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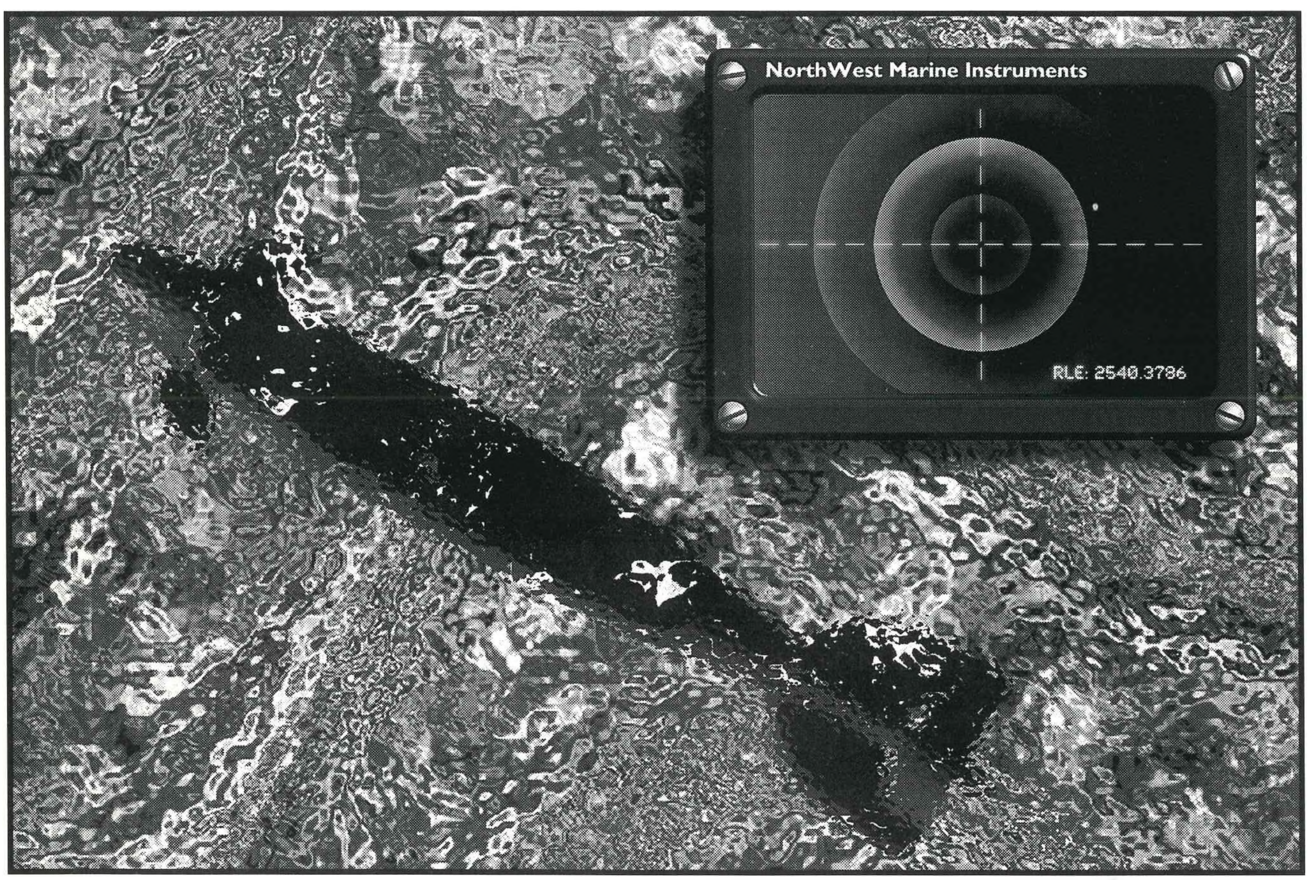

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CANADIAN ACOUSTICS publishes refereed articles and news items on all aspects of acoustics and vibration. Articles reporting new research or applications, as well as review or tutorial papers and shorter technical notes are welcomed, in English or in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

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

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MESSAGE FROM THE NEW PRESIDENT

To accept to be president of an association such as ours is to try to satisfy the aspirations of its members. In this regard, may I warmly congratulate Dave Chapman on your behalf for his effective contribution as president over the past two years. The vitality of the Association was clearly perceptible at the Toronto conference. Patient and generous work on the part of the organizers allowed more than 100 of us to share not only the results of research but also professional technical and, indeed, cultural preoccupations.

At the annual general meeting, several members expressed the desire to see the CAA become more involved in public affairs. This desire seems to me all the more appropriate when, in these times of great debate on problems of pollution, the accoustical environment is ignored, even though the stakes are high. Whether it be with respect to the lack of sensitivity to the risks and consequences of hearing loss due to noise exposure, problems of quality of life related to community noise, the accessibility of public places and services to hard-of-hearing persons, etc., the high stakes are obvious to acousticians.

I therefore support the aspirations of those members who want the CAA to increase its visibility and social relevance by becoming more involved with activities to increase public awareness of these problems. However, we must not simply improvise; it is by concentrating our resources and interests on priority questions that we will achieve our objective. In the first place, our visibility depends above all on the quality of our contributions to *Canadian Acoustics*. The invitation is urgent!

UN MOT DU NOUVEAU PRÉSIDENT

Accepter d'être président d'une association comme la nôtre signifie de tâcher d'être à la hauteur des aspirations de ses membres. A cet égard, je me fais votre porte-parole pour féliciter chaleuresement David Chapman pour sa contribution efficace comme président au cours des duex années passées. La vitalité de l'Association était bien perceptible lors du congrès de Toronto. Un travail patient et généreux de la part des organisatrices et organisateurs a permis à plus d'une centaine d'entre nous de partager non seulement des résultats de recherche mais aussi des préoccupations d'ordre professionnel, technique, voire culturel.

Lors de l'assemblée générale, plusieurs membres ont exprimé le désir de voir l'ACA s'impliquer davantage auprès du public. Cette volonté m'apparaît d'autant plus légitime qu'à l'heure des grands débats sur les problèmes de pollution, la question de l'environnement sonore fait figure de parent pauvre. Pourtant, ce ne sont pas les enjeux qui manquent en cette matière. Que ce soit le manque de sensibilisation aux risques de vie liée au bruit communautaire, la promotion de produits de consommation non bruyants, l'accessibilité des lieux et services publics pour les acousticiennes et acousticiens. Je souscris donc au souhait des membres qui veulent que l'ACA accroisse sa visibilité et sa pertinence sociale en s'impliquant davantage dans des activités de sensibilisation de divers publics. Mais, la mise en valeur de nos expertises exclut l'improvisation. C'est en conjuguant nos resources et nos intérêts autour de questions prioritaires que nous parviendront à atteindre cet objectif. Dans l'immédiat, notre visibilité dépend surtout de la qualité de nos contributions à l'*Accoustique Canadienne*. L'invitation est pressante!

NOTE FROM THE EDITOR

On pages 17-26 of this issue are published five two-page summaries of papers presented during Acoustics Week in Canada 1993. They were received too late to be included in the September Proceedings Issue.

MOT DU RÉDACTEUR EN CHEF

Aux pages 17-26 de ce numéro sont publiés cinq sommaires de conférences presentées lors de la Semaine Canadienne d'Acoustique 1993. On les a reçus trop tards pour les inclure dans le Cahier des Actes du mois de septembre.

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RAPID CALCULATION OF PROPAGATION PATH INFORMATION BY APPLICATION OF THE METHOD OF IMAGES

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ABSTRACT

Many problems in underwater acoustics require rapid computation of acoustic path information. Inversions that employ simulated annealing and Monte Carlo minimization techniques may require the computation of millions of acoustic paths for application to a problem. This paper describes the application of the method of images for rapidly computing propagation path lengths, time differences, and other path details between an acoustic source and a receiving hydrophone in a uniformly sloping ocean environment. The problem is kept simple by considering only a constant sound-speed profile. This assumption limits the applicability of the method. To test the accuracy of the method, expressions for the error are developed for a particular environment that represents a severe case. The constant-sound-speed calculations are shown to result in sufficient accuracy that they may be applied to short-range, steep-angle propagation problems.

SOMMAIRE

Beaucoup de problèmes dans le domaine de l'acoustique sousmarine exigent le calcul rapide d'informations portant sur les trajets acoustiques. Les inversions qui emploient des techniques de recuit simulé et de la minimalisation de Monte Carlo peuvent nécessiter le calcul de millions de trajets acoustiques pour qu'elles s'appliquent à un problème. Dans cette étude nous décrivons l'application de la méthode d'images pour le calcul rapide de longueurs des trajets de propagation, des différences temporelles et d'autres détails concernant les trajets entre une source acoustique et un hydrophone de réception dans un environnement océanique à pente uniforme. Nous facilitons le problème en ne considérant qu'un profil de vitesse du son constante. Cette supposition limite l'applicabilité de la méthode. Afin d'éprouver l'exactitude de la méthode, des expressions pour l'erreur sont développées visant un environnement particulier qui représente un cas sévère. Nous démontrons que les calculs utilisant une vitesse du son constante ont pour résultat une exactitude suffisante pour que l'on puise les appliquer aux problèmes de propagation de portée courte et d'angle raide.

1 INTRODUCTION

The solution of an acoustic problem may require the determination of acoustic propagation path details for thousands to millions of separate ray-paths. A specific example is the determination of an array's location from propagation time differences. The array's location can be determined by minimizing cost functions whose independent variables are the measured time differences for different propagation paths. Problems of this kind may be solved using simulated annealing and Monte Carlo minimization techniques[1]. Such problems require efficient path determination algorithms to allow the solution to be attained in a reasonable time period. When dealing with this kind of problem there is strong motivation to reduce the complexity of the acoustic modelling and, hence, reduce the computation overhead. This paper describes one method of reducing the computational load in determining acoustic path details such as path length, grazing angle, and range to bottom and surface interactions. The method described is the *Method of Images* and in the current form is applicable to two-

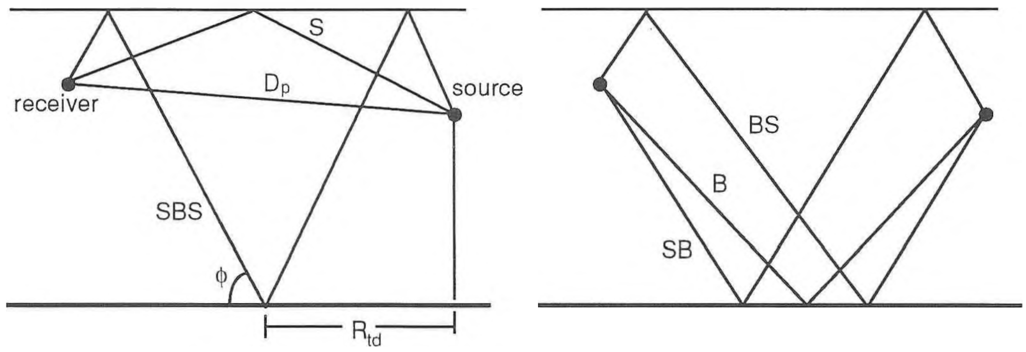

Figure 1: Definition of the primary paths of the acoustic signature.

dimensional problems with uniformly shelving sea-floor. The method described could handle three-dimensional problems with inclined flat bottoms, but extensions of this kind are not considered in this paper. The method implicitly assumes that the ocean sound-speed is constant, so that ray paths can be represented by straight lines. This constant-sound-speed approximation results in a degree of error that generally limits the use of the method to problems involving short-range, steep-angle propagation.

The following section defines the path names and variables, and describes an ocean environment which has a smooth sea-floor that may be inclined with respect to the ocean surface. In Section 3 equations are developed for the apparent source or receiver position in terms of matrix operators that are easily implemented on digital computers. Path parameters are extracted from the position vectors and the errors in using the method of images as opposed to a more accurate ray-tracing scheme are investigated. In Section 4 the method is applied to the interpretation of a marine seismic data stack. Finally, in Section 5 the application and limitations of the method are summarized.

2 PROBLEM DEFINITION

The primary acoustic paths between a source and receiver include the direct, bottom-bounce, and surface-bottom interactions. These paths are denoted by D_p, S, B, SB, BS, and SBS as defined in Fig. 1. The goal of this note is to develop equations for computing the path lengths, propagation times, and other details of these primary acoustic paths. Higher orders of bottom bounces are possible in practice and the equations developed here can be used to determine the details associated with them. In general it will be found that the method is limited to short ranges, and therefore most directly applicable to the primary paths.

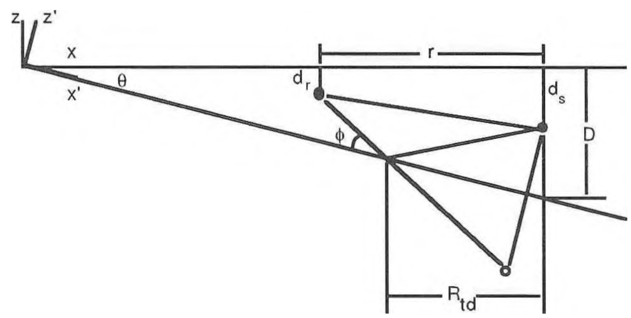

Figure 2: Geometry of the problem. The ocean bottom is assumed to be uniformly sloping at angle θ with respect to the horizontal.

Figure 2 shows the geometry of the problem. The source is located on the right-hand side of the figure and the receiver on the left. This figure also defines the symbols used in this note. To be specific, d_s is the depth of the source, d_r is the depth of the receiver, and D is the depth of the ocean at the source location. The symbol r is used to denote the horizontal range between the source and the receiver, while R_{td} denotes the horizontal range to the point where the ray *touches down*. The ocean bottom makes an angle θ with the horizontal and the angle ϕ is the grazing angle with respect to the ocean bottom. In the next section, expressions are developed to determine the path lengths, the propagation times, the grazing angle ϕ, and the range to the touch-down point R_{td}.

3 EQUATION DEVELOPMENT

The coordinate system (x, z) is relative to the ocean surface and the system (x', z') is relative to the ocean bottom. In both systems, z is positive in the upward direction. The ocean-bottom coordinate system can be obtained from the ocean-surface coordinate system by a simple rotation of angle θ about the origin. The transformation from the unprimed to the primed coordinate system is

$$\vec{P'} = \begin{pmatrix} x' \\ z' \end{pmatrix} = \mathbf{T} \cdot \vec{P} = \begin{pmatrix} \cos(\theta) & -\sin(\theta) \\ \sin(\theta) & \cos(\theta) \end{pmatrix} \cdot \begin{pmatrix} x \\ z \end{pmatrix} \quad (1)$$

In order to calculate the acoustic path details using the method of images it is necessary to determine the apparent coordinates of an image of the source and the coordinates of the receiver in the same reference system. The path length and grazing angle are then easily determined from the difference in the coordinates. Similarly, the range to a boundary interaction can be determined from the difference in the coordinates of the source (or receiver) and the coordinates of the touch-down point Q.

To see how this method is applied, consider for the moment path B. We begin by determining the position vectors for the source and receiver. Eq.(1) is then used to transform these position vectors to the ocean bottom reference system.

Referring to Fig. 2 we can see that the source location vector in the surface coordinate system is

$$\vec{P_s} = (x_s, z_s)^\dagger = (D/\tan(\theta), -d_s)^\dagger \quad (2)$$

(where the $\dagger$ denotes the transpose of the vector). Similarly, the receiver location vector is

$$\vec{P_r} = (x_r, z_r)^\dagger = (D/\tan(\theta) - r, -d_r)^\dagger \quad (3)$$

Using Eq.(1) we obtain the location vectors in the ocean-bottom coordinate system

$$\vec{P'_s} = \mathbf{T} \cdot \vec{P_s} \quad (4)$$

and

$$\vec{P'_r} = \mathbf{T} \cdot \vec{P_r} \quad (5)$$

Once these are known, we need to find the location of the source image in the ocean bottom.

A matrix imaging operator is easily determined by noting that if the source is located at $(x'_s, z'_s)^\dagger$, then the image of the source is located at $(x'_s, -z'_s)^\dagger$. The matrix operator that performs this transformation is

$$\mathbf{M} = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \quad (6)$$

If $\vec{P'_s}$ is the position of the source with respect to the bottom coordinate system, then

$$\vec{P'_{sB}} = \mathbf{M} \cdot \vec{P'_s} = \mathbf{M} \cdot \mathbf{T} \cdot \vec{P_s} \quad (7)$$

is the position of the image of the source in the bottom coordinate system. The path length is then given by Pythagoras' theorem as

$$L = \sqrt{(\vec{P'_{sB}} - \vec{P'_r})^\dagger \cdot (\vec{P'_{sB}} - \vec{P'_r})} \quad (8)$$

The travel time is then just

$$t = \frac{L}{c} \quad (9)$$

where c is the speed of sound.

Consider now path S. For this path the imaging operation occurs at the ocean surface and it is not necessary to transform the locations to the ocean-bottom coordinate system. We merely find the image of the source in the surface and apply Pythagoras' theorem:

$$\vec{P_{sS}} = \mathbf{M} \cdot \vec{P_s} \quad (10)$$

and

$$L = \sqrt{(\vec{P_{sS}} - \vec{P_r})^\dagger \cdot (\vec{P_{sS}} - \vec{P_r})} \quad (11)$$

By combining the procedures for a surface and bottom reflection in the proper order, it is possible to compute the apparent source position for any number of surface and bottom reflections. For path SB the sequence of operations is

$$\vec{P'_{sSB}} = \mathbf{M} \cdot \mathbf{T} \cdot \mathbf{M} \cdot \vec{P_s} \quad (12)$$

For path BS the bottom imaging is done before the surface imaging. The sequence of operations would be

$$\vec{P'_{sBS}} = \mathbf{T} \cdot \mathbf{M} \cdot \mathbf{T}^{-1} \cdot \mathbf{M} \cdot \mathbf{T} \cdot \vec{P_s} \quad (13)$$

For path SBS the sequence of operations would be

$$\vec{P'_{sSBS}} = \mathbf{T} \cdot \mathbf{M} \cdot \mathbf{T}^{-1} \cdot \mathbf{M} \cdot \mathbf{T} \cdot \mathbf{M} \cdot \vec{P_s} \quad (14)$$

This application of imaging and rotation operators can be repeated indefinitely to obtain the apparent source position for paths with any number of bottom bounces. The path lengths and propagation times are then found by substitution for $\vec{P'_{sB}}$ in Eq.(8) and application of Eq.(9).

For those paths (B, SB, SBSB, etc.) that interact with the bottom immediately before reception at the receiver, the grazing angle ϕ at the last bottom interaction is determined from

$$\phi = \arctan\left(\frac{z'_s + z'_r}{x'_s - x'_r}\right) \quad (15)$$

where the x' and z' are the apparent ocean-bottom coordinates that result from the application of an appropriate sequence of imaging and rotation operators. For those paths that last interact with the surface (S, BS, etc.), the last surface grazing angle can be determined using Eq.(15) with ocean-surface coordinates substituted for the primed x and z coordinates. The determination of grazing angles at earlier boundary interactions can be done by applying operators to both the source and receiver and working toward the interaction point, Q, that is of interest.

For path B, the position of the touch-down point, Q, in the ocean-bottom coordinate system is

$$\vec{Q}' = \left(x'_s - \frac{z'_s}{\tan(\phi)}, 0 \right)^{\dagger} \tag{16}$$

This vector can be transformed to the ocean-surface coordinate system to obtain the touch-down range and the water depth at that range

$$R_{td} = x_s - x_Q \tag{17}$$

and

$$D_{td} = -z_Q \tag{18}$$

The touch-down range for more complicated paths is obtained by working toward the interaction region of interest, at point Q, from both the source and receiver. An intermediate position vector $\vec{q}'$ is then determined from the apparent source image location and the grazing angle. The vector $\vec{Q}$ is obtained by transforming the intermediate result to the ocean-surface coordinate system, and the difference between the x-components of the actual source position and the apparent image source position is added to x-component of $\vec{q}$. This addition to the x-component is necessary because each bottom interaction has the effect of moving the apparent source position closer to the origin. Eq.(18) can then be used to obtain the touch-down range and the water depth at that range.

In order to determine the limit of applicability of the iso-speed assumption an expression has been developed for the difference between the touch-down range from a straight ray path geometry and the touch-down range determined by ray-tracing [2]. A second expression was developed for the difference in the grazing angles. Both of these expressions were developed for the case of the source located at the surface of the ocean and for a horizontal ocean bottom.

Telford [2] gives the range to the touch-down point as

$$X(p) = \int_{d_s=0}^{D} \frac{pV(z)}{\sqrt{1 - p^2 V(z)^2}}\, dz \tag{19}$$

where p is the ray parameter $p = \sin\theta / V(z_s)$ (θ here is the angle of incidence), V(z) is the sound speed, and z is the depth. The range to the touch-down point for

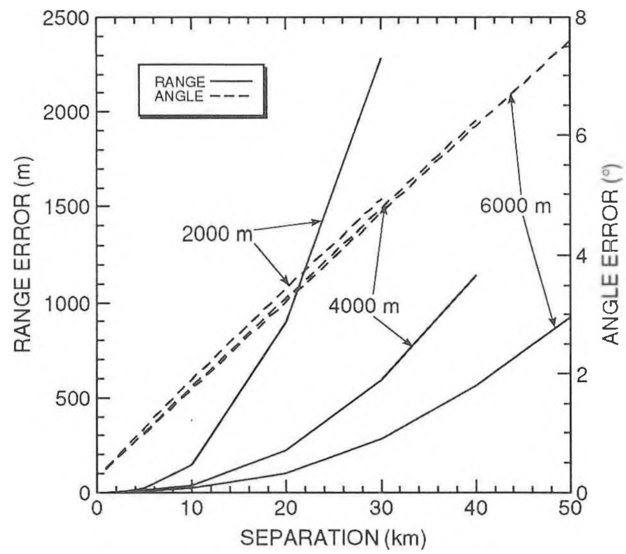

Figure 3: Error versus source-receiver separation for an idealized Arctic sound-speed profile.

a constant sound-speed environment with the source at the surface and a horizontal bottom is

$$R_{td} = Dr / (2D - d_r) \tag{20}$$

So the range error in using the straight line approximation is

$$E_{td} = R_{td} - X(p) \tag{21}$$

where p, the ray parameter must be determined for the eigenray of interest. The quantity E_{td} must in general be evaluated numerically for a particular sound-speed profile. An illustrative case is obtained when $V(z)$ is a linear profile that could represent an idealized Arctic sound-speed profile. Such an environment is a severe case, since upward refraction occurs at all locations within the water column. Typical sofar channel environments tend to result in less error for shallow sources, because the ray paths undergo an inflection. If $V(z) = az + b$, then $X(p)$ can be evaluated analytically

$$X(p) = \frac{\sqrt{1 - b^2p^2}}{ap} - \frac{\sqrt{1 - b^2p^2 - 2abDp^2 - a^2D^2p^2}}{ap} \tag{22}$$

where for an Arctic profile $a = 0.0164$ and $b = 1450$ (note that if $a = 0.$, then the sound-speed is constant and Eq.(19) reduces to Eq.(20) resulting, as it should, in $E_{td} = 0.$).

In similar fashion, the grazing angle for the ray-tracing case is $\phi(p) = 90 - \arccos\sqrt{1 - p^2V(D)^2}$ and for the constant sound-speed case the grazing angle is $\gamma = \arctan\frac{2D - d_r}{r}$. The error in grazing angle is given by the difference

$$E_\phi = \gamma - \phi \tag{23}$$

Figure 3 shows the errors in range and grazing angle with the idealized Arctic sound-speed profile for 2000, 4000, and 6000 m ocean depths. In all three cases the source is located at the surface and the receiver is at 1000 m depth. Range errors are seen to grow more rapidly as the source-receiver separation is increased. The steeper the angle of propagation the smaller the range error becomes. If a 200 m range error can be tolerated, then it is seen that the maximum allowable source-receiver separation goes from 11–26 km as the ocean depth is increased from 2000–6000 m under the current conditions. For many practical sound-speed profiles greater ranges will be permissable. Angle error is seen to increase almost linearly with source-receiver separation and is almost independent of the ocean depth.

4 AN EXAMPLE

A simple example is now given that illustrates the use of the method of images. Real data, collected during the WEDGEX experiment [3], is compared with the results from a signal arrival-time model based on the equations of the last section. The model calculates the time of flight from a source location to 32 receiver locations for the four components of the single bottom-bounce group of arrivals. The model implicitly incorporates dynamic moveout adjustments due to the different receiving hydrophone locations.

Figure 4 shows a marine-seismic stack of filtered data from the WEDGEX experiment carried out over the continental slope off the west coast of Vancouver Island. Modelled arrival times for the four components of the first bottom-bounce group are overlaid as dashed lines. In the example shown, agreement between the model and real data is not exact, but it is sufficient to show that the mean water depth in the bottom interaction region was approximately 1500 m and that the mean bottom-slope was 4° with depth increasing with range. This bathymetry is the opposite of what was expected and appears to be due to the presence of a shallow underwater canyon. In addition, source-receiver separation information can be obtained from the comparison, and the model serves as an interpretation aid by easing the identification of the surface interacting components.

With the development of appropriate cost functions measuring the differences between the real arrival times and the modelled results, the example given here suggests that the method of images would be useful in optimization techniques, such as simulated annealing, for determining the structure and properties of the sea floor. In such a problem involving hundreds of thousands of ray-path computations, the method of images represents a considerable saving in computation time over more exact procedures.

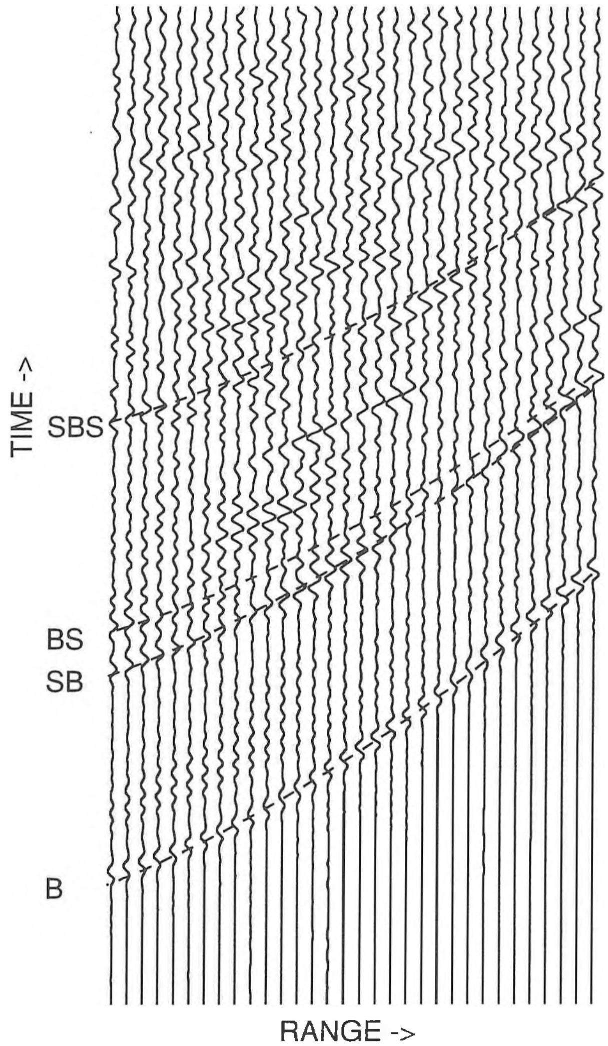

Figure 4: Comparison of a marine-seismic stack and modelled arrival times based on the equations developed in the last section. Vertical traces are from hydrophones separated by 38.1 m and represent about 1.3 seconds of data.

5 SUMMARY

In Section 3 equations describing the details of various ray-paths were developed for an iso-speed environment. The iso-speed assumption greatly simplifies the development of the equations and results in simple formulae that are particularly suited to implementation on a computer. The simplicity and the fixed rules for handling bottom and surface interactions result in fast computation times that are highly desirable for problems involving many path determinations. The constant sound-speed simplification limits the application of the equations in practical situations. Expressions were developed for the errors in range and grazing angle for an environment with monotonic upward refraction that represents a severe case. The results indicate that the method of images can be used to simplify the solution of certain acoustic problems subject to a range limitation based on the allowable errors. In many practical problems where range errors of several hundred meters and a few degrees are acceptable, the method is applicable at ranges exceeding 10 km.

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Canadian Acoustics / Acoustique Canadienne 21(4) 9-14 (1993) **Technical note / Note technique**

DAMAGE STUDY BY ACOUSTIC EMISSION: THE ROLE OF THE TRANSDUCER

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ABSTRACT

Acoustic emission is a powerful tool to study damage in materials. However, if in literature, reference is made to the energy released during the failure mechanisms, little attempts have been made to take into account the local time-varying discontinuities involved in the fracture processes. The objective of this study is to have an approach of the contribution of the source-event dynamic characteristics, and of their influence on the amplitude values of acoustic emission signals.

SOMMAIRE

L'émission acoustique est une technique largement utilisée pour l'étude de l'endommagement des matériaux. Si, dans la littérature, un intérêt particulier est porté sur l'énergie libérée durant les mécanismes de rupture, force est de constater que peu d'attention est accordée à la variation dans le temps des discontinuités locales créées lors de ces mécanismes. L'objet du présent travail est de dégager l'influence des caractéristiques dynamiques des processus de rupture sur l'amplitude des signaux d'émission acoustique.

1. INTRODUCTION

Failure processes create local strain and stress discontinuities that generate strain waves within materials. These signals propagate to the surface of the structure where they can be detected by one or an array of sensors.

If waves carry initially information about fracture mechanisms, there is a tendency for this information to be weakened through features resulting from their propagation, multiple reflections on the structure boundaries, their combinations, and also by transducers. While industrial acoustic emission (AE) applications and instrumentation developments have progressed well in recent years, the interpretation of AE signals still remains empirical and qualitative. The difficulty lies in the fact that the influence of the different parameters involved in the AE process has not yet been clarified. In this paper, the different types of AE transducers used in geotechnical applications and problems relating to their calibration will be reviewed. Then, the response of resonant transducers to a discontinuity created during microcracking will be considered.

2. ACOUSTIC-EMISSION PROCESS

Fracture mechanisms induce local mechanical discontinuities in materials. These discontinuities are responsible for a sudden release of energy stored in the cracked area. Part of the total strain energy is dissipated as transient waves that propagate from discontinuities through the medium. Acoustic emission can be considered as a system in which the input is the acoustic-emission event and the output is the acoustic-emission signal (Fig. 1).

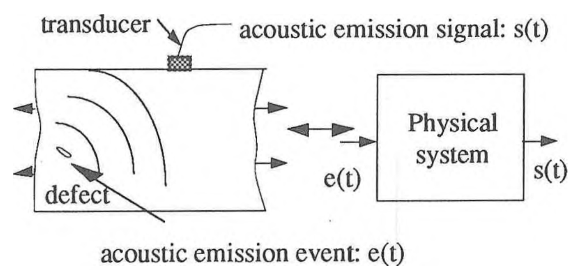

Figure 1: Acoustic emission process

It is generally known today that many materials emit AE when they are stressed or deformed. Discovery of this phenomenon led to the realization that it could be a powerful tool for detecting an AE event, localizing it and getting information on the nature of the source (crack creation or propagation). Most AE applications involve monitoring manufacturing and other dynamical processes, the integrity of structural components as well as fundamental investigations of the failure process in engineering and geological materials (Sachse et al.,1991)

The basis of AE measurement system consists of AE signal detection, conditioning, and analysis (Fig. 2). Since the problem with AE techniques is extracting from all information gathered those that are related to failure process, the role of the transducer is of a prime importance. However, many kinds of problems concerning AE transducer sensivity still remain; in particular, the precise physical meaning of the transducer mechanical-electrical conversion process makes interpretation of AE test results difficult. In the following paragraphs, a review of AE transducers used in geotechnical applications is given and the problem of their calibration is discussed.

3. ACOUSTIC EMISSION TRANSDUCERS AND THEIR CALIBRATION

The transducer converts the mechanical energy associated with an AE event into a suitable electrical signal. The detected AE signals typically range from low kHz values in geological materials to over 10 MHz in some laboratory specimens. Different types of transducers are used in geotechnical applications to detect AE activity at a specific point in the structure (Drnevich and Gray, 1981). Displacement gages are conveniently used to detect low frequency signals ($f < 1$ Hz), while accelerometers are usually employed when higher frequency signals ($f > 2000$ Hz) are involved. Signals between these extremes are picked up using velocity transducers (geophones). Hydrophones are generally not suitable as AE transducers, because they are ultra-sensitive pressure transducers and must be installed in a fluid-filled borehole. In this case, AE source location is difficult due to the composite media (fluid / rock) involved.

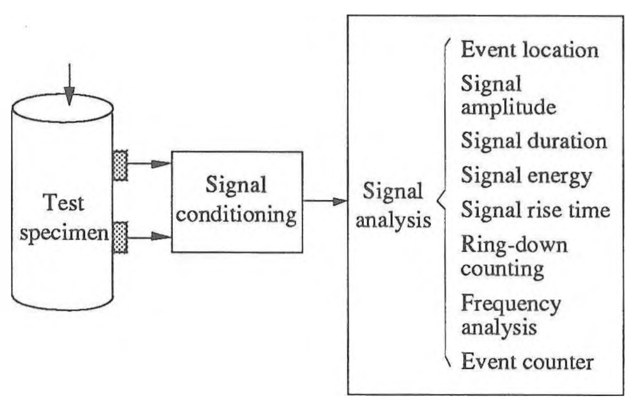

Figure 2 : Typical acoustic emission measurement system

While a number of new sensors, such as non-contacting optical and capacitance sensors as well as novel electromagnetic and embedded fiber-optic sensors, have been developed in the last decade, most laboratory studies on rupture mechanisms are still carried out with piezoelectric sensors. Ideally, the response obtained by the transducer would be the same as that obtained if the transducer were not present. This is not the case with piezoelectric transducers, so calibration is required.

AE transducer characterization has not yet been totally solved, mainly because there is no real standard event of known characteristics. Kim and Sachse (1986) and Yuyama et al (1988) indicated that the source function during the formation of a crack may be simulated by a step function with about one microsecond of rise time. Therefore, piezoelectric-transducer calibration generally consists of applying a step unloading force (glass capillary break, ball impact, pencil-lead fracture...) on the surface of a specimen and digitizing the corresponding transient response from a piezoelectric transducer located at a point on the surface of the specimen. Calibration results show that piezoelectric transducers respond both to displacement and velocity in a complex manner. Some authors (Hsu et al.,1981) have noted subjectively that piezoelectric transducers seem to respond primarily to velocity, while others (Maji et al.,1990) indicated that this assumption is valid only for the duration of the first P-wave.

It appears from this brief review of AE transducers that some questions concerning their characterization deserve more attention. Any success in accurately describing source mechanisms depends on an understanding of AE transducer functioning. The next section presents a study of the influence of transfer function of a resonant piezoelectric sensor on the AE signal characteristics.

4. IMPULSE RESPONSE OF A RESONANT TRANSDUCER

Ohtsu et al (1981 and 1982) reported a study on the source mechanisms of AE in concrete. These authors considered a transducer with a flat frequency response. In practice, acoustic-emission transducers are piezoelectric sensors with high sensivity along a narrow frequency band. The frequency response functions of the transducers are not well-defined, depending particularly on the type and incidence of the wave reaching the transducer. Another important problem lies in modelling the input of the acoustic-emission system. Ohtsu assumed that the input was the acceleration of the discontinuity created during microcracking. Previous study (Berthelot and Rhazi,1990) shows that the energy released during a fracture process depends on the type of fracture process (values of Young's modulus (E), and the average ultimate stress, σ_u, of the cracked area), on the fracture surface created (S) and on the interaction after rupture between the cracked area and the surrounding area (R_t). On the basis of these results, the case of a transducer sensitive to variations in time of the discontinuity $\Delta F(t)$ of the load in the cracked area (Fig. 3) is considered herein. The transducer input e(t) (Fig. 4.1) is therfore, except for one multiplicative factor, the derivative function of the load function (Fig. 3.1) of a duration approximately equal to the transfer time (duration of the discontinuity).

As a first approximation, this function can be represented by a rectangular time window of height a_0 and width T_f (Fig. 4.2), having the same energy as the real impulse. This approximation is equivalent to describing the discontinuity $\Delta F(t)$ as a linear function of the form (Fig. 5.1) :

$$\Delta F(t) = F_0 - \frac{dF_0}{dt} \cdot t \qquad (1)$$

of a duration $T_f = F_0 / \frac{dF_0}{dt}$. The input of an acoustic-emission system is then a window with a width T_f and a height $a_0 = \alpha \frac{dF_0}{dt} T_f$, with $\frac{dF_0}{dt}$ and T_f being the dynamic characteristic parameters of the input. Setting aside the influence of the propagation, the response function of an acoustic-emission system is identical to the transducer response.

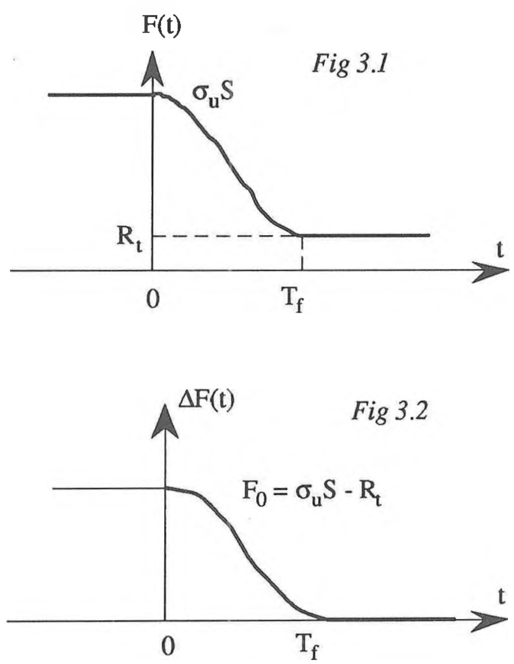

Figure 3: Variation of the local load during microcracking process

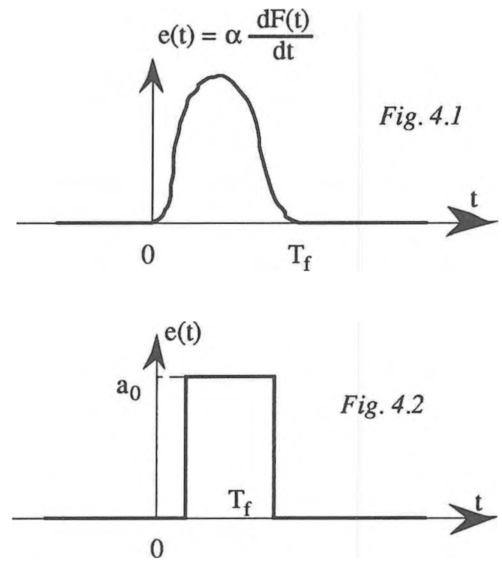

Figure 4: Input of the acoustic emission system

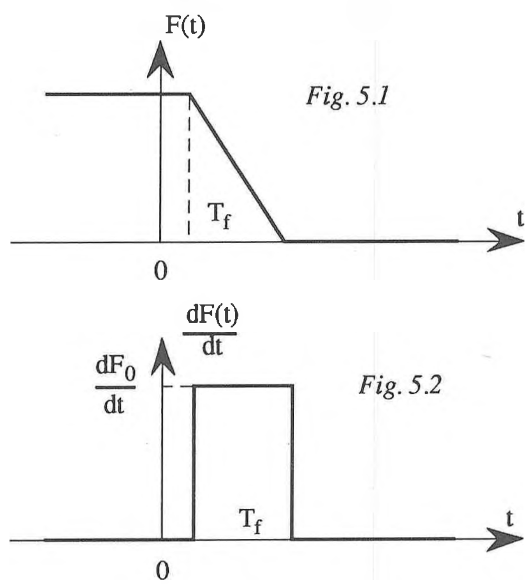

Figure 5: Variation of the load in the cracked area

The acoustic-emission transducer can reasonably be considered a resonant transducer characterized by its resonant frequency f_0, its gain factor (H_0) at frequency f_0, and its quality factor Q. The case of an ideal transducer of rectangular bandpath (Fig. 6), of height H_0, and width $\Delta f = f_0/Q$, centered on the resonant frequency is considered. To simplify calculations, it is assumed that the signal input is a rectangular window of width T_f centered on t = 0 (Fig. 7.1), and that the frequency response of the transducer is real, and composed of two symmetrical parts (Fig. 7.2).

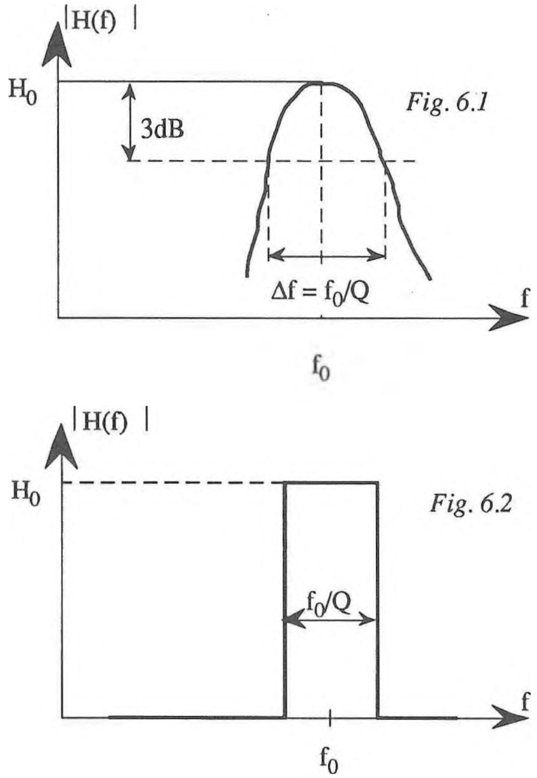

Figure 6: Real and ideal response of the transducer

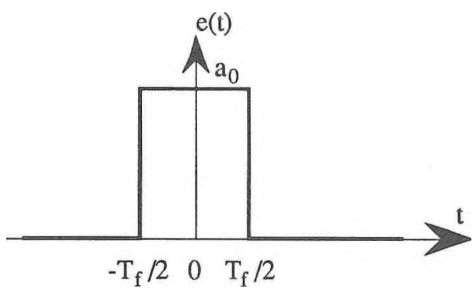

Figure 7.1: Signal input

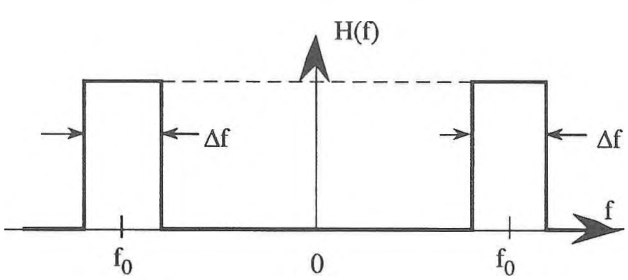

Figure 7.2: Frequency response of transducer

The Fourier transform $E(f)$ of the signal is (Fig. 7.3):

$$E(f) = a_0\, T_f \frac{\sin \pi T_f f}{\pi T_f f} \qquad (2)$$

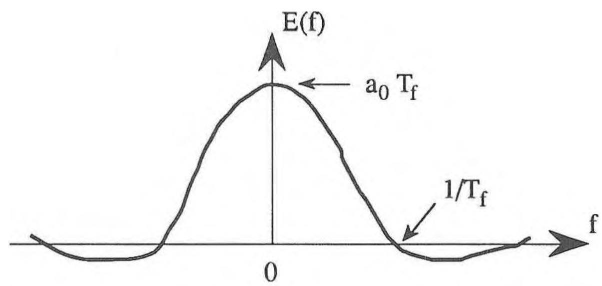

Figure 7.3: Fourier transform of signal input

The Fourier transform of the output signal can thus be expressed as:

$$S(f) = H(f).E(f)$$

and depends on the respective values of T_f and f_0 .

- If $1/T_f < f_0 - \Delta f/2 \sim f_0$, practically $H(f)\ E(f) \cong 0$. The output signal is null.

- If $1/T_f > f_0 + \Delta f/2$, the Fourier transform of the output signal comprises (Fig. 8.1) two windows of width Δf, centered on f_0 and $-f_0$, and practically equal in height to:

$$H_0 = a_0\, T_f \frac{\sin \pi T_f f_0}{\pi T_f f_0} \qquad (3)$$

The output signal (Fig. 8.2) is then obtained using the inverse Fourier transform, that is:

$$s(t) = \alpha\, H_0 \frac{dF_0}{dt} T_f \Delta f \frac{\sin \pi T_f f_0}{\pi T_f f_0} \frac{\sin \pi t \Delta f}{\pi t \Delta f} \cos 2\pi f_0 t \quad (4)$$

This result shows that the signal amplitude detected by the transducer depends on the variation of F_0 by unit of time, on its duration T_f, on the resonant frequency f_0, and on the bandwidth Δf of the transducer.

- For events of long duration, such as practically $T_f > 1/f_0$, no signals are detected by the transducer.

- For events of short duration, such as $T_f < 1/f_0$, the transducer detects signals (Fig. 8.2) for which the peak amplitude is given by:

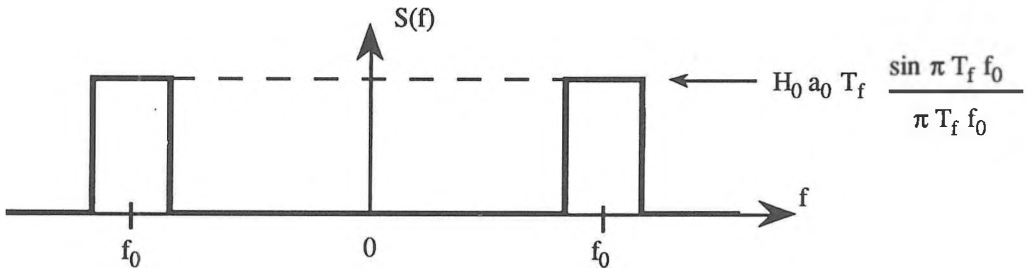

Fig. 8.1

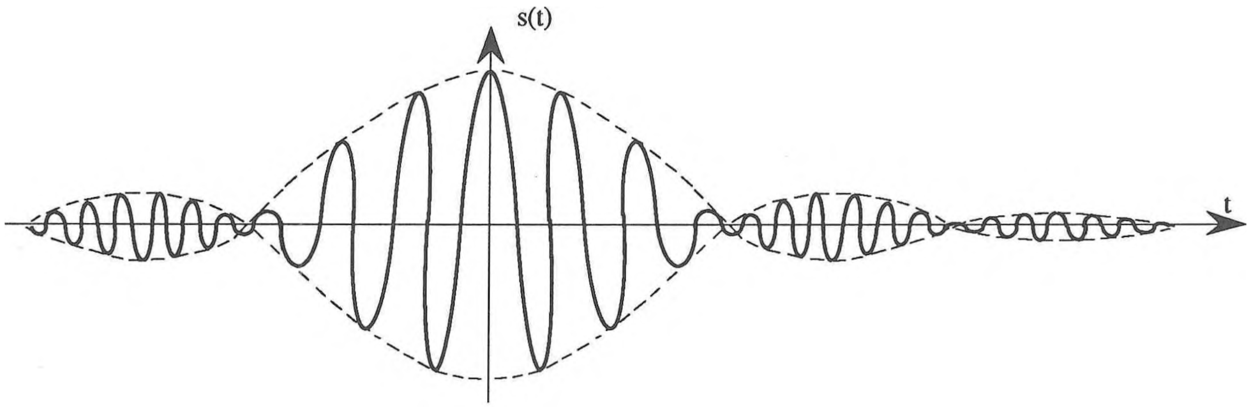

Fig. 8.2

Figure 8: Acoustic emission signal

$$s_0 = \alpha\, H_0 \frac{dF_0}{dt} T_f \Delta f \frac{\sin \pi T_f f_0}{\pi T_f f_0} \qquad (5)$$

The peak amplitude goes to a maximum for a duration T_f = $^1/_2$ f_0 of the input signal, then decreases as does T_f.

In the preceding discussion, the transducer response s(t) exists for $t < 0$. This is a result of choices made for the input signal and the response function in order to simplify calculations. In reality, the input signal begins at $t = 0$ (time of the rupture event), and the transducer response introduces a phase factor, which produces a supplementary temporal shifting t_0, that is a global shifting of the preceding output signal of $t_0 + T_f/2$. Moreover, there is no signal before $t = 0$.

5. INFLUENCE OF DYNAMICAL CHARACTERISTICS

The determining influence of an event duration can explain some experimental results published in the litterature. A few examples are given in this paragraph.

Rhazi (1987) used acoustic emission to monitor damage in five types of industrial composites: unfilled polyamide, polyamide with 0.40 mass fraction of mineral fillers and polyamide with 0.20, 0.30 and 0.50 mass fraction of glass fibres. He found that only composites of mass fraction 0.20 and 0.30 show significant acoustic activity. This result can be explained by assuming that the matrix rupture process proceeds by jumps, the average distance of which and hence the duration depends on fibre fraction. Thus, the dynamic characteristics of matrix cracking processes are adapted to those of the transducer, in the case of 0.20 and 0.30 fibre fractions.

A similar explanation can be advanced for the experimental results obtained by A.G. Benz et al (1983) in the case of particulate epoxy composites and by V.M. Malhotra (1976) in the case of concrete. These autors have studied the failure processes as a function of reinforcement size and dimension. It was observed that the acoustic activity goes to a maximum for a volume fraction which depends on the dimensions of reinforcements, but which corresponds to the same average distance between reinforcements.

6. CONCLUSION

An attempt has been made in this study to emphasize on the important aspect of the physical process involved in acoustic emission. A simplified study of the response of a resonant transducer shows that the peak amplitude of the output signal depends on the dynamic characteristics relative to the transducer and to the discontinuity created during microcracking. Thus, high fracture energy does not necessarily correlate with high signal amplitude.

It should be noted that only the case of an isolated impulse signal reaching the transducer has been dealt with. In reality, the rupture event creates longitudinal and transverse waves that propagate at different speeds and reflect on the surfaces of the structure. As a result of this, various signals, which can be relatively distorted, attenuated and dephased, arrive at the transducer. According to these phase differences, there may be a distinct modification of the amplitude of the initial impulse signal. This aspect must be kept in mind, and may help explain the relatively frequent anomalies observed in acoustic emission signals.

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COMMENTS ON "COMMON MISCONCEPTIONS ABOUT HEARING" by Marek Roland-Mieszkowski [*Canadian Acoustics*, 21(1), 27-28 (1993)]

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No doubt there are many misconceptions about human hearing that need to be clarified. This has been the object of the above Technical Note and, for that purpose, the author has used 'non-technical' language. However, most probably because of that, some not completely correct concepts have been expressed. This letter is to expand on some of them, so that a non-specialized reader would not be left with wrong concepts.

To avoid repeating the whole 'wrong' statement and its correction, I will only show the beginning of the statement and then expand over the answer:

1. **"Loud sound is not dangerous..."** - The threshold of pain can be used as a reference for instantaneous sounds. It is not related to (occupational) hearing losses resulting from long-term exposures to high-level noise. The quoted noise-level limit of 85 dBA (the 'A' should be included as well as the reference that it is for 8 hr/day exposure, 5 days a week, 40 years work life) is correct;

2. **"Hearing loss after sound exposure is temporary"** - The term "most of the hearing loss..." is incorrect. Noise-induced hearing loss is a function of the sound level and the duration of the exposure. One can be exposed to levels well in excess of 90 dBA for short times without any permanent hearing loss. One may also suffer temporary threshold shift (TTS) and will recover in no time. That is so true, that the preferred laboratory method for assessing effects from noise (that has been and is still used) involves exposing subjects to loud noises of different characteristics and measuring the resulting TTS. Therefore, the original statement regarding hearing loss is only true in certain circumstances;

3. **"Hearing loss can be repaired..."** - First of all, a loss cannot be 'repaired', because it is an effect from a damage to a part of an organ. The damage, itself, can or cannot be repaired. Surgery can today solve or ameliorate problems in the outer and middle ear. Noise-induced hearing loss results in most cases from damage of the cilia or the basilar membrane located in the inner ear. In general, damage to the inner ear cannot be repaired.

   With respect to hearing aids, conventional devices act basically as amplifiers, increasing the sound level at the tympanic membrane. However, new devices, called cochlear implants, 'replace' the cilia, sending filtered electrical signals to the terminals of the acoustical nerve. Although still in the experimental stage, they do promise a solution to the person suffering from hearing loss;

4. **"Most people like their music loud."** - A sound-level difference of 5 dB is generally perceived as twice as loud. Therefore, a difference of 15 dB will certainly be detected. Besides, at 85 dBA one can keep a conversation almost without straining one's voice. At 100 dBA, one has to virtually yell in order to be heard. Therefore, the statement that "most audiences note little perceptible difference between sound levels of 85 dB SPL and 100 dB SPL" is not correct;

5. **"Intensity range"** - Presumably, the author means 'sound-level range'. This is a common misconception; intensity is the ratio of energy flowing through an unit area. It is expressed in joule/m^2. Sound level is the logarithmic ratio of two pressures and it is expressed in dB.

L'UTILISATION DES MESURES INTENSIMÉTRIQUES EN ACOUSTIQUE ARCHITECTURALE

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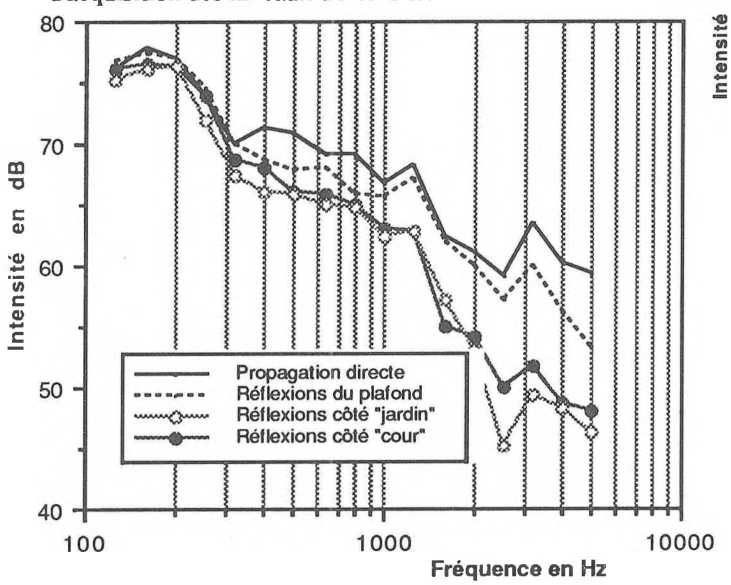
Les techniques intensimétriques ont été valorisées, depuis le début des années 80 pour leur utilisation dans le domaine de l'acoustique architecturale. Mais les principaux efforts ont porté surtout sur les problèmes de transmission ou d'isolation acoustique, afin d'analyser la radiation d'une paroi soumise au bruit, en présence ou non d'une ouverture, de même que, d'une façon plus spécialisée, sur la mesure des absorptions acoustiques [1, 2]. Du côté de l'acoustique des salles, l'analyse de la réponse impulsionnelle a continué à prévaloir, les techniques intensimétriques étant difficilement compatibles avec l'analyse temporelle. Il faut cependant mentionner le récent travail de ABDOU et GUY qui, à l'aide d'un système d'acquisition rapide des six canaux d'une sonde intensimétrique tri-dimensionnelle, sont capables de produire à la fois les informations temporelles conventionnelles (RT, EDT, C80, STI, etc.) et un relevé polaire des premières lignes de flux [3].

Différentes expériences ont été mentionnées en matière d'acoustique des salles ou des locaux industriels, avec des acquisitions directionnelles contrôlées ou bien omni-directionnelles, par la robotique ou à l'aide d'une sonde multi-dimensionnelle [4, 5, 6]. Dans des conditions de laboratoire ou en acoustique des salles, il est possible d'utiliser des sources fixes, de radiation constante dans le temps (en intensité et en directivité), cette situation corrrespond à un champ acoustique stationnaire. C'est d'ailleurs dans ces conditions qu'un système robotique peut être utilisé le plus rapidement, en réduisant à son minimum le temps d'acquisition des niveaux d'intensité.



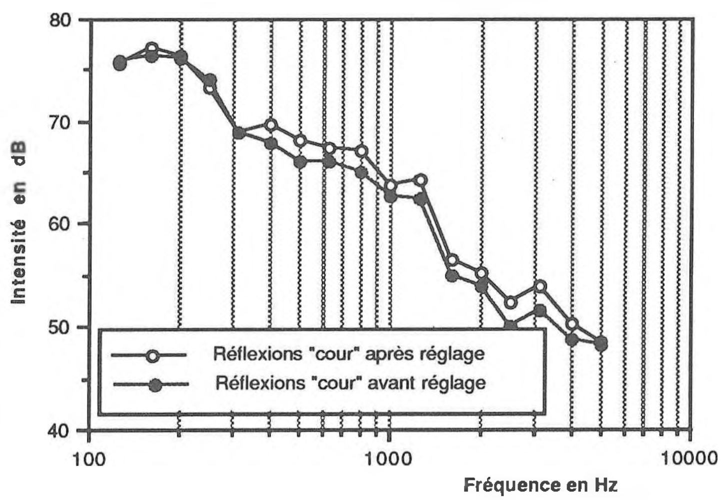
Exemple de distinction par balayage intensimétrique des différents chemins de propagation dans une salle de concert.

Il s'agit toujours d'exploiter le mieux possible les indications de directivité fournies par la nature vectorielle de l'intensité. En déterminant complètement (norme et direction) cette dernière, il est possible de localiser la provenance exacte du champ acoustique étudié et d'estimer simultanément sa contribution en énergie dans une direction donnée [7]. Quelques techniques, spécifiquement adaptées à l'acoustique architecturale, seront présentées pour l'analyse des réflexions et le bilan propagatif en différentes localisations d'une salle.

TECHNIQUE DU BALAYAGE DES SURFACES RÉFLÉCHISSANTES

Cette première technique consiste à balayer, en visant avec la sonde intensimétrique, une surface réfléchissante déterminée. En prenant certaines précautions et en moyennant la mesure pendant un temps suffisamment long, on peut obtenir une distinction très significative de la contribution des différentes parois réfléchissantes d'une salle, tant en bandes de fréquence qu'en énergie.

Une application immédiate de cette technique concerne le réglage des réflecteurs mobiles, comme le montre la figure suivante, à propos des réflecteurs d'avant-scène de la salle Louis-Fréchette du Grand Théâtre de Québec [8].



Application au réglage des réflecteurs latéraux d'avant-scène

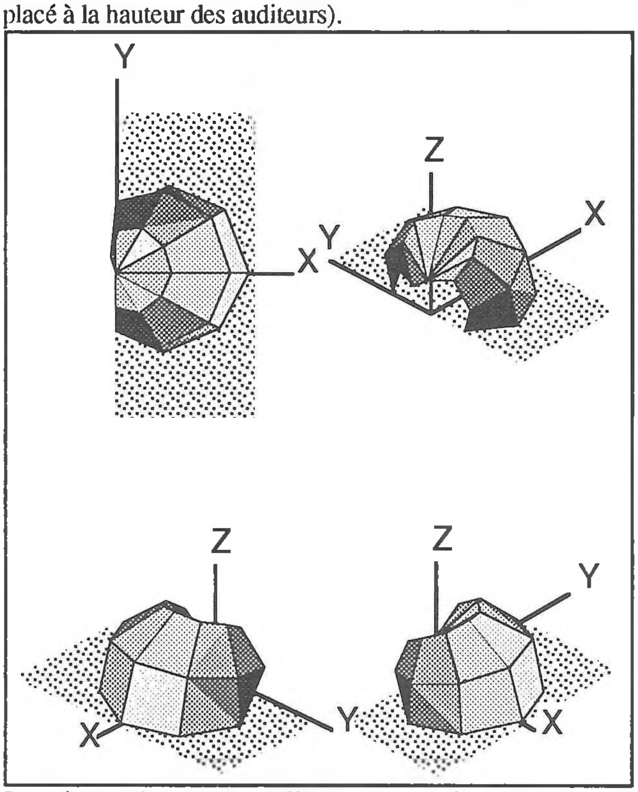
ACQUISITION ROBOTIQUE DE L'INTENSITÉ PROPAGATIVE

Le robot utilisé est construit autour de deux axes de rotation perpendiculaires entre eux, leur intersection étant placée juste au centre acoustique du doublet de microphones de la sonde. Les deux moteurs sont ramenés vers la base, afin d'agir comme contrepoids. Il peut être employé pour des relevés polaires automatiques de pas angulaire variable; le vecteur intensité composé étant toujours localisé dans un cône dont l'angle au sommet n'excède pas le pas angulaire de mesure. Les relevés polaires ont l'avantage de permettre d'interpréter convenablement tous les changements de signe.

Le temps moyen de déplacement entre deux positions de mesure est de 1 sec. et la précision de la position du centre acoustique de la sonde, dans toutes les directions de l'espace, de 1 mm. D'autre part, le robot peut être utilisé pour la recherche automatique de la ligne de flux; on peut procéder ainsi, de façon itérative, à la détermination du vecteur résultant (une procédure automatique rapide a été programmée, elle utilise un pas angulaire de 5°) [9].

APPLICATION À LA DESCRIPTION DE L'ESPACE SONORE

Les exemples qui suivent ont été relevés sur le parterre de la salle Albert Rousseau à Ste-Foy. Une source omnidirectionnelle de forte puissance a été placée au centre de la conque d'orchestre et le robot intensimétrique déplacé en différente localisation du parterre. Dans tous les cas, l'axe des X reste parallèle à l'axe principal de la salle et orienté vers la scène. Le pas de déplacement angulaire utlisé est de 30° et la procédure automatique d'acquisition programmée pour l'hémisphère supérieur (le doublet de microphones étant placé à la hauteur des auditeurs).

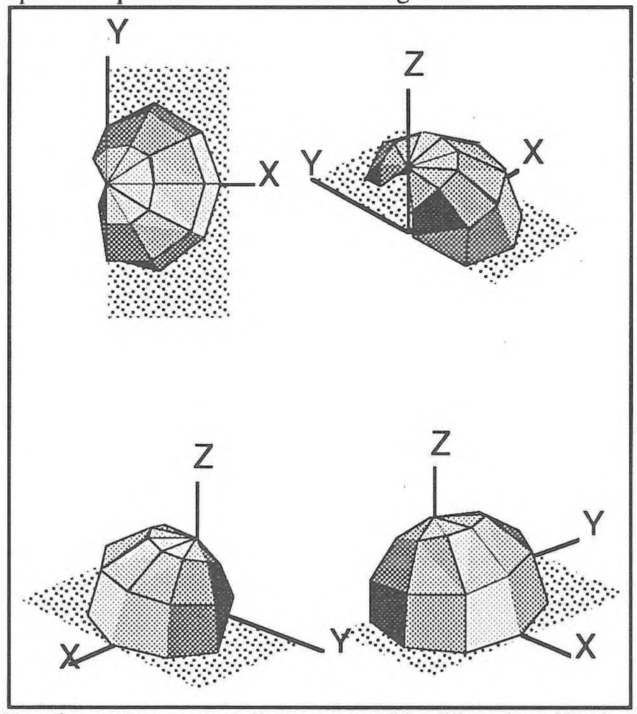


Représentation vectorielle montrant la faiblesse des réflexions du plafond (rangée "O" dans l'axe du parterre)

Le premier exemple montre, dans le fond du parterre avant les balcons, la proportion réduite des réflexions en provenance du plafond de la salle, alors que le son direct et les réflexions latérales dominent. Le second exemple, placé latéralement dans les premières rangées, montre l'influence des réflexions latérales du côté "cour", bien équilibrées cependant par le son direct, de même qu'une assez bonne efficacité des réflecteurs du plafond de la conque d'orchestre.

CONCLUSION

Les techniques intensimétriques présentées peuvent constituer un outil précieux pour l'analyse et le réglage fin des réflexions dans une salle de concert ou de spectacle, elles viennent compléter les procédures classiques de mesure de la réponse impulsionnelle ou de l'intelligibilité.



Représentation vectorielle montrant l'équilibre des réflexions latérales (rangée "EE" côté "cour")

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ENCLOSURE FOR LOW-FREQUENCY ASSESSMENT OF ACTIVE NOISE REDUCING CIRCUMAURAL HEADSETS AND HEARING PROTECTORS

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1.0 Introduction

Active Noise Reduction (ANR) technology is currently being employed in commercially available communication headsets [4]. ANR is most effective at frequencies below 1 kHz and complements the passive attenuation characteristics of conventional circumaural earcups.

Commonly used acoustic test fixtures (such as KEMAR), however, fail to provide sufficient sound isolation of the measuring microphone below 100 Hz for measuring the performance of these devices [2][3]. This can produce erroneous measurements of sound transmission. Even if adequate isolation could be achieved, there would remain the problem of generating a high-intensity sound field within a room at low frequencies.

To overcome these difficulties, an acoustic test cell has been designed for measuring the performance of ANR circumaural headsets and hearing protection devices (HPDs) at frequencies below 1000 Hz.

2.0 Design of a Low-Frequency Test Cell

The test cell is similar to that used by Shaw and Thiessen for research into passive HPDs [1]. This version, however, consists of two equal-sized chambers mounted vertically and excited by a moving-coil loudspeaker (see figure 1). The lower chamber contains the device under test while the upper chamber encloses the sound source.

To develop high sound pressure levels, the volume of the test cell must be kept as small as possible. The practical lower limit of the test cell's size is imposed by the device under test, in this case, one circumaural earcup. The maximum outer dimensions of the earcups that will be tested are approximately 110 to 120 mm. The upper and lower chambers, therefore, are constructed from aluminum tubing with an inside diameter of 200 mm and a wall thickness of 9.5 mm. Each chamber is 200 mm in length giving a total volume of 6.28×10^{-3} m^3. These dimensions allow sufficient internal space for the device under test, the clamping hardware and damping material required for the reduction of cross-modes.

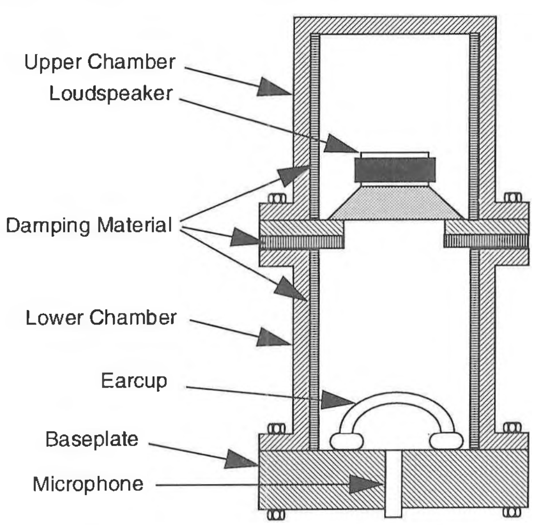

Figure 1. Low Frequency Test Cell (not to scale).

The enclosed volume is excited by a commercially available polypropylene woofer cone with an outer diameter of 150 mm. It is mounted in a rigid, 9.5 mm thick aluminum plate and is located between the upper and lower chambers of the test cell. The woofer's suspension provides a compliance equivalent to a 29.5×10^{-3} m^3 volume of air. Together with the driver's effective mass, this yields a free-air resonance of approximately 36 Hz. When the driver is mounted in the test cell (volume of 6.28×10^{-3} m^3), the test cell's compliance dominates, and the mounted resonant frequency changes to approximately 80 Hz.

The upper chamber is rigidly coupled to the loudspeaker mounting plate and the lower chamber is rigidly coupled to a massive (4 kg) baseplate using 1/4" bolts. The upper and lower chambers, however, are isolated from each other by a 1/4" layer of damping material. This reduces the transmission of vibration from the loudspeaker to the baseplate.

Measurements are performed by sealing the earcup cushion against the baseplate. The earcup contact force is controlled by a spring mechanism inside the test chamber. Sound pressure inside the earcup is measured by a 1/2" B&K 4133 microphone flush mounted in the baseplate. The earcup's transmission loss is determined by calculating the difference between the sound pressure level inside and outside the earcup. It is therefore important to ensure that the test cell does not produce any pressure nodes on the outer surface of the earcup and that adequate isolation of the microphone is provided.

3.0 Performance

The sound pressure levels measured in this test cell are quite high. For 1W electrical power input to the speaker at a frequency of 100 Hz, a sound pressure level of 134 dB re 2×10^{-5} Pa was recorded. The maximum attainable sound pressure level is determined by the maximum power rating of the loudspeaker, in this case 40W. At this power level, the sound pressure inside the test cell is 150 dB.

A measurement of sound pressure level versus frequency was made with the microphone mounted in the baseplate. The results are shown in Figure 2. The fractions shown below the plot indicate the length of the test chamber in wavelengths of various frequencies.

The acoustic behaviour of the test cell can be described in terms of lumped parameters up to a frequency at which the largest dimension approaches $\lambda/(2\pi)$. For a maximum dimension of 200 mm, this corresponds to a frequency of approximately 270 Hz.

In the lumped parameter region (frequencies below 270 Hz), the test cell exhibits a distinct low-pass filter characteristic. The cutoff frequency is determined by the driver's mounted resonance frequency of approximately 80 Hz. Above this frequency, the response exhibits a second-order, 12 dB/octave roll-off.

For frequencies above 400 Hz, wave behaviour begins to occur. The test chamber's first resonance frequency appears at approximately 650 Hz. Note that the length of the test chamber at this frequency corresponds to a standing wave between $\lambda/4$ (425 Hz) and $\lambda/2$ (850 Hz). This is because the driver's acoustic impedance is neither zero (corresponding to a pressure anti-node) nor infinite (corresponding to a pressure node).

To examine the variation of sound pressure with height above the baseplate, a probe microphone was inserted through the opening in the baseplate. The sound pressure level was recorded at heights above the baseplate from 0 to 80 mm. This range includes the maximum earcup height of 60 mm.

The measurements of sound pressure level versus height for four different frequencies are shown in figure 3. At 100 Hz, there is no change of sound pressure level with height; in fact, there is only a slight change (less than 1.5 dB) at 300 Hz. This is expected since the lumped parameter region extends to about 270 Hz.

The change in sound pressure level with height is higher for frequencies of 650 Hz and 1000 Hz; however, the reduction is still less than 15 dB up to a height of 60 mm (maximum height of typical earcup).

A final important characteristic is a measurement of indirect sound paths to the measuring microphone. To measure this, two swept-frequency measurements were made at the baseplate microphone, one with the microphone exposed to the sound field in the cavity and the other with the microphone covered by a rigid aluminum cap sealed with putty. The difference between the two measurements indicates the amount of sound which reaches the microphone indirectly. For the above configuration, indirect sound pickup was more than 60 dB below the direct sound pickup from 10 Hz to1 kHz.

4.0 Conclusions

A test cell has been constructed for low-frequency measurements of ANR circumaural headsets and HPDs. Sound pressure levels up to 150 dB at frequencies below 100 Hz may be generated within this test cell. The small dimensions of the test cell ensure that no sound pressure minima occur over the surface of the earcup. The completely sealed acoustic chamber provides sound isolation which permits the measurement of earcup attenuation to the bone conduction limit. The test cell is thus suitable for transmission loss measurements up to a frequency of 1000 Hz.

5.0 Acknowledgements

Work done in collaboration with the Defence and Civil Institute of Environmental Medicine. The authors would like to thank Mr. R. St. Denis for his assistance in this project.

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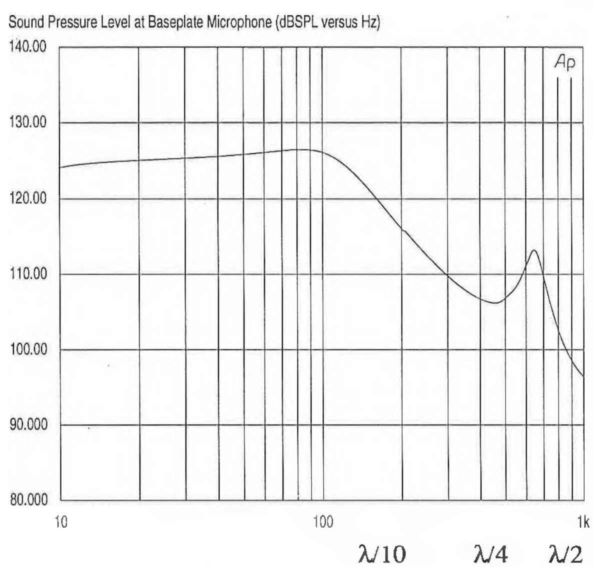

Figure 2. Sound pressure produced at baseplate for 1 Vrms input to loudspeaker.

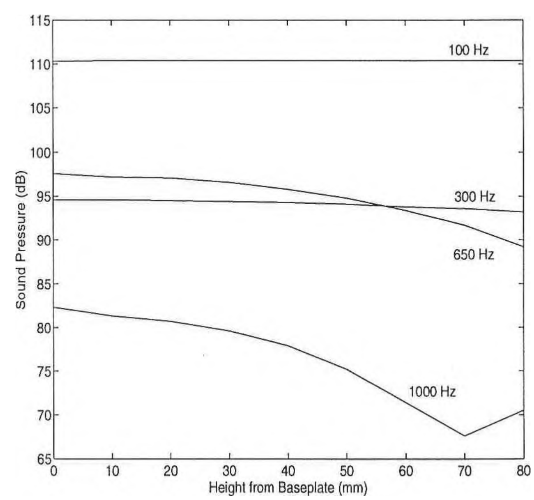

Figure 3. Variation of sound pressure with height above baseplate.

MACHINE IDENTIFICATION OF WAVEFORM CHARACTERISTICS, WITH APPLICATION TO SEAT MOTION

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1. Introduction

The purpose of this paper is to propose a method for distinguishing randomly occurring impulses and other intermittent or transient waveforms from a background of near-sinusoidal or Gaussian random signals, all with zero mean value. It involves computation of the higher-order root mean values and impulsiveness of the waveform, represented by a time series, and a measure of the tonal quality of its frequency spectrum. The procedure relies on establishing the statistics of the time series and is related to some techniques for signal detection,[1] for which purpose frequency domain and autocorrelation methods may be preferred for periodic impulses.[2]

The method has been used to establish the character of vibrations recorded at the seats of off-the-road vehicles, to provide information concerning potential health effects.[3]

2. Method

2.1 Higher-order mean values

The probability that the instantaneous magnitude of a time series $\mathbf{x}(t)$ falls within a narrow interval Δx, as illustrated in Figure 1A, is given by the probability density function (pdf):[4]

$$p_x(x,t) = \lim_{|\Delta x| \to 0} \frac{\text{Prob}[\mathbf{x}(t) \in \Delta x]}{|\Delta x|} \qquad (1)$$

For non-stationary signals, the pdf will depend on the time at which the function is evaluated. The expected values of the time series at time t are defined in terms of second-, and higher-, order moments of the pdf:

$$E(x^n,t) = \int_{-\infty}^{\infty} x^n p(x,t)dx \qquad (2)$$

where $n = 1,2,3..etc.$ The corresponding root mean values are then:

$$[E(x^n,t)]^{1/n} = \left[\int_{-\infty}^{\infty} x^n p(x,t)dx\right]^{1/n} \qquad (3)$$

Relationships may now be derived between the n^{th} even-order root mean value and the root mean square (RMS) value, $x_{RMS}(t)$. These will depend on the shape of the pdf, which in turn will depend on its time series. For signals with a Gaussian random distribution and zero mean value during the time interval of interest:[4]

$$\frac{[E(x^n,t)]^{1/n}}{x_{RMS}(t)} = \left[\prod_{k=1}^{n/2}(2k-1)\right]^{1/n} \qquad (4)$$

For such signals, the twelfth-order root mean value $x_{RMT}(t)$ (i.e. $n = 12$ in equation 4) is related to the RMS value by:

$$x_{RMT}(t) = 2.16 x_{RMS}(t) \qquad (5)$$

and corresponds to a cumulative probability of $P(x) = 0.97$.

2.2 Impulsiveness

The introduction of impulses will cause the probability distribution of the composite time series to deviate from that of the original signal. An example is shown in Fig. 1. In this diagram, the probability distribution of the time series in Fig. 1A is shown by the thick line in Fig. 1B, while those of its constituent impulse and Gaussian random signals are shown by the thin and dotted lines, respectively. Changes in a random distribution, such as that resulting from the occurrence of an impulse (i.e. from dotted to thick lines in Fig. 1B), will be reflected in the relative magnitudes of the expected values, which will hence deviate from the ratios in equation 4.

An alternative measure of signal magnitude that retains a specific probability value is obtained from the impulsiveness. This measure is defined in terms of positive and negative amplitudes of the time series, $x^+(t)$ and $x^-(t)$, at selected probability values which for the purposes of the present work are chosen to be $P(x,t) = 0.985$ and $P(x,t) = 0.015$, respectively:

$$I_{(0.97)} = \frac{x^+(t) - x^-(t)}{2x_{RMS}(t)} \qquad (6)$$

The impulsiveness provides a measure of the magnitude of amplitude excursions, including impulses, exceeded a specified fraction of the time, as can be seen from Fig. 1B. Hence, values of $I_{(0.97)}$ and $x_{RMT}(t)/x_{RMS}(t)$ for a time history of unknown characteristics will provide information on its waveform. Reference to Fig. 1 shows that the impulse has resulted in an increase in the former by a factor of 1.1 and the latter by 1.4 compared with the values for a Gaussian signal (2.16). These two parameters, together with a simple test for tonal components in the frequency spectrum,[3] may hence be used to characterize waveform signatures.

3. Results and Discussion

Computer recognition of different waveform characteristics has been explored by analyzing acceleration time histories recorded at vehicle seats, with a separate measure of the tonal content.[3] The basic requirement was to distinguish waveforms containing impulses from other signals (as illustrated by Fig.1). Four waveform signatures were identifiable by the method described: 1) Gaussian random motion; 2) periodic or almost periodic near-sinusoidal motion, which may be amplitude modulated; 3) intermittent motion - non-stationary random and transient deterministic signals; and 4) impulsive motion including shocks. The values of the parameters used to establish the four signal types are given in Table 1, where the peak-to-mean ratio of spectral components is SPECF. Note that signal types 2 and 3 are derived from two alternate conditions indicated by "or".

A subjective visual typing of 160 waveform signatures from off-the-road military vehicles was made by a jury of two observers, who examined each in sequence. The subjective typing was established by agreement between the observers. Although there were 10 records that were considered borderline between signal types, all but one were adjudicated in favour of the typing performed by the computer, which was known to the observers. Hence, machine typing of seat motion signatures was considered to be satisfactory in most cases and, at worst, resulted in 10/160 errors.

Acknowledgements

Part of this work was performed for the United States Army Aeromedical Research Laboratory under contract DAMD17-96-R-0142.

Table 1: Tests for Seat Motion

Motion Type	RMT/ RMS	I(0.97)	SPECF
1	> 2.0 < 2.5	< 2.3	< 4.0
2 or	≤ 2.0 > 2.0 < 2.5	< 2.3	≥ 4.0
3 or	≥ 2.5 > 2.0 < 2.5	> 2.6 ≥ 2.3	
4	≥ 2.5	≤ 2.6	

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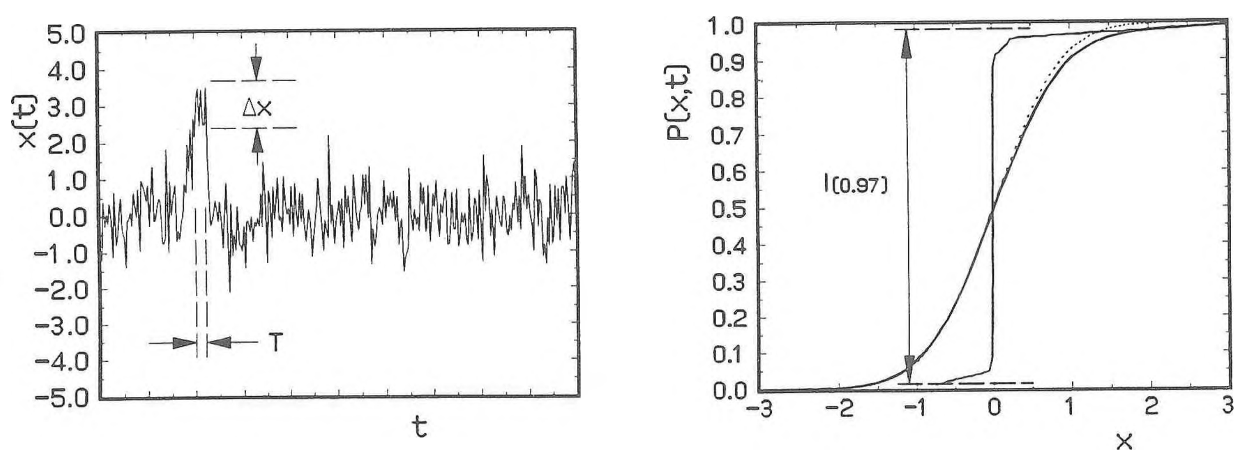

Figure 1: A - Impulse in a Gaussian random time series with magnitude in the range Δx for time T; and B - Probability distribution for this waveform (thick line), together with those of its constituent impulse (thin line) and random signal (dotted line). The values of $x_{RMT}(t)/x_{RMS}(t)$ and $I_{(0.97)}$ for the time series shown in A are 3.02, and 2.37, respectively, and 2.16 for the Gausian signal.

Acoustic Modelling and Low Frequency
Control of Furnace Noise

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INTRODUCTION

The high temperature hot water heating system at the University of Calgary uses three similar Dominion Bridge furnaces. The acoustic radiation from their stacks shows several distinct frequency components from 4 to 80 Hz. In order to explore techniques to reduce the levels in the 30-60 Hz range, finite element modelling of these furnaces was developed. Once the model confirmed that these frequencies were a result of resonant behaviour, it was further used to design a stack silencer which would meet architectural as well as acoustic criteria.

Evaluation of the silencer indicated that the reduction in overall level was close to that predicted by the finite element model.

MODELLING DETAILS

Initially a two-dimensional acoustic finite element model was formed as shown in Figure 1. The mesh was prepared with the ANSYS package while the analysis was done using the SYSNOISE software. The furnace was divided into four regions to account for

(1) the burner noise source - modelled as a moving wall
(2) the acoustic dissipation of the fire brick
(3) the open stack - modelled using a zero pressure condition with end correction
(4) the large temperature variation with the furnace - modelled using four areas

The acoustic pressure was calculated in the center of the physical end of the stack as shown in Figure 2 while those measured at the edge of the stack are shown in Figure 3. As the results were reasonably consistent a three-dimensional mesh was constructed. The results were only marginally different than the two-dimensional ones with essentially the same trends.

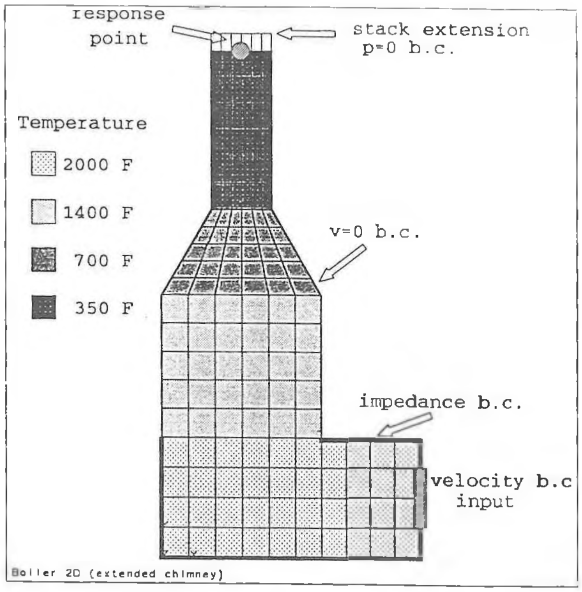
SILENCER DESIGN

As it was the 30-50 Hz frequencies which appeared to be the most bothersome, a silencer was added to the output stack as shown in the mesh of Figure 4. The silencer was simply a thick layer of insulation around a porous stack. The height of the stack was limited to maintain the architectural integrity of the building and to limit structural modification costs.

Figure 5 shows the frequency response plots for silencer lengths of 10, 12.5 and 15 feet. The model predicts a 7 to 8 dB reduction in the 30 Hz region with larger attenuations at higher frequencies.

CONCLUSIONS AND SUMMARY

A prototype silencer has been installed on one furnace and measurements of the stack noise radiation done. These results indicate that the levels have dropped 6-7 dB and that the resonances at approximately 30 and 45 Hz are not predominant.



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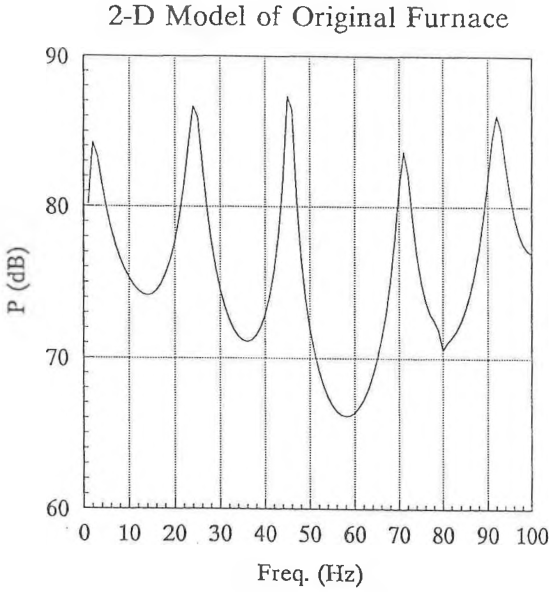

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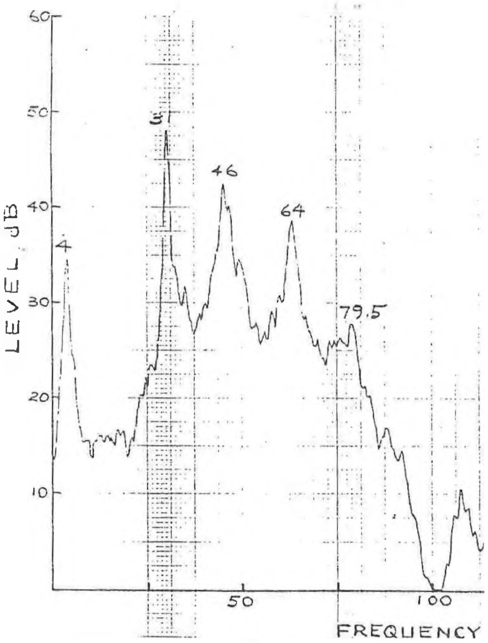

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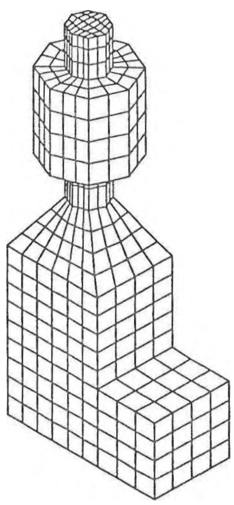

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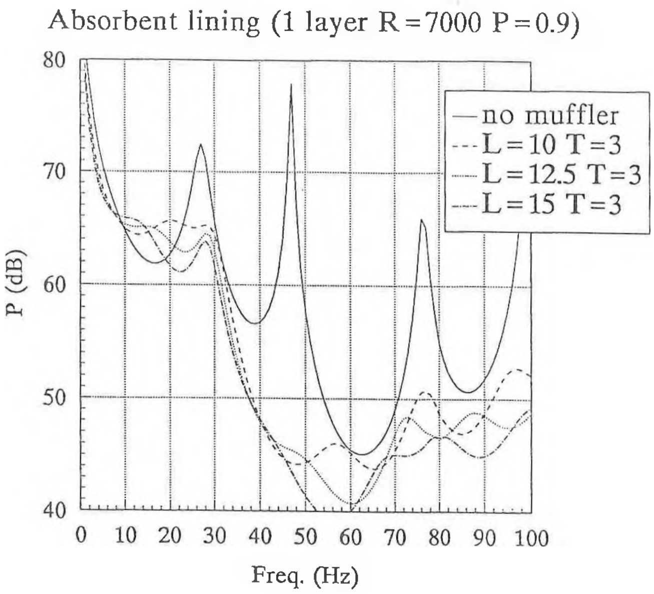

5

ANALYSIS OF ERRORS IN SOUND INTENSITY SCANNING TECHNIQUE FOR THE DETERMINATION OF SOUND POWER OF NOISE SOURCES

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Introduction

Sound intensity measurements are being increasingly used to determine sound power of noise sources. Assessment of measurement uncertainties is important for wider use of this technique.

This paper summarizes a recent study carried out to examine the bias and random errors associated with the scanning intensity technique under complex acoustic field conditions.[1] Based on experiments and theoretical formulations, errors were calculated for a complex acoustic source. Measurement errors under extraneous noise conditions were also examined.

1. Error Formulae

The two field indicators stipulated in ISO/WD9614-2[2], are the pressure-intensity indicator (F_{pI}), and negative partial power indicator ($F_{+/-}$). F_{pI} (or F_3 in ISO 9614-1[3]) is a key to measurement evaluation in this paper, and is defined by ten times the logarithm of the ratio of pressure to intensity. The latter indicator $F_{+/-}$ (or F_3-F_2 in ISO 9614-1[3]), warns of possible errors due to external noise sources. In a diffuse sound field, both can be estimated from the measurement environment.

The total pressure over the measurement surface can be estimated by the sum of the diffuse and direct pressures. The diffuse mean square pressure averaged over the measurement surface may be inferred from Jacobsen[4] as:

$$\frac{S_0 c T_{60}}{6V\ln 10}\,\frac{L_{W_I}+L_{W_{EN}}}{S_0}\rho c \tag{1}$$

where c is the speed of sound, ρ is the air density, L_{W_I} is the source sound power, $L_{W_{EN}}$ is the sound power from all external noise sources, S_0, V and T_{60} are the measurement room surface area, volume, and reverberation time, respectively.

To approximate the direct pressure, assume the vector intensity is perpendicular to the measurement surface, and near field effects are minimal. Under free field conditions the mean square pressure over the measurement surface is approximated by:

$$(L_{W_I}+2yL_{W_{EN}})\,\rho c/S_0 \tag{2}$$

where y ($0<y<1$) is a weighting representing the fraction of the total external noise power that passes directly through the measurement volume (i.e., $yL_{W_{EN}}$).

If expression (1) is large compared to expression (2), and the average intensity through the measurement surface is (L_{W_I}/S_0), then using expression (1), F_{pI} can be approximated as:

$$F_{pI}\approx 10\log\left(\frac{S_0 c T_{60}}{6V\ln 10}\,\frac{L_{W_I}+L_{W_{EN}}}{L_{W_I}}\right) \tag{3}$$

The second indicator, $F_{+/-}$, is the ratio of the total sound power to the source sound power passing through the measurement surface. $F_{+/-}$ is a maximum when external noise enters and exits through separate, infinitesimal areas. Thus $F_{+/-}$ is described by:

$$F_{+/-}\le 10\log\left((L_{W_I}+2yL_{W_{EN}})/L_{W_I}\right) \tag{4}$$

For valid measurements $F_{+/-}$ should be less than 3 dB.[2,3]

Using F_{pI}, the maximum measurement bias error (L_{ε_B}) due to phase errors is given by Gade:[5]

$$L_{\varepsilon_B}=-10\log\left(1-10^{0.1(-\delta_{pI_0}+F_{pI})}\right) \tag{5}$$

where δ_{pI} is the pressure-residual intensity index[2,3].

Making use of equation (3), under diffuse field conditions the theoretical random errors (ε_{BT} and ε_S) due to the bandwidth time (BT) product[5] and sampling errors[4] are:

$$\varepsilon_{BT}=\pm 0.42(K+1)/\sqrt{BT} \tag{6}$$

$$\varepsilon_S=\pm K/\sqrt{N_{eq}6(1+BT_{60}/(3\ln 10))} \tag{7}$$

where B is the analysis bandwidth, T is the total measurement time, K is the pressure-intensity ratio (i.e., F_{pI}=10log|K|), and N_{eq} is the equivalent number of uncorrelated measurements along the scanning path, approximated by:[4]

$$N_{eq}\approx(2l/\lambda)/[1+(\pi/2)l\lambda/S_0] \tag{8}$$

where l is the total length of the scanning path, and λ is the wavelength of sound at the frequency of interest.

In constructing the total error estimate (L_ε), errors were converted to decibels and combined as follows:

$$L_\varepsilon=\pm L_{\varepsilon_B}+10\log\left[1\pm\sqrt{\varepsilon_{BT}^2+\varepsilon_S^2}\right] \tag{9}$$

3. Apparatus

The sound source consisted of two identical loudspeakers separated by 50 cm and mounted in the large face of an undivided closed box baffle. The enclosure dimensions were 1 m² by 0.3 m high. Both speakers were driven from a single white noise source. The electrical input of one speaker was inverted with respect to the other and attenuated by 6 dB.

The sound source was centred on the floor of a 60 m³ room with calculated reverberation time between 1 and 2 seconds. Most room surfaces were made of either concrete or wood.

An external noise source outside the measurement volume was positioned, facing downwards, 1 m over the centre of the sound source. This source used a loudspeaker, of the same type as the sound source, mounted in a 25 litre closed box baffle.

Intensity measurements were made using a Brüel & Kjær type 3519 face to face two microphone intensity probe with 12 mm microphones and either a 12 mm or 50 mm spacer. Data were analyzed using a Brüel & Kjær type 2133, 1/3 octave, real time, constant percentage bandwidth intensity analyzer.

4. Procedure

Scanning acoustic intensity measurements were made according to ISO/WD9614-2[2] over a (box like) measurement surface located 40 cm from the sound source enclosure. Scan lines were oriented lengthwise along the surface with a 20±3 cm separation between successive scans. Each surface was manually scanned 6 times at a speed of 30 cm/s for at least 20 seconds. Measurements were repeated if differences between power levels from any single surface varied by more than 0.5 dB.

Phase measurements were within manufacturer's specifications, and variations in calibration levels were negligible. These were verified before each day's testing, at 250 Hz, using a pistonphone and a Brüel & Kjær type 3541 acoustic intensity coupler.

5. Results and Conclusions

Dominance of the diffuse field, and hence applicability of the above equations, was verified by both calculation and comparison with anechoic chamber measurements.[6] Calculations showed excellent agreement with individual measured values of F_{pI} and total error. Most differences could be attributed to measurement errors caused by the external noise source.

Measurements with external noise power over 6 dB greater than the power output of the sound source were inadmissible according to ISO/WD9614-2[2] (as indicated by $F_{+/-}$, and the dynamic capability of the analyzer[2,3]). It should be noted that, calculated $F_{+/-}$ values (eqn. (4), y=1) suggest external noise levels greater than -3 dB should be inadmissible. The difference between measured and calculated $F_{+/-}$ suggests external noise must enter and leave through the same measurement surface.

Results for 6 dB external noise are shown in Figure 1. Calculated errors used measured F_{pI} values. Measured errors were estimated from results without external noise. Below 800 Hz, results are typical. The measured data are conservatively approximated by the total calculated error (due mainly to equation (7)). Although measured errors are unacceptably large, they appear random, making them identifiable by a partial power repeatability test[2,3] and correctable by continued scanning of the surface. This contradicts equation (8) which, at low frequencies, indicates little effect of an increase in the scanning path length.

Above 1.2 kHz measured errors reach the limits of engineering grade accuracy[2,3] (± 3 dB). These errors reduced to calculated values for external noise power levels below -1 dB.

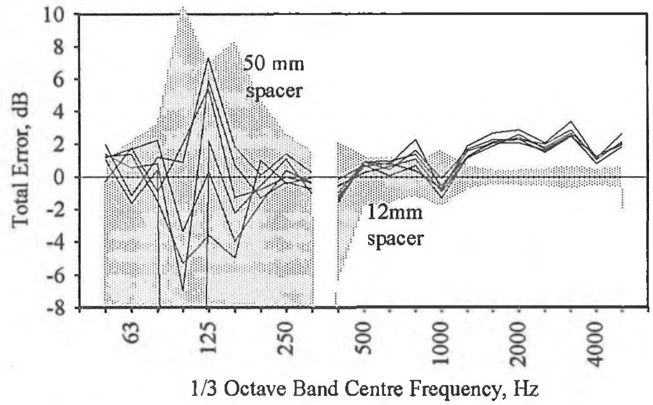

Figure 1: Calculated total error (L_ϵ) for 6 dB external noise, ; The lines show measured errors for 6 nominally identical tests

The present studies suggest that the procedure given in the ISO scanning document could be used with reasonable confidence to determine sound power of noise sources under moderate extraneous noise conditions.

Acknowledgements

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INTER-NOISE 94 IN YOKOHAMA, JAPAN

FIRST ANNOUNCEMENT

inter-noise 94

THE 1994 INTERNATIONAL CONGRESS ON NOISE CONTROL ENGINEERING

YOKOHAMA-JAPAN
AUGUST 29-31, 1994

INTER-NOISE 94, the 1994 International Congress on Noise Control Engineering, will be held at the PACIFICO YOKOHAMA (Pacific Convention Plaza Yokohama), Japan, from August 29 to 31, 1994. Technical papers in all areas of noise control engineering will be considered for presentation at the Congress and for publication in the Congress Proceedings. An Announcement and Call for Papers will be issued shortly.

INTER-NOISE 94 will be the 23rd meeting of this annual event dating back to 1972. The Congress is sponsored by the International Institute of Noise Control Engineering I/INCE, and is being organized jointly by the Institute of Noise Control Engineering of Japan and the Acoustical Society of Japan.

A technical equipment exhibition will be held in conjunction with INTER-NOISE 94, and will include acoustical materials, measurement and calculation software, instruments, and equipments for active noise control. A short session will also be made available for presentations by exhibitors. An accompanying persons program and social activities for all delegates will be organized. Technical visits will also be arranged.

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Further information on the Congress and the Exhibition may be obtained from the INTER-NOISE 94 Congress Secretariat.

INTER-NOISE 94 will be preceded by the 5th Western Pacific Regional Acoustics Conference in Seoul, Korea, from August 23 to 25, 1994 (Secretariat tel: +82-2-361-2783, fax:+82-2-365-4668).

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Please return this coupon if you are interested in being added to the mailing list for INTER-NOISE 94.

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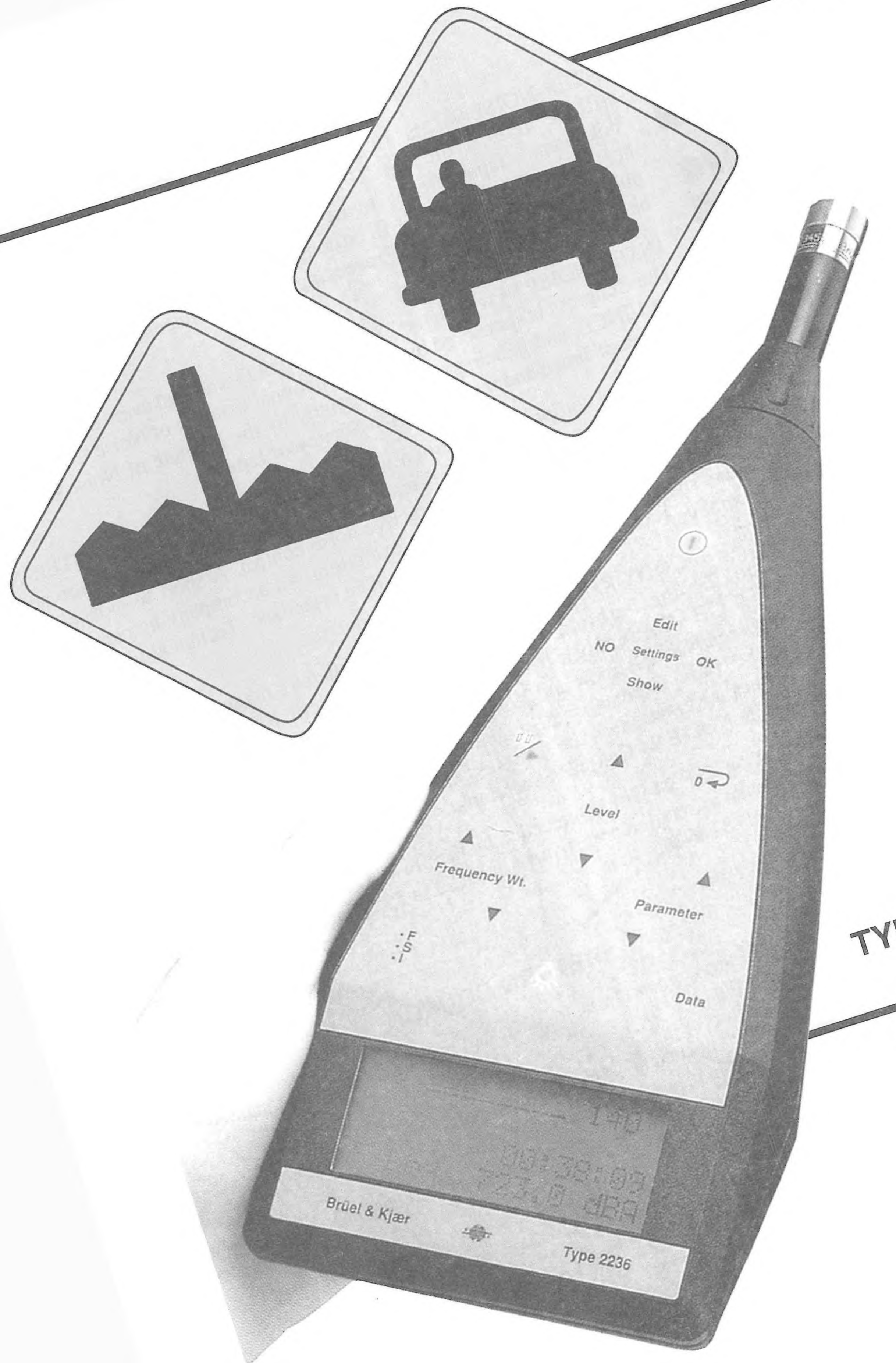
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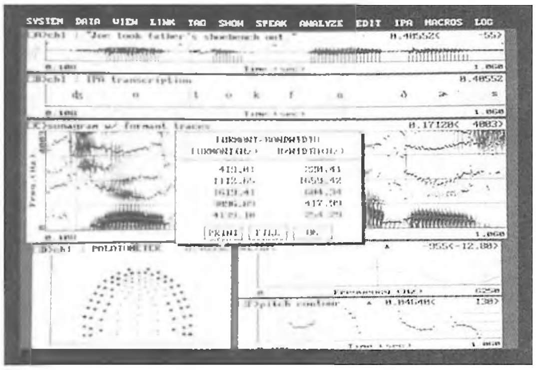

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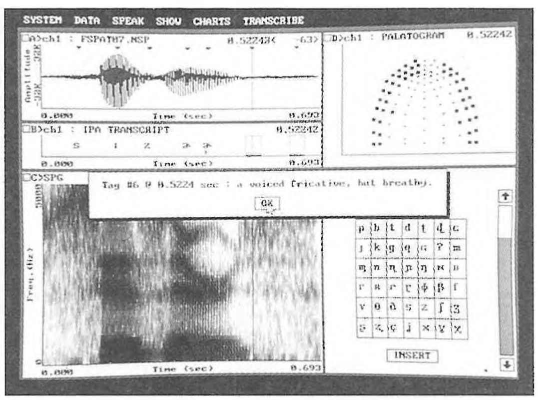

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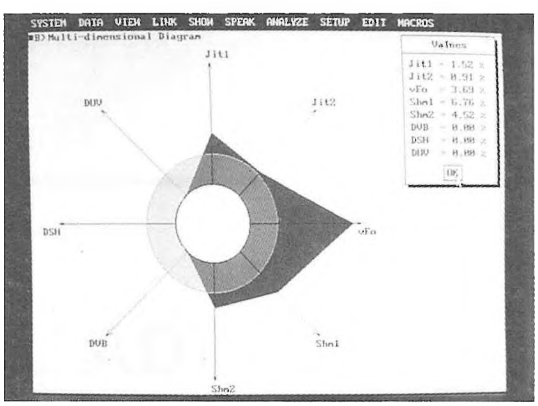

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BOUNDARY ELEMENTS IN ACOUSTICS
R.D. Ciskowski and C.A. Brebbia, Eds.

This is the first book published dealing with the use of boundary element techniques applied to acoustic. It if comprised of a collection of chapters from several authors from around the world. The major focus of the book is to present a brief history of the boundary element method in acoustics, to show some of the more common formulations and finally to display several practical applications of the method.

The first chapter contains a history of the development of the boundary element methods in acoustics. It begins with a discussion distinguishing between boundary integral equation methods (BIEM) and boundary element methods (BEM). Both Helmholtz (time harmonic) and transient types of problems are introduced as well. This is followed by a presentation of both direct and indirect methods of solving the resulting equations. It concludes with a look at potential future developments in this field.

Chapter 2 gives an introduction to the fundamental formulation of the boundary element method by first introducing its application to Laplace's and Poisson's equations. Examples of surface discretization using constant, linear, quadratic and cubic elements are presented as well as a description of the process of forming a set of linear, simultaneous equations for the problem in a matrix format. This is followed by a discussion of the boundary element method applied to the Helmholtz equation, a presentation of the dual reciprocity method to transient problems.

Chapter 3 deals with some aspects of radiation and scattering. It discusses how to treat full-space, half-space and half-space direct contact problems using the commonly applied direct boundary element method. The well-known non-uniqueness problem that occurs at characteristic frequencies with exterior boundary integral formulations is discussed. Several methods to overcome this problem are also presented, Several examples are given to show the effectiveness of the boundary element methods in treating some simple radiation and scattering problems.

The following chapter covers the topic of acoustic design sensitivity analysis. Sensitivity formulations to predict the effect of structural shape changes, boundary condition changes and frequency changes are presented. An alternate sensitivity formulation is discussed which must be applied in the vicinity of characteristic frequencies when dealing with the non-uniqueness problem. Finally the application of these methods is carried out on an engine valve cover to illustrate the usefulness of the sensitivity information.

Probabilistic acoustic analysis is covered in Chapter 5. When dealing with practical problems using the boundary element method, the geometry, boundary conditions, and system properties are often not well defined in advance and may be considered as random variables. This procedure is applied to the radiation and scattering of a sphere.

Chapter 6 introduces structural-acoustic coupling. The accuracy of the method is compared with analytical solutions of a spherical shell. It is shown how the computational efficiency of this method can be greatly increased by taking advantage of symmetries in the system as well as by making use of frequency interpolation methods.

The following chapter demonstrates some uses of the acoustic boundary element method in the automotive industry. Special attention is paid to the modelling of complicated boundary conditions that are present in automotive interiors. Applications are presented dealing with boom noise, and radiation from oil pans and engine head covers.

Chapter 8 covers the use of the BEM in bioacoustics. Coupled structural-acoustic models are developed for the outer ear, ear canal and supporting inner ear structure. The modelling and performance of elastic and visco-elastic foam-style earplugs are also presented and compared to experimental results.

Chapter 9 is entitled "Applications in Industrial Noise Control". A multiple domain boundary element implementation is described to take into account both interior and exterior regions of partially open enclosures. These techniques are then applied to simple cubical geometries and silencer designs.

The applications of the BEM in architectural acoustics is considered in Chapter 10. It introduces a boundary integral approach using Kirchoff's formula to predict the transient responses in rooms with rigid and absorbent walls and methods of modelling the sound transmission across audience seating. Many examples are cited including comparison with experimental data.

The final chapter describes the utilization of the acoustic boundary element method in environmental noise problems. Transient and harmonic formulations are described to deal with noise walls and barriers in both two and three dimensions. Moving sources are also considered to model car and airplane noise in residential areas. Results are presented primarily in the form of pressure contour plots.

Many of the chapters are clearly reworkings of published papers and thus tend to be stand-alone in nature. There is therefore much repetition in the book as the various authors of the chapters give their introduction to the theory and implementation of the acoustic boundary element method. The text is nicely typeset in TeX, but the figure quality in some chapters is marginal. Each chapter of the book contains an extensive reference list and the book's appendix contains a large collection of references, including some abstracts, given in chronological order.

Overall, the book is a good, but expensive, introduction to the boundary element method in acoustics. Many specializations of the method have been presented with numerous applications. My major disappointment with the book are some glaring omissions which include; BEM eigenvalue analysis, variational BEM analysis, sub-domain modelling and a frank discussion of the limitations of the boundary element method.

[This book (ISBN 1-85166-679-6) is available from Elsevier Applied Science at a price of $117 U.S.]

Reviewed by: Ken Fyfe, Department of Mechanical Engineering, University of Alberta.

The Canadian Acoustical Association
l'Association Canadienne d'Acoustique

1993 PRIZE WINNERS / RÉCIPIENDAIRES 1993

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

Roland Woodcock, University of British Columbia

"Acoustical characterization of poro-elastic surfaces and application to indoor sound propagation"

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

Aloknath De, McGill University

"Auditory distortion measure for speech coders - hidden Markovian approach"

FESSENDEN STUDENT PRIZE IN UNDERWATER ACOUSTICS
PRIZ ÉTUDIANT FESSENDEN EN ACOUSTIQUE SOUS-MARINE

Douglas James Wilson, Memorial University

"Acoustic measurement of sand ripples"

DIRECTORS' AWARDS / PRIX DES DIRECTEURS

Professional ≥30 years / Professionel ≥30 ans: **Sharon M. Abel, Mount Sinai Hospital**

"The effect of aging on reaction time in auditory detection and discrimination tasks"

Professional <30 years / Professionel <30 ans: **Li Cheng, Université de Sherbrooke**

"On the modelling and the prediction of the vibroacoustic behaviour of an aircraft structure"

Student / Étudiant: **S. Bellefleur, École Polytechnique de Montréal**

"Étude de l'efficacité d'un bélier amortisseur"

STUDENT AWARDS / PRIX ÉTUDIANT

Serge Brunet, Université de Sherbrooke

"Active noise control simulations in a cavity-backed flexible plate system"

Nicolas Lessard, Université de Sherbrooke

"An acoustic design method for lightweight structures supporting a vibrating source"

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"Frequency and the sensation of sounds"

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NEWS/INFORMATIONS

CONFERENCES

Third French Congress on Acoustics: Toulouse (France), May 2 - 6, 1994. Mail should be sent to: Secrétariat du Troisième C.F.A., Université Toulouse-le-Mirail, FRANCE, Tel. (33) 61 50 44 68, Fax. (33) 61 50 42 09.

127th Meeting of the Acoustical Society of America: August 23-25, 1994, Cambridge, Massachusetts, USA. Contact: Elaine Moran, Acoustical Society of America, 500 Sunnyside Blvd., Woodbury, NY 11797, USA. Tel. +1 (516) 576-2360, Fax. +1 (516) 349-7669.

5th Western Pacific Regional Acoustics Conference: August 23 - 25, 1994, Seoul, Korea. Contact: Conference Secretariat, Tel. +82 2 361-2783, Fax. +822 365-4668.

INTER-NOISE 94: The 1994 International congress on Noise Control Engineering, Yokohama, Japan, from August 29 to 31, 1994. Contact: Inter-Noise 94 - Congress Secretariat, Sone Lab. R.I.E.C., Tohoku University, 2-1-1 Katahira, Aoba-Ku, Sendai, 980 Japan. Fax: +81-22 263-9848, 81-22-224-7889. E-Mail: in94@riec.tohoku.ac.ip.

128th Meeting of the Acoustical society of America: November 28 - December 2, 1994, Austin, Texas, USA. Contact: Elaine Moran, Acoustical Society of America, 500 Sunnyside Blvd., Woodbury, NY 11797, USA. Tel. +1 (516) 576-2360, Fax. +1 (516) 349-7669.

129th Meeting of the Acoustical Society of America: May 31 - June 4, 1995, Washington, DC, USA. Contact: Elaine Moran, Acoustical Society of America, 500 Sunnyside Blvd., Woodbury, NY 11797, USA. Telephone: +1 (516) 576-2360, FAX: +1 (516) 349-7669

INTER-NOISE 95: July 10-12, 1995, Newport Beach, California, USA. Contact: Intstitute of Noise Control Engineering, P.O. Box 3206, Arlington Branch, Poughkeepsie, NY 12603, USA. Tel. (914) 462-4006, Fax. (914) 473-9325.

COURSES

Industrial Audiometry and the Effective Hearing Conservation Program: December 8-10, 1993. The 1986 Draft Noise Regulation stipulates that where workers are exposed to a daily TWA noise exposure of 85 dBA or greater, a Hearing Conservation Program (HCP) is required; where a weekly TWA is 85 dBA or greater, the HCP must include audiometric tests. This three-day course will provide the background necessary to introduce an effective HCP into your workplace. As well, it will offer the specific training required to meet the definition of "competent audiometric tester" as specified by the Code for Audiometry of Noise Exposed workers. Curriculum will include anatomy of the ear, noise-induced hearing loss, workers' compensation, ethics of audiometry hearing protection, legal requirements, etoscopy and audiometry laboratories. Participants are encouraged to bring their own audiometer, if one is available in-house. For further information contact Dr. Alan D. Stuart, summer Program Coordinator, The Penn State Graduate Program in Acoustics, P.O. Box 30, State College, PA 16804 Tel: (814) 863-4128 or FAX (814) 865-3119.

CONFERENCES

3e Congrès français d'acoustique: Toulouse, France, du 2 au 6 mai 1994. Renseignements: Secrétariat du Troisième C.F.A., Université Toulouse-Le-Mirail (C.P.R.S.), 5, allée Antonio Machado, 31058 Toulouse Cédex, France. Téléphone (33) 61 50 44 68; télécopieur (33) 61 50 42 09.

127e rencontre de l'Acoustical Society of America: Cambridge, Massachesetts, du 5 au 9 juin 1994. Renseignements: Elaine Moran, Acoustical Society of America, 500 Sunnyside Boulevard, Woodbury, NY 11797, USA. Téléphone (516) 576-2360; télécopieur (516) 349-7669.

5e conférence des pays du Pacifique ouest sur l'acoustique: Séoul, Corée, du 23 au 25 août 1994. Renseignements: Elaine Moran, Acoustical Society of America, 500 Sunnyside Boulevard, Woodbury, NY 11797, USA. Téléphone (516) 576-2360; télécopieur +82 2 365-4668

Conférence Inter-Noise 94: Yokohama, Japon, du 29 au 31 août 1994. Renseignements: Inter-Noise 94, Congress Secretariat, Sone Lab. R.I.E.C., Tohoku University, 2-1-1 Katahira, Aoba-Ku, Sendai, 980 Japon. Télécopieur +81-22-263-9848; +81-22-224-7889; courrier électronique en 94 @ riec.tohoku.ac.ip.

128e rencontre de l'Acoustical Society of America: Austin, Texas, du 28 novembre au 2 décembre 1994. Renseignements: Elaine Moran, Acoustical Society of America, 500 Sunnyside Boulevard, Woodbury NY 11797, USA. Téléphone (516) 576-2360; télécopieur (516) 349-7669.

129e rencontre de l'Acoustical Society of America: Washington, DC., du 31 mai au 4 juin 1995. Renseignements: Elaine Moran, Acoustical Society of America, 500 Sunnyside Blvd., Woodbury, NY 11797, USA. Téléphone (516) 576-2360; télécopieur (516) 349-7669.

Conférence Inter-Noie 95: Newport Beach, Californie, du 10 au 12 juillet 1995. Renseignements: Institute of Noise Control Engineering, P.O. Box 3206, Arlington Branch, Poughkeepsie, NY 12603, USA. Téléphone (914) 462-4006; télécopieur (914) 473-9325.

COURS

Industrial Audiometry and the Effective Hearing Conservation Program: du 8 au 10 décembre 1993. Le projet de loi américain de 1986 sur le bruit stipule l'existence d'un programme de préservation de l'ouïe sur les lieux de travail où l'exposition au bruit est de 85 dBA et plus, et des tests audiométriques lorsque l\exposition est de 85 dBA et plus. Ce cours de trois jours devrait fournir aux participants les éléments de base nécessaires à la mise sur pied d'un programme de préservation de l'ouïe sur leurs lieux de travail. Les participants recevront la formation d'évaluateur compétent en audiométrie, telle que prescrite dans le Code for Audiometry of Noise Exposed Workers. Les sujets suivants seront abordés: anatomie de l'oreille, perte d'audition due au bruit, audiométrie, protection de l'ouïe, programmes d'indemnisation des travailleurs, règlements, laboratoires d'étoscopie et d'audiomètrie. On demande aux participants d'apporter, si possible, laur propre audiomètre. Renseignements: Dr. Alan D. Stuart, Summer Program Coordinator, The Penn State Graduate Program in Acoustics, P.O. Box 30, State College, PA 16804, U.S.A., téléphone (814) 863-4128, télécopieur (814) 865-3119.

NEW PRODUCTS

ASA has new standards available to order. If you have individual orders for ASA standards they should be placed with: Professional Book Distributors, Inc. (PBD), ASA Standards Distribution Center, 1650 Bluegrass Lakes Parkway, P.O. Box 6996 Alpharetta, GA 30239-6996; Tel: (404) 442-8631; Fax (404) 442-9742. If you have standing orders they should be placed with: ASA Standards Secretariat, Standing Order Department, 335 East 45th Street, New York, NY 10017-3483; Tel: (212) 661-9404; Fax: (212) 949-0473.

NOUVEAUX PRODUITS

L'ASA tient à la disposition des intéressés une nouvelle série de normes. Pour les commandes individuelles: Professional Book Distributors, Inc. (PBD), ASA Standards Distribution Center, 1650 Bluegrass Lakes Parkway, P.O. Box 6996, Alpharetta, GA 30239-6996; téléphone (404) 442-8631; télécopieur (404) 442-9742. Pour les commandes permanentes: ASA Standards Secretariat, Standing Order Department, 335 East 45th Street, New York, NY 10017-3483; téléphone (212) 661-9404; télécopieur (212) 949-0473.

Some new Standards are as follows:

Scales and Sizes for Frequency Characteristics and Polar Diagrams in Acoustics, ANSI S1.22-1992.

Specifications for Personal Noise Dosimeters, ANSI S1.25-1991.

Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms, ANSI S3.1-1991.

Testing Hearing Aids with a Broad-Band Noise Signal ANSI S3.42-1992.

Standard Reference Zero for the Calibration of Pure-Tone Levels of Noise Sources Using Sound Intensity, ANSI S12.12-1992.

Evaluating the Effectiveness of Hearing Conservation Programs, ANSI S12.13-1991.

Methods for the Field Measurement of the Sound Output of Audible Public Warning Devices Installed at Fixed Locations Outdoors, ANSI S12.14-1992.

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MEMBERSHIP DIRECTORY 1993/ANNUAIRE DES MEMBRES 1993

The number that follows each entry refers to the areas of interest as coded below.
Le nombre juxtaposé à chaque inscription réfère aux champs d'intérêt tels que codifiés ci-dessous.

Areas of interest		Champs d'intérêt
Architectural acoustics	1	Acoustique architecturale
Electroacoustics	2	Electroacoustique
Ultrasonics	3	Ultrasons
Musical acoustics	4	Acoustique musicale
Noise	5	Bruit
Psycho and physio-acoustics	6	Psycho et physio-acoustique
Shock and vibration	7	Chocs et vibrations
Speech communication	8	Communication parlée
Underwater acoustics	9	Acoustique sous-marine
Other	10	Autre

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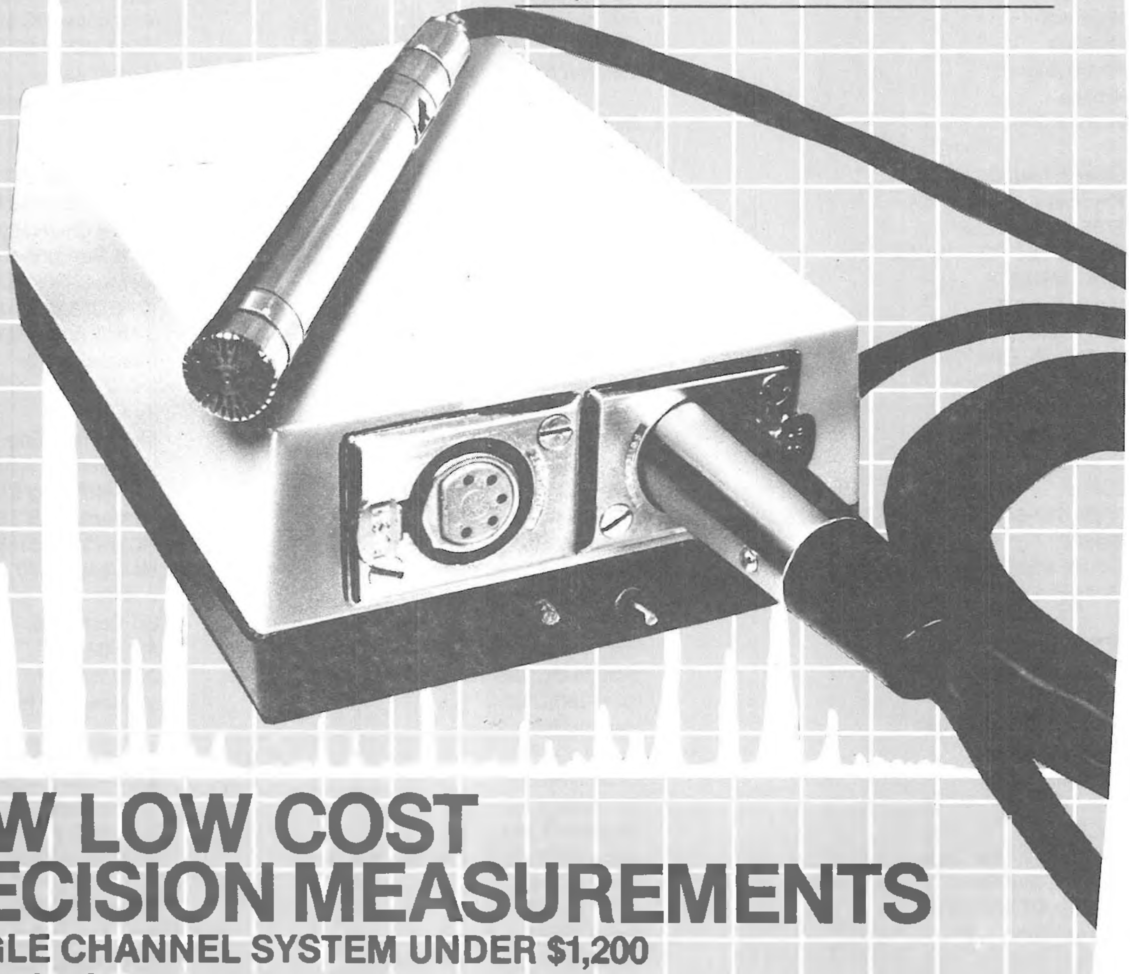

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June 13-15, 1994
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The Canadian Acoustical Association
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PRIZE ANNOUNCEMENT

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*
1993	*Roland Woodcock*	*University of British Columbia*

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*
1991	*Steven D. Turnbull*	*University of New Brunswick*
	Fangxin Chen	*University of Alberta*
	Leonard E. Cornelisse	*University of Western Ontario*
1993	*Aloknath De*	*McGill University*

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*
1993	*Douglas J. Wilson*	*Memorial University*

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.

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: position vacant.

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.

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. Quant aux quatre premiers prix, les candidats doivent soumettre un formulaire de demande ainsi que la documentation associée au coordonateur 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 coordonateur de prix.

Prix Post-Doctoral Edgar et Millicent Shaw en Acoustique

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

1990	*Li Cheng*	*Université de Sherbrooke*
1993	*Roland Woodcock*	*University of British Columbia*

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. Turnbull*	*University of New Brunswick*
	Fangxin Chen	*University of Alberta*
	Leonard E. Cornelisse	*University of Western Ontario*
1993	*Aloknath De*	*McGill University*

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*

Prix Étudiant Eckel en Controle du Bruit

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