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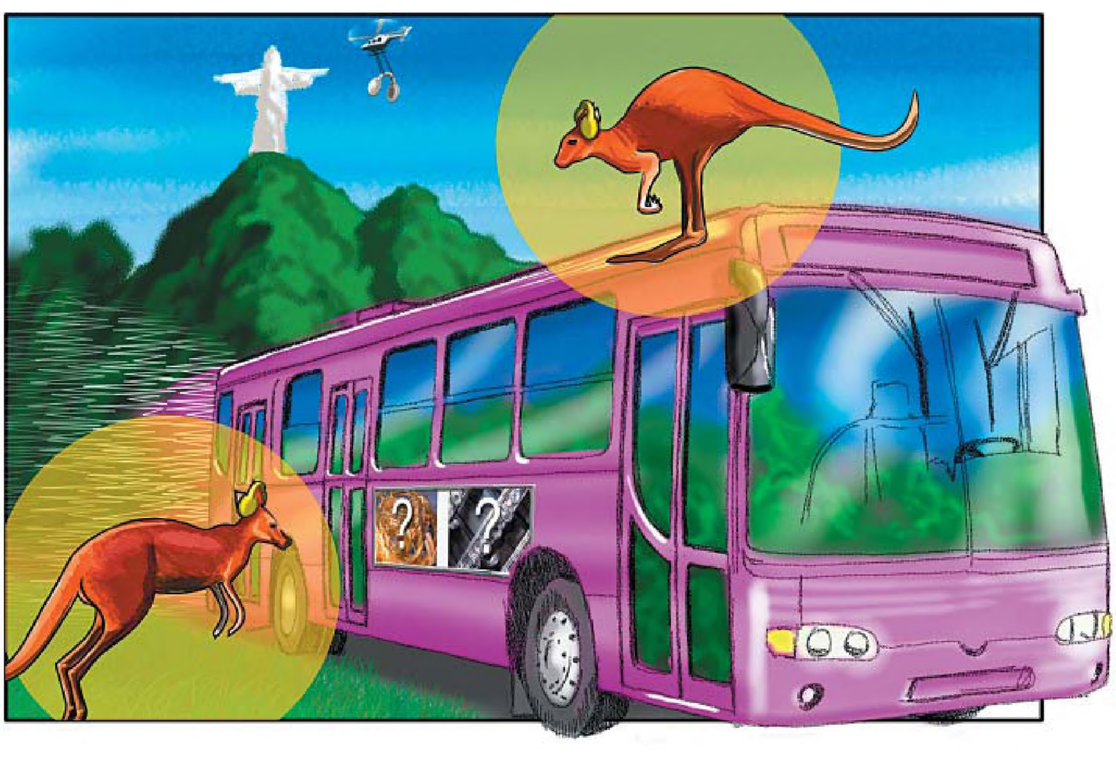

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PRESIDENT'S MESSAGE / MESSAGE DU PRÉSIDENT

I'm pleased to report that the recent Acoustics Week in Canada 2004 conference, held in Ottawa (Oct. 6–8), was one of our most successful CAA meetings to date, with our largest-ever attendance (over 150), excellent technical sessions on all aspects of acoustics, an enjoyable social program (reception, banquet, lunches), and interesting tours of the research facilities of NRC and Health Canada. Many thanks to John Bradley, Brad Gover, Christian Giguere and the others on the Organizing Committee for the great job, and to our Editor Ramani Ramakrishnan for the 224-page proceedings issue! It's also noteworthy that all of the CAA prizes were awarded this year, with presentations made at the conference banquet. The sole exception was the Student Paper Award, since no student papers appeared in Canadian Acoustics in the preceding year. However, that will not be the case next year—we have several (refereed) articles by student authors in the December issue, which is most encouraging.

Next year (2005) is a special year in that there will be two CAA conferences. Our regular Acoustics Week in Canada will be held Oct. 12–14 at the Lamplighter Inn and Conference Centre in London, Ontario, hosted by Meg Chessman and Vijay Parsa, and will include a tour of the National Centre for Audiololgy. This should be another great meeting—stay tuned to Canadian Acoustics and the CAA website (caa-aca.ca) for more information.

The additional event for 2005 is a Joint Meeting of the Acoustical Society of America (ASA) and the CAA, to be held May 16–20 at the Hyatt Regency Hotel in Vancouver, B.C. The conference will generally follow the ASA format, but will provide excellent visibility for the CAA at an international level. While quite a few CAA members are also members of the ASA, many are not, so I thought I'd take this opportunity to briefly introduce the ASA. The ASA has a total membership of approximately 7000, including about 2000 non-

Il me fait plaisir de vous informer que la conférence de la *Semaine de l'Acoustique Canadienne 2004*, qui a eu lieu à Ottawa du 6 au 8 octobre dernier, a été l'une des plus réussie de l'histoire de l'ACA, avec le plus haut taux de participation (plus de 150). Il y a eu d'excellentes présentations techniques sur tous les sujets liés à l'acoustiques, un bon programme social (réception, banquet, dîners), et une visite du centre de recherche du CNR et Santé Canada. Je tiens à remercier John Bradley, Brad Gover, Christian Giguère, et les autres membres du comité organisateur qui ont fait un excellent travail, ainsi qu'à notre éditeur Ramani Ramakrishnan pour la production du cahier de conférence de 224 pages! Il est important de mentionner que tous les prix de l' ACA ont été distribués cette année, à l'exception du prix de publication étudiante, puisque aucun étudiant n'a soumis d'articles. Cependant, ce ne sera pas le cas l'année prochaine, puisque nous avons déjà reçu plusieurs articles d'étudiants (acceptés et corrigés) qui seront publiés dans la parution du mois de décembre. Ce qui est vraiment encourageant.

L'année 2005 sera une année spéciale, puisqu'elle comprendra *deux* conférences de l'ACA. Le traditionnel évènement de la *Semaine de l'Acoustique Canadienne* se tiendra du 12 au 14 octobre, au Lamplighter Inn et au Centre de Conférence à London, Ontario, présidé par Meg Chessman et Vijay Parsa, et inclura une visite du Centre National d'Audiologie. Cette rencontre devrait être aussi intéressante que la précédente – pour plus d'information, consultez la revue de l'*Acoustique Canadienne* et le site Internet de l'ACA (caa-aca.ca).

La seconde conférence de 2005 sera une assemblée conjointe de la Société d'Acoustique d'Amérique (SAA) et de l'ACA. Elle se tiendra du 16 au 20 mai à l'hôtel Hyatt Regency à Vancouver, C.B. La conférence suivra le format de la SAA, et fera connaître l'ACA au niveau international. Il y a plusieurs membres de l'ACA qui sont aussi membre de

WHAT'S NEW ?? QUOI DE NEUF ?

Promotions	Retirements	Promotions	Retraites
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Americans of which 270 are Canadian. ASA meetings are held twice yearly with an average attendance of about 1000. By comparison, the CAA currently has about 400 members with a typical conference attendance of 100 or more (within a factor of two of the ASA numbers, if you scale by ten according to the relative populations of the two countries).

ASA meetings cover all aspects of acoustics and are formally organized into 13 Technical Committees including Acoustical Oceanography, Animal Bioacoustics, Architectural Acoustics, Biomedical Acoustics, Engineering Acoustics, Medical Acoustics, Noise, Physical Acoustics, Psychological and Physiological Acoustics, Signal Processing, Speech, Structural Acoustics and Vibration, and Underwater Acoustics. ASA meetings typically run up to 13 parallel sessions over five days, with 15-minute talks and published abstracts (no summary papers). Meetings include informal buffet socials on the Tuesday and Thursday evenings; however, there is usually no banquet and lunches are not provided.

The Organizing Committee for the 2005 ASA/CAA Meeting has strong Canadian content, with Murray Hodgson as Conference Chair, myself as Technical Chair, and several other CAA members on the committee. Information on attending and/or presenting a paper at the ASA/CAA Conference will be posted at the ASA website, asa.aip.org (note that CAA members are eligible for the member's registration rate).

It would be great to see you in both London and Vancouver in 2005!

Stan Dosso

la SAA, mais je profite de cette opportunité pour présenter brièvement la SAA pour ceux qui ne la connaissent pas. La SAA compte approximativement 7000 membres, dont 2000 non-américains (270 canadiens). Les rencontres de la SAA ont lieu 2 fois par année, avec une participation moyenne de 1000, comparativement l'ACA qui compte 400 membres, avec une participation moyenne de 100 ou plus (bien que le nombre de membre de l'ACA est plus faible que celui de la SAA, le ratio des membres se rendant aux conférences est comparable).

Les rencontres de la SAA couvrent tous les aspects liés au domaine acoustique. Il y a 13 différents Comités Techniques, incluant l'Océanographie Acoustique, la Bioacoustique Animale, la Bioacoustique Architecturale, l'Acoustique Biomédicale, le Génie Acoustique, l'Acoustique Médicale, l'Étude des Bruits, l'Acoustique Physique, l'Acoustique Psychologique et Physiologique, le Traitement des Signaux, la Parole, la Structure Acoustique et Vibration et l'Acoustique Sous-Marine. Les rencontres de la SAA sont généralement d'une durée de 5 jours et comprennent plus de 13 différentes présentations simultanées, de 15 minutes, et sont acompagnées d'un cahier de conférence, qui est constitué seulement de résumés (aucun article synthèse). Les rencontres comprennent un buffet social informel le mardi et le jeudi soir; Cependant, il n'y a pas de banquet et de dîner inclus.

Le Comité Organisateur de la rencontre SAA/ACA 2005 est composé de plusieurs membres de l'ACA, où M. Murray Hodgson assume le poste de Président de la Conférence et moi-même le rôle de Président Technique. Les informations sur les inscriptions et/ou les présentations pour la Conférence SAA/ACA seront disponibles sur le site Internet asa.aip.org (il est à noter que les membres de l'ACA sont éligibles aux même prix que les membres de la SAA).

Il serait bien de vous rencontrer à London et Vancouver en 2005!

Stan Dosso


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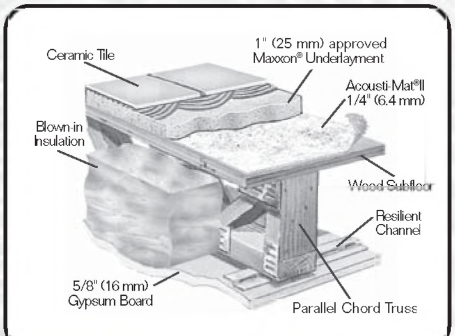

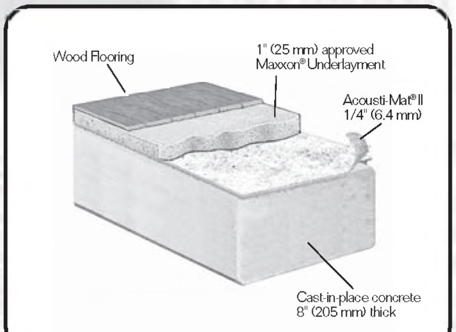

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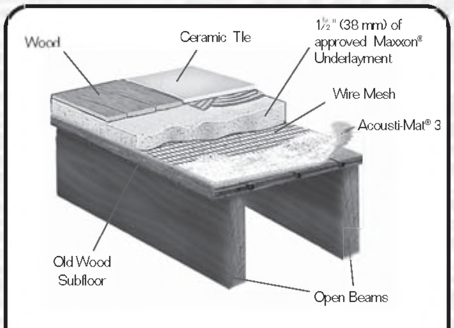

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Identifying The Number Of Instruments In Pairs Of Simultaneously Sounding Timbre

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ABSTRACT

Timbre as a source of variation in music has become increasingly important in music composition in recent years. The present study investigated the ability of listeners to appreciate pairs of different timbres simultaneously. The stimuli were combinations of the steady state portions (300 ms) of three instrumental timbres, including the clarinet, trombone and harp. Forty different pairs were constructed for the four stimulus conditions: three experimental conditions consisting of the instrumental timbres, and a control condition consisting of pure tones corresponding to the fundamental frequency of these timbres. Thirty undergraduates, with and without musical training, were required to listen to a total of 400 randomized tonal stimuli. Their task was to make a judgment on whether they heard one or two instrument(s) after listening to each stimulus. Overall, musicians could perceive two timbres more readily than non-musicians, thus suggesting that musical experience may enhance the perception of timbre. Performance differences between the groups across conditions are also discussed.

RÉSUMÉ

Cette etude a examine la perception de deux instruments joues en meme temps, les deux instruments etant choisis d'entre le clarinet, le trombone, et le harp. Les stimuli etait contenus dans deux portions fixes (300 ms) des timbres produits par les instruments choisi. Quarante paires etaient construites pour quatre types des conditions: trois conditions experimentales de timbre instrumental, et une condition controle de pure ton correspondant a la frequance fondamentale de ce timbre. Une trentaine d'etudiants, avec et sans formation musicale, ont ecoute a un melange de quatre cents stimuli randomises. Les participants devaient identifier si le stimulus presente etait compose d'un ou de deux instruments de musique. Nous avons trouves que les participants avec une formation musicales etaient en general plus doues. Ceci peut constituer une indication que la formation musicale ameliore l'abilite de reconnaitre des timbres. Une discussion des differences dans le groupe experimental est presente.

1. INTRODUCTION

1.1 Definitions

The concept of timbre has been a difficult topic to study in the field of musical acoustics. One major complication begins with defining the term "timbre." Many definitions of timbre have concentrated on what timbre is not, rather than what timbre is (Risset & Wessel, 1999). This often leads to vague definitions of timbre. For example, a well-known definition from the American National Standards of Institute defines timbre as: "that attribute of auditory sensation in terms of which a listener can judge that two sounds similarly presented and having the same loudness and pitch are dissimilar" (1960, p.45). This merely explains that any acoustic attribute that does not exclusively contribute to the perception of pitch, loudness, or duration could contribute to the perception of timbre. It does not, however, describe the physical parameters that contribute to the perception of timbre. Since the acoustic basis for timbre is undefined, timbre is regarded as a multidimensional attribute which cannot be measured on a single continuum (Plomp, 1976).

Presently, there is no truly satisfying definition of timbre as a psychophysical variable. However, timbre may still be communicated to a naïve listener. Timbre is easily understood as the perceptual attribute that enables us to distinguish musical tones produced by different instruments. Therefore timbre is often defined as the quality of sound, such as how "bright" or "dark" the tone sounds. But this vague definition does not take into account the complexities of the attributes of timbre and is not scientifically useful since it does not explicate a relationship between variables (Hajda, Kendall, Carterette & Harshberger, 1997). In order to study timbre scientifically and simply without using multidimensional scalings, researchers have continued to explore the time-varying aspects of the sound envelope.

Timbre is often described in terms of the transitions of a musical tone (or more specifically, the transitions of its harmonics, or partials) over time. This can be conceptualized overall as the time for the sound to grow to full amplitude and to decay to inaudibility (Handel, 1989). The changing portions of a tone can be described by the development of the amplitude envelope over time. In the case of an isolated musical tone, the envelope can be divided into three parts: the attack (onset), steady state (sustain) and decay (offset). In the early 1960s, transients became important variables in timbre studies. Many studies attempted to isolate the salience of the attack, steady state and decay by dividing and transforming isolated musical tones.

1.2 Early Studies of Timbre Attributes

Saldanha and Corso (1964) were one of the first groups of researchers to investigate the importance of transients in the identification of musical instruments. Specifically, they evaluated the relative importance of harmonic structure, frequencies of the equally tempered scale, vibrato, transient motion, both initial (attack) and final (decay), and steady-state duration as timbre cues in the absolute judgment of musical tones. They included 10 different instruments for timbre identification. Five types of stimuli resulted from the different divisions of the attack, steady state and decay of the tones.

The results of Saldanha and Corso's (1964) study indicated that there were great differences among the different instruments in their absolute identification using auditory cues. Identification was surprisingly poor for some instruments even without alteration, which suggests that some of the information listeners normally use to identify instruments is accumulated across several tones. The result of their study indicated that important information for instrument tone identification exists in the initial part of the sound event; the greatest decline in performance occurred when the attack was removed. With the absence of the attack, the steady state portion may still produce correct identification, however, accuracy is often much lower. Eliminating the decay portion did not seem to decrease recognition. Recognition of the timbre of musical tones with vibrato was less hindered by a missing attack portion than were musical tones that lacked vibrato.

The issue of partitioning isolated tones was re-introduced by Iverson and Krumhansl (1993), who used the technique of multidimensional scaling (MDS) to map participants' judgments on the perceived similarity of tones. Similarity scaling techniques are used to determine which acoustic attributes are most salient. MDS converts similarity judgments into a spatial map where distances in the space correspond to the perceived similarity.

Iverson and Krumhansl (1993) produced three multidimensional scalings of 16 digitally recorded musical instruments from three experiments. The purpose of their study was to examine the dynamic attributes of timbre by evaluating the role of onsets in similarity judgments. There were three experimental conditions, which involved: 1) unaltered signals (complete instrumental tones), 2) constant onset transients (first 80 ms), and 3) signals with onsets (first 80 ms) removed (known as "remainders").

The results of the study by Iverson and Krumhansl (1993) have revealed further complications regarding the dynamic attributes of timbre. They concluded that salient attributes for complete tones are present at the onset. However, ratings for complete tones also corresponded to those of remainders, indicating that the salient attributes for complete tones are present in the absence of onsets as well. This finding seemingly contrasted previous research (i.e., Saldanha & Corso, 1964), however, the researchers accounted for any comparable differences in the sounds and techniques used. They employed a similarity-scaling technique therefore it might be difficult to directly compare similarity judgments with identification judgments. Perhaps identification relies on onsets, but similarity judgments have no such reliance. The issue of dynamic attributes of timbre, in particular the role of onsets, is still unsettled. The current study used only the steady portion of all musical tones. In other words, the attack and decay portions were removed.

1.3 Simultaneous Instruments

Few studies have looked at the "blending" of timbre or the simultaneous perception of instruments. The first experimental investigations on the blending of concurrent timbres were carried out by Kendall and Carterette (1991, 1993). They conducted a series of studies examining the timbres of simultaneous orchestral wind instruments. They referred to pairings as "dyads." These dyads were constructed from all possible pairings of the following instruments: alto saxophone, oboe, flute, trumpet and clarinet. Different contexts of the dyads were used including: unisons (Bb4, approximately 466 Hz); unison melodies (D5, Eb5, F5 and D5, corresponding to 587, 622, 698, and 587 Hz played successively); major thirds (Bb4 and D5); and harmonized melodies (Bb4-D5, G4-Eb5, A4-F5, Bb4-D5). In the harmonized contexts, each instrument was used as the soprano. These different contexts were subjected to similarity scaling (1991) and identification of constituent instruments and ratings of blend (1993).

In the Kendall and Carterette studies mentioned above, it was found that the configuration of similarity scalings had two interpretable dimensions. These were identified as "nasal" versus "not nasal," "rich" versus "brilliant." A third dimension was interpreted as "simple" versus "complex." The extreme of the primary dimension were oboe (nasal) and clarinet (not nasal); of the second, trumpet (brilliant) and alto saxophone (rich). Overall, they found that "nasal" combinations blended less well than "brilliant" or "rich." Although not much work has been conducted in the perceptual blending of instrumental timbre, the work that has been done by

Kendall and Carterette has revealed important implications for orchestration and composition.

On the other hand, perception of auditory patterns, where a number of complex sound events occur simultaneously or sequentially, continues to challenge empirical investigation (Singh, 1987). The perceptual attributes of sounds are often transformed when presented in the dynamic context of a sequence. It has been pointed out by Singh that "[t]he process of sequencing, often augmented by repetition, allows similarities and differences between sounds to be discovered and used as criteria in organization and categorization" (p. 886). Melodies, or specifically, passages of orchestral music, have rarely been used in psychological studies, often due to the lack of control. However, in order to fully understand listeners' perception of timbre in an ecological sense, it is practical to look beyond the single musical tones and begin looking at complex auditory patterns. Although the current study did not examine complex-tone sequences, the results of a previous study that employed a combination of timbres and musical contexts created the impetus for the current study.

In Bonfield and Slawinski's (2002) study, participants were presented with brief passages from the first movement of Stravinsky's *Ebony Concerto* and they were required to identify all the orchestral instruments presented in a 1300 ms passage of interest. There were three conditions in which the targeted passage was presented. The first condition consisted of the passage in question. The second condition included 10 s of musical material leading into the targeted passage. The third condition provided musical material before and after the targeted stimulus. The three conditions were presented repeatedly in random order. Participants were provided with a broad list of ten instruments to select from although there were four instruments in the passage of interest, including a clarinet, trombone, harp and tom-tom.

Bonfield and Slawinski (2002) found that none of the participants could correctly name all four instruments. A more surprising finding was that all the participants (both musicians and non-musicians) named piano as one of the instruments presented in the targeted passage. Thus, the researchers speculated that a certain combination of the four instruments (perhaps two particular timbres) have created spectral qualities that were similar to the spectrum of the piano, thereby creating the perception of the piano timbre.

The present study aimed to follow up on the previous phenomena of timbre identification when more than one timbre is presented simultaneously. We wanted to examine whether the combination of two instrumental timbres would perceptually sound as a single timbre different from the other two timbres. More specifically, would listeners confuse the two combined timbres as one? Three of the four timbres presented in the musical passage used in Bonfield and Slawinski's (2002) study were also examined in this study. These included the clarinet, the trombone and the harp. Three experimental conditions were constructed from the pairings of the three timbres. In each condition one timbre was maintained at Eb5 while the other timbre began one octave apart and would progressively decrease in interval until both timbres merged at Eb5 or unison. Ten different intervals were included in the study. A control condition was also included which consisted of pure tone combinations at the fundamental frequencies. Since this study was concerned with spectral or static attributes, rather than temporal or dynamic attributes of timbre, only the steady-state portion of the musical signal was used.

Musicians and non-musicians participated in this study. They were required to make a judgment on whether they heard one or two instrument(s) after listening to each combination of timbres or pure tones. A major question of this study was whether or not listeners perceive the fusion of two instrumental timbres. Particularly, this study investigated whether musical training would improve the identification of the timbres; in other words, would there be a difference between those listeners who were musically trained (for eight years or more) and those who were musically untrained. It was hypothesized that musicians would perform better (higher percentage correct) in all conditions across all signals compared to non-musicians because of their extensive experience with musical tones. These results would indicate that musical experience can influence our perception of timbre.

2. METHODOLOGY

2.1 Participants

A total of 30 University of Calgary students (9 males and 21 females) participated in this 1-hour experiment for bonus course credits. Each participant filled a self report to indicate their hearing abilities and musical training. The division of participants into groups was made on the basis of their self reports. Nine participants were naïve listeners (i.e., they had received no musical training), 11 had received some form of musical training (i.e., they had received less than 8 years of musical training). These 20 participants (mean age = 22.8, *SD* = 2.96) were considered to be the non-musicians in this study. Only 10 participants (mean age = 21.9, *SD* = 2.38) were considered to be musicians (they had received 8 or more years of musical training). All participants reported normal hearing on a self-report questionnaire. This experiment was posted on a website system that scheduled and tracked experiments for students. Each participant received one bonus course credit after participating in the experiment.

2.2 Apparatus

The stimuli in this experiment were recorded and prepared in the Faculty of Fine Arts, Department of Music in the

Electro-acoustic Laboratory at the University of Calgary. Tonal samples of three above mentioned instruments were performed by experienced university musicians who played single tones on each of the three instruments. The tones were recorded and reproduced with by a 44 100 16-bit samples per second by a DigiDesign Audiomedia digital board controlled by a Macintosh G3 computer. Various programs on a Macintosh G3 computer generated and prepared the stimuli for the study. The recorded instrumental tones were edited in Peak (Version 2.1, produced by Berkley Integrated Audio Software). Those pitches that were not played by the musicians were transposed on Sonic Worx (Version 1.0.0, produced by Prosoniq Products Software). Tones were transposed up or down two semitones, at most, in order to reduce any effects of distortions in the sound waves. The edited tones were then imported into ProTools (Version 5.1, produced by DigiDesign, Avid Technology, Inc.) where prepared samples of two different timbres were merged and converted into interleaved stereo files at a rate of 44,100 16-bit samples per second. Pure tones in this experiment were generated using SoundMaker (Version 1.01). Using this program, these tones were also mixed into interleaved stereo files at the same rate as the instrumental tones.

2.3 Stimuli

The instrumental timbres used in this study were produced by a clarinet, a trombone and a harp. Two of the three timbres were combined in the experimental conditions. The pure tones in this experiment were fundamental frequencies corresponding to the instruments.

In the program Peak, the attack and decay portions of the amplitude envelope of each instrumental tone were excised to generate steady-state signals. The operational definition of envelope constituent boundaries at present is still not operationally defined (Hajda et al., 1997); therefore, it was determined in this study that the steady-state portions of the signals were the regions where the amplitude of the envelope fluctuated the least (i.e., appeared most at a plateau). All signals were generated to be approximately 300 ms in duration, similar to previous experiments of Grey (1977)).

Ten selected notes (or frequencies) were used in this study: Eb4 (311.13 Hz), G4 (392.00 Hz), Ab4 (415.30 Hz), A4 (440.00 Hz), Bb4 (466.16 Hz), B4 (493.88 Hz), C5 (523.25 Hz), C#5 (554.37 Hz), D5 (587.33 Hz), and Eb5 (622.25 Hz) (Pierce, 1983). These 10 notes were prepared for each of the three experimental instruments. There was also a control condition in which only pure tones were used which corresponded to the fundamental frequencies of these timbres. Briefly explained, the perception of instrumental pitches is created by many harmonic (or pure tone) components. Pure tones were included in order that the fundamental frequencies (or the first harmonics) of the 10 notes were heard by the participants. Hence, there were a total of 40 different signals: 30 experimental signals produced from three instruments, and 10 control signals produced by pure tones.

In ProTools, the 40 individual signals were combined into 40 pairs of stimuli. Each trial consisted of a hybrid of two instrumental timbres. One timbre was consistently at Eb5 and was paired with another timbre at 10 different notes, starting from Eb4 (one at Eb5 and the other at Eb4) (see Figures 1 and 2), which gradually blended together as one (both at Eb5) (see Figures 3 and 4). The combinations of the three timbres yielded three experimental groups: 1) clarinet-Eb5 / trombone (at 10 different pitches); 2) harp-Eb5 / clarinet (10 pitches); and 3) trombone-Eb5 / clarinet (10 pitches). The fourth group was the control group which consisted of fundamental frequencies corresponding to the combination of timbres in the experimental condition.

The combination of the 10 notes from the four groups produced 40 different stimuli. Each stimulus was repeated 10 times in random order for a total of 400 trials. These trials were broken into five blocks with 80 trials each. Each stimulus was repeated twice in each block. The stimuli were equalized for perceived loudness and duration, in order to reduce any confounding dimensions related to the judgments on timbre (Grey, 1977).

Examples of the Eb4 and Eb5 timbral combinations are shown in the spectrograms of Figures 1 thru' 4. Figure 1 shows the spectrum of two pure tones, one at Eb4 and the other at Eb5. Figure 2 shows the spectrum of a clarinet at

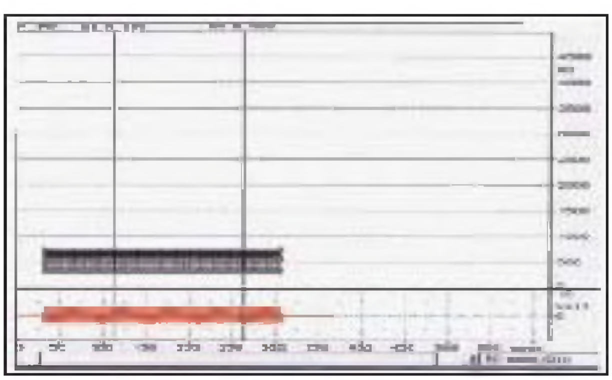

Figure 1. Spectrogram of Control Eb4 and Eb5 combinations.

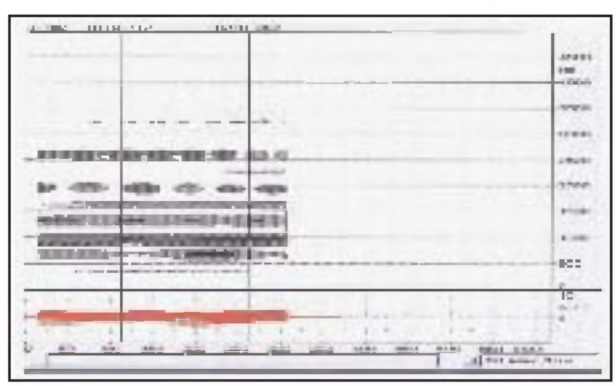

Figure 2. Spectrogram of Clarinet Eb5 and Trombone Eb4 combination.

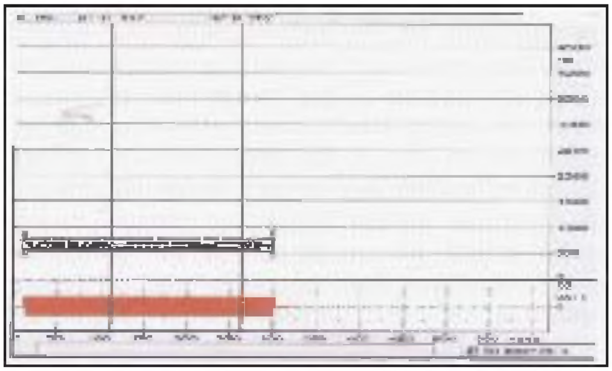

Figure 3. Spectrogram of Control Eb5 and Eb5 combination.

Eb5 combined with a trombone at Eb4. Figure 3 shows the spectrum of two pure tones at Eb5, and Figure 4 shows the spectrum of a clarinet and trombone both at Eb5. When comparing the two groups of spectra, the Control signals (Figures 1 and 3) show only the fundamental frequencies, while the Experimental signals (Figures 2 and 4) show many more partials, or mixtures of pure-tone frequencies.

2.4 Procedure

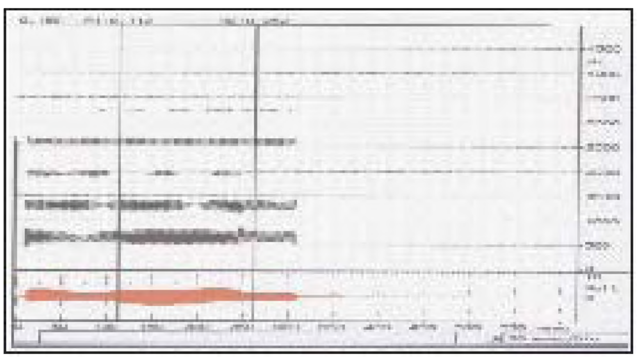

Figure 4. Spectrogram of Clarinet Eb5 and Trombone Eb5 combination.

All tests were conducted in the Speech and Audition Laboratory at the University of Calgary and each test was completed in an one-hour session. Participants were tested individually or as a group (up to six people). Participants were seated comfortably in a semi-circle facing the sound source. Each participant signed a consent form and filled out a questionnaire regarding their musical experience. Participants were verbally told about the experimental task, however, they were not told that there would be two timbres in each trial, nor were they aware of the different types of instruments involved. Before the experimental trials, there was a practice session in which participants heard 300 ms samples of a clarinet, a trombone, and a harp and samples of pure tones, each played at Eb4 and Eb5. They also heard random examples of the test stimuli (the combined signals).

For each trial, participants had to immediately offer a response to the combined timbre and decide whether they heard one or two instruments. They were required to write “1” or “2” in the numbered space provided for them on the answer sheets. There was a 2 sec break between trials for participants to make their responses. After each block of 80 trials, participants were offered the opportunity to take a short break. At the end of the experiment, participants were given a debriefing sheet containing more information about this study. The experimenter also verbally debriefed the participants.

3. RESULTS

The raw data consisted of 400 responses from each of the 30 participants. Participants’ responses of “1”s and “2”s were converted into raw percentages: “1” being an incorrect response was assigned a 0% and “2” being a correct response was assigned a 100%. With this new score, a percentage correct was calculated for each of the 40 timbres for each participant. Therefore, a set of 40 percentages for each

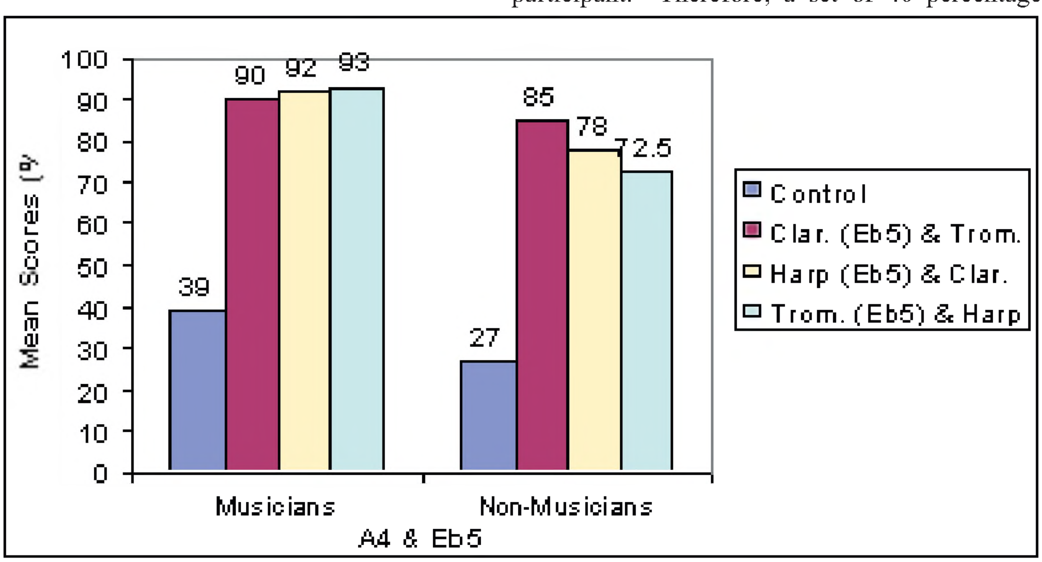

Figure 5. Mean scores for Musicians and Non-musicians for Eb4 and Eb5 combinations.

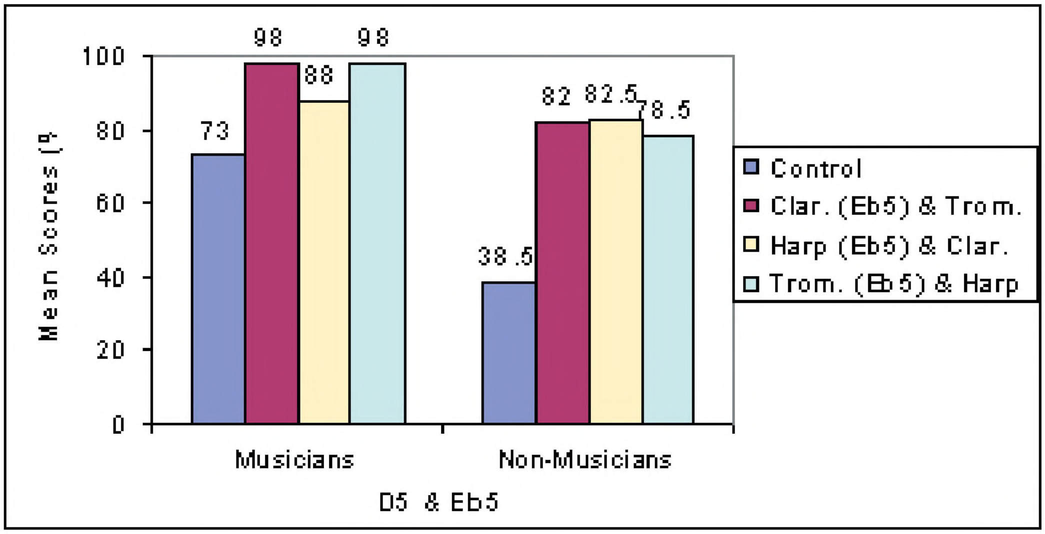

Figure 6. Mean scores for Musicians and Non-musicians for D5 and Eb5 combinations.

participant was obtained.

Mean percentages on the correct number of instruments identified was analyzed using a 10 (combinations) by 4 (conditions) by 2 (groups: musicians, non-musicians) repeated-measures analysis of variance. The omnibus ANOVA revealed that there were significant main effects of combination, $F(9,252) = 65.54$, $p < .001$ and condition, $F(3,84) = 11.78$, $p < .001$ as participants performed differently for each combination and each condition. The results of the analysis indicated that the mean values for group by combination were statistically significantly different, $F(9,252) = 3.01$, $p < .002$, as were the mean values for condition by combination, $F(27,756) = 25.40$, $p < .001$. Thus, there was a systematic difference between musicians and non-musicians, and the effect of condition and combination was different for musicians and non-musicians.

There was also a significant 3-way interaction between the three variables, $F(27,756) = 3.72$, $p < .0001$, which showed that the effect of one variable depended on the levels of two other variables. Further analyses were required to find the source of the significant interactions, however, post-hoc analyses were not conducted due to the large amount of possible comparisons; an unacceptably high error rate would result if all possible pairs of means were compared. However, since the focus of the study was on performance differences between musicians and non-musicians, overall means and standard deviations (SD) were compared and certain timbral combinations of interest were presented here; these included the Eb4, A4, D5 and Eb5 combinations (see Figures 5 to 8).

The results of the A4 and Eb5 combinations (Figure 5) show the typical findings for most of the other combinations. Generally participants performed much better in the Experimental conditions than in the Control condition. On average, both groups could perceive the two timbres, but it appeared that musicians were consistently better able to do so. For the D5 and Eb5 combinations (Figure

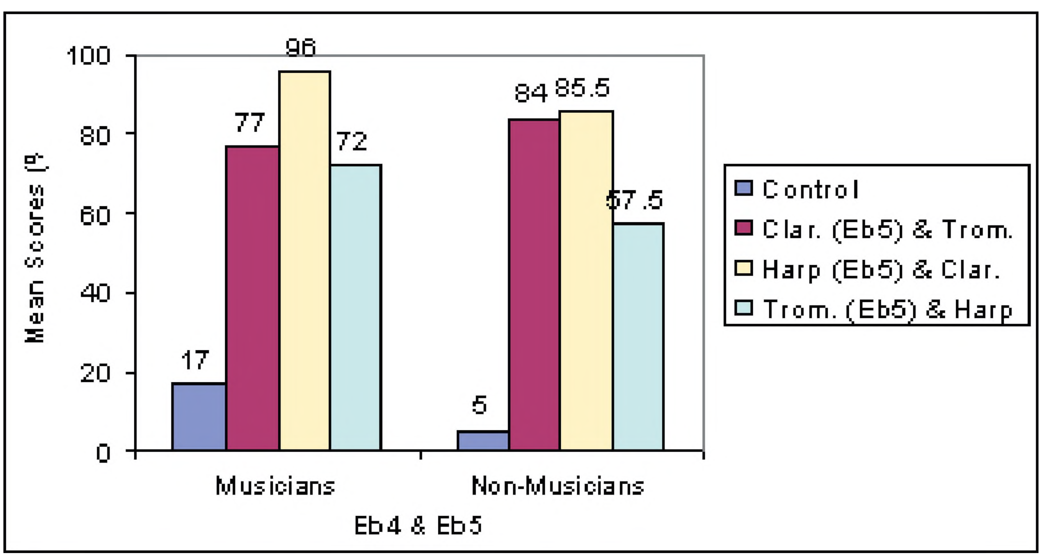

Figure 7. Mean scores for Musicians and Non-musicians for Eb4 and Eb5 combinations.

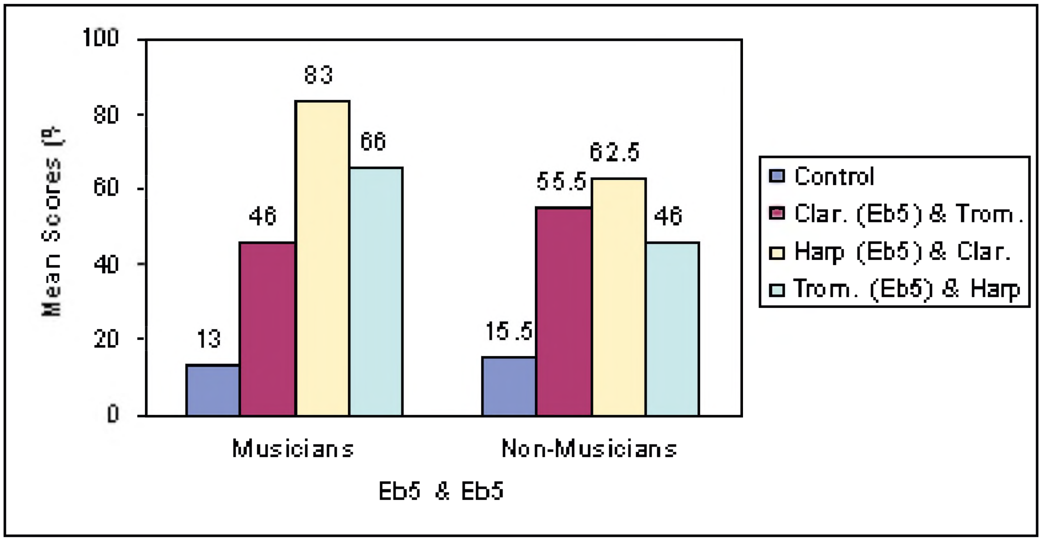

Figure 8. Mean scores for Musicians and Non-musicians for Eb5 and Eb5 combinations.

6), both groups performed well across all conditions, with musicians performing better. It was found that for the octave combinations (Eb4 and Eb5) (Figures 7 and 8), means scores for both groups were typically lower. It is interesting to note that two combinations where non-musicians performed better than musicians were the octave combinations played by the clarinet and trombone pair. The first signal was the Clarinet-Eb5/Trombone-Eb4 signal where non-musicians achieved a mean of 84% (*SD* = .230), and musicians a mean of 77% (*SD* = .295). Clarinet- Eb5/Trombone-Eb5 was the other signal where non-musicians (*m* = 55.5%; *SD* = .287) outperformed musicians (*m* = 46%; *SD* = .353).

4. DISCUSSION

In this study, the perception of timbral fusion in musicians and non-musicians was examined. The hypothesis that musicians would perform better than non-musicians across all conditions was mainly supported. Significant differences were found in this study. Overall, musicians had higher percentage scores than non-musician in identifying that there were two timbres in each stimulus. Thus it was easier for musicians, than non-musicians to hear two simultaneous sounding timbres. This may suggest that musical training or experience enhances the perception of timbre. This difference between musicians and non-musicians is in accordance with other studies (e.g., Kendall, 1986).

Pairs of instrumental timbres (Experimental Conditions) were more accurately perceived by both groups than pairs of pure tones (Control Condition). This was also found in Miller and Carterette's (1975) study where participants had to make similarity judgments between pairs of tones. In their study no differences were observed between musicians and non-musicians in the judgments of the fundamental frequencies. However, in the present study, musicians on average performed slightly better on pure tone combinations than non-musicians even though musicians typically do not have experience with sine tones. In a study (Spiegel & Watson, 1984) which involved frequency-discrimination tasks by musicians and non-musicians, single tones, including 300 ms sine-wave and square-wave tones, and complex sequential patterns of ten tones were used. In the single tone condition, musicians attained thresholds that were lower (better discrimination performance) to only one-half of the non-musicians. The other half of the non-musicians attained thresholds almost as low as musicians. The experimenters suggested that these listeners had probably gained a great degree of psychoacoustic experience and had learned quickly to discriminate single tones. Therefore, musicians tend to perform better than non-musicians on studies of the auditory system probably because of their ability to transfer their previous musical training to new tasks.

The differences in performance between the Experimental Conditions and the Control Condition in this present study can be explained by the characteristics of the waveform. All tones produced by musical instruments are not pure tones but mixtures of pure-tone frequencies or so called partials (White & White, 1980). The perception of fusion depends on the synchrony of the frequency partials in complex sounds, therefore, the fusion of two instrumental timbres is often harder to perceive by non-musicians because there is a lower probability of synchronicity between all the partials; in other words, there is a higher probability of segregation when the partial are not strictly harmonic (Handel, 1989). In contrast, a pure tone has only one harmonic (the first harmonic, or the fundamental frequency (F0)), therefore when two pure tones are combined there is a higher probability of fusion; however, this also depends on whether the two tones are harmonic or not (Handel). For example, participants reported after the experiment, that the signal of Control-D5 was usually heard as two sounds, whereas, Control-Eb4 and Eb5 were easily confused as one.

Generally, the octave combinations were more difficult for listeners to perceive as two timbres. A similar result was also found in a study by Handel, Molly and Erickson (2001). The participants in that study were unable to determine whether two different notes separated by an octave were played by an identical or a different wind instrument. The researchers concluded that "listeners can extrapolate the timbre of an instrument or voice over only a relatively short pitch range" (p. 126). When tones are separated by an octave they are considered to be musically and perceptually equivalent (they are given the same name) (Handel, 1989). Physically, the octave is the only interval in which the harmonics will coincide exactly, therefore, two notes that are separated by octaves cannot create dissonance. Numerous studies have found that octave equivalence is perceived by both experienced and inexperienced listeners, however, the percentage of accuracy ranged from 33% to 50% (Handel). It can be seen in this study that the octave combinations was often lower compared to the other pitch combinations. Surprisingly, the only combinations where non-musicians appeared to perform better than musicians were the Eb4 and Eb5 combinations (i.e., Control-Eb5, Clarinet-Eb5/Trombone-Eb4 and -Eb5). This result was unexpected; perhaps musicians have more experience with harmonic sounds (i.e., triads and chords), therefore they can fuse the harmonic partials more readily than non-musicians.

One limitation to the current study which was similar to previous studies (i.e., Grey, 1977) was the brevity of the signals (300 ms). Steady state timbres were used as the stimuli for this experiment because our goal was to examine only spectral features of timbre. However, other transient features play a crucial role in helping with the identification of an instrument (Iverson & Krumhansl, 1993), especially the attack (Saldanha & Corso, 1964). Since musical tones are in fact, not like the signals of this study, it would be practical to replicate this study by using complete tones (with attack, steady state and decay) to see whether there will be a difference in performances; perhaps there will be an increase in accuracy for both groups.

Although the use of musical passages as stimuli may provide realistic situations in which we may understand perceptual fusion (i.e., Bonfield & Slawinski, 2002), one must be cautious that such experiments may introduce many uncontrolled variables. The methodology of the current study may provide a more controlled way to study this perceptual phenomenon. However, a next step to this timbre-fusion paradigm is to include a single-tone condition. Although there were always two tones present in this study, listeners systematically reported hearing only one tone, therefore a follow-up study with a single-tone condition is necessary in order for a more comprehensive picture to emerge.

Another limitation of this study may be due to the instrumentals timbres used as the stimuli. We have attempted to equate for loudness and pitch across all signals. However, to perceptually equalize natural, albeit, brief tones is difficult because real musical signals are complex and time-variant. It is often the case that a single tone has variable pitch and loudness. For example, the harp has no true steady state; after a sharp attack, the amplitude envelope immediately decays. At no single time frame will the sound be exactly the same or equalized. Since the rationale of this study proceeded from the findings of Bonfield and Slawinski's (2002) study, the instrumental timbres chosen were based on their previous study. Perhaps this study could be replicated by using other instrumental timbres. Participants stated that the trombone and the clarinet sounded very similar, thus they perceived the stimuli of any trombone and clarinet to be identical. But at the same time, it would be interesting to further investigate why the particular combination of clarinet and trombone played at Eb5 was harder to perceive compared to other pitch combinations.

The study of timbre as a musical attribute has received much more attention in recent decades (e.g., Saldanha & Corso, 1964; Grey, 1977; Risset & Wessel, 1999). However, we still do not fully understand its multidimensional nature. Timbral fusion or timbral combination appears to be an important area of study since most music is created by the simultaneously sounding of instruments, however, timbral fusion is still a relatively unexplored area in timbre research. In recent years, musicians and composers have taken interest in the science of music. Therefore, this study may be important in both the fields of music and psychology. The preliminary findings of this research will be useful for traditional composers and orchestrators, as well as electronic composers.

In listening to orchestral music, the perception of fusion also depends on the type of conducting. Conductors may manipulate timbre by combining and emphasizing instruments in a certain way. The fact that timbral manipulation is practiced in the real world, reminds us that, in order to understand music in an ecological sense, we must strive to understand timbre. This study, despite its limitations, has taken a step further into understanding the phenomenon of timbral fusion, as well as gaining more knowledge on the musical attribute of timbre.

5. ACKNOWLEDGMENTS

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Extraction De La Fonction D'aire Du Conduit Vocal Par Excitation Externe

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ABSTRACT

Knowledge of vocal tract area function is important for the understanding of phenomena occurring during speech production. We present here a new measurement method based on external excitation of the vocal tract with a known pseudo-random sequence, where the area function is obtained by a linear prediction analysis applied at the cross-correlation between the sequence and the signal measured at the lips. The advantages of this method over methods based on sweep-tones or white noise excitation are (1) a much shorter measurement time (about 100 ms), and (2) the possibility of speech sound production during the measurement. This method has been checked against classical methods through systematic comparisons on a small corpus of vowels. Moreover, it has been verified that simultaneous speech sound production does not perturb significantly the measurements. This method should thus be a very helpful tool for the investigation of the acoustic properties of the vocal-tract in various cases such as vowels.

SOMMAIRE

La connaissance de la fonction d'aire du conduit vocal est importante pour la compréhension des phénomènes qui se produisent lors d'une élocution. Nous présentons, ici, une nouvelle méthode de mesure fondée sur un mode d'excitation externe du conduit vocal par une séquence pseudo-aléatoire. La fonction d'aire est obtenue à l'aide d'une analyse par prédiction linéaire appliquée à l'intercorrélation entre le signal issu des lèvres et de la séquence pseudo-aléatoire. Les avantages de cette méthode par rapport aux méthodes à balayage de fréquence ou à excitation par bruit blanc sont (1) un temps de mesure très court (environ 100 ms) et (2) possibilité de phonation pendant la mesure. Cette méthode a été testée sur un petit corpus de voyelles. Par ailleurs, nous avons vérifié que la condition de phonation ne perturbe pas, d'une manière significative, les résultats de mesures. Enfin, cette méthode peut constituer un très bon outil pour la compréhension des propriétés acoustiques du conduit vocal lors de la production des voyelles.

1. INTRODUCTION

L'étude de la forme du conduit vocal et de son évolution au cours d'une élocution est importante pour une meilleure compréhension du phénomène phonatoire et pour ses applications dans les domaines de la reconnaissance et de la synthèse de la parole.

Plusieurs études ont été déjà faites sur l'extraction des caractéristiques géométriques du conduit vocal à partir des caractéristiques acoustiques : Schroeder (Schroeder, 1967) a décrit analytiquement la relation entre les pôles et les zéros de l'admittance du conduit vocal mesurée aux lèvres et le logarithme de la fonction d'aire des sections du conduit vocal (représenté par le développement en série de fourrier en cosinus). L'analyse a été effectuée pour des variations dans les limites de l'applicabilité de la théorie de la perturbation d'ordre 1. Pour des grandes variations, Mermelstein (Merlmelstein, 1967) a développé une procédure numérique pour estimer la fonction d'aire (paramétrer par les 6 premiers coefficients de la série de fourrier en cosinus) des singularités de l'admittance. Il a été démontré que les fréquences des formants, qui correspondent aux pôles de l'admittance, sont insuffisantes pour déterminer, uniquement, le logarithme de la fonction d'aire. Les informations nécessaires restantes peuvent être obtenues à partir des zéros de l'admittance, lesquelles, malheureusement ne peuvent être estimés à partir du signal de parole. Schroeder (1967) a alors développé un dispositif expérimental pour mesurer l'admittance du conduit vocal aux lèvres, et en utilisant une approche fréquentielle, il a été capable de déterminer de bonnes approximations de la fonction d'aire. Cependant, le problème d'estimation de la fonction d'aire à partir du signal de parole reste sans solutions.

Avec l'apparition de la prédiction linéaire (LPC) appliquée au signal de parole (Atal et al., 1971) Wakita

(Wakita, 1973, 1979) a développé une technique de filtrage inverse pour estimer la fonction d'aire à partir du signal vocal. Cependant, cette technique fait usage d'informations sur la source voisée, distribution des pertes, longueur du conduit vocal et rayonnement aux lèvres qui ne peuvent être supposés connus, à priori, avec précisions. En fait, Sondhi (Sondhi, 1979) a montré que le signal de parole, seul, ne contient pas assez d'informations pour déterminer une fonction d'aire unique, confirmant les conclusions de Mermelstein (1967) et Schroeder (1967). Yehia (Yehia et al., 1996) propose une solution se basant sur une combinaison explicite des contraintes morphologiques et acoustiques du conduit vocal.

Nous proposons dans ce travail une nouvelle méthode de mesure basée sur un mode d'excitation externe du conduit vocal par une séquence pseudo-aléatoire (Djeradi et al., 1991). La fonction d'aire du conduit vocal est obtenue à l'aide d'une analyse par prédiction linéaire de l'intercorrélation entre la séquence pseudo-aléatoire et le signal mesuré aux lèvres.

Les avantages de cette méthode sont : (1) un temps de mesure très court (100ms), (2) possibilité de phonation pendant la mesure.

2. FORMALISME THEORIQUE

Le conduit vocal peut être considéré comme un filtre acoustique linéaire de réponse impulsionnelle notée h(t). Les échantillons de cette réponse sont notés h (n), n étant le numéro de l'échantillon, et la fonction de transfert du filtre est H. La sortie, y (n), du filtre peut s'écrire alors :

$$y(n) = [b(n) + x(n)] * h(n) \tag{1}$$

Où b(n) est un bruit, indésirable, superposé à l'excitation x(n). La corrélation, R_{xy}, entre x(n) et le signal de sortie y(n), s'exprime par:

$$R_{xy} = R_1(n) + R_2(n) \tag{2}$$

Où

$$R_1(n) = \sum_{k=-\infty}^{k=\infty} h(k) \left[\sum_{m=-\infty}^{m=+\infty} x(m).x(m+n-k) \right] \tag{3}$$

Et

$$R_2(n) = \sum_{k=-\infty}^{k=\infty} h(k) \left[\sum_{m=-\infty}^{m=+\infty} x(m).b(m+n-k) \right] \tag{4}$$

Par ailleurs, soit $\varphi_{xx}(k)$ l'autocorrélation du signal x(n) et $\varphi_{xb}(n)$ la corrélation entre x(n) et b(n). L'équation (2) s'écrit alors :

$$R_{xy} = [h*\varphi_{xx}](n) + [h*\varphi_{xb}](n) \tag{5}$$

Sachant que x(n) et b(n) sont décorrélés, $\varphi_{xb}(n) = 0$
Alors

$$R_{xy}(n) = [h*\varphi_{xx}](n) \tag{6}$$

Il est évident que si $\varphi_{xx}(n)$ est une impulsion de Dirac, la réponse impulsionnelle h(n) serait une image exacte de $R_{xy}(n)$. Une bonne approximation des propriétés statistiques d'un bruit blanc est une séquence pseudo-aléatoire (Julien et al., 1972), dont l'autocorrélation est un train d'impulsions e_N de période N. De ce fait :

$$R_{xy}(n) = [h*e_N](n) \tag{7}$$

Dans le cas où la longueur de la réponse impulsionnelle serait plus petite que N, la séquence $R_{xy}(n)$ correspond exactement à h(n) pour n allant de 0 à N-1.
En utilisant le modèle de prédiction linéaire, il a été démontré que le conduit vocal est modélisé par un filtre tout pôles H(Z) donné par (Atal et al., 1971) :

$$H(z) = 1/(1 + \sum_{i=1}^{p} a_i \cdot z^{-i}) \tag{8}$$

Où : p : est l'ordre de prédiction et a_i : coefficients de prédiction (paramètres du filtre).

Le problème consiste à trouver un ensemble de coefficients a_i ($1 \le i \le p$) tel que l'erreur e_n, entre le signal original et le signal prédit, soit minimale. En traitement de la parole, le critère usuel utilisé est la minimisation de l'énergie de l'erreur (ou critère des moindres carrés), car il conduit, souvent, à une solution mathématique intéressante.
Il suffit donc de minimiser l'erreur quadratique totale ou énergie de l'erreur, que nous désignons par E, qui s'écrit:

$$E = \sum_n e_n^2 = \sum_n (h_n + \sum_{i=1}^{p} a_i h_{n-i})^2 \tag{9}$$

On obtient le système d'équations suivantes:

$$\sum_{i=1}^{p} a_i \cdot R_{|k-i|} = -R_k ; 1 \le k \le p \tag{10}$$

R_k : est l'autocorrélation de la réponse impulsionnelle du filtre, donnée par:

$$R_k = \sum_{n=0}^{N-1-|k|} h_n \cdot h_{n+|k|} \tag{11}$$

Ce système d'équations peut être résolu par l'algorithme récursif de Levinson (Levinson, 1947). L'énergie de l'erreur minimale est donnée par:

$$E_i = (1-k_i^2).E_{i-1} \tag{12}$$

k_i : sont les coefficients de corrélation partiels ou coefficients de réflexions, et sont calculés par la méthode de Leroux (Leroux et al., 1977).

L'énergie de l'erreur normalisée, notée Vp, est définie par:

$$V_p = E_p / R_0 = \prod_{i=1}^{p} (1 - k_i)^2 \quad (13)$$

Avec Ep : énergie de l'erreur d'ordre p et R_0 : l'autocorrélation d'ordre zéro.

Wakita (1979) a montré que le jeu de coefficients k_i, représentent les coefficients de réflexion aux jonctions entre les sections cylindriques d'égales longueurs constituant un tube acoustique, peuvent sous certaines conditions représentés une approximation de la fonction d'aire du conduit vocal. En effet, si Ai représente l'aire de la section d'indice i, prise à partir des lèvres, alors :

$$k_i = (A_i - A_{i+1}) / (A_i + A_{i+1}) \quad (14)$$

Les aires des p sections sont calculées en posant $A_{p+1} = 1$, les aires suivantes sont, alors, estimées dans une échelle relative, pour obtenir un profil de fonction d'aire significative.

3. SIMULATION DE LA METHODE DE MESURE DE LA FONCTION D'AIRE

3.1.1. Principe

Le schéma de principe est donné à la figure 1. Pour réaliser cette simulation (Djeradi et al., 1991), il faut disposer du signal pseudo-aléatoire. Ce signal x(n) est construit à partir d'une suite de nombres binaires, constituant un 'champ de nombres finis' nommé communément 'champ de Galois' (Schroeder, 1979). Dans le cadre de ce travail, qui se limite à une étude de quelques voyelles, la largeur spectrale intéressante est égale à 5Khz, nous prendrons ainsi une fréquence d'échantillonnage de 10 KHz et la durée de la séquence pseudo-aléatoire sera de 1023 échantillons. Le conduit vocal est simulé ensuite par le modèle S.I.M.O.N.D (Castelli, 1989). Ce modèle utilise les coefficients de réflexion telle que proposé par Kelly (Kelly et al., 1962). Dans ce modèle à paramètres localisés, les variations de géométrie du conduit vocal sont représentées par une succession de coefficients de réflexions. Par ailleurs, ce modèle inclut toutes les pertes : à savoir, pertes par viscosité- chaleur, par vibrations des parois et par rayonnement aux lèvres. Pour une fréquence d'échantillonnage de 10 KHz, la longueur de chaque section élémentaire est de L= 1.765 cm (Fe = 2C/L), où C est la vitesse du son.

Dans un premier temps, afin de valider la méthode, on utilisera, en simulation, un modèle sans pertes. Pour cela, on excite le modèle SIMOND (sans pertes) par une entrée pseudo-aléatoire pour une configuration du conduit vocal bien déterminée. La figure (2.a) donne le résultat du calcul de la fonction d'aire obtenu à l'aide d'une analyse par prédiction linéaire appliquée sur l'intercorrélation entre le signal issu du conduit vocal, sans pertes, et de l'excitation pseudo-aléatoire. Il apparaît que l'on retrouve exactement la fonction d'aire de configuration. On suppose connu le nombre de sections, c'est à dire la longueur du conduit vocal.

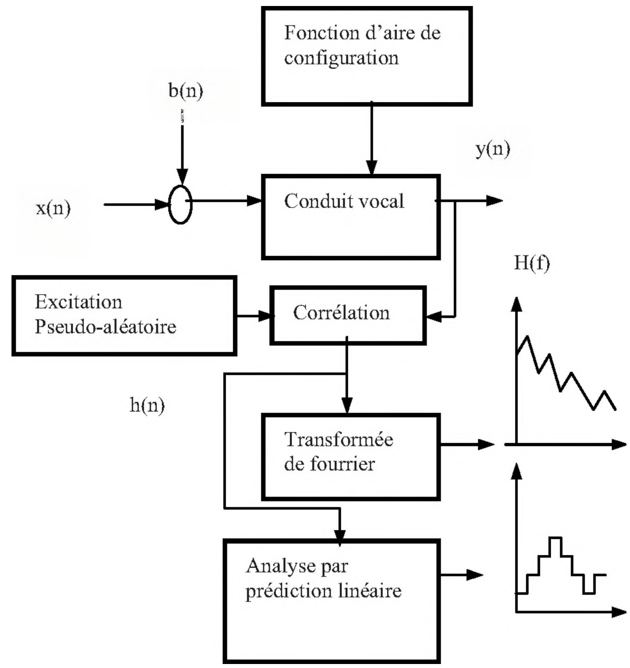


Figure 1. Diagramme du principe de mesure de la fonction d'aire et de la fonction de transfert du conduit vocal.

Pour approcher le cas réel, nous avons étudié le comportement du modèle d'inversion dans le cas d'un conduit vocal avec pertes. Les résultats obtenus ont montré que la configuration calculée ne correspondait pas à la fonction d'aire initiale. La figure (2.b) donne un exemple de résultat.

En ne prenant en compte, successivement, que l'une des sources de pertes, nos études ont montré que les pertes par viscosité chaleur et vibrations des parois n'ont pas beaucoup d'influences sur la fonction d'aire calculée, mais que les pertes par rayonnement aux lèvres jouent un rôle important lors de l'inversion pour retrouver la fonction d'aire (Teffahi, 2000).

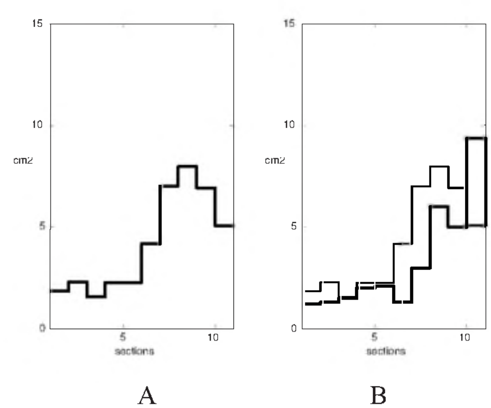


Figure 2. Résultats de simulations. (En trait fin: sans pertes; en trait gras: avec pertes. A- cas sans pertes ; B- cas avec pertes.

4. COMPENSATION DES DIFFERENTES PERTES

Pour prendre en compte les différentes pertes dans le modèle d'inversion, nous avons étudié différentes stratégies d'égalisation. Trois mécanismes de compensation vont être utilisés pour se ramener dans les conditions qui simulent la réponse d'un modèle sans pertes.

4.1 Blanchiment du spectre

La première compensation consiste à réduire la pente du spectre de la fonction de transfert du conduit vocal par application d'une préaccentuation à sa réponse impulsionnelle, représentée par h. En effet, cet affaiblissement global est dû au filtrage de la séquence pseudo-aléatoire par les tissus du cou (Pham et al., 1994). Cette fonction est de la forme:

$$Q(Z) = 1 - b.z^{-1} \text{ avec } |b| < 1 \tag{15}$$

Par conséquent, si l'on souhaite une préaccentuation adaptée au signal, il convient d'estimer la valeur de b. On peut remarquer que Q(z) est un prédicteur d'ordre 1. Dans ce cas simple, nous avons d'après le modèle de prédiction linéaire:

$$b = R_1 / R_0 \text{ avec } R_i = \sum_n h_n \cdot h_{n-i} \qquad 1 \le i \le p$$

4.2.Amortissement de la réponse impulsionnelle

Pour éviter des variations trop importantes d'une section à la suivante (non réalistes) et assurer une meilleure stabilité du filtre modèle, on élargit les bandes passantes des formants (Elmallawany, 1975). L'approche consiste à optimiser par prédiction linéaire le filtre modèle sur une séquence de signal, soit calculer les coefficients a_k modèle, dont la réponse impulsionnelle est de la forme :

$$D(z) = 1 - \sum_{k=1}^{p} a_k \cdot z^{-k} \tag{16}$$

Ensuite, en multipliant la réponse impulsionnelle D(z), qui est directement fonction des a_k, par une exponentielle décroissante, on réalise un élargissement équivalent des bandes passantes. On obtient ainsi de nouveaux coefficients

$$a'_k = a_k . \exp(-c.k) \tag{17}$$

La valeur de c est liée à l'élargissement B des bandes passantes des formants par la relation:

$$c = \pi . B . T_e \text{ (Te est la période d'échantillonnage).} \tag{18}$$

La meilleure adéquation est obtenue en prenant B = 50 Hz.

4.3 Compensation du rayonnement aux lèvres

Dans le modèle du conduit vocal à réflexion, le rayonnement aux lèvres est approché comme une connexion en parallèle sur le dernier tube du conduit vocal, d'une inductance L et d'une résistance R (Degryse, 1981). Cette impédance est équivalente, alors, à une section supplémentaire qui vient s'ajouter à la dernière section du conduit vocal.

Pour cela, pour un conduit ayant N sections, on calcule à l'aide du modèle d'inversion (N+1) sections et on considère que la section d'ordre (N+1) est équivalente à l'effet du rayonnement aux lèvres. Il suffit alors de ne considérer que les N premières sections pour avoir la forme du conduit vocal.

5. MESURE DE LA LONGUEUR DU CONDUIT VOCAL

Nous proposons un critère simple pour l'estimation du nombre N de sections du conduit vocal. Cette approche fait appel à la définition d'un intervalle de valeurs possibles, avec les bornes suivantes :

$N_1 = 2*12/35300*T_e$ (l=12 cm, valeur minimale)

$N_2 = 2*20/35300*T_e$ (l=20 cm, valeur maximale).

Pour Fe = 10 KHz, on a N1 = 7 et N2 = 12. La méthode consiste à calculer pour toutes les valeurs de l'intervalle, le critère suivant:

$$J(p) = (V_{p-1} - V_p) / V_{p-1} \tag{19}$$

Où Vp est l'énergie de l'erreur normalisée (équation 13). Le nombre de sections, N, sera égal à la valeur de p qui correspond au maximum de la fonction J(p). En effet augmenter N au-delà de la valeur recherchée revient à modéliser la source d'excitation sous forme d'une source de débit, ce qui ne fait plus partie de la configuration du conduit vocal. L'erreur normalisée a alors atteint son minimum, on est donc dans le cas optimal pour la modélisation par analyse par prédiction linéaire. On rappelle que le calcul de Vp porte sur le signal issu du conduit vocal après application d'une excitation pseudo-aléatoire.

La figure (3), représente la courbe d'évolution de l'erreur normalisée V_p en fonction de p pour deux voyelles (/a/ et / u/).

Cet exemple illustre les différences qui peuvent exister entre les courbes de V_p pour différents sons. Néanmoins, la courbe part toujours de l'unité pour p=0 et décroît en permanence jusqu'à sa valeur minimale quand p tend vers l'infini. Chaque courbe présente plusieurs segments de transitions rapides qui signifient que l'incrémentation de la valeur de p d'une unité améliore sensiblement l'approximation du spectre. A titre d'exemple, le "a" connaît des transitions relatives importantes pour p<3 et puis de p=8 à p=10. Pour p>11, V_p est quasi-constante, ce qui tend à signifier que p=10 est la valeur pour laquelle l'approximation de l'enveloppe du spectre est optimale. Ainsi, pour des valeurs de p, plus faibles, l'approximation serait plus grossière.

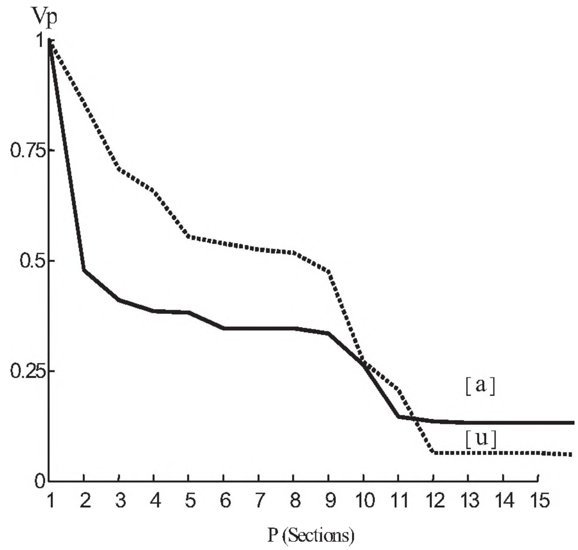


Figure 3: Courbes de l'erreur normalisée pour deux voyelles /a/ et /u/.

Alors, pour p>10, le conduit vocal sera complété par un tube uniforme de grande longueur et de très faible section, ce qui ne modifie pas la fonction de transfert.
Nous donnons sur la figure (4), quelques exemples de fonctions J(p) obtenues après analyse, par simulation, de quelques voyelles.

Nous remarquons que le maximum de la fonction J(p) dans l'intervalle considéré permet de retrouver, exactement, le nombre de sections de la voyelle analysée.

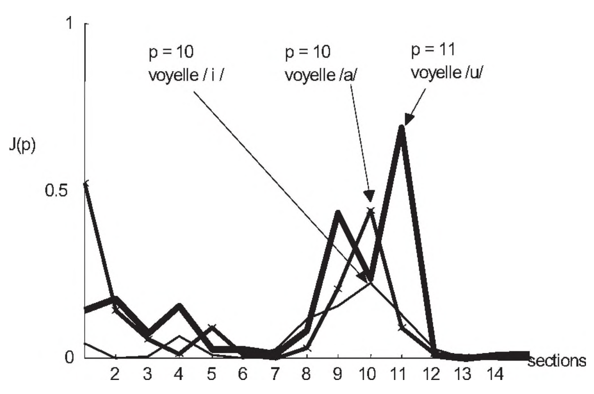


Figure 4: Courbes J(p) pour les voyelles /a, i et u/.

6. APPLICATION A LA MESURE DE LA FONCTION D'AIRE DE QUELQUES VOYELLES DU FRANÇAIS

Nous présentons sur la figure 5, un exemple de résultats obtenus, par simulation, pour trois configurations du conduit vocal [a, i, u]. Nous remarquons que la méthode, après application du triple mécanisme de compensation, donne des fonctions d'aires calculées (colonne B) qui se rapprochent beaucoup des fonctions d'aire initiales. D'une part la forme générale est bien conservée, d'autre part, le calcul de la fonction de transfert à partir de la fonction estimée se superpose également assez bien avec celle de la fonction d'aire de départ.

7. EXPERIMENTATION

Le dispositif expérimental est présenté à la figure 6. La chaîne de mesure se compose de : (1) une carte de traitement de signal connectée à un micro-ordinateur, possédant des cartes de convertisseurs A/D et D/A, et qui génère un signal d'excitation pseudo-aléatoire numérique, (2) un amplificateur, (3) un excitateur, (4) un microphone avec son préamplificateur connecté à la voie A/D de la carte de traitement de signal, ainsi qu'au casque audio porté par le sujet. Une plaque en fibre de verre est utilisée afin de minimiser le rayonnement acoustique de l'excitateur vers le microphone.

Le conduit vocal est excité de manière externe au niveau du larynx ; le microphone placé à environ 2 cm des lèvres capte le signal modulé par les cavités supra-glottiques à la sortie du conduit vocal.
Pour une articulation donnée, l'opération se déroule en quatre phases:

a- la première est une phase d'excitation par bruit blanc, qui aide le sujet à positionner correctement ses articulateurs en écoutant le retour ;
b- le sujet maintient son articulation pendant une phase de silence ;
c- excitation par le signal pseudo-aléatoire et enregistrement du signal issu des lèvres ;
d- calcul de l'intercorrélation et de la fonction d'aire.

Dans le cas de mesure de la fonction d'aire en condition de phonation, la production du son commence juste avant l'application de l'excitation pseudo-aléatoire.

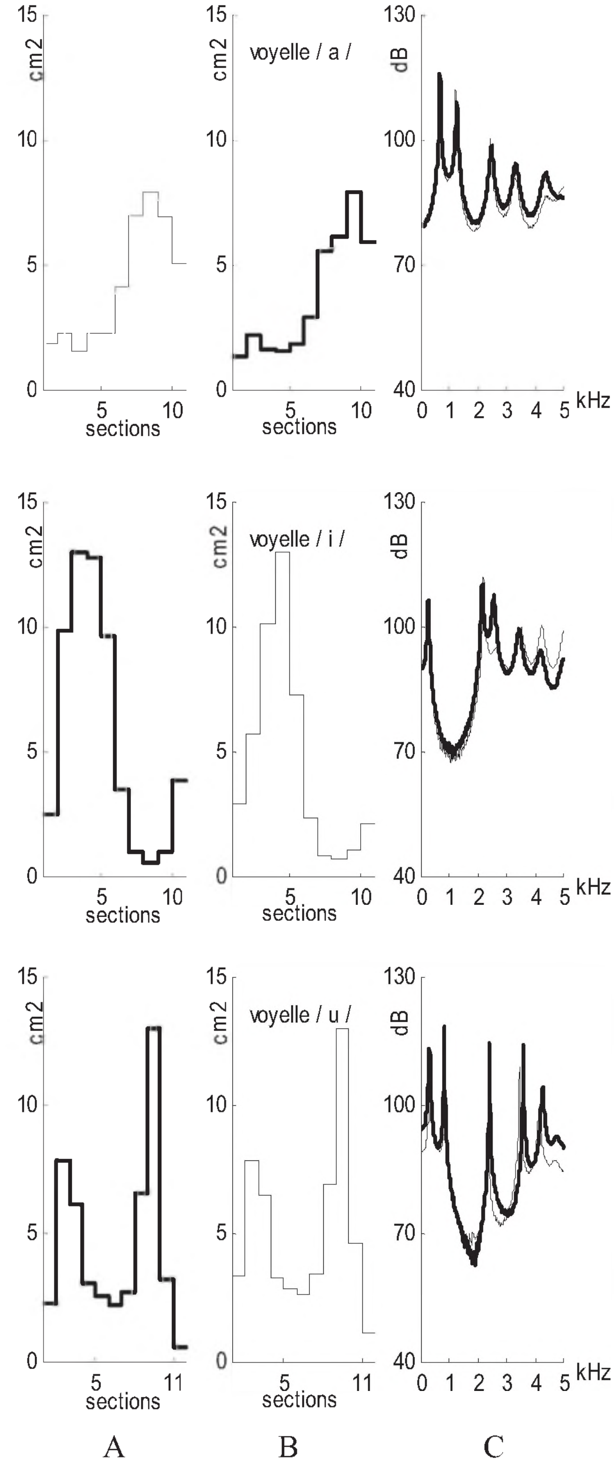


Figure 5. Résultats de simulations après compensations A: Fonction d'aire de configuration, B: Fonction d'aire estimée C: Fonction de transfert de configuration en gras, calculée en fin

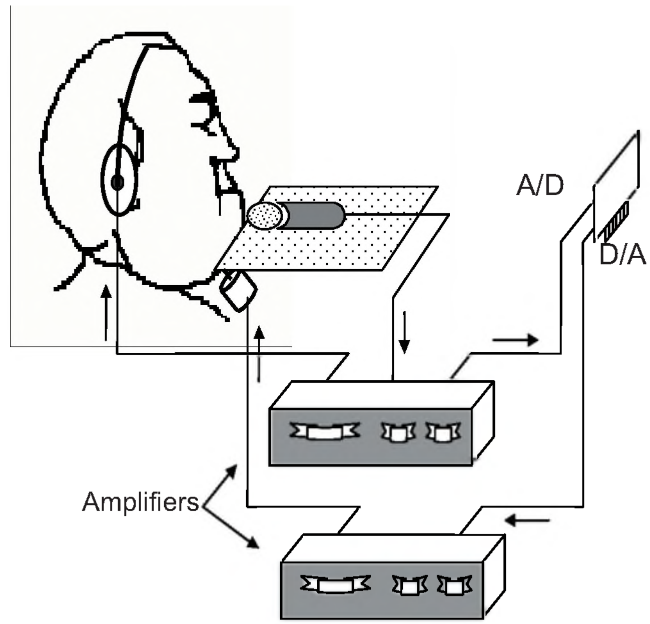


Figure 6: Dispositif expérimental (Djeradi et al, 1991).

Les fonctions de transfert du conduit vocal des onze voyelles orales du français [i, e, E, a, A, O, o, u, y, eu, oe] ont été enregistrées systématiquement par deux sujets masculins de langue maternelle française. Les enregistrements ont été effectués dans un studio isolé phonétiquement. Le signal est directement numérisé à la fréquence d'échantillonnage de 10 KHz, ce qui est suffisant pour les voyelles dans le domaine de validité du modèle de production. La durée de la mesure est d'environ 100 ms, correspondant à une séquence pseudo-aléatoire de 1023 échantillons. Chaque voyelle est enregistrée douze fois afin de vérifier la stabilité, et de différencier les pics ayant une réalité physique des pics liés à des artefacts de mesure.

Deux fonctions de transfert sont mesurées successivement pour la même articulation dans deux conditions différentes : en phonation (production d'une voyelle voisée), et à glotte fermée. Pour cela, le sujet soutient l'articulation en phonation, pour la première mesure, puis ferme sa glotte sans bouger les autres articulateurs, pour permettre la deuxième mesure (Pham et al., 1994). Les fonctions d'aires sont mesurées, ensuite, par la méthode de prédiction linéaire.

Notons qu'il est extrêmement difficile de réaliser une source de débit acoustique ayant une impédance interne assez grande pour assurer que son signal de sortie serait indépendant de l'impédance acoustique le chargeant. Il est encore plus difficile d'envisager d'insérer une telle source dans le conduit vocal du sujet près de la glotte. C'est pourquoi nous sommes obligés d'exciter le conduit vocal de manière externe. Il en résulte que la fonction de transfert inconnue de la peau, des cartilages et du cou est ajoutée à la fonction de transfert du conduit vocal mesurée.

Il a été vérifié de manière expérimentale que la peau et les cartilages du sujet se comportent comme un filtre passe-bas à bande passante large, ce qui assure qu'aucun pôle ou zéro supplémentaire à bande passante étroite dans la fonction de transfert mesurée ne peut provenir de la fonction de transfert du cou (Pham et al., 1994). Le blanchiment du spectre décrit au paragraphe 4.1 permet de réduire la pente spectrale, parasite, introduite par le filtrage de l'excitation pseudo-aléatoire par les tissus du cou.

7. RESULTATS

Pour apprécier les fonctions d'aire obtenues, nous avons utilisé les données publiées par Majid (Majid, 1986). Nous avons tout particulièrement porté notre attention sur le lieu d'articulation, l'aire correspondante et l'aperture aux lèvres. Notons que les fonctions d'aire obtenues ont été normalisées, en volume, par rapport à celles publiées par Majid, pour les voyelles du français. Nous présentons ici les résultats correspondant aux trois voyelles cardinales (/ i /, / a / et / u /), pour douze mesures successives. Ces fonctions d'aire nous ont servi pour sélectionner, pour chaque voyelle, une configuration ''type''.

A première vue, les fonctions d'aire que nous avons obtenus présentent des variations, mais une lecture articulatoire permet de remarquer que (figure 7):

- Pour la voyelle / i /, le lieu d'articulation (la position de la constriction) est bien situé à l'avant du conduit vocal (à 13 cm de la glotte), et l'aire aux lèvres varie dans une gamme limitée (2 à 4.5 cm^2).
- Pour la voyelle / a /, le lieu d'articulation se trouve bien dans la zone pharyngale (8 cm de la glotte) et l'ouverture des lèvres est plus grande et relativement précise (4 à 5 cm^2).
- Nous avons bien trouvé, pour la voyelle arrière / u /, deux constrictions : l'une à l'intérieur du conduit vocal bien localisée (7 cm de la glotte) et l'autre aux niveaux des lèvres (0.5 à 1 cm^2).

Ces résultats peuvent se résumer comme suit:

- Les voyelles cardinales / i /, / a / et / u / produites par le modèle présentent toutes les caractéristiques bien connues du lieu d'articulation et de l'aperture aux lèvres, c'est une première validation du modèle. Il y a, parfois, des différences entre les fonctions d'aire, mais pas au point de présenter des configurations ayant des lieux d'articulations différents, et des aires aux lèvres très variables.
- Dans cette génération extensive fournie par le modèle, la description vocalique classique en terme de lieu et d'aperture aux lèvres n'est donc pas prise en défaut.

Sur la colonne B de la figure 7 nous présentons les résultats obtenus en phonation. Notons que l'existence d'un signal parasite lié à une intercorrélation non rigoureusement nulle entre le signal pseudo-aléatoire et les signaux extérieurs (signal glottique, bruit ambiant…) induit des perturbations sur la fonction de transfert mesurée, par conséquent sur la fonction d'aire. Nous avons vu que l'intercorrélation entre la sortie y(n) et le signal pseudo-alétoire x(n) est la somme de deux composants R1(n) et R2(n) : R1 correspond à la réponse impulsionnelle du conduit vocal, s'atténue au bout d'une certaine durée D ; R2 provenant d'une intercorrélation non rigoureusement nulle en pratique entre x(n) et le signal parasite, b(n), dont l'amplitude maximale est à peu près constante mais faible relativement au maximum de l'amplitude de la réponse impulsionnelle. Cette dernière composante n'apparaît vraiment que dans la partie où la réponse impulsionnelle est suffisamment amortie, et elle se présente sous la forme de l'apparition d'un pic de résonance à la fréquence fondamentale du signal perturbateur (Djeradi et al., 1991). Pour atténuer l'amplitude de ce pic, nous pondérons par une fenêtre de Hanning (Bellanger, 1984) l'intercorrélation entre x(n) et y(n). Ce traitement présente l'inconvénient de modifier aussi les valeurs des bandes passantes des résonances. Des essais ont montré que le meilleur compromis entre l'erreur introduite dans la mesure des bandes passantes et la diminution du perturbateur, sachant que la résolution spectrale est de l'ordre d'une dizaine de Hz, correspond à une fenêtre de Hanning de largeur 30 ms.

La comparaison des fonctions d'aire mesurées à glotte fermée (colonne A) avec celles mesurées en phonation (colonne B), pour les trois cas, montre que les profils sont bien retrouvés et que les constatations articulatoires restent valables.

Sur la figure 8 nous avons superposé les fonctions de transferts obtenus, colonne A, et les fonctions d'aire, colonne B, pour les deux conditions de mesure (en phonation et à glotte fermée). Ces fonctions d'aire se rapportent aux trois voyelles cardinales du français, prononcées par un locuteur masculin. Sur la colonne C, nous présentons les résultats publiés par Majid (1986), pour les mêmes voyelles. On notera l'assez bonne cohérence des lieux d'articulation, de leur degré d'aperture, de l'aire aux lèvres et de la longueur du conduit vocal.

Le dispositif mis en place, nous a permis d'extraire les fonctions d'aire et de transfert des onze voyelles du français, pour deux locuteurs masculins, dans les deux conditions d'enregistrements. Les résultats obtenus ont été jugés réalistes.

8. FORMANTS

A l'aide d'un simulateur analogue du conduit vocal et pour valider nos fonctions d'aire, nous avons calculé les valeurs des trois premiers formants des onze voyelles correspondants aux configurations obtenues, pour deux locuteurs. Sur les figures 9.a et 9.b, nous avons superposé les valeurs calculées à partir des fonctions d'aire extraites avec celles mesurées sur les fonctions de transfert. Nous remarquons que les valeurs sont assez proches, avec un léger déplacement du troisième formant pour certaines voyelles.

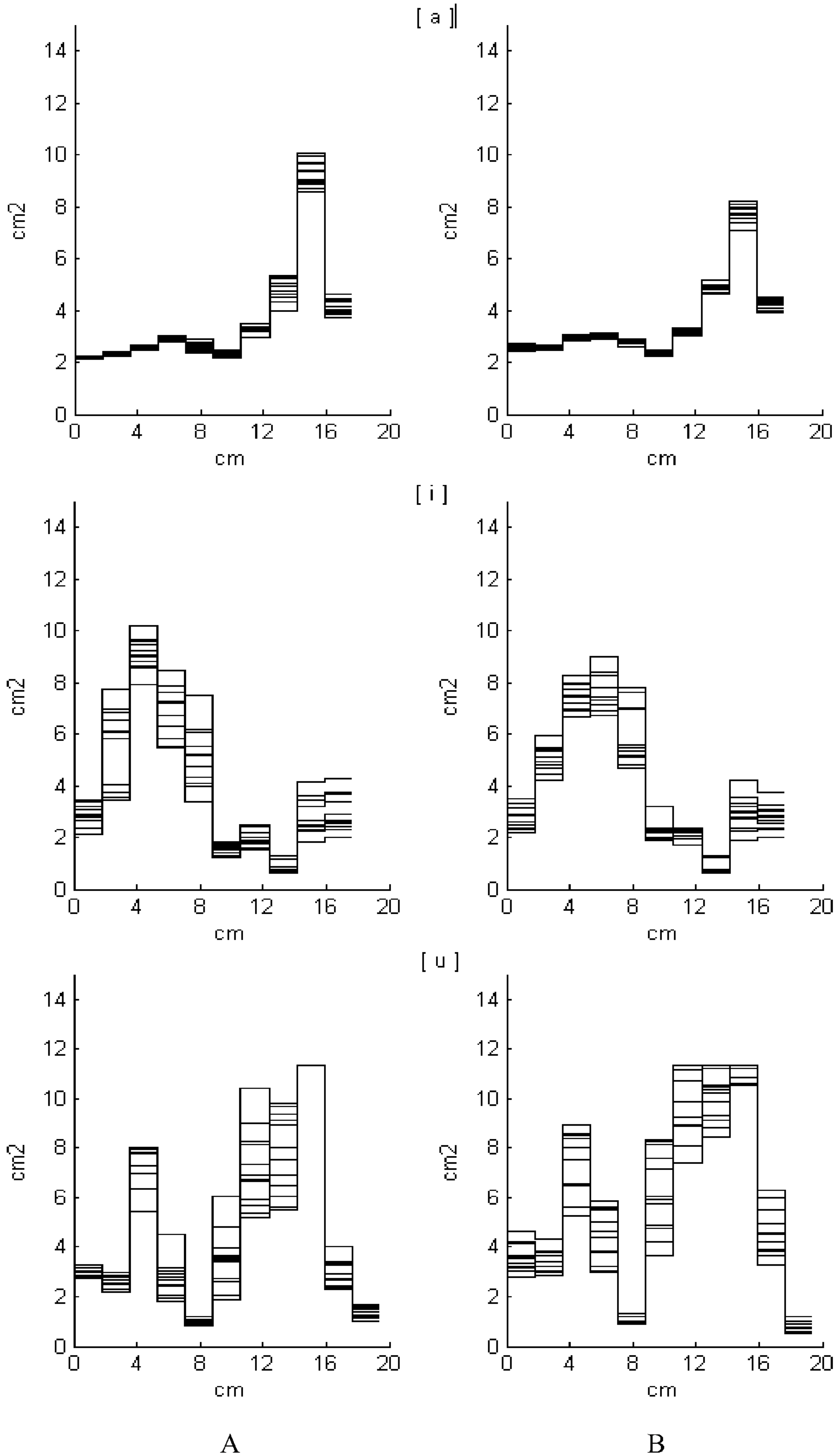


Figure 7: Fonctions d'aire des voyelles / a /, / i / et / u/ A: glotte fermée; B: En phonation.

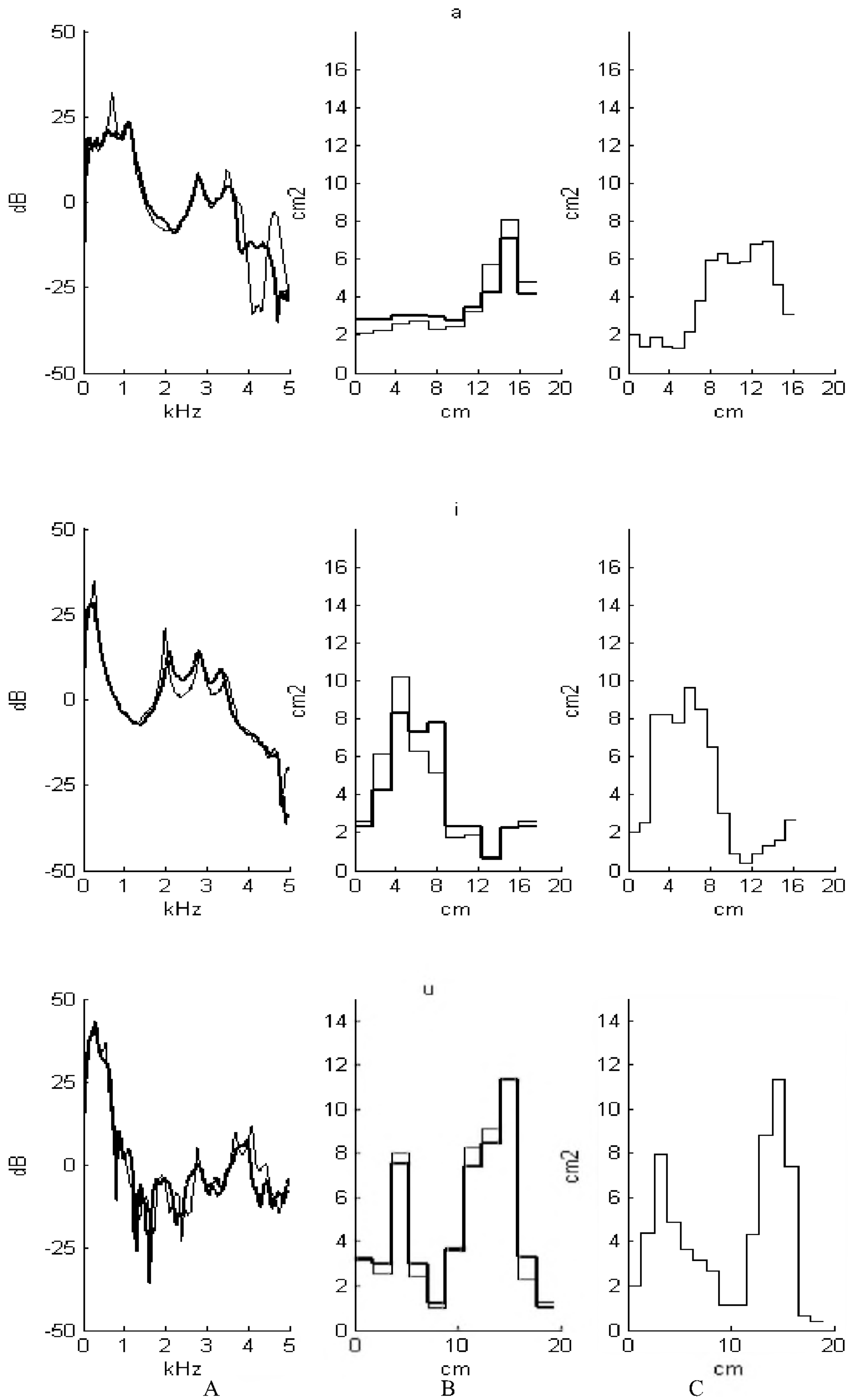
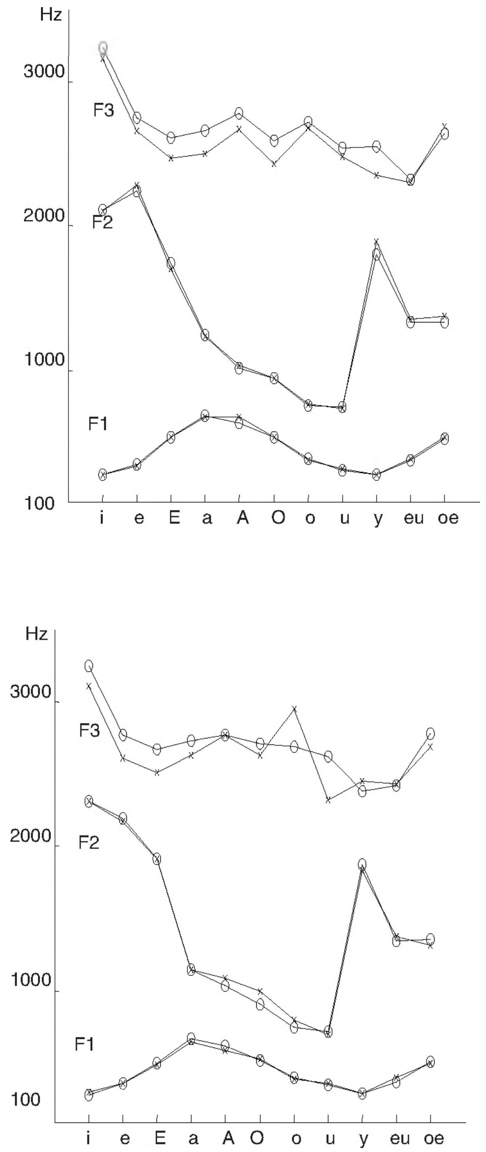
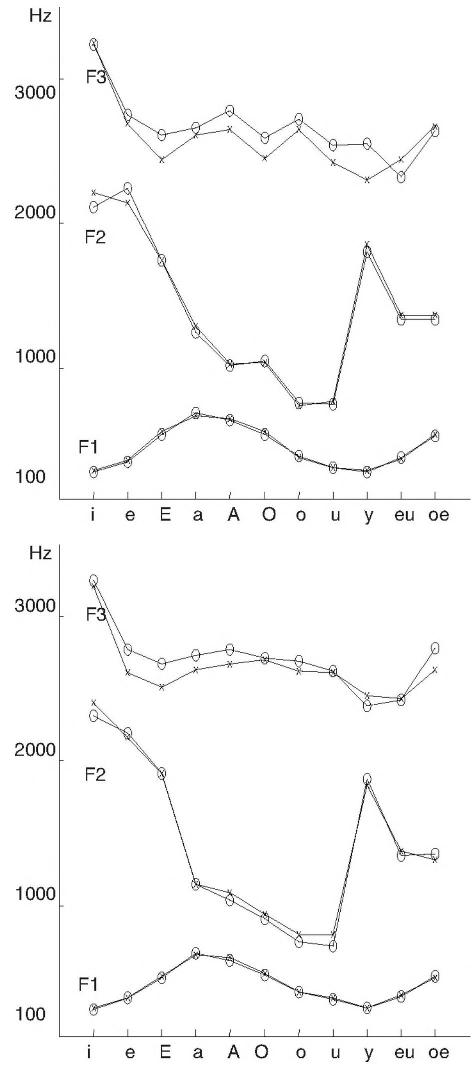


Figure 8: Fonctions de transfert et d'aire du conduit vocal pour les voyelles [a, i, u], (sujet masculin). (En trait gras: phonation, en trait fin : glotte fermée) - A: Fonctions de transfert; B : Fonctions d'aires; C: Fonctions d'aires d'après Majid (1986).



Locuteur 1

Figure 9a : Présentation des voyelles orales du français selon les valeurs des trois premiers formants. (En haut: glotte fermée ; en bas : en phonation)
x: valeurs calculées à partir des fonctions d'aire o: valeurs mesurées sur les fonctions de transfert.



Locuteur 2

Figure 9b: Présentation des voyelles orales du français selon les valeurs des trois premiers formants. (En haut: glotte fermée; en bas: en phonation)
x: valeurs calculées à partir des fonctions d'aire o: valeurs mesurées sur les fonctions de transfert.

9. CONCLUSIONS

Les résultats de simulation, puis de mesure sur quelques voyelles, montrent que la méthode de mesure de la fonction d'aire du conduit vocal par excitation pseudo-aléatoire est fiable.

Ainsi, nous avons montré à travers ce travail que l'extraction d'une fonction d'aire unique directement de la réponse impulsionnelle du conduit vocal était possible à l'aide d'une méthode de prédiction linéaire en simulation dans le cas sans pertes.

Dans le cas avec pertes, plusieurs traitements complémentaires sont nécessaires. Nous avons notamment étudié les différentes stratégies d'égalisation en vue de la prise en compte des influences des différentes pertes, en particulier celles par rayonnement aux lèvres.

Enfin nous avons proposé et testé un critère pour l'estimation du nombre de sections du conduit vocal. Les longueurs obtenues pour les onze voyelles du français sont valables.

Les résultats de mesure sur des cas réels montrent que les profils de fonctions d'aire obtenus pour les onze voyelles sont très satisfaisants. Les lieux de constrictions et l'aperture aux lèvres sont très proches de ceux fournis en littérature (Majid, 1986), (Yehia et al., 1996).

Par ailleurs, nous avons vérifié qu'en condition de phonation, la perturbation apportée par une intercorrélation non nulle pouvait être atténuée et que les résultats finaux restaient réalistes et exploitables.

Il est clair que le système que nous venons de développer présente des limites. Celles-ci résident dans la difficulté à positionner l'excitateur, exactement au niveau du larynx et de s'assurer que le conduit vocal est stable pendant la mesure. Par ailleurs, la technique peut être améliorée en comparant les fonctions d'aire du sujet à ceux que nous mesurerons directement par la technique d'imagerie (IRM). Cette option est difficile à réaliser mais pas impossible.

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Helmholtz Resonator for Reducing Tire Cavity Resonance and In-Vehicle Noise

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ABSTRACT

Automotive manufacturers expect tire suppliers to investigate alternative approaches of controlling the tire cavity resonance in vehicles other than changing the shape and design of the tire. The intention of this case study is to demonstrate such an approach in eliminating the tire cavity resonance by installing a sound-damping resonator on the wheel assembly. The predicted transmission loss for such a resonator model given in this paper is compared to the experimental result. In terms of quietness, the sound-attenuating resonator controls the cavity resonance and noise. However, this investigation should be extended to include multiple resonator units of different dimensions to attenuate the cavity resonance at a wide range of frequencies.

SOMMAIRE

Les fabricants automoteurs prévoient que les fournisseurs de pneu examinent des approches alternatives de contrôler la résonance de cavité de pneu dans les véhicules changeant autrement que la forme et la conception du pneu. L'intention de cette étude de cas sera obligé à démontrer telle une approche dans éliminer la résonance de cavité de pneu en installant un résonateur de son-étouffe sur l'assemblée de roue. La perte prédite de transmission pour un tel résonateur modèle donné dans ce papier en comparaison du résultat expérimental. Sur le plan de calme, le résonateur de son-modère contrôle la résonance de cavité et le bruit. Cependant, cette investigation devrait être étendue pour inclure les unités de résonateur multiples de dimensions différentes pour modérer la résonance de cavité à une gamme large de fréquences.

1. INTRODUCTION

The noise, especially cavity noise, produced by tires has been a concern in the automotive industry. The cavity resonance of the air column inside the tire is a major contributor to the vehicle's interior and exterior noise. A clear understanding of this phenomenon is required to design a suitable noise control solution in eliminating the tire cavity noise.

One of the main sources of in-vehicle noise is the vibration of the tire carcass, which is caused by the resonance frequencies of the tire construction. Thus, the cavity resonance becomes an issue, which is dependent on tire shape and design. The carcass' vibration causes the sidewalls to radiate sound in phase from both sides. As a result of better impedance matching, the sound level emitted inside the carcass usually approaches peak-level of up to 140 dB. Part of this noise is radiated outside through the sidewall but most of this noise is radiated through the suspension and vehicle components, thus reaching the vehicle interior. Changing the design of the tire alone to control the cavity noise is a challenging and frustrating task. Today automotive manufacturers are looking for an alternative method to changing the tire design, in order to control the cavity noise.

The air cavity of a given tire resonates at a certain frequency or at a multiple of frequencies. This is caused by the Doppler effect, which depends on the rotating speed of the tire. In this work, a model of a rectangular resonator, whose mechanical analogy is a simple oscillator, is investigated as a damper to attenuate the cavity resonance inside the tire cavity.

2. MATHEMATICAL MODEL OF RESONATOR DAMPING

The sound damping-resonator model is based on the Helmholtz resonator principles, which acts as a damper and is proposed in this investigation. The resonator model can be incorporated in the air cavity area of the tire. Such a damper unit should eliminate the cavity resonance and improve the in-vehicle noise quality. The resonator can be designed to match the unique need of each tire type and would be marketable as a supplementary rubber product to control cavity resonance. An advantage to this approach is that a unit of multiple resonators can be incorporated into the tire cavity such that by slightly varying the design parameters of each resonator the concerned range of frequencies due to the Doppler effect can be focused.

The Helmholtz resonator, which is used as an acoustics damper, has a resonant frequency tuned to the tire cavity resonance. The geometry of each resonator, as in figure 1, is determined by the size of the cavity of the resonator and the size of the orifice or the opening through which the energy enters and escapes from the cavity of the tire. In the illustrated resonator models, dimensions are chosen for a particular tire-wheel structure so as to be tuned to the cavity resonance of the tire.

Helmholtz resonators may be compared to a typical mechanical spring-mass system. The equivalent of the spring is the compressibility of the air in the cavity and the equivalent of the mass in the spring-mass system is the effective mass of the air in the orifice. When the resonator is tuned to the tire cavity's resonance, then the acoustic pressure disturbances in the tire cavity causes the resonator to oscillate. Thereby, the resonator acts as a large air source and sink at that frequency to effectively absorb the pressure disturbances from further propagation.

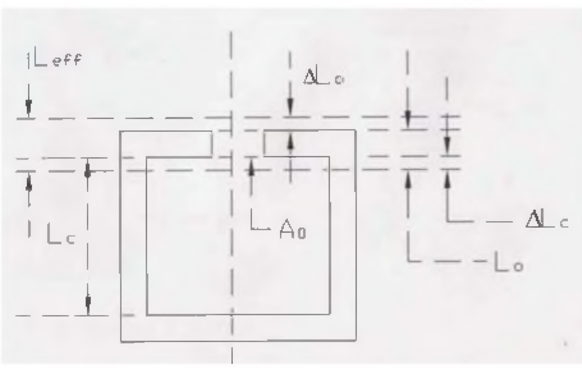

Figure 1 – Helmholtz Resonator

In Figure 1 of the Helmholtz resonator, A_0 is the orifice cross sectional area, A_c is the cavity cross sectional area, L_0 is the length from the opening to the cavity, and V_c is the volume of the cavity. The following mass equation is given as,

$$m = \rho A_0 L_{eff} .$$

The effective length, L_{eff} , is given by,

$$L_{eff} = L_0 + \Delta L_0 + \Delta L_C = 0.96 A_0^{1/2} .$$

For a spring mass system, as in Figure 2, where m is the mass and K is the spring constant, the natural frequency of the system is

$$f_n = \frac{1}{2\pi}\sqrt{\frac{K}{m}} .$$

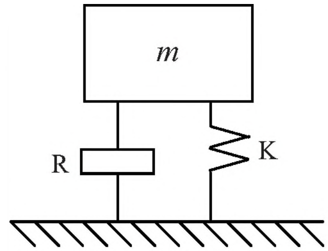

Figure 2 – Mechanical Oscillator

Consequently, at 273 ^{0}K and at the velocity of sound C_0 (3.31/10^4 cm/s for air), the resonator frequency is

$$f_n(T) = \frac{C_0}{2\pi}\left(\frac{A_0 T}{273 \times V_C L_{eff}}\right)^{1/2} .$$

The ratio of orifice radius r_0 to cavity volume V_C is approximated using,

$$\frac{r_0}{V_C} = \frac{9.96 \times f^2}{10^8 T} .$$

In the above equation, f is the frequency of the tire cavity resonance. These equations can be used to determine the size of the resonator and to tune the tire cavity resonance.

Figure 3 is a model of a duct with a side branch in which the resonator is attached. This model is often used in industries to attenuate pure noise tones propagating along the duct. A tire cavity may be considered similar to a duct, where the standing wave propagation results in cavity noise.

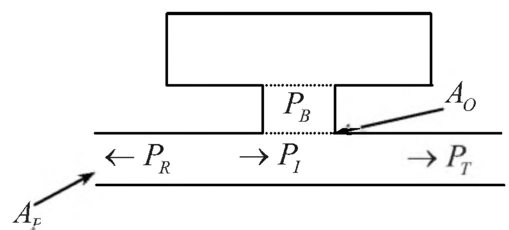

Figure 3 – Transmission loss across the resonator

At resonance frequency, the resonator short-circuits the transmission of acoustic energy so that $\left|\frac{P_R}{P_I}\right|$ approaches unity and $\left|\frac{P_T}{P_I}\right|$ approaches zero.

The resonator effectively simulates a pressure release termination and results in transmission loss which is given by,

$$T_L = -20\log_{10}\frac{P_T}{P_I} = 20\log\left(1+\frac{\rho C A_0^2}{2A_P R_a}\right).$$

In the above equation, the resistance is given by,

$$R_a = \frac{\rho C A_0^{5/2}}{2\pi V_C} \text{ at } f = f_n.$$

The transmission loss at frequencies for $f^2 << f_n^2$ becomes

$$T_L = 10\log_{10}\left[1+\left(\frac{\pi V_C f}{CA_P}\right)^2\right],$$

which tends to zero as $f \to 0$.

At frequencies $f^2 >> f_n^2$, the equation becomes

$$T_L = 10\log\left[1+\left(\frac{CA_0}{4\pi A_P L_{eff} f}\right)^2\right];$$

which tends to zero as $\frac{f}{f_n} \to \infty$.

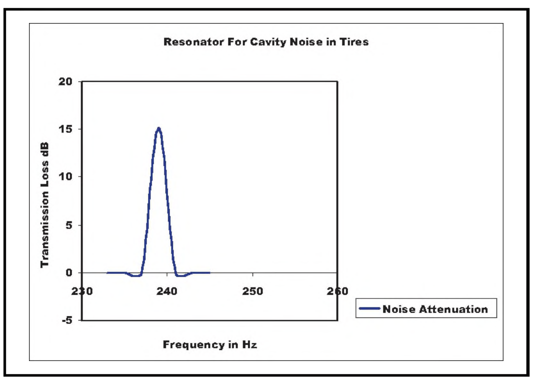

Figure 4. Predicted transmission loss of the propagating sound waves inside the tire cavity

The resonator model predicts a transmission loss that should attenuate the cavity noise up to 14 dB as shown in Figure 4. According to predictions, it is believed that the magnitude of transmission loss reduces to zero as the frequency of the tire cavity resonance moves further away from the frequency of the resonator.

3. EXPERIMENTAL TIRE

An experimental tire was mounted onto a minivan left front wheel and tested on a smooth surface in the laboratory. A tire with customer compliant for cavity resonance was selected for the experimental study. Based on the prediction and test results, the cavity resonance was determined to be around 230 Hz. As mentioned earlier, the Doppler effect and speed variation can cause the cavity resonance to be spread over a small range of frequencies. However, this investigation is limited to only 230 Hz, as the resonance is highly noticeable at the normal highway speed of 55 to 60 mph. In order to address the range of frequencies, a sound-damping unit of multiple resonators with varying dimensions, should be investigated.

Table 1 shows the predicted values of resonance frequency when the speed variation was included in the estimation.

Input Tire size: W = 215 mm; Aspect Ratio = 70%; Rim Diameter = 15 in.				
Input Contact Length = 6.75 in.				
Tire Size: 215/70 x 15; Circumference = 61.36 in.				
Speed, mph	Freq1, Hz	Freq2, Hz	Freq3, Hz	Freq4, Hz
0	215.5	215.5	225.2	225.2
5	214.4	216.5	224.1	226.2
10	213.4	217.5	223.0	227.3
15	212.4	218.6	221.9	228.4
20	211.3	219.6	220.8	229.5
25	210.3	220.6	219.8	230.5
30	209.3	221.7	218.7	231.6
35	208.2	222.7	217.6	232.7
40	207.2	223.7	216.5	233.8
45	206.2	224.7	215.5	234.9
50	205.1	225.8	214.4	235.9
55	204.1	226.8	213.3	237.0
60	203.1	227.8	212.2	238.1
65	202.0	228.9	211.1	239.2
70	201.0	229.9	210.1	240.3
75	200.0	230.9	209.0	241.3

Table 1 – Cavity resonance between 0 to 75 mph.

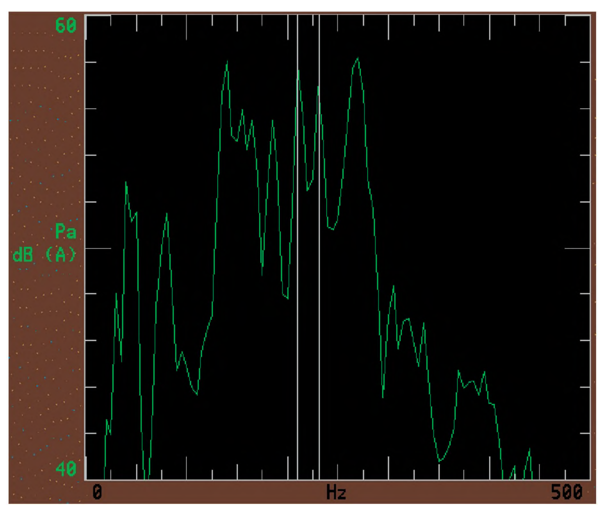

Figure 5 – Peak hold noise spectrum

A coast down test was conducted in the speed range of 70 to 20 mph on a smooth surface. The test result shown in Figure 5, peak hold between 209.9 Hz and 229.8 Hz, confirms the range of the predicted cavity resonance in Table 1.

The dimensions of the resonator were calculated based on the mathematical model shown in Figure 1 to attenuate the tire cavity resonance of 230 Hz between 55 and 60 mph. Figure 6 and Figure 7 show the experimental model that was built and mounted to the wheel.

Figure 6 – Side view of the mounted resonator.

Figure 7. Resonators are wrapped around the dip of the base

4. EXPERIMENTAL VERIFICATION

A 15-inch tire was fitted onto a minivan front wheel and tested in the Goodyear's Acoustic Study Laboratory on a smooth surface. Noise was measured at the interior and exterior of the vehicle along with the acceleration levels at the spindle vertical, F/A and lateral directions.

Measurements were repeated for the same test conditions with a unit of multiple resonators wrapped around the base of the wheel as shown in Figure 7. The parameters of the resonators are identical and tuned to 230 Hz in this investigation.

Figure 8 and Figure 9 show the interior noise measured for a regular wheel and a resonator attached wheel. The effect of the resonator was noticed between 40 to 70 mph, however, the effect was peak at 55 mph. A drop in noise level up to 8 dB is observed at the cavity resonance.

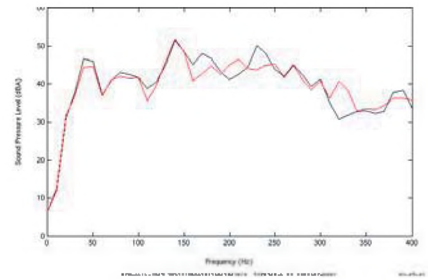

Figure 8. Interior noise attenuation at 60 mph
Dark – without resonator; Light – with resonator.

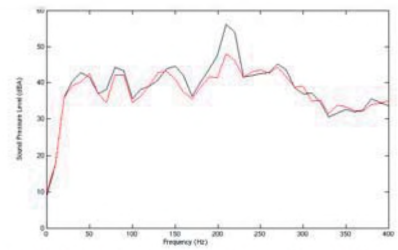

Figure 9. Interior noise attenuation at 55 mph
Dark – without resonator; Light – with resonator.

Similarly Figure 10 through Figure 12 are for the spindle vertical, F/A, and lateral vibration. The spindle vertical, F/A, and lateral vibration have been reduced up to 10 dB in all cases at the cavity resonance frequency.

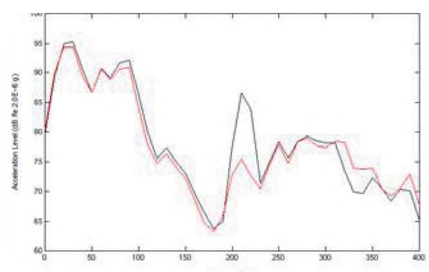

Figure 10. Reduction in Spindle vertical vibration at 55 mph
Dark – without resonator; Light – with resonator.

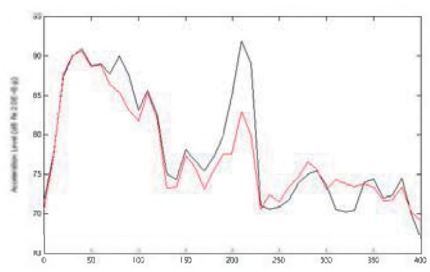

Figure 11. Reduction in Spindle F/A vibration at 55 mph
Dark – without resonator; Light – with resonator.

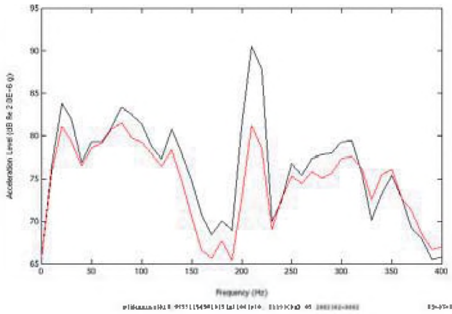

Figure 12. Reduction in Spindle lateral vibration at 55 mph Dark – without resonator; Light – with resonator.

5. CONCLUSIONS/RECOMMENDATIONS

This study shows that the concept resonator works on reducing the cavity noise as expected. It is expected that incorporating resonators of different dimensions into the multiple resonators unit, the cavity noise at a broad frequency range can be controlled. It is recommended that further investigation into multiple resonator units with varying resonator dimensions be conducted. These resonator units may be designed and manufactured in different sizes using hard rubber or plastic to suit specific tire sizes.

6. ACKNOWLEDGMENTS

Author thanks Basil Elkurd of BP Oil for building the experimental sample. Ray Jones and Robert Peffer for conducting the noise test in the Goodyear Acoustic Laboratory. Tim Lovell for allowing the test to be conducted under the Chrysler minivan program.

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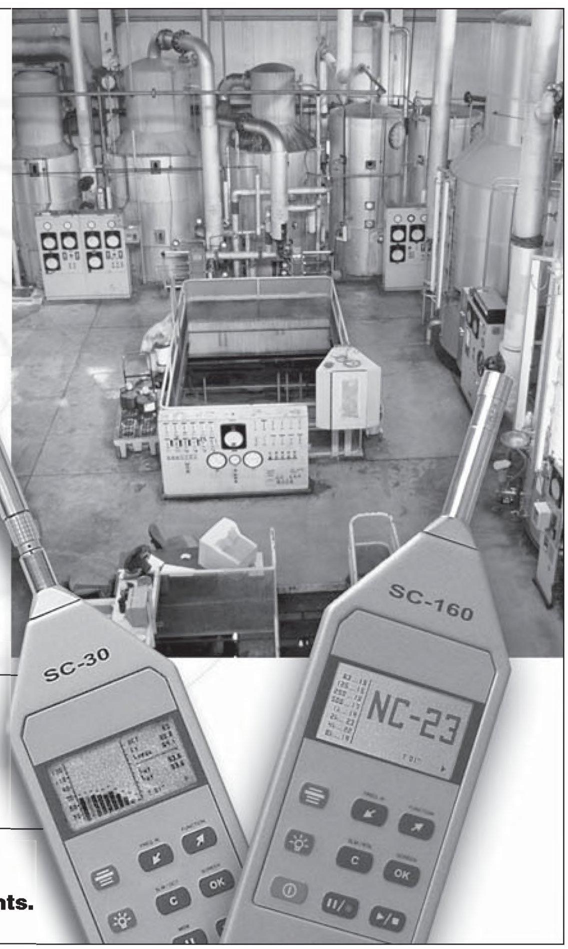

Adapative Delay System (ADS) For Sound Reinforcement

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ABSTRACT

At concerts and presentations, the sound system must be carefully calibrated to ensure the entire audience can hear the presenters clearly. For both indoor and outdoor venues, this is done by positioning speakers throughout the audience to reinforce the sound produced on stage. This technique introduces an added complexity, whereby the electrical signal to the speakers in the crowd travels much faster than the sound wave coming from the stage.

The Adaptive Delay System (ADS) for Sound Reinforcement is a new method for synchronizing the sound throughout the audience. Unlike existing methods, it does not require complex calculations when initially configuring the sound system. Furthermore, it is also capable of accounting for time-variant conditions such as wind, which are neglected in the current methods of speaker synchronization. Maximum length sequences, a special type of pseudo-random noise, are injected into a speaker for several seconds. A specially placed microphone picks up this sound which is then cross correlated with the original noise to determine the propagation delay. As this sound is barely audible it can be used during a concert to adaptively correct for changing conditions.

SOMMAIRE

Pendant concerts et présentations, la système auditif doit être précisément calibré pour que tous entendent la présentation. Des haut-parleurs, placés stratégiquement dans l'audience, renforcent le son produit sur la scène. Cette méthode est efficace dans une salle bien qu'en plain air. Cette technique introduit une nouvelle complexité, vue que les signaux électriques destines aux haut-parleurs se propagent plus vite que le son provenant de la scène.

La Système de Délai Adaptif (SDA) pour renforcir le son constitue une nouvelle méthode pour synchroniser le son dans l'audience. Contrairement aux méthodes existantes, celui-ci ne nécessite pas des calculassions complexes lors de la configuration initiale du system du son. En plus, la SDA est capable de prendre en compte les variables comme le vent, qui changent avec le temps. Ces variables sont omises dans les méthodes de synchronisation des haut-parleurs actuelles.

1 BACKGROUND

1.1 Statement of the Problem

There are many situations where multiple sets of speakers (called delay towers) are dispersed amongst a crowd or a room to reinforce music or speech for the entire audience. In these situations, the electrical signal traveling to the delay towers moves much faster than the sound wave coming from the stage speakers, thus the electrical signal must be delayed so that the two sound waves are synchronized. In some cases, such as convocations in gyms or large conferences, the delay is neglected, resulting in poor intelligibility. For large outdoor concert venues, the existing methodology for determining the delay for each speaker is cumbersome. It requires estimates of the weather for concert days and is not adaptable to changing conditions. Thus there is a need for an automated, adaptive system for calculating sound delay.

2.2 Requirement for Adaptive Delay

Large outdoor concerts are often held over two or three days in the summer, when weather changes can be most extreme. Temperature, relative humidity (RH), and changing wind speeds can greatly affect the speed of sound [1]. With a change in the speed of sound comes a corresponding change in the time it takes for sound to travel between delay towers. This means that if the delay is calculated at the beginning of a concert, by the end, the weather conditions might have changed sufficiently to create a noticeable error in the configured delay. The speed of sound can be shown to depend on temperature in the form of the following equation [1]:

$$c = 331.45\ (1+t/273)^{1/2} \tag{1}$$

where c is the speed of sound in m/s, and t is the temperature in degrees Celsius. Relative humidity has a smaller but still

		Temp.	RH	Wind speed	Speed of sound	Delay (ms) for distance:		
		(^{o}C)	(%)	(km/hr)	(m/s)	40 m	60 m	100 m
Typical change	Day	22	80	0	344.4	116.2	174.2	290.4
	Night	10	40	25	330.8	120.9	181.4	302.3
					Error:	**4.7**	**7.2**	**11.9**
Extreme change	Day	40	100	0	358.9	111.5	167.2	278.6
	Night	15	80	55	325.9	122.7	184.1	306.9
					Error:	**11.2**	**16.9**	**28.3**

Table 1. Delay Errors introduced y changing weather conditions.

noticeable effect on the speed of sound.

The delay errors introduced by a typical and extreme change in weather are shown in Table 1. The weather data is extracted from the Environment Canada website [2]. The delay errors are calculated for minimum, typical, and large distances between delay towers, corresponding to 40 m, 60 m, and 100 m. From the table it can be seen that typical changes in weather are sufficient to cause noticeable delay error.

2.3 Perception of Delay

Sound degradation can begin when the primary sound source and the secondary sound source are as little as one millisecond apart [3]. Below this limit, the delay results in stereophonic sound; above this limit, changes to the sound become noticeable, as the tone colour of the sound changes and the 'centre of gravity' (where the listener perceives the sound source to be) begins to shift towards the secondary sound source. Once the delay reaches a certain threshold, known as the echo threshold, what was previously perceived as a single sound event is separated into two distinct events. There is no clear rule for determining the delay at which an echo threshold is reached. In the worst possible case, the echo threshold is reached at two milliseconds; however, in different circumstances the threshold may not be reached until the delay is 30 milliseconds. The threshold depends on multiple factors, such as the angle of the listener to the sound source, the type of sound, and the level of the sound. In the case of sound level, the louder the sound, the shorter the delay before the echo threshold is reached.

A delay that may cause minimal degradation in some circumstances may exceed the echo threshold in other circumstances. Even in cases where the echo threshold is not breached, and two distinct sounds are not recognizable, sound degradation may still be a factor. Therefore, because no standard for delay tolerance can be set, and changing conditions can produce delays varying from 5 ms to 30 ms, it is desirable to minimize the delay as much as possible in all circumstances.

3 SOLUTION

3.1 Solution Framework

It was decided that an open loop analysis would be used to determine the delay time between speakers. This was decided upon because of the ease with which delay can be calculated by using a microphone (behind the rear speaker) to record the sound from the front speaker. Figure 1 shows the setup for this acquisition. By having the same computer processor control the output from the stage speaker *and* record the input sound from the microphone, various mathematical methods (described in section 2.2) can be used to calculate the delay between the two speakers. This setup is considered an open-loop analysis because there is no feedback from the sound downstream of the second speaker to the system used to calculate and adjust the delay.

For the measurement of sound decay, it has been established

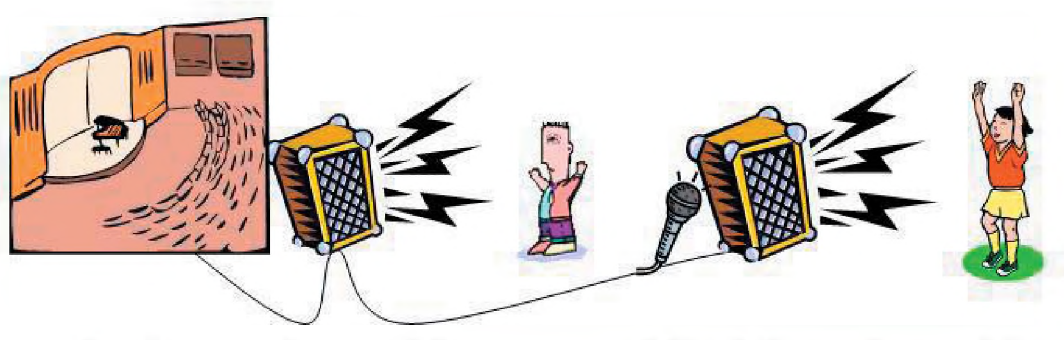
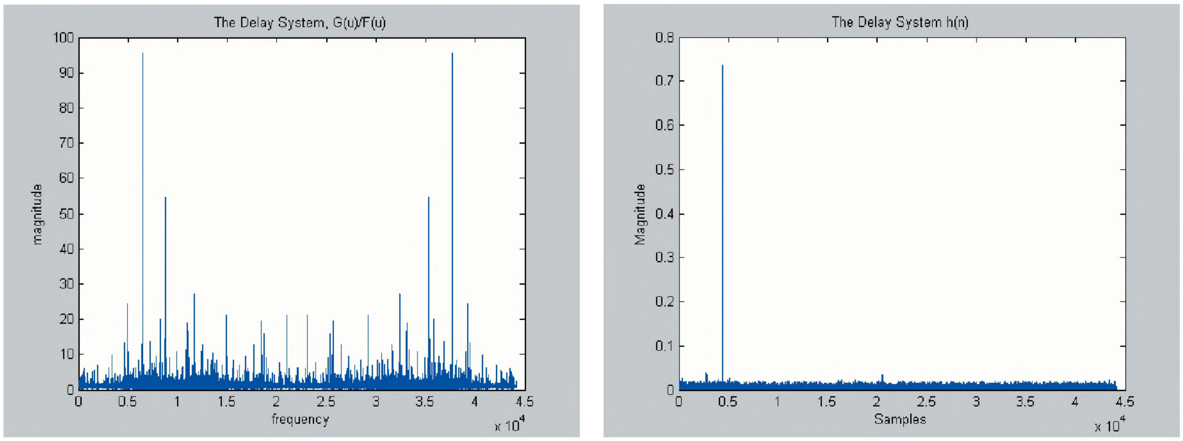


Figure 1. Delay tower set up



(a) (b)

Figure 2. The delay system (a) in the frequency domain, H(u), and (b) in the time domain, h(t)

that a room or outdoor environment can be modelled as a linear time-invariant (LTI) system with respect to its acoustics [4]. The general framework for an LTI system can be expressed as [5]:

$$g(t) = f(t) * h(t), \quad (2)$$

where * is the convolution operator, f(t) is the input (in this case the sound at the stage speaker), g(t) is the output (sound behind the rear speaker), and h(t) is the impulse response of the system, which here is a delay process with an impulse at some unknown delay time. The location of the impulse in h(t) is required to accurately determine and implement the required delay for the rear speaker.

The need for an adaptive delay system stems from the fact that the properties of an outdoor concert venue are time-varying. It is, nonetheless, reasonable to consider such a venue an LTI system over the short time (on the order of seconds) required to calculate the delay. Over a time period of several seconds, the factors affecting the speed of sound do not vary wildly, and thus the venue can be considered LTI for the duration of a single test to determine the delay time.

3.2 Alternate Solutions

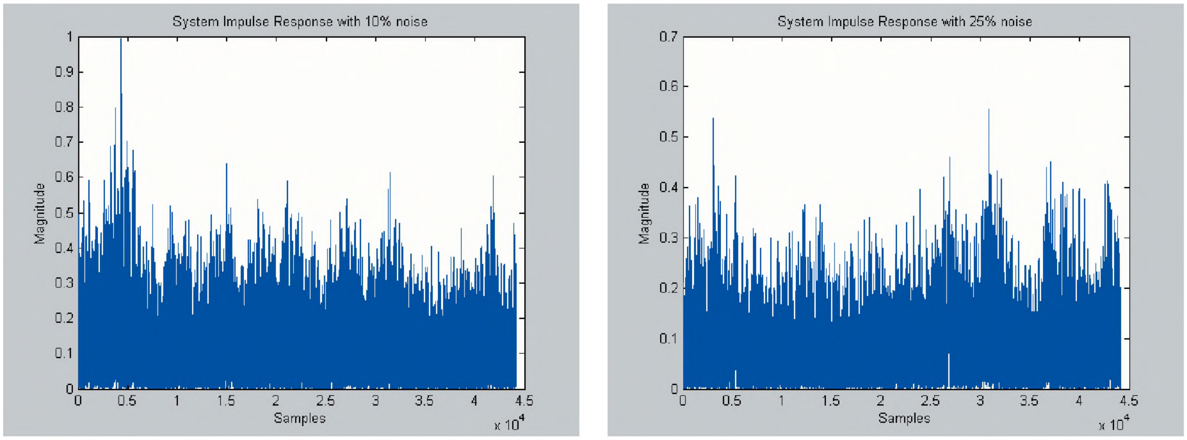
Many possible methods exist to determine the delay. The first two possible solutions examined used the music that would be normally played through speakers at a concert as the signal for determining the required delay. The first method that was investigated uses the inverse system to take advantage of the LTI nature of the sound propagation. The recovery of the delay system requires solving the so-called deconvolution problem in order to determine the delay time encompassed within h(t). This can be most easily solved in the frequency domain where the system equation becomes the following:

$$G(u) = F(u)H(u),$$
or solving for H(u), (3)
$$H(u) = G(u) / F(u).$$

Therefore, taking the Fourier transform of the sample and record systems, dividing, and returning to the time domain should yield an impulse at the time of the delay. Figure 2 shows the delay system H(u) in the frequency domain and the delay system h(t) in the time domain when the above methodology is implemented in Matlab with a 100 ms artificial delay created in software. In Figure 2b, an impulse is present at sample 4410, which at a sampling rate of 44.1 kHz corresponds to a 100 ms delay. This impulse represents the delay in the system and can in theory be used to determine how long to delay the music at the delay tower to ensure that all the music waves are in phase.

This system is straightforward to implement, using well-established signal processing theory. It would cause no concert interference as this system uses only the concert sound and existing speakers to measure the delay. There is, however, a major weakness to this solution. In the presence of noise (such as audience members cheering and clapping, as would be the case at any concert), the signal to noise ratio of the spike from inverse system begins to decrease. This condition was simulated by adding acoustic noise on top of a music file and performing the subsequent inverse system calculation. Figure 3 shows the results of calculating h(t) when adding acoustic noise at 10% and 25% of the total speaker output (with the other 90% and 75% being the music, respectively). With 10% acoustic noise, the impulse is still present, but the 25% case is the marginal situation where the noise floor of h(t) has equal power to the impulse, meaning the delay can no longer be confidently determined. As a result, the inverse system methodology of measuring the delay has poor robustness for external acoustic noise and is not practical for implementation.

A second approach considered using the cross-correlation of the original sound with the delayed sound. Cross correlation is a method for mathematically comparing two signals. At the point where the two signals are perfectly in phase, all the peaks and valleys of the waves will be aligned and the cross correlation yields a detectible spike. When the waves are not in phase, most of the peaks and valleys will cancel one another. The location of the spike from cross correlating the



(a) (b)

Figure 3. (a) Impulse corresponding to 10% noise and (b) 25% noise

speaker and microphone signals will thus provide an impulse at the delay time between the two signals. This method is simpler than the inverse system method to implement because it does not involve Fourier Transforms, and like the inverse system, it does not interfere with the concert. However, like the inverse system, cross correlation of the music signals fails in the presence of external acoustic noise.

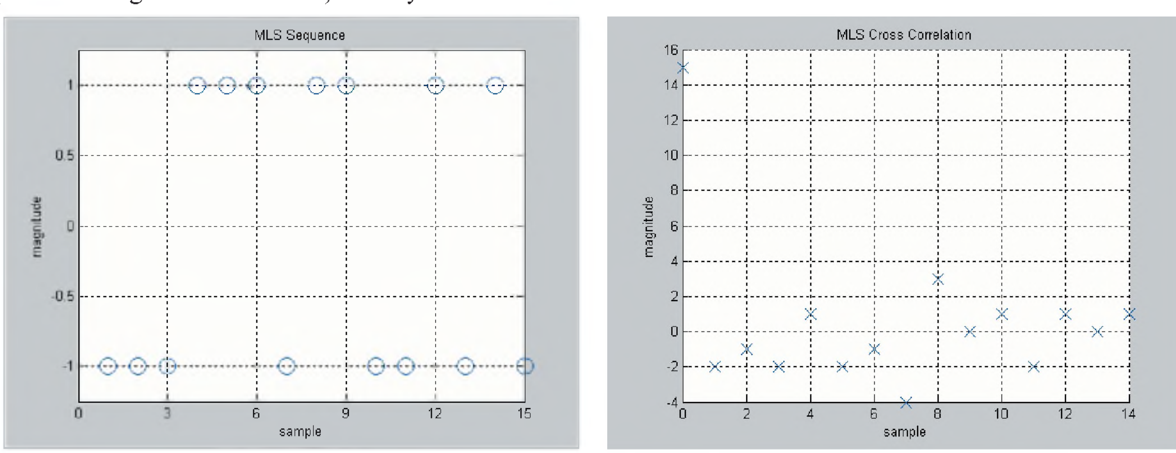
3.3 Maximum length sequences (MLS)

To deal with the problem of acoustic noise, a method to recover the impulse response of a system using maximum length sequences (MLS) [6] and a cross correlation operation was examined. MLS is pseudo-random binary white noise, specifically designed to have no internal periodicity. An MLS sequence can be of any length L, such that

$$L = 2^n - 1, \text{ where n is a positive integer} \qquad (4)$$

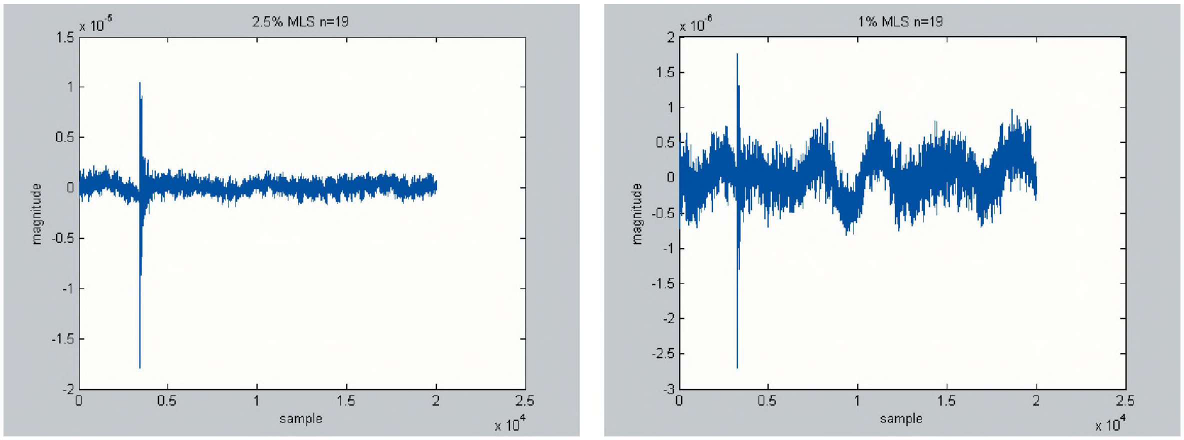
and its elements are either +1 or –1. When an MLS sequence is cross correlated with itself the result for all elements except at element zero (corresponding to zero phase between the two sequences being cross correlated) is very small. This occurs because the cross correlation yields a series of plus-ones and minus-ones, and when these are summed the plus-ones approximately cancel with the minus-ones. In the case where the sequences are in phase, the cross correlation yields a series completely of plus-ones and therefore the sum adds to L, the length of the sequence. Figure 4a shows a sample MLS sequence of length 15. Figure 4b shows the result of that sequence cross correlated with itself.

The MLS illustrated in Figure 4a is 15 elements long and thus the cross correlation results in a spike of value 15; the value of the next largest element is three. This sequence, however, is atypically short, for illustrative purposes. If a more typical MLS of length $2^{18}–1$ (six seconds at a 44.1 kHz sampling rate) is generated, the spike has a value of $262x10^3$ and the next largest element has value 600. The delay of an acoustic propagation system can therefore be characterized by playing MLS through the stage speaker, recording it at the delay tower, cross correlating both the original and recorded signals, and locating the spike. The pseudo-random nature of MLS makes it sound like static, similar to noise heard when tuning a radio. As a result of this property, low-level MLS can be injected into a sound system while a concert is



(a) (b)

Figure 4. (a) MLS of length 15 and (b) MLS cross correlated with itself



(a) (b)

Figure 5. (a) Impulse generated by cross correlating an MLS sequence lasting 12 seconds at an intensity of (a) 2.5% and (b) 1.0%

in progress without an overly adverse affect on sound quality. Because the spike from cross correlating MLS is significantly larger than the background noise, MLS can be injected at a fraction of the intensity of the music [5]; for example, MLS noise can be controlled to be 10% of the total sound output of the speaker with the other 90% being the concert music.

Implementing MLS only differs from implementing the cross correlation solution in two ways. Firstly, MLS must be mixed in with the music for the period during which the system is being characterized, and secondly, the recording taken at the delay tower is cross correlated with the original MLS signal rather than the music. The use of MLS to initially characterize a system and establish the delay time has no negative impact on the concert because the calibration can be done before the audience has arrived. In order to *adaptively* correct delay to account for changing conditions, MLS must be played during the concert, which will have some impact on sound quality. In low-noise applications, barely audible MLS can be used to calculate delay; in noisier environments the MLS power must be boosted. Therefore, the interference caused by MLS is proportional to the background noise; however, the noisier the environment, the less sensitive the audience will be to the added noise generated by MLS. Furthermore, the interference caused by MLS can be optimized through a balance of intensity and duration; the longer the sequence used, the lower the required intensity to generate a measurable spike. Therefore, as crowd noise increases, the duration of the MLS can be increased instead of its intensity. Conversely, a shorter MLS at a higher intensity can also be used measure the delay.

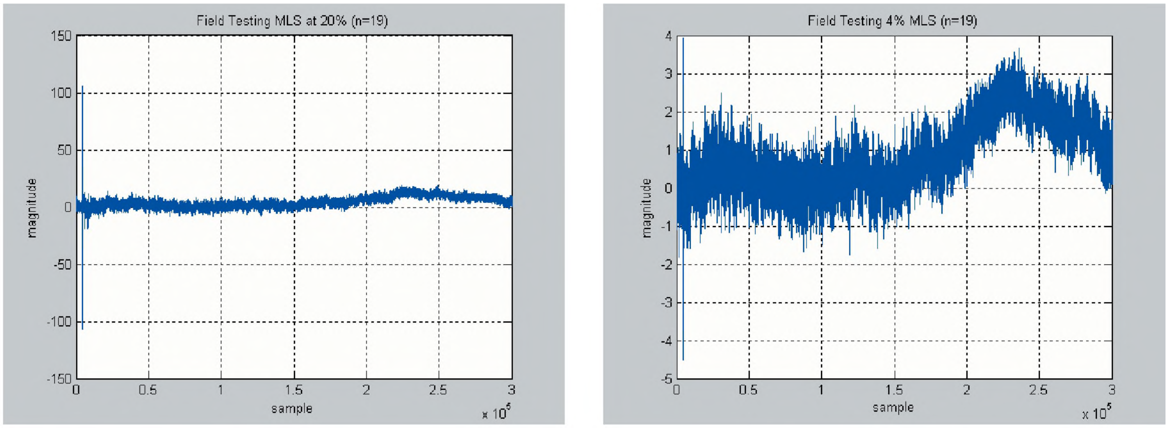
The most significant benefit to using MLS is its ability to reject noise. Because the cross correlation is done against the original maximum length sequence and not the music, noise is treated differently here than in the other solution concepts. Here, MLS is the signal of interest and both the music and crowd noise is regarded as noise in the cross correlation. Figure 5 shows the impulse generated using an MLS sequence lasting twelve seconds ($L = 2^{19}-1$). This sequence length was chose because it is practical for use. In Figure 5a, the MLS power is 2.5% of the speaker output and in Figure 5b it is 1.0%, yielding signal-to-noise ratios of 39 and 99 respectively. The spikes in both cases are clearly discernable.

4 IMPLEMENTATION

The Adaptive Delay System (ADS) is comprised of Matlab software written to calculate the delay of a system using MLS. This software is run on a personal computer that controls the output of both the stage and delay speakers and receives input from the microphone. An MLS sequence is generated using software obtained from the Matlab website [7]. This MLS sequence is then added on top of the output music of the front speaker at a fraction of total speaker output that is controllable. The delayed signal at the position of the rear speaker is recorded with a microphone, and this recorded signal is cross correlated with the original MLS sequence, yielding a spike at the delay time between the two speakers. The rear speaker is then delayed by the time corresponding to this spike in order to synchronize the sound from the two speakers.

One problem encountered with the software was computer-specific calibration. The delay calculation depends on playing MLS and immediately starting to record the sound being captured by the microphone. However in Matlab it takes a certain amount of processing time after calling *wavplay* before the computer can process the record command *wavread*. This causes the measured delay to be offset by the amount of processing time required by the specific computer being used. Therefore, calibration software was written to determine the computer-specific processing delay error. Note that this problem is relevant only when using Matlab on a personal computer, and that the idealized final product would use a microchip that would not have this calibration issue.

In theory, the MLS methodology is sensitive to a single sample, which at 44.1 kHz is approximately 0.02 ms. The calibration calculations, however, typically have a standard deviation of 1.0 ms so in practice this limits the sensitivity



(a) (b)

Figure 6. Field testing result using an MLS sequence of 12 seconds at (a) 20% and (b) 4% of total speaker output

of the calculation to one millisecond. To test this limitation, a series of five measurements was repeated using the same parameters, including a 100 ms delay. The resulting five calculated delays had an average of 100.1 ms with a standard deviation of 0.1 ms which confirmed that the sensitivity is within one millisecond.

5 TESTING

Two large speakers, a microphone, and all necessary equipment to connect this audio setup to a personal computer in order to test the ADS was installed in the main gymnasium at the University of Waterloo to perform field measurements and validate the ADS prototype. The two speakers were set up 100 metres apart, with a microphone placed behind the second speaker. The speakers and microphone were hooked up to a laptop computer running the ADS software as described in section 3.

Figure 6a shows the result of injecting MLS for 12 seconds at a level of 20% of the total speaker output. The spike in this case is prominent over the background noise. At this level, however, the MLS was deemed to be intrusive. Tests were repeated until the minimum intensity of MLS that still produced a discernable spike was found. This occurred when the MLS was at a level of 4% and is shown in Figure 6b. In order to evaluate the potential to use longer sequences at a lower intensity, the test was repeated with an MLS lasting 48 seconds, which is the longest sequence that can be cross correlated using Matlab and one gigabyte of memory. The lowest intensity for a sequence of this duration was found to be at 2% of total speaker output (results for this case shown in Figure 7). This confirmed the hypothesis that longer sequences can be used as an alternative to playing the sequences at a higher volume. The improvement in audio

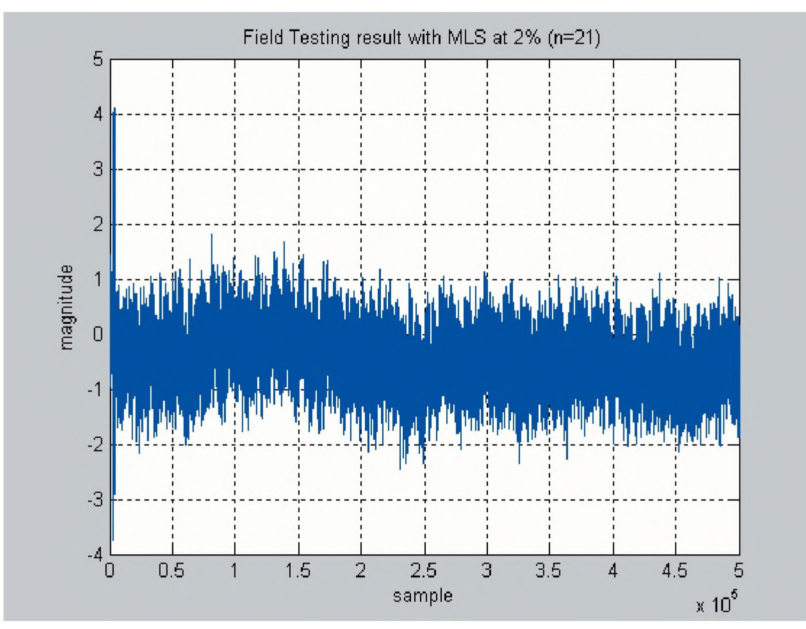


Figure 7. Field testing result with a longer MLS sequence (48 seconds) at 2% total speaker output

quality after implementing the ADS system was significant.

6 CONCLUSIONS

Issues with audio delay at large venues can cause poor sound quality and low speech intelligibility. The existing tools on the market to deal with delay are not adaptive to changing conditions, and more significantly, are time-consuming to configure and set up. The Adaptive Delay System is a new adaptive and automated method for synchronizing the sound between speakers at these large venues, in order to compensate for the electrical impulses that travel faster to the delay towers than the sound that travels from the stage.

In order to deal with the noise present at concerts, the ADS uses low level MLS added on top of the audio coming from the stage speaker in order to accurately determine the required delay time to the delay towers. This prototype was validated through field testing done in the University of Waterloo's main gymnasium. Positive results from prototype testing clearly demonstrated the success of the Adaptive Delay System for Sound Reinforcement.

The ADS was entered into the Ontario Engineering Competition and Canadian Engineering Competition in the Corporate Design category, where it placed first and second respectively.

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Occupational Noise Control In Australia – Its Policy And Management

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ABSTRACT

Noise has long been recognized as one of the priority occupational hazards in Australia. Noise-induced hearing loss (NIHL) is probably the most prevalent occupational disease in Australian industries and it is the major cause of deafness in Australia. All six Australian States, the two Territories and the Commonwealth Government have their own legislation to manage occupational noise. Whilst these are not all the same they are similar and nearly all States and Territories have now adopted the Australian National Occupational Noise Standard into their legislation. The government structures and agencies that administer occupational noise legislation are also different in the different States and Territories. In this paper occupational noise legislation in the Commonwealth jurisdiction and in all Australian States and Territories will be summarized. Brief comparisons with legislation in American and European countries will be made. The government structure and relevant legislation and policies for occupational noise management in Western Australia will be explained. The role of WorkSafe Western Australia in enforcing the legislation and assisting workplaces to comply with it will be discussed.

SOMMAIRE

Le bruit est depuis longtemps reconnu comme étant l'un des principaux dangers dans le milieu professionnel en Australie. La perte auditive due aux nuissances sonores est, probablement, la maladie professionnelle la plus répandue dans les industries australiennes et est considérée comme étant la cause principale de surdité en Australie. Les six états composant l'Australie, les deux territoires et le gouvernement du Commonwealth ont chacun leur propre législation pour contrôler le bruit dans le milieu professionnel. Même si ces législations ne sont pas toutes identiques, elles présentent des similitudes et presque tous les états et territoires ont jusqu'à présent adopté dans leurs législations les normes nationales australiennes concernant les nuisances sonores dans le milieu professionnel. Par ailleurs, chaque état et territoire est doté de structures et d'agences gouvernementales propres pour lutter contre le bruit au travail. Cet article résumera les législations appliquées en matière de bruits dans la juridiction du Commonwealth ainsi que dans tous les états et territoires australiens. De brèves comparaisons avec les législations américaines et européennes seront faites. Des explications seront apportées concernant la structure gouvernementale, la législation et les politiques appropriées mises en place pour la gestion du bruit dans le milieu professionnel en Australie Occidentale. Le rôle que joue l'organisme "WorkSafe Western Australia" dans le renforcement de la législation et dans l'aide apportée sur les lieux de travail, pour faire respecter les lois, sera examiné en détail.

1. INTRODUCTION

Noise at workplaces is one of the major occupational hazards in Australian industries and a major cause of deafness in Australia. Noise-induced hearing loss (NIHL) is one of the most common occupational diseases and costs Australian industry around $33 million annually in compensation costs. The Australian National Occupational Health and Safety Commission (NOHSC) has declared noise as one of the seven national priority standards[1], which together are estimated to cover eighty percent of work related injury, death and disease within Australia.

Occupational noise had been managed in all six Australian States, the two Territories and the Commonwealth Government under their own legislation. Since declaration of the Australian National Standard for Occupational Noise in 1993, which introduced the occupational noise exposure level of 85 dB(A), it took several years for most of the Australian jurisdictions to adopt the National Standard into their own legislation. This adoption process has not been completed yet, as South Australia is still in the final stage of its adoption. The adoption of the amendment made to National Standard for Occupational Noise in 2000 was much quicker. This changed the peak sound level from 140 dB(lin) to 140 dB(C). Most of the jurisdictions have already made the change in their legislation.

With the declaration of the new European Union Directive on the Minimum Health and Safety Requirements Regarding Exposure of Workers to the Risks Arising from Physical Agents (Noise) on 15 February 2003 (EU Directive 2003/10/EC 2003), which requires action to be taken at significantly lower noise levels, NOHSC has recommended a full review of the Australian National Standard for Occupational Noise commencing in mid-2004[1]. It is expected that some major changes are going to be made through the review, which will help significantly improve the acoustical environment of Australian workplaces.

2. REGULATIONS FOR NOISE CONTROL IN AUSTRALIA

As a commonwealth country, Australia consists of six States – New South Wales (NSW), Victoria (VIC), Queensland (QLD), Western Australia (WA), South Australia (SA) and Tasmania (TAS), and two Territories – Northern Territory (NT) and Australian Capital Territory (ACT). Combined with the Commonwealth Government, there are nine jurisdictions in Australia and each of them is responsible for its own occupational health and safety acts and regulations, making occupational noise related regulations vary across the nation.

2.1 Australian National Standard for Occupational Noise

The National Standard for Occupational Noise, which referenced Australian Standard AS 1269, was declared by NOHSC in 1993. This gave the exposure standard in the occupational environment as an eight-hour equivalent continuous A-weighted sound pressure level, $L_{Aeq,8h}$, of 85 dB(A). The peak noise level standard started as a linear peak sound pressure level, L_{peak} of 140 dB(lin). In 2000, NOHSC amended the National Standard for Occupational Noise and the relevant Code of Practice to update the measurement of peak noise level to a C-weighted peak sound pressure level, $L_{C,peak}$, after AS/NZS 1269 made this revision in 1998.

The Australian NOHSC National Standard is generally consistent with most international practices, such as the United States NIOSH (National Institute for Occupational Safety and Health) recommended standard, the New Zealand standard and most Canadian standards (like Australia, exposure level standards set in Canada vary across its 14 jurisdictions). The Australian NOHSC National Standard is generally consistent with the present European legislation but differs from the new EU Directive 2003/10/EC 2003, as follows[1]:

the EU Directive requires the provision of worker information and training, noise assessment, personal hearing protectors and audiometric health surveillance at an exposure level of 80 dB(A)$L_{Ex,8h}$;

the EU Directive identifies an 87 dB(A) continuous exposure limit and 137 dB(C) peak exposure limit.

the EU Directive requires that noise risk assessments take into account exposure to ototoxic chemicals.

NOHSC is planning a full review of the National Standard and National Code of Practice from mid-2004[1]. The issues listed below are recommended for consideration as part of the review:

1. whether to adopt an 80 dB(A) action point and a peak noise level $L_{C,peak}$ of 135 dB(C);
2. whether to include the risks associated with the non-auditory effects of noise;
3. whether up-stream responsibilities should be incorporate in the National Standard or retained in the National Code of Practice;
4. whether to include information on the effects of noise in the range 55-85 dB(A);
5. whether to include reference to the effects of ototoxins in the Code of Practice;
6. whether to include information on acoustic shock in the Code of Practice.

2.2 Occupational Noise Regulations across Australia

The National Standard in itself does not have any legislative force. In Australia's nine jurisdictions, each has its own legislation for occupational health and safety. National Standards and Codes of Practice are declared as guidance and encouragement for a uniform approach across the Nation. However there is no compulsion on jurisdictions to take up the National Standards. Some jurisdictions have automatic update to the latest version of any Australian Standard referenced in their legislation, while others require an amendment. More and more States and Territories have now adopted the National Standard for Occupational Noise into their legislation. Ten years after the declaration of the National Standard, the process of adoption is still going on. The status of adoption of the National Standard for Occupational Noise cross Australian jurisdictions is shown in Table 1.

Table 2 summarises the Acts and Regulations across Australian jurisdictions for administering occupational noise[2]. It can be seen that in some jurisdictions, the Occupational Safety and Health Regulations also cover the mining and petroleum sectors, and in other jurisdictions, there are individual regulations for mining and petroleum industries.

Key Element	Consistency by Jurisdiction								
	NSW	VIC	QLD	WA	SA	TAS	NT	CWTH	ACT
1 Exposure is an eight-hour equivalent period.	Y	Y	Y	Y	Y	Y	Y	Y	Y[4]
2 Continuous exposure is an A-weighted level of 85dB.	Y	Y	Y	Y	N[3]	Y	Y	Y	Y[4]
3 Peak noise exposure is a C-weighted level of 140dB.	Y	Y	Y	Y	M[2]	M[2]	M[2]	Y	Y[4]
4 Exposure is measured at the employee's ear position.	Y	Y	Y	Y	Y	Y	Y	Y	Y[4]
5 Measurement does not take account of protection from personal hearing protectors.	Y	Y	Y	Y	Y	Y	Y	Y	Y[4]

Table 1 Status of adoption of the National Standard for Occupational Noise (as at 30 January 2004)

NOTES:

1. Adoption is assessed against key elements of the National Standard (which are defined as aspects of the standard for which national consistency is considered important). The assessment is as follows:
2. the following coding has been used to record each jurisdiction's legal requirements against each key element:

   Y the key element has been fully adopted in the jurisdictional framework;

   M most of the key element has been adopted in the jurisdictional framework;

   N the key element has not been adopted in the jurisdictional framework; and
3. the assessment is not restricted to OHS regulations. It is determined by whether a jurisdiction has a legal requirement equivalent to the key element irrespective of the body of legislation or legal practice that provides the basis for the requirement.
4. Peak noise measurement was revised from linear to C-weighting in the second edition of the National Standard, which was released in 2000. Some jurisdictions have not yet adopted this change, although all intend to do so.
5. South Australian (SA) regulation, which still has an exposure standard, $L_{Aeq,8h}$, of 90 dB(A) for existing workplaces, is currently being revised to adopt the national exposure standard of 85dB(A). The new regulation is expected to be declared in 2004.
6. The National Standard and Code of Practice are adopted as codes of practice under the ACT *Occupational Health and Safety Act 1989.*

3. NOISE-INDUCED HEARING LOSS IN AUSTRALIA

One of the most important and also obvious consequences of noise exposure is noise-induced hearing loss (NIHL). Occupational induced deafness represents a very significant social and economic burden for Australia, and it is still the only indicator for the impact of occupational noise.

3.1 NIHL Compensation Claims and Costs

Workers compensation data from 2000-01 identify that 3.9% of all claims were for sound and pressure related injury, and deafness accounted for 22.1% of all work-related disease claims. In total there were 5565 work-related deafness compensation claims. The average cost of each of those claims is about $6000, which sums up to over $33 million a year[3]. It has been estimated that the actual cost, direct and indirect, of workers' compensation claims is at least 10 times the average direct cost[4]. Based on the national average this would be a cost of $330 million per year to the country.

When compared with data of the previous years, it can be seen that the number of NIHL claims decreased significantly from 1995 (Fig. 1[1]). The total number of NIHL claims in 2000-2001 was only 43% of that in 1995-1996. The total cost of NIHL compensation dropped even more, from about $85 million in 1995-1996 to about $33 million in 2000-2001. Preliminary figures for 2001-2002 show similar results with 4792 claims costing $32 million[5].

Jurisdiction	Regulations
ACT	ACT has no regulations on occupational noise, but approved the National Standard and National Code as its own Code of Practice on 1 March 2001.
NSW	(i) Occupational Health and Safety Regulation 2001. (ii) Mines Inspection General Rule 2000. (Covers minerals) (iii) There are currently no regulations on occupational noise for coal and shale mines. The government is intending to adopt the relevant provisions of the Occupational Health and Safety Regulation 2001 by November 2004.
VIC	(i) Occupational Health and Safety (Noise) Regulations 2004. (Also covers mines)
QLD	(i) Workplace Health and Safety Regulation 1997 (Part 10 : Noise). (ii) Mining and Quarrying Safety and Health Regulation 2001 (Covers minerals). (iii) Coal Mining Safety and Health Regulation 2001.
SA	Occupational Health, Safety and Welfare Regulations 1995 (also cover mines and petroleum).
WA	(i) Occupational Safety and Health Regulations 1996. (ii) Mines Safety Inspection Regulations 1995 (covers coal and minerals). (iii) Petroleum Act 1967 (Onshore). (iv) Petroleum (Submerged Lands) Act 1982 (Coastal Waters).
TAS	Workplace Health and Safety Regulations 1998.
NT	(i) Work Health (Occupational Health and Safety) Regulations 1992 (ii) Mining Management Act 2001. (iii) Petroleum (Occupational Health and Safety) Regulations 2001.
CWTH	Occupational Health and Safety (Commonwealth Employment) (National Standards) Regulations 1994.

Table 2. Regulations and Acts in Australian jurisdictions governing occupational noise (as at 31 March 2004)

Although the NIHL claim reduction appears significant, it does not mean that noise-induced deafness in Australia has been reduced significantly. On the contrary, a recent study by MINEHEALTH of the Department of Industry and Resources of the Western Australian Government has found that the proportion of mine workers with a hearing loss more than five per cent (adjusted for age) has increased by 4.3 per cent over the past 5-6 years, despite high levels of industry compliance with existing noise control regulations[6].

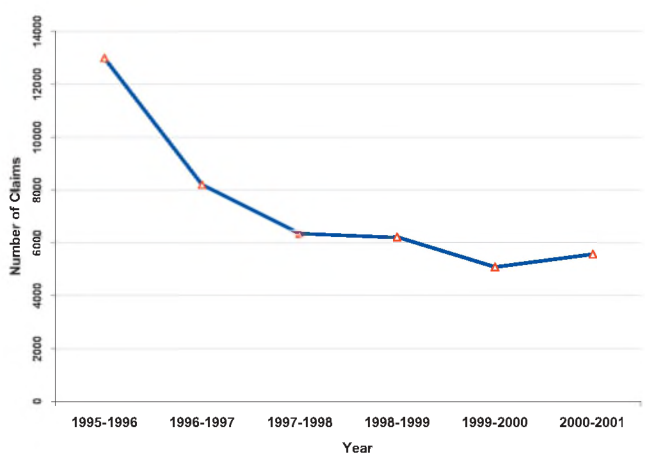

Figure 1. Five-year trend of NIHL claims.

4. Thresholds for NIHL Compensation

A likely reason for the decreasing number of deafness claims is that the various jurisdictions in Australia have introduced compensation thresholds for percentage loss of hearing (PLH) in the past few years. These thresholds vary between jurisdictions[1], as illustrated in Table 3. The thresholds used in each jurisdiction require that a certain PLH be attained before a NIHL claim is valid. Also introduced with the thresholds were more closely controlled audiometric testing and analysis procedures. Other factors in the changing labour market, such as more self-insured, casual, contract hire, subcontracting workers, may also have contributed to the decreasing number of NIHL claims in the national compensation statistics.

Table 4 shows the number of deafness claims and its percentage ratio to all work-related diseases in each Australian jurisdiction in 2000-2001[3]. It demonstrates that variations in the treatment of deafness claims across jurisdictions do affect the number of deafness claims and also its ratio over all disease within a jurisdiction. For instance, WA, TAS, NT and the Commonwealth had very few claims approved in 2000-2001.

Jurisdiction	WA[a]	SA	NT[b]	ACT	CWTH[c]	TAS[d]	QLD	VIC	NSW
% hearing loss threshold	10	5	5	5	20	5	5	7	6

Table 3 Industrial deafness thresholds in Australian jurisdictions (as at 30 November 2001)

NOTE:

a. Above baseline hearing loss previously assessed.
b. Binaural hearing impairment.
c. New legislation with 5% threshold has been implemented since 2001.
d. Whole person impairment (percentage loss of whole body).

Jurisdiction	WA	SA	NT	ACT	CWTH	TAS	QLD	VIC	NSW	Australia
All disease	1431	3190	223	171	651	416	3557	4111	10246	23978
Deafness	95	270	0	0	24	0	447	465	3999	5300
%	6.6	8.5	0	0	3.7	0	12.6	11.3	39.0	22.1

Table 4 Number of occupational deafness claims and its ratio to all work-related disease claims across Australian jurisdictions in 2000-2001

Government Department	Acts and Regulations	Jurisdiction	Standards
Comcare Ministry of Employment and Workplace Relations Australian Commonwealth Government	Occupational Health and Safety Act 1991 (Commonwealth Employment) Occupational Health and Safety (Commonwealth Employment) (National Standards) Regulations 1994	Employees of Commonwealth Government within WA	$L_{Aeq,8h}$: 85dB(A) L_{peak}: 140 dB(C)
Safety, Health and Environment Division **Petroleum Division** Department of Industry and Resources Government of WA	1. Mines Safety and Inspection Regulations 1995 (covers coal and minerals) 2. Petroleum Act 1967 (Onshore) 3. Petroleum Act 1982 (Coastal Waters).	Employees in the mineral and petroleum resources industries within WA	$L_{Aeq,8h}$: 85dB(A) L_{peak}: 140 dB(lin)
WorkSafe WA Department of Consumer and Employment Protection Government of WA	1. Occupational Safety and Health Act 1984 2. Occupational Safety and Health Regulations 1996	Employees of all other workplaces within WA	$L_{Aeq,8h}$: 85dB(A) L_{peak}: 140 dB(C)

Table 5 Government Departments administering occupational noise in WA

5. OCCUPATIONAL NOISE MANAGEMENT IN WESTERN AUSTRALIA

In Western Australia (WA), noise at workplaces not only causes most of the deafness in the state, but also leads to increased absenteeism, employee turnover and lowered work performance. However, as Western Australia currently has the highest threshold for compensable hearing loss in Australia, the extent of the occupational noise problem might be significantly underestimated, compared with other jurisdictions.

5.1 Government structure in managing occupational noise in Western Australia

There are three government departments administering different occupational noise related Acts or Regulations in different jurisdictions within Western Australia, as illustrated in Table 5.

Comcare also manages the compensation of work-related injuries and diseases for commonwealth employees through the administration of the Safety, Rehabilitation and Compensation Act 1988. Another Western Australian government department - WorkCover - administers the Workers' Compensation and Rehabilitation Act 1981 for all other employees in Western Australia, in which $L_{Aeq,8h} > 90$ dB(A) and $L_{peak} > 140$ dB(lin) are currently used to define the "prescribed noisy workplaces" for baseline hearing tests.

5.2 The role of WorkSafe Western Australia

The WorkSafe Division of the Department of Consumer and Employment Protection (WorkSafe) is the state government agency in Western Australia responsible for the administration and enforcement of State's Occupational Safety and Health Act and Regulations through its 80 inspectors. Its jurisdiction covers all employees across the state except for Commonwealth employees and those working in the mining and petroleum sectors. This accounts for over 80% of all workers within the state. In addition to its regulatory role, WorkSafe provides information to industry and the community to assist in the prevention of work-related injury and disease. Its internet service, SafetyLine: Online (www.safetyline.wa.gov.au), is one of the leading services of its kind in the world and provides ready access to high quality information on occupational safety and health.

Regulations and Codes of Practice for controlling occupational noise

Western Australia's Occupational Safety and Health Regulations 1996 adopted the National Standard for Occupational Noise and reduced the state's daily occupational noise exposure standard $L_{Aeq,8h}$ from 90 dB(A) to 85 dB(A) in 1999, and changed the peak level L_{peak} standard from 140 dB(lin) to 140 dB(C) in 2002. For technical aspects of noise measurement and selection of hearing protectors the regulations make reference to Australian/New Zealand Standard AS/NZS 1269[7]. The WorkSafe WA Commission published the *Code of Practice for Managing Noise at Workplaces* in 2002[8], which provides Western Australian workplaces with practical guidance for managing excessive noise. Another Code of Practice, *Control of Noise in the Music Entertainment Industry*, originally issued in 1991, was revised and reissued by WorkSafe WA Commission in 1999 and again in 2003[9]. This was the first such Code of Practice in Australia and provides additional information on controlling noise in the entertainment industry.

All WorkSafe Inspectors are empowered to inspect all occupational hazards - including noise – in workplaces. They are supported technically by WorkSafe noise specialists. They have to check if the noise level in the workplace is excessive or not, and if so, they check if the noise has been controlled to its minimum practicably achievable level or not.

Practicable and control hierarchy

In many workplaces, when there is an excessive noise problem, employers simply choose the easy solution by providing their employees with hearing protectors. However, according to WA Occupational Safety and Health Regulations 1996, the employer '…. must, as far as practicable, ensure that noise to which a person is exposed at the workplace does not exceed the exposure standard for noise.' Hearing protectors are to be used when it is not practicable to reduce the noise by other means.

The Code of Practice actually describes a noise control hierarchy when there is excessive noise in the workplace;

1. Eliminate the noise by replacing the noise sources or modifying the production techniques or procedures.
2. Engineering control of the noise by using passive or active noise control technologies.
3. Administrative control of the noise exposure levels by organising the work patterns to limit the exposure time of workers.

Thus, it is obvious that what is practicable is very important in controlling the noise at workplaces. When there is an excessive noise at a workplace, it is the employer's duty to demonstrate that the best practicable control measures have been implemented by assessing the noise problem and the control measures. WorkSafe Inspectors need to check if the employer has followed the control hierarchy and implemented the best practicable control measures.

Proactive investigation of occupational noise issues in WA

In addition to responding to noise complaints, WorkSafe Noise Specialists also conduct proactive noise control projects, which target industries that have been identified as having more noise problems. A research project in the construction and metal manufacturing sectors was completed in 1998/99[10]. Through this project, examples of practical noise control in these industries were gathered and made available to a wide audience via case studies and a SafetyLine Institute lecture[11] on the WorkSafe website. In particular, a guide " Noise Management in the Construction Industry - A Practical Approach" was produced[12], illustrating how noise control measures should be taken into account through the phases of construction.

Music entertainment is another industry with many noise problems in Western Australia. The problem is becoming more serious due to the introduction of new, more powerful equipment for both live and pre-recorded music. The risk of people working in this industry suffering noise induced hearing loss and tinnitus has been recognised in WA by issuing the Code of Practice - Control of Noise in the Music Entertainment Industry[9]. The Code gives practical guidance on reducing noise exposure in venues and how to meet legislative obligations. It is aimed at venue owners, designers and operators, performers, promoters, technical and service staff and suppliers of sound equipment.

Previous experience in Western Australia and other Australian States shows that compliance with the noise aspects of occupational safety and health legislation is very low in the music entertainment industry. In March 2000, WorkSafe Western Australia noise specialists developed a project to carry out a series of inspections within the industry to establish whether venue operators were implementing appropriate noise management measures. More studies and investigations in this industry have been planned in the near future.

Problems and concerns

Some problems exist in Western Australia's occupational noise management and control, which need to be addressed and solved. They are:

1. *Gap between the knowledge of new noise control technologies and the action taken by WA workplaces*

This gap is even more obvious in Western Australia, a State with a very large percentage of small business (with less than 20 employees). It is estimated that almost half of Western Australian workers are employed by small business. It is more difficult for small business to implement the latest noise control technologies, due to the small production scale, lack of funds, and lack of information.

WorkSafe tried to bridge this gap and did a research project in the construction and manufacturing industries in 1999[10]. The companies in these industries were encouraged to share their successes in practical noise control. The successful practices were promoted in WorkSafe's SafetyLine website as case studies.

Although some success was achieved in the previous attempt, the gap is still there and needs more efforts to fill.

2. *Gap between the noise action standards adopted by WorkSafe and WorkCover*

As discussed above, WorkCover, the State department administering the State's Workers' Compensation and Rehabilitation Act 1981, has an action level for hearing tests of $L_{Aeq,8h}$ = 90 dB(A), which is 5 dB higher than WorkSafe's exposure standard. This can lead to confusion in workplaces that have employees exposed to noise between 85 and 90 dB(A). On one hand, they have to do everything practicable to reduce their noise exposure levels. On the other hand, they do not need to provide WorkCover hearing tests to their employees. As a result, employers may lack incentive to control the noise when it is within this range.

Also WorkCover currently has the highest threshold (10%) for compensable NIHL in Australia. Therefore, taking the number of compensation claims as the main indicator, significantly underestimates the occupational noise problem in the State compared with other jurisdictions. NOHSC is presently trying to develop new performance indicators that will give a clearer picture.

3. *Managing low-level occupational noise*

Worksafe has received many inquiries, concerns, and complaints of noise at workplaces where the noise levels are not over the noise exposure standard. These workplaces include offices, call centres, schools, hospitals, etc. The noise problem within these working environments is not hearing loss, but noise-induced stress, lack of concentration, lack of privacy, etc. With the IT revolution and changing work environment, more and more employees are working in office environments. It is expected that Worksafe will receive more and more concerns from these workplaces and have to deal with the noise problems in these working environments.

However at present, all the regulations for occupational noise in Australia are based only on hearing loss protection. They lack strong legal supports in managing and controlling low level noise.

6. CONCLUSIONS

There are variations in occupational noise standards and legislation adopted by Australian States, Territories, and the Commonwealth Government. These variations are not only in noise management and control regulations, but also in noise-induced disease compensation and rehabilitation standards and legislation. Now more and more jurisdictions have already adopted or are going to adopt the National Standard in occupational noise management. However, the variation in hearing loss compensation thresholds is likely to remain in the foreseeable future.

A major review of Australian National Standard for Occupational Noise is to commence this year. This will consider the new EU Directive on occupational noise, which significantly reduces the action noise level. If similar standards are adopted, these changes could lead to a significant reduction in the noise-induced hearing loss of employees and improvement in the acoustical quality of our workplaces. However, success is dependent upon how quickly the nine Australian jurisdictions review and make their own changes in accordance with the National Standard, and on how workplaces are encouraged to implement noise controls through a balance of enforcement and advice.

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Assessment Of The Solution And Prediction Algorithms During The Optimization Of Fluid-Structure Interaction Dynamic Systems

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ABSTRACT

For optimization problems based on dynamic criteria the system eigenvalues must be re-computed for each iteration as the values of the design parameters are changed. From a computational point of view it would be more efficient to replace the laborious process of determining the eigenvalues by direct prediction. The suitability and advantages of this scheme are examined here. The number of operations required by the direct and the predictive solution algorithms are compared. The prediction scheme has been applied to the problem of maximizing the separation of two adjacent eigenvalues for structural and couple fluid-structure systems.

SOMMAIRE

Les problèmes d'optimisation basés sur des critères dynamiques doivent obtenir les valeurs propres de système, qui dépendent directement des valeurs des variables de conception. Pendant le processus d'optimisation la fonction objective est calculée à plusieurs reprises pour chacun nouvel ensemble de variables de conception, et alors une alternative plus économique du point de vue informatique devrait prévoir les valeurs propres pour le nouvel ensemble de variables au lieu de résoudre le problème encore. Ainsi, le but de ce travail est de déterminer la convenance et les avantages d'employer la prévision de valeurs propres, au lieu des solutions directes, dans les itérations pendant le processus d'optimisation. Puis, le nombre d'opérations entre la solution *directe* et *prédictive* du système est comparé pour une itération principale pendant l'optimisation. Généralement, il est nécessaire de résoudre le système ou de le prévoir plus d'une fois pour avancer à la prochaine itération principale; la prévision est meilleure dans ce cas-ci, parce qu'elle doit calculer seulement la sensibilité des valeurs propres une fois pour une itération principale de l'algorithme. Après, une analyse d'erreur des valeurs propres et des vecteurs propres prévus est faite en vue de limiter la portée de la prévision dans le processus d'optimisation. L'analyse est faite pendant la maximisation d'espace entre deux valeurs propres adjacentes sur les systèmes structuraux et couplés de fluide-structure, modifiant une certaine variable structurale géométrique précédemment définie du modèle fini d'élément.

1. INTRODUCTION

It is common to find cases where two or more systems interact with one another. Those situations where it is not realistic to model each system independently of the others are known as coupled systems. Fluid-structure interactions belong to this class: neither the fluid domain nor the structural domain can be solved independently, as the forces at the interfaces exert a significant influence.

The problem of fluid-structure dynamic interaction is analyzed herein. It has applications in the analysis of sound transmission through the walls of pressure vessels, ducts, and vehicle cabins. Even though the displacements imposed on the fluid are assumed to be small, it is not possible to decouple the motions of the fluid and the solid.

It is inevitable that resonances will occur in such systems. These may reduce the sound transmission properties, and may even lead to structural failures. Thus it is desirable to identify these resonances, and, if possible minimize any adverse effects by re-designing the structure. It is during the re-design phase that optimization is employed.

Problems involving incompressible fluids are commonly referred to as hydro-elastic problems. Here the effects of fluid compressiblity are to be ignored, resulting in an elasto-acoustic problem. The systems are assumed to suffer but small perturbations about stable equilibrium points. This renders the governing equations in the fluid to be acoustic in nature and structure is considered to be a linear elastic solid.

Within this frame work it is important to chose appropriate variables that describe the system response. In the fluid domain displacement, pressure, velocity potential, or a combination thereof can be used. Here the non-symmetric ***u-p*** formulation and a finite element method have been chosen. Here ***u*** is the displacement of the structure and ***p*** is the pressure in the fluid. This choice is appropriate for the types of systems analyzed below.

Deneuvy [1] was one of the first to study coupled systems with a view to optimizing certain dynamic parameters. The goal was to design an optimal structure where separation of two adjacent natural frequencies was the design objective. One of the difficulties encountered was the choice of an appropriate convergence parameter that was needed to stabilize the optimization scheme.

More recently Pal and Hagiwara [2, 3] studied the optimization of noise level reduction in a coupled structural-acoustic problem. The objective was to minimize the changes in the design parameters to reach a predetermined response. Their method could only deal with those cases where the acoustic and structural resonant frequencies of the systems matched.

2. OBJECTIVE

Optimization problems based on dynamic criteria make use of the system eigenvalues, which in turn depend on the design variables. The optimization process requires that the objective function be calculated repeatedly. This re-computation is time-consuming for most systems. It would be desirable to be able to predict the eigenvalues for the new set of design parameters that are being identified during each loop of the iteration. The objective of this work is to determine the suitability and advantages of eigenvalue prediction.

The advantages of the proposed scheme is judged by the match of the predicted eigenvalues and eigenvectors with those derived by direct computation. Also, there should be a computational savings in terms of the number of floating point operations –*flops*- . *Flops* counting is a rather basic approach for evaluating the efficiency of a program or algorithm in as much as memory traffic and other operations associated with the operation of the code are not counted. Golub and Van Loan {4} argue that *flops* counting is a simple, but inexact accounting method that captures but one of the many factors that influence the computational efficiency of a code. Nevertheless, we believe that *flops* counting is adequate to test the viability of the predictive method. Also, the *flops* counter is a convenient feature of the *Matlab* software that was used to perform the necessary computational analysis.

3. ANALYZED SYSTEMS

3.1 Structural system *SE3* – bi-fixed beam of circular cross section

The structural system *SE3*, as shown in Figure 1, consists of a bi-fixed beam where the elements have length L_i and circular cross sections of inertia moment I_i. Possible control variables are the cross sections areas of the elements, A_i, or their diameters, ϕ_i. The structure has Young's modulus E and density ρ_s. L_T is the total length of the beam.

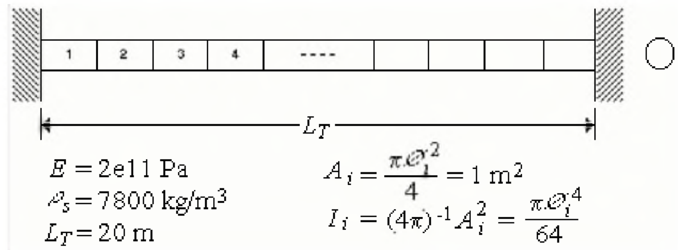

Figure 1. Structural system *SE3*

3.2 Structural system *SE4* - bi-fixed beam of rectangular cross section

This system is a bi-fixed beam under flexure with rectangular cross section of unitary width, b, as shown in Figure 2. The beam is modeled with elements of length L_i and cross sections of inertia moment I_i. Possible design variables are the cross sections areas of the elements, A_i, or their heights, e_i. It is observed that the mass matrix varies linearly and the rigidity matrix varies with the cube of the height, e.

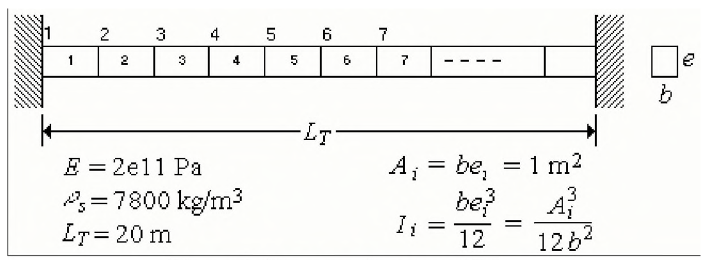

Figure 2. Structural system *SE4*

The structure has Young modulus E and density ρ_s, and the total length of the beam is L_T. Structural system *SE4* is classified as being of order 3, due to the exponent of the relation between the inertia moment and the area, $I=A^3/12$, for the unitary width.

3.3 Fluid-structure system *SFE1* - reservoir

The fluid-structure coupled system consists of a rectangular two-dimensional acoustic cavity of H=40m height and L_T=20m length, as shown in Figure 3. This model was presented previously by Olson and Bathe [5], Grosh and Pinsky [6] and Sandberg [7] among others; being a classical example where the basic phenomenon of the fluid-structure coupling can be evidenced. Boundary conditions are rigid sidewalls (R.W.) and free surface (F.S.) at the top; while the bottom side is modeled as a bi-fixed beam of rectangular cross section in flexure and unitary width, initially of square shape with uniform height of 1 m.

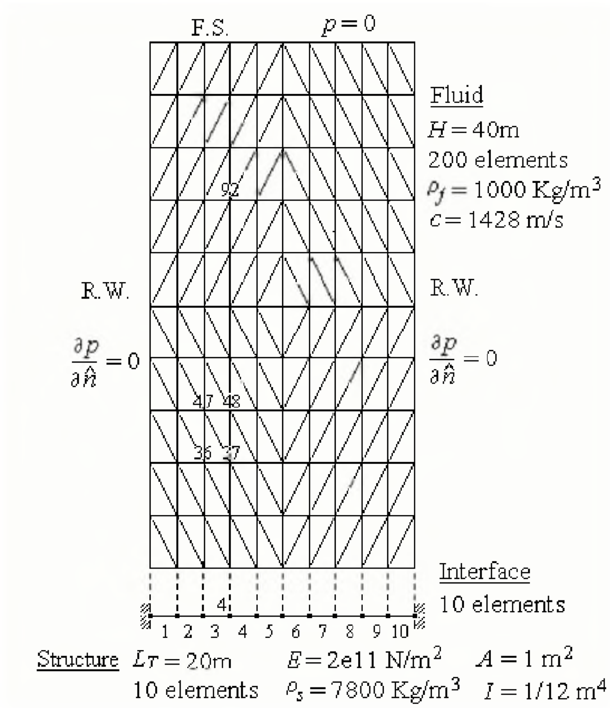

Figure 3. Fluid-structure system *SFE1*

Design variables are the heights of the beam elements, although the areas of the cross sections can also be used. The system is classified as being of order 3, due to the exponent of the relation between the inertia moment and the area of the structural cross section, $I=A^3/12$.

3. PERFORMANCE VERIFICATION OF THE *PREDICTIVE* FORMULAS

The sequential quadratic programming algorithm, implemented in the commercial software Matlab®, was used in this work, supplying the analytical expressions of the gradients of the objective function and the restrictions.

For verifying the numerical performance of the predictive formulas, regarding the number of float point operations, the fluid-structure coupled system *SFE1* was studied, choosing as design variables the heights of the structural elements which had a variation of up to 15%.

Figure 4 shows the quantity of flops and analyzed modes for solving the eigenvalues and eigenvectors problem just once, using both *solution* and *predictive* processes. It is observed fewer flops if the *predictive* option is used for few modes.

The *solution* process uses the *sptarn*© function supplied with the *Matlab® Partial Differential Equation Toolbox©*. The *sptarn*© function solves problems of generalized eigenvalues of the $(\boldsymbol{A}-\lambda\boldsymbol{B})\boldsymbol{x}=0$ system in the [*lb*,*ub*] interval, where $\boldsymbol{A}$ and $\boldsymbol{B}$ are sparse matrices, $\boldsymbol{x}$ is the vector of independent variables, *lb* and *ub* are lower and upper limits of the searched eigenvalues. The *sptarn*© function uses the Lanczos method initially with *jmax*=100 base vectors, requiring a *jmax**DOF workspace where DOF is the number of degree of freedom of the system.

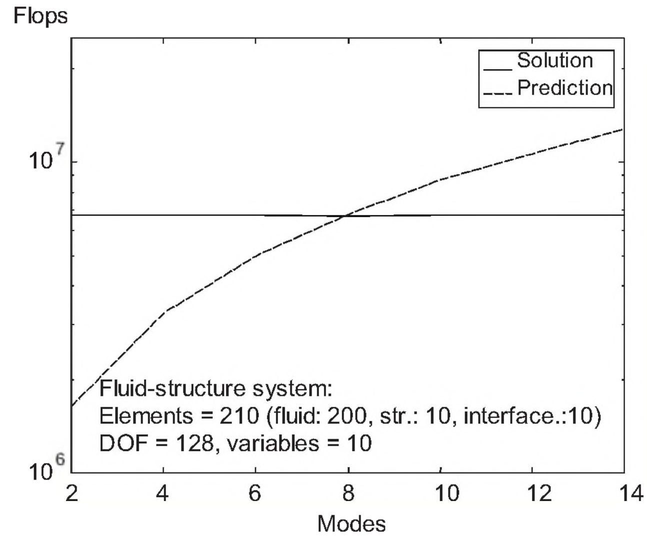

Figure 4. Flops with modes for solving the *SFE1* system once

Commonly, the algorithm stops when a sufficient number of eigenvalues converge; nevertheless, as the number of base vectors was maintained constant throughout the process, the quantity of flops in the interval varied little (Figure 4).

The quantity of flops, when the system is solved twice for a main iteration of the optimization, using the *solution* and *predictive* processes, is shown in Figure 5. In this case, the quantity of flops is fewer with the *predictive* option for all analyzed modes, which justifies its use for optimization of these systems, where many cycles must be performed for any iteration.

From these results it can be concluded that when it is used the predictive formulas in coupled fluid-structure systems, more efficient algorithms can be obtained regarding its computational cost. However, special techniques for solving the eigenvalues and eigenvectors problem can lead to situations more favorable to the *solution* process [7].

4. ACCURACY EVALUATION OF THE *PREDICTIVE* FORMULAS

An error analysis is carried out for the predicted eigenvalues, these calculated with the Rayleigh quotient method of Equation (1). Other error analysis is carried out for the predicted eigenvectors, these calculated with the finite difference method of Equations (2) and (3). The analyses are realized as a function of the allowable variation of the design variables. The aim of this study is to verify the validity of the *predictive* formulas, in such a way that the optimization processes can adequately converge.

$$\lambda_j^* = \frac{\bar{\boldsymbol{\phi}}_j^{(DF)^T} \boldsymbol{K}^* \boldsymbol{\phi}_j^{(DF)^T}}{\bar{\boldsymbol{\phi}}_j^{(DF)^T} \boldsymbol{M}^* \boldsymbol{\phi}_j^{(DF)^T}} \equiv \lambda_j^{(R)} \quad (1)$$

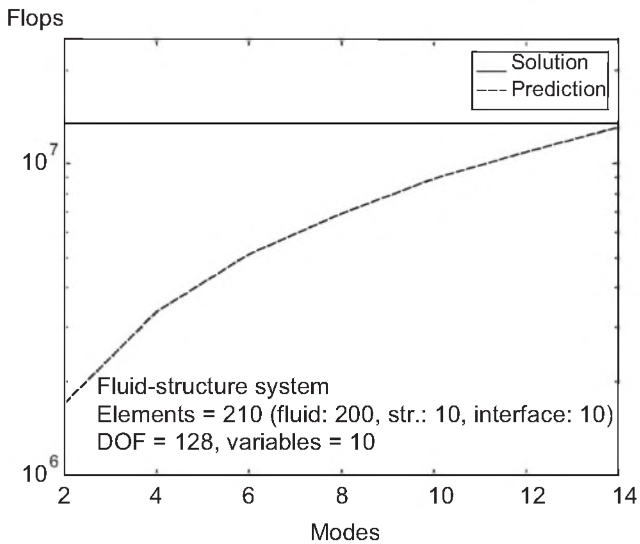

Figure 5. Flops with modes for solving the *SFE1* system twice

$$\boldsymbol{\phi}_j^* \approx \boldsymbol{\phi}_j + \boldsymbol{\phi}_j' \Delta e \equiv \boldsymbol{\phi}_j^{(DF)} \quad (2)$$

$$\bar{\boldsymbol{\phi}}_j^* \approx \bar{\boldsymbol{\phi}}_j + \bar{\boldsymbol{\phi}}_j' \Delta e \equiv \bar{\boldsymbol{\phi}}_j^{(DF)} \quad (3)$$

λ_j^* is the j^{th} eigenvalue and $\lambda_j^{(R)}$ is the j^{th} predicted eigenvalue of the modified system, ***K**** and ***M**** are the modified rigidity and mass matrices, $\bar{\boldsymbol{\phi}}_j^{(DF)}$ and $\boldsymbol{\phi}_j^{(DF)}$ are the j^{th} left and the j^{th} rigth predicted eigenvector of the modified system using the finite difference method, $\bar{\boldsymbol{\phi}}_j^*$ and $\boldsymbol{\phi}_j^*$ are the j^{th} left and the j^{th} right eigenvector of the modified system, $\bar{\boldsymbol{\phi}}_j^{(DF)}$ and $\boldsymbol{\phi}_j^{(DF)}$ are the j^{th} left and the j^{th} right predicted eigenvector of the modified system calculated with the finite difference method, $\bar{\boldsymbol{\phi}}_j$ .and $\boldsymbol{\phi}_j$ are the j^{th} left and the j^{th} right eigenvector of the coupled system, $\bar{\boldsymbol{\phi}}_j'$ .and $\boldsymbol{\phi}_j'$ are the derivatives of the j^{th} left and the j^{th} right eigenvector of the coupled system in relation to the structural variable *e*, and Δe is the variation of the structural height.

In order calculate the eigenvalues error, it was necessary to place in-phase the eigenvectors obtained by the *predictive* process, $\boldsymbol{\phi}_{prediction}$, in relation to the eigenvalues obtained by the *solution* process, $\boldsymbol{\phi}_{solution}$, according to Equation (4).

$$\frac{\boldsymbol{\phi}_{solution}^T \boldsymbol{\phi}_{prediction}}{\boldsymbol{\phi}_{solution}^T \boldsymbol{\phi}_{solution}} = \begin{cases} < 0, & \boldsymbol{\phi}_{prediction} = -\boldsymbol{\phi}_{prediction} \\ > 0, & \boldsymbol{\phi}_{prediction} = \boldsymbol{\phi}_{predicition} \end{cases} \quad (4)$$

For evaluating the error of the predicted eigenvector, erro$\boldsymbol{\phi}_{prediction}$, it was used the Euclidian norm that defines the error as,

$$\text{erro}\boldsymbol{\phi}_{prediction} = \left\| \boldsymbol{\phi}_{prediction} - \boldsymbol{\phi}_{solution} \right\| \quad (5)$$

First, the structural system *SE3* was analyzed, where the beam was discretized in 20 elements, which means 30 DOF. The system variables are the areas of the elements with a random variation between specified intervals, keeping unchanged the initial volume and the symmetry of the beam.

Figure 6 shows a maximum error of 0.96% in the prediction of the first ten frequencies, value found for a simultaneous variation of the areas of up to 25-30%. This error is smallest than the maximum error of approximately 5% obtained by Fox and Kaapor [8], who only studied the first three frequencies of a fixed-free beam of circular cross section, with a diameter variation of up to 30%.

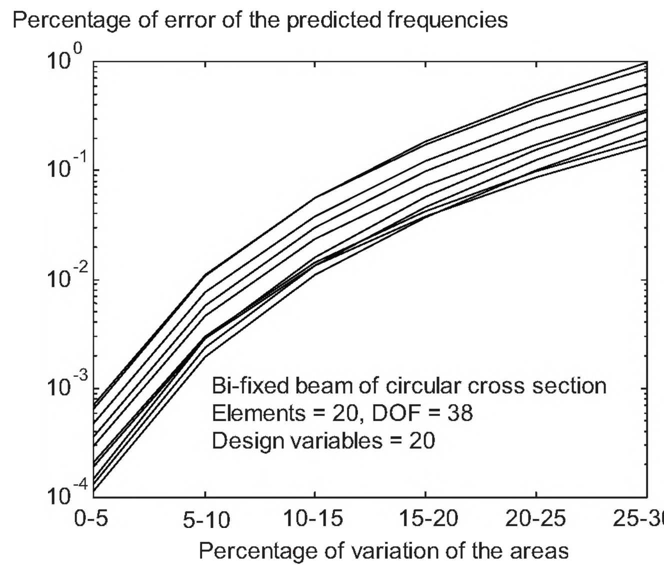

Figure 6. Prediction error of the first ten frequencies of the *SE3* system

The curves in Figures 6 to 11 are not labelled because the principal interest is to analyze the maximum error of the first ten predicted eigenvector and eigenvalues. Additionally, it is observed that the errors of the first frequencies do not correspond necessarily with the lower curves of the graphs.

Figure 7 shows a maximum error of 10.48% in the prediction of the first ten modes of the system *SE3*, taking a variation of the design variables of up to 25-30%. It is observed that for a variation of up to 10-15%, the maximum error is 2.45%, which is acceptable for optimization terms.

For obtaining major conclusions about modal error of the prediction, the *SE4* system was studied. The bi-fixed beam is discretized in 20 elements, producing a model with 38 DOF. The system variables are the heights of the elements, with a random variation between specified intervals, keeping unchanged the initial volume and the symmetry of the beam with a unitary width.

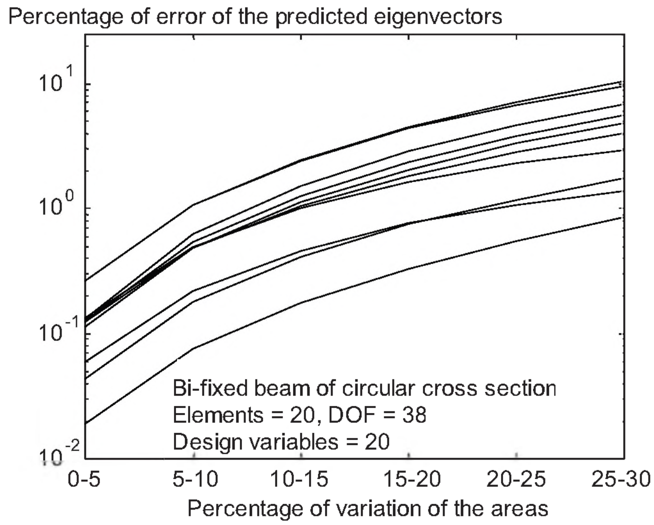

Figure 7. Prediction error of the first ten eigenvectors of the *SE3* system

Figure 8 shows a maximum error of 7.28% in the prediction of the first ten eigenvalues, for a simultaneous variation of the variables of up to 25-30%. This value is higher than the 0.96% of the second order *SE3* system, and higher than the maximum error of about 5% obtained by Fox and Kapoor (1968). This result shows the error increasing as a function of the non-linearity order given by the exponent of the relation between the inertia moment and the area, $I=kA^n$.

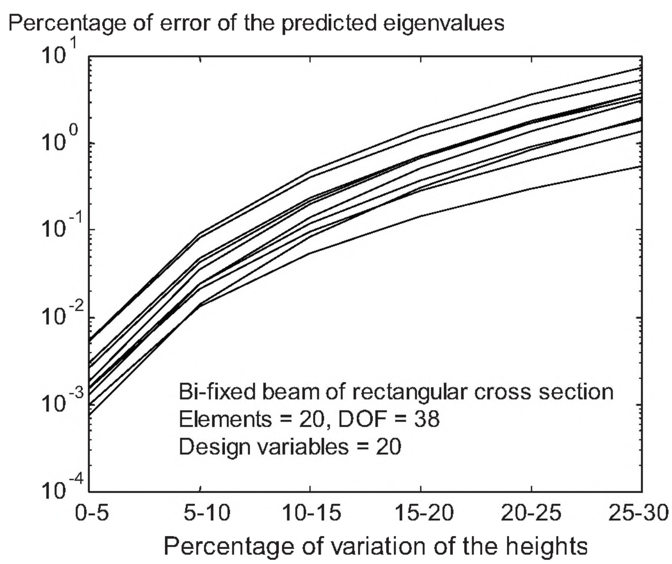

Figure 8. Prediction error of the first ten eigenvalues of the *SE4* system

Figure 9 indicates a maximum error of 30.58% in the prediction of the first ten eigenvectors, for a variation of the design variables of up to 25-30%. Moreover, it is observed that up to a 10-15% variation, the maximum error was 7.27%, value that could be high for the optimization, but it is important to remind that in practice the variables do not vary simultaneously in the same way.

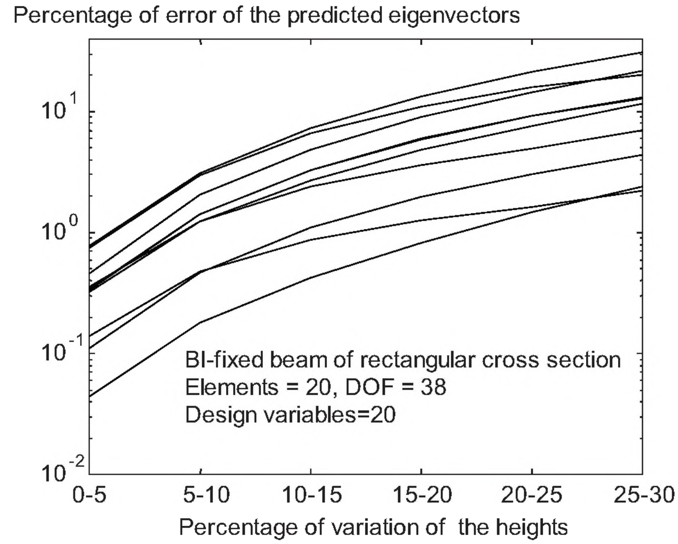

Figure 9. Prediction error of the first ten eigenvectors of the *SE4* system

Finally, the error of the modal prediction of the third order *SFE1* system is studied with the aim to establish conclusions on the prediction of eigenvalues and eigenvectors in coupled systems. The variables of the system were the heights of the elements, whose variation were made randomly in the intervals previously specified, maintaining the initial volume and the symmetry of the beam with an unitary width. It is observed that the order of the exponent of the relation between the moment of inertia and the area is three, identical to the previously analyzed case.

It is observed, from Figure 10, a maximum error of 0.42% in the prediction of the ten first frequencies for a simultaneous variation of the variables of up to 25-30%, value sufficiently lower than the maximum error of 7.28% of the *SE4* structural system. Some explanation originates by the fact that the error of the six fluid predominant frequencies must present a low value, because they vary little when the structural heights are modified. On the other hand, for the structural predominant coupled frequencies, i.e. frequencies 2nd and 3rd, the maximum error is lesser for the coupled case compared with the structural case of the system *SE4*.

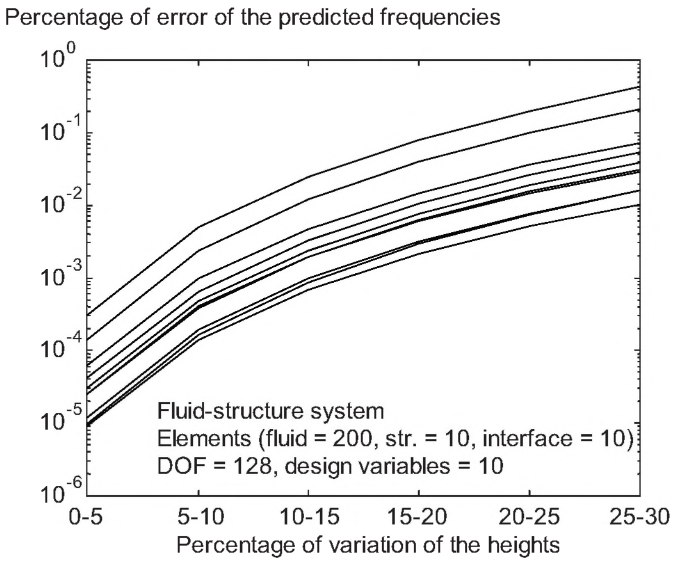

Figure 10. Prediction error of the first ten frequencies of the *SFE1* system

Figure 11 shows a maximum error of 9.60% in the prediction of the first ten natural modes, for a variation of the heights of up to 25-30%. This value is lower than the maximum error of 30.58% for the *SE4* structural system. It is also observed that for a variation of the variables of up to 10-15%, the maximum error of the predicted eigenvectors was 2.38%, which is lower than the maximum error of 7.27% in the system *SE4*.

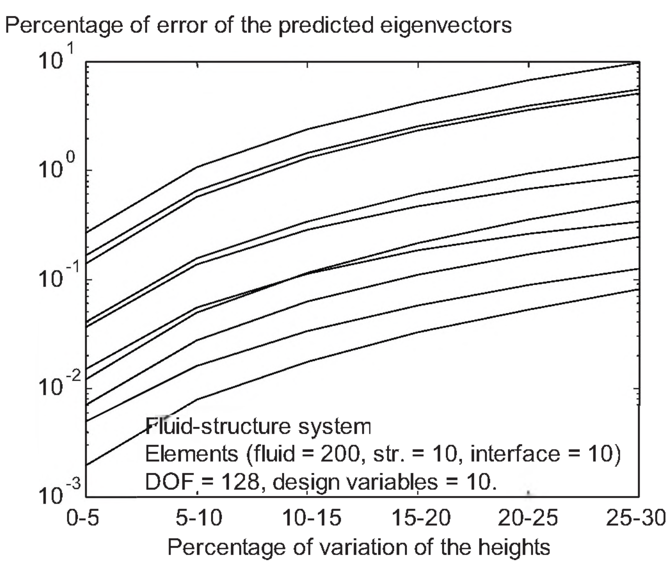

Figure 11. Prediction error of the first ten eigenvectors of the *SFE1* system

5. CONCLUSIONS

A methodology of using predictions for eigenvalues and eigenvectors has been presented. The formalism has been applied to a coupled fluid-structure system with the aim of optimizing the separation of two adjacent frequencies. The eigenvalues are predicted using the Rayleigh quotient and the eigenvectors are predicted with the aid of a finite difference scheme. The prediction formulas are restrained by certain conditions during the optimization process. These are in the form of the maximum allowable variation of the design variables.

The results suggest that the method is suitable for the optimization of structural and coupled fluid-structure optimization problems. Care must be taken to constrain the maximum variation of the design variables to values no greater than 10-15%.

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NOISE LEVEL AND ITS PERCEPTION BY COMMUTERS IN URBAN BUSES OF CURITIBA

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ABSTRACT

The aim of this study was to evaluate the sound pressure level in commuter buses, as well as investigate the resulting hearing perception of commuters about the bus noise levels. This was accomplished by measuring the noise levels inside city buses as well as through a questionnaire completed by 808 commuters. This questionnaire requested information about vehicle characterization, noise perception inside the buses (noise presence, intensity, causes and effects), bus stations, and bus stops in different areas of Curitiba. The maximum noise level inside the vehicles was 81 dB (A), which is a high value since the World Health Organization (WHO) considers that a sound above 70 dB (A) may be harmful to human beings. The survey showed that although the noise was not considered as one of the main factors which cause discomfort in buses, commuters were able to identify the noise sources inside the buses. Commuters aslo complained about the noxious effects of the noise, such as irritability and headaches.

SOMMAIRE

Le but de cette recherche étais d' investiguer les niveaux de bruit présents dans les autobus urbains et d'étudier la perception auditive de ce bruit par les utilisateurs du transport en commun de la ville de Curitiba -Paraná - Brésil. Pour ce fairele niveau de bruit a été mesuré à l'intérieur de quelques autobus de la ville et un questionnaire a été rempli par 808 utilisateurs dans les gares routières et les arrêts d'autobus de différents secteurs de la ville, visant la caractérisation du véhicule et la perception du bruit à l'intérieur de celui-ci (présence, intensité, causes et effets du bruit). Le niveau maximum de bruit mesuré à l'intérieur de ces véhicules était 81 dB (A), valeur élevée étant donnée que l'Organization Mondiale de la Santé (OMS) considère qu'un bruit au-dessus de 70 dB (A) peut causer des dommages aux gens. L'analyse des réponses au questionnaire a permis de constater que le bruit n'est pas le principal facteur dérangeant à l'intérieur des autobus. Cependant, les utilisateurs sont en mesure d'identifier les sources de bruit à l'intérieur des véhicules et se plaignent des effets désagréables du bruit, comme l'irritabilité et les maux de la tête.

1. INTRODUCTION

In the last few decades, public transportation became one of the most important means of transportation in major cities; however the users' well-being has not always been taken into account. External factors, such as noise, temperature, humidity, comfort and hygiene are, most of the time, causes of countless complaints from passengers, mainly in commuter buses, since thousands of people rely on this means of transportation to travel to and from work, school or even to go out every day.

Urban noise originates from different emission sources such as industrial and commercial business, building sites and mainly traffic (CETEC, 1987). Research carried out in several parts of the world shows that the aerial, railway, road, or automobile traffic are the modes of transport that contribute most to the for increasing noise rate observed in major urban centers. (Hygge, 1993; Stanfeld et al., 1993); Ogusola et al. 1994; Orlando et al. 1994; Beyragued et al., 1998)

Other factors that contribute to the environmental sound pollution are: sound amplification in movies, theatres, show houses, children parties, social meetings and shopping malls, gymnasiums, electric and mechanical machinery, as well as churches, and neighbours. (Celani et al., 1991; Souza & Álvares, 1992; Jorge Jr, 1996; Lichtig & Carvallo, 1997; Lacerda, Morata & Fiorini, 2001)

It is well known that extended exposure to high sound pressure levels (SPL) may harmfully influence human health. High sound levels not only impact the hearing system, but also impact the organism as a whole. Intense and permanent SPL may cause a series of disturbances such as significantly altering people's sense of well-being, interfering with human metabolism, decreasing immunological resistance activities, and causing a series of psychological and physiological effects. (Stanfeld et al., 1993; Patwardhan et al., 1993; Asahina et al. ,1994; Evens et al., 2001; Kawwada, 1995; Koszarny, 2000).

World Health Organization - WHO (1997), ranks the impact of noise levels as follows: a) up to 50 dB (A) may be inconvenient, but the organism is able to adapt easily; b) at 55 dBA and above, the occurrence of mild stress and discomfort is possible; c) from 70 dB (A) up, the stress reactions are more noticeable and the organism starts a self consuming stage, with an increase in the occurrence of several pathologies; d) when the 80 dB (A) limit is reached, there is a momentary pleasure sensation, due to the endorphins liberation; and e) auditive protection is highly recommended when exposure exceeds 85 dB(A), especially if the exposure is prolonged. Damage to the hearing system due to constant exposure to high noise is cumulative and irreversible, thus being one of the most important causes of permanent acquired deafness.

With technological progress, and the growth of cities, sound pollution is surpassing its limits and causing serious consequences to human health. Scientific research and preventive work have been elaborated in order to make the population aware of the damages excessive noise can bring to our health. (SOBRAC, 1992, Axelsson et al. 1995)

The current study's main objective is to investigate noise levels inside urban buses as well as to investigate the perception that the users have of the noise levels inside these vehicles. The research was conducted in the city of Curitiba, the capital of the state of Paraná located in southern Brazil. The city is also known as the "Ecological Capital" due to the constant concern for environmental preservation and self-sustained development demonstrated by the population and local authorities. The city has a strong world-class commuting system to serve its approximately three million inhabitants.

2. BRAZILIAN NOISE LEGISLATION

Brazil, like in several other countries, due to the concern with noise pollution has a set of federal, state, and municipal laws to deal with noise issues.

2.1 Federal Laws

The *CONSELHO NACIONAL DO MEIO AMBIENTE* – National environmental Council (*CONAMA*), incorporated to the *Secretaria Nacional do Meio Ambiente* -National Environmental Bureau, adopted the following resolutions:

The resolution No. 001, from March 8, 1990, determines the emission, patterns, criteria and guidelines, concerning any industrial, commercial, social or recreational activities, including political propaganda, backed by the Law no. 7804/89 - National Environment Policy. In this resolution the sounds and noises which propagate to the exterior and produce a noise level that is 10 dBA, above the baseline noise, without traffic, are considered harmful to the safety and the public serenity. In addition in absolute terms if the noise levels in the exterior is above 70 dB A, during the night, the noise will be considered harmful.

The resolution No. 002, from March 8, 1990, establishes the National Program for Education and Sound Pollution Control (*SILÊNCIO*), maintained by the Law No. 6938/81, which outlines the national policies towards the environment.

Number 1, from February 11, 1993, establishes the maximum noise limit for vehicles, backed by the following federal laws - No. 6.938, from 8/31/1991, No. 8.028, from 4/12/1990, No. 8.490, from 11/19/92 and the ordinance No. 99.274, from 6/6/1990.

Number 2, from February 11, 1993, establishes the maximum noise limits for motorcycles, scooters, tricycles, auto cycles, bicycles with auxiliary engines, backed by the law no. 6.938, from 8/31/1981, altered by the law No. 8.028, from 4/12/1990, No. 8.490, from 11/19/1992, and for the ordinance No. 99274, from 6/6/1990, bearing its internal regiment.

The Brazilian legislation, in Regulation No. 15 from of Labour State Department, Decree 3214/1978, establishes the maximum tolerance limit concerning the exposure to occupational noise, and foresees that a continuous exposure to noises above 85 dBA may cause permanent hearing losses and, above this level, increases of only 5 dB, warrant reduction of the exposure time by half. This legislation is applied in Brazilian industries only. The other work places do not have to comply.

The Brazilian Association for technical rules - *ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS (ABNT)* has the Brazilian Registration Norma (*BRN*) 10.151 that sets the standards for evaluation of the noise acceptability in communities. It specifies a method for noise measurement, the application of the corrections for the measured levels (according to duration, spectrum characteristic and peak factor) and a comparison of the corrected levels, with a criterion that takes into account several environmental factors. The same Association also applies the Brazilian Registration Norm (*BRN*) 10.152 which establishes noise levels compatible with acoustic comfort in several environments.

2.2 State Laws

The Environmental Institute of Paraná Instituto - *Ambiental do Paraná (IAP)*, acts on behalf of the state of Paraná, and applies the guidelines of *CONAMA* and *ABNT* described above, without any additional resolutions on this subject.

2.2 Municipal Laws

Various city halls are setting a limit to the sounds and noise emission areas classified as residential zone (RZ), commercial zone (CZ), and industrial zone (IZ), among others. In each of the zones limits have been set for sound pollution according to the period of the day: day, evening or night.

The city of Curitiba, through its environmental legislation, Law Number 8.583 on urban noises, concerning the protection of well-being and public serenity, has divided the period into three durations: day time is from 7:00 a.m. to 7:00 p.m.; the evening is from 7:00 p.m. to 10:00 p.m.; and the night is from 10:00 p.m. to 7:00 a.m. According to the Municipal environment bureau, the noise limits in Curitiba are divided into zones according to the different areas of the City. The following noise limits apply: in the case of a strictly residential zone, a 55 dBA limit should be respected during the day period, 50 dB A during the evening period and 45 dB A during the night.

3. METHODOLOGY

The transportation system in Curitiba offers a comprehensive range of routes and vehicles that connects the downtown area to the suburbs. The lines offered by the commuter system in Curitiba are: *interbairros* (routes that connect several neighbourhoods), *expresso simples* (buses that run in a special lane for buses only) and *biarticulado* (an extended version of the expressos), *ligueirinho* (with only a few stops, link the city's most crowded areas),, *alimentadores* (connect neighbourhoods to bus terminals) and *convencional* (regular type buses).

The objective of the current investigation was to determine the hearing perception of the noise present in Curitiba buses, a questionnaire was elaborated (Appendix 1) including items that addressed the following variables: (1) type of bus used (model and route); (2) commuter use habits (reason of use and for how long the person has used the bus system); (3) noise perception (noise presence, intensity causes and effects).

The questionnaire was applied during the months of June to September 2001, in different points of Curitiba (downtown, neighbourhood and suburbs), on every week day, between 8:00 a.m and 6:00 p.m. The sample included 808 users, who were chosen randomly in different bus stops around the city. The interviewees' average age was 26. 77 years; 67% were female and 33% male.

The 808 interviewees were approached in different bus stops, including: squares, bus stations, bus stops and "tube type" bus stops.

With the purpose of documenting the actual noise levels in the buses, noise was measured in some of the most frequently mentioned models, according to the norms recommended by *ABNT*. The criteria used in the measurement of the sound pressure levels were: A-weighting sound; slow detection mode; 8 hour exposure time conversion rate equals to 5 dB (5 dB exchange rate) and 85 dBA criterion level. The collected values were computed in the form of average equivalent level (leq) and three positions in the buses were given importance: front seats (close to the driver and to the engine), seats in the middle of the vehicle and back seats. The measures were taken twice, once with the vehicle stationary and the other with the vehicle in movement. In every situation, the engine noise was taken into account along with the noises made by passengers, other vehicles passing by, etc. The measurement instrumentation included: a of sound pressure level meter, Quest model 215, a callibrator Quest model CA 15 and a octave filter Quest model OB 45.

The data from the questionnaires were typed into electronic spreadsheets, for subsequent statistical treatment using the program LEXICAL SPHINX. The main data are synthesized in the tables and graph, which are shown and discussed below.

4. SURVEY RESULTS

The interviewees' average daily bus usage is 2.24 times a day, and the mean time spent on the bus daily is 54.35 minutes. Concerning the reasons for usage, 52.48% of the sample use buses to go to work, 37.13% go to school and 13.,24% to go out.

Results regarding vehicle type use are shown in graph 1. The total number is higher than the observations number since some users take more than one bus to get to their destination, so multiple answers were accepted.

In order to verify how important users think the physical agent "noise" is, they were asked to identify negative points observed inside the buses. The results are shown in Table 1. The total number of answers is higher than the number of interviewees due to multiple answers.

When asked about the noise intensity inside the vehicles, 28.96% of the sample considered the noise as excessive, 58.91% considered it as moderate and 11% considered it low. In addition 48.76% of the sample indicated that the noise caused inconveniences, whereas 49.01% answered that it did not.

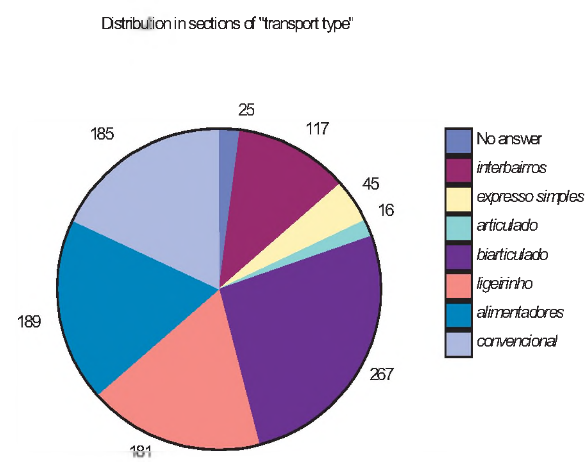

Figure 1: Number of interviewees using each bus type

Negative Points	Number of occurences	Percent of sample
Capacity	567	70.17%
Price	452	55.94%
Ventilation	335	41.46%
Schedules	331	40.97%
Noise	286	35.40%
Hygiene	219	27.10%
Comfort	181	22.40%
Lighting	36	4.46%
Other	45	5.57%

Table 1.: Negative points observed in the buses

The types of noise, users notice in the buses, are listed in Table 2. The total number of answers is higher than the number of interviewees due to multiple answers.

Noise source	Number of occurences	Percent of sample
Engine	351	43,44%
Opening of doors	177	21,91%
Traffic noise	176	21,78%
People talking	162	20,05%
Bell	153	18,94%
Announcer's voice	70	8,66%
Other	32	3,96%

Table 2: noise sources noticed by the interviewees

When questioned about looking for a specific place for sitting down in the buses, most people, 43.44%, reported not worrying about this. However, 26.49% preferred sitting down close to the doors, 13.61% preferred sitting down in the front seats, 7.8% in the middle seats and 10.27% in the back seats. When asked about the reason for this choice, 18.94% of the sample referred to comfort, 34.1% mentioned that they wanted to leave the vehicle quickly, and only 1.98% mentioned noise as the reason for their choice.

Interviewees were also asked if they noticed that noise inside the buses caused any noxious effects on their health. Table 3 shows the complaints related to the noise effects on users.

Effect / symptom	Number of occurences	Percent of sample
no symptoms	258	31,93%
Irritability	255	31,56%
Headache	201	24,88%
Lack of concentration	131	16,21%
Tinnitus	77	9,53%

Table 3: Effects of the noise on the bus users

Results show that 31.93% of the interviewees do not have any complaint regarding noise effects. Although 49.01% of the sample had not previously taken into account noise as a discomfort factor, 31.6% claim that noise in the buses causes irritability, 24.88% complain about headaches, and other complaints were also mentioned, including the ones literature indicates as being characteristic signs of exposure to high sound pressure levels.

The results of the noise level measurement are shown in Table 4. Predominant noise frequency in the vehicles is 31Hz. Sound pressure level is higher when the vehicle is in motion.

Moreover, the noise level is higher at the front of the buses, where the engine is located. The highest level found was 81 dB (A) in an *alimentador* type bus when in movement, and the lowest 58 dB (A) in a *biarticulado*, when it was stopped. In the vehicles that have announcing system the speech stimulus level during the messages presentation was 90 dB (A).

Bus type	Measure at the front		Measure at the middle		Measure at the back	
	A*	B*	A*	B*	A*	B*
Biarticulado	80	67	80	62	68	58
Ligeirinho	79	68	80	65	65	60
Alimentador	81	70	79	65	67	60
Convencional	80	68	80	67	68	61

* A represents vehicle in movement
* B represents vehicle stopped

Table 4: Sound pressure levels evaluation results in dBA according to the bus type and evaluation conditions

5. DISCUSSION

Hearing perception is an ability that depends on several capabilities, such as detecting sounds, discriminating, paying attention, selecting, analyzing, recognizing and understanding (Boothroyd, 1994). Selective attention is a very commonly used resource, whereby people concentrate their hearing attention on a certain stimulus in detriment of other stimulus.

Noise is linked to a non-pleasant sensation. Each being may present a different answer to noise, depending on their emotional state, the exposure circumstances, and their personality. This may explain the fact that most of our sample did not recognize noise as a negative point or a harmful agent to their health in the vehicles.

Noise was identified as a negative point inside the buses by 35.4% of the users. It therefore appeared in fifth place among the agents that cause discomfort to users; however, noise came right after the capacity, the price, the schedules and ventilation. Considering the fact that the predominant age group sampled was formed by young adults it is possible that the users could have been exposed to different noise forms since childhood and, therefore, are not inconvenienced by its presence. In research done by *Jornal da Tarde de São Paulo* Newspaper on July 3, 2002 about the conditions in certain buses in the Capital, price, capacity, schedule and noise were also targets of numerous complaints.

Although they did not consider noise as a source of discomfort; most of the respondents could identify greatest noise sources in the vehicles. 43.44% of the interviewees indicated the engine as the main noise source, which is corroborated by objective measures showing that the front part, close to the engine, was the noisiest place in the buses. It appears that users, used to the bus noise, do not spontaneously identify it as a noxious agent to health or as a discomfort factor, however when questioned they could point out the greatest noise source. These results may explain why noise is known as the invisible enemy, not allowing victims to be aware of the harm, because unlike other pollution types, it doesn't leave any tangible trace.

The noise from vehicles is one of the main contributors to the high noise levels observed in urban centers, and the complaints filed by the populations in these centers. *CONAMA* Resolutions 01/93 and 08/93, which went into effect on January 1, 1995, demand that new vehicles should follow a series of technical requirements, such as respect maximum emission of vehicular noise. In spite of the demands placed on new vehicles, some vehicles in use may be very noisy, especially the oldest ones that are not maintained appropriately.

In this study, noise levels of moving buses exceeded 70 dB(A), a level considered by WHO as a stressful factor for the human organism. In a research carried out by Carvalho (1997) about sound pollution in the urban buses of Belo Horizonte (Br) the noise levels found also exceeded the limits of WHO. Similarly, a research carried out by Patwardhan et al (1991) found high sound levels (from 89 to 106 dB) in drivers' booth.

An important issue to consider is that the average time spent on the bus is 54,35 minutes (to go to work, to go to school or to go out), and users present a series of complaints attributed to the noise, as for instance irritability (31,56%), headache (24,88%), lack of concentration (16,21%) and tinnitus (9,53%). In addition, bus drivers with a work day of approximately 6 hours should not be forgotten, as they could be the most harmfully affected people being exposed to increased noise effects. They are at risk for hearing loss due to occupational noise exposure, an effect documented by Talamini (1994) and Patwardhan et al. (1991). Therefore the inclusion of this professional category in the hearing loss prevention programs should be considered extremely important.

Vehicular traffic noise control measures are necessary and should involve a wide urban planning effort that promotes changes to the volume and the composition of the traffic, changes in the drawing and road pavement. Reduction of the runway width can reduce noise levels in buildings and on sidewalks due to the reduction of the traffic. The pavement type has a significant effect on urban noise, because it can reduce the noise levels by 3 to 5 dBA. Irregular material surfaces are likely to create an increase in the noise level (Barbosa et al. 1998).

Other alternatives for controlling vehicular noise include the limitation of the speed, with the installation of radars and electronic speed bumps, as well as increased awareness regarding driving style. Lower driving speeds lead to lower engine rotations and consequently, less noise. The exhaust of vehicles should be inspected in a careful way and car pooling areas should be created in the suburbs of the metropolises. Downtown, only light trucks should be allowed and in established schedules. Maintenance of streets and highways should be frequent. (Rapin, 1992)

Some noise control measures are being applied by several companies in the capital; however the initiatives are still very small and need wide administrative planning.

6. CONCLUSIONS

The data presented in this research show that most Curitiba bus users are not inconvenienced with the noise inside the vehicles and they do not recognize it as a noxious agent to their health. However, if there were more campaigns about hearing health, and the damages caused by noise, people may pay more attention to it and consequently they would demand solutions to fight it. Such steps could change this study's results.

Curitiba commuters' participation in this study represented an essential dimension of the evaluation process of the noise inside the vehicles. The hearing perception of the population was a precious instrument in the sense of alerting everyone who is involved with hearing health, that the noise is really an invisible enemy and that every day we are more and more habituated with it.

Future research on this subject, should look into the understanding of the population on the effects of urban noise. Professionals should initiate campaigns to guide and to inform the public regarding the noxious effects of noise, as well as possible steps to control this pernicious and noxious agent.

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APPENDIX 1

Survey Questionnaire

USER IDENTIFICATION

Name: Age: Gender:
Address: Profession:
Route used: Number of times a day:
Time spent on bus daily:
Why do you use the bus:
( ) transport from home to work
( ) transport from home to school
( ) to go out
( ) other

ROUTE IDENTIFICATION

Route:
Bust type: ( ) *interbairros ( ) expresso simples*
( ) articulado·
( ) biarticulado ( ) ligeirinho ( ) alimentadores
( ) convencional

Place of interview:

QUESTIONS

How long have you used the public transit in Curitiba?

Which are the negative points you identify in the commuter system?

( ) capacity ( ) hygiene ( ) noise ( ) price
( ) schedules ( ) comfort ( ) ventilation ( ) illumination
( ) other

Which aspects in the bus system do you believe are harmful to your health?

( ) hygiene ( ) comfort ( ) noise ( ) ventilation
( ) illumination ( ) other

Do you look for a particular seat when sitting on the bus?

( ) no ( ) in the front seats ( ) in the middle
( ) in the back seats
( ) close to the exit doors

Why?
( ) comfort ( ) it`s close to the exit ( ) lighting ( ) noise
( ) other

How would you rate the noise level in the buses?

( ) low ( ) moderate ( ) excessive

Does this noise annoy you?
( ) yes ( ) no
Which noise is the most inconvenient for you?

( ) engine ( ) people talking ( ) traffic noise
( ) bell ( ) opening of the doors ( ) the announcer's voice
( ) other

Does the noise interfere with your communication with other users on the bus?

( ) yes ( ) no

For you, the noise in the bus causes:

( ) irritability ( ) lack of concentration ( ) headache
( ) tinnitus
( ) nothing ( ) other

The noise in the bus makes impossible for you to:

( ) nothing ( ) talk ( ) read ( ) study
( ) rest ( ) listen to music ( ) other

Acoustics Standards Activity In Canada
2004 Update And Invitation To Participate

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ABSTRACT

This article is an update for 2004 of Acoustics Standards activities in Canada, especially those of the Canadian Standards Association. CSA currently has 10 Acoustics Standards and three more with significant acoustics content. More than twice that number of acoustics standards from other organisations, such as ANSI and ISO, have been reviewed and either endorsed or adopted as suitable for use in Canada. We intend in the coming year to replace these with a major omnibus standard which will act as a guide on the contents and use of all these standards. Canadian acousticians are invited to contact the author to become more involved with the many acoustics standards activities currently underway in Canada.

SOMMAIRE

Cet article est une mise à jour des activités de normalisation en acoustique au Canada pour 2003, spécialement celles de l'Association canadienne de normalisation (ACNOR). L'ACNOR a présentement 10 normes acoustiques et 3 autres comportant un contenu acoustique important. Plus du double de ce nombre de normes provenant d'autres organisations telles que ANSI et ISO ont été revues et soit endossées ou soit adoptées comme étant acceptable pour une utilisation au Canada. Pour l'année qui s'en vient, nous avons l'intention de remplacer celles-ci par un recueil majeur de normes qui va agir à titre de guide sur leur contenu et leur utilisation. Les acousticiens canadiens sont invités à contacter l'auteur pour s'impliquer dans les nombreuses activités en rapport avec les normes acoustiques actuellement en cours au Canada.

1. INTRODUCTION

Recently the author became chair of CSA Technical Committee Z107 – Acoustics and Noise Control. This committee and its subcommittees look after all but one of the 11 Canadian Acoustics Standards (rhe exception is Z94.2 Hearing Protection Devices, which has its own technical committee). Z107 coordinates all Canadian acoustics standards activity, with representatives from Z94.2 and from Canada's international standards effort providing liaison to their activities. The major goals of this article are to inform Canadian acousticians of progress in Canadian Standards activities and to invite those who are interested to become more involved with these activities. Participation is an excellent way to stay in touch with progress in the field and meet those who are leading it in many fields. It is also one of the best ways to stay in touch with this fast moving field. Any acoustician interested in becoming involved with Acoustics standards in Canada is invited to contact the author or any of the subcommittee chairs.

2. COMMITTEE ACTIVITIES

2.1 Z107 Acoustics and Noise Control

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

During the most recent executive meeting an initiative was started to more closely integrate Z107 and its subcommittees with the Standards Council's Canadian Advisory Councils for IEC TC 43 chaired by Stephen Keith. Specifically, this is one of several groups who review ISO and IEC acoustics standards and cast Canada's ballot for any draft international standards. The problem has always been to find sufficient people with the expertise to review all the diverse standards being reviewed. The Z107 solution for IEC TC43 would be to have each subcommittee chair assist Stephen in finding the most suitable member to assist with a particular standard. This initiative is still getting underway.

Another recent initiative is the development, under the guidance of Cameron Sherry, Editorial Subcommittee chair, of an omnibus standard which will replace the existing adopted and endorsed standards. The intent is to have a listing of all Canadian and International acoustics standards recommended and reviewed by Z107 with a brief description of each standard and what it is for. CSA would reissue this document annually in an electronic format so that it is kept constantly up to date. The hope is that this document will provide Canadian acousticians with a definitive list of national and international acoustics standards from a Canadian perspective. For example, guidance would be given on the most appropriate building acoustics standards from ISO and ASTM within the Canadian context.

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

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

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

Powered Machines, which no longer has standards of its own but recommends adopting or endorsing ANSI, SAE or ISO standards. Currently a search is underway for a chair. Otherwise the subcommittee will be disbanded.

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

- **Z107.51-M1980 (R1994)** Procedure for In-Situ Measurement of Noise from Industrial Equipment. This standard is being replaced with a series of international standards, within the framework of the new Z107.58 standard.
- **Z107.52-M1983 (R1994)** Recommended Practice for the Prediction of Sound Pressure Levels in Large Rooms Containing Sound Sources. This standard is in need of major updating and a chair is being sought to do this work. The intent is to provide guidance to Canadian industry on how to design quiet plants. It is seen as building upon Z107.58, which provides advice on buying quiet equipment.
- **Z107.53-M1982 (R1994)** Procedure for Performing a Survey of Sound Due to Industrial, Institutional, or Commercial Activities. This standard will be replaced with ISO1996, which will be balloted shortly. A working group chaired by Chris Krajewski and including several Ontario consultants examined using 1996 as a way of updating the way tonal and impulse sounds are handled in community noise[1]. They have run several round robin tests of the procedures with sample sounds[2]. Stephen Keith of Health Canada is acting as liaison with the ISO committee. Unfortunately, ISO recently came out with a new standard, which will require a re-examination of how the new standard fits the Canadian context. Meanwhile, 1996 will be balloted for adoption as a Canadian standard, with the deviations to be balloted later.
- **CAN3-Z107.54-M85 (R1993)** Procedure for Measurement of Sound and Vibration Due to Blasting Operations. A working group, chaired by Ramani Ramakrishnan and Vic Schroter, is revising this standard. This activity is just getting started.
- **CAN/CSA-Z107.55-M86** Recommended Practice for the Prediction of Sound Levels Received at a Distance from an Industrial Plant. A joint CSA/ANSI working group co-chaired by Rich Peppin and Tim Kelsall is looking at ISO9613. This standard was originally written by an ISO working group chaired by Joe Piercy of NRC. It may ultimately replace or become the basis for a revised version of Z107.55, however the group has identified a number of shortcomings which need to be addressed. A new draft has recently been pulled together and is being reviewed. A recent meeting of this working group in Ottawa was standing room only.
- **Z107.56-94** Procedures for the Measurement of Occupational Noise Exposure is referenced in Federal and some provincial regulations and has been updated by a working group chaired by Alberto Behar. At the subcommittee meeting in June 2002 it was decided to remove all reference to a 5 dB exchange rate although Ontario and Quebec still use it. The subcommittee felt that this exchange rate was no longer technically defensible and that only the 3 dB exchange rate should be used. Consultation with the provinces is ongoing, but a recent request by Ontario to revisit this issue was overwhelmingly turned down by the subcommittee members. The Editorial Subcommittee is currently reviewing this standard before the latest revision goes to ballot.
- **Z107.58-2002** Guidelines For Machinery Noise Emission Declarations Levels was written by a group chaired by Stephen Bly and was published[3] in 2003. It is a voluntary guide on noise emission declarations for machinery to be used in Canada and is compatible with European regulations to allow Canadian machinery to be sold into that market. It is intended to help workplace managers (purchasers) to purchase quieter machinery and plan noise control strategies. It does so by enabling manufactureres to formally provide sound-level data in an agreed format.

A Noise Emission Declaration is a statement of sound levels produced by equipment, which would usually be included with the instruction or maintenance manual. Measurements are made according to ISO standards and include estimates of the likely variability of the measurements. Canada recommends use of a declaration stating the level and uncertainty as two numbers, although in some cases they may be added together into a single number.

In addition, the Industrial Noise subcommittee undertakes reviews of proposed federal and provincial regulations,often at the request of the regulators, and other activities affecting industrial noise.

Transportation Noise, chaired by Soren Pedersen, is responsible for CAN/CSA-Z107.9-00: Standard for Certification of Noise Barriers. This standard is an adaptation of the Ontario MTO Highway Noise Barrier specification. It provides municipalities, developers, road and highway departments, railways and industry with a standard specification which can be used to define the construction of barriers intended to be durable enough for long term use in Canadian conditions.

Manufacturers and their specific barrier designs are certified as complying with the standard in such areas as: plant facilities, design concept, materials used, quality control, durability, and acoustical performance.

In addition, each barrier installation is reviewed and certified for compliance with such items as structural and foundation design, quality assurance, field assembly and installation.

The US Department of Transportation, Federal Highway Administration, Highway Noise Barrier Design Handbook is already harmonized with the CSA standard, as is the Ontario Provincial Standard, and numerous US state transportation agencies, making this the de-facto standard for barriers across North America.

Editorial, chaired by Cameron Sherry, (which reviews all proposed standards) and is responsible for reviewing and endorsing ANSI S1.1-1994 Acoustical Terminology. They are currently reviewing the latest revision to Z107.56. In addition, they will be the main group pulling together the omnibus standard from input by each subcommittee chair. Cameron is actively looking for new members to assist in this work and can be contacted directly or through the author.

Building Acoustics, chaired by David Quirt, does not have its own standards, but review other standards from a Canadian viewpoint, mostly from ASTM and ISO. The immediate task is review of endorsed standards on building acoustics (a large part of the current Z107 list) and preparation of appropriate entries for the new Z107 omnibus document. David Quirt is also chair of the Standards Council of Canada Steering Committee for ISO TC 43 SC2, Building Acoustics.

Instrumentation and Calibration, chaired by George Wong, which liases with Canadian activities on ANSI, IEC and ISO instrumentation standards and provides recommendations on Canadian use of these standards. They have been actively involved in ongoing work to prevent changes to the A-weighting at the international level. This subcommittee is harmonised with the Standards Council of Canada Steering Committee for IEC Acoustical Instrumentation standards, TC29.

Liaison with the Canadian Steering Committee for ISO TC43 (Acoustics) and TC43(1)(Noise), chaired by Stephen Keith provides Canadian comments and votes on ISO standards and coordinates the work of Canadian representatives on several ISO working groups. The Steering committee is run by the Standards Council of Canada and is harmonised with the Z107 committee to which Stephen reports regularly on progress. Draft international standards are provided on a private website to which members have access in order to review them and recommend Canada's position. Stephen is working closely with Z107 to expand the pool of reviewers.

2.2 Z94 – Hearing Protection

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

3. Canadian Acoustics Standards

Table 1 shows all the Canadian Standards currently in force and also lists three standards with significant acoustical content. This table will also soon be found at the CAA website and will be kept up to date there. Meanwhile the list can be found at
http://www.csa-intl.org/onlinestore/GetCatalogDrillDown.asp?Parent=430
although at the time of writing, the following list was more up to date.

There are also 24 acoustics standards from ANSI, ISO and ASTM endorsed by Canada. They are listed in Table 1 following the CSA standards.

Table 1- CSA Acoustics Standards

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

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

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

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

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

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

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

Z107.56-94 Procedures for the Measurement of Occupational Noise Exposure / Méthode de mesure de l'exposition au bruit en milieux de travail

Z107.58-2002 Guidelines For Machinery Noise Emission Declarations

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

Standards with Acoustics Component:

Z62.1-95 Chain Saws
CAN/CSA-Z412-M00 Office Ergonomics / L'ergonomie au bureau
CAN/CSA-M5131-97 (R2002) Acoustics - Tractors and Machinery for Agriculture and Forestry - Measurement of Noise at the Operator's Position - Survey Method (Adopted ISO 5131:1996)

Endorsed Standards

ANSI S1.1-1994 Acoustical Terminology(R1999)
ANSI S1.4-1983 Specification for Sound Level Meters (R2001)
ANSI S1.11-1986 Specifications for Octave-band and Fractional (R1998) Octave-band Analog and Digital Filters
ANSI S1.13-1995 Measurement of Sound Pressure Levels in Air (R1999)
ANSI S12.31-1990 Precision Methods for the Determination of (R1996) Sound Power Levels of Broad-band Noise Sources in Reverberation Rooms
ANSI S12.32-1990 Precision Methods for the Determination of (R1996) Sound Power Levels of Discrete-frequency and Narrow-band Noise Sources in Reverberation Rooms
ANSI/ASTM Standard Test Method for Sound Absorption and C423:00 Sound Absorption Coefficients by the Reverberation Room Method
ANSI/ASTM Standard Test Method for Laboratory E492-90 (1996) E1 Measurement of Impact Sound Transmission Through Floor-ceiling Assemblies Using the Tapping Machine
ASTM C384-98 Standard Test Method for Impedance and Absorption of Acoustical Materials by the Impedance Tube Method
ASTM E90-99 Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements
ASTM E336-97 Standard Test Method for Measurement of Airborne Sound Insulation in Buildings
ASTM E596-96 Standard Test Method for Laboratory Measurement of the Noise Reduction of Sound-isolating Enclosures
ASTM E795-00 Standard Practices for Mounting Test Specimens During Sound Absorption Tests
ASTM E966-99 Standard Guide for Field Measurement of Airborne Sound Insulation of Building Facades and Facade Elements
ASTM E989-89 Standard Classification for Determination of (1999) Impact Insulation Class (IIC)
ASTM E1007-97 Standard Test Method Field Measurement of Tapping Machine Impact Sound Transmission Through Floor-ceiling Assemblies and Associated Support Structures
IEC 60651-2001 Sound Level Meters
ISO 4872-1978 Acoustics – Measurement of Airborne Noise Emitted by Construction Equipment Intended for Outdoor Use – Method for Determining Compliance with Noise Limits
ISO 6393:1998 Acoustics – Measurement of Exterior Noise Emitted by Earth-moving Machinery – Stationary Test Conditions
ISO 6394:1998 Acoustics – Measurement at the Operator's Position of Noise Emitted by Earth-moving Machinery – Stationary Test Conditions
ISO 6395-1988 Acoustics – Measurement of Exterior Noise Emitted by Earth-moving Machinery – Dynamic Test Conditions
ISO 6395:1998 Acoustics – Measurement of Exterior Noise Emitted by Earth-moving Machinery – Dynamic Test Conditions – Amendment 1
SAE J919-1995 Sound Measurement – Off-road Work Machines – Operator Singular Type
SAE J1096-2000 Measurement of Exterior Sound Levels for Heavy Trucks under Stationary Conditions

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3. Stephen Keith, Stephen Bly, Tim Kelsall, A preview of the Draft CSA Guideline – Noise Emission Declarations for Machinery, Canadian Acoustics, Volume 29, No. 3, September, 2001

Canada Wide Science Fair

From File Reports

Benjamin Schmidt is the winner of this year's Special Award from the Canadian Acoustics Association for his project - Robotic Sound Localization.

Benjamin Schmidt earned the Canadian Acoustical Association Award ($400) for "An outstanding project related to Acoustics, the science of sound," and a Senior Engineering Science Honourable Mention ($100). Benjamin is a student at Centre Wellington District High School, Fergus, Ontario. Ben was a member of Team-Canada at the Intel Science and Engineering Fair this spring in Portland, Oregon. He was awarded Acoustical Society of America First Award ($500) (Each winner also receives a one-year ASA membership). Society of Exploration Geophysicists Award of Merit ($250), for projects that display excellence related to the geophysical sciences.

Editor's Note: We are very happy to note that Benjamin Schmidt submitted a brief summary of his project work that won the prize at the fair. His full article is reproduced below.

ROBOTIC SOUND LOCALIZATION*

Benjami Schmidt
Grade 11, Centre Wellington District High School, Fergus, Ontario, jambschm@golden.net
Winner of the CAA Youth Science Foundation Award, 2004

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

ABSTRACT

The purpose of this project was to build a system capable of estimating the direction of a sound source using a static array of sensors without measuring time delays. Such a system would aid in tracking a robotic vehicle over a short range and is a prototype for a radio-based tracking system. The project consisted of several parts, the first of which was the construction of an adjustable sound source, providing a constant amplitude and variable voltage. After testing many designs, a crystal earphone and a square wave tone source were used as the sound source. Next, a sound sensor consisting of a microphone and a housing to make the microphone response directional were constructed. Circuitry to convert the amplitude of the sound into a DC voltage, to be able to read by a microcontroller, was built. Several designs for directional sound sensors were tested. By rotating the sensor and sampling at different angles, the data that would be generated by a group of sensors pointing in different directions, was simulated. A static array based on the simulations, consisting of seven sensors arranged radially at 35° intervals, were used for the final design. A second-order polynomial regression was used as the basis of an algorithm to estimate the angle to the sound source. Experiments to determine the effect of the signal frequency, sampling protocols and microphone housing design on the accuracy of the angle estimates, were conducted. The best results were obtained for a frequency of 2.15 kHz. At distances of 50cm-100cm, the final array design was able to locate the direction of the sound source with an accuracy of about ±3°.

1.0 Introduction

Using only auditory cues, humans can easily locate the source of a sound. Most of the time one doesn't even notice when people orient themselves towards a speaker. Sound localization can be accomplished without head movement using binaural hearing. Two basic mechanisms are usually applied in source localization by human ears - interaural time differences (ITD) and interaural level differences (ILD). An automated system capable of similar localizing of sound sources would have many applications, including short-range tracking of mobile robots. The purpose of this project was to create a stationary tracking system capable of estimating the azimuthal angle of a receiver relative to a sound source.

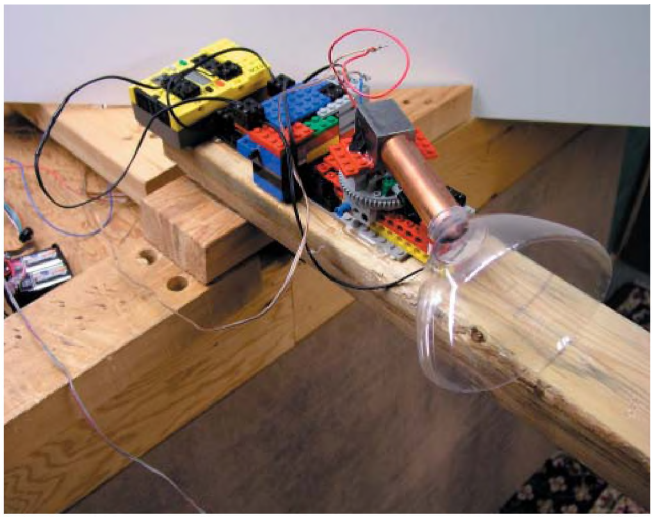


Figure 1. Tone Source Set-up

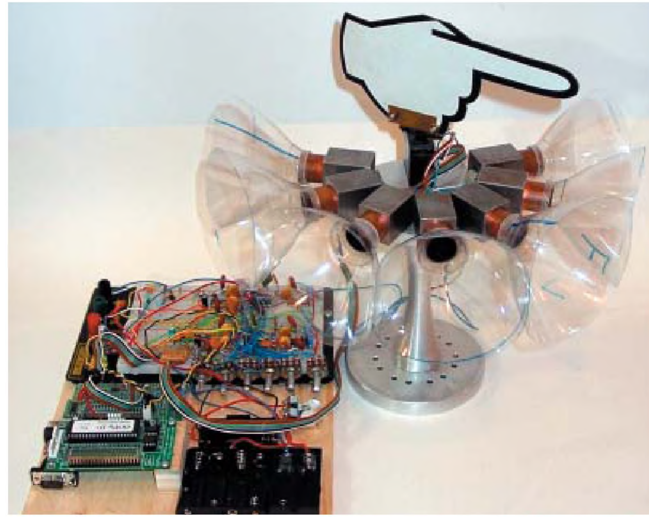


Figure 2. The Sensor Array

The system used, was based on an ILD approach, using the directional differences in sound amplitude detected by each sensor in a static array to determine the angle relative to the sound source.

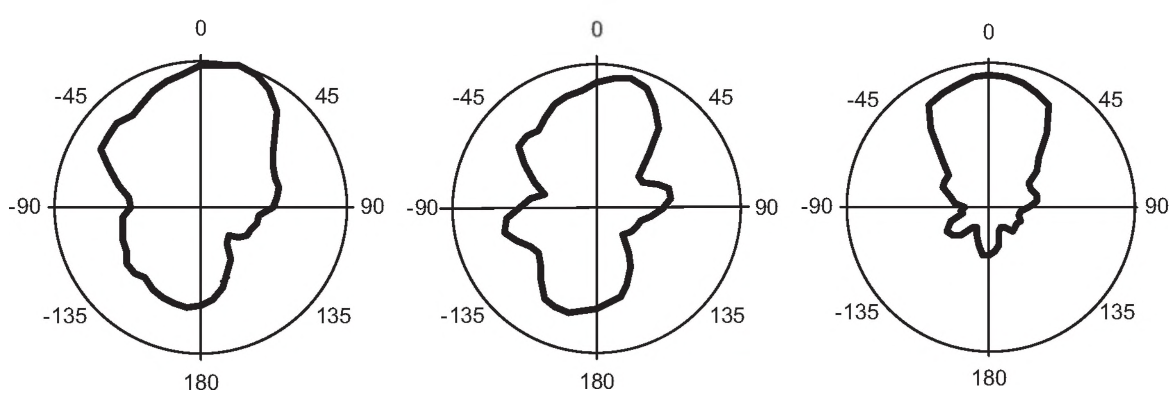
2.0 Procedure

First, a reliable tone source was constructed and tested. The test source had fixed amplitude, a controllable frequency and an omnidirectional speaker housing. The final design used a variable-frequency square wave generator and a crystal earphone as the sound source. Next, the required circuitry was designed and tested to convert the amplitude of sound waves detected by a microphone into a DC voltage that could be read as an input by a computer. One also needed a housing for the microphone that ensured that its sensitivity was directional. Because of the complexity of interactions between factors such as reflections, refraction, interference and resonance, it was necessary to test the housing designs experimentally. A computer-controlled turntable allowed one to test the proposed designs at specific angles relative to the sound source. The basic housing structure had a single opening, a short tube of adjustable length, and space for a cone and/or baffle. The directional characteristics of different housing designs using various funnel sizes, tube lengths and signal frequencies, were tested.

Using the data from the turntable experiments, one was able to simulate static arrays of different numbers and arrangements of sensors. An algorithm that fitted the signal strength data from specific, known angles to a parabolic curve was developed. The maximum value of the regression estimated the angle to the sound source. Based on the simulation results using a single microphone, a static radial array of seven sensors, spaced 35 degrees apart, was built. The accuracy and precision of the estimated azimuthal angle using the same funnel sizes, tube lengths and signal frequencies that had been tested on the turntable were also measured.

3.0 Results and Discussion

Figure 3 shows examples of data collected using the turntable. The graphs show the responses of three sensor designs incorporating different microphone housings.



(a) No Tube or Cone (b) Tube c) Tube and Cone

Figure 3. Sample Angle Versus Intensity Graphs For Three Sensor Designs.

Angle Relative to Sound Source	Number of Sensors Used for Polynomial Regression				
	3	4	5	6	7
0°	-2.9 ± 2.9	-28.1 ± 11.9	5.7 ± 3.6	-5.5 ± 5.0	8.9 ± 4.3
17.5°	21.3 ± 2.9	-68.9 ± 5.9	37.9 ± 11.4	13.6 ± 9.2	20.7 ± 23.5

Table 1. Mean Estimated Angles ± S.D. Using Different Numbers Of Points For Calculation.

Tube Length (cm)	Cone mouth Diameter (cm)	Estimated angle to sound source (Actual Angle: 0 degrees)	Estimated angle to sound source (Actual Angle: 17.5 degrees)
4.0	10.5	-3.0 ± 1.6	15.7 ± 2.5
5.0	10.5	-1.5 ± 1.2	30.6 ± 10.5
5.0	8.0	1.7 ± 2.9	-38.4 ± 374.8
5.0	2.0	2.5 ± 6.8	64.6 ± 197.2
8.0	8.0	9.5 ± 16.3	29.7 ± 23.5
8.0	10.5	3.3 ± 3.4	27.0 ± 8.4
8.0	10.8	0.5 ± 2.4	28.1 ± 23.3
8.0	2.0	-12.0 ± 93.0	-28.4 ± 24.4
4.0	8.0	1.3 ± 5.5	3.2 ± 7.5
4.0	10.8	1.8 ± 1.6	-47.6 ± 131.0
4.0	8.0	1.9 ± 2.2	15.0 ± 8.1
4.0	10.5	-1.3 ± 1.5	10.2 ± 2.9
4.0	10.8	-0.2 ± 2.4	15.8 ± 2.0

Table 2. Calculated angles and standard deviations for different combinations of cones and tubes.

Intensity was measured as the peak amplitude of the incoming signal. Sound source was located at 0 degrees and the source frequency was 2150 Hz.

The plot shown in Figure 3c was obtained using the design that was selected for the static array. The housing had a 2 cm wide tube that was 4 cm long, and a 7 cm long funnel that was 10.5 cm wide. Between –52.5 degrees and +52.5 degrees the signal amplitude is a smooth curve that resembles a parabola. Therefore, a quadratic function can be used to model the data, and its maximum value will be near zero degrees.

Many simulations, using both turntable and static array data, were conducted. Table 1 shows the results of an experiment using different numbers of sensors for the angle estimation. Data in Table 1 was generated using a static radial array of 7 sensors spaced 35 degrees apart. Distance from source to array was 50 cm and each trial consisted of 100 observations.

If seven detectors are spaced 35 degrees apart, three sensors will always fall within the range of the curve (±52.5 degrees). However, the use of data from sensors other than the three that register the largest response decreases the accuracy and precision of the system. The relationship between signal frequency and the accuracy of the estimated angle using the static array was complex. The directional gain of the sensors, and the resulting accuracy of the estimated angle, would

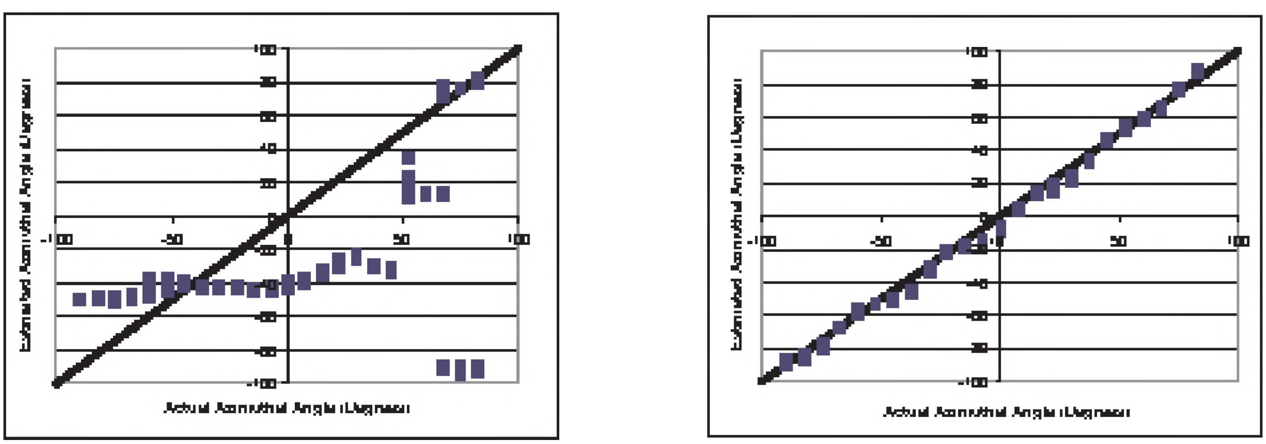


Figure 4. Actual versus estimated angles using two sensor housings: tube only (L) and tube and funnel (R). The black line represents perfect estimation.

depend on the dimensions of the cone and tube relative to the wavelength of the sound. Testing demonstrated that 2150Hz generated the most accurate results. This frequency was related to the structure of the sensor, the length of the tube (4 cm) being approximately ¼ wavelength. Having selected a frequency for the sound source, the array using the same combinations of cone and tube dimensions that had been tested on the turntable was tested. The design selected based on the results from a single sensor (4 cm long tube, 10.5 cm wide funnel) produced the most accurate and precise angle estimated (Table 2). This confirmed the trends seen in the turntable experiments. The conditions for the data shown in Table 2 were: distance to sound source 100 cm, and the sound frequency 2150 Hz. Each treatment consisted of 20 observations. Data was generated using a static radial array of 7 sensors, 35 degrees apart.

At a distance of 50 cm, the final array design could locate the direction of the sound source with an accuracy of about ±3 degrees (Figure 4). Data, shown in Figure 4 was based on 10 samples at each angle (-90 degrees to +90 degrees) in 7.5 degree increments, taken at a distance of 50 cm and at a frequency of 2150 Hz.

The system was very susceptible to environmental noise. Use of multiple samples compensated for some of the noise, but this did not eliminate biases introduced by such acoustical effects as reflected signals from fixed surfaces in the vicinity of the array.

4.0 Conclusions

The current investigation has shown that it is possible to determine the direction of a sound source with a single static array of directional sensors. Because it does not move, it can calculate the position more quickly than a rotating detector and it is not subject to mechanical failure. The accuracy of this system is comparable to that reported for humans (Yost 2000). It may be possible to further refine the system using genetic or neural programming instead of polynomial regression, improving the sensor design, or incorporating phase and timing measurements into the calculations. Furthermore, it should be possible to use a similar process with directional radio antennae. Such a system would have a greater range, and could be used to track wildlife, cell phones or a robot exploring on the surface of another planet.

Acknowledgements

I would like to acknowledge Mr. Priester, my manufacturing teacher, for helping me to design and fabricate components. Dr. Graeme Cairns provided ideas from the world of underwater exploration. And finally, thanks are due to my father and mentor, Mr. Jonathan Schmidt.

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vi. www.oopic.com Documentation for the OOPic microcontroller
vii. www.prosoundweb.com/install/spotlight.cardioid.cardioidmics.shtml How a cardioid microphone works.
viii. www.shure.com/support.technotes/app-micreach.html How directional microphones work.
ix. www.wikipedia.org/wiki/Microphone Microphone types, directionality and recording techniques.

NEWS / INFORMATIONS

CONFERENCES

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

2004

8-10 December: 10th Austrailian International Conference on Speech Science and Technology. Sydney, Australia. Web: www.assta.org

2005

14-17 March: 31st Annual Meeting of the German Acoustical Society (DAGA). Munich, Germany. Web: www.daga2005.de

15-17 March: Spring Meeting of the Acoustical Society of Japan. Nakaura 5th Bldg., 2-18-20 Sotokanda, Chiyoda-ku, Tokyo 101-0021, Japan. Fax +81 3 5256 1022, Web: www.asl.gr.jp/index-en.html

19-23 March: International Conference on Acoustics, Speech, and Signal Processing. Philadelphia, PA, USA. Web: www.icassp2005.org

21-22 March: Sonar Transducers and Numerical Modelling in Underwater Acoustics. Teddington, UK. Fax: +44 1727 850553, Web: www.npl.co.uk/acoustics/events/ioaconference2005

18-21 April: International Conference on Emerging Technologies of Noise and Vibration Analysis and Control. Saint Raphael, France. Fax: +33 4 72 73 87 12, email: goran.pavic@insa-lyon.fr

16-19 May: SAE Noise and Vibration Conference, Grand Traverse Resort, Traverse City Michigan. Contact: Mrs. Patti Kreh, SAE International, 755 W Big Beaver Rd, Ste 1600, Troy, Michigan, 48084. Tel: (248) 273-2474, E-mail: pkreh@sae.org

16-20 May: 149th Meeting of the Acoustical Society of America, Vancouver, BC, Canada. Contact: Acoustical Society of America, Suite 1NO1, 2 Huntington Quadrangle, Melville, NY 11747-4502; Tel: 516-576-2360; Fax: 516-576-2377; E-mail: asa@aip.org; Web: asa.aip.org

23-26 May: Alberta Acoustical Society Spring Conference on Environmental and Occupational Noise. Banff, Alberta. Web: www.eub.gov.ab.ca/BBS/new/announcements

1-3 June: 1st International Symposium on Advanced Technology of Vibration and Sound. Hiroshima, Japan. Web: http://dezima.ike.tottori-u.ac.jp/vstech2005

20-23 June: IEEE Oceans05 Europe. Brest, France. Web: www.oceans05europe.org

23-24 June: 2nd Congress of the Alps-Adria Acoustics Association (AAAA2005). Opatija, Croatia. Web: http://had.zea.fer.hr

CONFÉRENCES

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

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8-10 decembre: 10th Austrailian Internationale Conference sur Speech Science et Technology Sydney, Australia. Web: www.assta.org

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14-17 mars: 31st Annual Meeting de l'Acoustica Society du Germany (DAGA). Munich, Germany. Web www.daga2005.de

15-17 mars: printemps Meeting de l'Acoustical Society du Japan. Nakaura 5th Bldg., 2-18-20 Sotokanda Chiyoda-ku, Tokyo 101-0021, Japan. Fax +81 3 5256 1022, Web: www.asl.gr.jp/index-en.html

19-23 mars: Conference Internationale sur Acoustics Speech, et Signal Processing. Philadelphia, PA, USA Web: www.icassp2005.org

21-22 mars: Sonar Transducers et Numerical Modelling dans Underwater Acoustics. Teddington, UK. Fax: +44 1727 850553, Web www.npl.co.uk/acoustics/events/ioaconference2005

18-21 avril: Conference International sur Emerging Technologies de Noise et Vibration Analysis et Control Saint Raphael, France. Fax: +33 4 72 73 87 12, email goran.pavic@insa-lyon.fr

16-19 mai: SAE Noise and Vibration Conference, Grand Traverse Resort, Traverse City Michigan. Contact: Mrs Patti Kreh, SAE International, 755 W Big Beaver Rd Ste 1600, Troy, Michigan, 48084. Tel: (248) 273-2474 E-mail: pkreh@sae.org

16-20 mai: 149e rencontre de l'Acoustical Society o America, Vancouver BC, Canada. Info: Acoustica Society of America, Suite 1NO1, 2 Huntington Quadrangle, Melville, NY 11747-4502; Tél.: 516-576-2360; Fax: 516-576-2377; Courriel: asa@aip.org; Web asa.aip.org

23-26 mai: Alberta Acoustical Society Spring Conference on Environmental and Occupational Noise Banff, Alberta. Web www.eub.gov.ab.ca/BBS/new/announcements

1-3 juin: 1st Symposium International sur Advanced Technology de Vibration et Sound. Hiroshima, Japan Web: http://dezima.ike.tottori-u.ac.jp/vstech2005

20-23 juin: IEEE Oceans05 Europe. Brest, France Web: www.oceans05europe.org

23-24 juin: 2nd Congress de l'Association Acoustique Des Alps-Adria (AAAA2005). Opatija, Croatia. Web http://had.zea.fer.hr

28 June - 1 July: International Conference on Underwater Acoustic Measurements: Technologies and Results. Heraklion, Crete, Greece. Web: http://UAmeasurements2005.iacm.forth.gr

04-08 July: Turkish International Conference on Acoustics 2005. Web: www.tica05.org/tica05

11-14 July: 12th International Congress on Sound and Vibration (ICSV12). Lisbon, Portugal. Web: www.icsv12.ist.utl.pt

18-21 July: 17th International Symposium on Nonlinear Acoustics (ISNA 17). Pennsylvania State University, PA, USA. Web: http://outreach.psu.edu/c&i/isna17

6-10 August: Inter-Noise, Rio de Janeiro, Brazil. Web: www.internoise2005.ufsc.br

28 August - 01 September: World Congress on Ultrasonics Merged with Ultrasonic International (WCU/UT05), Web: www.ioa.ac.cn/wcu-ui-05

28 August – 2 September: Forum Acusticum Budapest 2005, Budapest, Hungary. Fax: +36 1 202 0452; Web: www.fa2005.org; E-mail: sea@fresno.csic.es

4-8 September: 9th Eurospeech Conference, Lisbon, Portugal. Contact: Fax: +351 213145843. Web: www.interspeech2005.org

4-8 September: 9th Eurospeech Conference (EUROSPEECH2005). Lisbon, Portugal. Web: www.interspeech2005.org

5-9 September: Boundary Influences in High Frequency, Shallow Water Acoustics. Bath, UK (Details to be announced later)

11-15 September: 6th World Congress on Ultrasonics (WCU 2005). Beijing, China. Web: www.ioa.ac.cn/wcu2005

14-16 September: Autumn Meeting of the Acoustical Society of Japan. Sendai, Japan. Web: www.asj.gr.jp/index-en.html

18-21 September: IEEE International Ultrasonics Symposium. Rotterdam, The Netherlands. Web: www.ieee-uffc.org

27-29 September: Autumn Meeting of the Acoustical Society of Japan. www.asj.gr.jp/index-en.html

17-21 October: 150th Meeting of the Acoustical Society of America JOINT with NOISE-CON 2005, Minneapolis, Minnesota. Contact: Acoustical Society of America, Suite 1NO1, 2 Huntington Quadrangle, Melville, NY 11747-4502; Tel: 516-576-2360; Fax: 516-576-2377; E-mail: asa@aip.org; Web: asa.aip.org

19-21 October: 36th Spanish Congress on Acoustics and 2005 Iberian Meeting on Acoustics. Terrassa-Barcelona, Spain. Web: www.ia.csic.es/sea/index.html

2006

15-19 May: IEEE International Conference on Acoustics, Speech, and Signal Processing (IEEE ICASSP 2006). Toulouse, France. Web: http://icassp2006.org

5-7 June: 6th European Conference on Noise Control (Euronoise2006). Web: www.acoustics.hut.fi/asf

28 juin - 1 juillet: Conference Internationale sur Underwater Acoustic Measurements: Technologies and Results. Heraklion, Crete, Greece. Web: http://UAmeasurements2005.iacm.forth.gr

04-08 juillet: Turkish International Conference sur Acoustics 2005. Web: www.tica05.org/tica05

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18-21 juillet: 17th Symposium Internationale sur Nonlinear Acoustics (ISNA 17). Pennsylvania State University, PA, USA. Web: http://outreach.psu.edu/c&i/isna17

6-10 août: Inter-Noise, Rio de Janeiro, Brésil. Web: www.internoise2005.ufsc.br

28 août - 01 septembre: World Congress on Ultrasonics Merged with Ultrasonic International (WCU/UT05), Web: www.ioa.ac.cn/wcu-ui-05

28 août – 2 septembre: Forum Acusticum Budapest 2005, Budapest, Hongrie. Fax: +36 1 202 0452; Web: www.fa2005.org; E-mail: sea@fresno.csic.es

4-8 septembre: 9e Conférence d'Eurospeech, Lisbon, Portugal. Contact: Fax: +351 213145843. Web: www.interspeech2005.org

4-8 septembre: 9th Eurospeech Conference (EUROSPEECH2005). Lisbon, Portugal. Web: www.interspeech2005.org

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14-16 septembre: Autumn Meeting de la Society Acoustical du Japan. Sendai, Japan. Web: www.asj.gr.jp/index-en.html

18-21 septembre: IEEE International Ultrasonics Symposium. Rotterdam, The Netherlands. Web: www.ieee-uffc.org

27-29 septembre: Autumn Meeting de l'Acoustical Society du Japan. www.asj.gr.jp/index-en.html

17-21 octobre: 150e rencontre de l'Acoustical Society of America AVEC NOISE-CON 2005, Minneapolis, Minnesota. Info: Acoustical Society of America, Suite 1NO1, 2 Huntington Quadrangle, Melville, NY 11747-4502; Tél.: 516-576-2360; Fax: 516-576-2377; Courriel: asa@aip.org; Web: asa.aip.org

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15-19 mai: IEEE Conference Internationale sur Acoustics, Speech, et Signal Processing (IEEE ICASSP 2006). Toulouse, France. Web: http://icassp2006.org

5-7 juin: 6th European Conference on Noise Control (Euronoise2006). Web: www.acoustics.hut.fi/asf

5-9 June: 151st Meeting of the Acoustical Society of America, Providence, Rhode Island. Contact: Acoustical Society of America, Suite 1NO1, 2 Huntington Quadrangle, Melville, NY 11747-4502; Tel: 516-576-2360; Fax: 516-576-2377; E-mail: asa@aip.org; Web: asa.aip.org

26-28 June: 9th Western Pacific Acoustics Conference. Seoul, Korea. Web: www.wespac8.com/WespacIX.html

3-7 July: 13th International Congress on Sound and Vibration (ICSV13). Vienna, Austria. Http://info.tuwien.ac.at/icsv13

13-15 September: Autumn Meeting of the Acoustical Society of Japan. Web: www.asj.gr.jp/index-en.html

17-21 September: Interspeech 2006 - ICSLP. Web: www.interspeech2006.org

28 November – 2 December: 152nd meeting, 4th Joint Meeting of the Acoustical Society of America and the Acoustical Society of Japan, Honolulu, Hawaii. Contact: Acoustical Society of America, Suite 1NO1, 2 Huntington Quadrangle, Melville, NY 11747-4502; Tel: 516-576-2360; Fax: 516-576-2377; E-mail: asa@aip.org; Web: asa.aip.org

3 - 6 December: INTER-NOISE 2006, Honolulu HA, USA (Same Hotel at ASA meeting the week preceeding)

2007

17-20 April. IEEE International Congress on Acoustics, Speech, and Signal Processing (IEEE ICASSP 2007). Honolulu, HI, USA

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

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

2-7 September 19th International Congress on Acoustics (ICA2007), Madrid Spain. (SEA, Serrano 144, 28006 Madrid, Spain; Web: www.ia.csic/sea/index.html)

9-12 September: ICA2007 Satellite Symposium on Musical Acoustics (ISMA2007). Barcelona, Spain. Web: www.ica2007madrid.org

2008

23-27 June: Joint Meeting of European Acoustical Association, Acoustical Society of America, and Acoustical Society of France. Paris, France E-mail: phillipe.blanc-benon@ec-lyon.fr

5-9 juin: 151e rencontre de l'Acoustical Society o America, Providence, Rhode Island. Info: Acoustica Society of America, Suite 1NO1, 2 Huntingtor Quadrangle, Melville, NY 11747-4502; Tél.: 516-576 2360; Fax: 516-576-2377; Courriel: asa@aip.org; Web asa.aip.org

26-28 juin: 9e Conférence Western Pacific Acoustics Seoul, Korea. Web: www.wespac8.com/WespacIX.html

3-7 juillet: 13th Congress Internationale sur Sound e Vibration (ICSV13). Vienna, Austria Http://info.tuwien.ac.at/icsv13

13-15 septembre: Autumn Meeting de l'Acoustica Society du Japan. Web: www.asj.gr.jp/index-en.html

17-21 septembre: Interspeech 2006 - ICSLP. Web www.interspeech2006.org

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

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17-20 avril. IEEE Congress Internationale su Acoustics, Speech, et Signal Processing (IEEE ICASSF 2007). Honolulu, HI, USA

9-12 juillet: 14th Congress Internationale sur Sound e Vibration (ICSV14). Cairns, Australia. Email n.kessissoglou@unsw.edu.au

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

2-7 septembre 19e Congrès international su l'acoustique (ICA2007), Madrid Spain. (SEA, Serranc 144, 28006 Madrid, Spain; Web www.ia.csic/sea/index.html)

9-12 septembre: ICA2007 Satellite Symposium su Musical Acoustics (ISMA2007). Barcelona, Spain Web: www.ica2007madrid.org

2008

23-27 juin: Rencontre jointe de l'European Acoustica Association, l'Acoustical Society of America, e l'Acoustical Society of France. Paris, France E-mail phillipe.blanc-benon@ec-lyon.fr

Canadian Acoustical Association

Minutes of the Board of Directors Meeting
5 October 2004
Ottawa, Ontario

Present: S. Dosso (chair), D. Giusti, D. Quirt, C. Buma, A. Behar, M. Cheng
C. Giguère, M. Hodge, R. Ramakrishnan, J. Bradley

Regrets: V. Parsa, R. Panneton, D. Stredulinsky

The meeting was called to order at 5:30 p.m. After a brief review of progress on action items, the minutes of Board of Directors meeting on 30 May 2004 were approved as published in Canadian Acoustics (June 2004 issue). *(moved A. Behar, seconded R. Ramakrishnan, carried).*

President's Report

Stan Dosso reported that there have been no major changes or problems in the affairs of the Association.

Secretary's Report

David Quirt reported that gradual increase in membership has continued through FY2003/04. Before the conference, total paid membership was 366 (an increase of 33). The number of Sustaining Subscribers is also up. About 84% of the members are from Canada.

Mailing list (1 October)	Canada	USA	Other	Change
Member	201	20	11	**+20**
Emeritus	2			–
Student	53	1	5	**+8**
Sustaining	36	3	1	**+3**
Direct	7	1	3	–
Indirect	10	6	6	**+2**
		Total = 366		**+33**

To ease membership renewal, the Secretary and Treasurer have continued the option of payments by VISA, and 35% used this method. This year several measures were introduced to counter the typical non-renewal by 10-15% of members; this has improved the renewal rate to 93%. To improve use of e-mail for CAA communication, and to reduce errors in mailing Canadian Acoustics, systematic updating of all membership address data including e-mail was added to the renewal process.

Secretarial operating costs for FY2002/03 were $970.10, mainly for mailing costs and postal box rentals; these costs have been limited by eliminating paid administrative support. Issues of Noise News International were mailed as they arrived, to the 39 members who have requested this optional service, but shipment from the printer in the USA has been <u>very</u> erratic. A budget increase for the next fiscal year to $1100 was requested (to cover increased mailing costs) and immediate transfer of $1000 from the Treasurer was requested.

(R. Ramakrishnan moved acceptance of report and the approval of the funding transfer, seconded A. Behar, carried)

Treasurer's Report

The Treasurer, Dalila Giusti, submitted a report and a financial statement prepared by our auditor, Paul A. Busch, for the fiscal year ending August 31, 2004. It was a good year financially. Interest on our capital fund ($9600) exceeded the $7700 requirement for prizes this year. Most major expenses were under budget, and the conference in Edmonton made a profit. Overall, total assets at year-end had risen to $250,228.

Movement of $10,000 from the operating to the capital fund was authorized. (Moved D. Giusti, second by A. Behar, carried). After further discussion of the balance in all funds, a further $15,000 transfer from operating to capital, and investment of $25,000 from the capital fund, were proposed. (Moved A. Behar, second R. Ramakrishnan, carried)

A draft budget for FY2004/05 was presented and discussed. Given the slowly rising membership, and small increases forecast in most expenses, the margin of revenue over expenses should be $1000 if fees are held constant and the conference in Ottawa has no excess revenue (which seems pessimistic). After extensive discussion, it was decided that no increase would be recommended in membership/subscription fees. The Treasurer's detailed budget plan, and her accurate budget forecast for the past year were commended by the Board. The Treasurer repeated her wish for a successor, but the Board clearly expressed their enthusiasm for her continued service.

(Mark Cheng moved acceptance of Treasurer's report, C. Buma seconded, carried)

Editor's Report

The Editor, Ramani Ramakrishnan, presented a brief report. A number of specific issues related to content, appearance, and publication process for *Canadian Acoustics* were discussed. The special issue in June based on papers from a conference in underwater sound was commended. The Board endorsed the Editor's plan to publish a similar issue for a planned conference in Banff next spring. There were a few problems requiring editing of the nominally publication-ready pdf files submitted by authors for the September issue, and it was agreed that the Editor should continue with all available methods to promote uniform appearance of articles in the conference issue next year. Despite the few problems, the September issue looked great and was ready 2 days after receipt of the pdf files from Ottawa, thanks to the excellent organization of the submissions by Brad Gover.

Ramani announced that he has a comfortable backlog of publishable papers, with many from international sources. The relationship with the current printer is very smooth, and each issue goes out promptly. Overall, the publication is proceeding smoothly with steadily increasing technical content, and the Board expressed their thanks for the huge effort by the Editor.

(D. Giusti moved acceptance of Editor's report, C. Giguerre seconded, carried.)

Past and Future Conferences

2003 Edmonton: Corjan Buma provided an overview of the report for the 2003 meeting, and expressed his appreciation for the whole organizing team's contributions. The submitted papers were supplemented by excellent plenary talks, a site visit to Winspear concert hall, and a successful exhibition. Total registration was 97, and income exceeded expenditures by $420. The Board congratulated the Edmonton team on their success.

2004 Ottawa: John Bradley reported that arrangements with the Lord Elgin Hotel have proceeded smoothly, and that registrations are likely to go well over 100. Paper submissions filled all available time slots, a plenary session will begin each day, and the exhibition will showcase a good variety of products. It was noted that the main budget worry is the commitment for catering, but the strong advance registration suggests the conference will be financially successful.

2005 (Vancouver): Stan Dosso reported that arrangements are proceeding for the joint ASA/CAA meeting in Vancouver on 16-20 May 2005. Murray Hodgson will be Conference Chair, Stan Dosso is Technical Program Chair, and other CAA members in Vancouver are participating in key roles on the organizing team. Attendance is expected to exceed 1000, and CAA members may register at the "Members' rate". A satellite conference organized by Alberta Energy Utilities Board is planned at Banff in the following week. Board members agreed the next meeting of the Board should be held at the Vancouver conference.

2005 (London): Stan Dosso relayed a report from the London team that preliminary arrangements have been made in London Ontario for a conference on 12-14 October 2005. Arrangements with the hotel will be confirmed soon. M. Cheesman will be Conference Chair, and several members in London have agreed to participate in the organizing team. The Board agreed that this team should proceed, and approved the plan as presented.

Awards

Christian Giguère presented a report, based on submissions from the Awards Coordinators. Requirements for most prizes are now presented correctly on the CAA web site (although some clarifications are planned) and most include French translations. Reminders were sent to the membership and to academic institutions by the coordinators, to encourage applications. Specific progress for various awards was reported:

- Shaw Prize awarded,
- Bell Prize awarded,
- Fessenden Prize awarded,
- Eckel Prize awarded,
- Hétu Prize awarded,
- Award for the Canada-Wide Science Fair presented at St.John's.
- Directors' Awards for Student, no candidate.
- Directors' Awards for Professional awarded,
- Student subsidy for travel to conference on underwater sound or signal processing not yet awarded (later dates)
- Student travel subsidies and presentation awards for CAA conference will use the full budget allocation (strong competition).

Only two of the smaller prizes were not awarded – a major improvement – and awards are distributed well across Canada. Some changes to award conditions were discussed and the Coordinator was asked to implement these.
(Acceptance of report moved by C. Giguère, seconded D. Quirt, approved)

CAA Website

There was no formal report on the CAA website. Content is steadily expanding, and now includes the index for Canadian Acoustics, updated information on CAA awards, quite active job advertisement and job-wanted sections, improved pages for Sustaining Subscribers, and downloadable membership and subscription applications. Overall, there was enthusiastic support for the content, especially the pages used for the annual conference. The Board expressed their thanks to Dave Stredulinsky, who has agreed to continue as webmaster for the time being.

Nominations / Change of Directors

One Director (Dave Stredulinsky) came to the end of his term this month. The President recognized his huge contributions to the website and expressed the thanks of the Board for his efforts on behalf of the Association; a slate of one nominee has been established for presentation at the AGM, with due regard for regional distribution. Dalila Giusti has agreed to continue as Treasurer until a replacement is recruited, but it was noted that she has expressed willingness to be replaced, and volunteers will be welcomed.

Other Business

The Board agreed that:

- Two nominees as new Emeritus Members were approved. Letters will be sent to notify them, and a brief news item in Canadian Acoustics was suggested.
- Expanding CAA student awards will be considered, rather than making a voluntary contribution to subsidies at ICA.
- Stephen Keith was approved as CAA representative to INCE Working Group 6 on community noise, with a request to submit a brief progress report to Canadian Acoustics.
- Teleconferencing (possibly supplemented by video) will be used on a trial basis for the spring meeting of the Board in 2006.

Adjournment

A. Behar moved to adjourn the meeting, seconded by D. Giusti, carried. Meeting adjourned at 9:00 p.m.

Special Action Items (Continuing or Arising from the Meeting)

- *D. Quirt:* Update database information as part of annual membership renewal process and develop address list for e-mail communication to the CAA membership.
- *D. Quirt and S. Dosso:* prepare and send letters to new Emeritus Members.
-
- *D. Giusti:* Transfer funds to secretarial account for administrative expenses, and transfer advance funds for London conference. Transfer $25,000 as authorized from Operations to Capital account, and proceed with investments fro Capital Fund.
- *C. Giquère and D. Stredulinsky:* Continue t update Awards pages on the CAA website.

Canadian Acoustical Association

Minutes of Annual General Meeting

Lord Elgin Hotel, Ottawa, Ontario
7 October 2004

Call to Order

President Stan Dosso called the meeting to order at 5:08 p.m. with 42 voting members of the Association present. Minutes of the previous Annual General Meeting on 16 October 2003 in Edmonton were approved as printed in the December 2003 issue of Canadian Acoustics. (Moved by Cameron Sherry, seconded by George Wong, carried)

President's Report

Stan Dosso summarized the results of the Board meeting on 5 October. He emphasized that the society is in good condition, and he thanked all those who have made major contributions to our activities, both in the annual conferences and in ongoing activities such as the website and the journal.

Secretary's Report

David Quirt presented a brief report: the Association's membership has grown slowly over the last two years, to 366 members as of 1 October. Details are in the report from Board of Directors meeting on 5 October.

The administrative budget of $970 covered mailing, database, and correspondence expenses in the last fiscal year; an itemized account was presented to the Board of Directors. A slight increase to $1100 is proposed for the next year, to cover the increased mailing costs for distribution of Noise News International. Aside from very erratic delivery of NNI from the publisher, all activities are proceeding smoothly.
(Acceptance of the report moved by Alberto Behar, seconded Harold Forrester, carried.)

Treasurer's Report

Dalila Giusti reported on the Association finances. We are in good shape, with assets of $250,228 at yearend and a variety of securities that provided $9600 in interest last year, which more than covered the cost of awards. Financially successful meetings and income from advertising and subscriptions have also generated funds. There has been no need to dip into fixed assets for several years.

We budget each year's expenses and track costs and revenues; this allows us to plan. This year the budget predicts a modest surplus if the conference in Ottawa breaks even. Hence, the Board is proposing no increase in fees this year. Given the likelihood of a substantial surplus from this conference, Murray Hodgson suggested the Directors consider increasing the value of the Hétu Prize for next year; there was widespread support for this.
(Acceptance of this report and unchanged fee structure was moved by Harold Forrester, seconded Sharon Abel, carried.)

Editor's Report

Ramani Ramakrishnan gave the Editor's report. *Canadian Acoustics* highlights were:

- For the first time, the Editor has a significant backlog of papers – enough for two issues. Articles will be very welcome and will generally be published within 6 months. Historically about 25% of papers get rejected. This will be published to substantiate that the articles are refereed.
- A special issue in June 2004, presented refereed conference papers on underwater sound. The conference organizers supported the review process for the issue and covered part of the expenses, so this both provided excellent content that is of interest to our audience, and helped with the publication budget. The Editor gave special thanks to Francine Desharnais for her role in preparing this issue.
- Another special conference proceedings issue is being considered for June 2005.

In response to questions, the Editor assured the meeting that papers are readily accessible via database searches.
(Acceptance of the report moved by Alberto Behar, seconded Murray Hodgson, carried.)

Award Coordinator's Report

Christian Giguère reported the awards to be presented this year. CAA is awarding the Shaw Prize, Bell Prize, Fessenden Prize, Eckel Prize, Hétu Prize, Directors' Award (Professional), and Award for the Canada-Wide Science Fair. In addition, there are the student paper awards. (See separate announcement in this issue for names of recipients.)

Christian acknowledged the hard work of the awards committees, and the contributions of David Stredulinsky in updating the web pages for awards. For 2005 the major effort to promote the prizes will continue.
(Acceptance of the report moved by Vijay Parsa, seconded Chantale Laroche, carried.)

Past/Future Meetings

Brief reports were presented on meeting status:

Edmonton (2003): Corjan Buma gave a report on the meeting. The technical papers were supplemented by excellent plenary talks, a great site visit to the Winspear concert hall, and an exhibition with very good representation of acoustical product manufacturers. An effective website based on the PEI model was very useful in the organizing process. Corjan recognized the significant efforts by the whole Edmonton team. The President repeated the thanks from the Association for a great success

Ottawa (2004): John Bradley gave a preliminary report on this year's conference. Attendance is well over 150; the organizers have sold out tickets for the banquet and run out of programs. There should be a significant financial surplus. There is a full slate of technical papers, and the plenary sessions have been excellent. The exhibition has been well-attended, and hospitality at the coffee breaks has been outstanding. Overall, the organizers are optimistic. Stan Dosso expressed the attendees' thanks to the organizing team.

Vancouver (May 2005): Murray Hodgson reported that there will be a joint ASA/CAA meeting on 16-20 May 2005 in Vancouver. Murray will be the Chair, and Stan Dosso is Technical Program Chair. CAA members will receive the members' rate for registration, student registration is free, and there are student travel subsidies. The deadline for abstracts is mid-January.

London (October 2005): Vijay Parsa reported that we will have a CAA meeting as usual in October. A team from London Ontario has offered to organize the meeting on 12-14 October, and the Board has given approval to proceed.

CAA Website

Stan Dosso reported that David Stredulinsky has agreed to continue as webmaster. There were many comments supportive of the very useful and effective website.

Nominations and Election

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

This year all but one of the Directors are eligible for another year and have agreed to serve. To fill the vacancy, the nominating committee proposed Nicole Collison from Nova Scotia. John Bradley read the names of the slate of proposed Directors. There were no additional nominations from the floor. (Rich Peppin moved to approve the candidates for Director, second by Ramani Ramakrishnan, approved.)

John Bradley read the names of the proposed members of the executive: Stan Dosso as President, David Quirt as Secretary, Dalila Giusti as Treasurer, and Ramani Ramakrishnan as Editor. There were no other nominations. (Alberto Behar moved to approve the candidates, Gilles Daigle seconded, approved.)

David Stredulinsky was enthusiastically thanked for his efforts as Director for the last 5 years.

Adjournment

Harold Forrester moved and Vijay Parsa seconded, that the meeting be adjourned. Carried. Meeting adjourned at 5:55 p.m.

The Canadian Acoustical Association
L'Association Canadienne d'Acoustique

PRIZE ANNOUNCEMENT • ANNONCE DE PRIX

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

Deadline for Underwater Acoustic and/or Signal Processing Student Travel Subsidy: **31 March 2005**
Échéance Subvention de Voyage pour Étudiants en Acoustique Sous-marine ou Traitement du Signal: **31 Mars 2005**

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

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

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

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

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

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

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

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

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

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

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

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

DIRECTORS' AWARDS • PRIX DES DIRECTEURS

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

STUDENT PRESENTATION AWARDS • PRIX POUR COMMUNICATIONS ÉTUDIANTES

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

STUDENT TRAVEL SUBSIDIES • SUBVENTIONS POUR FRAIS DE DÉPLACEMENT POUR ÉTUDIANTS

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

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

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

Canadian Acoustical Association
Association canadienne d'acoustique

2004 PRIZE WINNERS / RÉCIPIENDAIRES 2004

SHAW POSTDOCTORAL PRIZE IN ACOUSTICS /
PRIX POST-DOCTORAL SHAW EN ACOUSTIQUE

Nicholas Smith, McMaster University
"Measuring Infants' Auditory Thresholds using Anticipatory Eye Movements and Adaptive Psychophysical Procedures"

BELL GRADUATE STUDENT PRIZE IN SPEECH COMMUNICATION AND BEHAVIOURAL ACOUSTICS /
PRIX ÉTUDIANT BELL EN COMMUNICATION VERBALE ET ACOUSTIQUE COMPORTEMENTALE

Carrie Gotzke, University of Alberta
"Speech Intelligibility Probe for Children with Cleft Palate: Assessment of Reliability and Validity"

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

Mark Fallat, University of Victoria
"Characterization of Geoacoustic Properties of the Seabed in Range-dependent, Shallow-water Environments"

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

Wei Shao, Queen's University
"Acoustic Analyses of MRI Scanner"

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

Elizabeth McFadden, University of Prince Edward Island
"Acquisition of Musical Grammar Compared with Language Grammar"

Canada-Wide Science Fair Award / Prix Expo-sciences pancanadienne

Benjamin Schmidt, Centre Wellington District High School (Ontario)
"Robotic Sound Localization"

Directors' Awards / Prix des Directeurs

Individual Member / Membre Individuel :

Christian Giguère, Unversity of Ottawa
"Evaluation of Audible Traffic Signals for Pedestrians with Visual Impairment"

Student Presentation Awards / Prix pour Communications Étudiantes
Lord Elgin, Ottawa 2004

William E. Hodgetts, University of Alberta
"Advanced Measures of Bone Anchored Hearing Aids: Do they Correlate with Perceptual Judgments?"

Dominic Pilon, Université de Sherbrooke
"Influence of Micro-structural Properties on the Acoustic Performances of Novel Metallic Foam"

Emmanuelle Gros, Université de Sherbrooke
"A Missing Mass Method to Measure the Open Porosity of Porous Solids"

Underwater and Signal Processing Student Travel Subsidy / Subvention de Voyage pour Étudiant en Acoustique Sous-marine ou Traitement du Signal

Jan Dettmer, University of Victoria
"Geoacoustic Inversion with Strongly Correlated Data Errors"

CONGRATULATIONS / FÉLICITATIONS

CAA Annual Conference in London
October 12-14, 2005
www.caa-aca.ca/london-2005.html

First Announcement
The 2004 annual conference of the Canadian Acoustical Association will be held in London October 12-14, 2005. There will be three days of parallel sessions of papers on all areas of acoustics and auditory perception. In addition to various associated meetings, there will be a tour of laboratory facilities at the University of Western Ontario. Mark your calendars and plan to join us in London in 2005!

Special sessions
We will have a number of special sessions. If you would like to suggest a topic for a special session or would like to organize a special session, please contact the Conference Convener (cheesman@uwo.ca) or the Papers Chair (parsa@nca.uwo.ca).

Venue and Accommodation
The conference will be held at the Lamplighter Inn and Conference Centre. The Lamplighter offers standard rooms (2 queen beds) or upgraded rooms (king suites) at a CAA delegate room rate of $109/night and $119/night (+ taxes), respectively. (1-888-232-6747; www.lamplighterinn.ca). Please stay at this hotel to be with your friends and to support the CAA.

Travel
The conference center is located just minutes from the 401 and 402 highways with easy access for participants arriving by car. Parking is free. London International Airport (Air Canada Jazz, Northwest Airlink, and WestJet) is a 20-minute drive away.

Exhibits
There will be an exhibit of measurement equipment and other acoustical products. As usual, the exhibit area will also be the central coffee break area. Please contact our exhibit coordinator for early information on the planned exhibit and sponsorship of various aspects of this meeting.

Student Participation
CAA encourages and supports student participation in the Annual Conference. Student members who make presentations can apply for travel support and can win one of a number of student presentation awards. See our website for details.

Submissions
The deadline for the submission of abstracts will be 1 May 2005. Details of the electronic submission process will be contained in the March 2005 issue of Canadian Acoustics.

Congrès annual de l'ACA à London
12 au 14 octobre 2005
www.caa-aca.ca/london-2005.html

Premier avis
Le congrès annuel de l'Association canadienne d'acoustique se tiendra à Londres du 12 au 14 octobre 2005. Trois jours de communication scientifiques comprenant des sessions parallèles sont prévus touchant tous les domains relevant de l'acoustique et de la perception auditif. En plus des réunions habituelles, des visites de laboratoires a l'université de Western Ontario seront également au programme. Veillez planifer dès maintenant de participer et nous joindre à London en 2005!

Session spéciales
Des sessions speciales seront structurées autour de les sujets suggérer par les délégués. Si vous désirez suggérer un sujet de session spéciale ou organizer une de ces sessions, veuillez communiquer avec le Président du congrés (cheesman@uwo.ca) ou le Directeur scientifique (parsa@nca.uwo.ca).

Lieu du congrès et hébergement
Le congrès se tiendra au *Lamplighter Inn and Conference Centre*. L'hôtel offre des chambres (2 grands lits) ou des suites (très grande lits) avec un tariff prefere pour les delegues de $109/nuit and $119/nuit (+ taxes), respectivement (1-888-232-6747; www.bestwesternontario.com/french/lamplighter.html). Choisissez cet hôtel pour participier pleinement au congrès et encourager l'ACA.

Travel
Le *Lamplighter Inn and Conference Centre* est situé à 4 km de autoroute 401 et à 15 km de l'aéroport international de London (Air Canada Jazz, Northwest Airlink, et WestJet).

Exposition technique
Il y aura une exposition d'instruments et d'autres produits en acoustique. La salle d'exposition agira aussi comme lieu central lors des pauses. Veuillez communiquer dès maintenent avec de l'exposition pour de plus amples renseignements et pour la commandite d'événements particuliers lors du congrès.

Participation étudiente
L'ACA accorde beaucoup d'importance à la participation des étudiants. Les membres étudiants qui présenteront une communication pourront soumettre une demande de subvention pour frais de déplacement au congrès et pourront se voir mériter l'un des prix pour communications étudiantes. Veuillez consulter notre site Internet.

Appel de communications
Les échéances pour soumettre vos résumés seront le 1 mai 2005. Les renseignements seront announcées dans le numéro du mois de mars 2005 de l'*Acoustique Canadienne*.

The Canadian Acoustical Association
l'Association Canadienne d'Acoustique

MEMBERSHIP DIRECTORY 2004 / ANNUAIRE DES MEMBRES 2004

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

Areas of interest		**Champs d'intérêt**
Architectural acoustics	1	Acoustique architecturale
Engineering Acoustics / noise Control	2	Génie acoustique / Contrôle du bruit
Physical Acoustics / Ultrasonics	3	Acoustique physique / Ultrasons
Musical Acoustics / Electroacoustics	4	Acoustique musicale / Electroacoustique
Psycho- and Physio-acoustics	5	Psycho- et physio-acoustique
Shock and Vibration	6	Chocs et vibrations
Hearing Sciences	7	Audition
Speech Sciences	8	Parole
Underwater Acoustics	9	Acoustique sous-marine
Signal Processing / Numerical Methods	10	Traitement des signaux / Méthodes numériques
Other	11	Autre

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

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

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

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

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Abstracts: English and French versions. Headings, 12 pt bold, upper case, centered. Indent text 0.5" on both sides.

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Page numbers: In light pencil at the bottom of each page.
Reprints: Can be ordered at time of acceptance of paper.

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