996) have shown that point light displays of facial movement can influence auditory speech perception in subjects who do not recognize the light motions as facial movements. In both of these experiments the auditory and visual signals share a common time signature but are lacking other significant correspondences.

In closing, the finding that spatial and temporal coincidence has limited influence on the McGurk effect adds to what we feel is a growing list of uncertainties about the McGurk effect. These include individual differences in subjects' perceptions of the effect and individual differences in stimulus effectiveness in evoking the effect (Munhall et al., 1996), influences of familiarity of the faces used as stimuli (Walker, Bruce & O'Malley, 1995), cross linguistic differences (Massaro, 1987; Massaro, Cohen, Gesi, Heredia & Tsuzaki, 1993; Sekiyama & Tohkura, 1991, 1993) and attentional differences (Kuhl, Green & Meltzoff, 1988; Massaro, 1987). This diverse list suggests that we still know little about the subject variables, stimulus parameters, processing limitations and perceptual strategies that govern the McGurk effect.

ACKNOWLEDGMENTS

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ENDNOTES

[1] A between-subject design was used because pilot studies in our lab have shown that the magnitude of the McGurk effect is greatly influenced by subjects' experience with the auditory stimuli in *Auditory Only* cconditions.

[2] The rationale was that /b/ responses would indicate that the visual stimulus did not influence subject's perceptions and non-/b/ responses would indicate that visual influences existed. It is possible that non-/b/ responses could be the result of errors in auditory perception. However, because the auditory stimuli were the same for all conditions, any systematic differences would not be the result of errors in auditory perception. Thus, the number of /b/s reported by subjects is taken as an index of the strength of the McGurk effect; smaller number of /b/s in comparison to the control condition indicating a McGurk effect.

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TRACKING IN RANGE VERSUS TIME WITH APPLICATION TO MATCHED FIELD PROCESSING OF VERTICAL LINE ARRAY DATA

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ABSTRACT

Efficient linear three dimensional tracking techniques have been used to improve source localization over that from a single matched-field processing (MFP) ambiguity surface. This paper describes an efficient MFP tracker for data collected by a Vertical Line Array (VLA). The tracker assumes that the source moves at constant speed. Our two dimensional algorithm differs from tracking in three dimensions in that only source range and depth information are required, as would be available for a VLA in an essentially azimuthally independent environment. The source's initial and final range as well as its speed are estimated by the algorithm described in this paper. The method was applied to data which were collected from a VLA as part of PACIFIC SHELF 93. This trial was carried out in the shallow water of the continental shelf and slope off the western coast of Vancouver Island in the north-eastern Pacific Ocean during September 1993. Source track parameters recovered by applying the linear tracker at both 45 and 72 Hz were found to be within the uncertainty associated with the GPS records for the track when the 100 m range uncertainty introduced by the array tether was taken into account. The source level at 45 Hz was typical of a strong line on a merchant vessel while the 72 Hz line was 20 dB lower.

SOMMAIRE

Des techniques de poursuite linéaires à trois dimensions ont servi à améliorer la localisation de sources par rapport à l'emploi d'une selle surface de doute au traitement de champs appariés (TCA). Dans cet article nous décrivons un suiveur au TCA efficace pour des données saisies au moyen d'un réseau à ligne verticale (RLV). Le suiveur présume que la source se déplace à une vitesse constante. Notre algorithme à deux dimensions diffère de la poursuite à trois dimensions puisque seulement les renseignements à propos de la portée et de la profondur des sources sont nécessaires, tels que seraient disponibles pour un RLV dans un environnement essentiellement indépendent de l'azimut. Nous avons employé l'algorithme décrit dans cet article pour calculer par approximation les portées initiale et finale ainsi que la vitesse de la source. Nous avons appliqué la méthode aux données saisies d'un RLV en tante que parti du projet PACIFIC SHELF 93. Cet essai a éta exécuté dans les eaux peu profondes du plateau continental et du talus continental sur la côte ouest de l'île de Vancouver au nord-est de l'Ocean Pacifique durant septembre 1993. Nous avons constaté que les paramètres de poursuite des sources recouvrés en appliquant le suiveur linéaire à 45, aussi bien qu'à 72 Hz, étaient dans le cadre de l'incertitude associée avec les données du systeme mondial de positionnement pour la voie lorsque l'on a tenu compte de l'incertitude de la portée de 100 m introduite par l'amarre du réseau. Le niveau de la source à 45 Hz était typique d'une ligne forte sur un navire de commerce tandis que la ligne à 72 Hz était 20 dB plus faible.

1. INTRODUCTION

This paper describes a tracker that may be employed to track a source when its range alone is known as a function of time. Our application is to ranges determined from Matched Field Processing (MFP) in underwater acoustics. However, the algorithm may be applied to other acoustics problems or tracking with radar.

MFP is an advanced signal processing method for the localization and detection of acoustic sources.[1] In MFP the measured acoustic field is matched against a prediction of the acoustic field for all possible source positions in the search region. The (unnormalized) correlation between measured and predicted fields is called an ambiguity surface. In many cases, however, especially for low SNR sources, it is impossible to infer a source's position unambiguously based on these matches from an individual ambiguity surface. For a set of MFP ambiguity surfaces contiguous in time, an efficient three dimensional (i.e., range, depth and bearing) technique to track acoustic sources moving linearly at constant speed and heading has been proposed.[2,3] The method has been successfully applied to both simulated[2,3] and measured data.[4] For this tracker the strongest peaks on the set of ambiguity surfaces are used to define possible source tracks. Linear tracks passing through pairwise combinations of the positions of these strongest peaks, taken from ambiguity surfaces corresponding to different times, are candidate source tracks. In the next stage of the algorithm tracks corresponding to target speeds that are not physically possible are rejected. To find the most likely tracks the averages of the processor output are found for each position predicted by the remaining candidate source tracks. The track with the largest average, provided that it is also greater than a preassigned threshold, is considered a source track. The number of tracks examined is orders of magnitude less than the exhaustive case of all linear constant speed tracks through the possible source positions that comprise the ambiguity surface.

As noted above an efficient three dimensional tracker, for sources with constant speed and heading, has been successfully applied to both simulated [2,3] and measured data.[4] Reference 4 tracks the source in three dimensions in the PACIFIC SHELF data, assuming it is moving at constant speed and heading, by approximating the two legs of the track as radial tracks. Reference [7] also tracks the source in three dimensions but removes the radial track restriction. Reference [8] exhaustively searches in two dimensions for constant speed radial tracks in a similar experiment, called SWellEX-3, by determining the track with the largest average value for the normalized Bartlett processor i.e. *correlation* along the track.[9]

When acoustic data comes from a Vertical Line Array (VLA) in an essentially azimuthally symmetric environment only source range and depth can be determined. The azimuth of a source can not be determined because of the environmental and array symmetry. Under such conditions a two dimensional tracker, in many respects similar to the three dimensional tracker just described, is required for combining the positions on the range-depth ambiguity surfaces. The difference from the three dimensional tracker is that the source's bearing is not obtained; only its depth, start and stop ranges and speed, or their equivalent, can be estimated. To estimate these quantities with the VLA tracker source ranges at three distinct times are required. This differs from the three dimensional tracker [7] for which (range,depth,bearing) coordinates at two distinct times are required. The input to these trackers is chosen to be the Bartlett processor[1] output as a function of time and range *for a constant depth*, although other processors could be used. The tracker can be generalized to track sources that have constant diving or surfacing rates. This paper describes and applies a tracker to a signal at a single frequency, however the algorithm would work equally well for broadband radiated energy from a sound source.The algorithm described efficiently searches in two dimensions for the constant speed and heading track, radial or non-radial, with the largest Bartlett average along the track. Localization is restricted to range and depth in this study on account of the symmetry of the array and environment.

The paper is organized as follows. Following this introduction a brief description is given of the environment and VLA data collected during the PACIFIC SHELF experiment and of the generation of ambiguity surfaces. Next the tracking algorithm for VLA data is outlined and the algorithm applied to track the source at two of the source frequencies.

2. PACIFIC SHELF EXPERIMENT AND MFP PROCESSING

2.1 Scenario

A series of ocean acoustic experiments referred to as the PACIFIC SHELF trials were completed in September, 1993 by the Defence Research Establishment Pacific, Victoria, B.C., and the Applied Research Laboratory, University of Texas at Austin. The experiment is summarized below and described more fully in Ozard et al.[4] The experiments were conducted at the site shown

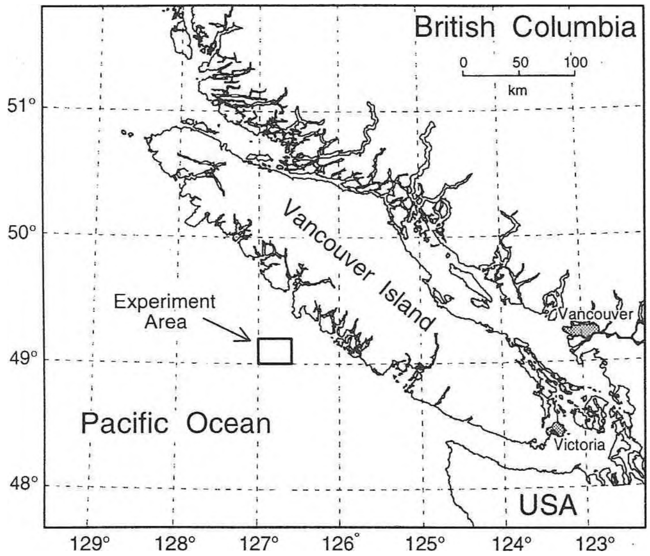

Figure 1: The location of the experiment is shown with respect to the south-western coastline of British Columbia, Canada.

in Figure 1 on the continental slope and shelf regions off Vancouver Island, which is situated in the North-East Pacific Ocean.

The CSS WE RICKER was the source ship for the impulsive sources and the multi-frequency Continuous Wave (CW) towed sound source, while the CFAV ENDEAVOUR collected acoustical data from either a Vertical Line Array or Horizontal Line Array (HLA). In the portion of the trial analyzed here a CW multi-frequency source was towed at constant speed and heading along two segments that formed a dog leg pattern shown in Figure 2.

As can be seen the towed source's track began on the continental shelf, where the water depth was about 150 m, and proceeded towards the VLA located in deeper water on the continental slope at an approximate water depth of 375 m. The source tow took a total of about 65 minutes. At the start time, the initial source to receiver range was about 12 km. As can be seen in Figure 2, there was an abrupt source ship course change 41 minutes after the start time. Since the algorithm tracks a source of constant speed and heading the data analysed in this paper was partitioned into two data sets. These two data sets will be referred to as far-range (before the course change) and near-range (after the course change). The array float position and tow ship position were measured with Global Positioning System (GPS) receivers. The GPS measurement errors (100 m), combined with the error associated with the tether length between array and buoy containing the GPS and telemetry electronics (100 m), resulted in an overall uncertainty of the source to receiver range of approximately 200 m.

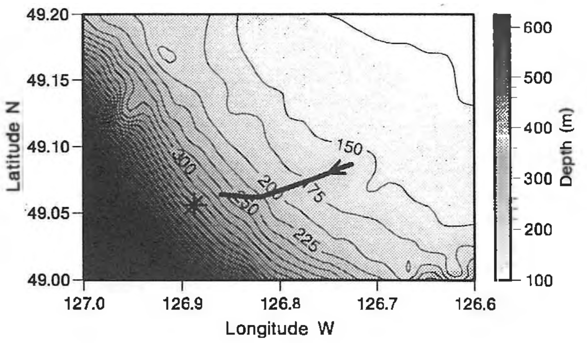

Figure 2: The towed source's track, which closed on the array, is shown superimposed on the bathymetry. The star represents the VLA location at the beginning of the experiment.

In Figure 3 the depths of the VLA are plotted over environmental information used to model the field. There were sixteen hydrophones equispaced at 15 m with the depth for the uppermost hydrophone being 90 m ± 2 m. The data were collected at a sample rate of 1500 Hz.

The environmental model was based on the measured sound speed profile, taken at the time of the experiment, and other parameters were obtained from the analysis of the impulsive source data collected in the vicinity of the array in an associated seismic experiment.[5]

2.2 MFP Processing

The Bartlett processor [1] $B(p)$, at position p, defined as

$$B(p) = \frac{1}{NA} \sum_{i=1}^{NA} \mid r(p)^* d_i \mid^2, \tag{1}$$

was used for this study. Here d_i, NA and r, represent respectively the transformed data vectors, the number of data averages and the unit norm replica vector. The transformed data is obtained from a 4096 point Fast Fourier Transform of the time series data at the signal frequencies of 45 or 72 Hz or the nearby noise frequencies of 43 or 75 Hz. The number of inner products averaged was NA=11; thus each Bartlett output represents about 30 seconds of data. The replica or modelled fields

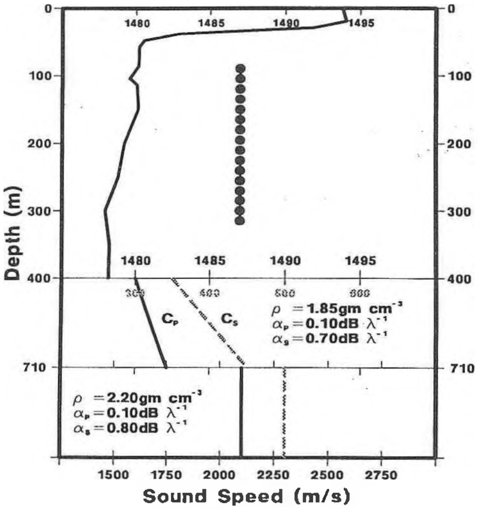

Figure 3: The sound-speed profile used in the environment model is shown as well as the shear speed (dashed) and compressional speed (solid) for which the two lower abscissa scales apply respectively. The hydrophone depths are also noted.

used in this analysis were based on previously described, but limited, environmental knowledge using Westwood's normal mode model, ORCA.[6] ORCA was selected for its reliability in finding the normal mode parameters in a shallow water environment. In the two dimensional analysis described here, the bottom bathmetry used to generate the replicas was that for the radial from the array to the starting point of the far range track position. The Bartlett output from Equation 1 was normalized to have a maximum value of unity by dividing by d^*d to form the Bartlett correlations. The maximum Bartlett correlations at 45 and 72 Hz ranged from 0.75 to 0.95 and 0.60 to 0.85, respectively.[4] These correlations reflect a good fit between the data and the replicas from the model. However the positions corresponding to these correlations did not always coincide with the source range and depth.

3. TRACKING ALGORITHM

The VLA tracking algorithm consists of five sets of computations performed at each possible source depth. While the algorithm described here applies to a source whose depth remains constant it can be modified to track a source that dives or surfaces at a constant rate over the track. The input is a time-versus-range ambiguity surface of the Bartlett outputs at some constant depth and frequency. The computations are:
(1) for each of the NT times, for which an ambiguity surface is available, the positions of the largest NPK peaks are determined;
(2) all combinations of three peak positions, at different times, are determined and the linear tracks, if any, passing through these combinations of points are found (See explanation at the end of this section). These are the combinatoric tracks ;
(3) a constraint to realistic maximum speeds for the source is imposed to reduce the combinatoric tracks to physically possible tracks;
(4) for each physically possible track the track statistic T is determined

$$T = \sum_{k=1}^{NT} \frac{1}{NT} B(p_k), \tag{2}$$

which sums the Bartlett output over the NT times for the points on the track. Here p_k represents the position from the range grid point which is nearest to the track at time k;
(5) the significant tracks are those with the largest estimated track SNR,

$$SNR = \frac{T - \bar{x}}{s} \sqrt{NT} \tag{3}$$

where $\bar{x}$ and s are the respective mean and standard deviation of the noise for the time versus range ambiguity surface at a neighbouring non-signal frequency at the depth of analysis.

The following is a description of the calculations used to determine the track parameters for the combinatoric tracks obtained at step 2 of the tracking algorithm. Recall that only range-versus-time information for the source position is available, so that no source bearing information can be deduced from the data. Any linear constant speed track can be characterized by its range a from the VLA at the origin O at time 0, its speed v and angle β which is measured from AO as shown in Figure 4. A is the source position at time 0. Note that the orientation of AO is unknown and cannot be determined in the azimuthally independent environment. At time t_i the range R_i obeys the Cosine Law

$$R_i^2 = a^2 + (vt_i)^2 - 2avt_i cos(\beta). \tag{4}$$

The data set $(t_i, R_i), i = 1, 2, 3; t_1 < t_2 < t_3$, obtained at step 1 of the algorithm, when substituted in Equation 4 results in a set of three equations with three unknowns. These equations define a linear constant speed track if they can be solved for a, v and $cos(\beta)$. When there is a solution the equations reduce to a set of two linear equations in a^2 and v^2, and then $cos(\beta)$ is easily found. The nature of the cosine means β is ambiguous; it could correspond to an angle measured clockwise or counterclockwise from AO. The dashed line in Figure 4 represents the alternate source track because of the ambiguity in β. Once a, v, and $cos(\beta)$ are estimated one can easily determine the range at the start time R_{st}, and range at the stop time, R_{sp}. The tracks found form families corresponding to the possible orientation of OA between 0 and 360 degrees and are ambiguous in the sign of β. These ambiguities are, of course, not apparent on a range versus time plot.

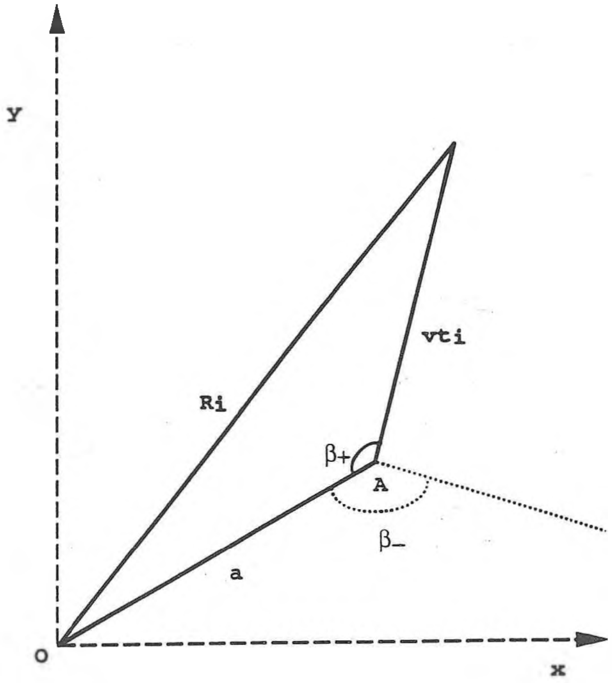

Figure 4: Parameters defining a linear track with constant speed v, distance a from the VLA at the origin O at time 0, and angle β in a cartesian coordinate system. A is the source position at time 0. The orientation of OA is unknown. The solid line corresponds to the track for the angle β measured clockwise from AO. The dotted line corresponds to the alternate track for the angle β measured counterclockwise from AO.

An exhaustive search for tracks passing through three points results in $[NT(NT-1)(NT-2)(NR)^3]/3!$ combinatoric tracks where NR is the number of ranges. In the efficient algorithm described here NR is replaced by the number of peaks NPK consequently the algorithm examines $[NT(NT-1)(NT-2)(NPK)^3]/3!$ combinatoric tracks. This reduces the number of combinatoric tracks by $(NPK/NR)^3$ or 1.5×10^{-5} for the example described here. Clearly such an algorithm is much more efficient than an exhaustive search.

4. TRACKING RESULTS

The VLA tracking algorithm operates on a time-versus-range ambiguity surface, i.e., the environment is treated as essentially azmuthally independent. There is slight symmetry breaking in the PACIFIC SHELF environment, as can be seen in Figure 2, however since azimuthal independence of the environment is not a requirement for the VLA tracker this data set can be used to demonstrate the application of the VLA tracker.

The ambiguity surface for the 72 Hz tone at 30 m depth, the source depth, is given in Figure 5. The dotted curve is the track range estimates from the VLA tracker for the far (5-12 km) and near (< 5 km) ranges. At any one time the source is likely to be at any of the bright regions in range while the tracker has identified the track with highest likelihood. Thus the tracker has reduced the ambiguity of the sound source's range throughout the time interval analysed. It should be noted that in the range time plot a linear track is a straight line only if the track is radial. The ambiguity surface and tracks at 45 Hz are similar. The VLA algorithm yielded the highest estimated track SNR at the 30 m source depth, indicating that the source was at a depth of 30 m, in agreement with the source depth in the trial log. For this analysis the 10 largest peaks were found for each snapshot in step 1 of the algorithm and the speed was constrained to be a maximum of 5 m/s. The estimated noise mean and standard deviation for 45 and 72 Hz were calculated from the 43 and 75 Hz ambiguity surfaces respectively. These estimates were used in Equation 3 to calculate the estimated track SNR. The source track parameter estimates for the algorithm for the far and near ranges for both tones are given in Tables 1 and 2. We do not use the Closest Point of Approach (CPA) as a track parameter because the CPA uncertainty can be very large at long ranges and is not a representative measure of the track position uncertainty. As can be seen from the table the range differences from the GPS results are between 17 and 190 m. Recall the error in measuring range position using GPS including the uncertainty from the array tether, is approximately 200 m. The speed estimates also agree well with estimates from the GPS values.

The track SNR in Equation 3 is measured in standard de-

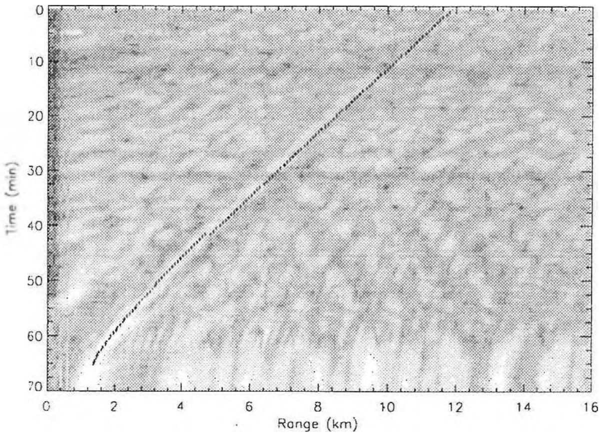

Figure 5: The logarithm of the Bartlett statistics for the PACIFIC SHELF 72 Hz tone, plotted for a time-versus-range ambiguity surface at a depth of 30 m. White represents a value of 30 dB and black 60 dB in this grey scale plot. The dotted curve is the track range estimates for the far and near ranges. The near range track extends to about 5 km while the far range set runs from 5 km to 12 km

viations of the noise ambiguity surface. If there is no mismatch, the noise is spatially uncorrelated and the SNR is constant along the track, the tracker increases the SNR by a factor of $NS * \sqrt{NT} * \sqrt{NA}$ (i.e., $16 * \sqrt{82} * \sqrt{11}$ or 26.6 dB) over the average sensor SNR. In practice we have mismatch in environmental parameters and array geometry and the sensor SNR is time dependent. Furthermore at 43 and 75 Hz the noise is spatially correlated. This is not surprising as the experiment was conducted in shallow water near a major shipping lane. The noisy tow ship and the recording ship near the array also contributed to the noise field. The over-estimation of the noise level through spatial leakage and from correlated noise sources as well as the presence of mismatch imply that the measured track SNR is expected to be lower than the theoretical value for the idealized scenario. Nevertheless, the track SNR was a maximum at 30 m and the track identified agreed with the known source track.

Table 1: Comparison of GPS track and estimates from the VLA algorithm at 45 Hz and 72 Hz for the 41 minute far range data set. R_{st} is the start range in m, R_{sp} is the stop range in m and v is the speed in m/s while the track SNR is in dB. The range differences in m from GPS results are in parentheses.

Far range				
	R_{st}	R_{sp}	v	SNR
GPS	11778	4820	2.86	
45 Hz	11607 (-171)	4650 (-170)	2.87	21.0
72 Hz	11878 (100)	4850 (30)	2.89	17.8

Table 2: Comparison of GPS track and estimates from the VLA algorithm at 45 Hz and 72 Hz for the near range 24 minute data set. For details see the caption of Table 1.

Near range				
	R_{st}	R_{sp}	v	SNR
GPS	4820	1291	2.90	
45 Hz	4630 (-190)	1274 (17)	2.71	26.5
72 Hz	4663 (-157)	1353 (62)	2.72	22.7

With one VLA the bearing of a point on the track is ambiguous. This ambiguity would be reduced with information from hydrophones that are nearby but horizontally separated from the VLA.

5. CONCLUSIONS

An efficient VLA tracking algorithm for an azimuthally independent environment has been described and applied to data collected in shallow water. At both 45 Hz and 72 Hz, estimates from the acoustic data for the source's initial and final range and its speed agreed closely with the GPS measurements. The range difference between the GPS and tracking algorithm estimates at both frequencies is less than 200 m. A substantial part of this difference can be ascribed to the uncertainty introduced by the array to GPS buoy tether. The VLA tracker significantly reduced source range ambiguity compared to that obtained from individual ambiguity surfaces by determining the track of highest SNR, enabling tracking of the source range at distances up to 12 kilometres.

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THE ACOUSTIC EMISSION OF SILICA GEL

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1. INTRODUCTION

Our research group has recently determined by infrared spectroscopy that the surface of booming sand particles is coated with an amorphous silica layer (1) and that by changing this layer the musicality of the sand is affected (2). It has also be reported that pure silica gel particles have acoustic emission (3). While it had previously been reported that the acoustic emission of booming sand was affected by the size of the particles and the number of particles (4) the following investigation looks at the effect of these factors on the acoustic emissions of silica gel.

2. RESULTS

By fractionating the silica gel particles and studying the acoustic emissions of varying numbers for each particle size, a relationship between the carrier period and the size and number of particles was determined. Figure 1 shows that, for silica gel particles in the size range of 150 - 300 microns varying from 1.5 to 10 million particles, the carrier period increased as both the size and number increased. The carrier period ranges from 1.4 ms to 2.6 ms corresponding to a carrier frequency ranging from 714 Hz to 385 Hz. Figure 2 shows an increasing beat period as the size and number of silica gel particles increased. The beat period ranges from 6.8 ms to 18.0 ms corresponding to a beat frequency from 147 Hz to 56 Hz.

The composition of silica gel particles was also investigated. The hypothesis that there is a layer of amorphous silica gel on booming sand which is necessary for its musicality leads to the idea that there may also be a layer on the silica gel particles. By using a scanning electron microscope it was possible to detect, on various silica gel particles, a layer around the silica gel core. This layer was found to be composed of the same material as the core but possessing a different density - presumably the presence of water.

3. CONCLUSIONS

The hypothesis that particle size and sample size affect the acoustic emissions of silica gel, as reported for booming sand, was verified for pure silica gel in the range of 150 to 300 microns. The layer of amorphous silica as seen on the silica gel particles using the scanning electron microscope, may lead to further investigation of the surface layer on musical sand particles and its effect on the acoustic emissions.

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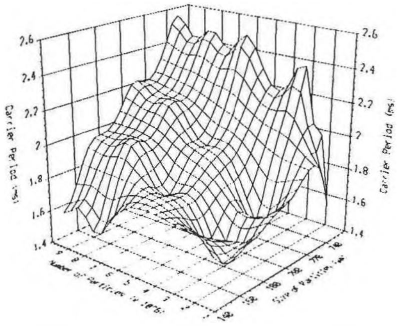

Figure 1. Carrier Period of Silica Gel as a Function of Particle Size and Number.

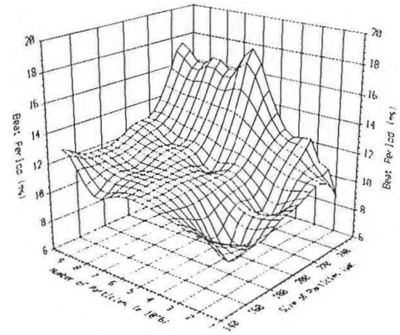

Figure 2. Beat Period of Silica Gel as a Function of Particle Size and Number.

DEVELOPMENT OF PROBES TO MEASURE IN-DUCT SOUND PRESSURE LEVELS OF A GAS TURBINE EXHAUST

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1.0 Introduction

The ability to measure in-duct sound power levels at the exhaust flange of a gas turbine would allow in situ verification of gas turbine exhaust sound power levels and, in conjunction with other measurements, verification of silencer dynamic insertion loss. The primary requirement for a measurement of sound power level is a procedure that will measure valid sound pressure levels in a high velocity, hot gas, highly turbulent turbine exhaust flow.

This paper describes the current state of development of two specialized wall mounted microphone probes: a perpendicular tube and a slit tube.

Early work established that specialized probes could be designed to desensitize microphones to turbulent pressure fluctuations [1, 2].

This type of device, called a slit tube or turbulence screen, is manufactured commercially [3]. It is utilized by an international standard, ISO 5136, to measure the sound power radiated into a duct by fans [4].

The commercially available turbulence screen is not a suitable probe for a gas turbine exhaust since the microphone would not survive the environment. Instead the probes are flush mounted and extend away from the wall similar to [5].

2.0 In-Duct Probe Designs

Fig. 1 shows the measuring tube arrangement. This consists of a one inch inner diameter stainless steel tube terminated by 100 feet of one inch inner diameter flexible clear plastic hose that is plugged at the far end.

The perpendicular tube probe is shown in Fig. 2. The essential features are the tip and the thermal break. The flush mounted tip is covered with three layers of glass silk cloth and wire mesh screen.

The slit tube probe is shown in Fig. 3. The essential features of this design are the 1mm wide by 635mm long slit and the thermal break. Four layers of glass silk cloth are used behind the flush mounted slit.

The two probes are calibrated for frequency response and turbulence rejection as described in reference [6].

3.0 In Situ Silencer Insertion Loss Measurements

Measurements were obtained for the exhaust of an operational 10 MW gas turbine. The perpendicular tube and slit tube microphone probes were attached at the end of the exhaust duct transition upstream of the silencer at the top and side walls.

The sound power at the turbine exhaust flange was calculated from the microphone probe measurements. The sound power radiated from the exhaust duct outlet was calculated from measurements obtained outside the duct in the plane of the outlet. The resulting silencer DIL is shown in Fig. 4.

For comparison a static test (i.e. zero flow) was performed using loudspeakers at the base of the exhaust duct as a sound source. The results of this test, after correcting for temperature, are also shown in Fig. 4.

Fig. 4 also shows the DIL expected from the silencer design. Note that the design DIL values assume a flanking limit of 50 dB, which, for this design, may be low by 5 dB to 10 dB based on the static test results.

There is good agreement between all three DIL curves in Fig. 4.

4.0 References

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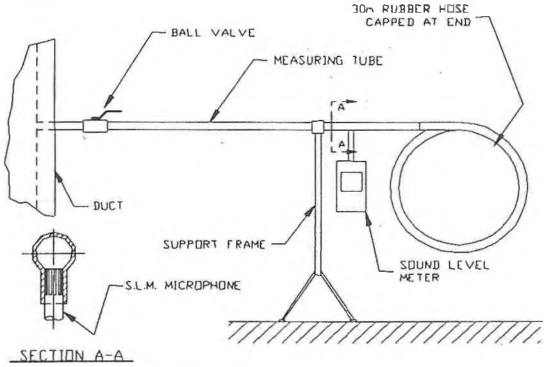

Fig 1 Measuring Tube

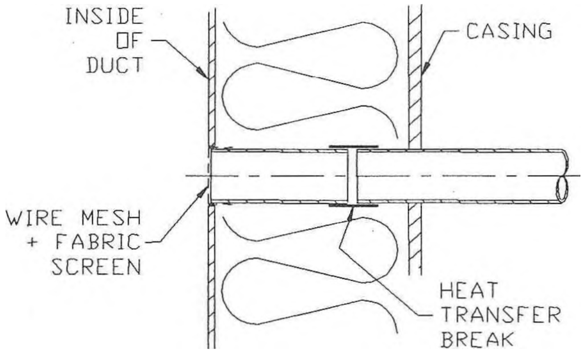

Fig 2 Perpendicular Tube Probe

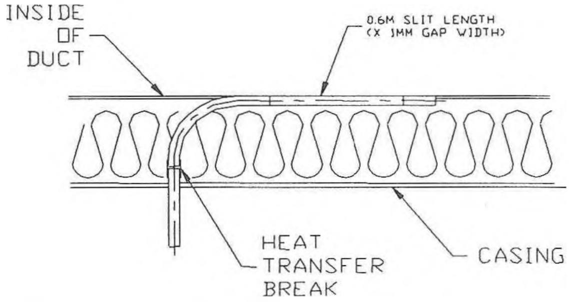

Fig 3 Slit Tube Probe

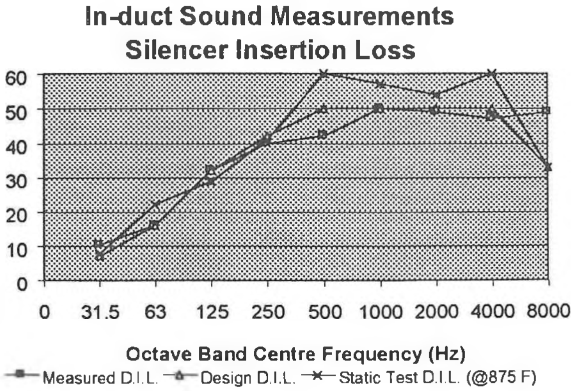

Fig 4 Insertion Loss Comparisons

Ultrasonic Hearing: Transient Evoked Otoacoustic Emissions Elicited by Bone-Conducted Ultrasonic Stimuli

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I Introduction

Transient Evoked Otoacoustic Emissions (TEOAEs) are a form of energy leakage from the cochlea to the ear canal during the active process of stimulus processing by the Outer Hair Cells (OHCs) of the cochlea [1]. TEOAEs can be elicited by short (0.1 - 1 ms) airborne or bone-conducted clicks or tones and can be recorded in more than 98% of normally hearing subjects [2]. Strong TEOAEs indicate normal physiological status of the cochlea.

The intriguing phenomenon of ultrasonic hearing has been investigated since the early 1960's [3]. When presented with bone-conducted ultrasonic stimuli, normally hearing subjects can perceive tones as high in frequency as 100 kHz. Abramovich [4] found an increased ultrasonic threshold of hearing in 81% of the patients having a sensorineural hearing loss associated with hair cell damage. The ultrasonic hearing mechanism has not been fully explained. Skin demodulation, piezoelectric effect of bone and cochlear-level reception have been proposed as underlying mechanisms.

We postulated the existence of TEOAEs due to bone-conducted near-ultrasonic (20 - 100 kHz) stimulation and developed a suitable investigation method and equipment. We recorded ultrasonic bone-elicited TEOAEs and examined their main features.

II Method

We used the AAS9000, a LabVIEW-based audiometric system currently under development in the Institute, as an investigation tool. The instrument generates tones or clicks and records cochlear responses using a miniature microphone in the Ear Probe (Fig. 1), processes them and displays both the time-domain waveforms and their FFTs for each ear on the computer screen.

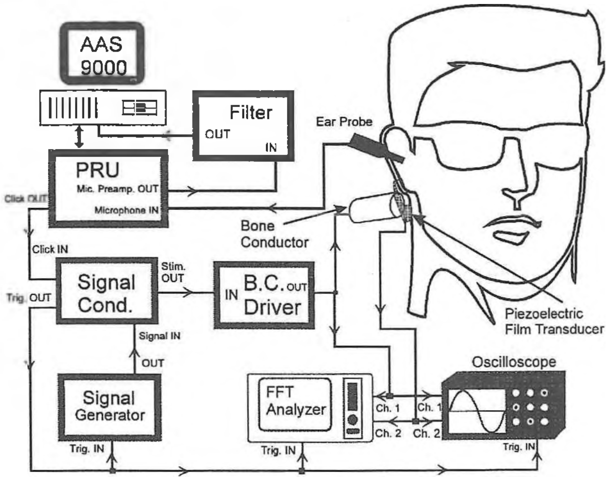

Fig. 1 Experimental Setup

During our study, the click normally used for TEOAE stimulation was rerouted to a custom-made Signal Conditioning Board which provides synchronization pulses for the Signal Generator, FFT Analyzer and Oscilloscope. This board also receives ultrasonic signal from the Signal Generator and outputs stimuli of adjustable duration and slope. These signals are further amplified by the Bone Conductor Driver and delivered to the subject's skull using a redesigned Bone Conductor and Headband. A piezoelectric film transducer inserted between the subject's head and bone conductor was used to monitor the shape and frequency spectrum of head vibration. A 40 kHz signal was used as a stimulus.

III Results

We tested three young male normally hearing subjects.

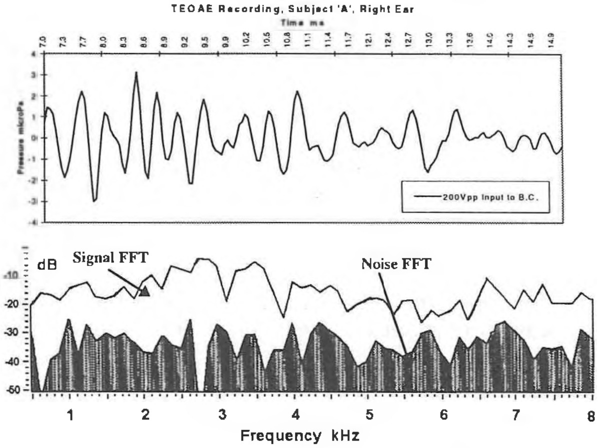

Fig. 2 Ultrasonic bone-elicited TEOAE

We found similarities of the ultrasonic bone-elicited TEOAEs to conventionally-elicited TEOAEs with regard to stimulus and response amplitude dependency, duration of the stimulus artifact and of the active response of the ear. The frequency spectrum of ultrasonic bone-elicited TEOAEs (Fig. 2) show stronger high frequency components than conventional TEOAEs, suggesting the method's potential as a fast screening method for the whole audiometric frequency range, from 125 Hz to 8 kHz.

IV Conclusions

We designed a suitable investigation method, recorded ultrasonic bone-elicited TEOAEs and proved the validity of our hypothesis. Our experimental results suggest that the cochlea is a good candidate for perception of ultrasonic signals because it produces otoacoustic emissions in response to ultrasonic stimuli.

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THE EFFECTIVENESS OF THE ISO 9614 F4 INDICATOR TO PREDICT UNCERTAINTY IN INTENSITY MEASUREMENTS

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Introduction

The ISO F_4 indicator given in ISO 9614 Part 1 ("Determination of sound power levels of noise sources using the sound intensity technique," 1996 edition) is evaluated as a method to assess uncertainty in intensity measurements due to under-sampling.

The F_4 indicator provides an estimate of the spatial variance in the intensity over the measurement surface and is given by $F_4 = \frac{1}{\overline{I_n}}\sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(I_{ni}-\overline{I_n})^2}$ where $\overline{I_n} = \frac{1}{N}\sum_{i=1}^{N} I_{ni}$ and I_{ni} is the measured normal intensity at the i^{th} measurement point. F_4 can be used to estimate the uncertainty in the measurement (i.e., the 95 percent confidence limits) due to sampling,

$$95\%CL = 10Log_{10}\left(1 \pm \frac{2F_4}{\sqrt{N}}\right)$$

where N is the number of measurement points. There are three measurement grades defined by ISO 9614: *precision, engineering, and survey.* When the number of measurement points exceeds CF_4 then ISO Criterion 2 is satisfied and the measurement will achieve a precision defined by the frequency and grade specific multiplier: C.

In this paper the predicted[1] and actual number of measurement points required to attain *precision* grade (shown in Figure 1) will be compared to assess the effectiveness of F_4 and Criterion 2.

Measured Data

The sound intensity radiated by a double leaf construction (1.52x1.55 m) separating a 350 cubic meter reverberation chamber and a hemi-anechoic chamber was measured in accordance with ISO 9614 Part 1 using a phase matched PP probe with a microphone spacing of 12 mm. The measurement surface consisted of 11 rows and 13 columns each 100 mm o.c. The probe was positioned between 120 and 130 mm from the surface and the integration time was 32 s.

Intensity data were collected at all 143 points. The total intensity and all field indicators were then computed. Systematically, the number of points used in each intensity computation were reduced by taking a subset of the data for the original 143 points. Seven grids each with fewer sample points were constructed and are listed in Table 1.

Figure 1 and Table 1 show that there is a maximum 0.2 dB change in the estimated radiated intensity as a result of reducing the number of measurement points from 143 to 78. This indicates that the 11x13 grid had adequately sampled the surface and that may be used as a reference to assess the effect of reducing the number of measurement points

Figure 1 and Table 1 indicate that when nine points are used (3x3 grid) the deviation of the intensity estimate exceeds the confidence interval allowed for *precision* grade.

The predicted results of Criterion 2 ($N \geq CF_4$) shown in Table 1 indicate that twenty points (4x5 grid) would be the smallest number to give an estimate of intensity within the acceptable precision limits; nine points (3x3 grid) would be insufficient. This is in good agreement with the measured results of Figure 1 and Table 1.

Conclusion

The ISO 9614 F_4 indicator appears to be a very useful and accurate method for calculating the uncertainty in the measured intensity due to under-sampling.

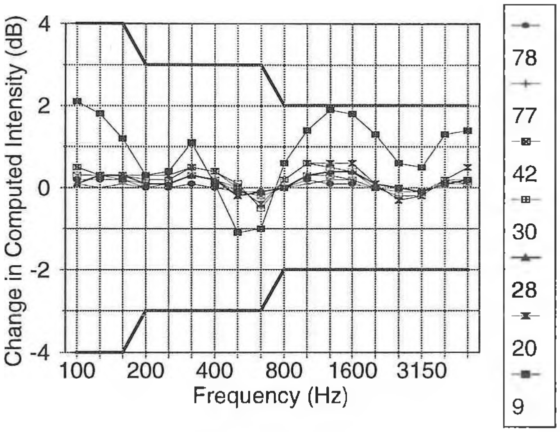

Figure 1: Change in the intensity estimate for various numbers of points used in the measurement grid relative to the full 143 point grid. Uncertainty limits (95% confidence limits) for precision measurements are shown by the solid lines.

Number of points	Rows Sampled	Columns Sampled	CF_4; Criterion 2 Pass/Fail	Maximum 95% confidence limits (dB)	Maximum Deviation re: 11x13 grid (dB); within *precision* limits
143	1 — 11	1 — 13	15; Pass	0.4	n/a ; n/a
78	1, 3, 5, 7, 9, 11	1 — 13	10; Pass	0.4	0.2; Pass
77	1 — 11	1, 3, 5, 7, 9, 11, 13	19; Pass	0.5	0.3; Pass
42	1, 3, 5, 7, 9, 11	1, 3, 5, 7, 9, 11, 13	11; Pass	0.6	0.3; Pass
30	1, 3, 5, 7, 9, 11	1, 4, 7, 10, 13	12; Pass	0.7	0.6; Pass
28	1, 4, 7, 10	1, 3, 5, 7, 9, 11, 13	17; Pass	0.8	0.4; Pass
20	1, 4, 7, 10	1, 4, 7, 10, 13	20; Pass	1.0	0.6; Pass
9	1, 6, 11	1, 7, 13	12; Fail	1.2	2.1; Fail

Table 1: The F_4 indicator correctly predicts when errors due to undersampling cause a deviation in the measured result to exceed the allowable limit for precision grade measurements. This is shown by the predicted number of points (CF_4) to be less than the measured for the 3x3 grid precisely where the measured deviation exceeded the limits for precision measurements.

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ON THE DEGRADATION OF SOUND INSUALTION BY FIRE STOPPING AT THE FLOOR/WALL JUNCTION IN WOOD FRAME MULI-FAMILY DWELLINGS

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Introduction

The National Building Code of Canada requires that fire stops be located in wood frame party walls at the floor/wall intersection. A recent study[i] at the Institute for Research in Construction has shown that fire stops can significantly degrade the apparent sound insulation between horizontally separated dwellings. This paper summarizes the results of the IRC project that systematically investigated the impact of the materials or techniques listed in the Code.

Specimen Constructions

The study was structured to allow the comparison of the apparent sound insulation measured with a fire stop to a reference construction that did not have any fire stopping at the floor/wall intersection. Figures 1 and 2 show the Reference A and Case 4 specimens, respectively, each had 39x235 mm joists 400 mm o.c. supported by the party wall.

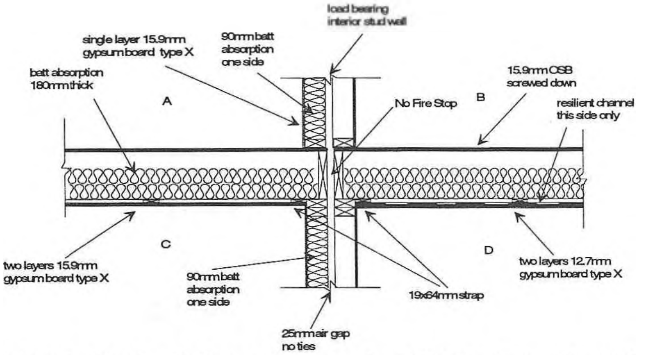

Figure1: Sketch of Reference A construction which does have a fire rated A-C floor/ceiling assembly.

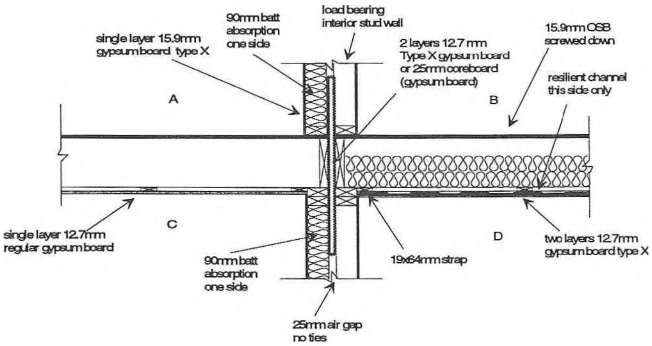

Figure2: Sketch of the Case 4 construction showing the vertically oriented fire stop between the joist headers (typical of Cases 3,4, and 5). Also shown is the non-fire rated A-C floor ceiling assembly.

Figures 1 and 2 show the *base* A-B party wall. To establish the limiting sound insulation this wall was replaced by a *superior* wall that had an additional layer of gypsum board on both sides and an extra layer of cavity insulation.

Case 2[*]: Add additional cavity absorption to the wall such that *the width of the air space in the cavity does not exceed 25 mm (1995 NBC 9.10.15.2.2.a).* With this condition met, an explicit fire stop is not required.

Case 3[*]. Case 4[#]: Gypsum board 25 mm thick[•] installed vertically in the nominal 25 mm space between joist headers at the wall/floor joint.

Case 5[#]: Semi-rigid batt material[ii] installed vertically in the nominal 25 mm space between joist headers at the wall/floor joint.

Case 6[#]: 0.38 mm sheet steel[•] (without profile) installed horizontally under the sole plates of the party wall.

Case 7[#]: 15.9 mm thick OSB[•] continuous under the sole plates of the party wall.

Case 11[#]: 15.9 mm thick Plywood[•] continuous under the sole plates of the party wall.

Measured Results and Conclusions

Table 1 shows the measured apparent airborne sound insulation (direct path plus all flanking paths) between rooms A and B. From the table it is evident that a fire stop in the form of a continuous surface (Case 7 and 11) is the least desirable. With a continuous OSB sub-floor, the apparent sound insulation will not be greater than FSTC 52, regardless of the A-B party wall construction. The gypsum board between the joist headers (Case 3 and 4) and the sheet steel (Case 6) have a limiting sound insulation of FSTC 57. Although the connection is rigid it is made in such a manor that bending waves will not be transmitted, unlike the continuous sub-floor of Case 7. The most desirable cases are ones which do not create any structural connections (Cases 2 and 5), in particular Case 2 where an additional layer of insulation was added to the wall cavity such that an explicit fire stop was not required.

Case	Base AB Party Wall		Superior AB Party Wall		Limiting sound insulation of fire stop (FSTC)
	Measured apparent sound insulation (FSTC)	Change Re Reference A or B (FSTC)	Measured apparent sound insulation (FSTC)	Change Re Reference A or B (FSTC)	
Ref. A	51	-	-	-	-
2	56	+5	-	-	-
3	51	0	-	-	57
Ref. B	50	-	66	-	-
4	50	0	57	-9	57
5	52	+2	-	-	-
6	51	+1	57	-9	57
7	50	0	52	-14	52
11	-	-	51	-15	-

Table 1: Measured apparent sound insulation between rooms A and B.

---

[i] “Flanking transmission at joints in multi-family dwellings Phase I: Transmission via fire stops,” T.R.T. Nightingale, R.E. Halliwell, Report A1042F, IRC-NRCC, October 1997.

[*] A-C floor/ceiling fire rated as shown in Figure 1.

[#] A-C floor/ceiling not fire rated as shown in Figure 2.

[•] This detail satisfies the NBCC criteria for fire stop location (9.10.15.2.1) and material (9.10.15.3.1).

[ii] This detail satisfies the criterion for fire stop location (9.10.15.2.1), but semi-rigid batt material is not listed (9.10.15.3.1) as an acceptable material. However, the fire resistance of semi-rigid materials were tested and found to comply with the intent of 9.10.15.3.g.


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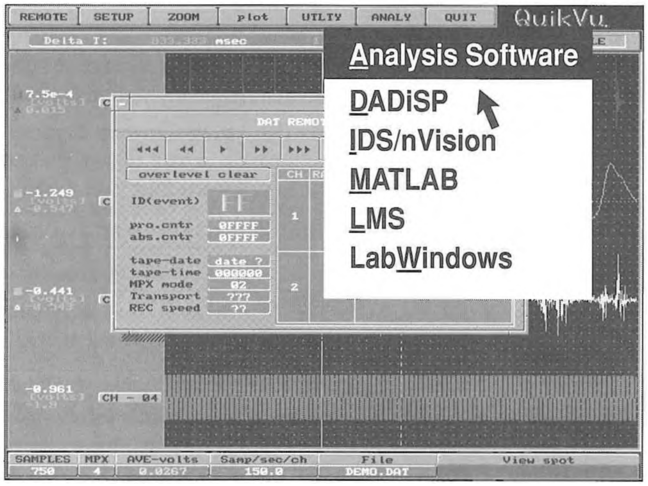

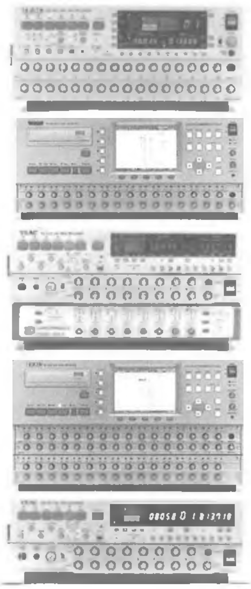

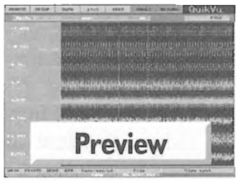

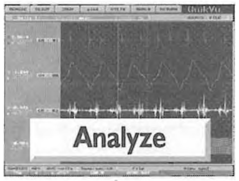

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A NOVEL NON-DESTRUCTIVE METHOD FOR THE MEASUREMENT OF AIRFLOW RESISTANCE OF JET ENGINE NACELLE COMPONENTS

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Introduction

As a noise control measure to reduce inlet fan noise of jet engines, the nacelles are often equipped with a thin resistive wire mesh placed over a honeycomb structure. Historically there has been a problem to measure, in non-destructive fashion, the airflow resistance of repaired or refurbished nacelle parts for the purpose of demonstrating OEM compliance. ASTM C522 is the traditional airflow resistance test method and is destructive requiring a sample be cut from the specimen and fit into an apparatus where the flow velocity due to a constant pressure drop can be measured. This paper presents a non-destructive test method for measuring the airflow resistance using an E1050 impedance tube.

Theory

Assume that plane wave is incident on the face of a nacelle as shown in Figure 1. In general, the impedance will have both a resistive and reactive component and can be obtained using a transfer matrix approach. The pressure and particle velocity on either side of a layered system are given by a two by two matrix[i],

$$\begin{bmatrix} p_1 \\ v_1 \end{bmatrix}_{x=o} = \begin{bmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{bmatrix} \begin{bmatrix} p_2 \\ v_2 \end{bmatrix}_{x=d} \qquad (1)$$

In the event that there are *n* layers in the system then the transfer matrix for the complete system is given by the product of the matrices for the individual layers i.e., $[T] = [T_1][T_2]\ldots[T_n]$.

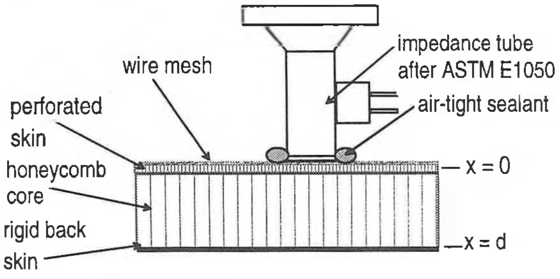

Figure 1: Sketch showing the nacelle and the impedance tube.

Assuming normal incidence, the transfer matrix for the airspace between the wire mesh and the rigid backing is,

$$[T_2] = \begin{bmatrix} \cos(kd) & i \cdot \rho_o c \cdot \sin(kd) \\ i \cdot \dfrac{\sin(kd)}{\rho_o c} & \cos(kd) \end{bmatrix} \qquad (2)$$

The transfer matrix for a thin layer having both mass and resistance is given by

$$[T_1] = \begin{bmatrix} 1 & Z_m \\ 0 & 1 \end{bmatrix} \qquad (3)$$

where Z_m is the impedance of the wire mesh and is given by,

$$\frac{1}{Z_m} = \frac{1}{R_m} + \frac{1}{i \cdot \omega \cdot m} \qquad (4)$$

and R_m is the resistance of the wire mesh, ω is the angular frequency, and m is the effective surface density.

For the system shown in Figure 1 the velocity at the rigid termination at x=d is zero and equations 1, 2 and 3 give the impedance of the total system as

$$Z_t = \frac{T_{11}}{T_{21}} = \frac{-i\cos(kd)}{\sin(kd)}\rho_o c + Z_m \qquad (5)$$

The first term is the air volume impedance and will become zero at the resonant condition,

$$kd = n\pi / 2 \qquad (6)$$

where n is an odd integer. For frequencies where this condition is satisfied, the measured impedance is just that of the wire mesh,

$$Z_m\Big|_{kd=n\frac{\pi}{2}} = \frac{-R_m\omega \cdot m}{-\omega \cdot m + iR_m} \qquad (7)$$

If the wire mesh is well bonded to the perforated skin it will not vibrate and the mesh will behave as if it had infinite mass. Equation 7 reduces to

$$Z_m\Big|_{kd=n\frac{\pi}{2}} = R_m \qquad (8)$$

and the measured impedance will be purely resistive; the mesh resistance. In the event that measured reactance is not zero (i.e., $R_m >> \omega m$) it might be an indication that the adhesive has completely filled the wire mesh or that the material is not adequately bonded to the substrate.

Measured Results

The impedance of the nacelle at the resonance condition was measured at nine points using an impedance tube as shown in Figure 1. Using the same nacelle nine specimens were cut and the airflow resistance measured using the ASTM C522. The results shown in Table 1 indicate that the proposed method provides an alternate non-destructive method for measuring the air flow resistance of materials.

	C522 Method (mks Rayls)	Proposed Method (mks Rayls)
Mean ± 95% conf. (mks Rayls)	362.5 ± 9.1	356.2 ± 3.3

Table 1: Mean measured airflow resistance of the nine samples using the two methods. A 9.5 cm/s flow velocity was used in both.

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[i] K.U. Ingard, *Notes on Absorption Technology,* Noise Control Foundation, Poughkeepsie, NY, 1994, p. A1—A8.

Comprehensive Audiological Assessment System

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I Introduction

To make differential and topical audiological diagnosis, an audiologist needs to perform an extensive battery of tests, using a variety of audiometric devices [1, 2, 3]. This leads to variability of the test results due to changes in the patient's physiological state; limits the accuracy and comparability of the tests due to differences in calibration of the devices [4]; requires a long time of testing, up to several days; creates inconvenience of moving the patient from device to device; and causes problems with electronic storage and processing of data. All these reduce the diagnostic value and the usability of the audiometric test results. To cope with these problems, the Institute of Biomedical Engineering and Poul Madsen Medical Devices Ltd. have introduced a new approach to comprehensive audiometry, and designed an integrated audiometric instrument, the Audiological Assessment System™, the AAS9000™.

II Comprehensive audiometry and the AAS9000

This new concept of audiological assessment makes it possible to perform a battery of tests , including pure-tone and speech, immittance, ERA, TEOAE and DPOAE , at the same work station during a single visit of the patient .

The computer-based instrument includes an Operator Room Unit with a Pentium processor, hard disk and floppy disk drives; a Patient Room Unit with headphones, bone conductor and acoustic probes; an Audiometric Keyboard™, and a colour monitor. The system combines five audiological devices in one instrument. *The clinical audiometer* is a full two-channel pure-tone and speech instrument covering the frequency range from 125 to 10,000 Hz including masking, air, bone, and free-field audiometry. *The acoustic immittance audiometer mode* provides tympanometry, acoustic reflex measurement, decay-test, and assessment of eustachian tube function. *The two-channel evoked response audiometer mode* provides electro-cochleography, brainstem response, steady-state brainstem response, middle latency, and cortical response audiometry. *The distortion product otoacoustic emissions mode* provides measurement of the DP in the range of 500 to 10,000 Hz with increased signal-to-noise ratio. *The transient otoacoustic emissions mode* provides measurement and FFT analysis of the emissions within wide frequency and stimulus level ranges. All functions are controlled from the Audiometric Keyboard™ with an embedded compact QWERTY keypad.

In the course of testing, patient records are automatically entered and stored in a unified, NOAH-compatible data base. They can be printed out, reviewed, restored, processed and shared on a local network. The system can also be used as a normal personal computer for word processing, spread-sheets, electronic communication etc.

III Areas of use

The AAS9000 can be used as a research tool for Audiology, Otolaryngology, Auditory Physiology, Occupational and Environmental Medicine. It is also a universal clinical audiometric instrument both for hospitals with extensive audiological programs and for private audiological clinics.

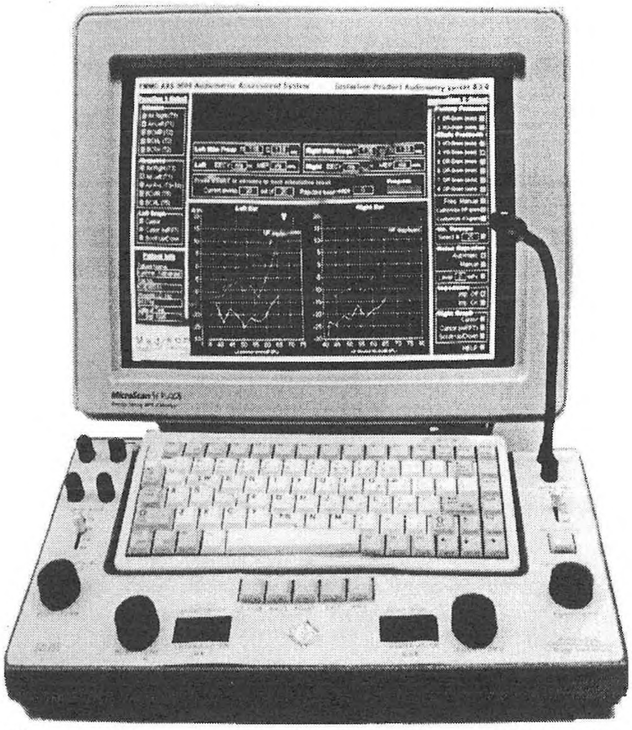

Figure 1: The Audiometric Keyboard™ and 17" Monitor.

The system can also be used in experimental physiological research on animals.

IV Conclusions

Comprehensive audiometry at a single workstation within a single patient's visit enables the audiologist to obtain thorough, comparable, reliable, and reproducible results of different audiometric tests, with less intra-subject physiological variations.

The combined system saves clinic space. It is easy and convenient to use due to uniformity and similarity of an operator interface to that in conventional arrangements. Maintenance, service, calibration and upgrading of the system is a one-step process. Thus it is time- and cost-effective. The system enables effective handling of clinical data.

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[3] Martin, F.N., *Introduction to Audiology*/6th ed., Boston et al: Allyn & Bacon, 1997.

[4] Wilber, L.A., *Calibration, Puretone, Speech and Noise signals,* Handbook of Clinical Audiology / 4th ed., Ed. J.Katz, Baltimore, MD: Williams & Wilkins, 73-94, 1994.

Acknowledgments

This work was supported by: IRAP, NSERC, and TPP.

THE CERTIFICATE OF APPROVAL FOR NOISE CONTROL - THE PROCESS

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Introduction

Section 9 of the Environmental Protection Act (EPA) requires that any equipment or process which may discharge to the atmosphere receive approval from the Ontario Ministry of the Environment and Energy (MOEE). This approval with respect to noise and vibration is contained in a document known as a Certificate of Approval (Air). The Certificate of Approval includes air emissions, noise and vibration.

The MOEE has several documents which detail the process including when a C of A is required, how an application is made and the background information needed to support the application. This paper addresses the need for a greater awareness at the municipal level of the requirements of the EPA with respect to Certificates of Approval.

Not all pieces of equipment nor all industrial processes require a C of A to operate. The MOEE has a document titled "Guide to Applying for Approval (Air): Noise & Vibration" dated November 1995. This document is basically a checklist to assist the applicant in determining if their equipment/process requires a C of A and if so what information is required to support the application. Further this Guide points the applicant to several other MOEE documents which need to be taken into consideration when preparing the C of A background information.

A Certificate of Approval is a statutory requirement under the EPA. The EPA is a legislated document. Therefore it is law. Unfortunately this is not common knowledge. Under the current system there is not a specific point where the need for a C of A is triggered. It is left up to the industry or source owner to "know" that a C of A may be required. Not the MOEE nor any other government agency has a process to routinely inform industry that a C of A may be required. In the past this may not have been critical because the development of large areas of residential land did not usually locate adjacent to lands zoned for medium to heavy industry.

Now in the GTA as more land is required for residential purposes, land adjacent to existing industries or land zoned for future industrial development is being developed for residential purposes. This potentially could lead to some interesting scenarios.

Scenario 1

Under the EPA the onus for compliance with the noise and vibration guidelines is with the industry. That is, if complaints arise from an existing residential development with respect to the industry, the industry must prove compliance or mitigate in order to comply with the guidelines. In the case where a residential development is proposed adjacent to existing industries, the proponent of the residential development is required to assess the potential noise and vibration impact and provide adequate mitigation, at the residential site or preferably at the source. During this process it may become evident that a C of A is required for some of the industry's equipment in addition to what may already be approved.

This scenario though potentially controversial is relatively straightforward insofar as where the obligation and expense for mitigation lies.

Scenario 2

The more difficult situation is when a residential development is proposed adjacent to land which is zoned for future industrial/commercial development. In this case some planning techniques such as separation distance and/or placement of noise insensitive uses along the common boundary can be utilized. However, because it is usually not known what type of industry will be located along the common property line, there is much reluctance on the part of municipalities and developers to do this. Further, most municipalities do not require that industries have a noise and/or vibration study conducted as a condition of site plan approval and as most small to medium sized industries appear to not be aware of the C of A process a potentially volatile situation is set up.

Possible Solutions

Industries should be made aware that the MOEE has the authority to shut down an industry if the terms of the EPA are violated. Based on the above discussions, it has become apparent that a greater effort needs to be made to ensure that industries are aware of the C of A requirements. The most obvious place to let new industries know of these requirements is at the time a building permit application is made. The municipalities need to take a more active role in informing industries that a C of A may be required. This could take the form of a simple statement on the list of items required prior to the issuance of building permits directing the proponent to the MOEE to determine if a C of A is needed, and if so requiring that each industry have a noise and/or vibration report prepared and obtain a C of A prior to issuance of the occupancy permit.

Proposed residential developments have been required to prepare noise and vibration reports for many years. Now it is time to require that all new industries and any industries proposing modifications address the issues of noise and vibration as a condition of approval at the municipal level and obtain a Certificate of Approval from the MOEE.

Reference: "Guide to Applying for Approval (Air): Noise & Vibration", MOEE, Nov. 1995

Application of Virtual Acoustics to Automotive Sound Quality

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1. INTRODUCTION

Traditionally, automotive sound quality engineering is based on empirical acoustic measurements, and therefore requires the availability of physical prototypes. This poses a number of problems with respect to the continuing desire to reduce product development costs and shorten development schedules. Physical prototypes that are suitable for assessing the sound quality performance of a vehicle design are generally expensive to produce due to the accuracy required, and because they are fabricated largely without the benefit of production tooling. Furthermore, the high cost of such prototypes restricts the numbers that are available to the engineer, leading to development delays. Also, limited access to test facilities suitable for sound quality work can also pose a bottle neck for empirically based engineering. Finally, because "sound quality" prototypes are often not available until well into a design cycle, sound quality motivated design changes can have significant ramifications on production and tooling costs.

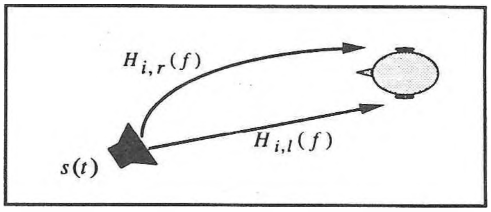
Virtual prototyping addresses these problems by making available, to the engineer, noise performance data for a vehicle or component design before it is possible to build and empirically test a physical prototype. Virtual prototyping depends on several enabling capabilities. The first is the capability to analytically predict the vibro-acoustic response of a structure design based solely on an engineering description (i.e. the virtual vehicle) and a target driving excitation. [1] The second enabler, virtual acoustics, provides the capability to predict the left/right ear signal (e.g. the binaural signal) for a virtual listener that is immersed in the predicted acoustic field of a virtual vehicle.

DESCRIPTION

When a customer forms an impression of the sound quality of a particular vehicle, it is primarily based on the sound as received through both the left and right ears, e.g. binaurally. The chief reason why the binaural format is important is that it preserves directional hearing information. When one listens to binaural sound data, the location and size of acoustical objects are preserved. In contrast, single point or monaural sound data completely lacks this directional information. Furthermore, the timbre of a sound source can also depend on direction. In point of fact, many established methods for quantifying automotive sound quality are based on analyses of binaural sound data.

Given a prediction of the acoustic radiation over the interior surface of a vehicle, it would seem a simple matter to determine the net acoustic signal at a point equivalent to a hypothetical driver's ear. It could be done by simply summing contributions from various acoustic sources, considering attenuation due to distance from each source. However, this strategy will not produce an acoustic prediction that accurately reflects the subjective characteristics of the sound field as it is perceived by the customer because it lacks the directional hearing characteristics of the human auditory system as mentioned above. For the same reason, a pair of spaced omnidirectional microphones is also a poor approximation of the human hearing process.

Virtual acoustics is the technology of predicting/synthesizing binaural sound data for a given listener at a given location in a 3-dimensional sound field. Virtual acoustics is based on having a detailed characterization of directional dependent hearing response for both the left and right ear. This characterization is usually realized as a set of paired (left & right), complex transfer functions, also known as head related transfer functions (HRTF). For a source located at a particular azimuth and elevation angle, there exists a unique pair of HRTF's from the source to each of a hypothetical listeners ears. The signal entering each of the ears can therefore be predicted by using the HRTF pair as a set of directional filters to modify the source signal, as shown in the figure below.



Here s(t) represents the predicted acoustic radiation for some part of a vehicle's body structure. The functions, $H_{i,l}(f)$,and , $H_{i,r}(f)$, are the left and right ear directional transfer functions (e.g. HRTFs). The signal entering the left ear of the virtual listener is therefore computed as:

$$x_{i,l}(t) = h_{i,l}(t) * s_i(t) \qquad \textbf{(EQ 1)}$$

where $h_{i,r}(t)$ is the time domain impulse response for the left ear transfer function. Given a set of HRTF's distributed across azimuths and elevations surrounding ones head, one can compute the directional dependent left ear signal for multiple sound sources as,

$$x_l(t) = \sum_i h_{i,l}(t) * s_i(t) \qquad \textbf{(EQ 2)}$$

and similarly for the right ear signal. The resulting left/right ear signals will be a subjective and objectively good prediction of what a real person would experience if a real prototype were available.

CONCLUSIONS

Virtual prototyping will be a powerful tool for helping automakers cut costs and reduce vehicle development time. Virtual acoustics is the part of virtual prototyping that allows an engineer or customer to experience the virtual noise environment of a virtual vehicle, and is thus make possible the application of automotive sound quality engineering without the need for costly physical hardware.

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EXPERIMENTAL TESTING OF INTAKE MANIFOLD NOISE

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INTRODUCTION

There are a large number of moving parts and associated processes involved with the operation of a modern day internal combustion powered vehicle significantly contributing to the amount of noise heard within the passenger compartment of the vehicle. Many improvements to vehicle design have been made in recent years to improve overall sound levels produced. Examples of these are stiffer and better acoustically insulated bodies and quieter muffler systems. This, however, has resulted in other potential noise sources, induction noise in particular, becoming more noticeable. The objective of this project was to develop an experimental model that would simulate the pressure pulses which propagate through a production intake manifold under operating conditions. Development of this model would provide a tool to facilitate future research in areas that are currently difficult or impossible to achieve with other experimental or numerical techniques.

METHOD

The experimental simulator developed consisted of an intake manifold from a Chrysler Neon which had a dynamic speaker mounted to each of the four runners of the manifold. Intake pressure data taken from Ricardo Wave, a noise modelling software package, was digitized and stored on a personal computer. A program written with Labview, a data acquisition software package, would read the pressure data and convert it to four channels of output voltage to be sent to each of the four speakers in the same sequence as the firing order of the engine. A microphone located 5 centimetres above the throttle body would then pick up the manifold noise output and send this signal back to the computer. The Labview program would digitize the signal and output the measured results in a time domain and frequency domain format for analysis. Manifold noise measurements were also made of an actual Neon engine motored on a dynamometer and stored on a digital audio tape. This information was fed into the same analysis program used before which would again output the time and frequency domain results of the intake manifold.

RESULTS

To ascertain the validity of the output produced by the experimental model, the measurements amassed from the simulation model were compared to the same measurements performed on both the actual Neon engine and to the outcome as predicted by the theoretical Ricardo Wave model. The two data types used for comparing the results of the three output sources were the time domain signal and the frequency domain signal. It was found that the time domain signal for the theoretical and actual engine results were very similar. Both sources produced the same characteristic peaks and troughs with similar amplitudes as the same corresponding engine crank angles. Comparing these curves to the output produced by the experimental simulator illustrated similar correlations with the addition of some sub-peaks preceding the beginning of each of the four combustion cycles of the engine. It is suspected that these are the result of non-lineararities in the performance of the speakers used to produce the simulated pressure pulses at the manifold runner openings. In addition to the above qualitative assessment, a quantitative evaluation comparing the simulation results to the measured results from the actual engine was pursued using statistical parameters. Specifically, the calculated mean, standard deviation, correlation coefficient and covariance was determined as illustrated in Tables 1, 2 and 3. It can be seen that the two sets of data have similar central tendencies as well as dispersion about the mean. Perhaps the most convincing affinity between the two sets of data lie within the correlation and covariance analysis which demonstrate good correlation with similar trending of the data curves. For the analysis of the frequency domain signal, all three sources produced nearly identical results for a given engine rpm. The results showed that for an engine rpm of 2400, all the outputs produced a fundamental frequency of 80 Hz followed by a second and third harmonic frequency of 160 and 240 Hz respectively. These results further reinforce the correlation of the experimental results with the theoretical and actual engine results.

Table 1: Mean and Standard Deviation for Modelled and Actual Manifolds

Statistical Evaluation	Data Source	
	Simulation Model	Actual Engine
Mean	-0.02	0.01
Standard Deviation	0.58	0.45

Table 2: Correlation Matrix

	Simulation Model	Actual Engine
Simulation Model	1	-
Actual Engine	0.6	1

Table 3: Covariance Matrix

	Simulation Model	Actual Engine
Simulation Model	0.34	-
Actual Engine	0.16	0.21

CONCLUSIONS

Given a theoretical input signal at the interface between the intake manifold runner and engine head, it has been shown that it is possible to reproduce these pressure pulses. Analysis of the time domain signal for the actual engine compared favourably to the theoretical time domain signal thus validating the use of either source as a reference for comparing experimental results. Also, the statistical parameters determined for the experimental and actual time domain signals compared favourably. It is suspected that any differences are the result of non-lineararities in the low frequency operation of the speakers. The frequency distribution of all three sources were very similar thus further reinforcing the validity of the experimental simulation.

ACKNOWLEDGMENTS

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JURY EVALUATION OF ELECTRIC POWER STEERING SOUNDS

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1. INTRODUCTION

The present study explores the sound generated by a brushless motor-assisted steering system. The objective of the investigation was to determine the acceptable levels of in-vehicle structure-borne induced noise (SBN) and airborne radiated noise (ABN) contributors relative to the current baseline system. These acceptable levels will then later be cascaded down to the electric motor requirements.

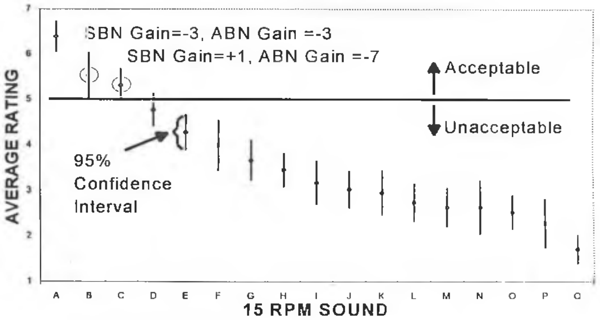
2. METHOD

The electric power steering under investigation consists of a brushless motor connected to the steering column to provide assist. The electric motor generates a static torque to assist the driver. Due to the commutation of the motor, numerous commutation events occur per motor rotation. Switching of the current between phases generates an impulse that results in a broadband airborne sound. The torque fluctuation caused by each commutation event generates a lower frequency tonal noise that is synchronous with the motor RPM and is structure-borne. The structure-borne and airborne contributions were determined through an airborne acoustic noise wrap study.

Jury evaluations of acceptability using semantic differential category scaling [1] were conducted to determine the levels of acceptance of the tonal structure-borne and broadband airborne sound contributors. This was accomplished by applying Kalman filters to extract the commutation orders to approximate the structure-borne component. The airborne noise was estimated by highpass filtering the sound. Sounds for the evaluation were then generated by summing weighted versions of the structure-borne and airborne contributors in the presence of an engine idling background. The sounds were presented to a jury, and the jury was asked to rate the acceptability from extremely unacceptable to extremely acceptable. Seventeen sounds at three handwheel rotational speeds were generated: 15 RPM, 30 RPM, and 45 RPM.

3. DISCUSSION AND RESULTS

Jury evaluation raw data were transferred to a seven point scale and averaged over the 28 subjects, consisting of both technical and non-technical employees. Sounds with an average rating of five or greater were considered acceptable. Results indicate that a wide range of acceptability levels were found. Below is an example for a 15 RPM handwheel rotational speed.



In general, results indicate that at lower handwheel rotational speeds the airborne sound dominates the perception, while at higher rotational speeds the structure-borne component becomes a large contributor. However, at each handwheel speed at least two sounds were found to be acceptable by reducing SBN more than ABN, or ABN more than SBN. The table below shows the reduction from baseline that resulted in acceptable sounds.

Speed	Average	SBN Gain	ABN Gain
15 RPM	5.5	-3 dB	-3 dB
	5.3	+1 dB	-7 dB
30 RPM	5.5	-7 dB	-4 dB
	5.1	-3 dB	-8 dB
45 RPM	5.1	-10 dB	-3 dB
	4.9	-6 dB	-7 dB

Two-variable regressions were calculated using the structure-borne and airborne dB level adjustments from baseline to predict the average jury ratings, as shown below:

$$\textit{average rating} = b_0 + b_1 * \textit{SBN Gain} + b_2 * \textit{ABN Gain}.$$

R^2 results at the three rotational speeds were equal to 0.84 (15 RPM), 0.87 (30 RPM), and 0.89 (45 RPM). High correlation allows system specifications to be set that are correlated to jury acceptance results.

4. CONCLUSIONS

Acceptable electric power steering levels were found that allow tradeoffs between structure-borne and airborne noise sources. Changes in electric motor structure-borne and airborne sound levels were highly correlated to jury acceptance results.

5. REFERENCES

[1] Meier R. C., Otto N. C., Pielemeier W. J., Jeyabalan V., *A New Tool for the Vibration Engineer*, SAE Paper 971979

Blachford

'The ABC's of noise control"

L. Blachford's ɔmprehensive aterial Choices

ɔise treatments can be tegorized into three basic ɜments: Vibration Damping, ɔund Absorption and ɔund Barriers.

bration Damping

s well known that noise is ɲitted from vibrating structures substrates. The amount of noise n be drastically reduced by ɜ application of a layer of a ɔration damping compound to ɜ surface. The damping ɪmpound causes the vibrational ɪergy to be converted into heat ɪergy. Blachford's superior ɪmping material is called ɴTIVIBE and is available either a liquid or a sheet form.

ɴTIVIBE DL is a liquid ɪmping material that can be ɔplied with conventional spray ɥuipment or troweled for naller/thicker application.

is water-based, non-toxic ɪd provides economical and ghly effective noise reduction ɔm vibration.

NTIVIBE DS is an effective rm of damping material provided sheet form for direct application your product.

Sound Barriers

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

Blachford Sound Barrier materials:

BARYMAT

Limp, high specific gravity, plastic sheets or die cut parts. Can be layered with other materials such as acoustical foam, protective and decorative facings to achieve the desired TL for individual applications.

Sound Absorption

Blachford's CONASORB materials provide a maximum reduction of airborne noise through absorption in the frequency ranges associated with most products that produce objectionable noise. Examples: Engine compartments, computer and printer casings, construction equipment, cabs,...etc.

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

Suggest Specific Material or Design

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

A Quality Supplier

The complete integration of:

- Experience
- Quality-oriented manufacturing technology
- Research and development
- Problem solving approach to noise control

Our Mississauga Plant is ISO-9001 CERTIFIED

Result in:

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Canadian Acoustical Association
l'Association Canadienne d'Acoustique

1997 PRIZE WINNERS / RÉCIPIENDAIRES 1997

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

Monica Rohlfs, University of Alberta

"Effects of facial paralysis and presentation mode on perceptual acoustic measures of consonant place"

ECKEL PRIZE IN NOISE CONTROL
PRIZ ECKEL EN CONTROLE DU BRUIT

Andrew Wareing, University of British Columbia

"Predicting sound fields in rooms with extended-reaction surfaces using beam-tracing and Biot theory"

DIRECTORS' AWARDS / PRIX DES DIRECTEURS

Professional ≥30 years / Professionel ≥30 ans: **John Osler, Defence Research Est'ment Atlantic**

"Seismo-acoustic determination of the shear-wave speed of surficial clay and silt sediments on the Scotian shelf"

Student / Étudiant(e): **Russell Ovans, Simon Fraser University**

"Equalization in sound reinforcement: psychoacoustics, methods and issues"

STUDENT AWARDS / PRIX ÉTUDIANT

Monica Rohlfs, University of Alberta

"Effects of facial paralysis and presentation mode on perceptual acoustic measures of consonant place"

Frank Russo, Queen's University

"Evaluation of perceived tonality across the musical pitch range"

Nicholas Smith, University of Toronto

"Patterns of tension/relaxation in music: a consideration of psychoacoustic and cognitive influences"

CONGRATULATIONS / FÉLICITATIONS

Canadian Acoustical Association
l'Association Canadienne d'Acoustique

Minutes of the Board of Directors Meeting
Windsor, October 8, 1997

Present: J. Hemingway D. Jamieson D. Giusti J. Bradley
A. Cohen C. Sherry S. Abel

Regrets: L. Cheng S. Dosso D. Quirt
M. Hodgson E. Slawinski J. Nicolas

Meeting called to order at 7:13 PM

President's Report

The president reported on correspondence with H. Jones which subsequently was published as his report on the World Congress on Ultrasonics in Canadian Acoustics.

Secretary's Report

The secretary reported a total of 339 payed up memberships, a decrease of 10% from one year ago and a decrease of 17% over the past two years. The abrupt increase in membership fees one year ago is thought to be one factor that has led to a decreased membership. The secretary recommended that CAA take strong steps to improve the quality of the annual conference and Canadian Acoustics to make our association more attractive to new members.

The processing of membership renewals is operating smoothly with the aid of a computer database. Renewals this year will include a request to revise address details for each member to correct changes that may have occurred.

The secretary reported a total of $898.45 of expenditures over the past twelve months including secretarial help in maintaining the membership database. These costs were down to almost a half of the previous years costs. The secretarys report was accepted. (Moved by A. Cohen, seconded by S. Abel, passed)

Treasurer's Report

The treasurer reported that our financial state is greatly improved over that of one year ago. Income in our operating account totaled $44,023.10 which included a large transfer from our capital account to correct for previous expenditures and also a significant GST rebate. Also included was over $3,271.83 From the Calgary CAA conference. Total expenditures against our operating account over the past financial year were $18,512.11. Various cost cutting measures over the past year were successful in reducing expenses and providing a more satisfactory balance.

The expected interest from our invested capital funds is $6,925.00 which is less than the $8,100.00 required to fund all of the prizes that we offer.

After a discussion of subsidies for student travel to the annual CAA conference, it was decided that the total budget for subsidizing student travel should be set one year in advance. (Moved by S. Abel seconded C. Sherry, passed). A second motion set the limit for this and next years meeting to be $1,500.00 (Moved by S. Abel, seconded by D. Jamieson, passed).

The treasurers report was accepted. (Moved S. Abel, seconded by D. Jamieson, passed).

Editor's Report

No report available.

Membership

Various ideas for increasing membership were discussed. The Membership Chair requested the restoration of funds for mailing out promotional materials. He is revising the CAA brochure which will be available to anyone wishing to promote CAA. The CAA web page is alive and well and was a source of last minute program information for the Windsor meeting.

Awards

The directors prizes for best papers in Canadian Acoustics, the Bell prize, and the Eckel prizes are to be awarded this year. There were no candidates for the Shaw fellowship or the Fessenden prize. The Youth Science Fair prize was awarded.

Meetings

Last years Calgary meeting was very successful and also generated much needed funds for CAA. This years meeting was smaller but is expected break even.

The next meeting will be in London, Ontario in October 1998. D. Jamieson has taken this on at the last minute when other plans did not materialize.

Charlottetown and Sherbrooke are possible locations for the 1999 meeting and it was suggested that the 2000 meeting should be on the west coast.

Nominations Committee

A slate of nominations for the CAA executive was proposed for presentation at the annual general meeting. The terms of two directors finish this year (E. Slawinski and C. Sherry) and nominations for their replacement were also proposed.

Meeting adjourned at 9:35 PM. (Moved by S. Abel, seconded by D. Giusti, passed)

Canadian Acoustical Association
l'Association Canadienne d'Acoustique

Minutes of the Annual General Meeting
Windsor, October 9, 1997

J. Hemingway called the meeting to order at 5:05 PM.

President's Report

No new business.

Secretary's Report

The secretary reported a serious (17%) drop in the number of members over the past two years and recommended that strong efforts be taken to improve both the Annual meeting and Canadian Acoustics to make CAA more attractive to new members.

The secretary reported success in reducing secretarial costs by almost a half to a total of $898.45 over the past year.

The secretarys report was accepted (moved by G. Clunis, seconded by S. Abel, passed).

Treasurer's Report

The treasurer reported a marked improvement in the financial state of CAA. Over the past year operating income has totaled $44,023.11 and operating expenditures $18,512.11. Income included a large transfer from capital funds as well as a significant GST rebate.

Due to current interest rates, interest income in our capital account is insufficient to fund all of the prizes that we offer.

The treasurers report was accepted. (Moved B. Chapnik, seconded by R. Peppin, passed).

Membership

Due to illness, the membership chair could not attend but his comments in his report to the board of directors were passed on to the members.

Editor's Report

No report available.

Awards

The directors prizes for the best papers in Canadian Acoustics, (Russell Ovans under 35), (John Osler and Dave Chapman over 35) the Bell prize (Monica Rohlfs), and the Eckel prize (Andrew Wareing) are to be awarded this year. There were no candidates for the Shaw fellowship or the Fessenden prize. The Youth Science Fair prize was awarded.

Past/Future Meetings

1996 Calgary

A very successful meeting with a surplus of $3,271.83.

1997 Windsor

Initial reports suggest approximately 60 to 70 participants and that we will financially break even.

1998 London

D. Jamieson has agreed to head the organisation of the 1998 meeting to be held in London.

Either Charlottetown or Sherbrooke were suggested for 1999 as well as a west coast location or Toronto for 2000.

Nominations Committee

The following nominations were proposed for the executive:
President: J. Bradley, Treasurer: J. Hemingway, Secretary: T. Nightingale, Membership Chair: D. Jamieson, Editor: M. Hodgson.

Accepted by acclamation.

The terms of two directors finish this year (E. Slawinski and C. Sherry) and A. Behar and D. DeGagne were proposed as nominations for replacements. A nomination from the floor was made for W. Sydenbourgh for the eastern directors position and a vote was held. D. DeGagne and W. Sydenbourgh were elected as the two new directors. A. Cohen was accepted as the new Awards Coordinator.

Meeting adjourned 6:21 PM. (Moved by S. Abel, seconded by C. Andrews, passed).

"Interdisciplinary Views of Classroom Hearing Accessibility: The Sum of the Parts"

February 21 and 22, 1998
GF Strong Auditorium, 4255 Laurel St., Vancouver (pay parking @ Oak and 28th)

Co-chairs: Lisa Dillon and Ruth Warick
Faculty Liaison: Kathy Pichora-Fuller

A conference organized by members of the Institute of Hearing Accessibility Research (IHEAR), in cooperation with the Faculty of Education and the School of Audiology and Speech Sciences at UBC, the Vancouver/Richmond Health Board Audiology Centre, and Phonic Ear Inc.

Objectives:

Researchers, professionals, and students from a range of disciplines will be brought together with consumers so that potential solutions to the complex problems of classroom hearing accessibility can be developed.

Presenters:

Presenters will include IHEAR faculty, invited faculty, students, professionals, and consumers with converging interests in the everyday hearing problems encountered in classrooms. They come from a range of disciplines, including education, audiology, electrical engineering, mechanical engineering, architecture, psychology, linguistics, anthropology, health promotion, and communications. Confirmed presenters include:

IHEAR faculty:	Janet Jamieson, Educational Psychology and Special Education, UBC
	Carolyn Johnson, Audiology and Speech Sciences, UBC
	Murray Hodgson, Mechanical Engineering/Occupational Hygiene, UBC
	Perry Leslie, Educational Psychology and Special Education, UBC
	William McKellin, Anthropology and Sociology, UBC
	Daniel Paccioretti, Vancouver/Richmond Health Board Audiology Centre
	Kathy Pichora-Fuller, Audiology and Speech Sciences, UBC
IHEAR students:	Arlene Carson, Audiology and Speech Sciences, UBC
	Lisa Dillon, Audiology and Speech Sciences, UBC
	Carol Jaeger, Electrical Engineering, UBC
	Ruth Warick, Educational Studies, UBC
Invited faculty:	Michel Picard, Université de Montréal
	Bruce Schneider, University of Toronto
	Mark Ross, University of Connecticut
Professionals:	Suzanne Bailey, BC Min of Education, Skills & Training, Victoria
	Joan Bennett, Educator, North Vancouver
	Leslie Bennett, Educational Audiologist, Coquitlam, BC
	John Bradley, Acoustics Lab, National Research Council, Ottawa
	Edward DeGrey, Architect, Vancouver
	Carolyn Edwards, Educational Audiologist, Toronto
	John Lane, Campus Planning and Development, UBC
	Susan Lane, Educational Audiologist, Delta, BC
	Barry McKinnon, Acoustical Consultant, North Vancouver
	AnneMarie Newroth, BC Public Health Audiology Council, Victoria
	Ben Ostrander, Architect, Vancouver
	Laurie Usher, BC Public Health Audiology Services, Burnaby
Consumers:	Members of the Community and the Canadian Hard of Hearing Association

CONFERENCE SCHEDULE

SATURDAY: The Parts

12:00-2:00	Registration/Technology Exhibits	

A. Views on Listening and Communication in the Educational Process

Student and Teacher Views

2:00-2:45	Primary and Secondary:	Suzanne Bailey
2:45-3:30	Post-secondary:	Ruth Warick
3:30-3:45	Coffee Break	

Researcher Views on Child Development

3:45-4:30	Auditory	Bruce Schneider
4:30-5:15	Social	Janet Jamieson
5:15-6:00	Linguistic	Carolyn Johnson
6:00-7:00	Dinner Break on-site	

B. Views on the Classroom Environment

Effects of the Classroom Environment on Listening Demands and Experiences

7:00-7:45	Primary and Secondary	Carolyn Edwards
7:45-8:30	Post-Secondary	Lisa Dillon

SUNDAY MORNING: The Parts Continued

Acoustical Views

8:00-8:45	Primary and Secondary	Michel Picard
8:45-9:30	Post-Secondary	Murray Hodgson
9:30-9:45	Coffee Break	

Architectural and Technological Views

9:45-10:30	Architects' View	Edward deGrey
10:30-11:00	Current Assistive Listening Technology	Daniel Paccioretti
11:00-11:30	Current Research	Carol Jaeger
11:30-12:00	Future	Mark Ross
12:00-1:00	Lunch Break on-site	

SUNDAY AFTERNOON: The Sum

C. Collaborations and New Solutions

Consultants' Views on Solutions

1:00-1:30	Hearing Loss	Carolyn Edwards
1:30-2:00	Self-care and Family Support	AnneMarie Newroth
2:00-2:30	Acoustics	Barry McKinnon
2:30-3:00	Architect	Ben Ostrander
3:00-3:30	Coffee Break	

Implementers' Views on Solutions

3:30-4:00	Policy/Planning Panel: Arlene Carson (Chair), Suzanne Bailey, John Bradley, AnneMarie Newroth, John Lane
4:00-4:30	Classroom Panel: Perry Leslie (Chair), Joan Bennett, Leslie Bennett, Susan Lane, Barry McKinnon, Laurie Usher
4:30-5:00	Parent/Student Panel: Lisa Dillon (Chair), Community and CHHA members

D. Epilogues/Future Directions

5:00-5:15	Environmental Design	John Bradley
5:15-5:30	Anthropology	Bill McKellin
5:30-5:45	Health Promotion	Arlene Carson
5:45-6:00	Educational Services	Ruth Warick
6:00-6:15	Closure/Final Discussion	Kathy Pichora-Fuller

NEWS / INFORMATIONS

CONFERENCES

The following list of conferences was mainly provided by the Acoustical Society of America. If you have any news to share with us, send them by mail or fax to the News Editor (see address on the inside cover), or via electronic mail to desharnais@drea.dnd.ca

1997

1-5 December: 134th Meeting of the Acoustical Society of America, San Diego, CA. Contact: Acoustical Society of America, 500 Sunnyside Blvd., Woodbury, NY 11797, Tel.: 516-576-2360; Fax: 516-576-2377; Email: asa@aip.org; WWW: http//asa.aip.org

15-18 December: 5th International Congress on Sound and Vibration, Adelaide, Australia. Contact: ICSV5 Secretariat, Department of Mechanical Engineering, University of Adelaide, South Australia 5005, Australia; Fax: +61 8 8303 4367; Email: icsv5@mecheng.adelaide.edu.au

16-17 December: Underwater Acoustics Conference, Loughborough, UK. Contact: Institute of Acoustics, 5 Holywell Hill, St. Albans, Herts AL1 1EU, UK; Fax: +44 1727 850 533; Email: acoustics@clus1.ulcc.ac.uk

1998

2-6 February: Ultrasonic Technological Processes - 98, Moscow, Russia. Contact: Secretariat, UsTP-98, 64 Leningradski prospekt, MADI-TU, Moscow, Russia; Fax: +7 095 151 7911; Email: utp@madi.msk.su

9-13 February: 1998 Ocean Sciences meeting, San Diego, CA. Contact: American Geophysical Union, 2000 Florida Ave., N.W., Washington, DC 20009; Tel.: 202-462-6900; Fax: 202-328-0566; WWW: www.agu.org

19-21 February: 23rd Annual National Hearing Conservation Association Conference, Albuquerque, NM. Contact: NHCA, 611 E. Wells St., Milwaukee, WI 53202; Tel: 414-276-6045; Fax: 414-276-3349; Email: nhca@globaldialog.com

4-5 March: 4th Annual Conference of the Society of Acoustics of Singapore, Singapore. Contact: W. Gan, Acoustical Services Pte. Ltd., 209-212 Innovation Centre, NTU, Nanyang Avenue, Singapore 6397989, Republic of Singapore; Fax: +65 7913665, Email: wsgan@singnet .com.sg

23-27 March: DAGA 98 - German Acoustical Society Meeting, Zürich, Switzerland. Contact: DEGA, Physics/ Acoustics Department, Universität Oldenburg, 26111 Oldenburg, Germany; FAX: +49 441 798 3698; Email: dega@aku.physik.uni-oldenburg.de

31 March - 2 April: Acoustics 98, Cranfield University, UK. Contact: Institute of Acoustics, 5 Holywell Hill, St. Albans, Herts AL1 1EU, UK; Fax: +44 1727 850 533; Email: acoustics@clus1.ulcc.ac.uk

5-8 April: NOISE-CON 98, Ypsilanti, MI. Contact: Noise Control Foundation, P.O. Box 2469, Arlington Branch, Poughkeepsie, NY 12603; Tel.: 914-462-4006; Fax: 914-463-

10-14 May: 6th Meeting of the European Society of Sonochemistry, Rostock-Warnemunde, Germany. Contact: D. Peters, FB Chemie, University of Rostock, Buchbinderstr. 9, 18051 Rostock, Germany; Fax: +49 381 498 1763; Email: ess6@chemibm1.chemie1.uni-rostock.de

CONFÉRENCES

La liste de conférences ci-jointe a été offerte en majeure partie par l'Acoustical Society of America. Si vous avez des nouvelles à nous communiquer, envoyez-les par courrier ou fax (coordonnées incluses à l'envers de la page couverture), ou par courrier électronique à desharnais @drea.dnd.ca

1997

1-5 décembre: 134e rencontre de l'Acoustical Society of America, San Diego, Californie. Info: Acoustical Society of America, 500 Sunnyside Blvd., Woodbury, NY 11797, Tél.: 516-576-2360; Fax: 516-576-2377; Email: asa@aip.org; WWW: http//asa.aip.org

15-18 décembre: 5e congrès international sur les sons et vibrations, Adelaide, Australie. Info: ICSV5 Secretariat, Department of Mechanical Engineering, University of Adelaide, South Australia 5005, Australia; FAX: +61 8 8303 4367; Email: icsv5@mecheng.adelaide.edu.au

16-17 décembre: Conférence en acoustique sous-marine, Loughborough, Royaume-Uni. Info: Institute of Acoustics, 5 Holywell Hill, St. Albans, Herts AL1 1EU, UK; Fax: +44 1727 850 533; Email: acoustics@clus1.ulcc.ac.uk

1998

2-6 février: Procédés technologiques ultrasoniques - 98 Moscou, Russie. Info: Secretariat, UsTP-98, 64 Leningradski prospekt, MADI-TU, Moscow, Russia; Fax: +7 095 151 7911; Email: utp@madi.msk.su

9-13 février: Rencontre 1998 sur les sciences de l'océan, San Diego, CA. Info: American Geophysical Union, 2000 Florida Ave., N.W., Washington, DC 20009; Tél.: 202-462-6900; Fax: 202-328-0566; WWW: www.agu.org

19-21 février: 23e conférence annuelle de l'Association nationale de la conservation de l'audition, Albuquerque, NM. Info: NHCA, 611 E. Wells St., Milwaukee, WI 53202; Tél: 414-276-6045; Fax: 414-276-3349; Email: nhca@globaldialog.com

4-5 mars: 4e conférence annuelle de la Société d'acoustique de Singapour, Singapour. Info: W. Gan, Acoustical Services Pte. Ltd., 209-212 Innovation Centre, NTU, Nanyang Avenue, Singapore 6397989, Republic of Singapore; Fax: +65 7913665, Email: wsgan@singnet.com.sg

23-27 mars: DAGA 98 - Rencontre de la Société allemande d'acoustique, Zürich, Suisse. Info: DEGA, Physics/ Acoustics Department, Universität Oldenburg, 26111 Oldenburg, Germany; FAX: +49 441 798 3698; Email: dega @aku.physik.uni-oldenburg.de

31 mars - 2 avril: Acoustique 98, Université de Cranfield, Royaume-Uni. Info: Institute of Acoustics, 5 Holywell Hill, St. Albans, Herts AL1 1EU, UK; Fax: +44 1727 850 533; Email: acoustics@clus1.ulcc.ac.uk

5-8 avril: NOISE-CON 98, Ypsilanti, MI. Info: Noise Control Foundation, P.O. Box 2469, Arlington Branch, Poughkeepsie, NY 12603; Tél.: 914-462-4006; Fax: 914-463-0201; Email: noisecon98@aol.com; WWW: users.aol.com /noisecon98/nc98_cfp.html

10-14 mai: 6e Rencontre de la Société européenne de sonochimie, Rostock-Warnemunde, Allemagne. Info: D. Peters, FB Chemie, University of Rostock, Buchbinderstr. 9, 18051 Rostock, Germany; Fax: +49 381 498 1763; Email: ess6@chemibm1.chemie1.uni-rostock.de

18-22 May: 7th Spring School on Acousto-optics and Applications, Gdansk, Poland. Contact: B. Linde, Institute of Experimental Physics, University of Gdansk, ul. Wita Stwosza 57, 80-952 Gdansk, Poland; Fax: +48 58 41 31 75; Email: school@uni.gda.pl

25-27 May: Noise and Planning 98, Naples, Italy. Contact: Noise and Planning, Via Bragadino 2, 20144 Milano, Italy, Fax: +39 248018839; Email: md1467@cmlink.it

8-10 June: EAA/EEAA Symposium "Transport Noise and Vibrations", Tallinn, Estonia. Contact: East-European Acoustical Association, Moskovskoe Shosse 44, 196158 St.-Petersburg, Russia; FAX: +7 812 127 9323; Email: krylspb@sovam.com

9-12 June: 8th International Conference on Hand-Arm Vibration, Umea, Sweden. Contact: National Inst. for Working Life, Physiology and Technology Dept., P.O. Box 7654, 90713 Umea, Sweden; Fax: +46 90 165027; Email: hav98@niwl.se

22-26 June: 135th meeting of the Acoustical Society of America/16th International Congress on Acoustics, Seattle, WA. Contact: ASA, 500 Sunnyside Blvd., Woodbury, NY 11797, Tel.: 516-576-2360; FAX: 516-576-2377; Email: asa@aip.org, WWW: http://asa.aip.org

26 June - 1 July: International Symposium on Musical Acoustics, ISMA 98, Leavenworth, WA. Contact: Maurits Hudig, Catgut Acoustical Society, 112 Essex Ave., Montclair, NJ 07042, Fax: 201-744-9197; Email: catgutas@msn.com, WWW: www.boystown.org/isma98

7-12 July: Vienna and the Clarinet, Ohio State Univ., Columbus, OH. Contact: Keith Koons, Music Dept., Univ. of Central Florida, P.O. Box 161354, Orlando, FL 32816-1354; Tel.: 407-823-5116; Email: kkons@pegasus.cc.ucf.edu

9-14 August: International Acoustic Emission Conference, Hawaii, HI. Contact: Karyn S. Downs, Lockheed Martin Astronautics, PO Box 179, M.S. DC3005, Denver, CO 80201; Tel: 303-977-1769; Fax: 303-971-7698; Email: karyn.s.downs@lmco.com

7-9 September: Nordic Acoustical Society Meeting 98, Stockholm, Sweden. Contact: Swedish Acoustical Society, c/o Ingemansson AB, Box 47321, 10074 Stockholm, Sweden; Fax:+46 818 2678; Email: nam98@ingemansson.se

13-17 September: American Academy of Otolaryngology--Head and Neck Surgery, San Francisco, CA. Contact: American Academy of Otolaryngology--Head and Neck Surgery, One Prince St., Alexandria, VA 22314. Tel.: 703-836-4444; FAX: 703-683-5100.

14-16 September: Biot Conference on Poromechanics, Louvain-la-Neuve, Belgium. Contact: J.F. Thimus, Unité de 0201; Email: noisecon98@aol.com; WWW: users.aol.com /noisecon98/nc98_cfp.html

14-18 September: 35th International Conference on Ultrasonics and Acoustic Emission, Chateau of Treste, Czech Republic. Contact: H. Kotschova, Geophysical Institute, AS Bocni II/401, 14131 Prague 4, Czech Republic; Fax: +42 2 761 549; Email: hko@ig.cas.cs; Web: www.ig.cas.cz

12-16 October: 136th meeting of the Acoustical Society of America, Norfolk, VA. Contact: ASA, 500 Sunnyside Blvd., Woodbury, NY 11797, Tel.: 516-576-2360; FAX: 516-576-2377; Email: asa@aip.org; WWW: http://asa.aip.org

18-22 mai: 7e Étude de printemps sur l'acousto-optique et ses applications, Gdansk, Pologne. Info: B. Linde, Institute of Experimental Physics, University of Gdansk, ul. Wita Stwosza 57, 80-952 Gdansk, Poland; Fax: +48 58 41 31 75; Email: school@uni.gda.pl

25-27 mai: Bruit et planification 98, Naples, Italie. Info: Noise and Planning, Via Bragadino 2, 20144 Milano, Italy, Fax: +39 248018839; Email: md1467@cmlink.it

8-10 juin: Symposium EAA/EEAA "Bruit et vibrations des transports", Tallinn, Estonia. Info: East-European Acoustical Association, Moskovskoe Shosse 44, 196158 St. Petersburg, Russia; FAX: +7 812 127 9323; Email: krylspb @sovam.com

9-12 juin: 8e conférence internationale sur les vibrations main-bras, Umea, Suède. Info: National Inst. for Working Life, Physiology and Technology Dept., P.O. Box 7654, 90713 Umea, Sweden; Fax: +46 90 165027; Email: hav98@niwl.se

22-26 juin: 135e rencontre de l'Acoustical Society of America/16e congrès international d'acoustique, Seattle, WA. Info: ASA, 500 Sunnyside Blvd., Woodbury, NY 11797, Tél.: 516-576-2360; FAX: 516-576-2377; Email: asa @aip.org; WWW: http://asa.aip.org

26 juin - 1 juillet: Symposium international sur l'acoustique de la musique, ISMA 98, Leavenworth, WA. Info: Maurits Hudig, Catgut Acoustical Society, 112 Essex Ave., Montclair, NJ 07042, Fax: 201-744-9197; Email: catgutas@msn.com, WWW: www.boystown.org/isma98

7-12 juillet: Vienne et la clarinette, Ohio State Univ., Columbus, OH. Info: Keith Koons, Music Dept., Univ. of Central Florida, P.O. Box 161354, Orlando, FL 32816-1354; Tél.: 407-823-5116; Email: kkons@pegasus.cc.ucf.edu

9-14 août: Conférence internationale sur les émissions acoustiques, Hawaii, HI. Info: Karyn S. Downs, Lockheed Martin Astronautics, PO Box 179, M.S. DC3005, Denver, CO 80201; Tél: 303-977-1769; Fax: 303-971-7698; Email: karyn.s.downs@lmco.com

7-9 septembre: Rencontre de la Société nordique d'acoustique, Stockholm, Suède. Info: Swedish Acoustical Society, c/o Ingemansson AB, Box 47321, 10074 Stockholm, Sweden; Fax: +46 8182678; Email: nam98@ingemansson.se

13-17 septembre: Académie américaine d'otolaryngologie - Chirurgie de la tête et du cou, San Francisco, CA. Info: American Academy of Otolaryngology--Head and Neck Surgery, One Prince St., Alexandria, VA 22314. Tél.: 703-836-4444; FAX: 703-683-5100.

14-16 septembre: Conférence Biot sur la poro-mécanique, Louvain-la-Neuve, Belgique. Info: J. F. Thimus, Unité de Génie civil, Université catholique de Louvain, Place du Levant 1, 1348 Louvain-la-Neuve, Belgium; Fax: +32 10 472179; Email: biotconf@gc.ucl.ac.be; Web: www.gc.ucl .ac.be/gc/geotech/geoma.html

14-18 septembre: 35e Conférence internationale sur les ultrasons et les émissions acoustiques, Château de Treste, République Tchèque. Info: H. Kotschova, Geophysical Institute, AS Bocni II/401, 14131 Prague 4, Czech Republic; Fax: +42 2 761 549; Email: hko@ig.cas.cs; Web: www.ig.cas.cz

12-16 octobre: 136e rencontre de l'Acoustical Society of America, Norfolk, VA. Info: ASA, 500 Sunnyside Blvd., Woodbury, NY 11797, Tél.: 516-576-2360; FAX: 516-576-2377; Email: asa@aip.org; WWW: http:// asa.aip.org

16-18 November: Inter-Noise 98, Christchurch, New Zealand. Contact: New Zealand Acoustical Society, P.O. Box 1181, Auckland, New Zealand.

20 November: Recreational Noise, Queenstown, New Zealand. Contact: P. Dickenson, NZ Ministry Health, PO Box 5013, Wellington, New Zealand; Fax: +64 4 496 2340; Email: philip.dickenson@mohwn.synet.net.nz

23-27 November: ICBEN 98: Biological Effects of Noise, Sydney, Australia. Contact: N. Carter, NAL, 126 Greviile St., Chatswood 2067, Australia, Fax: +61 2 411 8273.

30 November - 4 December: 5th International Conference on Spoken Language Processing, Sydney, Australia. Contact: ICSLP Secretariat, Tour Hosts, GPO Box 128, Sydney, NSW 2001, Australia; Fax: +61 29262 3135; Email: tourhosts@tourhosts.com.au; WWW: http://cslab.anu.edu.au/icslp98

1999

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

15-19 March: 137th Meeting of Acoustical Society of America/European Acoustics Association Forum Acusticum, Berlin, Germany. Contact: ASA, 500 Sunnyside Blvd., Woodbury, NY 11797; Tel: 516-576-2360; Fax: 516-576-2377; Email: asa@aip.org; WWW: asa.aip.org

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

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

1-4 September: 15th International Symposium on Nonlinear Acoustics (ISNA-15), Gottingen, Germany. Contact: W. Lauterborn, Drittes Physikalisches Institut, Universitat Gottingen, Burgerstr. 42-44, 37073 Gottingen, Germany; Fax: +49 551 39 7720; Email: lb@physik3.gwdg.de
Génie civil, Université catholique de Louvain, Place du Levant 1, 1348 Louvain-la-Neuve, Belgique; Fax: +32 10 472179; Email: biotconf@gc.ucl.ac.be; Web: www.gc.ucl.ac.be/gc/geotech/geoma.html

16-18 novembre: Inter-Noise 98, Christchurch, Nouvelle-Zélande. Info: New Zealand Acoustical Society, P.O. Box 1181, Auckland, New Zealand.

20 novembre: Bruit récréatif, Queenstown, Nouvelle-Zélande. Info: P. Dickenson, NZ Ministry Health, PO Box 5013, Wellington, New Zealand; Fax: +64 4 496 2340; Email: philip.dickenson@mohwn.synet.net.nz

23-27 novembre: ICBEN 98: Effets biologiques du bruit, Sydney, Australie. Info: N. Carter, NAL, 126 Greville St., Chatswood 2067, Australia, Fax: +61 2 411 8273.

30 novembre- 4 décembre: 5e conférence internationale sur le traitement de la langue parlée, Sydney, Australie. Info: ICSLP Secretariat, Tour Hosts, GPO Box 128, Sydney, NSW 2001, Australia; Fax: +61 2 9262 3135; Email: tourhosts@tourhosts.com.au; WWW: http://cslab.anu.edu.au/icslp98

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

15-19 mars: 137e Rencontre de l'Acoustical Society of America et de l'Association d'acoustique européenne Forum Acusticum, Berlin, Allemagne. Info: ASA, 500 Sunnyside Blvd., Woodbury, NY 11797; Tél: 516-576-2360; Fax: 516-576-2377; Email: asa@aip.org; WWW: asa.aip.org

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

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

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

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Architectural acoustics	1	Acoustique architecturale
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Physical Acoustics / Ultrasonics	3	Acoustique physique / Ultrasons
Musical Acoustics / Electroacoustics	4	Acoustique musicale / Electroacoustique
Psycho- and Physio-acoustics	5	Psycho- et physio-acoustique
Shock and Vibration	6	Chocs et vibrations
Hearing Sciences	7	Audition
Speech Sciences	8	Parole
Underwater Acoustics	9	Acoustique sous-marine
Signal Processing / Numerical Methods	10	Traitement des signaux / Méthodes numériques
Other	11	Autre

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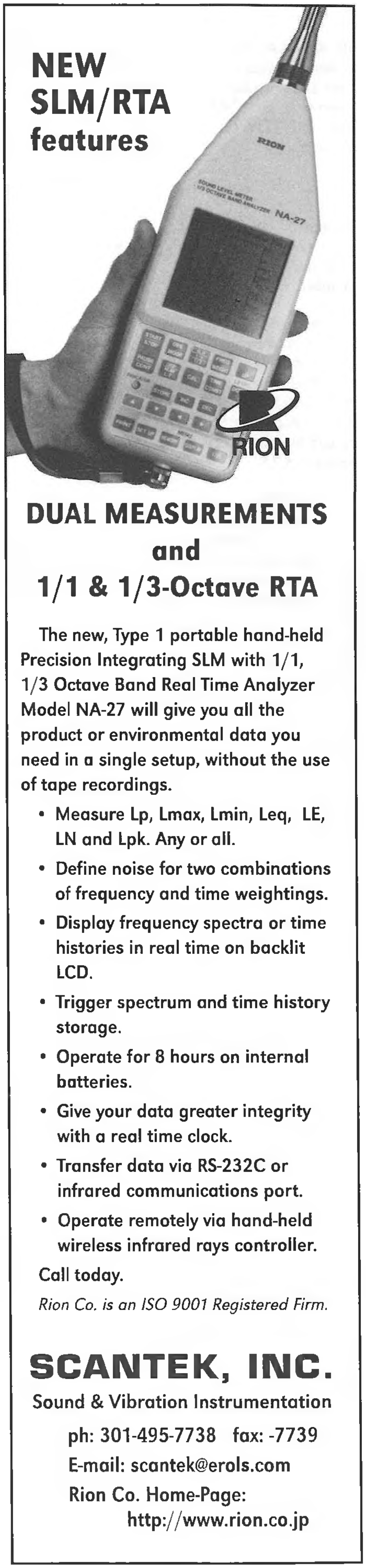

The Canadian Acoustical Association
l'Association Canadienne d'Acoustique

ANNONCE DE PRIX

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

PRIX POST-DOCTORAL EDGAR ET MILLICENT SHAW EN ACOUSTIQUE

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

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

PRIX ÉTUDIANT ALEXANDER GRAHAM BELL EN COMMUNICATION VERBALE ET ACOUSTIQUE COMPORTEMENTALE

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

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

PRIX ÉTUDIANT FESSENDEN EN ACOUSTIQUE SOUS-MARINE

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

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

PRIX ÉTUDIANT ECKEL EN CONTROLE DU BRUIT

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

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

PRIX DES DIRECTEURS

Trois prix sont décernés, à tous les ans, aux auteurs des trois meilleurs articles publiés dans l'*Acoustique Canadienne*. Tout manuscrit rapportant des résultats originaux ou faisant le point sur l'état des connaissances dans un domaine particulier sont éligibles; les notes techniques ne le sont pas. Le premier prix, de $500, est décerné à un(e) étudiant(e) gradué(e). Le deuxième et le troisième prix, de $250 chacun, sont décernés à des auteurs professionnels âgés de moins de 30 ans et de 30 ans et plus, respectivement. Coordonnateur: David Quirt, Section d'acoustique, Institut de Recherche en Construction, NRCC, Ottawa, ON K1A 0R6.

PRIX DE PRESENTATION ÉTUDIANT

Trois prix, de $500 chacun, sont décernés annuellement aux étudiant(e)s sous-gradué(e)s ou gradué(e)s présentant les meilleures communications lors de la Semaine de l'Acoustique Canadienne. La demande doit se faire lors de la soumission du résumé. Coordonnateur: Alberto Behar, 45 Meadowcliffe Drive, Scarborough, ON M1M 2X8.

The Canadian Acoustical Association
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PRIZE ANNOUNCEMENT

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

EDGAR AND MILLICENT SHAW POSTDOCTORAL PRIZE IN ACOUSTICS

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

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

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

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

1990	*Bradley Frankland*	*Dalhousie University*	*1994*	*Michael Lantz*	*Queen's University*
1991	*Steven D. Turnbull*	*University of New Brunswick*	*1995*	*Kristina Greenwood*	*University of Western Ontario*
	Fangxin Chen	*University of Alberta*	*1996*	*Mark Pell*	*McGill University*
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FESSENDEN STUDENT PRIZE IN UNDERWATER ACOUSTICS

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

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

ECKEL STUDENT PRIZE IN NOISE CONTROL

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

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

DIRECTORS' AWARDS

Three awards are made annually to the authors of the best papers published in *Canadian Acoustics*. All papers reporting new results as well as review and tutorial papers are eligible; technical notes are not. The first award, for $500, is made to a graduate student author. The second and third awards, each for $250, are made to professional authors under 30 years of age and 30 years of age or older, respectively. Coordinator: David Quirt, Acoustics Section, Institute for Research in Construction, NRCC, Ottawa, ON K1A 0R6.

STUDENT PRESENTATION AWARDS

Three awards of $500 each are made annually to the undergraduate or graduate students making the best presentations during the technical sessions of Acoustics Week in Canada. Application must be made at the time of submission of the abstract. Coordinator: Alberto Behar, 45 Meadowcliffe Drive, Scarborough, ON M1M 2X8.

INSTRUCTIONS TO AUTHORS FOR THE PREPARATION OF MANUSCRIPTS

Submissions: The original manuscript and two copies should be sent to the Editor-in-Chief.

General Presentation: Papers should be submitted in camera-ready format. Paper size 8.5" x 11". If you have access to a word processor, copy as closely as possible the format of the articles in Canadian Acoustics 18(4) 1990. All text in Times-Roman 10 pt font, with single (12 pt) spacing. Main body of text in two columns separated by 0.25". One line space between paragraphs.

Margins: Top - title page: 1.25"; other pages, 0.75"; bottom, 1" minimum; sides, 0.75".

Title: Bold, 14 pt with 14 pt spacing, upper case, centered.

Authors/addresses: Names and full mailing addresses, 10 pt with single (12 pt) spacing, upper and lower case, centered. Names in bold text.

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Page numbers: In light pencil at the bottom of each page.

Reprints: Can be ordered at time of acceptance of paper.

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Soumissions: Le manuscrit original ainsi que deux copies doivent être soumis au rédacteur-en-chef.

Présentation générale: Le manuscript doit comprendre le collage. Dimensions des pages, 8.5" x 11". Si vous avez accès à un système de traitement de texte, dans la mesure du possible, suivre le format des articles dans l'Acoustique Canadienne 18(4) 1990. Tout le texte doit être en caractères Times-Roman, 10 pt et à simple (12 pt) interligne. Le texte principal doit être en deux colonnes séparées d'un espace de 0.25". Les paragraphes sont séparés d'un espace d'une ligne.

Marges: Dans le haut - page titre, 1.25"; autres pages, 0.75"; dans le bas, 1" minimum; latérales, 0.75".

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