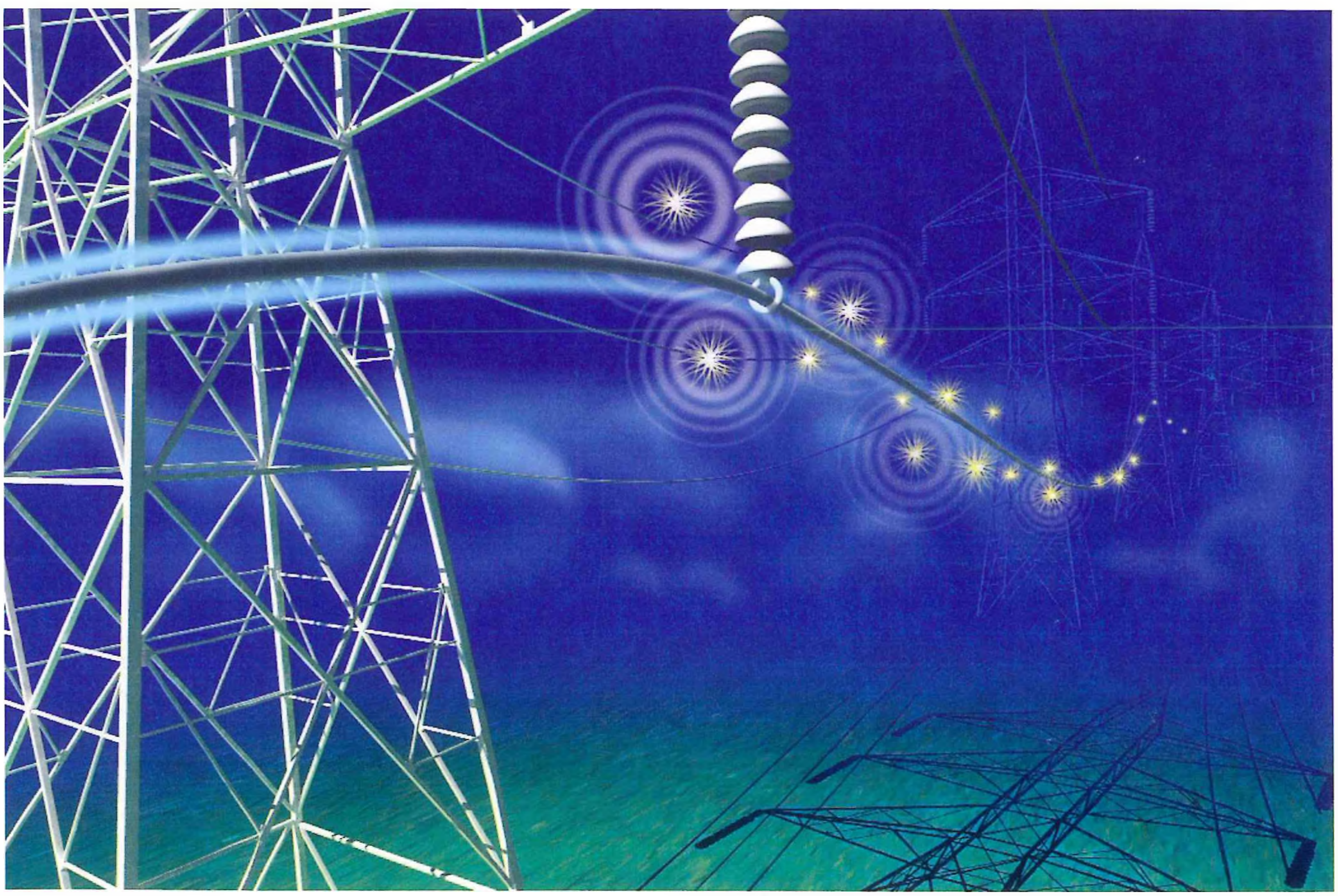
ISSN 0711-6659

# canadian acoustics
# acoustique canadienne

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

MARCH 2003 | MARS 2003
Volume 31 -- Number 1 | Volume 31 -- Numéro 1





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## EDITORIAL / ÉDITORIAL

Perhaps, you have noticed the appearance of colour covers for our journal. Our new printers, Business Printing of Toronto, has started printing the journal digitally. Since our print run is less than 500, we are able to keep the costs down with this printing format and the added cost of colour is minimal. Now, we are also able to print colour plots, if it is necessary. We attempted to do that with one page where the colour sonograms in the article by Ms. Natalie Silvanovich, the winner of the Canada Wide Science Fair Acoustics award, sponsored by CAA, were necessary to convey the meaning. The additional cost was only Cd$150. I wanted to bring this to our member's attention, so that future authors can print, may be a page or two in colour, if I can be convinced that the added cost is worthwhile. Of course, I am taking some liberties and I hope to convince our executive that this is a worthwhile exercise.

Our President, John Bradley wrote, in the December 2002 issue of Canadian Acoustics, that we seem to think that we are a secret society. He meant that we have a strong acoustical association with a journal and the rest of the acoustical community seems to be unaware of our existence. I'd like to extend this to the overall Canadian Acoustical Community and point out that we seem to be even shy about talking about the varied and excellent acoustical work, we as a small country, seem to be conducting. I can mention some renowned names such as Tom Northwood, Floyd Toole, Tony Embleton and Herb Ribner who have conducted exemplary research as part of Canadian institutions. This is not an exhaustive list and forgive me if I had omitted some names. I, as your mouthpiece, would like to publicize this work. And I had requested a number of organizations to send in a few pages summarizing their work. I had only one success so far. This is an open invitation to all those organizations, such as NRC, DREA, University of Sherbrooke, University of Western Ontario and UBC to start sending information about their work in either of the two official languages. These are your pages, so use them please!

Ramani Ramakrishnan

Je suppose que vous avez constaté l'aspect de la couverture couleur de notre journal. Notre nouvel éditeur, "Business Printing of Toronto", a commencé l'impression du journal en format digital. Nous sommes en mesure de garder le coût de tirage bas avec ce format car notre tirage est inférieur à 500 copies. Le coût lié aux pages couleurs reste minime. Actuellement, nous sommes en mesure d'imprimer des figures couleurs si nécessaire. Nous avons déjà essayé sur une page pour le Sonogramme couleur dans l'article de Natalie Silvanovitch, la gagnante du prix de Canada Wide Science Fair Acoustics, sponsorisé par ACA. Le coût additionnel était de 150 dollars canadien seulement. Je voulais reporter ceci à nos membres pour leur dire que les futurs auteurs peuvent avoir une ou deux pages couleurs d'imprimer si je peux être convaincu du coût supplémentaire. Bien sure, je suis entrain de prendre quelques libertés, et j'espère pouvoir convaincre nos directeurs.

Notre President, John Bradley a écrit, dans l'édition de Décembre 2002 du journal Acoustique Canadienne, nous semblons être une société secrète. Il a voulu dire que nous sommes une association acoustique forte avec un journal et le reste de la communauté acoustique semble ignorer notre existence. J'aimerais étendre ceci sur toute la communauté acoustique canadienne et préciser que nous semblons être timides de parler de notre excellent et divers travail acoustique, nous comme petit pays. Je peux mentionner certains noms renommés comme Tom Northwood, Flyod Toole, Tony Embleton, Herb Ribner qui ont conduit des programmes de recherche exemplaires dans les établissements canadiens. Ce n'est pas une liste approfondie et pardonnez-moi si j'ai oublié quelques noms. Moi, en tant que votre éditeur, voudrait faire de la publicité à ce travail. J'avais sollicité plusieurs organismes de m'envoyer un résumé de quelques pages récapitulant leurs activités. Je n'ai eu qu'un seul succès jusqu'à maintenant. Ceci est une invitation ouverte à tous les organismes, tels que CNRC, DREA, Université de Sherbrooke, Université d'Ontario Occidental et Université de British Columbia pour commencer à m'envoyer des informations sur leur travail dans l'une ou l'autre des deux langues officielles. Ce sont vos pages, utilisez-les s'il vous plaît!

Ramani Ramakrishnan

## WHAT'S NEW ??

Promotions
Retirements
Deaths
Degrees awarded
New jobs
Distinctions
Moves
Other news

Do you have any news that you would like to share with Canadian Acoustics readers? If so, send it to:

## QUOI DE NEUF ?

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Décès
Obtention de diplômes
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Distinctions
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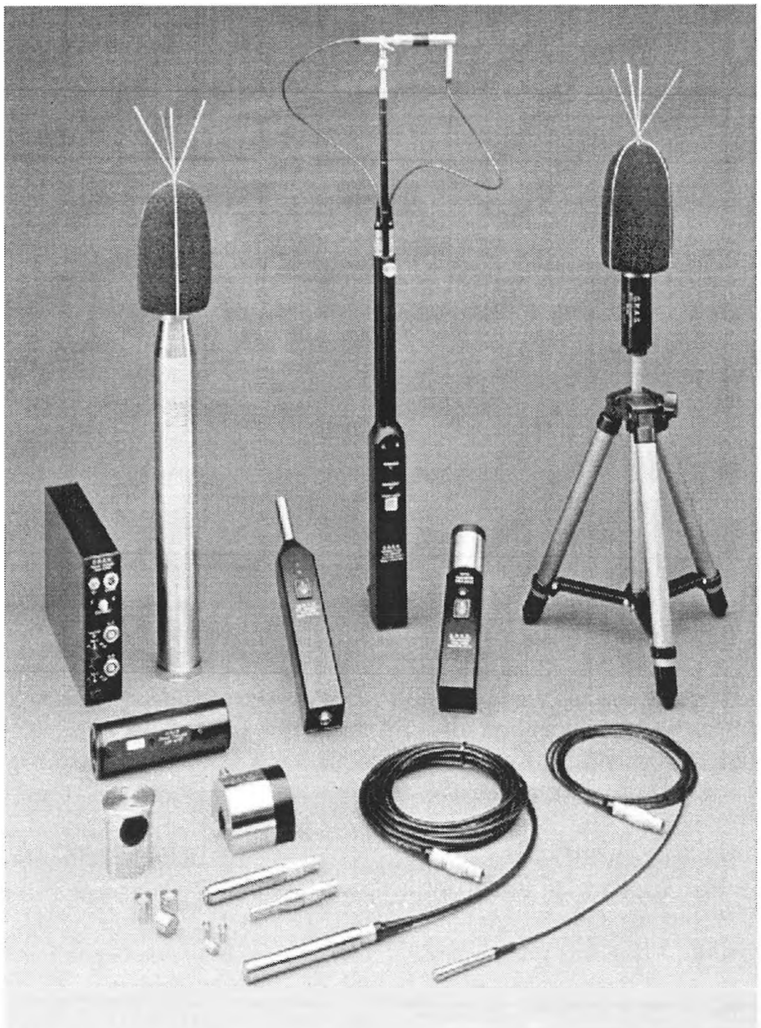
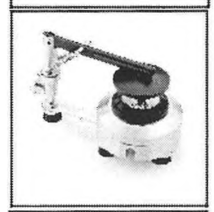
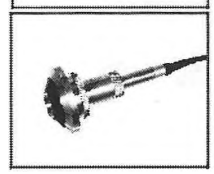
Francine Desharnais, DREA Ocean Acoustics, P.O. Box 1012, Dartmouth NS, Email: desharnais@drea.dnd.ca









# ANALYSIS OF ATTITUDINAL RESPONSE TO AUDIBLE NOISE FROM HIGH VOLTAGE TRANSMISSION LINES AND TRANSFORMER STATION

**John E. K. Foreman* and Tom G. Onderwater****
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## ABSTRACT

Procedures for statistical analysis of audible noise from 550 and 735 kV transmission lines and a 735 kV transformer station are discussed. The research also entails psycho-acoustic testing of people to determine attitudinal response to this form of noise as compared to other environmental noises. The evaluation of subjective response to corona noise in a laboratory environment are also discussed. A Participation Program between the Canadian Electrical Association, the American Electric Power Service Corporation and the National Bureau of Standards in Washington is outlined.

## SOMMAIRE

Les procédures pour l'analyse statistique du bruit audible des lignes de transmission électriques de 550 et 735 kV et d'une station de transformateur de 735 kV sont discutées. La recherche fait également intervenir des tests psycho-acoustique faites sur des personnes pour déterminer le comportement et l'attitude de ces gens face à ces sources de bruit par rapport à d'autres sources de bruit environnementales connues. Les évaluations de la réponse subjective au bruit de corona dans un environnement de laboratoire sont également discutées. Un programme de participation entre "Canadian Electrical Association", "American Electrical Power Service Corporation" et le Bureau des Normes à Washington est aussi décrit.

## 1 INTRODUCTION

With the development of EHV and UHV lines in recent years for the transmission of electric power, the field of corona discharge has gained considerable prominence, particularly with reference to the influence of corona discharge on line design and accompanying energy losses and noise generation. Typical noise from the lines occurs when droplets form on the line, and energy from the line is then discharged from the droplets to "ground" (air). This results in large energy loss from long transmission lines. Research [1] tended to indicate that audible noise is of concern in current 550 and 735/765 kV lines and could be the predominant design factor in future high voltage transmission lines, especially where adverse weather conditions such as rain, fog and wet snow pertain.

Audible noise due to transmission line corona discharge has not received the same public recognition that general community, transportation and industrial noise problems has received. This potential noise problem has been of concern in the scientific community primarily because of the anticipated energy demands which will result in the need for higher capacity lines in the future, and the desire of public utilities to ensure that disturbances such as noise from these high voltage lines do not present an adverse environmental impact on community life.

The Sound and Vibration Laboratory of The University of Western Ontario, under a contract from the Canadian Electrical Association, undertook field measurements of, and attitudinal responses to, existing high voltage lines and a high voltage transformer station. The aims of the research were to carry out (1) long-term audible noise measurement of existing high voltage transmission lines and a typical high voltage transformer station, and (2) a subjective evaluation of the annoyance of people caused by the transmission line and transformer station audible noise. It was intended that information from this study, together with information from a study being carried out at the Institut de Recherche de l'Hydro-Quebec (IREQ) on the effect of conductor design on audible noise, would, through extrapolation of results, enable predictions to be made of the effect of noise on people from future lines of higher voltage.

Throughout the planning stages of a procedure to be followed in this project, the Laboratory had been conscious of tests which had been carried out by other agencies, particularly in the U.S.A.; the Laboratory had also taken note of the report prepared by the Task Force of the Radio Noise and Corona Subcommittee of the Transmission and Distribution Committee of IEEE [2], together with the guide for measurement of audible noise from transmission lines prepared by an earlier IEEE Radio Noise Subcommittee [3]. The Laboratory had also benefited from the comprehensive papers which appeared in the Proceedings of the Workshop on Power Line Noise as Related to Psycho-Acoustics, sponsored by the Radio Noise and Corona Subcommittee of the IEEE Transmission and Distribution Committee [1]. Further, valuable upgradings of the techniques of field measurements of corona noise and laboratory attitudinal response testing were obtained from the Symposium on Transmission Line Audible Noise sponsored by the Radio Noise and Corona Subcommittee of IEEE [4].

## 2 Field Measurements

The field tests were carried out on 550 kV and 735 kV lines, and a 735 kV transformer station, for a period of approximately one year using continuous automatic monitors; the data from the monitors were statistically analyzed in conjunction with the processing facilities of the Laboratory and the Computing Centre at The University of Western Ontario.

Two measurement systems had been developed: (1) a digital recording system which logged corona noise (and, in one case, transformer substation noise) in octave band frequencies centred from 31.5 Hz to 16 kHz, overall sound level, overall background noise, wind direction and velocity, temperature, relative humidity, radio interference, rain and snow precipitation, and (2) a system for recording corona sound from the line (and the transformer substation) on a four-track analog tape recorder of studio quality, controlled by a microprocessor.

Four test sites were established. These were at La Plaine on the 735 kV line of Hydro-Quebec leading into Montreal from Churchill Falls, a 735 kV transformer station at Boucherville, outside Montreal, a 550 kV line at Kleinberg north of Toronto and a 735 kV site at the Ohio Power line near Canton, Ohio.

The operating personnel of the various local divisions of the utilities participated in a collaborative effort in obtaining this data. In addition to the measurement trailers which housed the instrumentation at each site, the mobile facility of the Laboratory was used for on-the-spot instruction with regard to instrumentation, calibration, measurement techniques, and for general troubleshooting. The test trailer at each site was insulated and heated for winter operation and fan-cooled for summer operation.

Protection of the test microphone from the rain was probably the most important consideration for installation of long-term recording stations. A Bruel and Kjaer Model 4921 outdoor microphone system was chosen for the measurements. The unit consisted of: a 1/2 inch quartz-coated back-vented condenser microphone, a windscreen housing a rain cover, and an electrostatic actuator for microphone calibration at the upper end; a stainless tubula stem which enclosed the preamplifier and its heater and connected the microphone to a silica gel dehumidification system at its lower end; a cast aluminum weatherproof case and glass panel for observing the condition of the silica gel; an internal power supply and individual voltage generators for microphone polarization, electrostatic actuator, preamplifier power supply, and heater; a 60 dB amplifier; calibration potentiometer; and sealed cable entries. The overall omnidirectional response of the unit satisfied the requirements of IEC 179 for precision sound level meters; the unit had a frequency response from 20 to 20,000 Hz and, with the sensitive condenser microphone, the system was capable of measuring down to 26 dBA (which was 5 dB above the electronic noise floor of the system).

Digital Acoustics meters were used to log the measurement data and a PDP 11digitizing computer (with magtape storage) was used for the measurements. The specifications were:

1. Sampling rate from 4 to 32 samples per second;
2. Dynamic range of 100 dB (autoranging);
3. Frequency response from 20 Hz to 20 kHz;
4. Measured Data points - corona noise in 10 octave bands, overall corona noise level, background microphone noise, environmental and line conditions;
4. The 20 data ponits (4 second interval between data points) were scanned every 80 seconds;
5. The scanner was controlled from a tape advance mechanism in the digital monitor;
6. Each tape storage capacity was 8 days of data;
7. Digitized data capable of producing various combination of acoustic data for further analysis.

Corona <u>sounds</u> were recorded on a four-track studio-type Otari tape recorder. The recorder used ½ in. professional recording tape, and at a recording speed of 15 in./sec, the frequency response was up to 20 kHz and recording time was approximately 3 hours. A microprocessor had been developed by the Laboratory to control the recorder. The microprocessor had been designed so that it would turn the tape recorder on when preset levels of (1) acoustic signals through a 16 K filter, (2) radio interference, and (3) wind velocity, had been reached. At the same time, a crystal clock and a tone coding system (part of the microprocessor) inserted a calibration and a time signal on the tape at the start of recording (which was eventually identified on playback of the field tape through the microprocessor decoder at the Laboratory). This time of recording, when cross-referenced with the time of the digital data recording system, gave all information regarding sound pressure levels vs frequency, background noise, weather, RI data, etc. The microprocessor also controlled the time interval at which the tape recorder was turned on (for example, 3 to 5 minutes every 20 to 30 minutes) and, through the remote control input to the tape recorder, sensed when the tape was at the end of each track, rewound the tape to the beginning, indexed the recording head to the next track, restarted the tape recorder, and, at the end of Track 4, rewound the tape to the beginning and shut down the unit. The 16 K acoustic signal identified the presence of corona noise (as opposed to most background noise), as did the RI signal. The wind velocity sensing ensured that noise recording took place only when the wind speed was below a predetermined level. With the precision sound level meter; the unit had a frequency response from 20 to 20,000 Hz and, with the sensitive condenser microphone, the system was capable of measuring down to 26 dBA (which was 5 dB above the electronic noise floor of the system).

## 2.1 Participation Program with the American Electric Power Service Corporation

On behalf of the Canadian Electrical Association, the Laboratory negotiated an "AEP-CEA Participation Program" with the American Electric Power Service Corporation. The Laboratory and AEP worked closely with the High Voltage Section of IREQ and the Environmental Noise Program Team of the National Bureau of Standards. The program provided for undertaking noise measurements and attitudinal response testing on a joint basis, in which instrumentation, measurement procedures and response testing procedures were coordinated and selected in such a way that there was compatibility and interchangeability of data, tapes, etc. associated with measurements and testing being carried out by the various research groups.

The Laboratory carried out all attitudinal response testing. In addition to assessing attitudinal response to contemporary corona noise from high voltage transmission lines, and predicting attitudinal response to higher voltage transmission lines of the future, a major objective of the study between AEP and the Laboratory was to develop a comprehensive cataloguing and library of contemporary noise from high voltage transmission lines and the associated environmental and line conditions [Reference 5, part 2].

## 3. Development of Subjective Testing

The existing or proposed regulations on audible noise

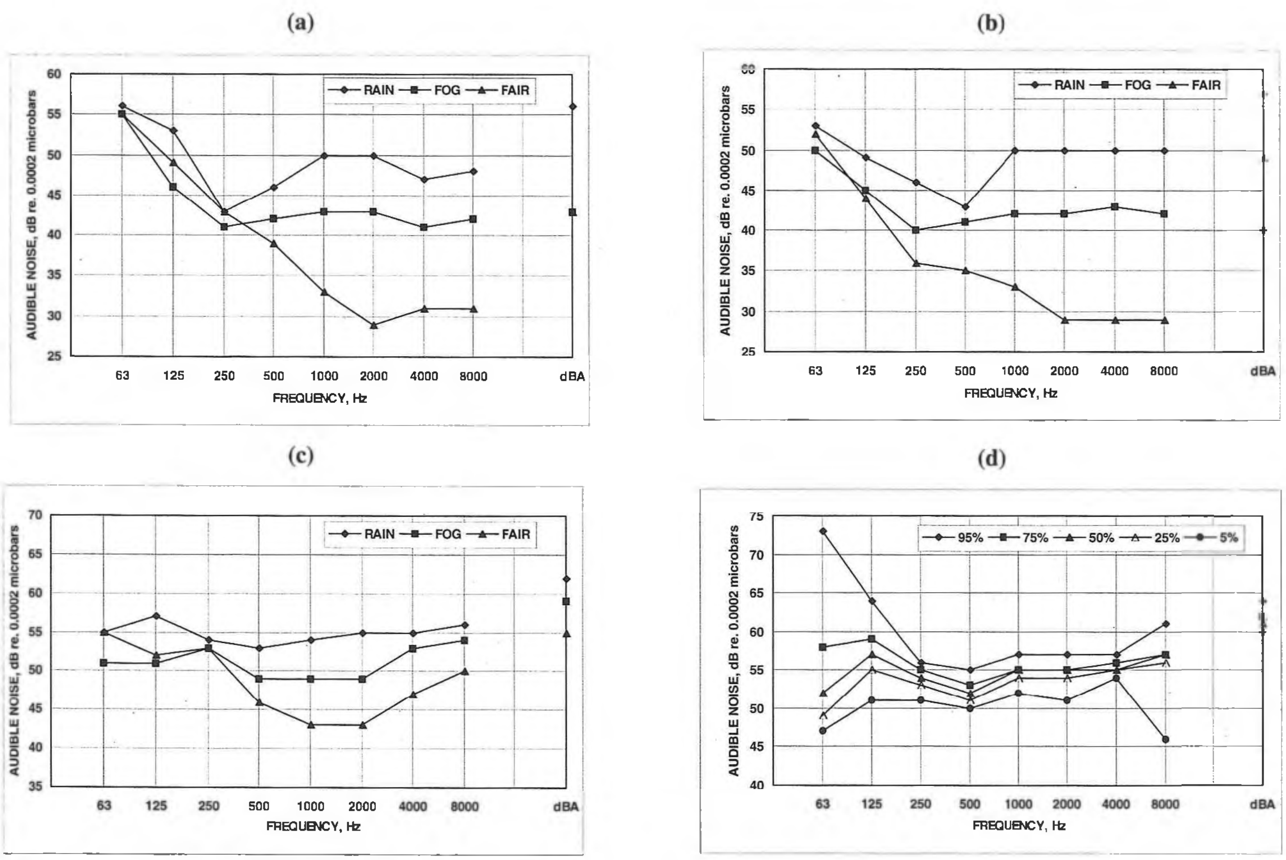


**Figure 1. Frequency Spectra of Trasmission Lines - (a), (b) and (c) Three separate 750 KV Transmission Lines. d) Spetra of Percentile Levels of Line (c) during Rain.**

have been normally developed with noise sources such as traffic and industry in mind, rather than audible noise from transmission line corona. The noise spectra associated with these types of disturbances normally covered the low to mid-frequency range, while corona noise spectra during rain and fog was relatively broad-band or flat up to and beyond 20 kHz. Typical spectra of corona noise from three different 750 kV lines are shown in Figure 1. In addition, there were sometimes pronounced peaks at the pure tone components which are harmonics of the fundamental 60 Hz frequency, and to these may be added, under special circumstances, a modulation caused by subconductor vibrations of 1 to 4 Hz. These latter vibrations were caused by wind or conductor corona phenomena or both. Consequently, regulations which embody descriptors reflecting a correlation between attitudinal response or annoyance and the traditional forms of environmental noise could not necessarily be expected to apply to the situations of corona noise.

In addition, many noise regulations differentiate between day and night values, while the audible noise from transmission line corona does not depend upon the time of day but rather upon the prevailing weather conditions—and it would appear that, even at comparable precipitation rates, the noise spectra and levels could vary markedly day-by-day or hour-by-hour on the same line, presumably due to local wind condition. Furthermore, it should be recognized that an increased level of corona noise during inclement weather may be tolerated by most people, since, on the average, inhabitants of the rain-affected region would be expected to be indoors at the time with their windows closed, and that the rain beating on roofs and windows, and usually accompanied by winds, would have a tendency to mask the corona noise. No such provision of course was included in any present regulations.

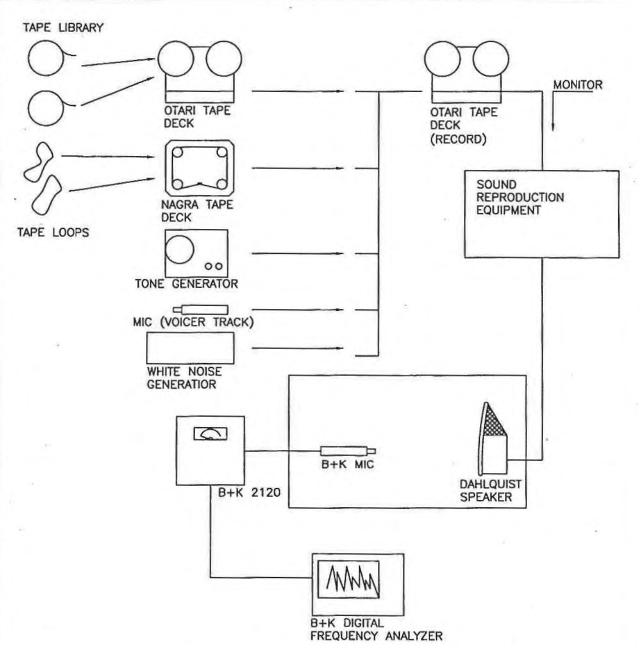


**Figure 2. Test Tape Preparation**

Further, present regulations do not take into account the slow variation with time of audible noise from transmission lines. The literature [1] indicates that noise complaint rating (NCR), which takes into account the time variation of noise, could be used as a descriptor for corona noise. This would appear to be a reasonable approach to the evaluation of annoyance of relatively fast-varying noises, such as traffic noise which fluctuates up and down with the passage of vehicles, perhaps having a mean cycle rate of seconds or minutes. In comparison to this, however, the variation of transmission line noise must be considered slow as it fluctuates only with changes in weather. For a day in which the rain is fairly steady, noise may stay fairly constant for hours at a time. Similarly, during a period of fog, noise levels may remain unchanged for prolonged periods of time. In this connection, it should be noted that steady noises have less of a disturbing effect than do periodic or intermittent noises. [6]

It can be seen then that the question of interpreting attitudinal response or annoyance to transmission line noise, and the development of a suitable descriptor or measure to be used by regulatory bodies, are fraught with all sorts of difficulties. It is therefore extremely important that an accurate and viable means of eliciting attitudinal response to corona noise be developed (in particular, in comparison with the response to other forms of contemporary environmental noises). The Laboratory had evaluated the relative merits of test tapes played back to subjects through a speaker in an isolated test room of the Laboratory, as compared with subjecting subjects to corona and other environmental noises through the use of quality headphones. The Laboratory

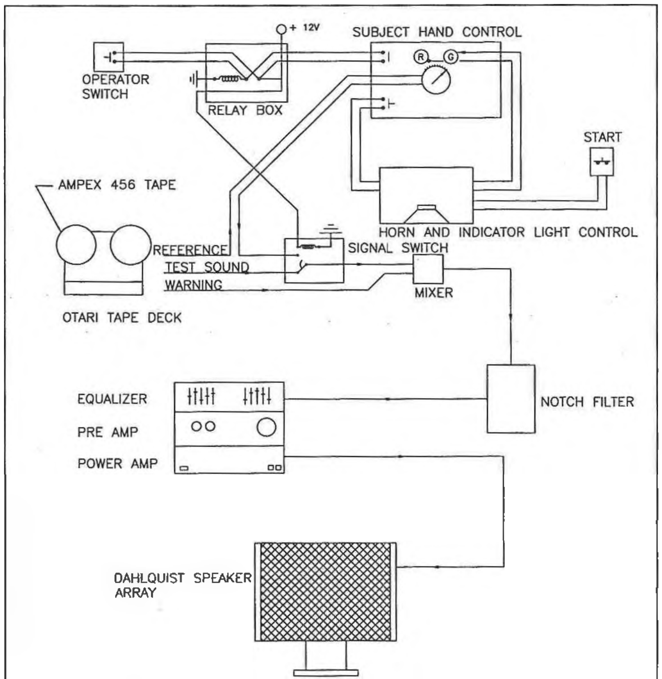


**Figure 3. Sound Reproduction System**

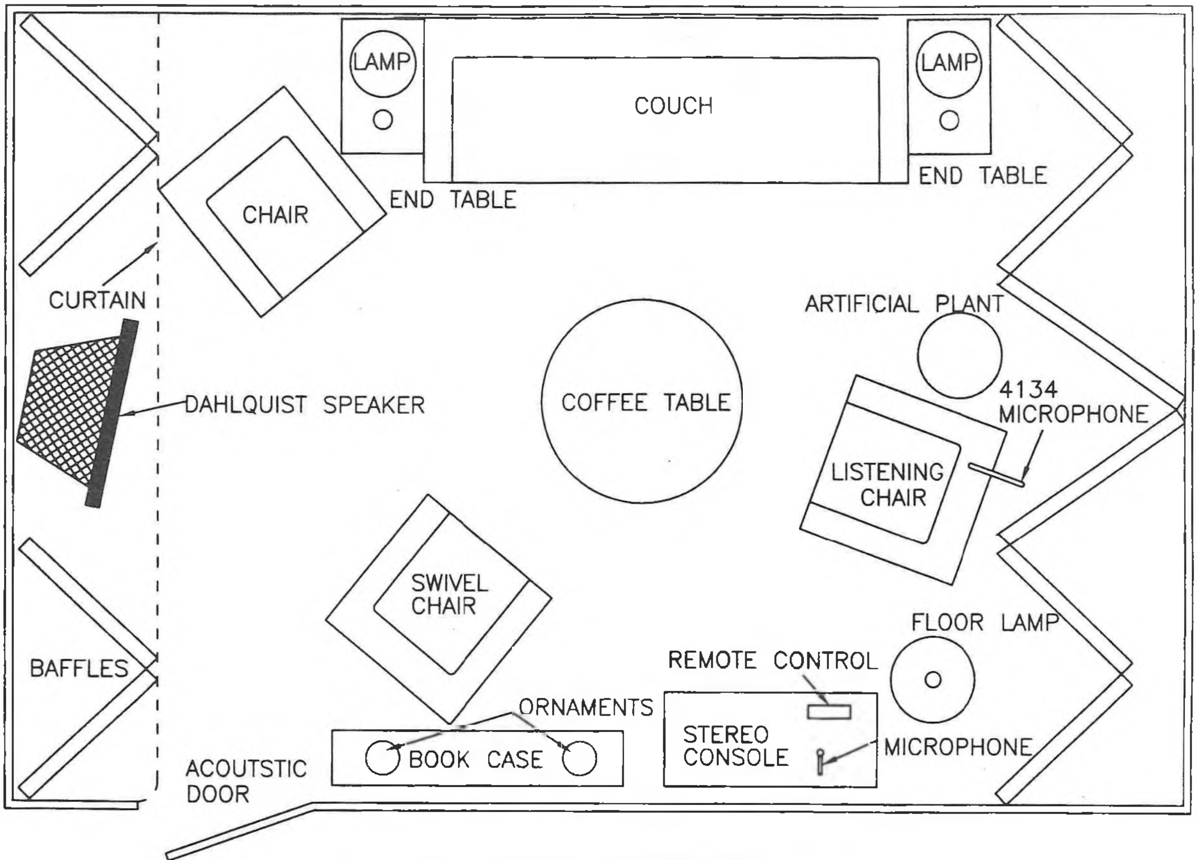


**Figure 4. Psychoacoustic Test Room**

ruled out the use of headphones, primarily because of the deterioration in frequency response of these units above 12 to 14 kHz, plus the fact that task performances which may be asked of subjects would be carried out in an 'unnatural' setting (i.e. headphones on one's ears) which could prejudice results.

The field tapes of corona line and transformer station noise, including field tapes from 765 kV lines of AEP were edited, catalogued, and subsequently used in the preparation of a 30- minute test tape for subjective response of people to this form of noise (and, as mentioned previously, for comparative purposes, to other forms of environmental noise). A block diagram of preparation of the test tapes is shown in Figure 2 and a diagram of the test tape playback procedure to the test room is shown in Figure 3. The test room was isolated from external airborne sound transmission, and was located on a separate foundation in the Laboratory which effectively isolated the room from building structural vibrations. The room was suitably decorated and furnished (i.e. simulating a family room or study - see Figure 4) and it was acoustically calibrated and equalized apropos of standard procedures which have been developed at the National Bureau of Standards [7, 8, 9].

The acoustic calibration of the test room, in particular at the position where the subjects were seated during attitudinal testing, was carried out by a microphone moved to various positions around the subject's head (Figure 4). It should be noted that audio signals, even though they are well defined in the reproduction system, can become distorted at various points in the room by the room's physical layout, absorption and reflections—with the result that it was necessary to equalize audio distortions at the listener's ear. This was accomplished through the use of spectrum shapers, which consisted of electronic attenuators and amplifiers associated with the frequency bands of interest; this instrumentation is of the type used in high-quality stereo reproduction in studios. [5]. Absorption baffles were also used in this equalization. (Figure 4)

## 4. Attitudinal Testing

The site at one of the locations had to be abandoned because of malfunctioning and difficulty in servicing the equipment (Capreol). At this point, there were three units functioning in Canada - one at La Plaine (a 735 kV transmission line) in Quebec, one at Boucherville ( a 735 kV transformer station) in Quebec, and one at Kleinberg ( a 550 kV transmission line in Ontario). The data from these three locations were thoroughly analyzed, and, from the analysis tapes, preferred samples of corona sound were selected (as well as the other environmental sounds) for play back to lis-

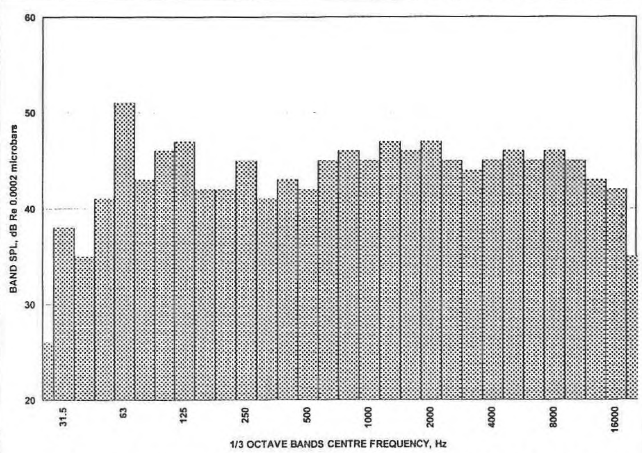


**Figure 5. Sample of Corona Noise from 750 KV Line**

teners in the listening room. At the same time, categorizing of all samples of corona noise on the tapes [see reference 5] was done, there were 25 samples categorized, and from these four corona test samples were chosen for psychoacoustic testing, along with five other environmental sounds.

A typical corona spectra which was measured from one of the high voltage transmission lines is shown in Figure 5. Note the frequency of the current in the line (63 hz) and its harmonics, and the wide band frequency (up to 16 kHz) associated with the corona discharge.

A behavioural conversion procedure, the "paired comparison", was used to assess human aversiveness to noise. Reproduced samples of corona noise (four separate stimuli), transformation noise, and other environmental noises (jet engine, traffic, lawn mower, air conditioner) were compared with an artificial reference stimulus in the above-mentioned listening room (see Figures 3 and 4). The artificial reference stimulus was an octave band of white noise centred at 1000 Hz. There were 32 participants (16 male, 16 female) evenly divided in the age groups of 30 years and under and 45 years and over. The nine test stimuli were presented to participants in random order. Each participant was involved in two separate test sessions, where the nine test stimuli were presented four times in different order during each session. This resulted in 256 responses per stimulus.

The background noise spectrum was below the preferred noise criteria (PNC 25) recommended for bedrooms and quiet residential areas [10]. The background noise spectrum was at or below that of each noise stimuli. The instrumentation for the reproduction of the sound stimuli in the listening room and the means whereby the listener adjusted the reference sound (comparison to each stimulus for equal aversiveness) is shown in Figure 3. The measuring equipment which was used in monitoring each stimulus and in recording the levels to which the reference sound was adjusted by the listener is shown in Figure 3. The intercom system which was used for verbal communication between the operator (who was outside the listening room) and the listener is also shown in Figure 6.

## 4.1 Procedure

The listening room tests were conducted in three stages. A pilot study was first conducted in order to familiarize the Laboratory with psychoacoustic testing to obtain some preliminary responses of people as to the annoyance of corona noise, and to assess the efficacy of the test room and the testing procedures as far as how listeners reacted (i.e. were they comfortable with the room and the procedures, were there any improvements for instance which could be made in the furnishings, etc.?). For details of this pilot study, refer to reference 11.

A major aspect of the present study (the second stage) involved an assessment as to how people responded to recorded and reproduced sound versus the original live

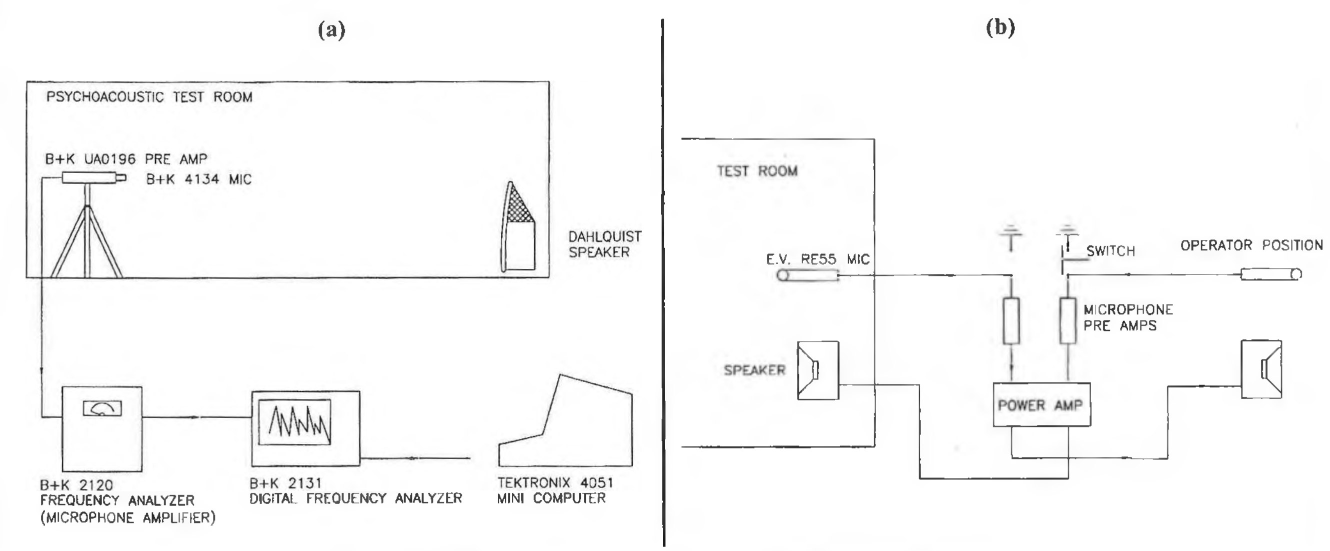


**Figure 6. (a) Measureemht Equipmenmt; (b) Intercom System**

sound, both presented at the same sound level to the listener [11].

Although it has been realized for some time in the recording industry that limitations in electronic instrumentation produce distortions in recorded and reproduced sound, it has not been known to what extent this might have an effect. The Laboratory carried out a series of tests using the same recording equipment as was used for field recording of the stimuli used in the final testing and tested several different reproduction systems (amplifiers, speakers, etc.). The sound from a spark generator was used as both the live sound and the reproduced sound and both were presented to listeners from behind the drapes (as in Figure 4). Listeners then adjusted the level of the reproduced sound until it was equally aversive to that of the live sound, as judged in a side-by-side comparison test. A statistical analysis of the results showed that respondents judged the recorded and reproduced sounds to be more aversive than the live sounds, when both sounds were presented at the same overall level. This indicated that the electronically recorded and reproduced sounds had been adversely modified (as far as human annoyance was concerned) by electronic distortion in the recording and/or reproduction system. This has, of course, considerable significance in use of listening rooms and reporduced sounds during psychoacoustic testing for attitudinal response of humans to noise aversion.

It was not possible to draw any conclusions regarding the problem of the response to reproduced vs live sound because of the limited nature of the testing which was carried out. In subsequent meetings between the liaison engineers to Project 77-27, and representatives from IREQ, Ontario Hydro, and American Electric Power, and representatives from the Laboratory, it became evident that considerable further testing would have to be carried out involving facilities where people could be exposed to real corona live sound and its reproduced version, in order to arrive at some indication as to the extent of the problem. Measures could then, perhaps, be applied to listening tests as a correction to the results.

The main difficulty in accurately reproducing a recorded sound appears to be in the speaker system. Inasmuch as IREQ [22] and the National Bureau of Standards [8, 9, 12, 13, 14) had carried out listening room tests using a Dahlquist Model No. DQ-10 speaker, it was decided that, in the interest of consistency, the Laboratory would use a similar speaker in its final psychoacoustic testing.

The final stage of psychoacoustic testing involved 32 participants. The selection of the number of participants and age groups, and the testing procedures (outlined below) were arrived at after consultation with Dr. Brian Shelton of the Department of Psychology at the University. A copy of the consultant's report and recommendations is included in Appendix I of reference 5. Each participant was audiometrically screened for hearing acumen (no more than 20 dB deficiency in each of the octave bands from 125 Hz to 8 kHz). An appointment was then made for each participant who successfully passed the hearing test for two separate occasions when he or she would be available to participate in the main test. Each participant was briefed with regard to the testing, and given a set of instructions to read at the beginning of the first test (see Appendix II of reference 5). Each test took approximately one hour (although this depended on the time that it took the listener to adjust the reference sound so that it was equally aversive to the test stimulus). There was a short session at the beginning of each hour to familiarize the participant with the testing procedure which consisted of nine samples of white noise at different levels to be compared with the octave band reference sound. The nine acoustic test stimuli were then presented in 4 blocks randomly distributed within each block (see Appendix III of reference 5 for a description of the tape format). Two warm-up (and "throw-away") test stimuli were presented at the beginning of blocks 1 and 3; there was a 3-minute break between the presentation of blocks 2 and 3. Each stimulus test signal was of 60 seconds duration and the participant had control of the sequential presentation of the test signal and the reference sound through anotated buttons on a console held, usually, on the participant's lap. A volume control knob on the console allowed the participant to adjust the level of the reference sound (white noise in the octave band at 1 kHz); by sequentially calling up the test signal and the reference sound and adjusting the volume of the reference sound, the participant then established a sound pressure level at which he or she judged the reference sound to be equally aversive to that of the test signal. The participant then pressed another button on the console which activated a horn at the operator's position at the outside of the listening room. The level at which the participant had ajusted the reference sound was then measured on the 2131 Analyzer (Figure 4) by the operator, and duly recorded.

**TABLE I - Sound Levels of Test Stimuli Presentations (dB)****

| | | Linear | A-wt | D-wt |
|---|---|---|---|---|
| Corona | CR-1 | 57 | 55 | 62 |
| | CR-2 | 60 | 58 | 65 |
| | CR-3 | 55 | 53 | 59 |
| | CR-4 | 60 | 58 | 65 |
| Transformer Station | TRN | 60 | 51 | 57 |
| Traffic | TRF | 58 | 46 | 52 |
| Jet Engine | JET | 60 | 60 | 68 |
| Lawnmower | LWN | 58 | 51 | 57 |
| Air Conditioner | A-C | 57 | 47 | 53 |

** All decibel levels quoted in this report are referenced to 20 μPa.

The levels of presentation of the nine test stimuli, as measured by the microphone at the listener's ear (linear setting of measuring system, A-weighted setting and D-weighted setting) are recorded in Table I. The rationale for the choice of these measurement ratings is discussed in the next section.

The levels (Linear) at which the stimuli were presented to the listeners were chosen such that (1) the stimuli spectra would be above the room background spectrum, and (2) the octave band reference sound, when adjusted for equal aversion to each stimulus, would not exceed a maximum of 80 dB. (80 dB had been stipulated as the permissible upper limit of exposure levels to subjects as required by a University Senate Committee which monitored procedures in the use of human subjects for research.) The corona and air conditioner stimuli were presented at the levels at which they were recorded in the field. The transformer, traffic, jet and lawnmower stimuli were adjusted from the field recorded levels. Althouh the stimuli presentation levels in these tests were somewhat higher than were used by other experimenters in similar tests [6, 15, 16] it should be noted that higher levels of presentation of acoustic stimuli result in smaller standard deviations of listerners' responses [10].

## 5. Results and Discussion

The procedure which was adopted for the presentation order of the test stimuli resulted in 2 x (9 x 2) = 36 responses per participant per test session. With 32 participants and two test sessions per participant, this resulted in a total of 36 x 32 x 2 = 2304 responses (or 256 responses per stimulus).

The responses were analyzed and statistical comparisons made using the Statistical Package for Social Sciences (SPSS) and a UWO statistical package called BALANOVA (balanced analysis of variance). A summary of statistical tests which were carried out to check for significance of tape order effect, noise stimuli effect, day effect, gender/age effect, block effect, and an assessment of the use of the six participants with slightly impaired hearing in one ear, is given in Appendix IV of reference 5.

It has been noted earlier in this report that the objective in this part of Project 77-27, and the results as noted in this report, were to assess the attitudinal response of people (i.e. their aversiveness) to corona noise from HV transmission lines as compared to other forms of contemporary environmental noise and to also assess which of the most commonly used noise ratings might best fit the requirements for sound measuring equipment to be used in future monitoring and control of corona noise. The study was therefore concerned with the relative annoyance of various noises, and does not assess the annoyance levels of noise in absolute terms. (For a preliminary assessment of corona noise and a limited number of contemporary environmental noises with respect to the standard octave band of white noise at 1 kHz, expressed in terms of word descriptors ranging from "very pleasant" to "very annoying", see reference 21; also see reference 8 for a discussion and comparison of respondents' reactions, again in absolute terms, to various levels of corona noise obtained by (a) measurements in the field and (b) playback or recorded corona sound in a laboratory.)

As was mentioned in the Introduction, the measurement scales which will be assessed in this study are confined to Linear, A-weighting, and D-weighting, these being the most commonly used and most readily available in contemporary instrumentation. The Linear and A-weighted level of each stimulus as presented to listeners was obtained from the Bruel and Kjaer 2131 real-time analyzer (Figure 2); the linear 1/3 octave band spectra for the nine acoustic stimuli were used to arrive at the equivalent D-weighted levels. Equations and procedures for deriving these latter values may be found in Pearsons and Bennet [10]. These various levels are recorded in Table 1.

No attempt was made to account for transmission losses encountered when outdoor noises are heard indoors. The results thus approximate the situation of listeners located in a family room close to a large open window.

Figures 7, 8 and 9 show the ΔdB values (mean, standard

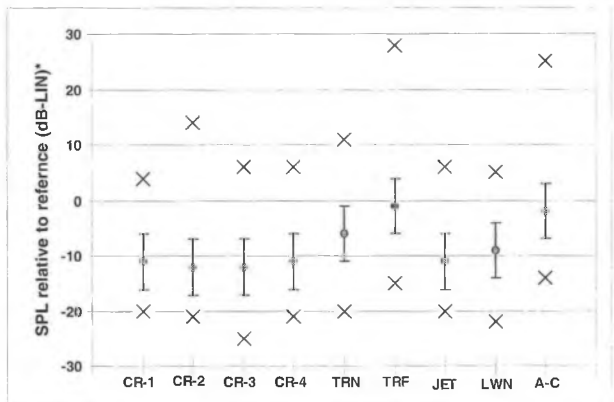


**Figure 7. Difference in SPL-LIN between Test Sound and 1 KHz Octave Noise**

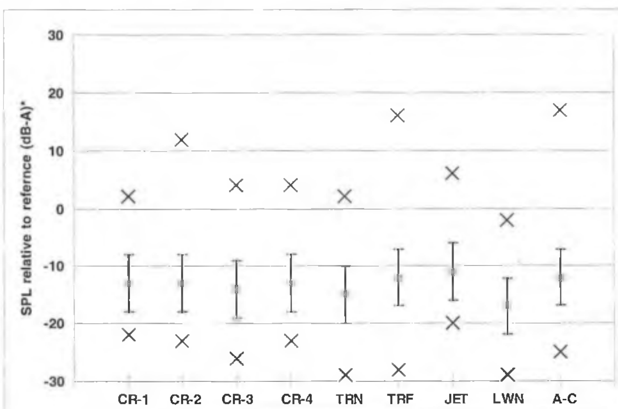


**Figure 8. Difference in SPL-A between Test Sound and 1 KHz Octave Noise**

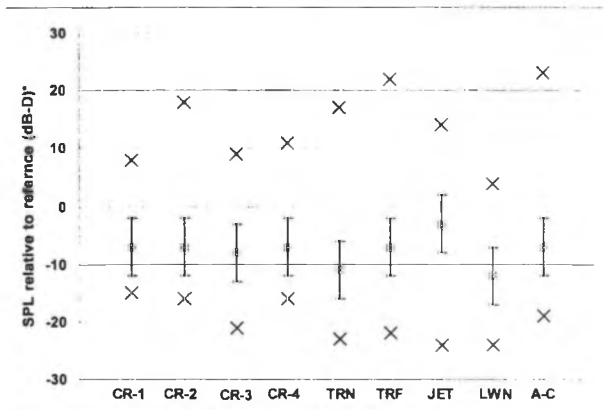


**Figure 9. Difference in SPL-D between Test Sound and 1 KHz Octave Noise**

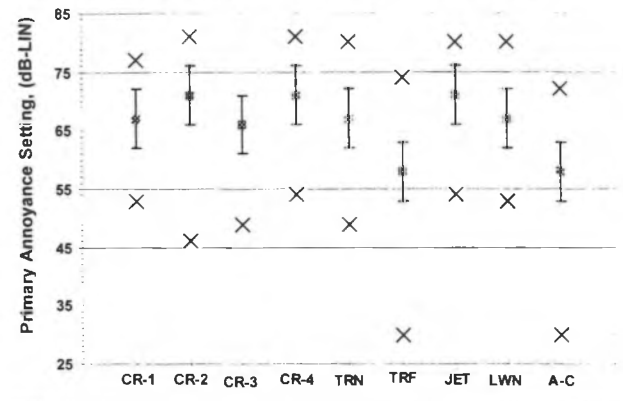


**Figure 10. Distribution of P.A.S. in Response to Test Sounds**

deviation and range) for each of the test stimuli, plotted for the three noise ratings of Linear, A-weighting, and D-weighting respectively. [x-x is the range, ⊢⊣ is the standard deviation plotted around the mean value] The ΔdB values are the difference between the sound pressure levels at which the stimuli were presented, and the levels to which respondents adjusted the reference (1 kHz octave band of white noise), for equal aversiveness of each. For instance, in Figure 7, for equal aversiveness (or, conversely, for equal preference), the stimulus CR-1 would have to be 11 dB lower than the reference noise, as measured by the linear scale. On the other hand, respondents adjusted the reference sound 0.5 dB lower (mean value) for traffic noise for equal aversiveness.

The values of SPL relative to the reference in Figures 7 to 9 (the ΔdB values) are thus an indication of relative aversiveness expressed by respondents to stimulus based upon actual assessment as measured in the listening room (Lin) and aversiveness as adjusted to the weighting measurement scales (A-weighting and D-weighting). The procedure for transforming the ΔdB Lin values to ΔdBA and ΔdBD is outlined in Appendix V of reference 5.

Referring to Figures 8 and 9, where the ΔdB values are the reference sound plotted using A-weighting and D-weighting respectively as the measurement scale, it can be seen that corona noises are rated basically comparable in aversiveness to traffic noise and more aversive than jet noise.

The primary annoyance settings (PAS) are shown plotted in a different form in Figure 10. (PAS is the level in dB to which respondents adjusted the 1 kHz octave band reference noise in order to achieve equal aversiveness with each stimulus). Mean values, standard deviations and ranges of PAS are shown. It can be seen that the predominately low frequency sounds (traffic and air conditioner) yield a greater variability in responses (larger standard deviations, larger ranges) indicating that people are less positive in defining aversiveness to low frequency content sounds than they are in defining aversiveness to high frequency content sounds. Figure 10 shows the preference of respondents for low frequency content sounds (PAS means of 58 and 57.8 dB, traffic and airconditioner) to higher frequency content sounds, including corona (PAS means from 67.5 to 70.8 dB).

Molino et al found that, with respect to the 11 dB difference for equal preference between corona sounds and the octave band reference sound for linear weighting, A-weighting increased this difference to 13 dB, while D-weighting reduced the difference to 8dB. Referring to Figures 7 and 8, the comparable values obtained in the current research are 12.9 dB and 6.8 dB respectively. There is good agreement.

Pearsons et al [10] concluded that, of the three measurement scales in question, the A-weighting and D-weighting scales were preferable to the Linear scale (there was little to choose between the two), because these scales gave the least standard deviation of listeners' responses. (Molino et al arrived at similar conclusions, but for somewhat different reasons [13]). Again, the results of the present research are in agreement with these conclusions.

This study showed that standard deviations were less than those found by Pearson [10], Molino [12], Merritt [15] and Maruvada [16], found that annoyance to corona noise varied linearly with the stimulus sound pressure level. The present research has also shown that aversiveness to corona noise has a direct relationship to sound pressure level, irrespective of the corona spectra shape. This can be seen in the consistent ΔdB values (sound pressure level relative to reference) of corona in Figures 7 to 9.

Maruvada et al [16] carried out listening tests using DC and AC corona and 1kHz octave band reference sound, and showed through a graph of MAR (Minimum Annoyance Rating) vs SPL (Sound Pressure Level) that annoyance with AC corona sound varied linearly with SPL; they also showed the relative annoyance of AC corona noise with respect to the 1 kHz octave band reference sound. When the results of the present tests (PAS vs SPL) are extrapolated to their MAR vs SPL graph, there is close agreement.

## 6 OBSERVATIONS

The main observatons to be drawn from this research are:

1. When measured as linear sound levels, the corona noises tested are equally aversive to a 1 kHz octave band of white noise (the reference sound) about 11.5 dB higher in sound pressure level, while the traffic noise is equally aversive to the reference sound which is about 0.5 dB higher in sound pressure level; the inference here is that for equal aversiveness to traffic noise, corona noise would have to be presented at approximately 11.5 dB lower than the traffic noise level;
2. When the measurements of the test signatures and reference sound were A-weighted, the difference between the corona sounds and traffic sound for equal aversiveness to the reference sound was reduced from 11.5 dB to approximately 0.5 dB;
3. When all sounds are measured as A-weighted sound levels, corona noise is about equally aversive to other common environmental sounds (Figure 8). The spread in judged aversiveness is about 5 dBA for all sounds tested, with the corona noise signals being in the middle of this range (e.g. corona noise is judged to be about 2 dBA more aversive than traffic noise, and 3 dBA more aversive than jet engine noise, and about 2 dBA less aversive than transformer station noise). Since the standard deviations are larger than those values, it is suggested that these differences are not statistically significant. (Further analysis could be undertaken to determine this point);
4. When all sounds are measured as D-weighted sound levels, the conclusions are identical to those in 3, except that the spread in judged aversiveness is about 8 dBD;
5. Aversiveness to corona noise appears independent of the corona spectre shape and is directly related to sound pressure level of the noise;
6. A-weighted and D-weighted measurement scales are preferable (with A-weighting slightly better than D-weighting) to the Linear measurement scale since the A and D scales have the lowest standard deviation and therefore are the most consistent predictors of judged aversiveness;
7. Since practically all environmental sound levels and criteria are normally quoted as dBA levels, A-weighted levels as quoted above would appear to be preferable to the D and Linear scales (an exception being that D-weighting might be better for jet noise);
8. The corona noise stimuli which were used in this research utilized noise samples which were selected (from long-term measurements on operating transmission lines) for individual uniqueness of spectre and weather conditions and for frequency of occurence [22], and were thus more representative of corona sounds than were those used in previous psychoacoustic experiments [8, 13, 14, 16, 17, 20, 21];
9. The paired comparison method of testing (with individual adjustment of a reference sound as used in this research appears to be a useful method for investigating aversiveness to environmental sounds such as corona noise from transmission lines;
10. Observations 1 to 6 above are in general agreement with results published by Molino [17]; Observation 6 is in agreement with results published by Pearsons [20] while conclusions 2, 3 and 4 are in contradictions.
11. The result of Pearsons' survey, coupled with observations 2 and 3 above, would suggest that, as a first pass, corona noise can be treated in a manner similar to traffic noise when establishing suitable criteria. Caution must be exercised, however, as there are many assumptions implicit in both studies which may invalidate this conclusion. (For instance, Horonjeff et al (reference 17, vol. 2) in a series of studies on sleep interference showed that the propability of awakening is about ten times as great from steady-state corona noise intrusion (in a bedroom) as compared with traffic noise.

## 7 SUMMARY OF RESULTS

It is felt that the instrumentation and procedures which were utilized in this current project sponsored by CEA resulted in comprehensive, accurate and reliable data regarding long-term statistical analysis of audible noise from high voltage transmission lines and the attitudinal response of people to these noises. The co-ordination of the CEA study with similar studies being conducted by the American Electric Power Service Corporation (in conjunction with the National Bureau of Standards) in the U.S.A., and with allied studies by IREQ in Canada, provided a much broader base for assessment of the environmental implications of contemporary corona noise.

It was found: that the corona noise samples were equally aversive to a 1 kHz octave band of white noise that was about 12 dB higher in sound pressure level (see Figure 7); that the corona noises tested are about equally aversive as jet engine noise, somewhat more aversive than transformer and lawnmower noises, and considerably more aversive than traffic and air conditioning noises; that aversiveness to corona noise appears independent of the corona spectra shape and is directly related to sound pressure level of the noise; that if A-weighting and D-weighting were the measurement scales used in assessing relative aversiveness, these would under-estimate the impact (i.e. the degree of judged aversiveness) of corona noise when compared with certain environmental sounds such as traffic, transformer station, air conditioner and lawn mower noises, and would slightly over-estimate the degree of judged aversiveness of corona noise when compared with jet noise (see Figure 8 for example of A-weighting); and that A-weighted and D-weighted measurement scales are preferable (with A-weighting slightly better than D-weighting) to the Linear measurement scale with respect to consistency (least standard deviation and hence variability) of responses from listeners.

## 8 Acknowledgement

The research associated with this paper was carried out under sponsorship of the Canadian Electrical Association, Research Contract 77-27. The authors gratefully acknowledges the assistance and advice of various colleagues who have contributed to this research: these are Messrs. R.M. Morris (NRC) and A.J. Lees (B.C. Hydro), Liaison Engineers between CEA and the Laboratory; Messrs. J. Reichman (Ontario Hydro) and P.S. Maruvada (IREQ), Liaison Engineers between the Laboratory and Ontario Hydro and Hydro Quebec; Messrs. T.K. Ho and D. Godard, all of the Sound and Vibration Laboratory; Dr. S.M. Sorrentino of the Department of Psychology at the University; Messrs. J. Watkinson, G. Aartsen and R. Kettlewell, of the Electronics Shop, and Mr. R. Kager of the Mechanical Shop, all of the Faculty of Engineering Science.

Special appreciation is extended to Dr. M.P. Sacks, acoustical consultant, whose review of the report contributed to a more accurate interpretation of the results in the light of contemporary measurement procedures.

Finally, the first author would like to express his sincere appreciation to his daughter, Elizabeth, in assisting with the copying of some texts and diagrams in this report.

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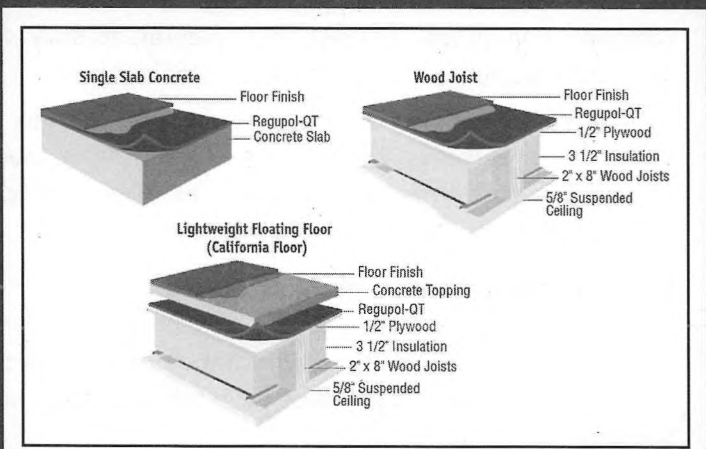


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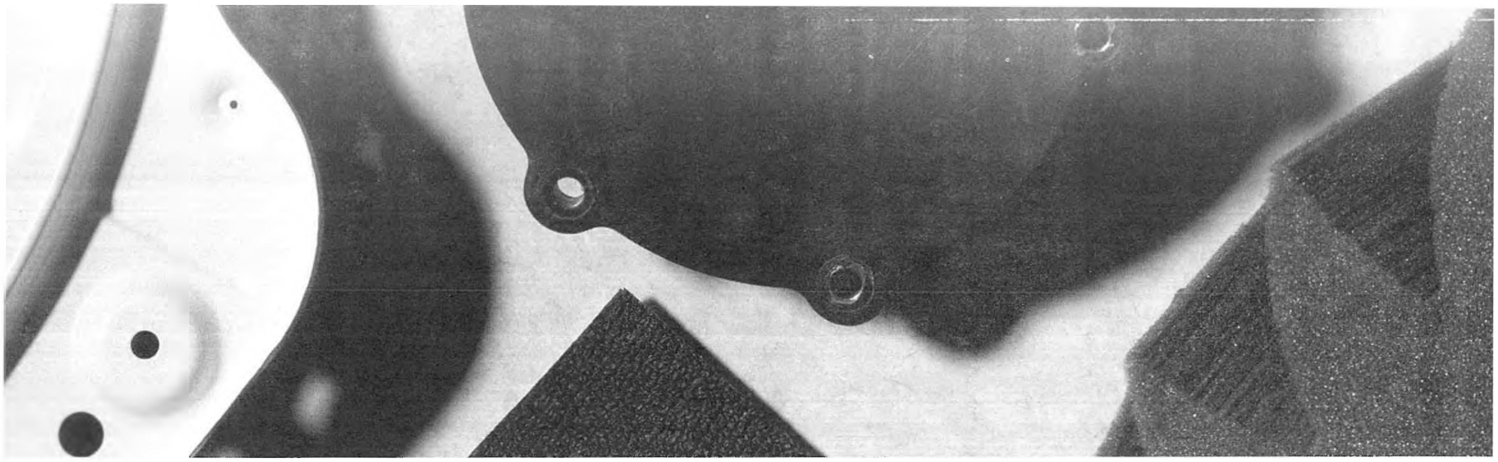

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# SCATTERING OF A PLANE WAVE BY A CYLINDER WITH SURFACE IMPEDANCE THAT VARIES WITH POSITION

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## ABSTRACT

In this work 'the source simulation technique' was used to calculate the scattering of a plane wave by a circular cylinder with surface impedance that varies with position. The basic idea of the source simulation technique is to replace the scatterer by a system of simple sources located within the envelope of the original body. The efficiency of the method was verified through the comparison between numerical results and experimental data. The calculation of the scattering was performed for the variants of the method: the single-layer method and the one-point multipole method. The matching between theoretical and experimental results was in the overall good, despite some occasional discrepancies.

## SOMMAIRE

Dans cet ouvrage, la technique de simulation de source a été utilisée pour calculer la diffusion d'une onde plane par un cylindre avec une impédance de surface qui varie avec la position. L'idée de base de la technique de simulation de source est de remplacer le diffuseur par un système de sources simples localisées à l'intérieur de l'enveloppe du corps original. L'efficacité de cette méthode a été vérifiée en comparant les résultats numériques et des données expérimentales. Le calcul de la diffusion a été faite par les variantes de cette méthode: la méthode de couche unique et la méthode multipôle à un point. Les résultats théoriques et expérimentaux étaient généralement comparables, en dépit de divergences occasionelles.

## 1. Introduction

The mathematical treatment of radiation and acoustic scattering represents a very old and much studied problem of mathematical physics. Both phenomena were first treated more than a century ago by Lord Rayleigh [1,2]. Rayleigh suggested that the sound field radiated from a transverse vibrating rigid body is built up from spherical wave functions. This is the basic idea of the source simulation technique, that is, to replace the vibrating body by a system of radiating sources, which act in an equivalent way on the surrounding medium as the original body. The sources are located inside the radiator, and the problem consists of finding the source amplitudes. As long as the source amplitudes are known, the pressure and the velocity can be mapped at each point in the field.

This work was aimed at 1) showing the formulation of the scattering problem with the source simulation technique and 2) presenting its variants, the one-point multipole method and the single layer method. These variants were employed in the calculation of the scattering by a rigid cylinder, an absorbent cylinder, and by a cylinder with variable surface impedance. The cylinder was always considered infinite. The numerical results thus obtained were compared to experimental data collected in an anechoic chamber.

## 2. Description Of The Radiation And Scattering Problem

Consider the scatterer or radiator with surface **S**. The interior from **S** is called $\mathbf{S_i}$ and the exterior field $\mathbf{S_e}$. The normal surface **n** is directed to the exterior field $\mathbf{S_e}$. Throughout this article, only the exterior problems will be treated [3].

In the exterior field, the complex sound pressure $p$ should satisfy the Helmholtz equation

$$\Delta p + k^2 p = 0 \tag{1}$$

where, $k = \omega/c$ is the wave number, $\omega$ is the circular frequency, c is the speed of sound and Δ is the Laplace operator. All the variables as functions of time should obey the function $e^{j\omega t}$. As long as the sound radiation in a free three-dimensional space is considered, the pressure $p$ should also satisfy the Sommerfeld radiation condition [4]:

$$Lim_{r\to\infty} r\left[\frac{\partial p}{\partial r}+jkp\right]=0 \qquad (2)$$

which could be considered as the boundary condition at infinity. Here,

$$r=|\vec{x}| \;,\quad \vec{x}=(x_1,x_2,x_3)$$

and $r$ is a position vector and denotes the distance from the center to each point $x$ in the field. Ochmann [5] termed the solutions of Eq. (1) satisfyimg the boundary condition of Eq. (2) as radiating wave functions. Typical functions that represent this class are called spherical wave functions ([5], [6]), which are generated when the solution of the wave equation is obtained in spherical coordinates. For the sake of simplicity, radiating wave functions will be called *sources* [5]. A complete description of the problem requires a description of boundary conditions on the surface of the radiator or scatterer. The Neumann boundary conditions will be considered here. In this case the normal velocity, $v_n$, and the gradient of the pressure

$$\partial p/\partial n = -j\omega\rho v_n \qquad (3)$$

on S are described. In Eq. (3), ρ is the density of the surrounding medium S and $\delta/\delta n$ is the derivative in the direction of normal **n** into the exterior field $S_e$. The problem of acoustic radiation is obtained if the normal velocity considered on the surface of the body is different from zero $v_n \neq 0$. Equation (3) represents an inhomogeneous boundary condition. Equations (1) and (2) describe the radiation problem for the radiated pressure $p$. With respect to the scattering problem, one should consider the incident wave $p_i$, which on its propagation encounters the surface S, then generating the scattered wave $p_s$. The scattering problem for the scattered

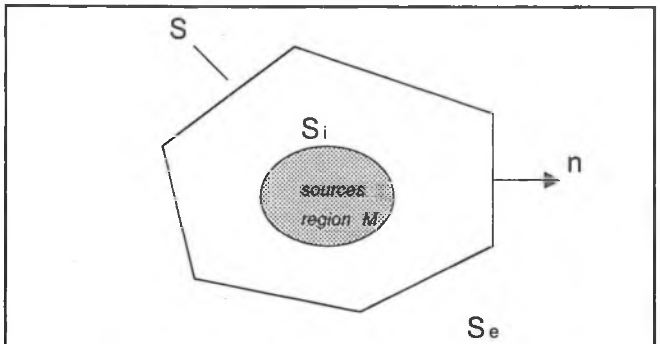


**Figure 1. Geometry of the radiation and scattering problem (Ochmann, 1999).**

wave $p_s$ is described by Eqs. (1) and (2), but the pressure $p$ should be accordingly substituted by pressure $p_s$ in both equations. Considering again the Neumann boundary value problem, the outcome is that for a totally rigid body, the surface velocity should be equal to zero, that is, $v_n = 0$. That is,

$$\partial p/\partial n = 0 \qquad (4)$$

In Equation (4) the pressure $p$ represents the total pressure $p_t = p_i + p_s$. Equation (4) thus represents a homogeneous boundary condition. The scattering problem can then be formulated as a radiation problem. One should then consider velocity $v_i$ of the incident wave $p_i$ on the surface S. If surface S vibrates with negative normal velocity ($-v_i$), the radiated pressure is identical to the pressure $p_s$, originated from the incidence of $p_i$ on S [4]. As a consequence, it is possible to write instead of Eq. (4)

$$\partial p/\partial n = -j\omega\rho(-v_i) \qquad (5)$$

for the scattering problem. Equation (5), similar to Eq. (3), represents an inhomogeneous boundary condition. Equations (1), (2) and (5) thus describe the scattering problem in an equivalent way to a radiation problem with respect to the scattered wave $p_s$.

## 3. Principle Of The Source Simulation Technique

The principle of the method is based on a treatment of the radiation problem or the scattering problem through a system of radiating sources, which should be chosen so that they reproduce as well as possible the sound field generated by the body of Figure 1. In the space previously occupied by the body S, the sources can now be found in region **M** shown in Figure 1. The sources are taken as point sources, and therefore do not represent an obstacle to the sound field. As a consequence the field generated by each one can be summed without taking into consideration interference effects. As the source amplitudes are known, the sound field can then be easily calculated through the sum of the fields generated by each source individually. The true problem consists then in finding the sources that can best replace the original body. As a consequence, two important questions arise:

1) Which is the type of source to be used and how should they be placed inside the body?
2) Which optimization method should be employed for the results?

Mathematically the problem is based on representing the sound field by summing up the contributions of the individual sources

$$p=\sum_{q=1}^{Nq}\sum_{m=-\infty}^{m=+\infty}A_{q,m}\phi_{q,m} \quad (6)$$

where $p$ represents the scattered pressure or the radiated pressure in the field; $A_{q,m}$ is the complex source strength of the $q^{th}$ source at a point $x_q$ in the field; $m$ is the order of each source and $\Phi_{q,m}$ is the sound field generated by the sources. In Eq. (6) $\Phi_{q,m}$ could also be called the source function. Equation (6) intrinsically has the condition that each field can be represented by a sum of functions of the type $\Phi_{q,m}$. This is naturally the case, only if all functions $\Phi_{q,m}$ satisfy the wave equation and if they form a complete function system. This condition is certainly satisfied if $\Phi_{q,m}$ represents, for example, the field generated by a monopole, dipole or quadrupole. As no difficulty has been noted by other authors ([5], [7], [8], [9], [10]) when multipole sources were used for the reconstruction of the acoustic field, the same procedure will be used in the present work. In other words, the multipole sources will be used to represent the radiation or scattering problem of the original body.

Two distinct situations pose themselves:

1) one can use a variable order multipole localized in a single point inside the body, that is, in Eq. (6) $Nq = 1$ and $M$ is very large, or
2) one can use only monopole sources positioned in several points inside the body, which renders $Nq$ very large and $M = 1$ in Eq. (6).

One can also have a combination of both extreme cases presented in a) and b), that is, to use a multipole positioned in several points. Together with the choice of the type and the positioning of the sources, the choice of the optimization criterion also imposes a fundamental question for the use of the source simulation technique. The error derived from this optimization should be minimized. Several methods can be used to that end, such as the null field method, the collocation method, or Cremer's method. The least square minimization method has been used in this work.

## 4. Source Function System

If a source alone generated the sound pressure $A_{q,m}$ $\Phi_{q,m}$, then the sum

$$p=\sum_{q=1}^{Nq}\sum_{m=-M}^{m=+M}A_{q,m}\phi_{q,m} \quad (7)$$

should approximate the original field as well as possible. Each of the individual source functions $\Phi_{q,m}$ is supposed to meet the radiation condition in Eq. (2) and the wave equation in Eq. (1) in the exterior field domain $\mathbf{S_e}$. When these conditions are satisfied, one can take them from any complete function system. In practical terms, source functions, which can be written in conventional coordinate systems, can be used: spherical coordinates (for three-dimensional problems) and cylindrical coordinates (for two-dimensional problems).

The velocity generated by the source function system at the radiator surface is calculated by inserting Eq. (7) in Eq. (3). For reasons of simplicity, we have taken the one-point multipole method, so that $q = 1$

$$v_n=-\frac{1}{j\omega p}\cdot\sum_{m=-M}^{m=+M}A_m\frac{\partial\phi_m}{\partial n} \quad (8)$$

Eq. (8) can be rewritten, since $k = \omega/c$, as

$$v_n=-\frac{1}{\rho_0 c_0}\cdot\sum_{m=-M}^{m=+M}A_m Z_m \quad (9)$$

where,

$$Z_m=(1/jk)\partial\Phi_m/\partial n$$

is a function defined in a similar way as in Heckl [8]. For example, the function $Z_m$ in the commonly cylindrical coordinates for two dimensions is given by

$$Z_m=+\frac{1}{j}\left[H_m^{'(2)}(kR)e^{+jm\phi}\frac{\partial r}{\partial n}+\frac{m}{k}H_m^{(2)}(kR)e^{+jm\phi}\frac{\partial\phi}{\partial n}\right] \quad (10)$$

where,

**R** is the radius from the radiated body;

$H_m^{'(2)}(kR)$ and $H_m^{(2)}(kR)$

are the derivative of the Hankel function of the second order; and the Hankel function of the second order, respectively. For the scattering problem, the calculations go in a similar way. The total velocity generated on the scatterer surface is given by

$$v_{t(n)}=v_1+v_2 \quad (11)$$

where $v_{t(n)}$ is the total generated velocity on the scatterer surface in the normal direction, $v_1$ is the velocity from a normally incident wave at the surface of the body, and $v_2$ is the scattered velocity when the body is present in the field

$$v_{t(n)}=-\frac{1}{j\omega p}\frac{\partial(p_1)}{\partial n}=-\frac{1}{j\omega p}\left[\frac{\partial(p_i)}{\partial n}+\sum_{q=1}^{N_q}\sum_{m=-M}^{m=+M}A_{q,m}\frac{\partial(\phi_{q,m})}{\partial n}\right] \quad (12)$$

where $p_t$ is the total pressure on the scatterer surface and is given by

$$p_t=p_i+p_s \quad (13)$$

$$p_t=p_i+\sum_{q=1}^{Nq}\sum_{m=-M}^{m=+M}A_{q,m}\phi_{q,m} \quad (14)$$

where $p_i$ is the pressure from the incident wave and $p_s$ is the scattered pressure in the field. For reasons of simplicity, we have taken again the one-point multipole method, so that $q = 1$,

$$p_t = p_i + \sum_{m=-M}^{m=+M} A_m \phi_m \tag{15a}$$

and

$$v_{t(n)} = -\frac{1}{j\omega p}\frac{\partial(p_t)}{\partial n} = -\frac{1}{j\omega p}\left[\frac{\partial(p_i)}{\partial n} + \sum_{m=-M}^{m=+M} A_m Z_m\right] \tag{15b}$$

The function $Z_m$ is the same as in Eq. (10) for the two-dimensional problem with cylindrical coordinates. If the incident wave is a plane wave in cylindrical coordinates

$$p_i = p_0 e^{-jkR\cos(\phi)} \tag{16}$$

so, $v_{t(n)}$ is rewritten as

$$v_{t(n)} = \frac{p_0}{\rho_0 c_0}\cos(\phi)e^{-jkR\cos(\phi)} - \frac{}{\rho_0 c_0}\sum_{m=-M}^{m=+M} A_m Z_m \tag{17}$$

The requirement that the velocity distribution given by Eqs. (9) and (17) generated by the sources at the surface should approximate the prescribed normal velocity as well as possible leads to a linear system of equations through which the complex source strength will be determined.

## 5. Optimization Criteria

Several methods can be used in order to minimize the error in the surface velocity approximation [10]. The least squares minimization method has been used in this work. The technique consists in minimizing the surface integral error

$$\int \left| v_{t(n)} - v_b \right|^2 dS = Min \tag{18}$$

which sums the errors generated in the approximation of the surface velocity. In Eq. (18) **S** is the surface of the scatterer, **dS** a surface element and $v_{t(n)}$ is the velocity generated by the source simulation technique. For the special case of scattering from a rigid body, the surface velocity is zero, so that $v_b = 0$.

$$\int_S \left| v_{t(n)} \right|^2 dS = Min \tag{19}$$

The velocity has the same form as in Eq. (15b) for the one-point multipole method. The system of equations for the determination of the sources strength $A_m$ is obtained through the calculation of the partial derivative of the integral in Eq. (19) with respect to $A_m$, and letting the result equal to zero

$$\frac{\partial}{\partial A_m}\left(\int_S \left| v_{t(n)} \right|^2 dS\right) = 0 \tag{20}$$

The solution of the linear system of Eq. (20) gives us the sources strength $A_m$ which when substituted in Eqs. (15a) and (15b) allow the calculation of the sound pressure and the sound velocity for each point in the acoustical field. Thus, the problem is perfectly solved. For the somewhat general case, that the body is not rigid but has a constant relation on the whole surface between the total sound pressure and the total sound velocity in the direction of the normal, this leads Eq. (18) to

$$\int_S \left| v_{t(n)} - \frac{p_t}{Z} \right|^2 dS = Min \tag{21}$$

where $Z$ is the surface impedance of the scatterer.

The condition imposed on impedance is that it should not have lateral couplings, that is, it should be locally reacting. This means that one part of the surface is not aware of the motion of another part, and the reaction of one part of the surface is proportional to the local pressure at that point. This condition indicates the non-inclusion of elastic surfaces (for example, surfaces where flexion waves are possible). This extremely rigid limitation should be verified in each case. Elastic bodies, as for example a thin-walled cylinder immersed in water, certainly do not satisfy it. For porous materials (for example foam) one can in principle assume that for air borne sound there is no lateral coupling, that is, the materials are locally reacting. In the same way, we can calculate the radiation problem with the least squares technique. This leads to the surface integral

$$\int_S \left| v_b - v_n \right|^2 dS = Min \tag{22}$$

and again the surface error should be minimized. In Eq. (22) $v_b$ is the velocity of the vibrating body and $v_n$ is the velocity generated from the sources. For the one-point multipole method and for the two-dimensional case in cylindrical coordinates $v_n$ is the same as in Eqs. (9) and (10). As in the case of scattering, if the partial derivative in Eq.(22) is calculated with respect to source strength $A_m$ and making the result equal to zero, one has a system of linear equations through which the complex sources strengths are determined. Substituting them in Eqs. (7) and (9) we have the pressure and the velocity at each point in the acoustic field.

## 6. Calculation Of Scattering Field by Source Simulation Technique

The next issue to be addressed is the problem of calculating sound scattering for an infinite circular cylinder, in which the random distribution of the surface impedance is considered. The calculation will be performed for the one-point multipole method and for the single layer method.

## 6.1 One-Point Multipole Method

In this case the approach includes the choice of multipole expansions up to high orders at only one location. Using the symmetry of the circular cylinder, the location point coincides with the center of the cylinder. The condition of an infinite cylinder means that the problem is treated independently of the axial direction, that is, $\delta/\delta z = 0$. It must also be pointed out that only plane harmonic waves are considered in this work.

The total pressure $p_t$ can be written as a sum of the incident plane wave $p_i$ and the scatterer wave $p_s$

$$p_t = p_i + p_s \tag{23}$$

The incident plane wave traveling in a direction perpendicular to the cylinder's axis is given by $p_i = p_0 e^{-jkx}$, and $p_0$ is the amplitude. The scatterer wave $p_s$ is given by Eq.(7) and Eq. (15), so that

$$p_t = p_0 e^{-jkr\cos(\phi)} + \sum_{m=-M}^{m=+M} A_m H_m^{(2)}(kr) e^{jm\phi} \tag{24}$$

In cylindrical coordinates, $x = r\cos(\Phi)$, and $r$ is the distance between the center of the cylinder and any point in the surrounding medium.

The expression for the velocity is obtained through Eq. (3), since the normal direction coincides with the radial direction and on the surface $r = R$.

$$v_{t(n)} = \frac{p_0}{Z_0}\cos(\phi) e^{-jkR\cos(\phi)} \frac{1}{Z_0} \sum_{m=-M}^{m=+M} A_m H'^{2}_m (kR) e^{+jm\phi} \tag{25}$$

where $Z_0 = \rho_0 c_0$ is the specific acoustical impedance of the air and

$H'^{(2)}_m(kR)$

is the second order derivative of Hankel function. All time varying quantities should obey the time dependence $e^{+j\omega t}$. As the exponential factor is shared by all field quantities, it can be omitted.

As mentioned earlier, the surface impedance is assumed to be locally reacting. Therefore, the boundary conditions for each surface element and for each angle $\Phi$ on the surface is,

$$v_{t(n)} = p_t / Z \tag{26}$$

where $Z$ is the surface impedance.

In this work it is considered that the impedance is randomly distributed on the surface. Hence, the impedance could be infinite, that is, for a rigid surface in the interval $\Phi_0 \leq \Phi \leq \Phi_1$, or could be finite, assume the value $Z$ in the interval $\Phi_1 \leq \Phi \leq \Phi_2$. The impedance $Z$ was measured with the standing wave apparatus for a 5 cm-thick foam, and will be used in the numerical calculation as inputs for the solution of the problem.

Considering the optimization criterion given by Eq. (21), we have

$$R\left[\int_{\phi_0}^{\phi_1} \left|v_{t(n)}\right|^2 d\phi + \int_{\phi_1}^{\phi_2} \left|v_{t(n)} - \frac{p_1}{Z}\right|^2 d\phi\right] = Min \tag{27}$$

Differentiating Eq. (27) with respect to the unknown source strength and making the result equal to zero, we obtain a system of linear equations with them the complex sources strength, that is, the solution of the posed problem, can be find.

## 6.2 Single Layer Method

In this method, several monopole sources are positioned on an auxiliary surface. The auxiliary surface is placed inside the body. Note that the auxiliary surface should not coincide with the surface of the original body. If the auxiliary surface coincides with the surface of the body, the problem cannot be solved by the source simulation technique. Instead other methods such as boundary element method (BEM) need to be applied. The auxiliary surface has the same form as the surface of the body being studied, that is, the circular cylinder. For the total pressure we have

$$p_1 = p_0 e^{-jkR\cos(\phi)} + \sum_{q=1}^{N_q} A_q H_{0,q}^{(2)}(kr) \tag{28}$$

where $r$ is the distance between a point with polar coordinates $(R, \Phi)$ on the cylinder surface and a source point $q$ with the polar coordinates $(r_{(q)}, \Phi_{(q)})$. $R$ is the radius of the circular cylinder. The cosine law gives us

$$r = \sqrt{R^2 + r_{(q)}^2 - 2Rr_{(q)}\cos(\phi_{(q)} - \phi)}$$

and the normal component of the velocity on the surface at a

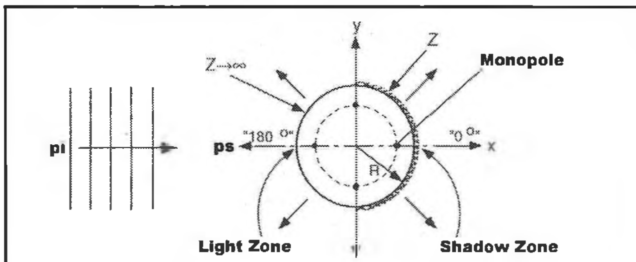


**Figure 2. Single Layer Method for the rigid and absorbing circular cylinder.**

point $(R,\Phi)$ is

$$v_{t(n)} = \frac{p_0}{Z_0}\cos(\phi)e^{-jkR\cos(\phi)} - \frac{1}{Z_0}\sum_{q=1}^{N_q} A_q H'^{(2)}_{0,q}(kr)r'(R) \quad (29)$$

where, $r'(R) = \partial(r)/\partial(R)$ and $H_0^{'(2)}(kR)$ is the second order derivatives of the Hankel function. Inserting Eqs. (28) and (29) into Eq. (27), the partial derivatives with respect to the unknown source strength are equated to zero, and then we obtain a system of linear equations similar to Eqs. (36). This system of equations give us the complex sources strength, that is, the solution of the problem.

## 7. Experimental Methodology

The experiments were performed in an anechoic chamber with a 3 m long rigid cylinder with a radius of 15 cm (see Figure 3). The cylinder surface was covered with a 5-cm thick porous absorbing material. The impedances of the absorbing material were measured for different frequencies (200-8000 Hz) by a standing wave apparatus. The absorbing cylinder was covered for half of its perimeter with a metal plate, thus resulting in a half-rigid/half-absorbing cylinder. This characterization depends on the face of the cylinder exposed to the incident wave. The sound was generated by a noise generator in 1/3 octave bands and after being amplified it was irradiated through a loudspeaker. The sound was measured by a microphone mounted on a turning table which could face either the shadow zone or the light zone. The sound pressure levels were measured at each 10° of approach of the turning table, first without the cylinder in the field and then with the cylinder in the field. The difference between these measurements gives us the sound attenuation due to the presence of the cylinder, which is dependent on the frequency, on the surface impedance, and on the distance from the microphone (measuring point) to the center of the cylinder.

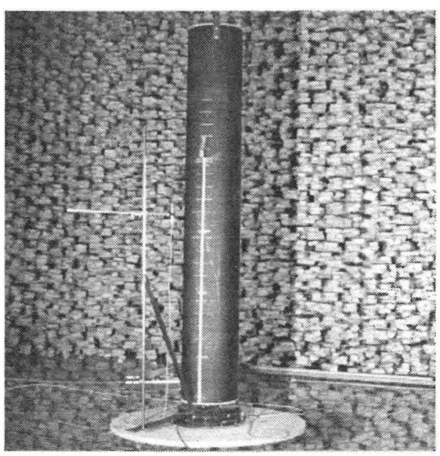

**Figure 3. The rigid cylinder and the turning table.**

## 8. Results And Discussion

The verification of the efficacy of the source simulation technique for the calculation of acoustical fields was by comparing the numerical results with the experimental data. In this sense, sound attenuation (shadow zone) produced by the presence of the cylinder in the field was both measured and calculated. It is impossible to present all the results obtained due to the great number of factors involved, such as frequency, distance from the point of measurement to the center of the cylinder, position angle, and surface impedance. Only some of the results obtained for the 1) rigid cylinder, 2) absorbing cylinder, and 3) absorbing and rigid, will be presented here. The results were calculated using the single-layer method, which were not essentially different from the ones obtained using the one-point multipole method.

Figures 4 to 6 show that although there is a very good agreement between the numerical results obtained with the source simulation technique and the experimental data, some discrepancies can be noted. Possible causes are discussed below. One possible reason for the differences in the values obtained for the sound attenuation in Figures 6 to 8 is that the calculation was undertaken for a bi-dimensional problem, while the measurements were performed in a three-dimensional model. The numerical calculation is always valid for a single frequency. However, the experiments used the sound generated by a band of 1/3 octaves. This fact can lead to inaccuracies in the numerical calculation, as the acoustical field generated by the scatterer changes too rapidly with the frequency and the angle of the measurement point. This numerical difficulty can be avoided if one takes the mean of the results for several frequencies inside each band of frequencies. In other words, the central frequency of the band of interest is considered and the frequencies below and above the central frequency are harmonically calculated. Several numerical tests were performed and one can conclude that a good approximation of the theoretical and experimental results can be obtained when the mean value was calculated out of 5 frequencies. However, one should not discard the possibility that, in some cases, the mean value should be calculated from a larger number of frequencies, especially in the high frequency range.

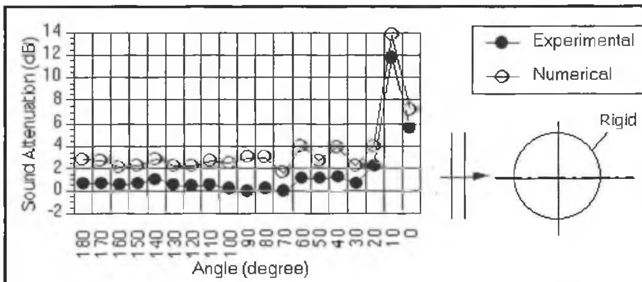


**Figure 4. Scattering from a rigid cylinder: kR=8.66; distance from a point in the field to the center of the cylinder: 58 cm, number of monopoles: N=35.**

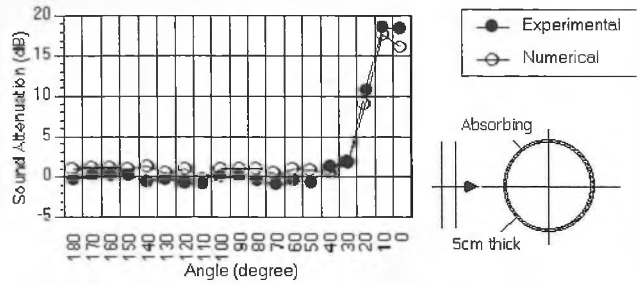


**Figure 5. Scattering from an absorbing cylinder: kR=23; distance from a point in the field to the center of the cylinder: 58 cm, number of monopoles: N=138, surface impedance: Z=1065.82 – j 29.81.**

The influence of possible reflections from chamber walls was tested if the sound attenuation in the shadow zone, ($\Phi = 0$) was above 20 dB, by placing the cylinder in other positions as well as at longer distances from the walls. However, the new measurements did not show any significant difference from the results obtained previously. Equation (27) is based on the hypothesis that the surface impedance is locally reacting. This hypothesis was also considered for the 5-cm thick foam with which the cylinder was covered, thus generating an absorbing cylinder. In order to confirm that the foam was locally reacting, fissures were made in the surface of the foam. But the sound pressure levels measured afterwards showed no significant modification when compared to the values obtained previously. One may thus conclude that the material used behaves as locally reacting. An ideal agreement between calculation and measurement would be obtained if the index $M$ in Eq. (24) or the index $N_q$ in Eq. (28) grow without any bounds. That is, in practical terms, impossible because of the immense computing time. Numerical simulations have shown that a good agreement between calculation and measurement is found for $M_{max} = 4\pi R\lambda$, and for $N_{q(max)} = 6\pi R\lambda$, where $R$ is the cylinder radius and $\lambda$ is the wavelength. Exceptions to this rule are in some regions of the shadow zone, between $-10° \leq \Phi \leq +10°$.

Another important reason for the differences between the numerical results and the experimental data resides in the fundamental principle of the method, that is, not exactly reconstructing each surface element at the given boundary conditions, but to minimize the error through an integration, like in Eq. (18), over the whole perimeter of the body. Equation (18) corresponds to the optimization of the error in the surface velocity approximation in the least mean square procedure. Equation (18), and thus the source simulation technique allows the control of the error as they satisfy the boundary conditions for every computation. This is a very important characteristic of this method, mainly when an analytical solution to the problem is not available. For practical cases, however, it would be important to assure a controlled accuracy not only of the surface velocity as in Eq. (18), but also in the determination of the sound power. The use of an

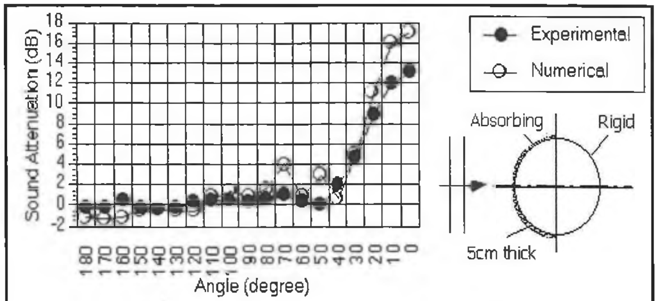


**Figure 6. Scattering from a half-absorbing and half-rigid cylinder: kR=14.65; distance from a point in the field to the center of the cylinder: 47 cm, number of monopoles: N=59, surface impedance: Z=250.3 – j 200.**

infinite number of sources would certainly allow the precise reconstruction not only of the surface velocity, but also of the sound power. It must be pointed out therefore, the reconstruction of the surface velocity is reasonably accurate due to the use of a finite number of sources (a maximum value for $M$ and $N_q$). However, the finite source number is nt sufficient for the determination of the sound power. With this limitation, one has in hand a very efficient method for the reconstruction of the acoustic field.

## 9. Conclusions

This work has presented the study of the scattering for an infinite cylinder with variable surface impedance, both numerically and experimentally. The theoretical analysis used the Method of Source Simulation. This method has been frequently used in the last decade for the solution of purely theoretical and/or numerical radiation and scattering problems. Very few works are found in the literature which allow a comparison between the numerical results obtained with the source simulation technique and experimental data. The contribution of the present work was then to present a comparison between numerical and experimental results so as to evaluate the practical usefulness of the source simulation technique. An important practical property of the source simulation technique is its controlled accuracy: the error is directly determined as a discrepancy in the boundary conditions on the surface of the body in each specific case. This property is very important especially if analytical solutions are not available. The principle of the method is very simple. Further research still needs to be done to investigate the influence of the type of source, type of surface over which the sources are positioned (single-layer method), the possible existence of resonance frequencies, and the applicability of the method for more complex surfaces. The main drawback of the source simulation technique is the fact that rules for the positioning of the source surface are not known a *priori*. The positioning of the source surface and in consequence of the sources themselves is based on the experience of the programmer.

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# WINDSCREEN INSERTION LOSS IN STILL AIR

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## ABSTRACT

Microphone windscreens are used to attenuate wind noise. However, even in still air, windscreens have an impact due to the added impedance between the source and microphone. This impedance is not accounted for when the system is checked by the use of an acoustical calibrator or when used in the field. The procedure for the characterization of the attenuation in still air has recently been addressed in ANSI S1.17-2000 part 1. But to date, no commercial windscreens have been tested in accordance with that standard. One of the reasons may be because the precision of the procedure has not been determined, even though the results of a round robin and the results of the uncertainty determination are available. Some of the commonly used windscreens were tested in a small chamber approaching free-field conditions. The results of the tests of insertion loss from the non-standard method and those based on S1.17 are presented here. It is shown that in some cases, the use of a windscreen can easily change the measurements using Type 1 instruments to Type 2 or worse. Without knowing information about a particular windscreen, the use of a windscreen in still air, can drastically change uncertainty of measurement. In moving air conditions can be expected to be even more severe.

## SOMMAIRE

Les écrans de protections des microphones sont employés pour atténuer le bruit de vent. Mais même en condition de vent faible, ces derniers ajoutent une impédance entre la source et le microphone qui n'est pas prise en compte lors de l'étalonnage ou lors de l'utilisation sur le terrain. La procédure pour la caractérisation de l'atténuation sous condition de vent faible a été récemment adressé dans la partie 1 de la norme ANSI S1.17-2000. Mais jusqu'ici, aucun écran de protection commercial n'a été vérifié selon les recommandations du standard. En partie à cause du fait que la précision de la procédure n'a pas encore été déterminée. Les résultats d'un round robin et de la détermination des incertitudes sont disponibles. En attendant, nous avons testé quelques modèles d'utilisation courante et d'autres dans une petite chambre dont les caractéristiques acoustiques approchent celles du champ libre. Nous présentons les résultats des deux méthodes: pertes par insertion obtenues par notre méthode non standard, et ceux obtenues par la méthode standard AINSI S1.17. Nous prouvons que, dans certains cas, l'utilisation d'un écran protecteur peut facilement changer la précision de la mesure avec l'emploi d'instruments de type 1 en type 2 ou plus mauvais. L'emploi d'un écran protecteur en condition de faible vent sans la connaissance préalable des caractéristique peut rigoureusement affecter l'incertitude de la mesure. Dans des condition de vent modéré à élevé, nous anticipons des problèmes encore plus graves.

## 1. INTRODUCTION

Microphone windscreens are used to attenuate wind noise. However, even in still air, they can have an impact not accounted for when the system is checked by use of an acoustical calibrator or when used in the field. The procedure for the characterization of the attenuation in still air has recently been addressed in ANSI S1.17-2000 part 1 (Microphone Windscreens-Part 1 Measurements and specifications of insertion loss in still air). But to date, no commercial windscreens have been tested in accordance with that standard. Partially, the reason is the precision of the procedure was not determined. The results of a round robin and the results of the uncertainty determination are now available but still no manufacturers have tested to the method.

Some of the samples used were tested in a small chamber approaching free-field conditions. The results of the tests of insertion loss from the non-standard, but well-controlled, method are presented in this paper. We show that, in some cases, the use of a windscreen can easily change a

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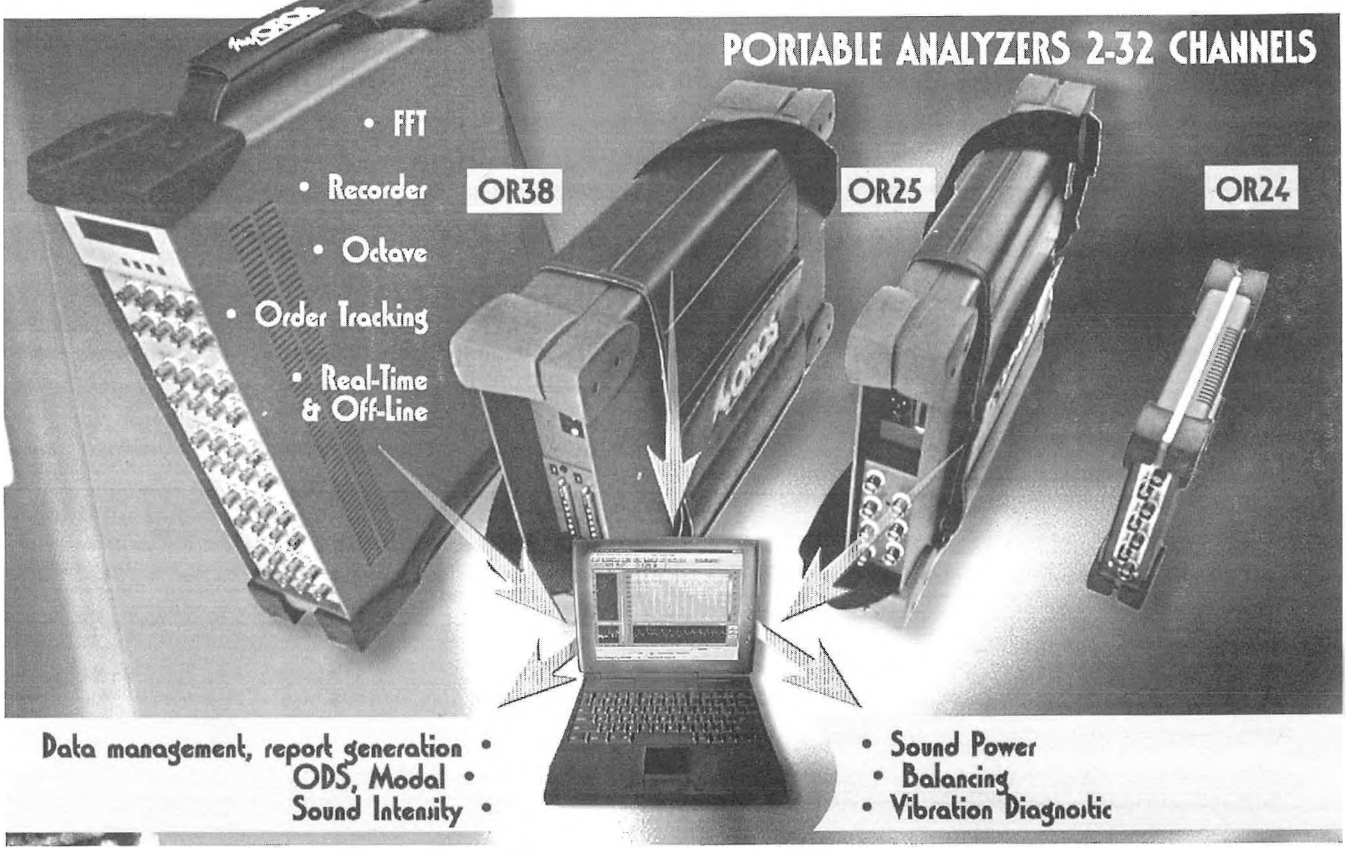


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measurement using Type 1 instruments to Type 2 or worse. Without knowing information about a particular windscreen, the use of a windscreen in still air, can drastically change uncertainty of measurement. In moving air conditions can be expected to be worse.

Since wind turbulence and its interaction with the surface of the microphone produces a noise that becomes part of the signal detected, it is useful to somehow reduce wind turbulence. But the reduction of turbulence and associated noise comes at a cost: The artefact used to reduce noise (windscreen) may interfere with the sound field in some respect. So the windscreens, used primarily to reduce noise generated by wind, should minimally affect measurements and should reduce all noise from wind. However, windscreens are also used in still air to protect microphones from damage and as general protection against wind gusts.

There are two types of windscreens: 1) general purpose, used for most outdoor measurements and 2) all-weather types for long term community noise. The general purpose type are usually spherical while the all-weather types are often ellipsoidal. The IL differences between the various types are available, but these results are not discussed here.

Windscreens are made of various materials that include:

- Fabric, with almost no acoustical influence - has durability problems
- Perforated metal, durable - but hole size effects measurements
- Metal screens - not common because they are hard to manufacture
- Polyurethane foam - open cell, the most common. Some manufacturers ‘seal’ the outside to make them waterproof. This affects IL.

Foam windscreens are the most popular and least expensive. The foam windscreens are produced by chemical activity that removes cell walls between adjacent cells. As the density of the foam increases, the insertion loss (IL) increases. Most cell density is between 70 to 150 cells per 10 cm.

## 2. DISCUSSION

When one places a windscreen on a microphone, the material properties and the size of the windscreen can alter the measured characteristics of the sound, usually in an unknown manner. The windscreen is affected by:

- Directivity effects: Sound coming from one direction compared to another may be altered by properties of the windscreen
- Non-homogenity: Windscreen characteristics may be different in different directions (especially for the non-spherical type.)
- Attenuation characteristics
- Moisture characteristics
- Wind effects on attenuation, on noise generation

The bare microphone has characterized directional properties, determined in controlled conditions: Random, Diffuse, Pressure, and Free field. These conditions hardly ever represent actual spaces. In general the description of the usual measurement field is unknown. So, the real directional characteristics of the microphone are unknown. Now a windscreen is added to the bare microphone, which further complicates the issue.

Sound pressure is measured at a point and is temporally varying. The measurements usually result in a signature of pressure level against frequency or against time. This pressure is unknown until it is measured. So the measurement *IS* the defined sound. And any error in measurement is usually not detected if systematic.

The effects of windscreens and wind are not discussed here, even though it is important. However, the basics of the effects of the windscreen on sound is as important. The reality of the uncertainty of the measurement chain is disturbing: 1) the level or frequency of the sound produced is not known; 2) the microphone characteristics are not known; 3) sound level meter (Type 1 or Type 2) that has a variability from ±1 dB to +3dB, is used; 4) windscreen with unknown characteristics is added; and finally 5) the reading is compared with some criterion: ordinance, guideline, etc.

## 3. WINDSCREEN CHARACTERISTICS

Since they introduce added impedance between sound and microphone, windscreens can affect the measured sound by insertion loss, by angle of sound, and perhaps by condition (old, damp, frozen)

Until now, there was no recognized standard for measuring windscreen insertion loss in still or moving air. Recently a standard was developed, ANSI S1.17-2000 Part 1 which requires hemi-anechoic space or reverberant space. This is a still-air standard; the moving air version has yet to be developed.

This paper discusses preliminary results of a series of insertion loss tests on the windscreens used for the round-robin of ASNI S1.17. The IL was measured in an ordinary space (an office with a loudspeaker sound source, measured with and without windscreen) and in a controlled space (a small anechoic box - 43.5" x 26" x 26," 1/2" walls, 9" wedges on each wall, with a windscreen-microphone-preamplifier at one end, and a loudspeaker at the others, excited by broadband or sine waves)

Windscreens were solicited from all major manufacturers but the following submitted their samples for testing: Scantek, Quest, Castle Group, ACO, Norsonic. A description of each of the windscreens is shown in Table 1.

Subsequent to the tests reported here, an extensive round robin was done to determine uncertainty of test method (not to characterize windscreens). The Labs that par-

**Table 1 Windscreen Description**

| Letter | Description |
|---|---|
| A | 2 1/2", black, small hole |
| B | 3 1/4", blue-green, small hole |
| C | 3 1/2", blue-green, foam missing, small hole |
| D | 3 3/4", black, larger hole |
| E | 3 3/4", black, larger hole |
| F | 2 3/8", black, small hole |
| G | 2 3/8", black, small hole |
| H | 2 3/8", black, small hole |
| I | 3/4"width/1 1/4" length, black, small hole |
| J | 3/4"width/1 1/4" length, black, small hole |
| K | 3 1/2", black, small hole L 3 3/4", black, larger hole |
| M | 3 1/2", black, small hole |
| N | 3/4"width/1 1/4" length, black, small hole |
| O | 3 1/2", black, small hole |
| P | 3", grey, small hole |
| Q | 7", grey, small hole |
| R | 3", grey and dirty, smooth surface, medium hole |
| S | 3", grey and smooth, medium hole |
| T | 3", grey, small hole |
| U | 3", grey, small hole |
| V | 3", grey and smooth, medium hole |
| W | 7", grey, small hole |
| X | 7", grey, small hole |
| Y | 2 1/2", grey, small hole |
| Z | 2 1/2", black, small hole |
| AA | 2 1/2", black, small hole |
| BB | 2 1/2", black, small hole |
| CC | 3", light grey, large hole, flat bottom |
| DD | 3", light grey, large hole, flat bottom |
| EE | 3", light grey, large hole, flat bottom |
| FF | 3/8"width/1"length, grey cylinder |
| GG | 3/8"width/1"length, grey cylinder |
| HH | 3/8"width/1"length, grey cylinder |
| II | 1"width/1 5/8"length, grey cylinder |
| JJ | 1"width/1 5/8"length, grey cylinder |
| KK | 1"width/1 5/8"length, grey cylinder |
| LL | 7/8"width/2 1/2"length, grey |
| MM | 7/8"width/2 1/2"length, grey |
| NN | 7/8"width/2 1/2"length, grey |
| OO | 8 1/2", grey, football shaped |
| PP | 3 1/2", black, small hole |
| QQ | 3 1/2", black, small hole |
| RR | 3 1/2", black, small hole |
| SS | 2 1/4", black, small hole |
| TT | 2 1/4", black, small hole |
| UU | 2 1/4", black, small hole |

ticipated were: NRC, Ontario, Canada; IAC, New York, USA; Manville, Colorado, USA; ATI, Pennsylvania, USA; WEAL, California, USA; Vibroacoustics, Ontario, Canada; and National Gypsum, New York, USA. The results of the round-robin are not discussed here. Samples of windscreen are shown in Figures 1 and 2.

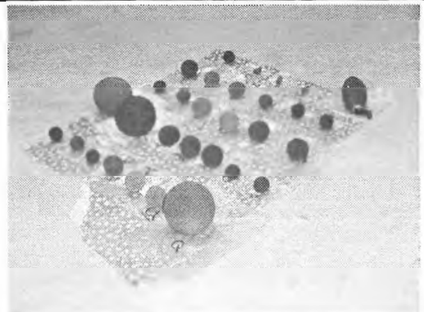

**Figure 1. Standard Winscreens**

**Figure 2. Standard Winscreens**

## 4. RESULTS

Only a few results of the preliminary tests can be discussed here. The tests were done in very controlled conditions: in the ordinary office, distances and sound levels were held very constant, although reflecting surfaces and background noise were rather not well defined. In the anechoic box, the background noise and reflecting surfaces were well characterized. Figure 3 shows the insertion loss and standard deviation for a single windscreen tested by one engi-

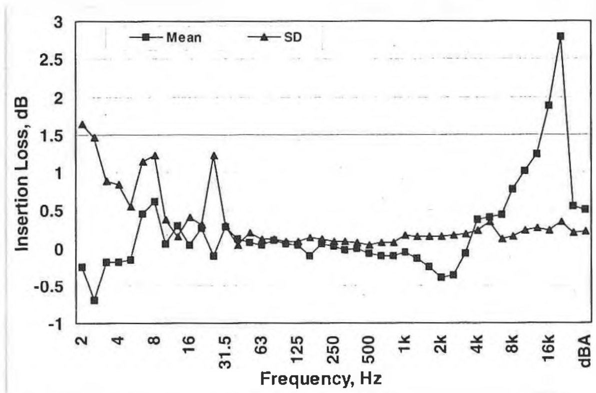


**Figure 3. Results of five repeat measurements of Windscreen M**

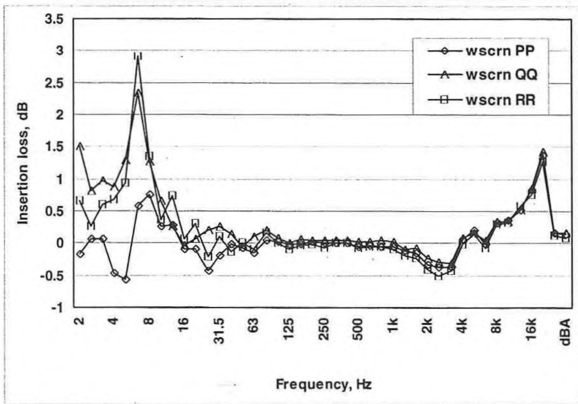


**Figure 4. Insertion loss for three of the same type of windscreen**

neer. This illustrates that the repeatability of a given test, by a single technician, is reasonably good for the " normal " frequency range of interesrt, from about 100 Hz to 15k or 20k Hz, it is important to note that, idealy, the insertion loss should be near zero which means any uncertainty, especially in an environment with some varying ambient noise, will often be greater than the insertion loss. Repeatability of measurements may be affected by a) position in box: from source to microphone, b) thickness of absorption on walls, c) sizes of windscreens compared to the volume of the box, d) placement of microphone in windscreen hole. Effects of

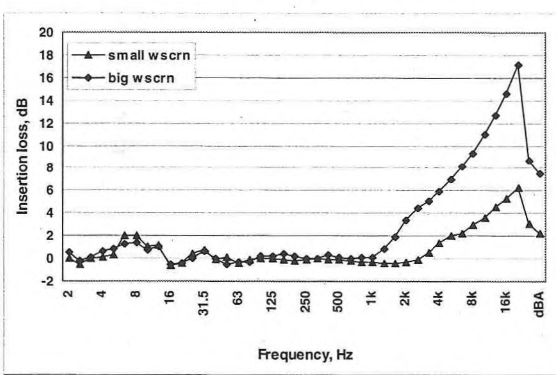


**Figure 5. Insertion loss of two outdoor windscreens**

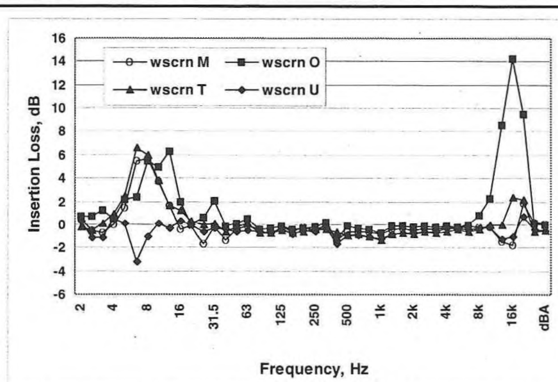


**Figure 6. Repeatability in an ordinary room**

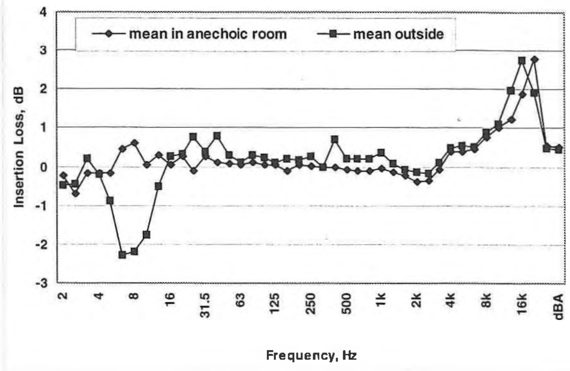


**Figure 7. Windscreen IL measured in different spaces**

these variables were not reviewed.

Figure 4 shows test results for three of the same type of windscreen. The windscreens are nominally the same material, same diameter, same porosity, and between the normal frequency range, the repeatability of insertion loss is good. The low frequency spread may be due to space effects.

The problem is, not all windscreens have similar insertion losses. For an arbitrarily chosen windscreen, the insertion loss vary significantly. Figure 5 shows the IL for two 'all-weather' windscreens. The IL above 3 kHz is rather high. The problem is, unless either there is little high-frequency sound to measure, or the insertion loss is known, one cannot tell what the windscreen does to the measured sound, by

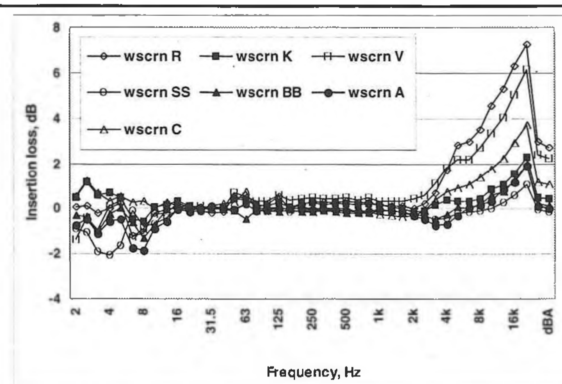


**Figure 8. Mean insertion loss for several windscreens**

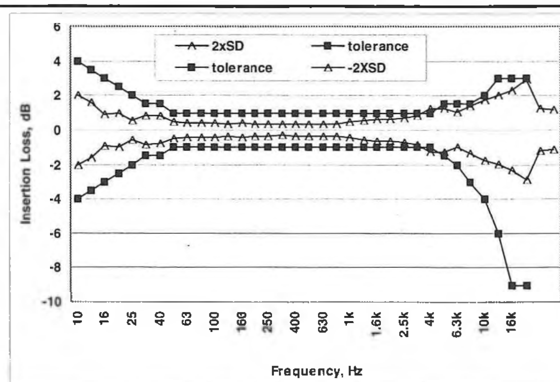


**Figure 9. Insertion loss compared to ANSI tolerances**

spectrum or even by A-weighted measures.

Figure 6 shows repeatability test for two measurements per windscreen, in an ordinary room. In general, for the frequency range of 20 Hz to 12 kHz, repeatability is less than 1 dB. So, even for a simple test, not necessarily using a controlled space, the insertion loss over normal frequencies is reasonably repeatable. However, it can vary a lot at the upper and lower frequency ranges, suggesting that it is better to use a controlled space for any type of IL tests.

Figure 7 shows the IL for the same windscreen measured in different spaces. Space does not seem to be critical.

Figure 8 shows the average insertion loss for several windscreens. Note that IL is most critical at upper frequencies. Significant here is that windscreens are different. One cannot use any windscreen and expect to obtain the same results with a measurement using another windscreen. And this is for controlled test! It seems critical to know what the windscreen is doing.

Figure 9 shows, for a given windscreen, the uncertainty of the measurements superimposed on the ANSI Type 1 requirements. Given the tolerances are shown w/o any windscreen, this suggests that the addition of a windscreen, albeit randomly chosen, will change Type 1 measurement to a Type 2 measurement. It must be pointed out that the tolerances given for Type 1 specifications are on the overall meter and the uncertainties of a windscreen are over and above those of the sound level meter meeting Type 1 specifications. Often manufacturers are just within Type 1 specifications and hence a windscreen with any insertion loss can change the precision of the measurement.

## 5. CONCLUSIONS

The following conclusions were the results of the simple insertion loss tests presented in this paper.

- Windscreen insertion loss can be measured but results may depend on measurement method.
- For a given test method, windscreens can have an Insertion Loss between 0.1 dB and 10 dB in the frequency range most are interested in.
- Without a characterization of some sort, insertion loss of windscreens can significantly affect your measurements in some unknown manner..

## ACKNOWLEDGEMENTS

Thanks go to the lab personnel who participated in the round robin: V. Clemente, B. Tinianow, A. Warnock, E. Mouratidis, E. Miller, G. Mange, and R. Menchetti. They did much to improve the S1.17 standard.

# DETECTING STEALTH AIRCRAFT

**Natalie Silvanovich**
Handsworth Secondary School, North Vancouver, British Columbia

## INTRODUCTION

Invisible to conventional radar devices, stealth aircraft poses a threat to national security. In addition, as commercial flights become increasingly common, alternatives to radar may be needed to ensure air-traffic safety. The purpose of this project is to determine whether sound is a viable method of aircraft detection and identification.

To determine this, it was necessary to show that different types of aircraft have "sound signatures" that are unique to them. Also, it was essential to show that sound could be used to discover the speed and position of an aircraft. In addition, mathematical analysis was used to determine the practicality of sound-detection in terms of range, sonic environment, and necessary amplification equipment.

In all, this experiment indicated that sound is a possible method of stealth aircraft detection

## PROCEDURE

The sounds emitted by landing aircraft at Vancouver International Airport were recorded on tape and the type of aircraft was noted. Sonograms were created for the half second each aircraft was estimated to be directly above the recorder using a Fourier transform sound analysis program (see diagram). Three seconds later, a second sonogram of the same aircraft was created to explore Doppler shift.

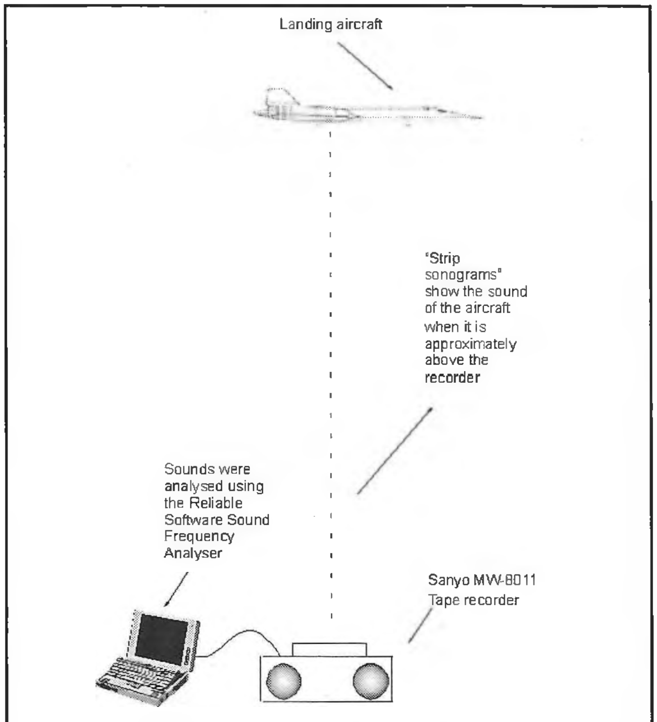


**Figure 1. Recording Setup**

### CANADA WIDE SCIENCE FAIR

### NATALIE SILVANOVICH WINS THE ACOUSTICS PRIZE

Natalie Silvanovich is a Grade 12 student at Handsworth Secondary School in North Vancouver, British Columbia. Last year, she was awarded the Canadian Acoustics Society Award alongside her Bronze Medal at the Canada-Wide Science Fair. Natalie first participated in the Science Fair when she was ten years old and has done four projects since. She became interested in aircraft detection and acoustics after reading articles in *Popular Science.*

**Editor's Note:** We are very happy to note that Ms. Silvanovich submitted a brief summary of her project work that won the prize at the fair. Her full article is reproduced above.

***Natalie Silvanovich (r) CWSF -2002***
***Recipient of the CAA Speicla Prize in Acoustics***
*She is shown here receiving the award.*

## RESULTS AND ANALYSIS

### Sound Signatures

The sonogram colours relate to the volume of the sound, as shown by this chart (Figure 2). Values shown in Table 1. are in arbitrary units (U) that can only be related to one another.

One can clearly use these sonograms to detect aircraft (the sound when there is an aircraft is very different from the sound when there is not one). Also, one can identify the type of aircraft recorded.

The Horizon Air propeller driven crafts are clearly the same type of aircraft. At 1500 Hz, there is a distinct loud sound (between 250 and 260 U), at 2800-3200 Hz there is a quieter (128-255 U) sound and these aircraft only make sound at frequencies below 5000 Hz.

A de Havilland Dash-8 made a very similar sound to the two "Unidentified Propellor Driven" craft. The Dash-8's had a distinct sound at 1500 Hz, but it was considerably quieter than that emitted from the Horizon aircraft (110-130 U). Also, unlike any other aircraft recorded, the volume of the sound dipped below 63 U at 3000 Hz. These three aircraft are likely all Dash-8's.

"Air Canada Double Engine II" and the United Airline double engine aircraft are likely the same type of aircraft. They both lack sounds louder than 256 U below 1000 Hz. As well, the volume of the sound they make dips below 63 U at 3500 Hz. Most importantly, around 2200 Hz they make a very distinct loud (above 256 U) sound. This is an excellent identifying mark, as no other aircraft recorded had any sounds that were perfect sine functions. Of all the aircraft recorded, it is most highly likely that that these two are the same type.

These sonograms show that different types of aircraft make unique sounds that can be used to identify them.

### Using Sound to Determine Speed

To determine whether sound can be used to determine an aircraft's speed, the Doppler shift of a very distinct sound was used to determine the speed of an aircraft.

This sonogram of the United Airlines flight, shown in Figure 4, was recorded when it was directly over the microphone.

| |
|---|
| 0-7 black |
| 8-15 blue |
| 16-31 light blue |
| 32-63 green |
| 64-127 yellow |
| 128-255 orange |
| 256 and up, red |

**Table 1. Sonogram Colour Code Values**

Figure 5 shows the sonogram that was recorded about three seconds later. Notice that in the first sonogram, the loud sinusoidal sound was at a frequency around 2600 Hz. On the second sonogram the sinusoidal function is around 1700 Hz. Using this data, the speed can be calculated using the formula for Doppler shift.

$$F = f_0(v) / (v \pm v_s)$$
$$1700 = 2600^* (332) / (332 + v)$$
$$v = 900 \text{ m/s} = 250 \text{ km/h}$$

This is a very reasonable speed for a landing aircraft, so it is likely that Doppler shift could be used to determine the speed of a passing aircraft.

### Detection Range

Mathematical analysis was also used to answer several practical questions regarding sound as a means of aircraft detection. One is its range. To determine this, it was assumed that that the volume of ambient noise is $10^{-8}$ watts per metre squared and the volume of an aircraft is 100 watts per metre squared. From this, it was calculated that a still aircraft could be detected 100 km away. This, in reality, would decrease according to the function 100 + 100v = d with the speed of the aircraft (v is the mach number). This range could be used to determine the position of the aircraft, because when it begins to be detected, it is a known distance (depending on its speed, which can be calculated from Doppler shift) from the station. If there were three stations, this information alone could be used to determine the position of the aircraft

### Amplification System

An amplification system which could be used as part of a sonic aircraft detection system was designed. As far as physical amplification goes, a horn would be a good device, as horns amplify sound without causing much distortion. To determine the mouth area of the most efficient horn for this purpose, I used a formula derived by James Mehuish. This area depends on where the horn is placed (expressed as a size factor), the maximum frequency it needs to pick up and the speed of sound. To determine the height of the horn, I used James Mehuish's online horn calculator. I determined that the most efficient horn would be 17 metres in diameter and 9 metres high.

## DISCUSSION

These results show that sound could be used to detect stealth aircraft. An ideal place to do this would be the Distant Early Warning line in the arctic. This is because in such a remote location, there is little noise and much space.

Unmanned stations consisting of horns, microphones and computers put in this location could be used to alert authorities when an aircraft that does not register on radar. This would give the nation warning of a stealth aircraft invasion.

One of the major obstacles in using such technology as an effective detection system are supersonic aircraft, which would not be detected until they are past the station. This limits the use of sound detection to early warning.

Also, it would be necessary to create a computer program that can not only detect and identify aircraft, but ignore other random sounds, such as ice cracking for this technology to be used.

## CONCLUSIONS

It is possible to identify aircraft and determine their speed by the sound they make. An ideal sound radar station would be in the arctic. It would consist of a horn 17m in diameter and 9 m high, a microphone, and a computer assisted sound analyser. The theoretical maximum distance a sound radar system could detect a plane from is 100 kms; this decreases as the speed of the aircraft increases. It is theoretically possible to use sound radar to determine velocity and position.


**Figure 2. Sono grams when aircrafts are directly overhead**

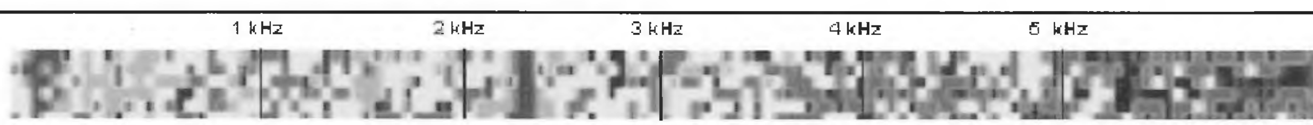


**Figure 3. Normal Sonogram**


**Figure 4. Shifted Sonogram**

**Fundamentals of Noise and Vibration**
**Editors: Frank Fahy and John Walker**
**E & FN Spon Press, 1998**
**ISBN 0419227008, 518 Pages - £41.99**

**Foundations of Engineering Acoustics**
**Frank Fahy; Academic Press – 2000**
**ISBN 0122476654, 43 Pages - US$84.95**

The first book is a compilation of the course material presented by the faculty of ISVR, University of Southampton. The two editors have presented material by different faculty members to provide a basic textbook in all aspects of sound. In eight concise chapters, the book takes the reader through: 1) Introduction to acoustics (P. A. Nelson); 2) Fundamentals of vibration (N. Lalor); 3) Human response to sound (I. H. Flindell); 4) Human response to vibration (M. J. Griffin); 5) Noise and vibration control (F. J. Fahy); 6) Signal processing (J.K. Hammond); 7) Underwater acoustics (T.G. Leighton); and 8) Principles of measurement and analysis techniques (R.J. Pinnington). Even though each chapter is between 50 to 60 pages long, the breadth of material covered is more than adequate. Instead of covering each chapter, (since some of the chapters - underwater acoustics and human responses - are outside the area of interest of this reviewer) let me highlight the merit of just two chapters to tweak the reader's interest.

In less than 60 pages, Prof. Nelson introduces the students to acoustics. The chapter traverses from a brief description of what constitutes acoustic disturbances to formulating the necessary governing equations to different methods of solving the wave equations, such as applying Green's functions. Simple one-dimensional wave equations, solving for sound in confined spaces, standing waves, various impedances, sound power, monopole, dipole and multipole analyses and a simple definition of the decibel scale are all handled deftly. The materials in this chapter are usually covered over three to four chapters in conventional textbooks such as Kinsler and Frey (1982), and Mores and Ingard (1968). The concise way the above materials are covered here seems to be sufficient for a basic understanding of the fundamentals. In a similar manner, Prof. Fahy has presented a thoughtful chapter on noise and vibration control and this chapter would be of great interest to practitioners. Beginning with the motivation for control and the necessary targets based on different regulatory applications, the chapter isolates what constitutes noise sources, their measures, and ranking methods. These new approaches make this book rather unique. Finally, the various noise control methods are presented with required amount of details. Each chapter provides enough problems at the end to assist in the understanding of the material covered. Of course, one must point out that most of the guidelines and regulations, described in the book, deal with the British and European applications and some of them are new to the North American readers. Even though each chapter has been written by a different author, the editors have succeeded in presenting cogent, consistent, and well flowing chapters. Even the variations in the graphic material from chapter to chapter are but a minor distraction.

The second book provides an insightful look at the basics of engineering acoustics. Prof. Fahy, in twelve chapters and seven comprehensive appendices, tackles what constitutes the physics of acoustical phenomena and hopes that this text would aid senior-undergraduate and graduate students to acquire more than a superficial knowledge in acoustics. This book is quite unconventional in its approach, as it does not follow the formats used by other books.

The book is divided into: 1) Sound Engineering; 2) Nature of sound and wave phenomena; 3) Sound in fluids; 4) Impedance; 5) Sound energy and intensity; 6) Sources of sound; 7) Sound absorption and absorbers; 8) Sound n waveguides; 9) sound in enclosures; 10) Structure-borne sound; 11) Sound transmission; and 12) Reflection, scattering, diffraction and refraction. Each chapter covers the material thoroughly as the presentation discusses the physics of the problem. The materials covered range from a simple description of what sound engineering to each subset of acoustics necessary to solve for typical problems such as jet noise, propeller noise or propagation through complex media. What I found interesting about Prof. Fahy's approach was his ability to cogently analyze each subset. For instance, the idea of impedance is cursorily dealt with in many textbooks with a brief definition in the correct context. Here, a full chapter is used to describe specific acoustic impedance, mechanical impedance, and radiation impedance as well as their usefulness in acoustical applications. The list continues. The chapter on absorbers provides a comprehensive description of physical reasons for energy transfer resulting in absorption. Other comparable textbooks (except the massive multi-volume tome on Physical Acoustics) provide only cursory information on physical reasons for sound absorption. Each chapter is a delight to read. It is a great guide to instructors who now can take a different approach for their class materials. Since Prof. Fahy was one of the pioneers of sound intensity techniques, the book is filled with intensity flow plots and phase contours. These graphs are difficult to fathom since they are not explained well. Even though, this is a shortcoming of the book, it is only a small distraction.

The first book is definitely suitable as an introductory textbook, whereas the second book is well worth for instructors and graduate students.

**Prof. Ramani Ramakrishnan, Ph. D., P. Eng.**
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**Ryerson University, Toronto, ON**
**e-mail: rramakri@ryerson.ca**

# NEWS / INFORMATIONS

## CONFERENCES

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

### 2003

13-15 March: American Auditory Society Annual Meeting, Scottsdale, AZ. Contact: American Auditory Society, 352 Sundial Ridge Cir., Dammeron Valley, UT 84783; Tel.: 435-574-0062; Fax: 435-574-0063; E-mail: amaudsoc@aol.com; Web: www.amauditorysoc.org

17-20 March: German Acoustical Society Meeting (DAGA2003), Aachen, Germany. Fax: +49 441 798 3698; E-mail: dega@akuphysik.uni-oldenburg.de

18-20 March: Spring Meeting of the Acoustical Society of Japan, Tokyo, Japan. Contact: Acoustical Society of Japan, Nakaura 5th-Bldg., 2-18-20 Sotokanda, Chiyoda-ku, Tokyo 101-0021, Japan; Fax: +81 3 5256 1022; Web: wwwsoc.nii.ac.jp/asj/index-e.html

24-26 March: 27th International Acoustical Imaging Symposium, Saarbrücken, Germany. Contact: Ms. Y. Spindler, Fraunhofer Institute for Non-Destructive Testing, Bldg. 37, University, 66123 Saarbrücken, Germany; Fax: +49 6819302 5903; Web: www.izfp.fhg.de

6-10 April: IEEE International Conference on Acoustics, Speech, and Signal Processing, Hong Kong, Hong Kong. Contact: Wan-Chi Siu, Hong Kong Polytechnic University, Hong Kong; Web: www.en.polyu.edu.hk/%7Ecassp03

7-9 April: WESPAC8, Melbourne, Australia. Web: www.wespac8.com

28 April – 2 May: 145th Meeting of the Acoustical Society of America, Nashville, TN. 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

5-8 May: SAE Noise & Vibration Conference & Exhibition, Traverse City, MI. Contact: P. Kreh, SAE International, 755 W. Big Beaver Rd., Suite 1600, Troy, MI 48084; Fax: 724-776-1830; Web: www.sae.org

19-21 May: 5 European Conference on Noise Control (Euronoise 2003), Naples, Italy. Contact: DETEC, University of Naples Federico II, P. le Tecchio 80, 80125 Napoli, Italy; Fax: +39 81 239 0364; Web: www.euronoise2003.it

8-13 June: XVIII International Evoked Response Audiometry Study Group Symposium, Puerto de la Cruz, Tenerife, Canary Islands, Spain. Fax: +34 922 27 03 64; Web: www.ierasg-2003.org

## CONFÉRENCES

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

### 2003

13-15 mars: Rencontre annuelle de la Société américaine de l'audition, Scottsdale, AZ. Info: American Auditory Society, 352 Sundial Ridge Cir., Dammeron Valley, UT 84783; Tél.: 435-574-0062; Fax: 435-574-0063; Courriel: amaudsoc@aol.com; Web: www.amauditorysoc.org

17-20 mars: Rencontre de la Société allemande d'acoustique (DAGA2003), Aachen, Allemagne. Fax: +49 441 798 3698; Courriel: dega@akuphysik.uni-oldenburg.de

18-20 mars: Rencontre de printemps de la Société japonaise d'acoustique, Tokyo, Japon. Info: Acoustical Society of Japan, Nakaura 5th-Bldg., 2-18-20 Sotokanda, Chiyoda-ku, Tokyo 101-0021, Japan; Fax: +81 3 5256 1022; Web: wwwsoc.nii.ac.jp/asj/index-e.html

24-26 mars: 27e Symposium international sur la formation d'image acoustique, Saarbrücken, Allemagne. Info: Ms. Y. Spindler, Fraunhofer Institute for Non-Destructive Testing, Bldg. 37, University, 66123 Saarbrücken, Germany; Fax: +49 6819302 5903; Web: www.izfp.fhg.de

6-10 avril: Conférence IEEE internationale sur l'acoustique, la parole, et le traitement de signal, Hong Kong, Hong Kong. Info: Wan-Chi Siu, Hong Kong Polytechnic University, Hong Kong; Web: www.en.polyu.edu.hk/%7Ecassp03

7-9 avril: WESPAC8, Melbourne, Australie. Web: www.wespac8.com

28 avril – 2 mai: 145e rencontre de l'Acoustical Society of America, Nashville, TN. 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

5-8 mai: Conférence et exhibition SAE sur le bruit et les vibrations, Traverse City, MI. Info: P. Kreh, SAE International, 755 W. Big Beaver Rd., Suite 1600, Troy, MI 48084; Fax: 724-776-1830; Web: www.sae.org

19-21 mai: 5e Conférence européenne sur le contrôle du bruit (Euronoise 2003), Naples, Italie. Info: DETEC, University of Naples Federico II, P. le Tecchio 80, 80125 Napoli, Italy; Fax: +39 81 239 0364; Web: www.euronoise2003.it

8-13 juin: XVII Symposium international du Groupe expérimental sur l'audiométrie des potentiels évoqués, Puerto de la Cruz, Tenerife, Iles Canaries, Espagne. Fax: +34 922 27 03 64; Web: -13 www.ierasg-2003.org

16-18 June: ACOUSTICS – Modeling & Experimental Measurements, Cadiz, Spain. Contact: Acoustics03, Wessex Institute of Technology, Ashurst Lodge, Ashurst, Southampton SO40 7AA, UK; Fax: +44 238 029 2853; Web: www.wessex.ac.uk/conference/2003/acoustics/index.html

23-25 June: NOISE-CON 2003, Cleveland, OH. Contact: INCE Business Office, Iowa State Univ., 212 Marston Hall, Ames, IA 50011-2153; Fax: 515-294-3528; E-mail: ibo@ince.org

29 June – 3 July: 8th Conference on Noise as a Public Health Problem, Amsterdam-Rotterdam, The Netherlands. Contact: Congress Secretariat, PO Box 1558, 6501 BN Nijmegen, The Netherlands; Fax: +31 24 360 1159; E-mail: office.nw@prompt.nl

7-11 July: 10th International Congress on Sound and Vibration, Stockholm, Sweden. Contact: Congress Secretariat, Congrex Sweden AB; Tel: +46 8 459 66 00; Fax: +46 8 8 661 91 25; E-mail: icsv10@congrex.se; Web: www.congex.com/icsv10

14-16 July: 8th International Conference on Recent Advances in Structural Dynamics, Southampton, UK. Web: www.isvr.soton.ac.uk/sd2003

6-9 August: Stockholm Music Acoustics Conference 2003 (SMAC03), Stockholm, Sweden. Contact: www.speech.kth.se/music/smac03

25-27 August: Inter-Noise 2003, Jeju Island, Korea. Contact: Dept. of Mechanical Engineering, KAIST, 373-1, Kusong-dong, Yusong-gu, Taejon 305-701, Korea; Fax: +82 42 869 8220; Web: www.icjeju.co.kr

1-4 September: Eurospeech 2003, Geneva, Switzerland. Contact: SYMPORG SA, Avenue Krieg 7, 1208 Geneva, Switzerland; Fax: +41 22 839 8485; Web: www.symporg.ch/eurospeech2003

7-10 September: World Congress on Ultrasonics, Paris, France. Web: www.sfa.asso.fr/wcu2003

16-19 September: Autumn Meeting of the Acoustical Society of Japan, Nagoya, Japan. Fax: +81 3 5256 1022; Web: wwwsoc.nii.ac.jp/asj/index-e.html

23-25 September: 2nd International Symposium on Fan Noise, Senlis, France. Contact: CETIAT, B.P. 2042, 69603 Villeurbanne, France; Fax: +33 4 72 44 49 99; Web: www.fannoise2003.org

5-8 October: IEEE International Ultrasonics Symposium, Honolulu, HI. Contact: W.D. O'Brien, Jr., Bioacoustics Research Lab., Univ. of Illinois, Urbana, IL 61801-2991; Fax: 217-244-0105; Web: www.ieee-uffc.org

15-17 October: 34th Spanish Congress on Acoustics, Bilbao, Spain. Contact: Sociedad Española de Acústica, Serrano 144, 28006 Madrid, Spain; Fax: +34 91 411 7651; Web: www.ia.csic.es/sea/index.html

16-18 juin: ACOUSTICS – Modélisation et mesures expérimentales, Cadiz, Espagne. Info: Acoustics03, Wessex Institute of Technology, Ashurst Lodge, Ashurst, Southampton SO40 7AA, UK; Fax: +44 238 029 2853; Web: www.wessex.ac.uk/conference/2003/acoustics/index.html

23-25 juin: NOISE-CON 2003, Cleveland, OH. Info: INCE Business Office, Iowa State Univ., 212 Marston Hall, Ames, IA 50011-2153; Fax: 515-294-3528; Courriel: ibo@ince.org

29 juin – 3 juillet: 8e conférence sur le bruit, un problème de santé publique, Amsterdam-Rotterdam, Pays-Bas. Info: Congress Secretariat, PO Box 1558, 6501 BN Nijmegen, The Netherlands; Fax: +31 24 360 1159; Courriel: office.nw@prompt.nl

7-11 juillet: 10e Congrès international sur le bruit et les vibrations, Stockholm, Suède. Info: Congress Secretariat, Congrex Sweden AB; Tél.: +46 8 459 66 00; Fax: +46 8 8 661 91 25; Courriel: icsv10@congrex.se; Web: www.congex.com/icsv10

14-16 juillet: 8e Conférence internationale sur les développements récents en dynamique structurelle, Southampton, Royaume-Uni. Web: www.isvr.soton.ac.uk/sd2003

6-9 août: Conférence 2003 d'acoustique musicale de Stockholm (SMAC03), Stockholm, Suède. Info: www.speech.kth.se/music/smac03

25-27 août: Inter-Noise 2003, Île Jeju, Corée. Info: Dept. of Mechanical Engineering, KAIST, 373-1, Kusong-dong, Yusong-gu, Taejon 305-701, Korea; Fax: +82 42 869 8220; Web: www.icjeju.co.kr

1-4 septembre: Eurospeech 2003, Genève, Suisse. Info: SYMPORG SA, Avenue Krieg 7, 1208 Geneva, Switzerland; Fax: +41 22 839 8485; Web: www.symporg.ch/eurospeech2003

7-10 septembre: Congrès mondial sur les ultra-sons, Paris, France. Web: www.sfa.asso.fr/wcu2003

16-19 septembre: Rencontre d'automne de la Société japonaise d'acoustique, Nagoya, Japon. Fax: +81 3 5256 1022; Web: wwwsoc.nii.ac.jp/asj/index-e.html

23-25 septembre: 2e Symposium international sur le bruit de ventilateur, Senlis, France. Info: CETIAT, B.P. 2042, 69603 Villeurbanne, France; Fax: +33 4 72 44 49 99; Web: www.fannoise2003.org

5-8 octobre: Symposium international IEEE sur les ultrasons, Honolulu, HI. Info: W.D. O'Brien, Jr., Bioacoustics Research Lab., Univ. of Illinois, Urbana, IL 61801-2991; Fax: 217-244-0105; Web: www.ieee-uffc.org

15-17 octobre: 34e Congrès espagnole d'acoustique, Bilbao, Espagne. Info: Sociedad Española de Acústica, Serrano 144, 28006 Madrid, Spain; Fax: +34 91 411 7651; Web: www.ia.csic.es/sea/index.html

10-14 November: 146th Meeting of the Acoustical Society of America, Austin, TX. 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

10-12 December: 3rd International Workshop on Models and Analysis of Vocal Emissions for Biomedical Applications, Firenze, Italy. Fax: +39 55 479 6767; Web: www.maveba.org

**2004**

17-19 March: Spring Meeting of the Acoustical Society of Japan, Atsugi, Japan. Fax: +81 3 5256 1022; Web: wwwsoc.nii.ca.jp/asj/index-e.html

22-26 March: Joint Congress of the French and German Acoustical Societies (SFA-DEGA), Strasbourg, France. Contact: Société Française d'Acoustique, 23 avenue Brunetière, 75017 Paris, France; Fax: +49 441 798 3698; E-mail: sfa4@wanadoo.fr

4-9 April: 18th International Congress on Acoustics (ICA2004), Kyoto, Japan. Web: ica2004.or.jp

24-28 May: 75th Anniversary Meeting (147th Meeting) of the Acoustical Society of America, New York, NY. 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

5-8 July: 7th European Conference on Underwater Acoustics ECUA 2004, Delft, The Netherlands. Contact: Debbie Middendorp, Secretariat of the 7th European Conference on Underwater Acoustics ECUA 2004, D'Launch Communications, Forellendaal 141, 2553 JE The Hague, The Netherlands; Tel.: +31 70 3229900; Fax: +31 70 3229901; E-mail: middendorp@dlaunch.nl

3-7 August: 8th International Conference of Music Perception and Cognition, Evanston, IL. Contact: School of Music, Northwestern Univ., Evanston, IL 60201; Web: www.icmpc.org/conferences.html

23-27 August: 2004 IEEE International Ultrasonics, Ferroelectrics, and Frequency Control 50th Anniversary Conference, Montreal, Canada. Contact: R. Garvey, Datum, 34 Tozer Road, Beverly, MA 01915-5510; Fax: +1 978 927 4099; Web: www.ieee-uffc.org/index2-asp

24-27 August: Inter-noise 2004, Prague, Czech Republic. Contact: I-INCE, Herrick Laboratories, Purdue University, West Lafayette, Indiana, USA; Fax: +1 765 494 0787; Web: www.i-ince.org

13-17 September: 4th Iberoamerican Congress on Acoustics, 4th Iberian Congress on Acoustics, 35th Spanish Congress on Acoustics, Guimarães, Portugal. Contact: Sociedade Portuguesa de Acústica, Laboratório Nacional de Engenharia Civil, Avenida do Brasil 101, 1700-066 Lisboa, Portugal; Fax: +351 21 844 3028; E-mail: dsilva@lnec.pt

10-14 novembre: 146e rencontre de l'Acoustical Society of America, Austin, TX. 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

10-12 décembre: 3e Atelier international sur les modèles et analyse d'émissions vocales avec applications bio-médicales, Florence, Italie. Fax: +39 55 479 6767; Web: www.maveba.org

**2004**

17-19 mars: Rencontre de printemps de la Société japonaise d'acoustique, Atsugi, Japon. Fax: +81 3 5256 1022; Web: wwwsoc.nii.ca.jp/asj/index-e.html

22-26 mars: Congrès conbiné des Sociétés française et allemande d'acoustique (SFA-DEGA), Strasbourg, France. Info: Société Française d'Acoustique, 23 avenue Brunetière, 75017 Paris, France; Fax: +49 441 798 3698; Courriel: sfa4@wanadoo.fr

4-9 avril: 18e Congrès international sur l'acoustique (ICA2004), Kyoto, Japon. Web: ica2004.or.jp

24-28 mai: 75e rencontre anniversaire (147e rencontre) de l'Acoustical Society of America, New York, NY. 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

5-8 juillet: 7e Conférence européenne sur l'acoustique sous-marine ECUA 2004, Delft, Pays-Bas. Info: Debbie Middendorp, Secretariat of the 7th European Conference on Underwater Acoustics ECUA 2004, D'Launch Communications, Forellendaal 141, 2553 JE The Hague, The Netherlands; Tél.: +31 70 3229900; Fax: +31 70 3229901; E-mail: middendorp@dlaunch.nl

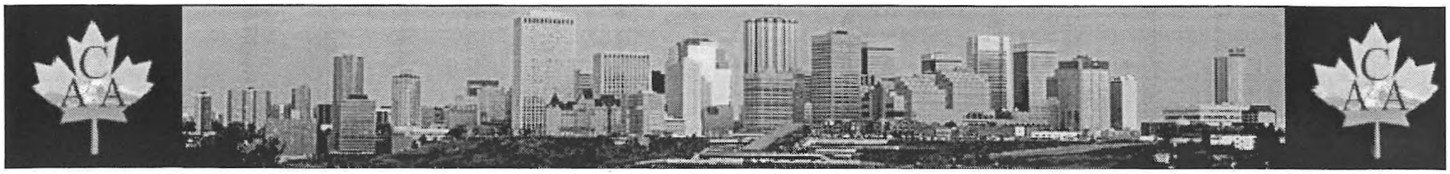
3-7 août: 8e Conférence internationale sur la perception et la cognition de la musique, Evanston, IL. Info: School of Music, Northwestern Univ., Evanston, IL 60201; Web: www.icmpc.org/conferences.html

23-27 août: 50e Conférence anniversaire internationale IEEE 2004 sur les ultra-sons, la ferroélectricité et la régulation par la fréquence, Montréal, Canada. Info: R. Garvey, Datum, 34 Tozer Road, Beverly, MA 01915-5510; Fax: +1 978 927 4099; Web: www.ieee-uffc.org/index2-asp

24-27 août: Inter-noise 2004, Prague, République tchèque. Info: I-INCE, Herrick Laboratories, Purdue University, West Lafayette, Indiana, USA; Fax: +1 765 494 0787; Web: www.i-ince.org

13-17 septembre: 4e Congrès ibéro-américain d'acoustique, 4e Congrès ibérien d'acoustique, 35e Congrès espagnol d'acoustique, Guimarães, Portugal. Info: Sociedade Portuguesa de Acústica, Laboratório Nacional de Engenharia Civil, Avenida do Brasil 101, 1700-066 Lisboa, Portugal; Fax: +351 21 844 3028; Courriel: dsilva@lnec.pt

# The Future of Quiet ?



**Acoustics Week in Canada    October 14–17, 2003    Edmonton, Alberta    The Westin Edmonton**
**www.caa-aca.ca/edmonton-2003.html**

## SECOND ANNOUNCEMENT AND CALL FOR PAPERS

**Conference Theme:** "The Future of Quiet ?": Where is the "happy medium" between privacy and being connected to others? We all appreciate that there are times we need to be by ourselves or in limited company and other times where large numbers of us want to communicate. The 2003 Edmonton Conference of the Canadian Acoustical Association aims to use this underlying theme for the plenary and technical sessions to be held 14-17 October 2003. Whether we work in speech pathology, underwater acoustics, noise control or in the marketing of communication-related products, it always seems to be the finest of lines as to where communication is "wanted" (... I want to hear and understand what you are telling me...) or "unwanted" (... do not disturb ...). Join us as we together, with friends and colleagues from Canada and abroad, explore this and many other aspects of the vital field of "acoustics in Canada".

**Scientific and Technical Papers:** As in previous Acoustics Week in Canada conferences, the 2003 Edmonton Conference will ensure that all areas of acoustics are represented. The sessions will include plenary lectures, invited and contributed papers, panel discussions and exhibits. To ensure that all areas of acoustics are represented the Technical Chairs are putting together a group of highly-skilled and motivated individuals to act as session chairs. They can only be successful if the membership, including students, attends the conference and deliver/present papers. The following technical areas are proposed:

| | | |
|---|---|---|
| Industrial Noise | Building/Architectural acoustics | Vibration |
| Outdoor sound propagation | Speech perception | Occupational hearing loss |
| Hearing protection | Acoustic materials | Underwater acoustics |
| Physiological acoustics | Sound quality | Legislation/Environmental noise |
| Transportation noise | Canadian standards | Instrumentation |
| Computer applications | Community noise | Musical acoustics |

**Abstracts:** A short **abstract** (maximum: 250 words) of your paper should be prepared and submitted **by Friday, 30-May-2003**. Your Abstract should be prepared in accordance with the Instructions-to-Authors appearing elsewhere in this Journal. Preparation of abstracts in all common word-processing software can be accommodated. Submission by email is strongly encouraged though submission of an abstract by fax or as a hard-copy or on floppy-disk by regular mail will be accepted. Abstracts will be peer-reviewed. Notification of acceptance of a paper will be by the end of June 2003. Included in this Notification will be a Registration Form. Upon acceptance of Abstracts, these will be posted on the Conference web-site (unless you request non-posting). The 2-page **Proceedings copy of your Paper** will be required **by Friday, 01-August-2003**. This deadline is firm for inclusion in the Proceedings Issue (September 2003) of the journal Canadian Acoustics. The Proceedings Copy of your Paper can be submitted in any common word-processing format or as 2 separate "pdf" files (1 file per page). For Papers received after the deadline, inclusion in the September Proceedings issue cannot be guaranteed but may, at the discretion of the Journal Editor, be included in the December-2003 issue.

Proposals for **Special Sessions** on a particular topic in acoustics are welcome. Please contact the Steering Committee soon if you wish to organize a special session or have a suggestion for a particular session, social event or activity.

**Student Participation** in Acoustics Week in Canada is strongly encouraged. **Awards** are available to students whose presentations at the conference are judged to be particularly noteworthy. To qualify, students must apply by enclosing an Annual Student Presentation Award form with their abstract. Students presenting papers may also apply for a **travel subsidy** to attend the meeting if they live at least 150 km from Edmonton. To apply for this subsidy, students must submit an Application for Student Travel Subsidy. Forms are available on the web-site. Lastly, a one-time **accommodation subsidy** may be applied for (one-time reimbursement of 50$CDN, in absence of other support); presentation of hotel receipt will be required. NB: to be eligible for either awards or subsidies, students **must** have membership in CAA ($15).

**Accommodation:** The Westin Edmonton is located in the heart of downtown Edmonton and will provide accommodation and meeting space (http://www.thewestinedmonton.com). The special (double/single occupancy) room rate for delegates is

$117.00 per night; a block of 60 guest-rooms has been made available to CAA conference delegates. The rate applies for two days prior to and after the conference (subject to availability). To reserve accommodation, please contact the hotel directly by telephone (1-800-WESTIN1; 1-780-493-8999, Fax 1-780-493-8968) or email (tara.jeffery@westin.com) and mention the CAA meeting. The reservation cut-off date is 5 p.m., Friday 12-September-2003. After this date, the special rates are subject to availability. Should the Conference Hotel be fully booked, other hotels, for every budget, are located within walking distance of the Conference site (check the web-site: http://www.edmonton.ca).

**Registration Form:** the Conference Registration Form, with pricing, is presently available at the Conference web-site and is reproduced in this issue of Canadian Acoustics.

Proposals for **Special Sessions** or for **Workshops/Seminars** on a particular topic in acoustics are welcome. If you wish to organize or present a **special session** or have a suggestion for a particular session, social event or activity please contact the Conference Convenor soon. Half-day or full-day **workshops** may be offered just before or after the technical program, giving opportunity for continuing education in acoustics. If you are interested in giving a workshop or have a suggested presenter, please contact the Convenor.

**Exhibits:** An exhibition of the latest technologies in acoustics and vibration equipment, materials and software will occur Wednesday and Thursday, 15?16 October. Exhibitors will be well integrated into the conference setting and featured in a special session of the conference program. Sponsorship by Exhibitors of breaks and/or lunches is also welcome. (Contact the Conference Convenor or Izzy Gliener).

**Canadian Standards Association:** Canadian Standards Association Committee Z 107 in Acoustics and Noise Control will hold a meeting (organizer: Cameron Sherry, Cwsherry@aol.com). All welcome.

**Hospitality:** In the tradition of past CAA meetings, preparations are underway for a delegate reception (Tuesday, 14-Oct), some joint lunches and a Conference Banquet with awards-ceremony. As much as feasible, opportunity will be provided for you to personally sample some of the best Edmonton hospitality, entertainment and culture. Remember, weather in Edmonton in October is unpredictable: it may be either mild/late-summer or snowed-in (i.e. bring a sweater ...). To begin exploring what Edmonton has to offer, check the web-site http://www.edmonton.ca and click on "Enjoying Edmonton".

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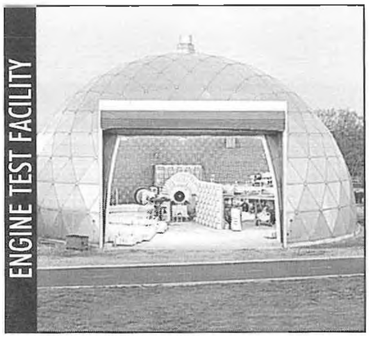
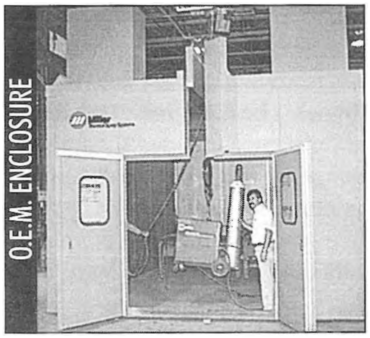
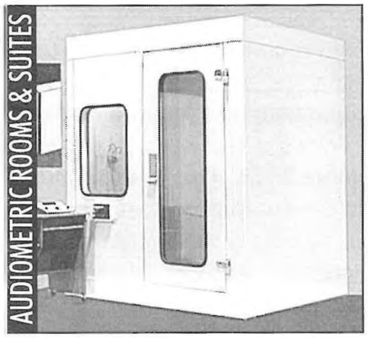
| **Important Dates 2003** | |
|---|---|
| Friday, 30-May | Deadline for receipt of abstracts |
| Friday, 27-June | Notice of acceptance of abstracts |
| Friday 01-August | Deadline for receipt of summary paper and early registration |
| Monday 01-September | Cut-off for early Registration |
| Friday 12-September | Cut-off, WESTIN reservation |
| Tuesday, 14-October | Acoustics Week in Canada begins: Registration, Workshops & Seminars |
| Wed.-Fri., 15-17 October | Acoustics Week in Canada: Technical Program and Exhibition |

| Contacts & Information | |
|---|---|
| Main Address: | #102, 9920 – 63 Avenue Edmonton, AB, T6E 0G9<br>Phone: (780) 414-6373 FAX: (780) 414-6376 |
| Web-site address: | http://caa-aca.ca/edmonton-2003.html |
| e-mail Address | conference@caa-aca.ca |
| Convenor: | Corjan Buma |
| Secretary: | Megan Hodge |
| Co-coordinator Technical Program: | Gary Faulkner |
| Exhibitor Co-ordinator: | Izzy Gliener |
| Web-Master: | Steven Bilawchuk |

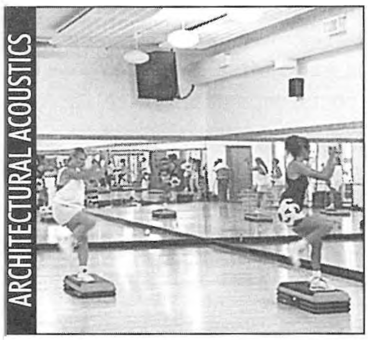


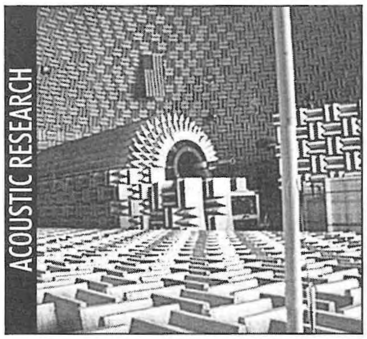


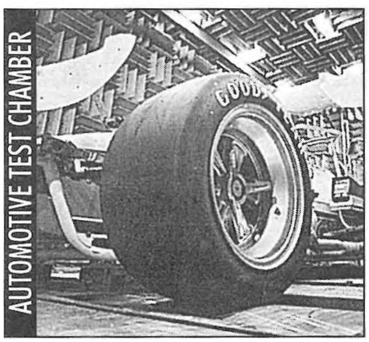


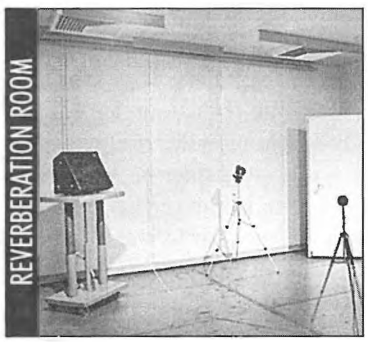




SOUND SOLUTIONS FOR THE FUTURE




# ECKEL

NOISE CONTROL TECHNOLOGIES

CANADIAN OFFICE

Box 776 100 Allison Avenue Morrisburg ON K0C 1X0
Tel: 613-543-2967 800-563-3574 Fax: 613-543-4173
Web site: www.eckel.ca/eckel e-mail: eckel@eckel.ca

ECKEL NOISE CONTROL TECHNOLOGIES

# *L'avenir du silence ?*

**Semaine canadienne d'acoustique, 14–17 octobre 2003, Edmonton, Alberta The Westin Edmonton**

**www.caa-aca.ca/edmonton-2003.html**

## DEUXIÈME ANNONCE ET APPEL DE COMMUNICATIONS

**Thème du congrès :** " *L'avenir du silence ?* " : Peut-on trouver un juste milieu entre l'intimité et les relations interpersonnelles ? La plupart d'entre nous apprécions tout autant les moments de solitude ou en compagnie restreinte que les activités sociales ou professionnelles où nous souhaitons communiquer avec un grand nombre de personnes. Le Congrès 2003 de l'Association Canadienne d'Acoustique (ACA) à Edmonton vise à sonder ce thème fondamental du silence lors des sessions plénières et techniques auront lieu du 14 au 17 octobre 2003. Que nous travaillions dans les domaines de la pathologie du langage, de l'acoustique sous-marine, du contrôle du bruit ou dans le marketing de produits de communications, il semble souvent difficile de tracer cette ligne fine qui sépare les échanges «souhaités» (... je veux entendre et comprendre ce que vous me dites ...) et les «indésirables» (...ne pas déranger ...). Amis et collègues du Canada et d'ailleurs, venez vous joindre à nous pour explorer ce domaine et bien d'autres aspects de «l'acoustique au Canada».

**Communications scientifiques et techniques:** À l'instar des Semaines Canadiennes d'Acoustique antérieures, le Congrès de 2003 à Edmonton s'assurera que toutes les branches de l'acoustique soient représentées. Le Congrès comprendra des sessions plénières, des conférences invitées et soumises, des discussions de groupe et une exposition. Afin d'assurer une représentation complète de toutes les spécialités reliées à l'acoustique, le Comité du programme scientifique sélectionnera des individus motivés et hautement qualifiés pour agir à titre de Présidents de session technique. Ces derniers ne pourront réussir qu'avec la participation des membres, étudiants inclus, au Congrès. C'est pourquoi nous sollicitons la soumission et la présentation d'articles dans les domaines techniques suivants :

| | | |
|---|---|---|
| Bruits industriels | Acoustique architecturale | Vibrations |
| Propagation des bruits d'extérieur | Perception du langage | Perte d'audition professionnelle |
| Protection de l'ouïe | Matériaux acoustiques | Acoustique sous-marine |
| Acoustique physiologique | Qualité du son | Réglementation/Bruits environnementaux |
| Bruits de transport | Normes canadiennes | Instrumentation |
| Applications numériques | Bruits communautaires | Acoustique musicale |

**Résumés :** Un court **résumé** (maximum de 250 mots) de votre article devrait être soumis **avant le vendredi 30 mai 2003**. Votre résumé devrait être préparé selon les «instructions de rédaction» apparaissant ailleurs dans ce Journal. Tout logiciel courant de traitement de texte peut être utilisé pour la préparation des résumés. Les soumissions par courriel sont grandement préférables, mais les soumissions par fax ou par la poste, sur papier ou sur disquette, seront acceptées. Les résumés seront évalués par des pairs. Les avis d'acceptation de conférence seront rendus avant la fin de juin 2003. Le formulaire d'inscription sera joint à cet avis. Les résumés retenus seront affichés sur le site Internet du Congrès (à moins d'avis contraire de la part des auteurs). Un **article** d'au plus deux pages devra être remis **avant le vendredi 1$^{er}$ août 2003**, s'il doit être inclus dans les Actes du Congrès. Cette date d'échéance est fixe pour les fins de publication dans le Cahier des Actes (septembre 2003) du journal Acoustique Canadienne. L'article doit être soumis en format électronique, soit à l'aide d'un logiciel courant de traitement de texte ou en deux fichiers de format « pdf » (une page par fichier). La parution dans le numéro de septembre du journal n'est pas assurée pour les articles reçus après la date de tombée; ils pourraient toutefois paraître dans le numéro de décembre 2003, selon la discrétion de l'éditeur du journal.

L'Association **incite les étudiants** à participer à la Semaine canadienne d'acoustique. Des **prix** seront décernés aux étudiants dont la conférence, lors du Congrès, sera jugée remarquable. Pour participer à cette compétition, les étudiants doivent s'y inscrire en joignant à leur résumé le formulaire «Prix annuel de la meilleure présentation étudiante» dûment rempli. De plus, les étudiants qui vivent à plus de 150 Km d'Edmonton peuvent bénéficier d'une aide financière de voyage pour leur permettre de présenter une conférence lors du Congrès. Pour demander cette subvention, les étudiants doivent soumettre le formulaire «Subvention de voyage pour étudiants». Les formulaires sont disponibles sur notre site Internet. Enfin, les étudiants peuvent aussi formuler une demande unique d'aide financière d'hébergement (un seul remboursement de 50$CDN, en l'absence d'autre soutien), sur présentation d'un reçu de l'hôtel. Note : Seuls les étudiants membres de l'ACA (15$) sont éligibles aux prix et aux subventions de voyage.

**Hébergement :** Le Westin Edmonton est situé au cœur du centre-ville d'Edmonton, à proximité du district des arts (*Citadel Theatre, Winspear Concert Hall, Edmonton Art Gallery*, etc.) et des lieux majeurs de magasinage et de récréation, incluant le réseau de sentiers du parc *North Saskatchewan River valley*. Le Westin Edmonton fournira l'hébergement et les salles de conférence (http://www.thewestinedmonton.com). Un bloc de 60 chambres à été mis à la disposition des délégués au Congrès de l'ACA; le tarif spécial des chambres (occupation simple /double) pour les délégués est de $117.00 la nuitée. Ce taux sera en vigueur deux jours avant et deux jours après la conférence (selon la disponibilité). Pour réserver, veuillez contacter l'hôtel directement par téléphone (1-800-WESTIN1; 1-780-493-8999), par fax (1-780-493-8968) ou par courriel (tara.jeffery@westin.com) et mentionnez votre participation au Congrès de l'ACA. La date limite de réservation est le vendredi 12 septembre 2003 à 17h00. Après cette date, le tarif spécial dépendra de la disponibilité des chambres. Advenant que l'hôtel du Congrès soit complet, d'autres hôtels, de tarifs divers, sont situés près du site du Congrès (visitez le site internet http://www.edmonton.ca).

**FORMULAIRE D'INSCRIPTION**: Le formulaire d'inscription pour le congrès, comprenant les tarifs d'inscription, est présentement disponible sur le site Internet du congrès et sera inclus dans l'édition de mars 2003 du journal *Acoustique Canadienne.*

Les propositions de **sessions spéciales** ou **d'ateliers/séminaires** traitant de sujets spécifiques en acoustique sont les bienvenues. Si vous souhaitez organiser une **session spéciale** ou suggérer un sujet de session, un événement ou une activité sociale, veuillez contacter le Comité organisateur dès que possible. Les ateliers d'une demi-journée ou d'une pleine journée peuvent être offerts avant ou après le programme technique, offrant ainsi une occasion pour la formation continue en acoustique. Si vous êtes intéressé à animer un atelier ou si vous souhaitez suggérer un présentateur, veuillez contacter le comité organisateur.

**Expositions**: Il y aura une exposition des plus récentes technologies en matière d'équipement, de matériaux et de logiciels d'acoustique et de vibrations, les mercredi et jeudi 15 et 16 octobre. Les exposants seront bien intégrés au déroulement de la conférence et se distingueront lors d'une session spéciale du programme du Congrès. Nous accueillons les commandites de la part des exposants pour les repas et les pauses (contactez le comité organisateur du Congrès ou Izzy Gliener).

**Normes canadiennes en acoustique**: Il y aura une réunion du comité Z 107 en Acoustique et contrôle du bruit, de l'Association canadienne de la normalisation (organisateur : Cameron Sherry, Cwsherry@aol.com). Bienvenue à tous !

**Hospitalité**: Dans le respect des traditions des réunions de l'ACA, des préparations sont en cours pour l'accueil des délégués (mardi, le 14 oct.), les dîners conjoints et un banquet avec cérémonie de remise des prix. Dans la mesure du possible, des occasions vous seront fournies pour découvrir ce qu'il y a de mieux en termes d'hospitalité, de divertissement et de culture à Edmonton. N'oubliez pas que les conditions météorologiques d'Edmonton au mois d'octobre sont imprévisibles : il pourrait faire un temps de fin d'été, comme il pourrait y avoir de la neige (apportez-vous un chandail !). Pour de plus amples renseignements sur la ville d'Edmonton, visitez le site Internet http://www.edmonton.ca et cliquez sur «Enjoying Edmonton».

| **Dates à retenir pour 2003** | |
|---|---|
| Vendredi 30 mai | Échéance pour la réception des résumés courts |
| Vendredi 27 juin | Avis d'acceptation des résumés |
| Vendredi 01 août | Échéance pour la réception des articles et l'inscription hâtive |
| Lundi 01 septembre | Date limite pour l'inscription hâtive |
| Vendredi 12 septembre | Date limite pour réservation au WESTIN |
| Mardi 14 octobre | Lancement de la Semaine Canadienne d'Acoustique: Inscription, Ateliers & Séminaires |
| mer.-ven.15-17 octobre | Semaine Canadienne d'Acoustique : Programme technique et exposition |

| Contacts & Information | |
|---|---|
| Adresse de correspondance: | #102, 9920 – 63 Avenue, Edmonton, AB, T6E 0G9, Tél.: (780) 414-6373, Fax: (780) 414-6376 |
| Adresse internet: | http://caa-aca.ca/edmonton-2003.html |
| Courriel: | conference@caa-aca.ca |
| Président du congrès: | Corjan Buma |
| Secrétaire: | Megan Hodge |
| Coordonnateur Programme Technique: | Gary Faulkner |
| Coordonnateur des exposants: | Izzy Gliener |
| Web-Master: | Steven Bilawchuk |

**ACOUSTICS WEEK IN CANADA 2003**
***SEMAINE CANADIENNE D'ACOUSTIQUE 2003***

**October 15, 16 and 17, 2003 / *du 15 au 17 octobre 2003***
**The Westin Hotel, Edmonton, Alberta**

## REGISTRATION FORM / *FORMULAIRE D'INSCRIPTION*

**(1) Full Three Day Registration.** Includes:

Conference + exhibits
Lunch each day for 2 days (15th, 16th)
Coffee breaks, morning and afternoon
Entertainment
Banquet Thursday night (except students)
All taxes & gratuities

***(1) Inscription complète.*** *Comprend:*

*La participation à la conférence + l'exhibition*
*Le dîner pendant 2 jours (le 15 et le 16)*
*Les pauses café, le matin et l'après-midi*
*L'hospitalité/le divertissement*
*Le banquet du jeudi soir (sans étudiants)*
*Toutes les taxes et les pourboires*

| **Registration/** ***Inscription*** | **CAA Members** ***Membres de l'ACA*** | **Non-members** ***Autres*** | **Students** ***Etudiant(e)s*** | |
|---|---|---|---|---|
| | | | **CAA Membres** | **Autres** |
| **Before** Sept. 1/ ***Avant*** *le 1 sept.* | $250.00 | $300.00 | $25.00 | $40.00* |
| **After** Sept. 1/ ***Après*** *le 1 sept.* | $275.00 | $330.00 | $25.00 | $40.00* |

*non-member student registration includes a 1 year CAA membership
**inclut l'adhésion à l'ACA pendant un an*

**(2) Daily Rates.** Includes:

Conference
Lunch each day
All taxes & gratuities

***(2) Tarif à la journée.*** *Comprend*

*Une journée à la conférence*
*Le dîner pour une journée*
*Toutes les taxes et les pourboires*

| **CAA Members** ***Membres de l'ACA*** | **Students** ***Etudiant(e)s*** | **Non-Members** ***Autres*** |
|---|---|---|
| $140.00 | $25.00 | $160.00 |

Note: All Conference passes are non-transferable.
*Les billets d'accès à la conférence sont personnels et ne peuvent être transférés.*

**(3) Extras/ *Suppléments***

Student Banquet Tickets / *Etudiant Billet pour le Banquet* — $15.00 each/*par personne*

Additional Banquet Ticket / *Billet Supplémentaire pour le Banquet* — $45.00 each/*par personne*

The Canadian Acoustical Association
l'Association Canadienne d'Acoustique

## REGISTRATION FORM / *FORMULAIRE D'INSCRIPTION*

Name/*Nom*:____________________________________________

Company/*Institution*:________________________________________

Address/*Adresse*:__________________________________________

______________________________Postal Code/*Code Postal*:__________

Tel:_________________________E-mail/*courriel*:________________________

| | | |
|---|---|---|
| **Full 3 day Conference** | $________ | ***Inscription complète*** |
| Additional banquet ticket(s) | $________ | *Billet(s) supplémentaire(s) pour le banquet* |
| Total | $________ | *Total* |

| | | | | |
|---|---|---|---|---|
| **Daily Rate**<br>Check applicable day(s) | Wednesday<br>*mercredi* | Thursday<br>*jeudi* | Friday<br>*vendredi* | ***Inscription à la journée***<br>*Entourez le(s) jour(s) choisi(s)* |
| Daily rate | $________ | | | *Montant* |
| Banquet ticket(s) | $________ | | | *Billet(s) pour le banquet* |
| Total | $________ | | | *Total* |

**Payable by cheque in Canadian Funds made out to CAA Conference 2003**
***Payable par chèque, en dollars canadiens, à l'ordre de* CAA Conference 2003.**

Mail/Fax to:
*Expédier ou faxer à:*

Mr. Corjan Buma
ACI Acoustical Consultants Inc.
Suite 107, 9920-63Ave
Edmonton, Alberta
T6E 0G9

Fax: (780) 414-6376

Tel: (780) 414-6373

**Please note: Hotel rooms must be booked by Sept. 12, 2003 to guarantee availability.**
***Veuillez noter : Pour des questions de disponibilité, les chambres d'hôtel doivent être réservées avant le 12 septembre 2003.***

The Canadian Acoustical Association — CAA — l'Association Canadienne d'Acoustique

## INSTRUCTIONS TO AUTHORS FOR THE PREPARATION OF MANUSCRIPTS

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

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

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

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

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

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

**Headings:** Headings to be in 12 pt bold, Times-Roman font. Number at the left margin and indent text 0.5". Main headings, numbered as 1, 2, 3, ... to be in upper case. Sub-headings numbered as 1.1, 1.2, 1.3, ... in upper and lower case. Sub-sub-headings not numbered, in upper and lower case, underlined.

**Equations:** Minimize. Place in text if short. Numbered.

**Figures/Tables:** Keep small. Insert in text at top or bottom of page. Name as "Figure 1, 2, ..." Caption in 9 pt with single (12 pt) spacing. Leave 0.5" between text.

**Line Widths:** Line widths in techincal drawings, figures and tables should be a minimum of 0.5 pt.

**Photographs:** Submit original glossy, black and white photograph.

**Scans:** Should be between 225 dpi and 300 dpi. Scan: Line art as bitmap tiffs; Black and white as grayscale tiffs and colour as CMYK tiffs;

**References**: Cite in text and list at end in any consistent format, 9 pt with single (12 pt) spacing.

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

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

## DIRECTIVES A L'INTENTION DES AUTEURS PREPARATION DES MANUSCRITS

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

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

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

**Titre du manuscrit:** 14 pt à 14 pt interligne, lettres majuscules, caractères gras. Centré.

**Auteurs/adresses:** Noms et adresses postales. Lettres majuscules et minuscules, 10 pt à simple (12 pt) interligne. Centré. Les noms doivent être en caractères gras.

**Sommaire:** En versions anglaise et française. Titre en 12 pt, lettres majuscules, caractères gras, centré. Paragraphe 0.5" en alinéa de la marge, des 2 cotés.

**Titres des sections:** Tous en caractères gras, 12 pt, Times-Roman. Premiers titres: numéroter 1, 2, 3, ..., en lettres majuscules; sous-titres: numéroter 1.1, 1.2, 1.3, ..., en lettres majuscules et minuscules; sous-sous-titres: ne pas numéroter, en lettres majuscules et minuscules et soulignés.

**Equations:** Les minimiser. Les insérer dans le texte si elles sont courtes. Les numéroter.

**Figures/Tableaux:** De petites tailles. Les insérer dans le texte dans le haut ou dans le bas de la page. Les nommer "Figure 1, 2, 3,..." Légende en 9 pt à simple (12 pt) interligne. Laisser un espace de 0.5" entre le texte.

**Largeur Des Traits:** La largeur des traits sur les schémas technique doivent être au minimum de 0.5 pt pour permettre une bonne reproduction.

**Photographies:** Soumettre la photographie originale sur papier glacé, noir et blanc.

**Figures Scanées:** Doivent être au minimum de 225 dpi et au maximum de 300 dpi. Les schémas doivent être scannés en bitmaps tif format. Les photos noir et blanc doivent être scannées en échelle de gris tifs et toutes les phoots couleurs doivent être scannées en CMYK tifs.

**Références:** Les citer dans le texte et en faire la liste à la fin du document, en format uniforme, 9 pt à simple (12 pt) interligne.

**Pagination:** Au crayon pâle, au bas de chaque page.

**Tirés-à-part:** Ils peuvent être commandés au moment de l'acceptation du manuscrit.

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

## Application for Membership

CAA membership is open to all individuals who have an interest in acoustics. Annual dues total $55.00 for individual members and $15.00 for Student members. This includes a subscription to *Canadian Acoustics*, the Association's journal, which is published 4 times/year. New membership applications received before September 1 will be applied to the current year and include that year's back issues of *Canadian Acoustics*, if available. New membership applications received after September 1 will be applied to the next year.

## Subscriptions to *Canadian Acoustics* *or* Sustaining Subscriptions

Subscriptions to *Canadian Acoustics* are available to companies and institutions at the institutional subscription price of $55.00. Many companies and institutions prefer to be a Sustaining Subscriber, paying $250.00 per year, in order to assist CAA financially. A list of Sustaining Subscribers is published in each issue of *Canadian Acoustics*. Subscriptions for the current calendar year are due by January 31. New subscriptions received before September 1 will be applied to the current year and include that year's back issues of *Canadian Acoustics*, if available.

*Please note that electronic forms can be downloaded from the CAA Website at* **caa-aca.ca**

**Address for subscription / membership correspondence:**

Name / Organization ____________________

Address ____________________

____________________

City/Province ____________________ Postal Code __________ Country ____________________

Phone ____________________ Fax ____________________ E-mail ____________________

**Address for mailing Canadian Acoustics, if different from above:**

Name / Organization ____________________

Address ____________________

____________________

City/Province ____________________ Postal Code __________ Country ____________________

**Areas of Interest:** (Please mark 3 maximum)

1. Architectural Acoustics
2. Engineering Acoustics/Noise Control
3. Physical Acoustics / Ultrasound
4. Musical Acoustics / Electro-acoustics
5. Psychological/Physiological Acoustic
6. Shock and Vibration
7. Hearing Sciences
8. Speech Sciences
9. Underwater Acoustics
10. Signal Processing / Numerical Methods
11. Other

For student membership, please also provide:

*(University)* *(Faculty Member)* *(Signature of Faculty Member)* *(Date)*

I have enclosed the indicated payment for:

[ ] CAA Membership $ 55.00
[ ] CAA Student Membership $ 15.00
[ ] Institutional Subscription $ 55.00
[ ] Sustaining Subscriber $ 250.00
includes subscription (4 issues /year) to ***Canadian Acoustics.***

Payment by: [ ] Cheque
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# l'Association Canadienne d'Acoustique

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