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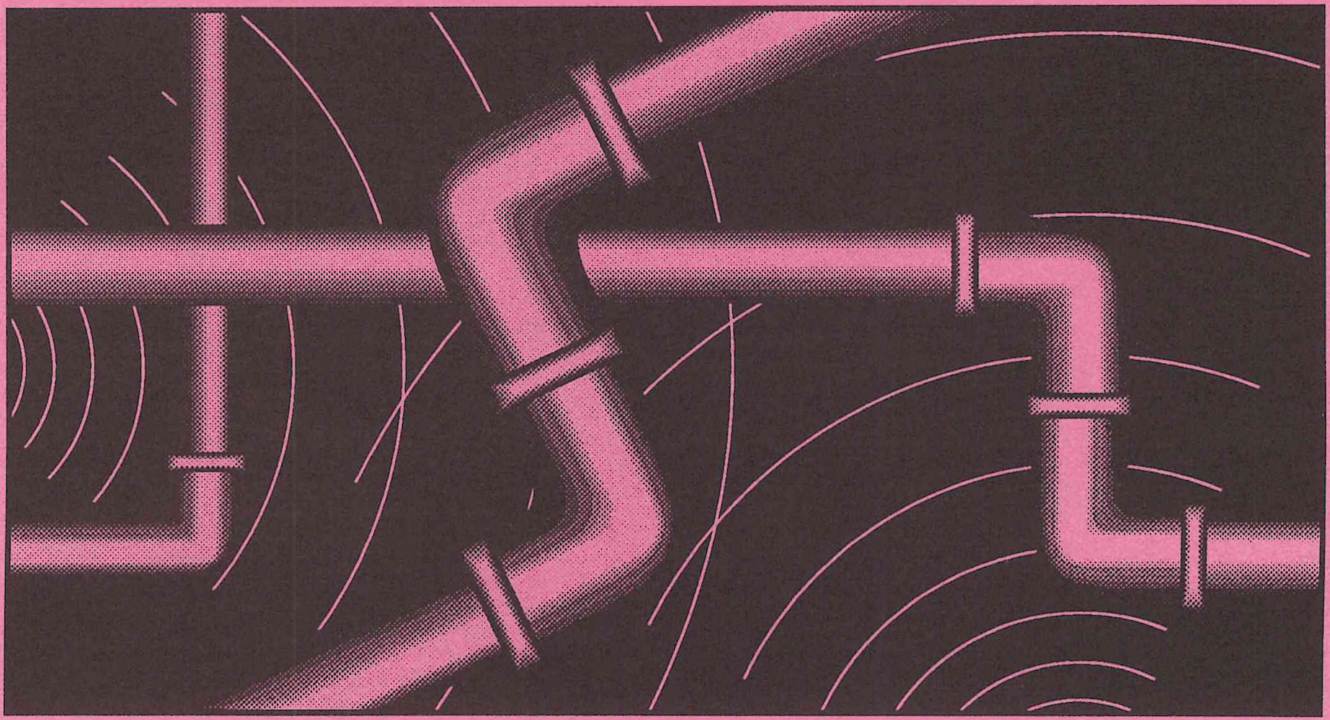

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EDITORIAL

Au printemps de l'année en cours, à l'occasion de la parution du deuxième numéro de l'*Acoustique canadienne*, nous avions inauguré une nouvelle rubrique intitulée "Point de vue". Celle-ci avait pour but d'offrir la possibilité aux membres de l'Association de faire valoir leur opinion concernant des sujets d'intérêt scientifique et professionnel en acoustique. Pour situer l'esprit dans lequel l'équipe éditoriale concevait cette chronique, les rédacteurs ont pris l'initiative de préparer chacun un texte qui exprimait leur avis sur des questions qui concernent leur engagement professionnel. Les réactions des lecteurs et des lectrices nous ont confirmé le bien fondé de cette initiative. C'est d'ailleurs à leur demande que nous avons reproduit dans le présent numéro une version anglaise du texte intitulé "Le caractère insidieux de la surdité professionnelle". Nous sommes étonnés cependant qu'aucun texte n'ait encore été soumis par les lecteurs et lectrices pour parution sous la rubrique "Point de vue". Les scientifiques et les professionnels(les) de l'acoustique sont pourtant intensément engagés dans leur discipline et ils(elles) ont certainement à coeur leur vision de la recherche et de la pratique de cette science. On peut se demander si les exigences habituelles de la publication à caractère rigoureusement scientifique sont responsable de ce mutisme. En effet, dans un compte rendu scientifique, l'accent est mis sur le compte rendu des observations et sur leur traitement statistique et mathématique. Les opinions non fondées sur des données expérimentales présentent relativement peu d'intérêt et sont souvent évacuées des manuscrits. Cette exigence découragerait-elle toute prise de position publique en dehors de la démarche strictement scientifique? Une menace d'être accusé de commettre des "délits d'opinion" pèserait-elle sur nous au point de nous décourager d'exprimer notre avis sur les activités et sur le savoir qui nous tient tant à coeur? Une telle hypothèse mérite de subir l'épreuve des faits! Elle pourrait être confirmée ou infirmée par votre réaction à la présente invitation à contribuer à la chronique d'opinion...

Last spring, in the second annual issue of *Canadian Acoustics*, a new chronicle titled "Viewpoint" was inaugurated. It aimed at offering the opportunity to members of the Association to express their opinions concerning matters of scientific and professional interest in the field of acoustics. In order to set the framework in which it was conceived by the editorial team, the editors have each taken the initiative of writing a text that state their opinion on issues that relate to their professional involvement. The readers' response confirmed the merits of this initiative. Furthermore, the English translation of the paper titled "Le caractère insidieux de la surdité professionnelle" is reproduced in the present issue upon requests from concerned readers. We are surprised however that no paper has yet been submitted for publication under the "Viewpoint" heading. Researchers and professionals in acoustics are nervertheless deeply involved in their discipline and they certainly keen to share their vision of research and practice of this science. One wonders if the usual requirements of rigorous scientific publication is responsible for this muteness. In a scientific paper, the emphasis is on the report of observations and their statistical and mathematical treatment. Opinions that are nor founded on experimental data bear little interest and are usually excluded from the papers. Could such a requirement discourage any public statement outside the strictly scientific approach? Would we be threatened for beliefs and convictions such that we are dissuaded to express our views on the activities and the knowledge that we are involved in? Such an assumption needs to undergo a test! It could be confirmed or invalidated by the response to the present invitation to contribute to the opinion chronicle...

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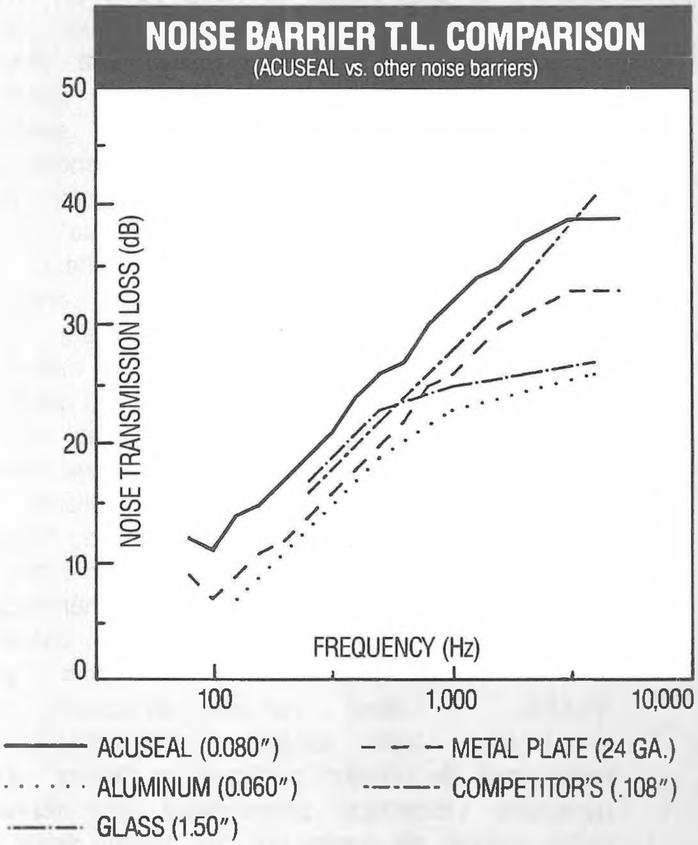

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ACOUSTICS OF PIPING AND DUCTS

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ABSTRACT

This paper describes a computerized procedure for the analysis of the acoustics of piping and duct work systems. The procedure can be used for the analysis of complicated network systems with multiple inputs and outputs. It combines transfer matrix and finite element methods, using finite element methods to model more complex elements and using exact solutions for the simpler interconnecting parts. The method has applications in modelling pulsations in gas pipelines, the design and analysis of muffler systems and calculating sound transmission in ventilation ducts.

SOMMAIRE

Cet article fait état d'une procédure d'analyse acoustique des systèmes de conduites et de canalisation. La procédure permet l'analyse de systèmes en réseaux complexes avec entrées et sorties multiples. Elle allie les méthodes de matrices de transfert et des éléments finis, en ayant recours aux méthodes des éléments finis pour modéliser les éléments les plus complexes et aux solutions exactes pour les composantes d'inter-connection les plus simples. La méthode peut s'appliquer à la modélisation des pulsations dans les gazéoducs, à la conception et à l'analyse des systèmes de silencieux et au calcul de la transmission sonore dans des conduites d'aération.

1. INTRODUCTION

This paper is concerned with the development of a procedure to be used on digital computers for studying the acoustics of piping and duct systems.

Various methods have been used for the analysis of noise propagation in pipes and ducts. The ASHRAE Handbook [1] gives an approximate semi-empirical method which tracks the sound power through elements along a duct path starting from the noise source and ending at the duct outlet into a room. This method does not consider the reactive effects of sound waves reflected back down the duct.

Transfer matrix techniques have been used by Munjal [7], To [8] and others for prediction of the acoustics of piping systems and acoustic mufflers. In this method the piping system is represented by a combination of discrete elements. The acoustic pressure and volume velocity at one station in the system is then related to those at another station using a two-by-two parameter matrix. The method works well for a long string of connected elements, but becomes more difficult to use when several interconnected paths, branches and multiple inputs and outputs are to be modeled. Where several pipes connect at a junction point, the continuity of pressure and conservation of mass are used to relate these quantities. The method does not consider the geometry of a junction. One advantage is that only two-by-two complex matrices are needed; thus computers with relatively small memories can be used.

Finite element methods have been used by Craggs [4], [5] and others for examining duct elements such as elbows and acoustic mufflers and lined ducts. This method is advantageous for analyzing systems with a complex geometry, and where three dimensional wave propagation effects become important. However the method would probably lead to prohibitively large matrix equations if used to analyze entire systems.

The hybrid method proposed in this paper combines the advantages of the above methods and still uses relatively small matrices. Here the input and output points and branch or junction points are considered as nodes. A global matrix equation is assembled relating the nodal acoustic pressures to the nodal volume velocity inputs and outputs. The equation is then solved to determine the nodal pressures, by first calculating a transfer matrix for each lineal string of pipe or duct elements along the paths between nodes. The transfer matrix is then converted into a network element matrix which relates the element nodal acoustic pressures and nodal volume velocities. Each network element matrix is assembled into the global matrix in "finite element" fashion. In elements such as expansion chambers and elbows where two or three dimensional wave propagation is important, true finite element methods are used. The finite element model is then reduced to a two-by-two transfer matrix relating the element input and output and is then treated as other transfer matrix elements. Junctions of several lineal strings can also be modeled using the finite element method. Again the finite element model of the junction is reduced to a network element matrix only involving its connecting nodes. This matrix is then assembled into the overall global matrix of the system.

Once the overall global matrix is assembled, it is modified to satisfy the nodal boundary conditions. For example, the acoustic pressure at the node, the volume velocity input, the incident pressure, or the terminating impedance can be specified. The modified matrix is then inverted and the pressures at each node calculated. Acoustic pressure, volume velocity, and transmitted sound power or ratios of these quantities including magnitude and phase between different points in the system can then be calculated.

2. THEORY

The detailed theory of transfer matrix methods and finite element methods used in this paper are presented by Craggs [4] and To [8]. The procedure used to link these methods is outlined below. The basic parameters used are the acoustic pressure given in the form $P \exp(j\omega t)$

and the volume velocity V exp(jωt) where P and V are complex quantities.

2.1 Two-node elements

Given an acoustic element with one input and one output, referred to subsequently as a two-node element, the four-pole transfer function matrix can be used to relate the pressures and volume velocities at the input (P1,V1) and output (P2,V2) by

$$\begin{Bmatrix} P1 \\ V1 \end{Bmatrix} = [a1] \begin{Bmatrix} P2 \\ V2 \end{Bmatrix} \tag{1}$$

where [a1] is the four-pole parameter matrix. In the above form [a1] is a two-by-two matrix with complex elements. The pressures and velocities can be split into real and imaginary parts for computational purposes. The matrix [a1] then becomes a four-by-four matrix with real elements. If a string of several two-node elements are connected in series then, for example, given a string of five elements a single transfer matrix [a] can be obtained relating the input of element 1 (station 1) to the output of element 5 (station 6) by

$$\begin{Bmatrix} P1 \\ V1 \end{Bmatrix} = [a] \begin{Bmatrix} P6 \\ V6 \end{Bmatrix} \tag{2}$$

where

$$[a] = [a1]\ [a2]\ [a3]\ [a4]\ [a5]. \tag{3}$$

If stations 1 and 6 are global nodes then equation (2) can be rearranged to give

$$[b] \begin{Bmatrix} P1 \\ P6 \end{Bmatrix} = \begin{Bmatrix} V1 \\ V6 \end{Bmatrix} \tag{4}$$

where [b] is the element network matrix relating the element pressures and volume velocities. Each network element matrix can be assembled into the global matrix [B] to give the following matrix equation

$$[B]\ \{P\} = \{V\} \tag{5}$$

where {P} is the vector of global node acoustic pressures and {V} is the vector of global node external input and output volume velocities.

The most basic two-node element is a rigid straight pipe for which an exact solution exists for one dimensional fluid motion along the pipe (refer to To [8]). This is the basic element used to connect other more complex elements where the one dimensional analysis is not applicable.

2.2 "Finite Element" Two-node elements

The finite element method can be used to model subcomponents of a system in which three dimensional waves are important. However, if the input and outputs to the subcomponent are simple pipes then it is possible to construct a much reduced connective matrix using the procedure outlined below.

If the input and output pressures are contained in the vector Pb and all other internal nodal pressures within the finite element model in vector Pi then the mathematical model of the component is in the form of the partitioned matrix equation:

$$\begin{bmatrix} a & . & b \\ \cdot & \cdot\cdot\cdot & \cdot \\ c & . & d \end{bmatrix} \begin{Bmatrix} Pb \\ \cdots \\ Pi \end{Bmatrix} = \begin{Bmatrix} Vb \\ \cdot\cdot \\ \theta \end{Bmatrix} \qquad (6)$$

where Vb is a vector of input and output node volume velocities and θ represent a vector of zeros. This equation can be solved to eliminate the internal pressures Pi to give:

$$[e]\ \{Pb\} = \{Vb\} \qquad (7)$$

This equation is now of the form given in equation (4) so that [e] is now the element network matrix and could be assembled directly into the global matrix [B] given in equation (5). Alternatively matrix [e] in equation (7) can be converted to transfer matrix form if this element is within a string of lineally connected elements.

2.3 Elements with three or more nodes

If several strings of two node elements meet at a common node then the network element matrices for each string can be assembled into a global matrix equation in "finite element fashion". This is based on equating the pressures at the node and using the equation for continuity of volume velocity at the node. This however does not consider the geometry of the junction and is only valid when the pipe or duct cross section dimensions are small compared to the wavelength of sound. The junction can be modeled using a finite element model as described above for two-node elements. On each input or output boundary connecting to the rest of the system, the pressures are constrained to a single value and an equation similar to equation (7) is obtained where [e] is now a network element matrix for the junction which can be assembled into the global matrix [B]. Note in this case since [e] now relates the pressures and volume velocities at more than two nodes it cannot be converted into a transfer matrix as was done with two-node elements.

3. COMPUTER PROGRAM DESCRIPTION

The computer program was developed on a Hewlett Packard 9816 desktop computer in the Basic 4.0 programming language. It is divided into several subprograms which are loaded and run separately through a small main program to reduce memory requirements. These include a data input program, a calculation program, and a program for displaying and plotting results. A separate program is used to generate finite element model data files for components such as elbows, branches, expansion chambers and transitions etc.

3.1 Data input program

The data for a given duct or piping system is entered in this section of the program. Once the data is entered the user can either go to the calculation section of the program or store the data in a disk data file. The file can later be recalled and the data modified, for example, if some components of the system are changed.

The first section of this program is used to enter data for the system nodes which are defined as any points where external input or outputs connect to the system and junction points between subsystems. The data entered for each node includes its geometric coordinates and the boundary condition at the node. Boundary conditions which are presently included are the total pressure, incident pressure, volume velocity input, or the terminating acoustic impedance. Real and imaginary parts of the above quantities can be specified.

The second section of the data input program is used to enter data for two-node subsystems. These are defined as lineally connected strings of two-node elements. The data entered includes the start and end global node numbers to which the string connects, the list of elements within the subsystem, the end coordinates, cross section dimension, type number and sub-type number of each element. As an option, the fluid properties can be specified for each element to allow,for example, variation of temperature and pressure throughout the system.

The third section of the data input program is used to enter data for three-node elements and at present is restricted to finite element models built from four or eight degree of freedom plane isoparametric elements. Data entered for each three-node element includes connecting global node numbers, a cross-section dimension, an element type and sub-type number and the fluid density and speed of sound within the element.

Elements connected to more than three global nodes have to date not been considered but could easily be incorporated into the program if required.

The fourth section of the data input program allows input of data for element sub-types. Types of elements include a straight rigid pipe, other elements which can be modeled directly using two-by-two transfer matrices and general types of finite element models. The finite element models incorporated to date include four or eight node axisymmetric isoparametric elements and four and eight node plane isoparametric elements. For each type of element sub-types can be created. For example, one element type is an expansion chamber with insertion tubes at each end. Data entered for each sub-type of this element includes the ratios of the chamber diameter and outlet diameter to the inlet diameter, and the ratio of the insertion lengths to the chamber length. For each finite element model sub-type, a data file name is entered. The data file contains the information defining a specific finite element model such as a particular elbow or branch configuration.

3.2 Calculation program

Once the input data has been entered directly into memory or loaded from a data file then the calculation program can be executed. First the frequency range and increment between points at which the calculations are to be performed is entered. To save memory the results are saved only for global nodes selected. The program then calculates and stores the complex pressures and input volume velocities for each global node selected at each frequency value in the selected range. The program then branches to the results presentation program.

3.3 Results presentation program

This program allows the calculated global node pressure and volume velocity results to be converted to the desired output which can then be displayed on the CRT display, or sent to a plotter or printer. The values of pressure and volume velocity at selected points between elements within subsystems can also be displayed if the values for the global nodes at each end of the subsystem have been saved. Pressures, volume velocities, or transmitted sound power can be graphed, stored or recalled from data files as a function of frequency. These quantities or ratios of these quantities can be graphed in terms of the real and imaginary parts or phase and magnitude where applicable, and on logarithmic or linear axes. This flexibility allows direct presentation of results, for example, in terms of transmission loss, insertion loss or attenuation. Logarithmic scales can be referenced to user chosen values so the sound pressure levels and sound power levels within the system can be presented.

4. EXAMPLES

The first example illustrates the use of the method to solve a simple piping network problem. The remaining examples show the use of the finite element method to model individual system components.

4.1 Simple piping network

This example considers a piping network shown in Figure 1. All pipes in this network have 0.05 m diameters. The system has three volume velocity inputs given by $V_1 = 1$ cu.m/s, $V_2 = -0.707 - 0.707j$ cu.m/s and $V_3 = -0.707 + 0.707j$ cu.m/s (independent of frequency) and three connecting pipes with anechoic terminations. A fluid density of 1.21

kg/m^3 and a speed of sound of 344 m/s has been used throughout the system. Each length of pipe between junctions and between junctions and boundary terminations has been modeled using an exact one dimensional pipe transfer matrix solution. The transfer matrix for each pipe section was converted by the computer program to a network element matrix. These were assembled to give a global matrix equation which was solved to obtain the pressures and volume velocities at each junction and termination. Figure 1 shows the ratios of the pressures at the three anechoic terminations to the volume velocity at input 1. Note that the calculations were performed at 5 Hz intervals so that some of the local maximum and minimum values may not be truly represented.

Each length of pipe in this simple system could be replaced by a string of several components. The computer method then combines the transfer matrices for the components in the string so that the final global matrix equation for this new system would be the same size as solved in the simple system.

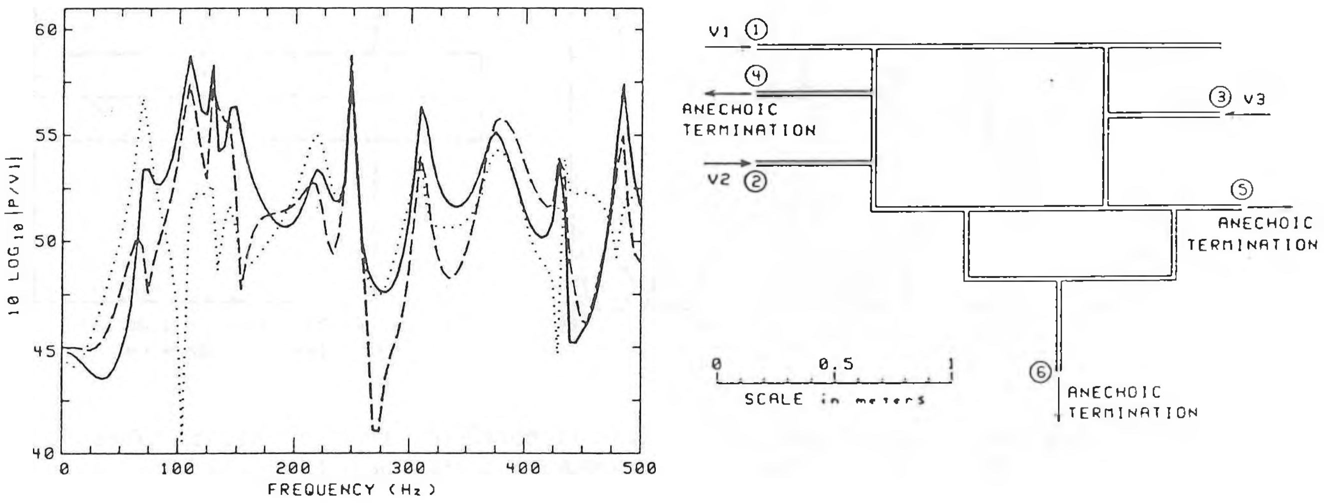

Figure 1. Piping network transfer impedance wrt Station 1
Stn. 4 - dotted, Stn. 5 - dashed, Stn. 6 - solid

In this example at each junction the pipes have been linked to a single node and the solution does not take into account the detailed geometry of the junctions or elbows and is thus only valid at low frequencies. Valid predictions could be extended to higher frequencies by using finite element methods to model the junctions and elbows. These could then be linked with one dimensional pipe elements.

4.2 Expansion chamber with insertion tubes

This example considers an expansion chamber with insertion tubes. The system considered starts with an arbitrary length of straight pipe which has an incident pressure boundary condition specified at the inlet. This is attached to one end of the expansion chamber. The outlet is attached to an arbitrary length of straight pipe with an anechoic termination.

The expansion chamber was modeled using the finite element method with isoparametric axisymmetric ring elements having eight degrees of freedom. The element mesh is shown in Figure 2. The pressures at nodes on the input and output surfaces were constrained to a single value and the finite element solution converted to a transfer matrix for the expansion chamber. The transfer matrices for the expansion chamber and the connecting one dimensional pipe elements were then combined and converted to a global network matrix equation which was solved to obtain the pressure at the anechoic termination.

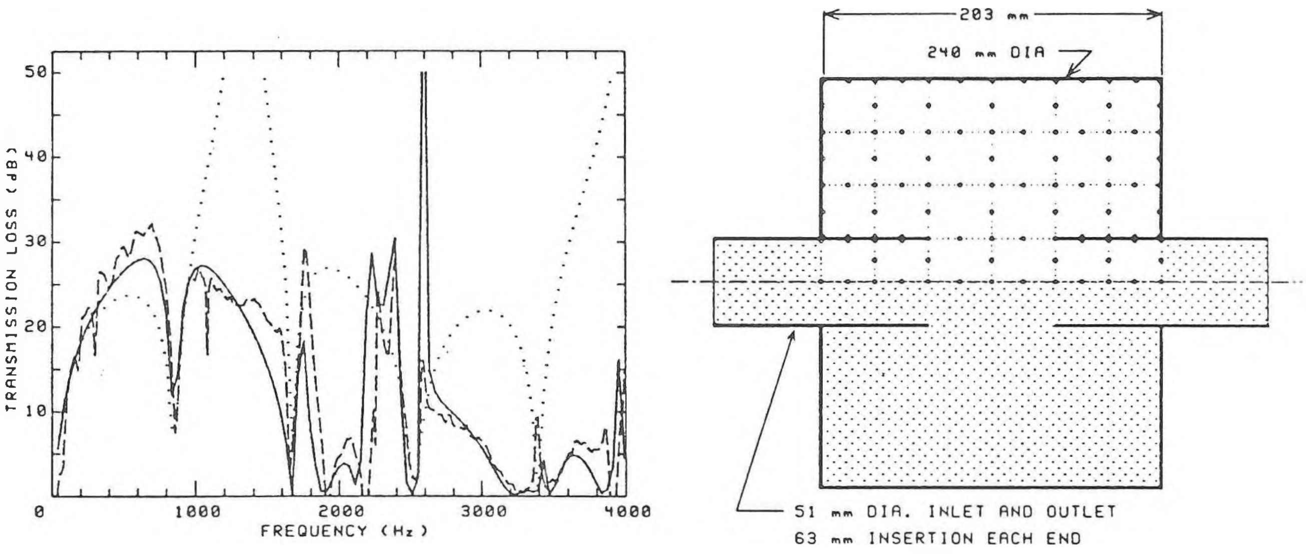

Figure 2. Axisymmetric expansion chamber with insertion tubes
FEM - solid, Experiment (MEANU) - dashed, ID - dotted

The transmission loss was then obtained by taking the ratio of the inlet incident sound power to the transmitted sound power at the anechoic termination and is shown in Figure 2 calculated at 40 Hz intervals. Also shown is an experimental result measured at the Mechanical Engineering Acoustics and Noise Unit (M.E.A.N.U.) using a two microphone technique used by Chung and Blazer [2], [3]. A third result is shown which was obtained by treating the expansion chamber as a series of one dimensional pipe elements including side branches. This demonstrates that the one dimensional analysis is inadequate for the frequency range considered.

4.3 Elbows

When two one-dimensional pipe elements join, the transfer matrix method and the assembly procedure of network elements does not consider the geometry of the junction. The pipes could be on a common axis or perpendicular to each other and the same result would be obtained. This is only valid for wavelengths much larger than the pipe cross section dimension. The model can be extended to higher frequencies by using a more detailed model of the junction which takes into account the junction geometry.

4.3.1 Square elbow

The finite element mesh used for a square elbow is shown in Figure 3. In this example an eight degree of freedom plane isoparametric element was used. As with the expansion chamber considered in section 4.2, the finite element model was linked to a one dimensional pipe element with the incident pressure specified at the inlet and to a second pipe with an anechoic termination. To compare directly with experimental results of Lippert [6] the results are shown in Figure 3 in terms of the pressure transmission coefficient (the ratio of the outlet pressure at the anechoic termination to the incident pressure at the inlet).

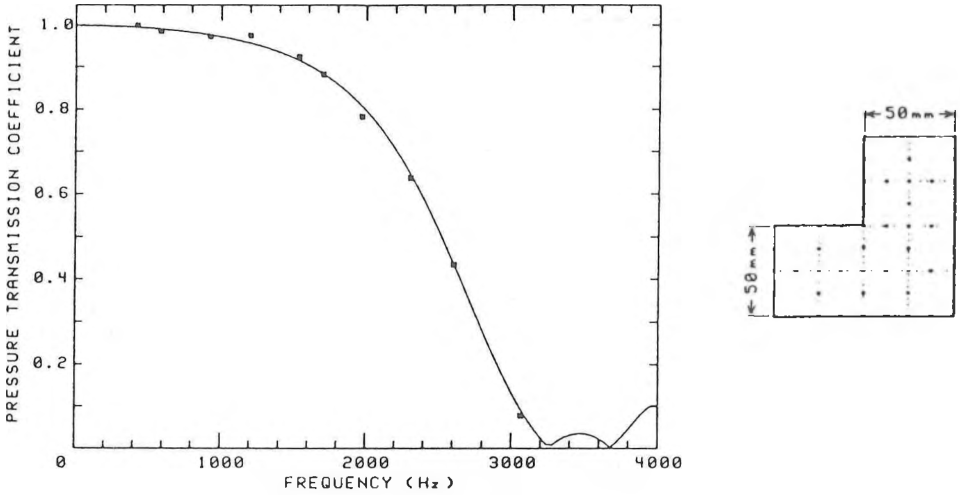

Figure 3. Square elbow with rectangular cross section
FEM - solid line, Experiment [6] - points

4.3.2 Round elbow with turning vane

Figure 4 shows the result obtained for a round elbow of rectangular cross section with a turning vane. The turning vane is modeled by disconnecting the nodes of adjacent elements along the line of the turning vane. Again isoparametric plane elements with eight degrees of freedom were used and the pressures at the inlet and outlet were constrained to single values and linked to one-dimensional pipes. The results are shown in terms of the transmission loss across the elbow.

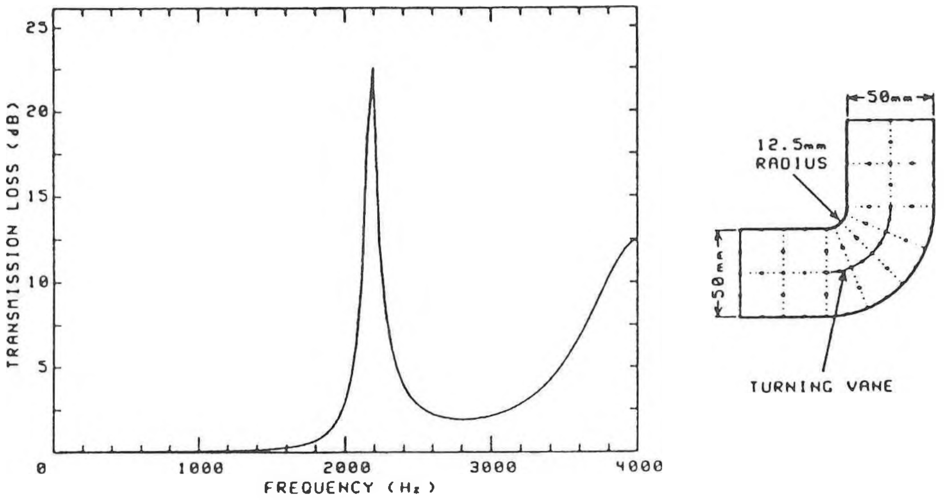

Figure 4. Round elbow of rectangular cross section with turning vane

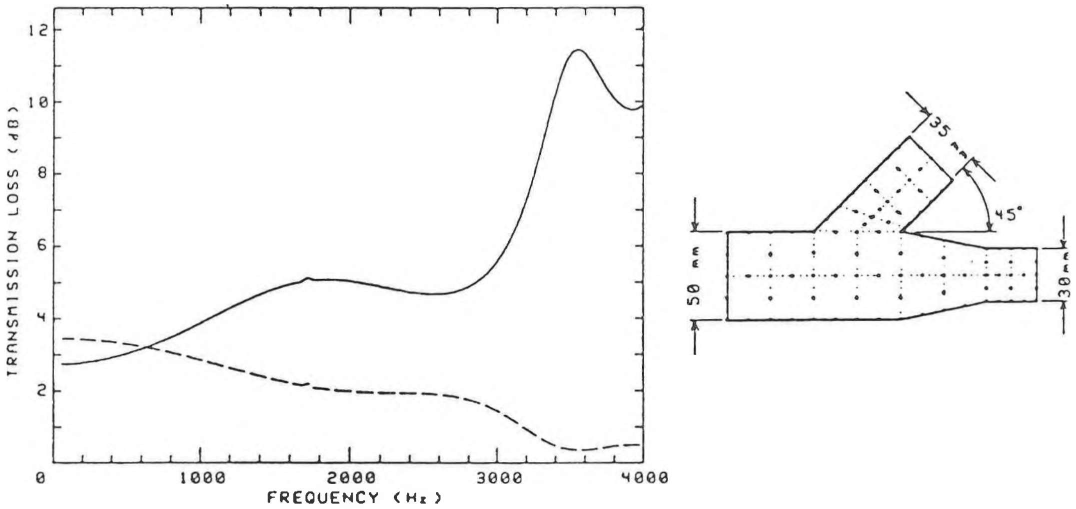

Figure 5. Rectangular duct with 45 degree branch
Branch - solid line, Continuing duct - dashed line

4.4 Branches or junction of more than two pipe elements

If a junction of three or more pipe elements is modeled by connecting the elements at a common node then the assembly procedure only considers the cross section areas of the joining pipes and does not consider the detailed geometry of the junction. The resulting prediction is frequency independent and is valid only when wavelengths are much longer than the cross sectional dimensions at the junction. The prediction can be extended to higher frequencies by modeling the junction using the finite element method as used above for elbows.

An example side branch in a duct of rectangular cross section is shown in Figure 5. This has been modeled using isoparametric plane elements with eight degrees of freedom. The 50 mm wide duct was considered as the inlet and transmission losses were predicted for the inlet to side branch path and the inlet to continuing duct path and are shown in Figure 5.

5. CONCLUSIONS AND SUMMARY

A computerized method has been developed to study the acoustics of duct and piping systems. The method combines transfer matrix procedures and finite element methods and can easily handle complicated networks with multiple inputs and outputs. It is assumed that within straight rigid piping or ducts that plane wave propagation occurs so that exact solutions can be used. In elements such as pipe junctions, branches, elbows, and in components with larger cross sectional dimensions such as plenums or expansion chambers finite element models are used to extend the validity of the method to higher frequencies. There is good agreement between the computer predictions and some experimental results obtained for individual components.

6. FURTHER WORK

The present work has considered components such as rigid ducts, elbows, and reactive mufflers in which there is assumed to be no internal dissipation of sound energy (with the exception of the one-dimensional rigid pipe transfer matrix element which can include viscous type fluid damping). The next step is to incorporate finite element models and possibly simpler transfer matrix models which can be used for components such as lined ducts or elbows and dissipative type silencers.

The finite elements incorporated into the program at present are limited to modeling of components having a plane or axis of symmetry. The elements used were created by applying constraints to an eight and a twenty degree of freedom hexahedral element. The hexahedral element could be easily incorporated in the program to model three dimensional components which have no symmetry. The major limitation would be the size of system that could be handled because of the limited memory of the desktop computer currently used for this work.

ACKNOWLEDGEMENTS

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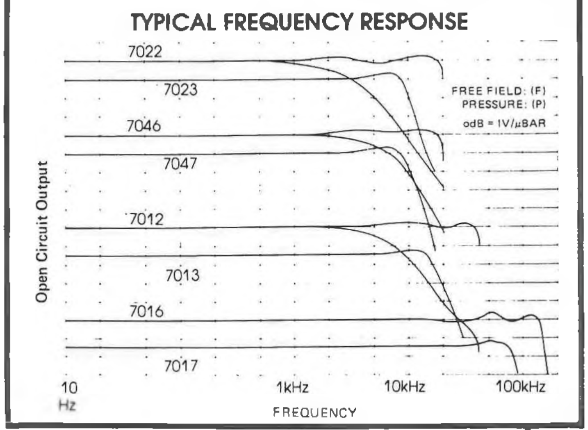
TYPICAL FREQUENCY RESPONSE



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Formant transitions as partly distinctive invariant properties in the identification of voiced stops[1]

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Abstract:

The F2 trajectories for /b, d, g/ in /CVd/ syllables are often summarized by the initial F2 frequency (F2i) and that of the "steady-state vowel" (F2v). Trajectories were measured for 660 Canadian English /CVd/ syllables (3 stops x 11 vowels x 10 speakers x 2 repetitions). Plots for each stop (vowels pooled) indicated a strong linear relationship between F2i and F2v. A regression line fitted to each plot represents an invariant relational property of the corresponding consonant. F2 trajectories are not sufficient to specify the stops uniquely, since the lines for the three consonants intersect (indicating category overlap). However, the slopes and intercepts for the three consonants are distinct and thus represent *partly distinctive invariant properties* or *partial invariants*. Similar patterns obtain for F3. Use of partial invariants of F2/F3 trajectories in a classification algorithm (based on minimum distance from category regression lines) result in an identification rate of over 70%, which compares favorably with a number of other statistical classification schemes. Possible extensions of this approach and relationships to aspects of perception are discussed.

Sommaire:

On représente souvent les trajectoires de F2 pour /b,d,g/ en syllabes du type /CV/ par la fréquence initiale de F2 (F2i) et sa fréquence dans l'état stable de la voyelle (F2v). Les graphiques obtenus pour chaque occlusive (avec regroupement de voyelles) à partir des mesures effectuées sur 660 syllabes du type /CVd/ en anglais canadien (3 occlusives x 11 voyelles x 10 locuteurs x 2 répétitions) révèlent sans équivoque un rapport linéaire entre F2i et F2v. Pour chaque graphique, la droite de régression représente une propriété relative invariante de la consonne, bien que les trajectoires ne soient pas suffisantes pour décrire les occlusives de façon non-ambigüe, puisque les droites de régression des trois consonnes se coupent (ce qui indique un chevauchement des catégories). Cependant, les pentes de ces droites et leurs points de rencontre avec les axes de coordonnées ont des valeurs distinctes et par conséquent représentent des *propriétés invariantes partiellement distinctives* ou *invariants partiels*. On note des résultats semblables pour F3. L'utilisation d'invariants partiels pour les trajectoires de F2/F3 dans une classification algorithmique (basée sur la distance entre chaque point et les droites de régression des trois catégories) aboutit à un taux d'identification de plus de 70%, résultat qui s'avère au moins aussi bon que ceux obtenus par plusieurs autres procédés statistiques de classification. L'article se termine par une discussion des ramifications possibles de cette approche et de ses rapports avec des problèmes de perception.

Introduction

The purpose of this study is twofold: 1) To show that vowel-dependent variation in the onsets of F2 and F3 transitions in stop+vowel syllables is systematic. 2) To show how this systematic variation can be exploited in a pattern recognition model for place in voiced stops. Variation in the onsets of CV transitions as a function of both the consonants and the vowels involved has been well documented (e.g., Fant 1973, see also Shammass 1985 for an extensive review). Preliminary examination of plots of formant transition data from the literature indicated that strong linear relationships existed between the onsets and steady states for voiced stop+vowel syllables. The present study was undertaken to clarify the nature of these relationships and to attempt to exploit them in a consonant recognition scheme.

Experiment

Subjects

Subjects were 10 (5 male and 5 female) phonetically trained speakers of Canadian English and were all graduate students or faculty members in linguistics at the University of Alberta.

Materials and Methods

Speakers were provided with a randomized list of phonetically transcribed syllables which they were asked to read. Two repetitions of each of 33 /CVd/ 's (with C ranging over /b, d, g/ and V ranging over /i, ɩ, e, ɛ, æ, ʌ, ɔ, o, ɷ, u, ɚ /, were collected from each of the speakers. The 660 tokens were digitized at 16 kHz and analyzed as follows. A 16 ms Hamming window was advanced in 5 ms frames over the first 80 ms following stop release. Each frame underwent an autocorrelation LPC-based spectral analysis. A lag window (rectangular in the frequency domain with a bandwidth of 50 Hz; see Tohkura, Itakura and Hashimoto 1978) was applied to the autocorrelation coefficients prior to the estimate of the inverse filter. A 20 coefficient analysis was used for all male speakers and 16 to 18 coefficients were used for females. Printouts of estimated formant frequencies and amplitudes (using a method similar to that described by Christensen, Strong and Palmer 1976, involving the second derivative of the smoothed log magnitude spectrum derived from the LPC analysis) were examined and four measurements were derived manually: 1) F2v, the frequency of "steady-state vowel" F2 at 60 ms following stop release; 2) F2i, the "initial" frequency of F2, taken as early as possible after stop release, subject to continuity of the track with F2v; 3) F3v and 4) F3i, analogous measures for F3. The measurement points for a typical stimulus are illustrated[2] in Figure 1. For some of the female voices, the initial estimates proved difficult to track. For each of these voices, an *ad hoc* adjustment of the number of coefficients was made on a few syllables until usable results were obtained. Data for these speakers was then re-analysed with the 16 ms windows which were advanced in 2.5 ms frames.

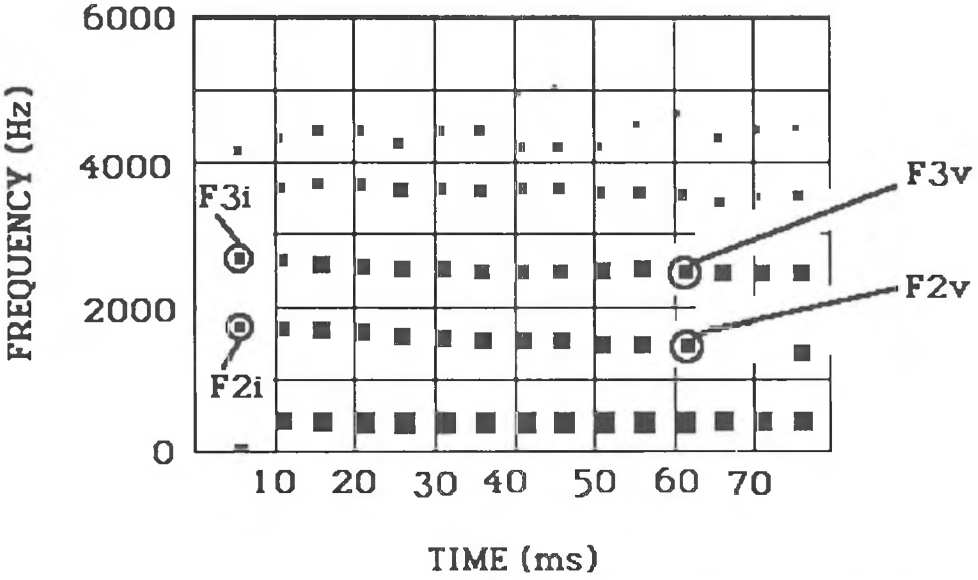

Figure 1. Schematic spectrogram showing measurement points for initial (F2i, F3i) and "steady-state" (F2v, F3v) formant frequencies.

ANALYSIS

Graphical analysis

Scatterplots of initial F2 as a function of F2 of the following vowel nucleus (F2i X F2v) confirmed that a strong linear relationship existed for each of the three consonants considered separately. These plots are shown in the left half of Figure 2. All three plots indicate a strong positive correlation between F2i and F2v. However, /d/ shows less "tuning" of F2 onset (F2i) with changes in F2v, consistent with a "/d/-locus" near 1800 Hz (Delattre et al. 1955; Fant 1973). On the other hand, /b/ and especially /g/ are more strongly vowel-dependent. Note that /b/-onsets generally occur at or below the diagonal (F2i=F2v), while /g/-onsets lie slightly above it . Similar patterns exist for the three consonants for F3. (See right half of Figure 2.) However, the differences in the distributions of the three consonants in F3 is less striking.

Regression analysis

The left half Figure 2 also displays the results of least-squares regressions[3] of F2i on F2v for each of the consonant categories considered separately. A similar analysis of F3i and F3v is presented in the right half. The regression coefficients coefficients reported in Figure 2 may be used as the basis of a simple minimum distance classification procedure as described below. It should be noted that the relationships described here are similar in many ways to those exploited by Klatt for formant frequency transition calculation in speech synthesis by rule (see Allen, Hunnicut and Klatt 1987: 111-116).[4]

Classification results

Minimum distance classification

After using the data as a training set for the regression lines, each spoken syllable was re-classified as a member of /b/, /d/ or /g/ on the basis of its distance to each of the corresponding regression lines. More precisely, each token is mapped into the F2i X F2v plane, where its vertical distance, D2c, to the regression lines for each consonant (c) is calculated. A similar set of distances, D3c, is calculated in the F3i X F3v plane. The decision was based on the combined distance measure $D^2c = [(D2c)^2 + (D3c)^2]$. A token is classed as the consonant for which D^2c is minimum.

This minimum distance classification rule results in a correct partition rate of 73.9%, when the training data are re-classified. A cross-validation approach, in which the data from an arbitrary subsample of five of the speakers were used as the training set while the remaining 5 were used as the test set, actually yielded slightly higher correct classification rate for the test data, 76.1%.

Alternative parametric classification methods

The present analysis shows that there is considerable information available in formant frequency transitions for the identification of stop consonants. It should be noted that the analysis used *acoustic context only* and did not require prior phonetic categorization of the following vowel. Kewley-Port (1982) investigated linear discriminant analyses of /b/, /d/ and /g/ based on F2-F3 transition measurements of syllables spoken by a *single* speaker. She found that automatic classification of place features for stop consonants was quite high (97%) when linear discriminant analyses were carried out separately for individual vowel contexts. However , it should be born in mind that only 5 repetitions for each vowel token were involved. Shammass (1985) reports separate vowel-wise linear discriminant analyses for the present data and finds an overall correct identification rate of 81% and ranging from 72% for / ɚ / to 90% for /ʌ /. Shammass's classification results involved 20 points per vowel (2 repetitions by each of 10 speakers). Furthermore her results were based on the so called U-method (or jackknife, Gray and Schucany 1972) of classification which reduces bias in classification scores for small samples. Classifications results reported by Kewley-Port were considerably lower (68% correct) when a single linear discriminant analysis (pooling over vowels) was conducted. A single linear discriminant analysis of the present multi-speaker data yielded an identification rate of 66% (compared to about 74% for the regression method described above).

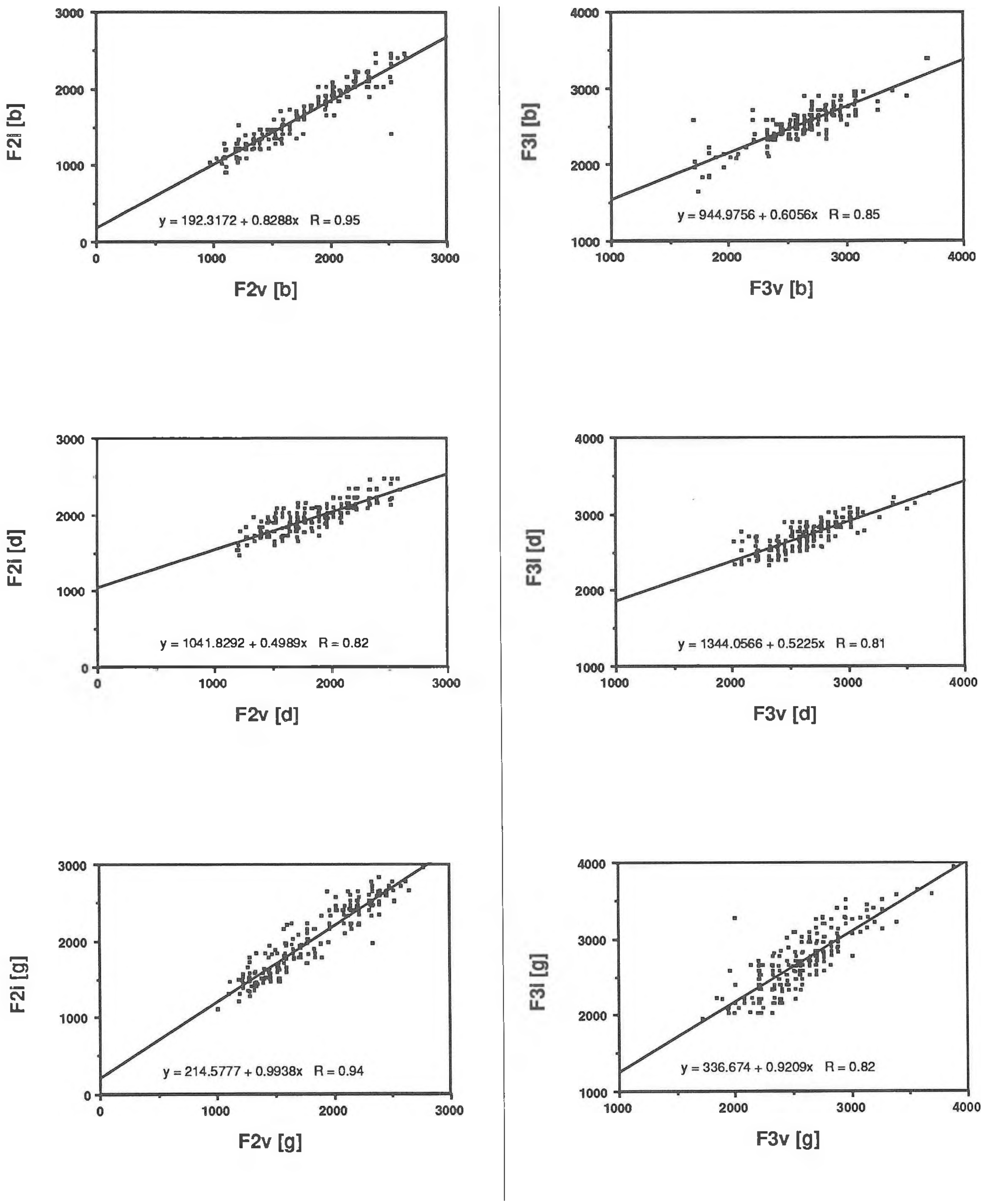

Figure 2. Left panel: Scatterplot of the frequencies of initial F2 (F2i) and F3 of the vowel at 60 ms from consonant release (F2v). Right panel: analagous plots for F3i and F3v. (Top to bottom in each panel: data for /b/, /d/, /g/). Least-squares regression lines, their coefficients and Pearson's r are shown for each analysis.

Linear discriminant analysis is based on the assumption that the samples used in the determination of the classification rule are drawn from normal distributions that differ only in their mean vectors (i.e., the means for F2i, F2v, F3i, F3v may be distinct for each of /b/, /d/, /g/) but that the groups have a common covariance matrix. The scatter plots and regression analysis indicate that this latter assumption is likely not correct, since, e.g. the regression of F2i on F2v has a substantially more positive slope for /g/ than for /d/. (Indeed, the differences in the orientations of these distributions seem more salient than their overall locations.[5]) A formal test of the equality of covariance matrices provides strong evidence for rejection of the common covariance assumption[6] (Box's M = 249.0, approximate F(6,120)=41.3, p<.0001). Bayesian classification schemes using separate estimates of the covariance matrices for each group are more appropriate than linear discriminant analysis in such cases. These procedures, sometimes referred to as quadratic discrimination (Lachenbruch 1975: 20-23), may be performed either in the full space of the original measurements or in a reduced dimensional space based on a prior linear discriminant analysis (Tatsuoka 1971: 232 -233). Classification of the present data using separate covariance estimates in a reduced (2-dimensional) space was investigated by Shammass (1985), resulting in 72% correct identification. A full 4 -dimension quadratic discriminant analysis (equivalent to a maximum likelihood classification scheme) actually showed a slightly lower overall classification rate of 71%. These rates are similar to that of the minimal distance regression rule. Confusion matrices for the regression classification, linear and quadratic discriminant analysis are given in Table 1. The similarity of the error patterns for the regression and quadratic methods may indicate they are exploiting essentially the same properties of the distributions.[7]

TABLE I: Consonant-wise identification rates (in percent) for selected classification procedures:

Linear Discriminant Analysis

Actual Group	Predicted Group		
	/b/	/d/	/g/
/b/	89.5	9.1	1.4
/d/	16.4	47.7	35.9
/g/	15.0	25.0	60.0

Quadratic Discriminant Analysis (2-Dimensional)

Actual Group	Predicted Group		
	/b/	/d/	/g/
/b/	84.1	10.0	5.9
/d/	10.5	71.4	18.2
/g/	11.8	26.4	61.8

Minimum distance Regression Classification (all data pooled)

Actual Group	Predicted Group		
	/b/	/d/	/g/
/b/	89.5	6.4	4.1
/d/	11.8	69.1	19.2
/g/	15.0	21.8	63.2

Discussion

The regression lines for each consonant may be regarded as representing invariant relational properties for each consonant. These invariants are not sufficient individually to separate the groups in all cases (superposition of Figures 2, 3 and 4 shows considerable category overlap). But, since the lines for the three categories are not identical, the properties may be considered partially distinctive.[8]

Other factors such as the shape of onset spectra and VOT are important cues in analytic recognition of stops (Blumstein and Stevens 1979; Edwards 1981; Searle et al. 1979; Kewley-Port 1982) as well as in speech perception (Blumstein and Stevens 1980). Walley and Carrell (1983) show that formant frequency information can, in certain cases, override other cues. Shammass (1985) confirms that both spectral shape information and formant frequencies play a role in listeners' perception of synthetic stops. She compares a regression classification of synthetic stimuli (similar to that presented here) to listeners' judgments. Predictions are good only in the case of front vowels. Further research is needed to clarify the nature of the interaction of cues in listeners' perception and to apply these results to automatic speech recognition. We hope that, given a suitable parametric representation of spectral shape information, methods similar to those applied here and in Shammass (1985) will result in improved recognition performance.

Notes

1. Portions of this research were presented as Poster Session D15, 111th Meeting Acoustical Society of America Cleveland, Ohio 13 May 1986 and stem from work performed in conjunction with the doctoral dissertation of the second author.

2. The size of the marks in Figure 1 is linearly related to the formant amplitude estimates (in dB). This figure is included for illustrative purposes only. The actual measurements were extracted manually from numerical printouts.

3. As noted by an anonymous reviewer, ordinary least squares regression is strictly justifiable only when the independent variables are error free. Daniel and Wood suggest: "As a rule of thumb, least squares analysis can be used safely if the variance of x is less than a tenth of the average scatter of the x's about their mean (1971:32)." Estimates of "pure error" (Draper and Smith 1981) from repetitions of the same syllable by the same speaker range between 53 and 152 Hz in the present data for all measures, while the standard deviations of F2v and F3v about their means range from 279 to 440 Hz. All but one of the regression lines in Figure 2 exceed Daniel and Wood's rule of thumb. The one exception, F3v of /d/ falls just short of this criterion, with a ratio of .106, or about 6% greater than their "safe" ratio. The reviewer suggested that principle components analysis might be preferable to regression. Then, presumably, the eigenvector associated with the largest eigenvalue would replace the regression line and a suitable distance metric would have to be applied (e.g. perpendicular distance to the eigenvector). We agree with the reveiwer that this is unlikely to make much difference in the present case. It might be more important in other cases where both variables showed large "pure error" variation compared to their ranges.

4. However, Klatt found that, for velars and alveolars, more than one regression line per consonant was required for accurate modeling of onset/target relationships, depending on whether the following vowel was back rounded, back unrounded or front. The present data do not seem to warrant such an approach (but see notes 5 and 8).

5. The mean vectors (F2i,F3i,F2v,F3v) are: (1601, 2442, 1699, 2637) for /b/; (1969,2727,1858, 2648) for /d/; and (2029,2702,1826, 2568) for /g/. /d/ and /g/ are very close , deviating by no more than 60 Hz on all measures. /b/ shows more markedly lower values (about 150 to 370 Hz) on all measures except F3v.

6. Separate histograms of F2i, F2v, F3i and F3v also indicate that the assumption of simple multinormal distribution about the mean is suspect. Several of these histograms showed tendencies toward bimodality, with one peak for front vowels and another for back. More detailed modeling of

these probability distributions in classification schemes is planned. It should be noted that more complex distributions could be used in classification schemes without explicit reference to categorical knowledge of the vowel categories in the classification phase itself.

7. This note is a response to some interesting comments from an anonymous reviewer. The regression classification technique would, in effect, constitute a maximum-likelihood classification procedure under the following conditions: 1) all errors of measurement are in the dependent variables; 2) error variances for F2i and F3i are equivalent for all the vowels; 3) residuals from F2 and F3 analyses are uncorrelated; 4) overall location of the distributions along the F2v and F3v axes are independent of the consonant (no systematic co-articulation effects of the consonants on the steady states). There is evidence that some of these conditions are at least moderately violated by this data. Condition 1 has been commented on in note 3. Regarding condition 2, standard errors for both F2 and F3 regressions for /b/ and /d/ ranged from 107 to 122 Hz. However standard errors for the /g/ regressions were 152 Hz for F2 and 214 Hz for F3. Experimentation with a modified regression analysis that weighted distances (in inverse proportion to the error variances) yielded highly similar identification rates to the unweighted method. Regarding condition 3, correlation analysis of the residuals of F2 and F3 analyses showed no significant relationship for /b/, but both /d/ and /g/ showed significant positive correlations: R=.299 for /d/ and R= .156 for /g/, accounting for about 9% and 2% of the residual variance respectively. Regarding condition 4, see note 5. Quadratic discriminant analysis (QDA) can accommodate all the above violations of assumptions of a maximum likelihood regression model. The fact that QDA does not show improvement over the regression model may be because 1) the violations involved are relatively mild; or 2) the violations occur in "directions" that do little harm; or 3) there are violations of additional assumptions of QDA itself (see note 6).

8. Shammass (1985) presents evidence that slightly different regression lines may characterize female versus male data for the same consonants in both F2 and F3. While this raises interesting questions related to speaker-normalization, exploratory investigation indicated that the differences are relatively unimportant for this data set. In particular, classification based on separate regression lines for males and females leads to only modest improvement in classification scores over the pooled male and female data reported below. Nonetheless, we believe the issue merits further study in larger data sets.

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INFLUENCE DE LA DYNAMIQUE ET DE LA COMPOSITION SPECTRALE SUR LA GENE RESULTANT DANS UN LOGEMENT, EN PRESENCE D'ECHANTILLONS DE BRUITS DE CIRCULATION REPRODUITS A NIVEAU EQUIVALENT CONSTANT

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Résumé:

Le choix d'enregistrements de bruit routier de distributions statistiques différentes et l'utilisation d'un compresseur ou d'un expanseur, ont permis de recréer en Laboratoire diverses situations environnementales derrière un échantillon de façade. Lors de ces expériences, menées à niveau équivalent constant, ont été étudiées l'influence de la dynamique résultante dans un logement, suivant différentes conditions d'ouverture de la fenêtre, ainsi que celle de la pente de l'isolation procurée par l'échantillon de façade. Les résultats très cohérents obtenus pour les gênes exprimées par les participants montrent bien les faiblesses de l'emploi systématique du seul niveau Leq comme descripteur de l'environnement.

Abstract:

With the aim of reproducing in laboratory conditions the transmission process and the annoyance of a traffic noise through a regular housing façade sample with a window frame, the authors have used traffic noise records with different statistical distributions and electronic devices as compressor, dynamic range processor and spectrum shaper. These experiments, conducted with a constant equivalent level on frontage, have permitted to obtain the reactions of groups subjects with different noise level dynamic ranges and different opening conditions of the window. The effects of the slope of the transmission loss of the façade sample have also been studied with a constant internal equivalent level. The coherent results obtained on the scale of annoyance clearly indicate the weakness of the generalized use of Leq level for the only one descriptor of the environment.

1. INTRODUCTION

La dynamique des niveaux de bruit communautaire a fait l'objet d'une étude extensive dans la période 1965-75, suite notamment aux travaux londonniens du "Committee on the problem of noise" et à l'apparition de dispositifs simples pour l'analyse de la distribution statistique [1]. Ces travaux ont culminé dans les années 70, avec les recherches parallèles de la B.R.S. en Grande-Bretagne et du C.S.T.B. en France, et la publication de la norme ISO R1996. Qu'on pense simplement à la floraison d'indices de bruit basés sur l'étendue de la dynamique comme le TNI (*"Transportation Noise Index"*) de Griffiths et Langdon ou bien aux savantes études de gêne de Aubrée, Auzou et Rapin [2, 3].

Paradoxalement, alors que les outils analytiques s'affirmaient, on a vu depuis lors un net recul des paramètres statistiques de niveau de bruit au profit de l'emploi généralisé du seul niveau continu équivalent Leq, tant en ce qui concerne la métrologie, les normes et les législations, que la modélisation et les études d'impact [4, 5]. Les recherches présentées ici tendent à démontrer que la gêne ressentie dans les logements évolue de façon beaucoup plus délicate qu'il n'y paraît au premier abord et que le niveau continu équivalent n'est peut-être pas le seul descripteur nécessaire et suffisant pour cerner tous les aspects de la nuisance du bruit de la circulation. D'ailleurs, de nombreux relevés sur le terrain et dans des logements voisins des principaux axes de circulation de la Région de Québec nous avaient laissé entrevoir dès 1982 la complexité du problème [6, 7].

2. ETUDE EN LABORATOIRE RELATIVE A LA PERCEPTION DE LA DYNAMIQUE DU BRUIT DE LA CIRCULATION AUTOMOBILE ET A SON EVOLUTION AU TRAVERS D'UNE FACADE

2.1 Dispositif expérimental

Cette étude réalisée au Laboratoire d'acoustique de l'Université Laval fait suite à une analyse détaillée des caractéristiques physiques de l'isolement acoustique d'un échantillon de façade. Du côté source, le dispositif expérimental retenu a permis de contrôler à la fois le niveau de pression, la composition spectrale, la dynamique et la directivité. Ces derniers paramètres ayant été ajustés par intensimétrie, de façon à obtenir un champ acoustique normal [8].

Du côté récepteur, la petite chambre réverbérante du Laboratoire a été traitée avec des matériaux absorbants (plafond suspendu et panneaux muraux), de façon à réduire son temps de réverbération aux environs de 0,5 s; ceci à la fois pour permettre des mesures intensimétriques de dispersion et pour accomoder les personnes participant aux tests de perception (voir Fig. nº 1). Le niveau de bruit de fond contrôlable a été obtenu à l'aide de quatre enceintes acoustiques balancées individuellement et installées dans le plafond suspendu (spectre calibré conformément aux courbes NR).

2.2 Expériences de perception à niveau équivalent constant en façade

Les niveaux de six rubans échantillons de circulation routière (d'une demi-heure chacun) ont été ajustés à la reproduction de façon à obtenir un niveau continu équivalent Leq = 65 dB(A), tel que relevé à 0,60 m de l'échantillon de fenêtre. Au cours des expériences les

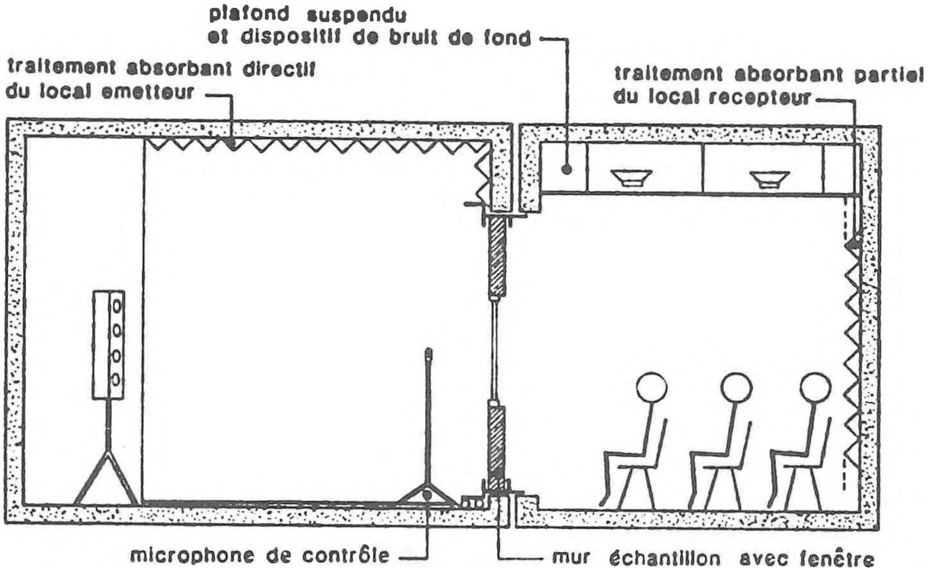


FIGURE Nº 1: Dispositif expérimental utilisé.

spectres émis ont été constamment visualisés sur un analyseur en temps réel ("B & K" 2131) et le comptage statistique des niveaux (notamment l'affichage du niveau Leq) contrôlé à l'aide d'un analyseur statistique ("B & K" 4426). Il a été tout d'abord vérifié que la distribution statistique réelle des niveaux de bruit, relevée au cours des enregistrements en bordure des voies de circulation, puisse être reproduite intégralement devant l'échantillon de façade. Les six rubans retenus correspondaient à des trafics routiers compris entre 670 et 5972 v/h, avec des pourcentages de poids lourds compris entre 1,4% et 12.5%. Quant à la dynamique totale, elle s'étendait de 17,3 à 43,3 dB(A) pour l'écart L1% - L99% (16,8 à 35 avec les niveaux équivalents égalisés à 65 dB(A)).

Deux modes ont été simulés autour de cette dynamique dite "normale" d'un même échantillon de bruit routier, soit la "compression" et l' "expansion", ces deux autres distributions des niveaux de bruit ayant été obtenues électroniquement (expanseur "Heath" AD-1706, et compresseur "Orban" 412A) (voir Fig. nº 2). Pour tous les échantillons, les circuits d'amplification et de commutation ont été calibrés de façon à assurer la constance du niveau Leq en façade. A titre d'exemple, les résultats des niveaux statistiques obtenus à l'intérieur du logement fenêtre fermée font l'objet du Tableau nº 1.

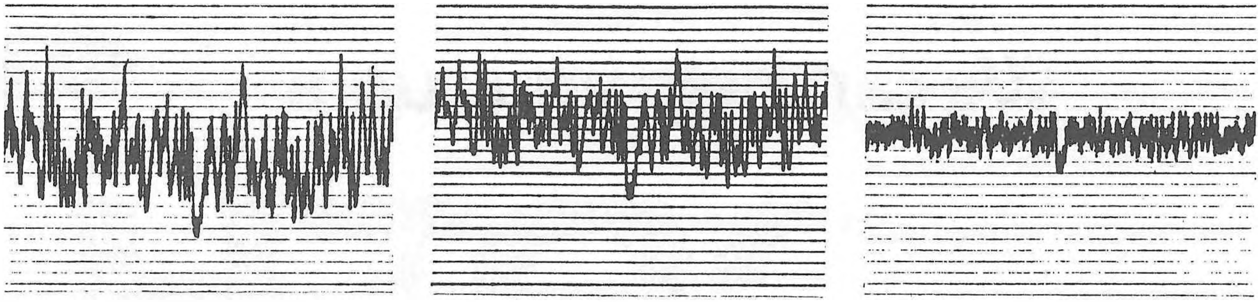
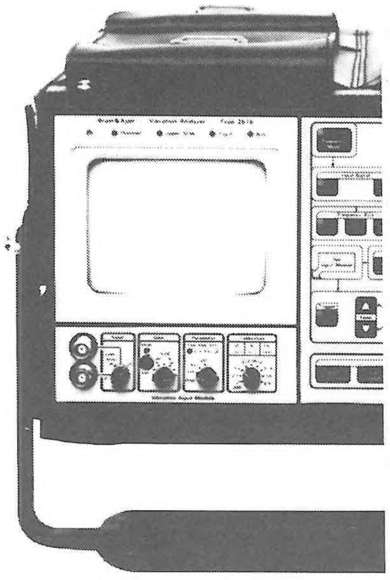


FIGURE nº 2: Effet de la compression et de l'expansion

2.3 Interprétation des résultats suivant les individus

L'incidence des différentes dynamiques a tout d'abord été étudiée, pour les six échantillons de bruit, par l'intermédiaire de tests d'écoute dont les résultats ont été ensuite comparés aux mesures acoustiques; les sujets testés devant exprimer leur évaluation des modes "compressé" et "expansé" en comparaison avec le ruban normal. Les bandes étant écoutées les unes à la suite des autres, les sujets ont pu se repérer au mode normal de la bande précédente pour débuter l'évaluation d'une nouvelle bande. Il leur est demandé:

- de quantifier leur gêne par un chiffre allant de 1 à 7 (de l'environnement sonore le plus acceptable à celui le plus dérangeant),



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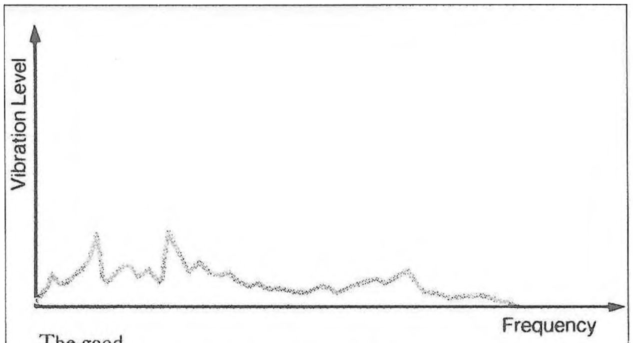
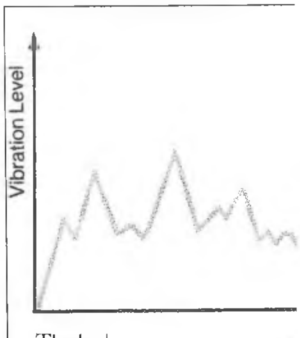


The good
Vibration spectrum soon after machine installation.



The bad
The spectrum two months late

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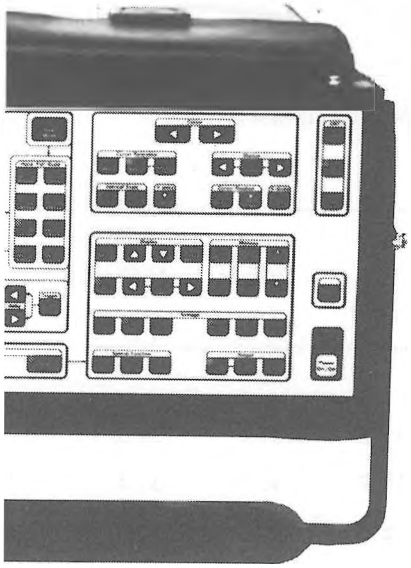

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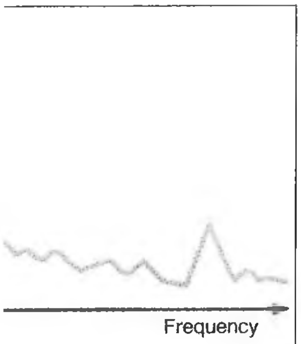
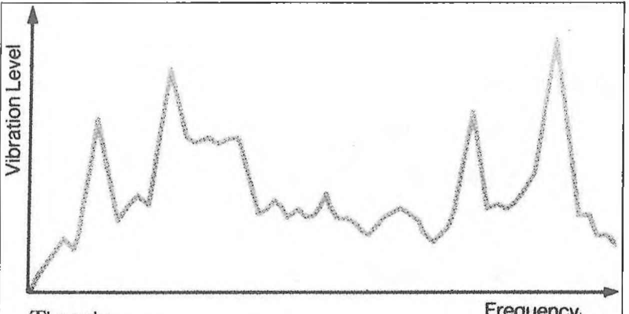


ration level is increasing.



The ugly
The spectrum three months later. Vibrations are increasing to breakdown level. Immediate repair is needed.

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TABLEAU Nº 1: Caractéristiques des échantillons de bruit routier tels que mesurés dans le local fenêtre fermée.

Echantillon nº	Mode	Leq	L1%	L10%	L50%	L90%	L99%	1%-99%	10%-90%	TNI	NPL	NBS
1	C	33.4	38.0	35.3	33.3	31.3	29.3	8.7	4.0	17.3	37.4	35.3
	N	31.9	40.3	34.8	30.0	26.0	24.0	16.3	8.8	31.2	40.7	34.4
	E	33.8	43.0	36.5	30.5	26.5	25.5	17.5	10.0	36.5	43.8	35.5
2	C	31.6	36.0	33.3	31.3	30.3	29.5	6.5	3.0	12.3	34.6	32.8
	N	31.8	38.8	33.8	30.8	29.3	28.8	10.0	4.5	17.3	36.3	33.0
	E	33.1	42.8	35.8	30.0	27.5	26.5	16.3	8.3	30.7	41.4	34.1
3	C	31.8	36.8	33.5	31.3	30.0	29.0	7.8	3.5	14.0	35.3	32.5
	N	29.8	37.8	33.0	27.8	25.0	24.0	13.8	8.0	27.0	37.8	31.8
	E	32.4	42.3	35.3	28.8	26.3	25.5	16.8	9.0	32.3	41.4	33.3
4	C	30.2	36.3	33.3	29.5	25.8	24.8	11.5	7.5	25.8	37.9	33.2
	N	36.8	39.3	31.8	26.3	25.0	24.0	15.3	6.8	22.2	43.6	29.7
	E	30.6	42.3	31.3	25.3	24.5	24.0	18.3	6.8	21.7	37.4	28.7
5	C	31.8	37.3	33.3	31.3	29.8	28.8	8.5	3.5	13.8	35.3	33.0
	N	32.0	41.3	34.3	29.8	27.0	25.5	15.8	7.3	26.2	39.3	33.4
	E	33.6	44.5	35.0	29.3	26.3	24.8	19.7	8.7	31.1	42.3	33.6
6	C	33.3	38.3	35.5	33.0	31.3	29.5	8.8	4.2	18.1	37.5	35.1
	N	32.9	42.3	35.8	30.3	27.3	26.0	16.3	8.5	31.3	41.4	34.5
	E	33.8	44.8	36.5	29.5	26.3	25.3	19.5	10.2	37.1	44.0	34.6

- et d'estimer, telles qu'ils peuvent les percevoir, les variations de vitesse, de proximité et de débit.

Au total 28 personnes ont participé aux différents tests d'écoute, néanmoins, suivant les expériences, la compilation statistique finale peut porter sur un nombre légèrement inférieur de répondants. Les participants ont écouté les six échantillons de bruit en situation passive (écoute attentive), par groupe de cinq personnes au maximum de façon à ne pas trop s'influencer mutuellement (ils avaient tous subi préalablement un test audiométrique). Les rubans ont été diffusés pour chaque groupe selon un ordre d'écoute quelconque. Les échantillons de bruit ont défilé au moins le temps nécessaire pour que l'ensemble des personnes présentes puisse noter les résultats perçus (de 3 à 5 minutes). D'autre part, entre les changements de mode, de "comprimé" à "expansé", on a permis aux participants de réentendre le ruban normal de façon à ce qu'ils puissent exercer au mieux leur jugement.

Au dépouillement des tests, on observe tout d'abord qu'une hiérarchie de la gêne s'établit pour chaque échantillon, que cette hiérarchie diffère suivant l'échantillon, et aussi qu'elle peut différer suivant les individus. Pour une même ouverture de fenêtre, les niveaux Leq étant maintenus constants en façade, les différences de gêne observées sont entièrement dépendantes des différences de dynamique du bruit. L'écart type moyen des notes brutes attribuées par les sujets pour trois positions de la fenêtre diminue légèrement de la fenêtre fermée à la fenêtre complètement ouverte: plus la fenêtre est ouverte et moins les résultats de gêne sont dispersés. La configuration de la fenêtre fermée est la plus délicate à traiter, puisque la perception du bruit semble plus ténue et l'évaluation de la gêne plus subtile.

Les résultats du Tableau nº 2, qui concernent le cas de la fenêtre fermée, montrent qu'une partie des sujets est sensible à la dynamique (le mode "expansé" les gêne), alors que

TABLEAU Nº 2: Notes moyennes distribuées par les trois groupes de tendances dans la configuration "fenêtre fermée". Les groupes "Compressé", "Expansé" et "Indécis" représentent respectivement 55, 25 et 20 % de l'effectif total des sujets.

Echantillon nº	Mode de reproduction	Notes de gêne fenêtre fermée						
		Groupes préférant les modes "Compressé"			ou "Expansé"			"Indécis"
		moy.	sn	sb	moy.	sn	sb	moy.
1	C	2.1	0.88	0.90	3.9	1.05	0.80	4.0
	N	2.4	0.33	1.01	3.3	0.45	0.75	3.5
	E	3.3	0.75	1.48	2.4	1.36	0.86	4.8
2	C	2.4	0.75	1.29	4.2	1.30	1.16	3.8
	N	2.9	0.75	1.67	3.8	0.75	1.16	3.8
	E	3.6	1.04	20.3	3.2	1.01	0.75	4.2
3	C	2.3	0.73	1.13	3.7	1.02	1.07	2.8
	N	3.0	0.61	1.18	3.8	0.93	0.67	3.5
	E	5.3	0.73	1.30	2.7	1.06	1.16	3.0
4	C	2.2	0.88	0.97	4.2	0.47	0.97	2.8
	N	2.6	0.68	1.18	4.0	0.75	1.41	3.7
	E	3.0	0.85	1.87	4.1	0.80	1.35	4.5
5	C	1.8	0.75	0.81	4.4	0.31	0.44	4.3
	N	1.6	0.54	0.93	2.7	0.62	1.01	3.5
	E	1.9	0.67	0.93	1.4	1.00	1.46	3.0
6	C	2.4	0.75	1.14	4.9	0.70	1.20	3.3
	N	2.5	0.71	1.23	3.9	0.65	1.11	3.0
	E	3.2	0.91	1.46	3.6	0.59	0.80	3.8
Moyenne des six échantillons	C	2.2			4.2			3.5
	N	2.5			3.6			3.5
	E	3.4			2.9			4.0

l'autre est sensible à la densité de bruit (ils préfèrent le mode "expansé") et qu'il reste finalement une faible proportion d' "indécis".

La Figure nº 3 illustre la différence de comportement de ces trois groupes: les personnes qui préfèrent le mode "comprimé" voient leur gêne croître avec la dynamique, alors que celles qui préfèrent le mode "expansé" se montrent sensibles au niveau de bruit de fond, qui est en général d'autant plus bas que la dynamique est importante. Quant aux "indécis", leur gêne ne semble pas liée de manière simple aux caractéristiques statistiques du niveau de bruit Cette figure schématise en quelque sorte, pour chacune des situations, l'évolution des notes de gêne de chacun de ces trois groupes en fonction de la dynamique. Compte tenu des pourcentages relatifs, qui s'établissent à 55% de "comprimés", 20% d' "indécis", et 25% d'"expansés", la gêne moyenne de l'ensemble des sujets réflète fortement celle du groupe des personnes sensibles à une forte dynamique (voir Tableau nº 3). On peut noter que les "indécis" ont un comportement qui tend à se rapprocher des "comprimés" lorsque la fenêtre est fermée ou entr'ouverte, mais qu'ils tendent plutôt à se rapprocher des "expansés" lorsque la fenêtre est grande ouverte, c'est-à-dire lorsque le bruit est le plus fort, et également le plus reconnaissable.

On peut mentionner finalement à propos des Tableaux nº 2 et 3, les écarts type sont indiqués de deux manières, soit sur les réponses brutes et sur les réponses normalisées. Dans la mesure où il ne nous intéressait pas de prouver que la gêne apparaissait toujours plus forte fenêtre ouverte que fenêtre fermée, il a été possible de normaliser les réponses en attribuant systématiquement une note moyenne de gêne de 4 pour les six rubans écoutés en mode normal par chacune des personnes, quelle que soit l'ouverture de la fenêtre (toutes les notes ayant été ajustées en conséquence pour les trois expériences et pour chaque répondant). On constate que les écarts type sont généralement plus petits (souvent bien inférieurs à l'unité) et les réponses de ce fait plus cohérentes en fonction de la dynamique.

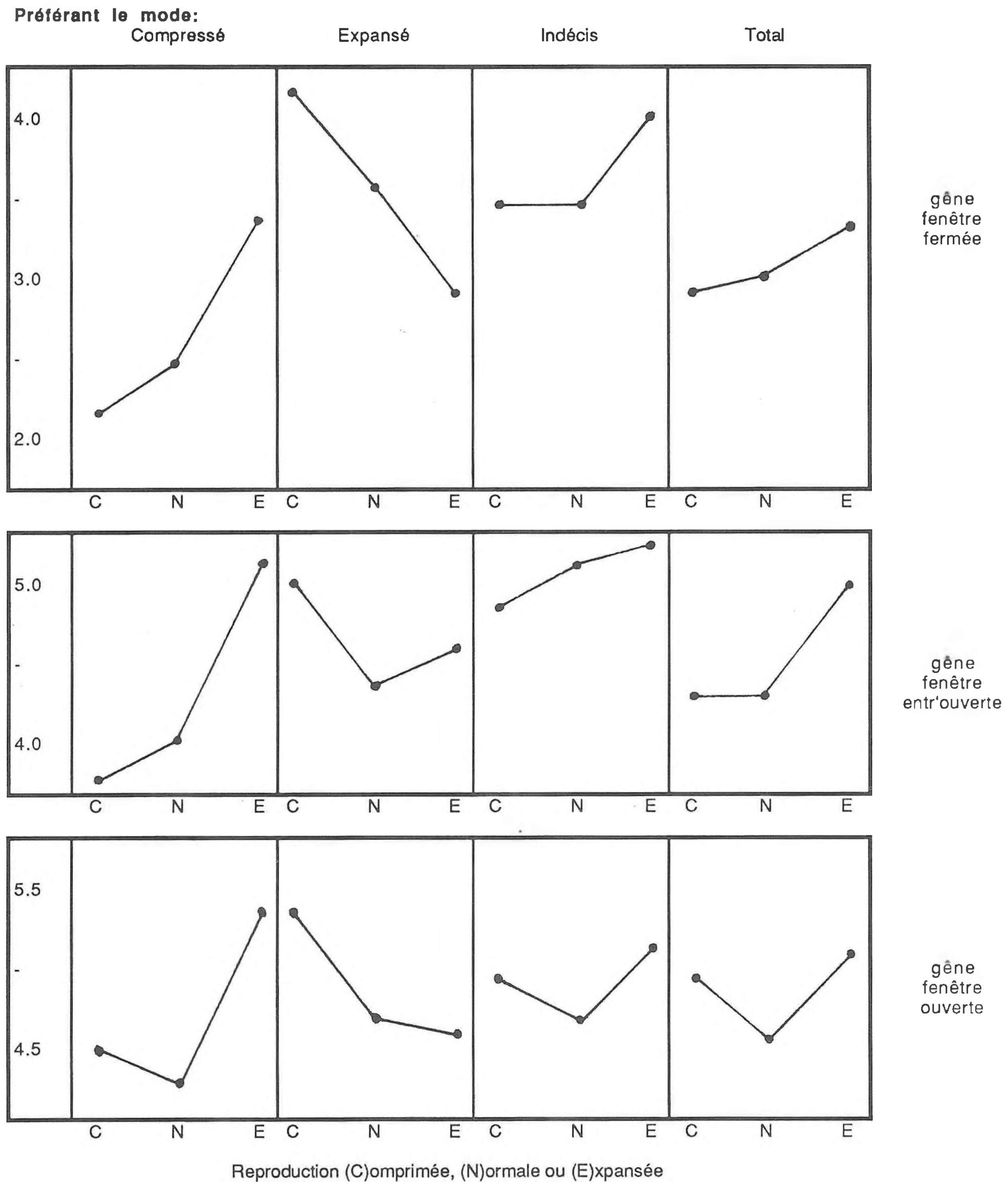

FIGURE Nº 3: Tendances de notation de chacun des trois groupes de sujets, et tendance de l'ensemble, pour chaque position de fenêtre testée.

TABLEAU Nº 3: Notes moyennes de gêne distribuées par l'ensemble des sujets.

Echantillon nº	Mode de reproduction	Position de la fenêtre					
		Fermée		Entr'ouverte (15°)		Ouverte (90°)	
		moy.	σn	moy.	σn	moy.	σn
1	C	2.9	1.11	4.2	1.03	4.7	0.88
	N	2.8	0.43	4.4	0.83	4.4	0.54
	E	3.4	1.34	5.1	1.04	4.8	1.22
2	C	3.1	0.93	4.2	1.06	5.0	0.78
	N	3.3	0.75	4.3	0.45	4.6	0.70
	E	3.6	1.10	4.9	0.99	5.0	0.94
3	C	2.7	0.84	4.6	1.02	5.1	0.76
	N	3.3	0.74	4.8	0.91	5.2	0.71
	E	3.2	1.26	5.5	0.96	6.0	0.97
4	C	2.8	1.02	4.3	0.81	4.9	0.76
	N	3.1	0.76	4.6	1.16	5.1	0.94
	E	3.7	0.84	5.1	1.10	5.3	1.11
5	C	3.0	0.97	4.3	0.90	4.9	0.73
	N	2.3	0.68	3.6	0.78	4.2	0.76
	E	2.1	1.07	4.3	0.79	4.9	0.95
6	C	3.2	0.92	4.2	0.87	4.8	0.75
	N	3.0	0.75	4.0	0.63	4.2	0.58
	E	3.4	0.88	4.6	1.33	4.4	0.61
Moyenne des six échantillons	C	2.9		4.3		4.9	
	N	3.0		4.3		4.6	
	E	3.3		4.9		5.1	

En ce qui concerne l'incidence de la variation de dynamique sur le comportement psychoperceptif, l'unanimité semble faite: les notes attribuées par l'ensemble des sujets à l'augmentation relative des vitesses, proximité et débits pour les modes "compressé" et "expansé" par rapport au mode normal, montrent que l'expansion du signal crée l'impression d'un rapprochement des véhicules et, surtout, une sensation d'augmentation de vitesse. Par contre, la compression du signal provoque une sensation nette d'augmentation du débit de circulation. Ces résultats sont présentés dans le Tableau nº 4. (Dans ce cas-ci, les notes accordées sont sur 5 points avec une moyenne d'indifférence égale à 3).

Lors d'une reproduction en mode expansé, le niveau des pointes augmente, de sorte que la base de temps semble diminuer: l'individu interprète cette variation comme une augmentation de la vitesse. Par contre, lors d'une reproduction en mode comprimé, l'importante réduction de dynamique par rapport au mode normal fait que l'individu assimile l'échantillon sonore à un bruit de voie de circulation à plus fort débit. Contrairement aux reproductions en mode expansé, les périodes de relaxation - correspondant à des intervalles à faible bruit de fond tels que ceux existant entre le passage de deux véhicules consécutifs - sont très courtes, voire inexistantes; ce qui influe sur la perception du bruit et sur le degré de gêne qui s'ensuit. Il convient d'ajouter que lors de ces expériences, même s'il s'agit d'une source monophonique, l'oreille et la perception temporelle ajoutent une dimension spatiale très précise et bien identifiable, du fait du réalisme des mécanismes de transmission au travers de l'échantillon de façade.

TABLEAU Nº 4: Impression psychoperceptive en fonction de la modification de la dynamique (notes moyennes)

Impression de	Mode de reproduction	Fenêtre fermée	Fenêtre entr'ouverte	Fenêtre ouverte
"Vitesse"	Compressé	2.90	2.92	2.80
	Expansé	3.26	3.30	3.34
"Proximité"	Compressé	3.07	3.20	2.69
	Expansé	3.49	3.20	3.31
"Débit"	Compressé	3.37	3.69	3.58
	Expansé	2.76	2.78	2.94

3. TESTS DE PERCEPTION À NIVEAU CONTINU EQUIVALENT CONSTANT AVEC CHANGEMENT DE LA COMPOSITION SPECTRALE

Un changement de pente d'isolation de l'échantillon de façade a été simulé en modifiant à l'émission la pente du bruit routier au moyen d'un égalisateur inséré dans la chaîne d'amplification ("Orban" 672A). Celle-ci a été réglée de manière à permettre la reproduction de trois des six échantillons de bruit routier précédents, en introduisant ou non une pente de -6 dB/octave ou +6 dB/octave et en maintenant constant le niveau continu équivalent dans le local récepteur. Afin de permettre une bonne reconnaissance des signaux extérieurs, la valeur de ce niveau intérieur a été prise égale à 45 dB(A). Le Tableau nº 5 indique les valeurs des paramètres statistiques obtenus dans ces conditions à l'intérieur du local, pour les trois échantillons reproduits avec les trois pentes précitées. Les spectres correspondant font l'objet de la Figure nº 4 (comme on peut le constater dans ce Tableau, le calage du niveau Leq est particulièrement délicat dans ces conditions expérimentales).

Tous les sujets participant au test ont été unanimes à estimer que la gêne évolue à l'inverse de la pente, comme le montre le Tableau nº 6. L'introduction d'une pente négative est perçue par les sujets comme un accroissement du pourcentage de véhicules lourds, avec une réduction de vitesse qui est jugée d'autant plus importante que le pourcentage réel de véhicules lourds est faible. Au contraire, l'introduction d'une pente positive est ressentie comme une diminution de la densité de circulation, accompagnée d'un relèvement de vitesse. En outre, du fait de l'importance attribuée aux hautes fréquences dans cette configuration, les sujets ont la sensation d'entendre les véhicules rouler sur une chaussée mouillée (comme précédemment, la gêne globale est notée sur 7 points et les impressions sur 5 points).

TABLEAU Nº 5: Caractéristiques des échantillons de bruit routier reproduits avec une pente, telles que relevées à l'intérieur du logement.

Echantillon nº	Pente de fréquence introduite	Leq	L1%	L10%	L50%	L90%	L99%	1%-99%	10%-90%
	+	45.7	53.8	49.0	44.0	39.8	37.0	16.8	9.2
2	0	45.6	54.3	49.0	42.8	38.8	36.0	18.3	10.2
	-	45.8	54.8	49.0	43.5	39.0	36.5	18.3	10.0
	+	45.7	55.8	51.0	39.3	29.3	27.8	28.0	21.7
4	0	45.7	56.8	49.5	39.5	34.3	33.5	23.8	15.0
	-	45.7	57.3	49.3	38.8	34.3	33.5	23.8	15.0
	+	44.9	52.8	48.3	43.0	38.5	35.8	17.0	9.8
5	0	44.9	53.8	47.5	42.3	38.5	35.0	18.8	9.0
	-	45.0	53.8	47.8	42.5	39.5	36.3	17.5	8.3

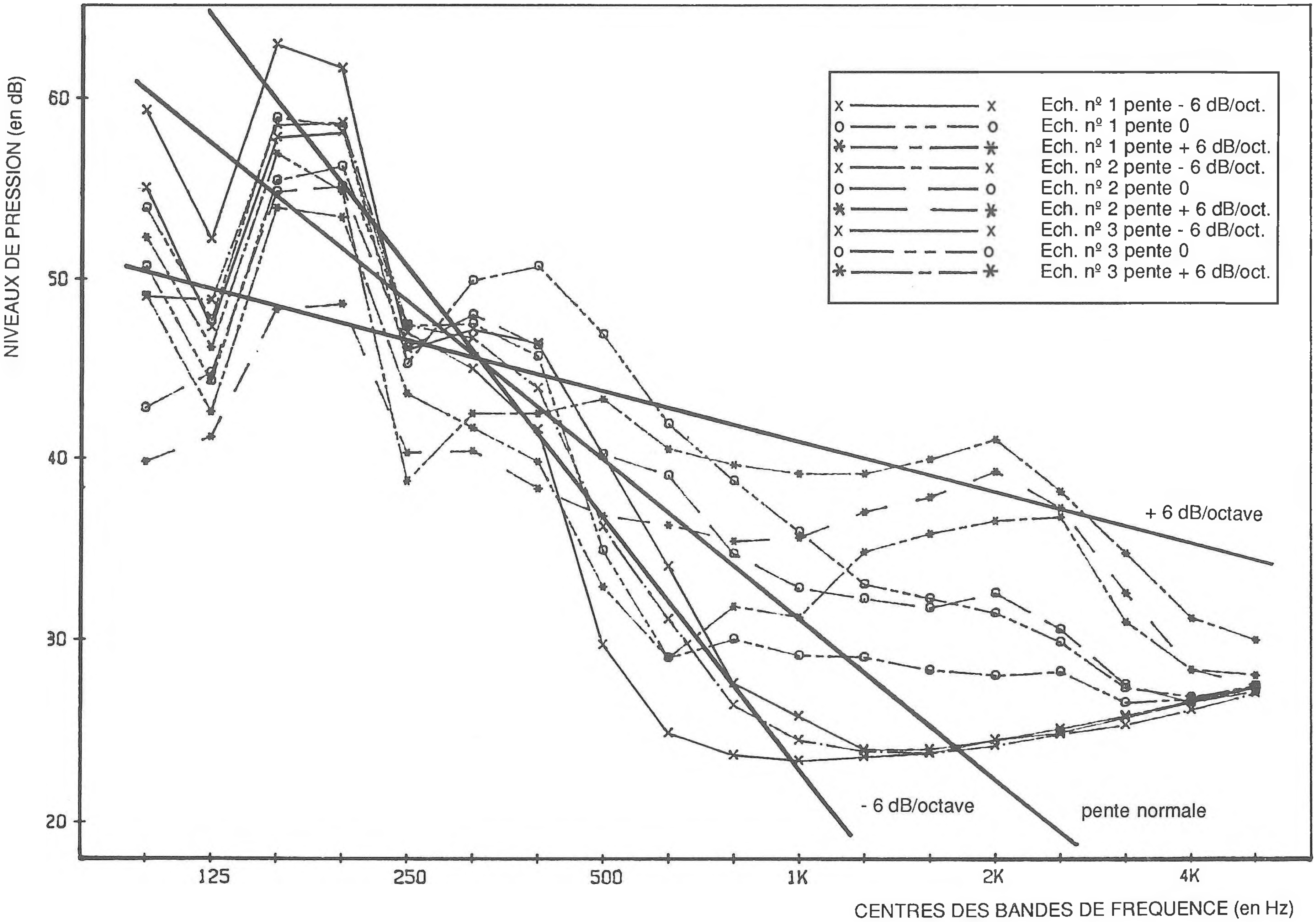

FIGURE Nº 4: Spectres de trois échantillons de bruit routier reproduits à niveau équivalent constant, mais avec une pente spectrale différente, tels que recueillis à l'intérieur du local récepteur.

TABLEAU Nº 6: Moyenne des notes distribuées par les sujets lors des tests d'audition à pente variable.

Echantillon nº	Pente de fréquence	Gêne globale	Impressions de			
			"Vitesse"	"Proximité"	"Densité"	"Humidité"
	+	3.80	3.66	3.58	2.66	4.16
2	0	4.17				
	-	5.47	2.66	2.58	3.91	3.00
	+	3.30	3.50	3.00	2.66	4.25
4	0	3.84				
	-	4.87	2.66	3.08	3.41	3.00
	+	3.20	3.50	3.33	3.00	4.50
5	0	4.00				
	-	4.54	1.90	2.25	3.75	2.83

4. CONCLUSIONS RELATIVES A LA GENE DANS LES HABITATIONS

Dans les tests in-situ, l'accoutumance au quartier, l'exposition relative du logement et surtout, la satisfaction par rapport au quartier, jouent un ròle non négligeable lors de l'élaboration des réponses des résidents. De ce fait, celles-ci ne sont pas toujours d'une grande fiabilité [3, 7]. Lors des divers tests effectués au laboratoire, il a été possible de constater que les réponses obtenues étaient particulièrement claires, cohérentes et spontanées, du fait de l'affranchissement de ces problèmes. Qui plus est, les tests in-situ posent souvent le problème de l'évaluation de l'isolement acoustique entre deux logements contigus; c'est alors implicitement le problème de la cohabitation avec le voisin qui est posé! Dans le cadre des tests au Laboratoire, les stimuli auxquels étaient soumis les sujets se réduisaient aux seuls bruits de la circulation, pour lesquels on discerne cependant une certaine habitude, due au fait qu'ils font partie de notre environnement quotidien.

Les résultats montrent clairement que la gêne induite par la pénétration du bruit de la circulation dans un logement est fonction de la dynamique résultante dans le quartier. Plus précisément, une partie de la population est plus particulièrement sensible à l'étendue de la dynamique, alors que l'autre partie semble être sensible à la rumeur et à la densité du bruit, donc au niveau de bruit de fond. Une telle subdivision n'est certes pas un facteur de simplification de l'évaluation de la gêne. Néanmoins, comme l'indique nettement la Figure nº 3 et le Tableau nº 3, pour l'ensemble des individus, on peut considérer que l'influence de la dynamique peut faire croître l'indice de gêne moyen de 1 à 1.5 points (sur une échelle de 7). Puisque ces expériences de perception ont été réalisées à niveau Leq constant, au plan législatif il serait donc important de mettre plus en évidence un indice simple susceptible de tenir compte de l'élévation de la dynamique du bruit. On peut considérer par exemple l'indice NPL ("*Noise Pollution Level*") proposé par Robinson dans les années 70 (voir Tableau nº 1) [9].

D'autre part, la présence d'un bruit de fond à l'intérieur de l'habitation est perçue par l'ensemble des sujets comme un élément diminutif de la gêne, dans la mesure où ce bruit de fond tend à réduire la dynamique résultante dans le logement. On pourrait ainsi, dans certains cas, envisager de réduire la gêne due au bruit de circulation en introduisant dans le logement un léger bruit de masque, soit à partir de l'équipement technique du bâtiment, soit généré artificiellement, comme cela se pratique dans certains locaux à usages de bureaux (les Tableaux de résultats d'expériences complémentaires n'ont pas été reproduits pour ne pas alourdir l'article).

Néanmoins, le niveau et la dynamique sont loin d'être les seuls facteurs intervenant dans la notion de gêne. Plusieurs auteurs ont montré que la nuisance est liée à la reconnaissance du signal. Certes, un bruit de circulation reste un bruit de circulation, mais le climat psychologique induit par le passage des véhicules peut être fort différent d'une personne à l'autre. Par exemple, le passage d'une motocyclette laissera-t-il rêveur et un peu envieux tel adolescent, énervera le père, et affolera un peu plus la grand-mère, qui verra là une manifestation supplémentaire de l'insécurité. Ainsi, lors de la détermination de la gêne, le contenu informationnel du signal doit être pris en compte, tâche d'autant plus ardue que celui-ci varie en fonction de la culture, voire même de l'état mental de l'individu.

Vian *et al.* ont montré que la gêne est d'autant plus sensible que le contenu en basses fréquences du signal est important [10]. Ceci semble bien confirmé par nos expériences sur la composition spectrale à niveau équivalent constant. Manifestement, pour un même isolement global donné, les répondants ont une préférence marquée pour les courbes d'isolement présentant un fort affaiblissement des basses fréquences. Ainsi, dans le cadre de la conception d'un projet de construction, il conviendrait de tenir compte du fait que, pour un même isolement global mesuré (en termes de STC par exemple), des éléments de façade peuvent présenter des caractéristiques de gêne fort différentes, selon la pente moyenne de leur courbe d'affaiblissement acoustique [11].

Dans le cas où la fenêtre est entr'ouverte ou ouverte, non seulement l'isolement global est fortement diminué, mais encore la pente de l'isolation tend vers une valeur nulle. Il n'est donc pas surprenant que, dans ces conditions, la gêne soit plus importante, indépendamment du niveau moyen. Autre fait aggravant, la dynamique du signal résultant dans le logement se rapproche d'autant plus de celle du signal extérieur que l'ouverture est importante, voire même elle la dépasse!

Pour toutes ces raisons, il convient donc de considérer avec une certaine circonspection toute proposition visant à associer sommairement le niveau continu équivalent Leq à une échelle de nuisance pour les secteurs résidentiels soumis au bruit de la circulation. Il faudrait au minimum analyser l'étendue de la dynamique en un point donné de l'espace urbain et tenir compte, tout comme pour le niveau continu équivalent, de son évolution au cours de la journée de 24 heures. Même au niveau de la modélisation informatique des impacts, il est possible de calculer l'écart type de la distribution des niveaux de pression en un point voisin d'un futur corridor et d'en déduire ainsi la valeur de l'écart L10% - L90%.

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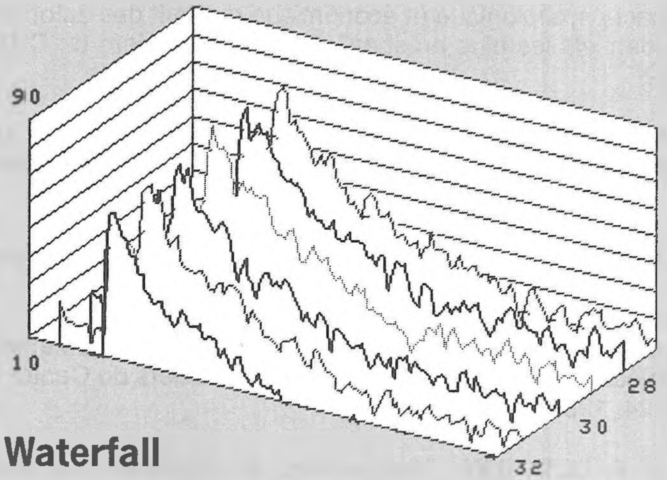

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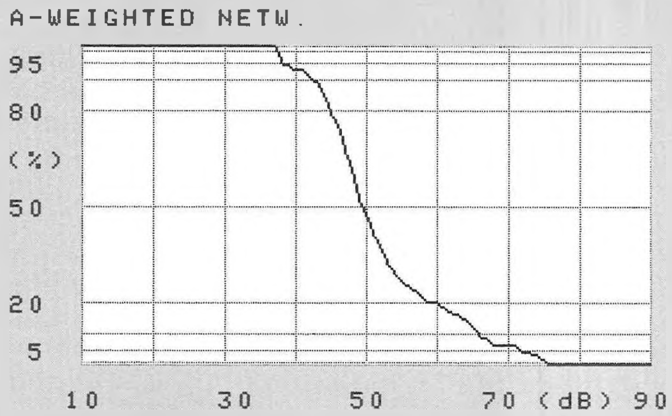

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VIEWPOINT / POINT DE VUE

The insidious character of occupational deafness*

R. Hétu
Groupe d'acoustique
de l'université de Montréal

The 12th International Congress on Acoustics marked a centenary. Researchers interested in the epidemiology of occupational deafness celebrated the one hundredth anniversary of the publishing, in 1886, of a report from Thomas Barr, an otologist from Glagow, on the results of one of the very first investigations of deafness carried out on workers exposed to noise.[1] He reported, among other things, that the 100 riveters examined had poorer hearing than a group of workers not exposed to noise.

This historical perspective raises a significant paradox: after 100 years of acquiring knowledge about occupational deafness, how can it be that noise is still so omnipresent in the industrial environment? How can we explain that hearing loss due to noise is the most prevalent irreversible occupational disease, and the most costly in terms of compensation? How can it be that this type of deafness today affects close to 2 per cent of the total adult male population and that noise in the workplace is consequently one of the most frequent causes of hearing loss?

Obviously, we cannot attribute this state of affairs to a lack of knowledge about the harmful effects of noise on hearing. It seems to be that one of the factors that can explain this situation is *the insidious nature* of the harmful effects of noise on hearing. There are four major reasons for this.

First, this insidious character is the result of the phenomenon of auditory fatigue. The employee assigned to a noisy work station suffers auditory fatigue from his very first day. The manifestations of this reversible disturbance of hearing have the same perceptual charachteristics as occupational hearing loss: loss of sensitivity at high frequencies, loss of frequency selectivity, altered perception of sound intensity, etc. Consequently, in the hours

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* This paper is the translation of the "Point de vue" that appeared in the April issue of this year under the title "Le caractère insidieux de la surdité professionnelle"

following the end of the work day, people exposed to intense noise have to cope with partial hearing impairment and impose inconveniences on those around them (turning up the volume of the television, speaking louder, asking to repeat during conversations in the presence of a background noise). Persons exposed to noise and those living with them therefore learn to cope with certain manifestations of noise-related deafness right from the start.[2] If hearing is measured when they go back to work, however, the results will be completely normal! Under such conditions, when will workers exposed to noise daily in the workplace discover that their hearing loss has become irreversible? The loss will have to be already considerable, with considerable effect on the victims and those around them.

Second, permanent hearing loss due to noise seems to evolve very slowly, according to the results of various surveys of occupational deafness, even if these are cross-sectional studies. These data, synthezised in the form of an etiological model, are given in an international standard.[3] It can be seen, for example, that at 100 dBA-8hours at the most affected audiometric frequency and in individuals most sensitive to the effects of noise, the annual rate of hearing deterioration is approximately 14 dB during the first year of exposure, 10 dB the second, 3 dB after five years and 1.5 dB after 10 years. At no time is there an abrupt drop in hearing. Contrary to most adult onset deafnesses, its appearance is generally not perceptible to the victim. Its evolution is so insidious that the most faultless hearing tests cannot detect significant varitions on an annual basis.[4-5]

The insidious character of the effects of noise on hearing is also related to two other aspects of the problem: the nature of the hearing disabilities and their social significance. On the one hand, the main consequence of hearing loss (temporary or permanent) due to noise is a loss of frequency selectivity, resulting in a lessened ability to communicate verbally in the presence of ambient noise or an reverberant environment. Thus, persons with such a loss presents hearing behaviour that is ambiguous to both themselves and those around them: their hearing ability fluctuates according to ambient noise conditions. Those around them interpret this ambiguity in terms of stubbornness, or refusal to communicate. The victim blame him(her)self for lack of concentration or interest, and in both cases the connection with deafness is not made.[6] The family also suffers from the consequences of this partial deafness without doing anything to minimize it; in fact the contrary is true.[2]

Moreover, even at an advanced stage of hearing disability, workers often refuse to admit deafness. They will acknowledge that a series of situations are incapacitating for them, but without explaining them by deafness.[2] This attitude may be explainable by the stigma connected with deafness. Being deaf is associated with being absent-minded or not too bright, or at the very least with premature aging. Workers' reaction seems to be that, if they acknowledge deafness, they are acknowledging being physically diminished.

There is, in short, an unfortunate convergence of the phenomenon of auditory fatigue, the way in which the deafness progresses, the nature and significance of its manifestations, all of which combine to make occupational deafness a stealthy and insidious condition. It is perhaps not very surprising, therefore, that elimination of noise in the workplace is so slow in coming. As professionals in the field of acoustics, it is in our best interests to understand this situation and make the public aware of the undesirable consequences of deafness due to noise.

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BOOK REVIEWS

FRONTIERS IN PHYSICAL ACOUSTICS

by D. Sette, Ed.
North-Holland, New york, 1986

Only ten years after the appearance of "New Directions in Physical Acoustics" in the Proceedings of the International School of Physics "Enrico Fermi", the School now publishes the Proceedings of Course XCIII, "Frontiers in Physical Acoustics". The course was organised and directed by D. Sette and given in Varenna, Italy, 10-20 July 1984. After a quick browse through the book, which includes timely topics like chaos, heat engines and acoustics in space, it is difficult to remember that Physical Acoustics is one of the oldest scientific disciplines. This present Course also answers some criticism of the l976 book by including topics such as acoustic holography and the scanning acoustic microscope.

More specifically, a significant portion of the book is devoted to non-linear acoustics and chaotic behavior. We find two chapters entitled "Chaotic and turbulent behavior of simple nonlinear systems" by R.H.G. Helleman and "Transition to chaotic convection " by M. Giglio, S. Musazzi and U. Perini. A chapter closely related to this topic is "The role of phase locking in quasi-periodic surface waves on liquid helium and water" by R. Keolian and I. Rudnick. There are two chapters dealing with the acoustic cavitation that occurs when a liquid is irradiated with an intense sound field; "Acoustic turbulence" by W. Lauterborn and "Physics of acoustic cavitation" by A. Prosperetti. Finally a very readable chapter by J. Wu, R. Keolian and I. Rudnick reports on the "Discovery of a non-propagating hydrodynamic soliton".

The two chapters, "Applications of acoustics in space" by T.G.Wang and "Intrinsically irreversible or natural engines" by J.C. Wheatley, provide scientifically stimulating reading. The chapters "Near-field acoustic holography" by J.D. Maynard, "The scanning acoustic microscope" by J.E. Heiserman and C.F. Quate, and "Acousto-optic transduction in optical fibers and in fiber optic acoustic devices" by E.F. Carome review the developments in the field of these acoustic devices and techniques. Finally several chapters deal with progress in the more traditional fields of Physical Acoustics. A more classical treatment of non-linear acoustics if found in "Basic theoretical nonlinear acoustics" by D.G. Crighton. Other chapters include "Physical origins of acoustical noise" by J.E. Ffowcs Williams; "Long-wavelength acoustical scatter from rough surfaces" by I. Tolstoy; "Recents developments in the acoustic properties of porous media" by D.L. Johnson; and a short chapter, "Reflection of pressure pulses at free surfaces of water" by H.N.V. Temperley.

I found all the chapters to be of a very high quality. The book can be recommeded reading for the nonspecialist as a good overview of the current interests in Physical Acoustics. Most of the chapters also serve as a good introductory survey of the field it covers. One should, however, be cautioned to some of the titles. Although the majority are self explanatory, a few can be deceiving. For example the chapter by Lauterborn does not deal with flow induced or atmospheric turbulence and the chapter by Johnson is focused on porous fluid-filled solid media like sedimentary rocks and does not cover explicitly the acoustical characteristics of rigid fibrous absorbents.

Gilles Daigle
Division of Physics
National Research Council
Ottawa, Ontario

NONLINEAR UNDERWATER ACOUSTICS

by B.K. Novikov, O.V. Rudenko, and V.I. Timoshenko
Translated by Robert T. Beyer and edited by Mark F. Hamilton, published for the Acoustical Society of America by the American Institute of Physics, New York l987, ISBN O-883l8-522-9

It has been known for more than a century that the equations governing the propagation of sound are nonlinear. Except for the observation of "Tartini tones" - the appearance under some circumstances of sum and difference frequencies - it was not until the mid part of the present century that nonlinear sound propagation effects received much notice. During World War II the propagation of shock waves from explosive detonations in water came under scrutiny. A bit later sonic booms from supersonic aircraft became important and high intensity ultrasonic waves were observed to be attenuated "too rapidly". In 1960 Peter Westervelt described how the difference frequency tone generated through the nonlinear interaction of two co-linear single frequency sound beams should display a highly directional characteristic. A little later H.O. Berktay described how such "parametric arrays" could be highly practical. For the rest of the story, a very good place to start would be Nonlinear Underwater Acoustics by B.K. Novikov, O.V. Rudenko and V.I. Timoshenko. This book contains the clearest theoretical treatment of parametric arrays that I know. The authors start from the equation of continuity, the equation of state, and the equation of motion for a viscous fluid, and proceed to simplify and approximate in a variety of well explained ways. One by one various phenomena such as absorption, diffraction, nonlinearity and dispersion are studied singly and in combination for plane waves, cylindrical waves, spherical waves and for radiation from a gaussian shaded transducer. The result is a near-complete description of three kinds of underwater parametric arrays: the transmitter, the receiver and the opto-thermo-acoustic array. This latter may seem bit of an oddity for this book but the mathematical formalism governing sound generated by the heating of water by light is very similar to that for parametric arrays.

The book then proceeds to describe experimental equipment for practical parametric arrays, fully engineered sonars for the user, and finally nomograms for determining the basic characteristics of general parametric arrays. Included for comparison with the more usual bi-harmonic primary wave are descriptions of a number of modulation schemes for the transmitter: amplitude modulation, frequency modulation and linear frequency modulation.

On the critical side, the book cannot be regarded as complete. It does not, as the title might suggest, deal with the propagation of shock waves from explosions, with acoustic cavitation, or go into detail on losses encountered by ultrasonic apparatus at the fundamental frequency. Even concerning the parametric transmitting array there are a few significant omissions. More important, there are several obvious omissions from the reference list; it was too much for the translation editor, so he rectified one or two of the most glaring omissions.

The translator is himself an expert in this branch of acoustics. The translation undoubtedly benefits from this knowledge. Although the basic Russian style remains to remind the reader of the authorship, it does not impede understanding.

At $ 25 US a copy, this book will not be found in every acoustician's library; it should have a place in the library of any organization specializing in underwater acoustics. It will also be useful to the student or practitioner interested in parametric arrays whether the atmospheric version or underwater. The sonar engineer might find parts of the book heavy going, but overall very useful.

Harold M. Merklinger
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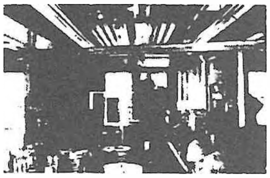

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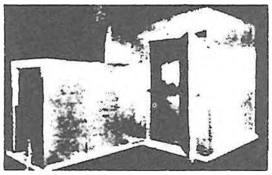

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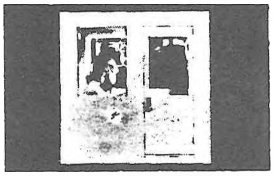

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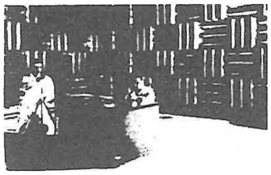

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The standard has been endorsed by reference in the new Federal-Provincial Guideline for Regulatory Control of Occupational Noise Exposure and Hearing Conservation. It is expected that provinces will accept measurements taken according to the standard as meeting or exceeding provincial requirements. Currently copies are being circulated to the provinces for their review.

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CAC/ISO TC43 LIAISON REPORT TO CSA COMMITTEE ON ACOUSTICS AND NOISE CONTROL (Z107)

The Canadian Advisory Committe to International Standards Organization Technical Committees TC43 "Acoustics", and TC43/SC1 "Noise" reported in detail on its activities to the CSA Z107 Executive Committee at their meeting on April 9, 1987 in Ottawa.

Since that meeting five members of the CAC attended the plenary meetings of ISO TC43 and ISO TC43/SC1 and associated working group meetings in Copenhagen, Denmark, May 4-7, 1987. A full report on this meeting is available upon request. Some salient decisions made at these international meetings are as follows:

(I) ISO 6393 and ISO 6394 "Acoustics - measurement of airborne noise emitted by earth moving machinery" - Amendments, editorial and incorporating back hoe loaders approved.

(II) ISO 9295 and ISO 9296 "Acoustics - noise from computers and business equipment" Approved. These use the BEL as measure of sound emission.

(III) ISO 5131 "Acoustics - tractors and machinery for agriculture and forestry" - measurement of noise at the operator's position - survey method". This is to be reviewed.

Results obtained for Canada include:

(IV) ISO 2204 "Acoustics - Guide to International Standards on the measurement of airborne acoustical noise - evaluation of its effects on human beings " - Revisions prepared by Canada accepted by mail ballot and are being proceeded with for publication.

(V) ISO 3741, 3742, 3743, 3745. "Acoustics - Determination of Sound Power Levels of Noise Sources" pending issue. ISO 3740 to ISO 3746 to be revised by a new WG 28, Canadian representative, Cameron Sherry.

(VI) ISO TR3352 "Acoustics - Assessment of noise with respect to its effect on the intelligibility of speech, ISO TC159 SC5 N69 "Assessing the effects of noise on speech communication at the workers'position" - Ad hoc group to see if these documents are consistent and to advise the TC re future action in the area of speech intelligibility.

(VII) A new work item on A - weighting for noise measurement establishment.

(VIII) WG26 "Isolated burst of sound energy emitted by machinery and equipment", of interest in Canada, but establishment delayed due to lack of member country participation.

CANADIAN ACOUSTICAL ASSOCIATION

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