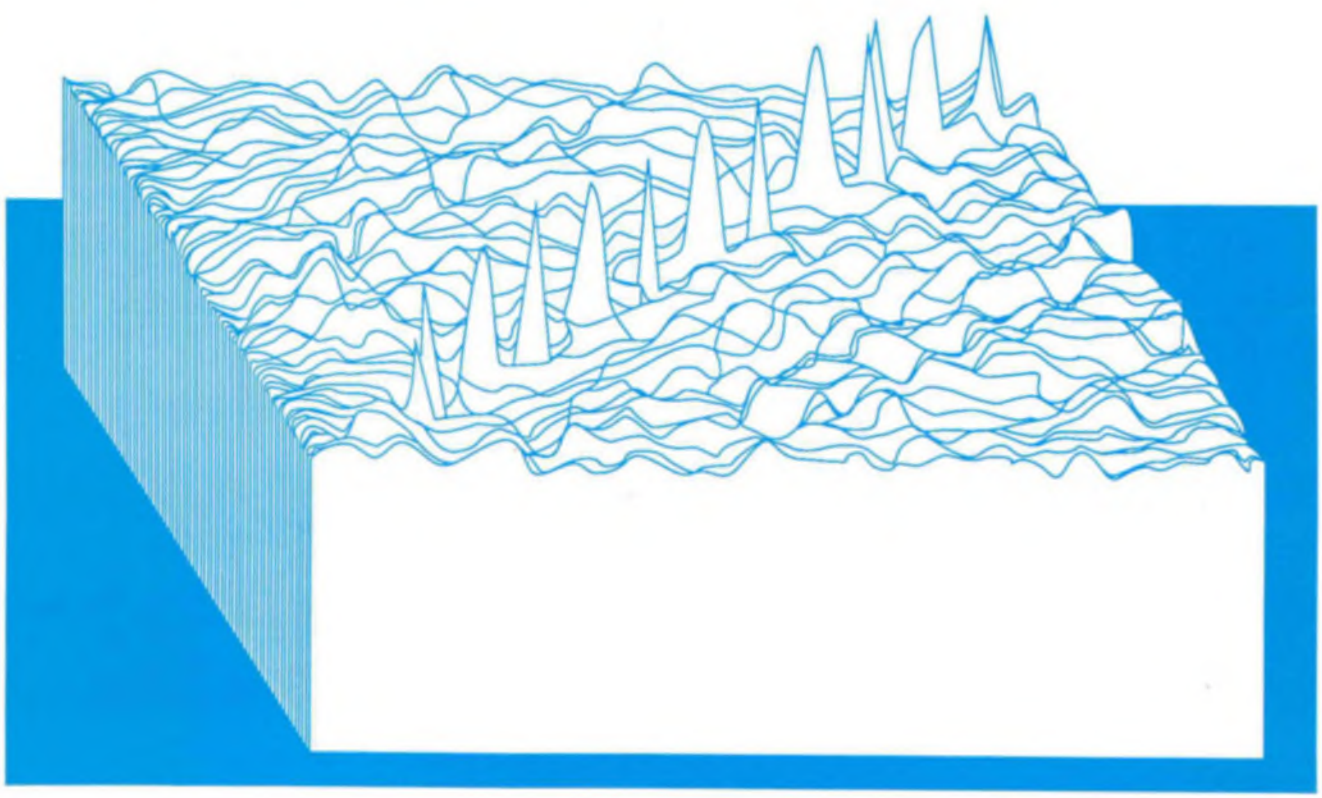
ISSN 0711-6659

canadian acoustics
acoustique canadienne

MARCH 1988 | MARCH 1988
Volume 16 — Number 1 | Volume 16 — Numéro 1



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EDITORIAL

Ce numéro inaugure un cadre nouveau de diffusion des résultats des travaux scientifiques des acousticiens-nes canadiens-nes. En effet, par le biais d'articles préparés sur invitation, nous escomptons faire davantage connaître les recherches effectuées dans différents laboratoires par des scientifiques dont la compétence est déjà bien établie. Cette forme de compte rendu peut en outre offrir la possibilité de dresser un tableau de l'ensemble des travaux effectués sur un thème donné ou d'exposer le cheminement parcouru par un-e chercheur-e au cours de plusieurs années de travail sur une même question.

Le présent numéro offre par ailleurs une excellente illustration de la diversité des disciplines qui font partie du champ de l'acoustique: de la neurophysiologie de l'audition et de la problématique du traitement de signal en passant par la phonétique expérimentale jusqu'à l'hygiène industrielle, on traverse une portion déjà large du "spectre" des domaines de connaissances appartenant à l'acoustique. Il y a tout lieu d'espérer que notre périodique continuera à élargir ses champs d'intérêts et à recruter de plus en plus d'adeptes parmi les scientifiques et les professionnels-les de l'acoustique au Canada et ailleurs. Il appartient toutefois aux membres de notre Association de continuer à faire connaître l'*Acoustique canadienne*.

This issue inaugurates a new framework for diffusing the results of scientific work from canadian acousticians. By means of invited papers, we believe that we will be able to make better known research conducted in different laboratories by scientists whose competence is already established. This form of record also offers the opportunity to outline a comprehensive view of the studies conducted on a given theme or to present retrospectively the various steps taken to investigate a question.

The present issue also gives an excellent illustration of the diversity of the disciplines that belong to the field of acoustics: from the neurophysiology of hearing and the related problems of signal processing to experimental phonetics and industrial hygiene, a relatively large portion of the "spectrum" of the fields of knowledge in acoustics is covered. There is every reason for believing that our journal will continue widening the areas of interest that it covers and recruiting more and more readers among scientists and professionnals of acoustics in Canada and elsewhere. It behoves however the members of our Association to continue making *Canadian Acoustics* known.

Canadian Acoustics /
Acoustique canadienne,
1988, 16 (1):3-15

WHITE NOISE ANALYSIS OF NON LINEAR SYSTEMS WITH APPLICATION TO THE AUDITORY SYSTEM

Jos J. Eggermont and Geoff M. Smith
Department of Psychology, The University of Calgary
Calgary , Alberta

ABSTRACT

Linear systems analysis with tones, clicks or white noise results essentially in the same information: the impulse response or frequency response of the system. In non-linear systems, such as the auditory system, these three methods provide different results. Furthermore the outcome will be level dependent. Higher order cross correlation with gaussian wide band noise as input signal provides, in principle, a method to analyze non-linear systems. For that purpose one needs noise with a zero valued second order auto correlation function. Commercially available pseudo-random noise generators do not produce noise with satisfactory properties. Software generated noise with gaussian amplitude distribution can easily be generated on basis of the uniform distributed random number generator. Using noise with these improved characteristics we studied neurons in the auditory midbrain of the grassfrog. Two examples are shown and a comparison is given between the results obtained with the white noise method and the more traditional pure tone analysis.

SOMMAIRE

L'analyse des sytèmes linéaires au moyen de sons purs, de clics ou d'un bruit blanc donne essentiellement la même information: la réponse impulsionnelle ou la réponse en fréquence du système. Dans les systèmes non-linéaires tel que le système auditif, ces trois méthodes donnent des résultats différents. De plus, la réponse dépendra du niveau d'excitation. L'inter-corrélation d'ordre supérieur avec une bande de bruit gaussien comme signal d'entrée fournit, en principe, une méthode d'analyse des systèmes non-linéaires. A cette fin, on a besoin d'un bruit dont la fonction d'auto-corrélation de second degré est nulle. Les générateurs de bruit pseudo-aléatoire disponibles sur le marché ne produisent pas un bruit qui rencontre ces exigences. Un bruit généré par programmation avec une distribution gaussienne d'amplitudes peut facilement être produit à partir d'un générateur de nombres uniformément distribués au hasard. En recourant à un bruit comportant de telles caractéristiques, nous avons étudié des neurones du cerveau moyen de la grenouille. Deux exemples sont présentées ainsi qu'une comparaison entre les résultats obtenus avec le bruit blanc et la méthode plus conventionnelle de l'analyse aux sons purs.

INTRODUCTION

Traditionally the auditory system has been studied using rather simple and mostly deterministic stimuli, such as continuous sinusoids, tone-pips or tone-bursts, repetitive click trains, and sinusoidally amplitude- or frequency-modulated tones.These stimuli have the advantage that they are characterized by a only a few independently variable parameters. For instance, continuous tones are completely determined by frequency and sound pressure level, and the response of neurons in the auditory system is usually presented in its dependence on these parameters, e.g., as tuning curves or iso-intensity contours. The tuning curve is a plot of sound pressure level-frequency combinations that produce a prespecified change in the spontaneous firing rate of neurons. The iso-intensity contour represents the firing rate of a neuron as a function of frequency for a constant sound pressure level. Tuning curves therefore represent an equal-output criterion, iso-intensity contours an equal-input one. If the system under study were linear, then both measurements could easily be converted into each other, however, the auditory system is highly nonlinear and tuning curves and iso-intensity contours generally highlight different aspects of its functioning. Constant response criteria can only be used if the non linear element is a threshold detector and the last stage in the chain of transformations. The problem with the tuning curve approach is that it is only based on a constant change in the magnitude of a response, for example in the firing rate of the neuron, the vibration amplitude of the basilar membrane or the receptor potential amplitude. A true constant response criterion should also consider phase (latency) and harmonic distortion.

A further consequence of the nonlinear nature of the auditory system is that the frequency response measured with one frequency at a time - the harmonic analysis method - cannot describe the behavior of the system for complex multi-frequency stimuli. A very simple multi-frequency stimulus is Gaussian wide band noise (GWN), that has wide spread use in linear systems analysis. Cross correlation between the system output and the GWN results in an estimate of the impulse response, and through Fourier transformation in an estimate of the frequency response of the system. This technique can also be applied when the output signal is discrete such as for a neural spike train. Depending on the precise technique used, the form of the nonlinearity that results in the spike production, and the form of the impulse response itself, the cross correlation technique either results in an unbiased estimate, a scaled version or a linear combination of the impulse response and its first derivative. For auditory nerve fibers with characteristic frequency below 4 kHz it has been established that an unbiased estimate is obtained (De Boer and De Jongh, 1978; Eggermont et al.,1983a). One manifestation of the nonlinear nature of the auditory system is that the estimate of the impulse response depends on the spectrum level of the noise that is used: in general the impulse response shows greater damping for higher noise levels, and consequently a broader frequency response (Moller, 1986). Therefore it is expected that nonlinear systems analysis offers some more insight into the specific nature of the auditory nonlinearity, which by virtue of the audibility of cubic difference tones is known to be at least of third order. The reader has to keep in mind that in non linear systems the result of an input-output characterization has by definition not much predictive value. Because the superposition principle only holds for linear systems, knowledge of the input-output relation of a non linear system is only valid for the actual test stimulus itself. Using the Wiener-kernel formalism a complete description of the non linear system will require determination of all Wiener kernels (Johnson,1980) which is usually not feasible because of computational constraints.

In this paper the main emphasis will be on the use of GWN stimuli, how to study their first and second order statistical properties and to find out how these affect the stimulus response relationships that are revealed by first- and second-order cross correlation. Methods to reduce computation time will be briefly discussed. Examples will be given from a study into the functioning of the auditory midbrain of the grass frog.

CHARACTERIZATION OF STIMULI

Noise that is used to measure first order properties of the system under study should have a flat spectrum and have a bandwidth greater than that of the system, and thus a relatively short and non-oscillating impulse response. When the noise is used to measure second order properties such as energy-time densities (Mecklenbrauker, 1987), ambiguity functions, bi-spectra (Spekreyse and Reits, 1982), or second order correlation functions (Marmarelis and Marmarelis,1978), the noise must have adequate second order properties itself. Thus the second order auto correlation should be equal to zero everywhere, or equivalently its bi-spectrum should be flat. A flat second order auto correlation requires that the amplitude distribution of the noise is symmetric, i.e., the skewness should be zero. When the (0,0) element of the second order auto correlation is zero then the skewness of the amplitude distribution is also zero. We have therefore investigated the amplitude distribution, and the first and second order auto correlation functions for pseudo-noise generated by a Wavetek 132 function generator, noise characterized as random and generated by the Bruel and Kjaer dual FFT analyzer (model 2032), and noise derived from uniformly distributed, software generated, random numbers after appropriately changing

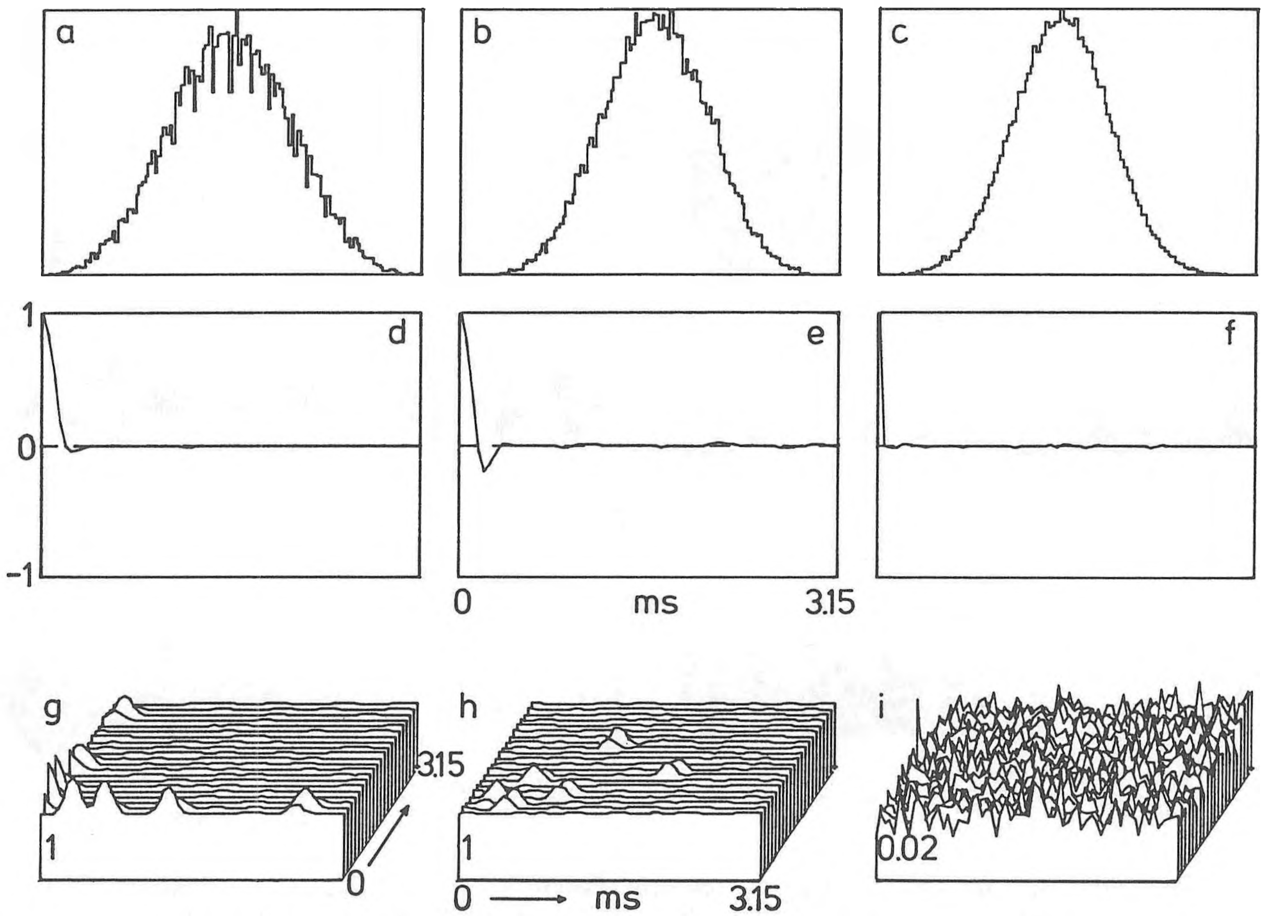

Figure 1. Characterization of pseudo-random noise.

the amplitude distribution to a standard normal distribution(as e.g. in Eckhorn and Popel,1979). The Wavetek and B&K noises were generated for a -3dB point of 2.5 and 3.2 kHz respectively and sampled at 20 kHz for a total of 32k samples.

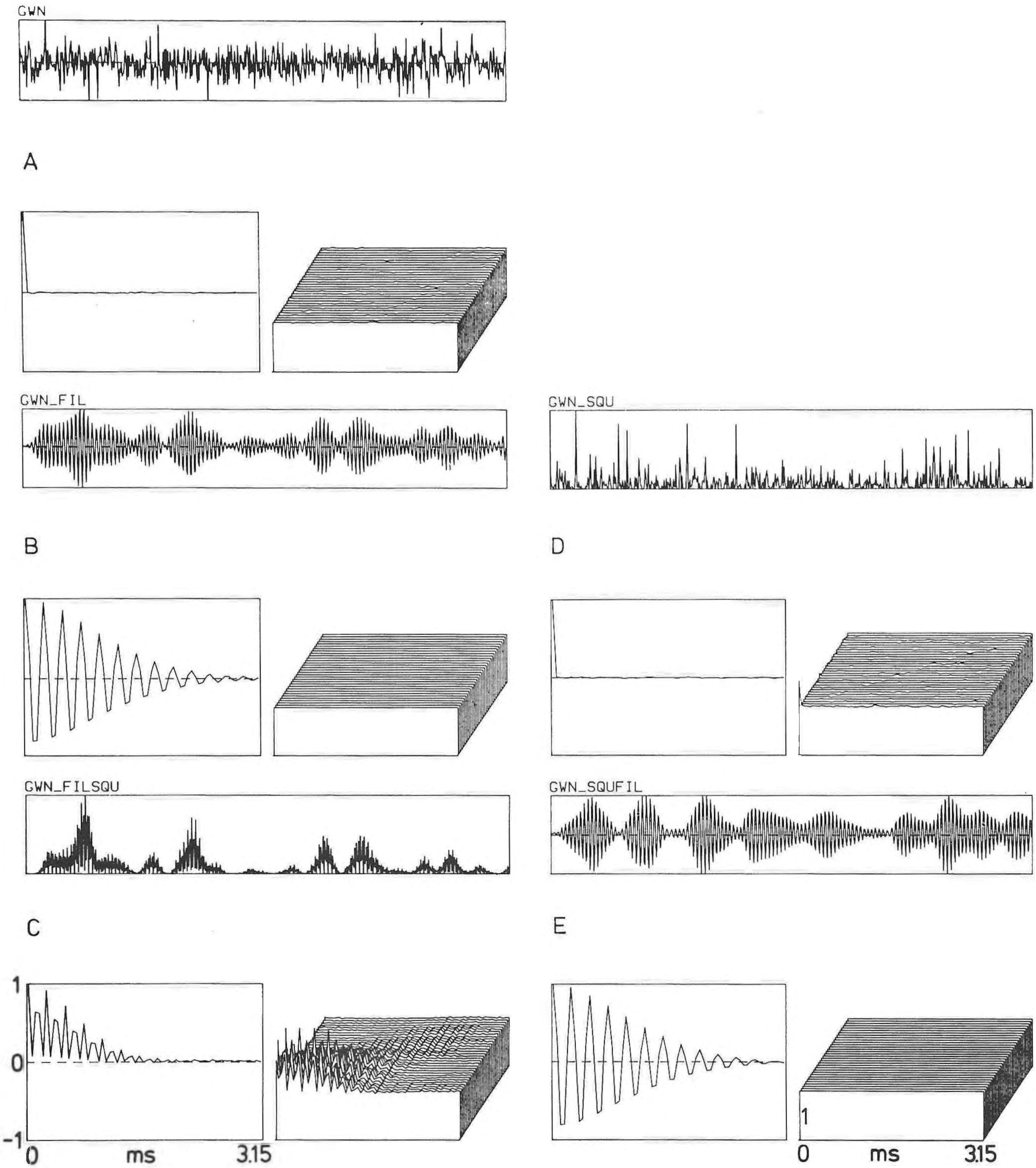

Figure 2. First and second order auto correlation functions for A) Gaussian wide band noise (GWN), B) 2 kHz bandpass filtered noise, C) filtered and squared noise, D) squared GWN, and E) squared and filtered noise.

All amplitude probability densities appear to be symmetrical; for the Wavetek noise with sequence length (2^{15}-1) the distribution is very close to Gaussian , the B&K noise and the computer generated noise do have a Gaussian probability density function (Figure 1 a,b,c). The first order auto-correlation functions for the three types of noise were computed for 64 lags (3.2 ms) and all of them are acceptably close to the ideal one as obtained for the computer generated noise (Figure 1 d,e,f).

The second order auto-correlation properties for the three types of noise differ greatly, however. Defined as:

$$R_{xxx}(\tau_1,\tau_2) = \frac{1}{T}\int_0^T x(t)\, x(t-\tau_1)\, x(t-\tau_2)\, dt \qquad (1)$$

for T sufficiently large, the second order auto correlation function can be represented in pseudo 3-dimensional view as in Figure 1 g,h,i. Part g shows the result for the Wavetek, part h the so-called random noise from the B&K, and part i the computer generated noise. One can observe that only the computer generated noise has satisfactory second order properties, and that the "random" B&K noise clearly has periodic components in it and therefore should better be labeled pseudo-random. Basically this means that the two commercial noise sources studied do not produce noise with properties that are acceptable for second order analysis of non-linear systems.

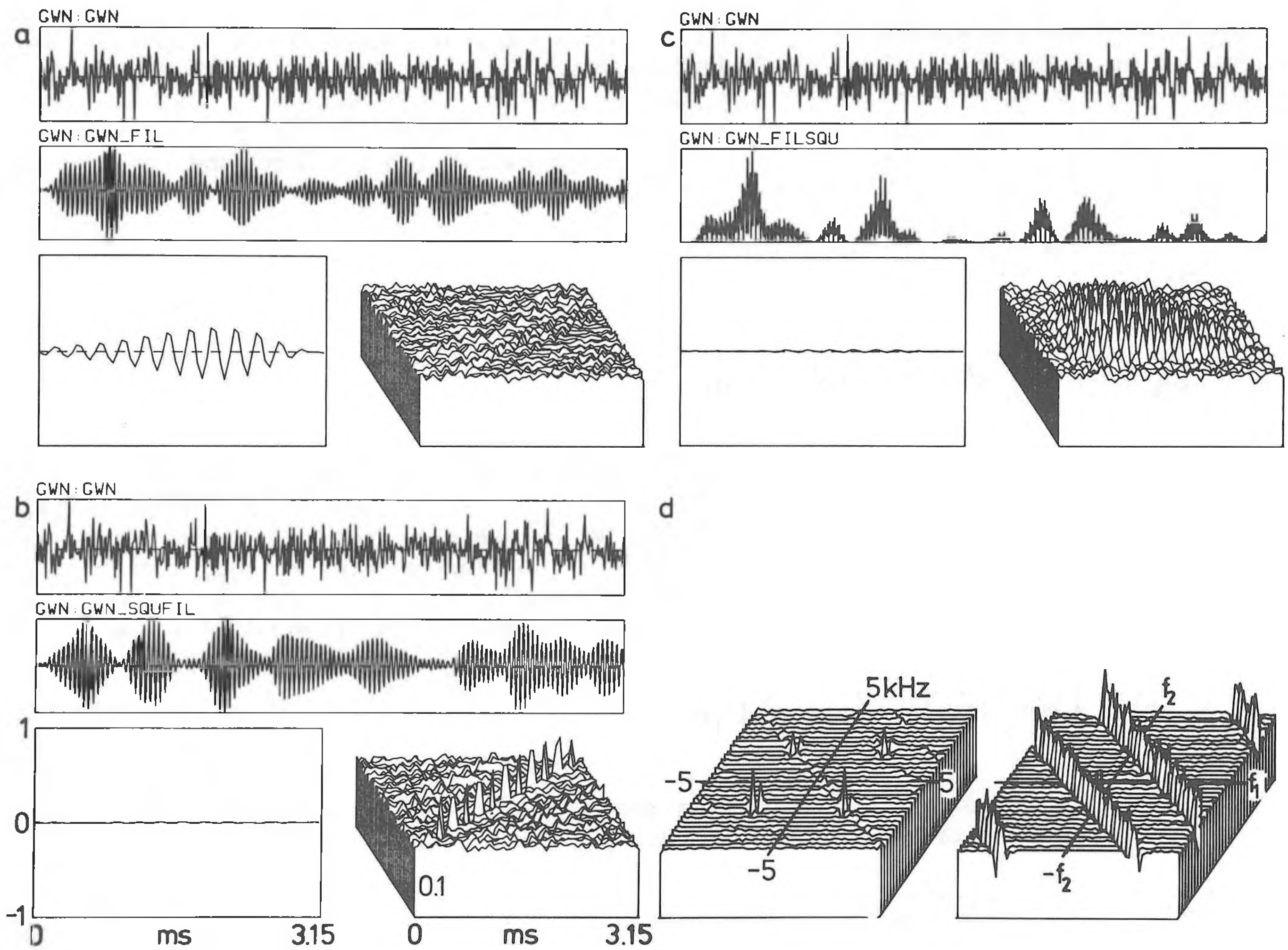

Figure 3. First and second order cross correlation functions for the three systems under consideration (a, b, c) and the bispectra for the systems in b and c (d).

STIMULUS RESPONSE RELATIONSHIPS

The power of non-linear analysis is best demonstrated for a model system. For that purpose we introduce two non-linear systems consisting of a linear band-pass filter (center frequency 2 kHz, slopes 135 dB/oct, -6 dB bandwidth 125 Hz) and a squarer in cascade: one system has the filter at the input, the other system has the squarer at the input. The input to the systems will be gaussian wide-band noise (GWN) and we will show the properties of signals and system through their first and second order correlation properties. Figure 2 presents the format for the auto-correlation analysis of the signals at various points in the systems. First of all the properties of the GWN are repeated in part a, part b gives the same for the filtered GWN showing the effects of the filter in the first order auto-correlation. Because the filter is linear the second order auto-correlation is not affected. Part c shows the signal properties after the signal is filtered and then squared: the first order auto-correlation is now the squared version of the filtered one and the second order auto-correlation reflects both the skew and the filter properties. In part d we study the first transformation in the squarer-followed-by-filter system and observe that squaring the signal does not affect the first order auto-correlation but the induced skewness clearly shows in the (0,0) element of the second order correlation which now has a value of 0.5. Passing this squared signal through the filter produces a first order auto correlation which is identical to that in the absence of the non-linearity, the second order auto correlation is zero since the filtering operation removes all skew from the signal.

As we know from linear systems theory the Fourier transform of the auto-correlation function of the output signal for a GWN input signal gives an estimate of the modulus of the frequency response but leaves us in the dark about the phase relationship between input and output signal (Bendat and Piersol, 1971). In order to identify the system completely we need to use the cross-correlation between input and output signals. The first and second order cross-correlations are defined as:

$$R_{yx}(\tau_1) = \frac{1}{T}\int_0^T y(t)\, x(t-\tau_1)\, dt \qquad (2)$$

$$R_{yxx}(\tau_1,\tau_2) = \frac{1}{T}\int_0^T y(t)\, x(t-\tau_1)\, x(t-\tau_2)\, dt \qquad (3)$$

In Figure 3a we show results for the analysis of the linear filter: samples of the input and output signal are shown together with both cross-correlation functions. The first order cross-correlation results in an unbiased estimate of the impulse response of the filter. For this linear system the second order cross-correlation should theoretically be zero, in this case for a limited signal length the extremes are smaller than 0.01. For the squarer-filter combination the first order cross-correlation nearly disappeared, as it should because:

$$R_{yx}(\tau) = \int h(\tau_1)\, h(\tau_2)\, R_{xxx}(\tau_1,\tau_2,\tau)\, d\tau_1\, d\tau_2 \qquad (4)$$

In contrast the second order cross correlation shows on the diagonal a stretched out version of the impulse response of the linear filter because:

$$h_2(\tau_1,\tau_2) = \delta(\tau_1-\tau_2)\, h(\tau_1) \qquad (5)$$

The filter-squarer combination (Figure 3c) again does not show a first order cross-correlation, however, a distinct second order cross-correlation equal to:

$$h_2(\tau_1,\tau_2)=h(\tau_1)\,h(\tau_2) \tag{6}$$

A bi-spectrum analysis of the two non linear systems shows (Figure 3d) that for the filter-squarer combination the only output is for signals at the filter frequency, however, for the squarer-filter an output is produced whenever the sum or difference of two frequencies equals the filter frequency. This illustrates the formation of sum and difference frequencies when a multifrequency signal is presented at the input of the squarer. Such phenomena are found in the auditory system, indicating that the filter stage is not likely to precede the nonlinearity.

THE AUDITORY NERVOUS SYSTEM

At this point we introduce a model representing current thinking about the auditory peripheral system with exclusion of the middle ear. The model (Figure 4) consists of a non-linear filter, located in the basilar membrane, that receives energy from an active process located in the outer hair cells (Ashmore, 1987), followed by a synapse responsible for auditory adaptation (Eggermont, 1973, 1975, 1985; Smith, 1979; Harris and Dallos, 1979), and finally a pulse generating device: the auditory neuron. Because techniques to deal with non-linear filtering are lacking we modify the model into a band-pass non-linearity (BPNL) model. In such a model the non-linear filter is split up into two linear filters with an algebraic non-linearity sandwiched in between. The first filter is a sharply tuned band-pass filter representing the tuning properties of the basilar-membrane-outer-hair-cell system, the second filter is a low-pass filter representing the action of the hair-cell-neuron-synapse (see Pfeiffer,1970; Johannesma, 1971; De Boer, 1976).

In the present model the occurrence of an action potential z(t) depends on the signal y(t), the generator potential of the auditory neuron. In case the pulse generator produces spikes proportional to y(t) it can be demonstrated that :

$$R_{zx}(\tau)=R_{yx}(\tau) \tag{7}$$

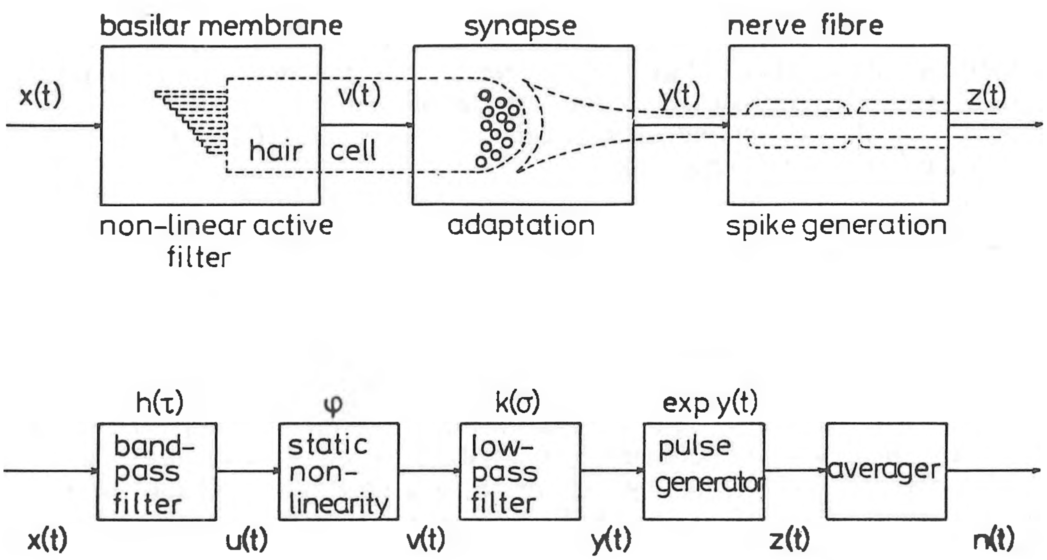

Figure 4. A model for the peripheral auditory nervous system, and its adaptation for non-linear systems analysis (from Eggermont et al., 1983c).

This appears to be the most likely situation for the auditory nerve fibers (De Boer and De Jongh, 1978). Thus instead of using, the rather inaccessible analog signal, y(t) we can perform the correlation with the spike train as the output signal (De Boer and Kuyper, 1968). The method can be extended to second order cross-correlation (Hermes et al.,1981; Eggermont et al.,1983a). In both cases the signal to noise ratio decreases by a factor of 1.8 respectively 3.4 as compared to the correlation on the basis of the analog signals.

Since the z(t) are unitary pulses occurring at times t_n, the cross correlation takes the form of averaging the pre-spike stimulus:

$$R_{zx}(\tau)=\frac{N}{T}\frac{1}{N}\sum_{n=1}^{N}x(t_n-\tau) \tag{8}$$

respectively the lagged product function:

$$R_{zxx}(\tau_1,\tau_2)=\frac{N}{T}\frac{1}{N}\sum_{n=1}^{N}x(t_n-\tau_1)\,x(t_n-\tau_2) \tag{9}$$

of the stimulus that precedes the action potentials. It turns out (Moller, 1986) that the first order cross correlation is stimulus dependent, at least in rodents, and becomes progressively more damped with increase in noise level. This is again a strong indication of a non-linearity of at least third order.

POLARITY AND TERNARY CORRELATION FUNCTIONS

Calculating higher order correlation functions requires fast computers and although these are now readily available a discussion of computationally less demanding procedures is still useful. An idea proposed by Veltman (1966) and later elaborated upon by Wolf (1973) and Klein and Yasui (1979) is to replace both the GWN and the analog output signal by a simple transformation of these signals. Such a transformation can be replacing the signal by its sign, and it can be shown (Figure 5 a,b) that correlation between two such transformed signals, polarity correlation, leaves the shape of the correlation function intact but reduces the amplitude by a factor 2/pi, and increases the variance by a factor 1.57 for first order correlation and 2.47 for second order correlation.

A slightly better result is obtained by using a ternary transform (Figure 5 c,d) in which the signal is transformed according to:

$x(t)>\mu+n\sigma$, x(t) = 1

$x(t)<\mu-n\sigma$, x(t) = -1

and otherwise x(t) = 0; usually n is taken equal to 1. In this case the variances for the first and second order correlation functions increase by 1.37 respectively 1.88, the reduction in amplitude is however larger and results in about 0.24 of the original size.

A draw back of the polarity and ternary correlation procedures is that in case of an even order non-linearity following the filter, such as in our example of the filter-squarer combination, the output signal will be extremely skewed. In such a case the transformations are not justified. This can be alleviated by adding a non-correlated random signal to the output before transforming it, this of course will further increase the variance but at least allows these computational faster methods to be used.

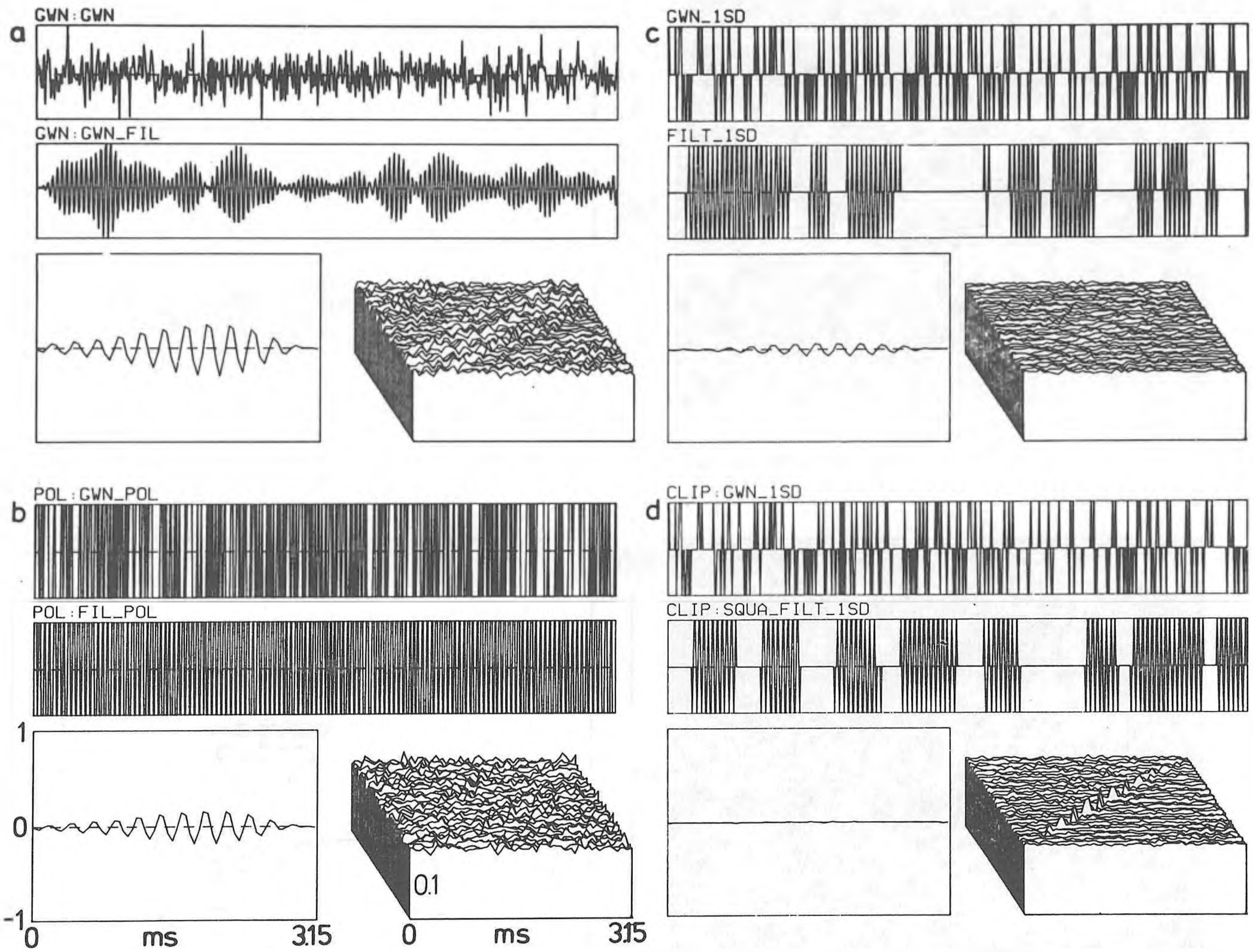

Figure 5. A comparison of cross correlation functions bases upon GWN (a), polarity representation (b), and a ternary representation (c). Part d is to be compared to Fig. 3b.

FREQUENCY-TIME REPRESENTATION OF SIGNALS AND CORRELATION FUNCTIONS

For the auditory nervous system, which is both a frequency and a time analyzer, it is intuitively more useful to represent second order correlations or bi-spectra in the form of time dependent spectra or spectrograms. The Fourier transform with respect to time of the time dependent autocorrelation function results in the spectrogram of a signal. Various forms exist such as the Wigner distribution (Yen,1987) or the Rihacek Costid (Johannesma et al.,1981). This can be extended to those parts of the stimulus signal that precede an action potential. Formally the correlation takes the form of a second order cross correlation between z(t) and x(t) in which z(t) is a series of delta functions. A Fourier transform with respect to the difference in lag times then results in a short-time-spectrogram. Averaging all these short-time-spectrograms results in the average spectrogram of signals preceding action potentials, and is considered to be causal in their generation. The latter form has been used extensively in the study of response properties of auditory neurons (Hermes et al.,1981; Eggermont et al.,1983a; Epping and Eggermont,1985). We will discuss two examples and then give an overview of results obtained in previous studies.

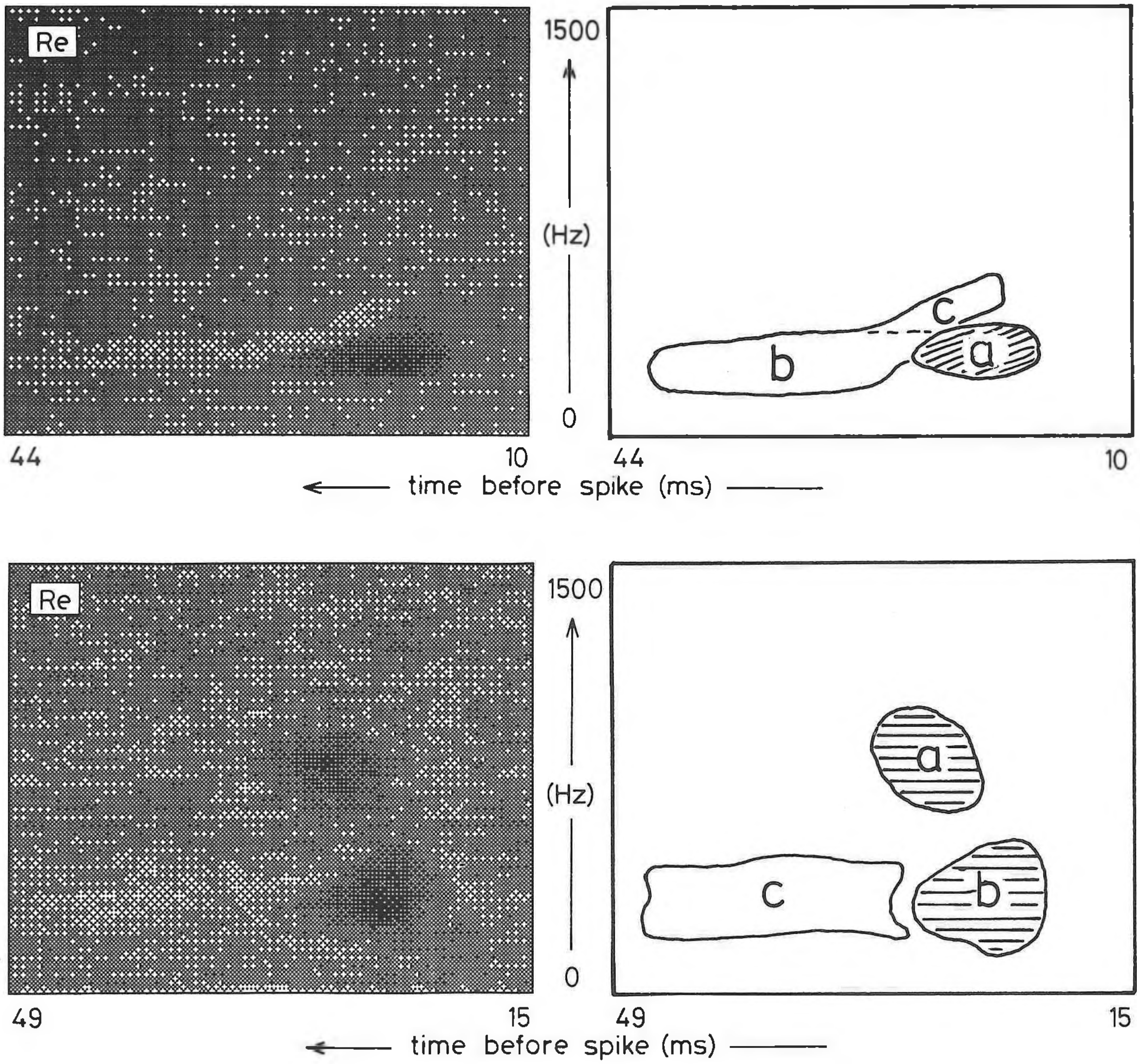

Figure 6. Average Costid's for signals preceding an action potential for two neurons in the auditory midbrain of the grassfrog.

Figure 6a shows the real part of the average Costid (short for coherent spectro-temporal intensity density) for a neuron in the auditory midbrain of the grassfrog. On the horizontal axis time before the action potential is indicated, the vertical axis represents frequency. The right hand side of the Figure schematically outlines the various areas of interest in the Costid. The coding used is a grey scale: grey is the level of the noise signal in case of random, not stimulus related, action potentials, dark represents more signal level and white less signal level than background. One can interpret part a of the Costid as those parts of the noise that increase firing probability in the neuron, i.e., those parts of the noise stimulus that are filtered out by the neuron. In this example the center frequency is about 250 Hz, the fact that this area is situated about 15 ms before the spike indicates that the latency of the neuron is about 15 ms. After this dark, activation, area one observes (part b) a lighter area indicating that in this time frame on average less noise than average was present in this frequency range. This is called post-activation suppression. Also some lateral suppression is noted (part c). The total number of spikes elicited by the noise, and thus the number of averages, was 666.

The second example (Figure 6b) shows a neuron that has a double peaked sensitivity: one region (part a) is centered around 750 Hz, the other region (b) around 250 Hz. The latter region also is accompanied by lateral suppression (c). Such double tuned neurons are quite common in the auditory midbrain of frogs and nearly absent at more peripheral levels. This indicates that neurons with widely differing best frequencies converge onto a single neuron at the level of the midbrain.

In two recent studies a total of 219 units was investigated with noise (Hermes et al.,1981; Epping and Eggermont,1985) of which 107 responded in a sustained way such that their Costids could be evaluated. Of these 107 neurons 58% showed unimodal excitatory results, 21% showed bimodal responsiveness, 19% had lateral suppression (as in Fig. 7a) and only 2% showed inhibitory Costids (i.e., certain frequencies in the noise actually decreased the spontaneous firing rate of the neuron). Comparing these results to that of an analysis with random single-frequency tone burst stimuli revealed that in 64% of the cases the same type of spectro-temporal sensitivity was obtained. The remaining 36% of the units had different spectrograms for the noise and the tonal stimuli: all of them had multimodal spectrograms for the tonal stimuli that was either changed into a unimodal one (27%) or in a different multimodal one (9%) in case of the response to noise.

DISCUSSION

The first question we obviously have to ask is what the particular benefits the GWN analysis is producing, especially in the light of its demanding computational aspects. The basic idea behind the use of gaussian white noise, is that in principle all possible stimuli are contained in it, although the probability of occurrence for each of these is very low. If we know the response of a system to noise, or approximate that knowledge by the evaluation of cross-correlation functions, it is possible to predict the response to any other stimulus, provided that our approximation was sufficiently good. This is the pervading view, however when using the cross-correlation approach the estimated Wiener kernels are only orthogonal with respect to GWN of that particular spectrum power level, unless we know all the Wiener kernels (Johnson, 1980). Furthermore when we only have an approximation of the response to GWN, because we have evaluated only a few of the possible cross correlation functions, it is impossible to obtain an accurate prediction to stimuli that are not close to GWN (e.g.,Eggermont et al.,1983 a,b,c for an experimental investigation). On the other hand it may be possible to approximate the properties of meaningful sounds such as speech by linear transformations of GWN, in that case the stimulus used for predictions is close to GWN and the procedure might work.

Stimuli used in this procedure should be very carefully evaluated before using them, because their second order properties will confound the second order cross correlations and related spectro-temporal representations. In general one cannot rely on information in technical manuals of potentially useful equipment. First of all most commercially available noise sources are destined for linear systems analysis, secondly it is not appreciated that when nonlinearities of the third order are present that this makes the estimation of the "impulse response" dependent on the noise power.

The differences in the sensitivity obtained for the noise and the tonal stimuli can be the result of the lateral inhibition that becomes manifest for the multifrequency, noise, stimulation and is absent in the tonal stimulation. Another aspect is the differing adaptation state for the neuron in case of continuous noise stimulation versus the pulsed tone burst stimulation.The differences observed between the responses of the auditory neurons to single tone stimuli and noise illustrates that in order to characterize the auditory nervous system, or parts thereof, one needs a large variety of stimuli. The theoretical background for analyzing the stimulus response relationships for GWN stimuli obviously is an important advantage. The fact that the neurons in about half of the cases do not respond in a stationary way to GWN makes it application not as widespread as wanted. The use of amplitude modulated noise stimuli can alleviate this problem.

Acknowledgements. This research was supported by grants from the Alberta Heritage Foundation for Medical Research, and the Natural Sciences and Engineering Research Council of Canada.

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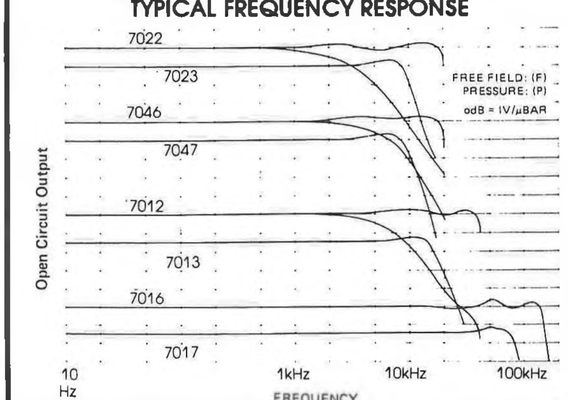

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PERIODICITY PERTURBATION IN NATURAL ENGLISH VOWELS *

Jan L. Adlington and Anton J. Rozsypal

Department of Linguistics, The University of Alberta
Edmonton, Alberta, Canada T6G 2E7

ABSTRACT

To establish normative values for natural production, jitter (glottal period perturbation) and shimmer (amplitude perturbation) were measured for nine Canadian English vowels, produced by eight male and eight female speakers in the sentence frame "Please say /hVd/ not /hVd/." The speech signals were digitized at a 20 kHz sampling rate. Following extraction of the vowel, the duration and peak amplitude of each period were measured using a semi-automatic peak-picking procedure with quadratic interpolation. Jitter and shimmer were determined as distance from a two-point linear trend line centered around the current period. Period measures were normalized by dividing this distance by the local mean period duration averaged across three periods; a similar measure was employed for shimmer. For both jitter and shimmer, unexpectedly large differences among speakers were found. The relation between jitter and shimmer within the vowel was also investigated by cross-correlating the signed jitter and shimmer perturbations of individual vowel periods. Significant correlations appeared for less than one quarter of the vowel tokens.

SOMMAIRE

Afin d'établir des valeurs normatives pour la production naturelle de la parole, des mesures de perturbation de la période glottale ou du "trémolo" ("jitter") et de perturbation d'amplitude ou de "miroitement" ("shimmer") ont été effectuées pour neuf voyelles de l'anglais canadien produites par huit locuteurs et huit locutrices dans la phrase suivante: "Please say /hVd/ not /hVd/." Les phrases ont été rendues numériques à une fréquence d'échantillonnage de 20 kHz et les voyelles en ont été extraites. La durée et l'amplitude maximale de chaque période vocalique ont été mesurées à l'aide d'une procédure semi-automatique avec interpolation quadratique pour déterminer chaque sommet. Le trémolo et le miroitement ont été définis pour chaque période comme étant la distance d'une ligne indiquant la tendance linéaire locale. Les mesures de période ont été normalisées en divisant cette distance par la moyenne locale de la durée périodique pour trois périodes. Une procédure analogue a été utilisée pour le miroitement. Pour le trémolo et le miroitement, contrairement à notre attente, de grandes différences inter-locuteurs ont été observées. Nous avons aussi étudié le rapport entre le trémolo et le miroitement au sein de la voyelle en comparant les valeurs algébriques de leurs perturbations pour des périodes vocaliques individuelles. Des corrélations significatives ont été observées pour moins d'un quart des voyelles étudiées.

1. INTRODUCTION

Small, cycle-to-cycle perturbations of the glottal period (jitter) and of peak amplitude (shimmer) have been extensively studied in attempts to non-invasively assess the functional status and health of the larynx (Heiberger & Horii, 1982). For this purpose, measurements are commonly made from the central portion of sustained vowels. However, more normal phonatory samples are required where the perceived quality of a healthy speaker's voice, or

* This paper was presented at the Acoustics Week '87, organized by the Canadian Acoustical Association, at Calgary, Alberta, in October 1987. It is based on parts of the M.Sc. thesis submitted by J.L. Adlington to the Faculty of Graduate Studies and Research of the University of Alberta.

the naturalness of a synthetic source, is at issue. The present study examines jitter and shimmer magnitudes in nine vowels produced in a sentential context. Since it was conceived as preliminary to a perceptual study of voice quality, perturbations were analyzed from the acoustic pressure wave rather than from a laryngograph signal. One aim was to confirm the results of a naturalness-rating experiment on synthetic speech (Rozsypal & Millar, 1979) which found the optimal amount of jitter to vary with the vowel quality. A secondary aim was to explore the relation between jitter and shimmer with correlations between the signed perturbation values for individual periods within each vowel token.

2. METHOD

The speakers were eight male and eight female adults, with no known speech or hearing defects. Their ages ranged from 19 to 38, with a mean of 27 years. Five male and five female subjects had never smoked.

Jitter and shimmer perturbations were measured for nine monophthongal Canadian English vowels, /i, ɪ, ɛ, æ, ɝ, ʌ, u, ʊ, ɑ/, spoken in the neutral vowel context /hVd/. To test for intonation effects, the vowels appeared in two stressed positions in the sentence frame "Please say /hVd/ not /hVd/." Thirty-six tokens (9 vowels x 2 positions x 2 replications) were produced in random order by each speaker; no vowel appeared twice in the same sentence. Subjects were instructed to speak at a comfortable loudness.

The speakers were digitally recorded in an acoustically isolated recording booth, using a high-quality microphone (Sennheiser MKH 405), a 12-bit analog-to-digital converter (Tecmar Lab Master), and an IBM AT microcomputer. A 20 kHz sampling rate was used. The amplitude sampling range was restricted to about 10 bits, providing a signal to quantization noise ratio of about 60 dB. The signals were bandpass filtered between 50 Hz and 7800 Hz; care was taken to ensure that all interfering signals were suppressed below detectable level.

A signal editor was used to isolate the vowel segment in each test word. Transitional portions were eliminated by digital gating at the vowel onset and offset, where amplitude changed rapidly over a small number of periods, or where waveshape changes suggested the start of a transition. Gating continued until playback produced a vowel percept.

The peak amplitudes and period durations within the gated vowels were found by a semi-automatic peak-picking program which allowed the operator to roughly position a forty-point wide bar cursor on a peak. The program then searched within the bar interval for the greatest sample point in the peak, and calculated the maximum of a parabola passing through this point and the ones immediately preceding and following. The y coordinate of the maximum was stored as peak amplitude; the x coordinate allowed the period duration, in ms, to be computed. This interpolation was implemented to improve the 50 μs temporal resolution given by the sampling rate. As shown by Titze, Horii, & Scherer (1987), interpolation with peak-picking can resolve jitter down to 0.1%, with fewer than 100 samples per period; about 500 samples per period would otherwise be needed to minimize the error caused by the finite duration of the sampling interval. As our calibration tests indicate, this measure could also reduce the amplitude measurement error by up to five quantization intervals.

The peak amplitude was always determined from the greatest sampling point in the period. Period durations were found by tracking a single, prominent peak throughout the vowel. Because of waveshape variations, the points from which these parameters were calculated did not always coincide. Jitter values for each of the vowels were calculated according to the following formula:

$$\text{Mean Jitter} = \frac{1}{N-2} \sum_{i=2}^{N-1} \left[\frac{\left| T_i - \frac{T_{i-1} + T_{i+1}}{2} \right|}{\frac{T_{i-1} + T_i + T_{i+1}}{3}} \right] \times 100\%$$

where T_i is the duration of the i^{th} period, and N is the number of periods included in the analysis. The numerator measures the absolute distance of T_i from an arithmetic average of the preceding and following period durations. This formula has been selected because it removes the effect of linear frequency trend on the jitter value. The denominator normalizes this value for frequency, since jitter without normalization is highly dependent on the frequency renge of phonation (Lieberman, 1963; Horii, 1979). Because frequency varies with intonation, a local average over three adjacent vowel periods was used. Shimmer was defined by an analogous formula, with peak amplitudes, A_i , replacing the period durations, T_i . Amplitude was measured on a linear scale.

Another analysis cross-correlated the signed (i.e. positive or negative) jitter and shimmer values, that is, deviations from the linear trend, for each period at lags of zero and one period. At a lag of zero, the period duration was correlated with the height of the peak within the same period; at a lag of 1, it was correlated with the peak of the following period.

3. RESULTS

3.1 Jitter and Shimmer Magnitudes

Mean jitter and shimmer magnitudes for each subject, averaged across the 36 tokens each produced, are presented in Table 1. Across all tokens, mean jitter ranged from 0.11% to 17.26%, and mean shimmer, from 0.73% to 84.43%. The exceptionally large values were taken to reflect the presence of a phenomenon additional to "normal" jitter and shimmer, often (but not always) identified as double periodicity. Based on distributional criteria, arbitrary upper limits on acceptable "normal" jitter and shimmer were established at 4.0% and 15.0%, respectively. Values above these levels were set to 1.0% for jitter and 3.5% for shimmer, the approximate overall means of the dependent variables. This step effectively eliminated them from the analysis. The outlying values were then examined separately.

From the total of 576 tokens, 29 jitter and 16 shimmer values were classed as outliers. These were not found to be dependent either on vowel quality, sentence frame position, or replication. As an example of the unpredictability of the outlier phenomenon, Figure 1 presents plots of the signed jitter and shimmer for each period in three repetitions of /æ/ produced by female speaker F5. "AEE1" (jitter = 17.20%, shimmer = 84.43%) shows the exaggerated, regular pattern typical of double periodicity; the inconsistent variations of "AEE2" (jitter = .55%, shimmer = 5.01%) and "AEW2" (jitter = .63%, shimmer = 2.54%) represent the more normal case. Outliers were characteristic of certain subjects, however, and multiple outliers occurred only with subjects F6, M2, and M3. With only one exception, the outlier tokens for shimmer were also outliers for jitter.

For both jitter and shimmer, three-way ANOVAs with repeated measures on vowels and position were performed, following adjustment of the outliers. In both cases, strong subject effects were found (jitter: $F(14,287) = 16.851$, $p<.001$; shimmer: $F(14,287) = 14.135$, $p<.001$). To examine this source of variance, hierarchical cluster analyses were produced using the Ward method. For jitter, the subjects clustered into two groups of six subjects each. Group membership was not determined by sex (nor, incidentally, by

Subjects	JITTER [%] All Values	JITTER [%] Outliers Adjusted	SHIMMER [%] All Values	SHIMMER [%] Outliers Adjusted
M1	.54	.54	3.34	3.34
M2	2.00	1.12	5.08	4.73
M3	4.81	1.27	14.27	5.46
M4	.46	.46	2.24	2.24
M5	1.21	.78	3.89	3.89
M6	.57	.57	2.15	2.15
M7	.54	.54	2.45	2.45
M8	.70	.70	4.11	4.11
F1	.43	.43	2.13	2.13
F2	.49	.49	2.33	2.33
F3	.79	.79	2.28	2.28
F4	1.11	1.11	3.14	3.14
F5	1.30	.85	5.05	2.80
F6	2.57	1.38	6.22	4.51
F7	.72	.72	2.64	2.64
F8	.80	.80	2.45	2.45

Table 1. Mean jitter and shimmer for all subjects. The effect of outlying tokens can be seen on subjects M2, M3, M5, F5, and F6.

Source	SS	df	MS	F	p
Groups	7.726	1	7.726	76.895**	.001
Subjects(G)	1.005	10	.100	1.127	
Vowels	3.889	8	.486	2.485*	.018
Groups x Vowels	.477	8	.060	.305	.962
Vowels x Subj(G)	15.653	80	.196	2.210**	
Position	.452	1	.452	4.513	.060
Groups x Position	.004	1	.004	.040	.845
Position x Subj(G)	1.002	10	.100	1.127	
Vowels x Position	.767	8	.096	1.012	.434
Groups x Vowels x Pos'n	.754	8	.094	.995	.447
Vowels x Pos'n x Subj(G)	7.576	80	.095	1.071	
Replication	.036	1	.036	.231	.641

Table 2. Analysis of variance summary table for jitter, with 12 subjects in two groups of six.

Source	SS	df	MS	F	p
Subjects	14.623	8	1.828	1.936	
Vowels	62.046	8	7.756	4.621**	.001
Vowels x Subj	107.416	64	1.678	1.778**	
Position	9.283	1	9.283	6.140*	.038
Position x Subj	12.094	8	1.512	1.602	
Vowels x Position	.710	8	.089	.120	.998
Vowels x Pos'n x Subj	47.457	64	.742	.786	
Replication	.066	1	.066	.030	.867

Table 3. Analysis of variance summary table for shimmer, for one group of nine subjects.

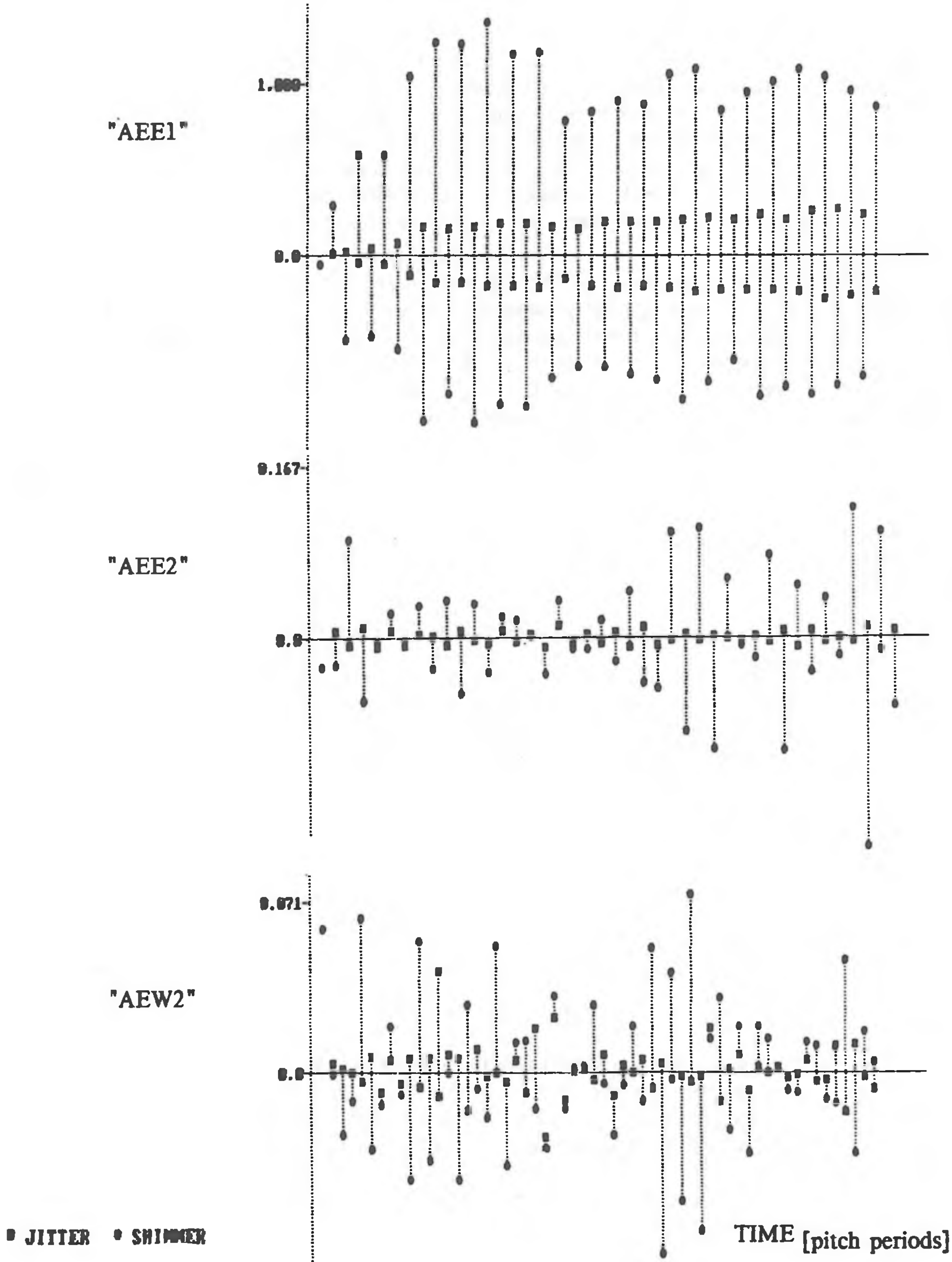

Figure 1. Signed jitter and shimmer for each period in three /æ/ segments produced by female speaker F5. "AEE1": sentence-final position, first replication; "AEE2": sentence-final, second replication; "AEW2": within sentence, second replication. The points represent relative perturbation values prior to the conversion to percentage. Note the differences in the ordinate scale.

smoking): group 1, the most homogeneous, contained two female and four male subjects, while group 2 contained four females and two males. The four remaining subjects were best treated as individuals. For shimmer, one group of nine subjects (six female, three male) was apparent. A second group of three subjects was loosely defined and not further analyzed, and four subjects were not grouped. Three of the ungrouped subjects, for both jitter and shimmer, were F6, M2, and M3, the speakers responsible for most of the outliers: even following removal of the extreme values, their measures appeared abnormal, in magnitude and consistency.

A new ANOVA was then performed on jitter for twelve subjects, with group membership as a factor. The results, presented in Table 2, show a significant vowel effect at the .05 level, and a vowel by subject interaction at the .01 level. From most to least jitter, the vowels were ordered /ɪ, u, ʊ, i, ɛ, æ, ʌ, ɑ, ɚ/, though the significant interaction indicates this would not necessarily hold for any given subject. A Tukey test showed only that the extreme cases, /ɪ/ and /ɚ/, differed significantly ($p<.05$).

Results of a shimmer ANOVA for the nine grouped subjects are given in Table 3. Vowels, and the vowel by subject interaction, were significant at $p<.01$, and position was significant at $p<.05$. From most to least shimmer, the vowels were ranked in the following order: /æ, ʌ, ʊ, ɑ, ɛ, ɪ, ɚ, i, u/. Here, a Tukey test showed /æ/ and /ʌ/ to differ from /i/ and /u/ ($p<.05$). Vowels in sentence-final position had significantly more shimmer than those within.

3.2 Jitter and Shimmer Correlations

At the .01 level, signed period-to-period jitter and shimmer perturbations were significantly correlated for 140 of the 576 tokens (24.3%). Significant positive correlations at a lag of 0, or negative correlations at a lag of 1, accounted for 115 of these cases (20.0% overall, 82.3% of the significant tokens). This number includes 26 of the 30 tokens for which jitter or shimmer was an outlier. In contrast, negative correlations at lag 0 or positive correlations at lag 1 appeared in only 25 cases (4.3% overall, 17.7% of the significant tokens). Thus, where peak amplitudes and period durations were positively correlated, long periods tended to follow high peaks. Examples of correlated and uncorrelated measures can be seen in Figure 1: "AEE1" is an outlier with highly significant jitter/shimmer correlations (lag=0, r=.97); "AEE2" is a "normal" token with a significant r (lag=0, r=.54); and "AEW2" is a "normal" token without correlations (lag=0, r=.08; lag=1, r=-.16).

4. DISCUSSION

This study's focus on the productions of healthy speakers, to be related to perceived voice quality, emphasizes the differences which exist among members of the normal population. The between-subject differences found suggest that jitter and shimmer should perhaps be considered among the parameters which characterize individual speakers. The measures from subjects F6, M2, and, particularly, M3, also indicate that large perturbations can be habitually produced with non-pathologic origins.

The significant vowel by subject interactions, found after grouping subjects, show that vowel differences must be interpreted cautiously. Results ranging from no vowel effects, to vowel by sex interactions, have been reported in the literature. Kasprzyk and Gilbert (1975), measuring jitter in five sustained vowels, concluded that differences did not exist among the vowels studied; Ramig and Ringel (1983), with shimmer in three comfortable duration vowels, also failed to note any vowel effect. In contrast, a study conducted by Sorensen and Horii

(1983) found that females produced more jitter and less shimmer than males for /i/ and /u/, but not for /a/. For main effects, Horii (1980) and Sorensen and Horii (1983) reported /i/ to have significantly more jitter than /u/ and /a/, and /a/ to have more shimmer than /i/ or /u/, while Wilcox and Horii (1980) found more jitter for /i/ and /u/ than for /a/. Across studies, /i/ is often seen to have more jitter and less shimmer than /a/, although the differences are not always significant. The present study is consistent with these observations. However, the variability among subjects suggests that the population of normal speakers is not homogeneous, nor can it be easily subdivided on the basis of sex, and that varying results can be expected. Speculation on the origins of vowel differences can also only be formulated in terms of tendencies.

The cross-correlation data reveal the general independence of jitter and shimmer within specific periods. While the mechanical and neurophysiological origins of the perturbations are undoubtedly complex (Baer, 1980), the same causative factors had been expected to influence and relate jitter and shimmer, to an extent greater than was found.

5. ACKNOWLEDGMENTS

The authors would like to thank Wm. J. Baker for his valuable suggestions and help with statistical data processing.

Travel assistance provided by the Faculty of Graduate Studies and Research and the Alma Mater Fund at the University of Alberta allowed presentation of this paper at the Acoustics Week '87 at Calgary, Alberta.

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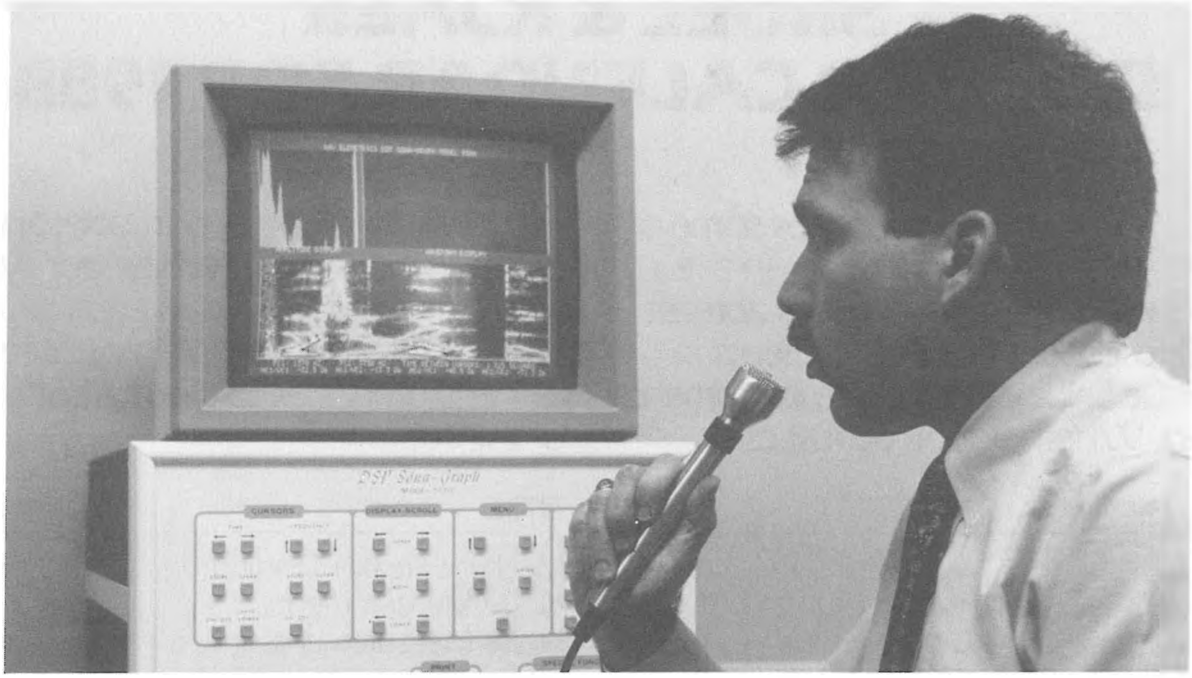

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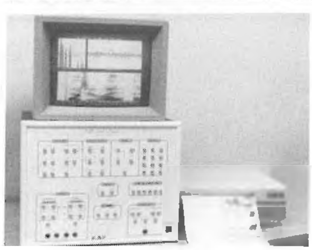

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Jan. 18-20	Vancouver, B.C.	Machine Health Monitoring
Jan. 20-21	Toronto, Ont.	Noise Measurements
Jan. 27-28	Ottawa, Ont.	Noise Measurements
Feb. 9-10	St. John's, Nfld.	Machine Health Monitoring
Feb. 10-11	Thunder Bay, Ont.	Noise Measurements
Feb. 17-19	Edmonton, Alta.	Machine Health Monitoring
Feb. 24-25	Toronto, Ont.	Intensity Measurements
Feb. 24-25	Sherbrooke, Qué.	Mesures de vibration pour la maintenance prévisionnelle
Mar. 9-10	Cambridge, Ont.	Noise Measurements
Mar. 10-11	Prince George, B.C.	Noise Measurements
Mar. 15-16	Winnipeg, Man.	Noise Measurements
Mar. 22-24	Toronto, Ont.	Vibration Testing/Structural Analysis
Apr. 5-6	Vancouver, B.C.	Paper Machine Monitoring/Structural Analysis
Apr. 6-7	Ottawa, Ont.	Machine Health Monitoring
Apr. 6-7	St. John, N.B.	Machine Health Monitoring
Apr. 13-14	Timmins, Ont.	Machine Health Monitoring
Apr. 19-20	Montréal, Qué.	Essai aux vibrations et analyse modale
Apr. 21-22	Montréal, Qué.	Vibration Testing/Modal Analysis
Apr. 21-22	Edmonton, Alta.	Human Environment
Apr. 27-28	Toronto, Ont.	Advanced Acoustics
Apr. 28-29	Trois-Rivières, Qué.	Mesures de vibration pour la maintenance prévisionnelle
May 4-5	Ottawa, Ont.	Advanced Acoustics
May 4-5	Edmonton, Alta.	Noise Measurements
May 4-5	Val d'Or, Qué.	Mesures de vibration pour la maintenance prévisionnelle
May 10	Baie Comeau, Qué.	Mesures des nuisances de l'environnement
May 11	Québec, Qué.	Mesures des nuisances de l'environnement
May 13	Jonquière, Qué.	Mesures des nuisances de l'environnement
May 11-12	Thunder Bay, Ont.	Machine Health Monitoring

DATE	PLACE	TITLE
May 24-25	Montréal, Qué.	Intensity Measurements
May 26-27	St. John's, Nfld.	Intensity Measurements
May 25-26	Toronto, Ont.	Signal Processing
May 31 – June 2	Winnipeg, Man.	Machine Health Monitoring
June 1-2	Ottawa, Ont.	Signal Processing
July 6-8	Fort St. John, B.C.	Machine Health Monitoring
July 18-19	Vancouver, B.C.	Noise Measurements
Aug. 10-12	Edmonton, Alta.	Intensity Measurements
Aug. 25-26	Jonquière, Qué.	Mesures de vibration pour la maintenance prévisionnelle
Aug. 30-31	Montréal, Qué.	Mesures de vibration pour la maintenance prévisionnelle
Sept. 7-8	Toronto, Ont.	Electroacoustics
Sept. 7-9	Québec, Qué.	Mesures de vibration pour la maintenance prévisionnelle (séminaire avancé)
Sept. 14-16	Saskatoon, Sask.	Machine Health Monitoring
Sept. 21-22	Thunder Bay, Ont.	Machine Health Monitoring (Advanced)
Oct. 19-20	Ottawa, Ont.	Machine Health Monitoring (Advanced)
Oct. 24-25	Winnipeg, Man.	Noise Measurements
Oct. 26-27	Windsor, Ont.	Machine Health Monitoring
Nov. 8-10	Winnipeg, Man.	Machine Health Monitoring
Nov. 16-17	Baie Comeau, Qué.	Mesures de vibration pour la maintenance prévisionnelle
Nov. 23-24	Toronto, Ont.	Machine Health Monitoring
Nov. 29-30	Halifax, N.S.	Machine Health Monitoring
Dec. 1	Winnipeg, Man.	Human Environment

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Noise Control Products & Systems

for the protection of personnel...
for the proper acoustic environment...

engineered to meet the requirements of Government regulations

---

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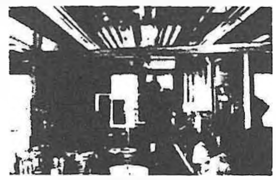
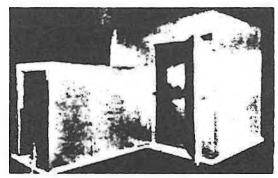
Durable, attractive panels having outstanding sound absorption properties. Easy to install. Require little maintenance. EFPs reduce background noise, reverberation, and speech interference; increase efficiency, production, and comfort. Effective sound control in factories, machine shops, computer rooms, laboratories, and wherever people gather to work, play, or relax.



Eckoustic® Enclosures

Modular panels are used to meet numerous acoustic requirements. Typical uses include: machinery enclosures, in-plant offices, partial acoustic enclosures, sound laboratories, production testing areas, environmental test rooms. Eckoustic panels with solid facings on both sides are suitable for constructing reverberation rooms for testing of sound power levels.



Eckoustic® Noise Barrier

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- Machinery & Equipment Noise Dampening

The Eckoustic Noise Barrier provides a unique, efficient method for controlling occupational noise. This Eckoustic sound absorbing-sound attenuating material combination provides excellent noise reduction. The material can be readily mounted on any fixed or movable framework of metal or wood, and used as either a stationary or mobile noise control curtain.

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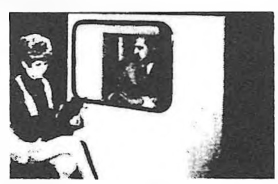
Diagnostic Rooms offer effective noise reduction for all areas of testing. Designed to meet, within ±3 dB, the requirements of MIL Spec C-81016 (Weps). Nine standard models. Also custom designed facilities.



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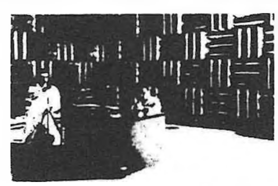
Echo-free enclosures for acoustic testing and research. Dependable, economical, high performance operation. Both full-size rooms and portable models. Cutoff frequencies up to 300 Hz. Uses include: sound testing of mechanical and electrical machinery, communications equipment, aircraft and automotive equipment, and business machines; noise studies of small electronic equipment, etc.



For more information, contact

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ECKEL INDUSTRIES, INC.

Canadian Acoustics / Acoustique canadienne, 1988, 16 (1): 29-36

A COMPUTER PROGRAM FOR THE CALCULATIONS IN THE CSA STANDARD Z107.56 "PROCEDURES FOR THE MEASUREMENT OF OCCUPATIONAL NOISE EXPOSURE"

By M. Kuindersma and A. Behar, P.Eng., CIH
Ontario Hydro
Pickering, Ontario

ABSTRACT

The CSA Standard Z107.56 "Procedures for the Measurements of Occupational Noise Exposure" comprises a main body and four Appendices. Appendix B deals with the measurement of noise exposure of groups of workers using statistical sampling methods. Some rather complicated mathematical treatments of the data are required. These calculations can be performed very easily using the computer program described in this paper. The program is menu driven and user friendly. It has been offered to CSA for distribution.

SOMMAIRE

Le Standard de la CSA Z107.56 "Methodes de Mesures de l'exposition au bruit en milieux de travail" comprend une section principale et quatre appendices. L'appendice B traite des mesures du bruit pour les groupes exposes par l'utilisation d'une methode d'echantillonage statistique. Ell exige des calculs mathematiques assez compliques. Ces calculs peuvent etre executes tres facilement par l'utilisation d'un programme sur ordinateur decrit dans cette communication. Le programme est dirige par menu et est facile d'utilisation. Il a ete offert a la CSA pour distribution.

1.0 INTRODUCTION

The CSA Standard Z107.56[1] was published in 1986. It is the first Standard published worldwide (as far as the authors know) that deals with the issue of noise exposure measurements. Because of this fact and because of its wide field of application, this is one of the most popular standards published by the Canadian Standard Association.

The Standard comprises one main body and four Appendices that address such issues as employee's involvement, calculation of different noise exposure indices and procedures for the use of the L_{OSHA} (the Standard is written in terms of $L_{eq,T}$).

Appendix B of the Standard deals specifically with the measurement of noise exposure of groups of workers. This is a very important subject for large industries, where it is very expensive to measure the exposure of every one of the exposed subjects. Instead, a statistical method is used where a sample is tested and the results are extrapolated over the whole population.

The starting point for the mathematical treatment of the data is the fact that the noise exposure data are normally distributed[2]. The Standard defines a Group as workers that are expected to have a similar noise exposure because of performing similar activities or being exposed to similar noise (e.g., in a large reverberant shop, almost every worker may have the same exposure, although several activities may be performed).

The objective of the measurement is to obtain the mean noise exposure level of the Group at the 95% confidence level, (L_{Trade}) and its Standard Deviation. With those data, a risk assessment can be performed by calculating the percentage of employees within the particular Group who have noise exposure levels exceeding a given criterion level (e.g., 85 dBA).

The procedure for the assessment is as follows:

1. The sample size is calculated to be statistically significant. This is done by either using existing tables[3] or, if the standard deviation of the population is known from previous measurements, by following a specific procedure outlined in the Standard.

2. The sample is surveyed for several days (generally one week). For each day the daily noise exposure level ($L_{eq,8}$) of each worker is calculated (using the elapsed time of the measurement and the dose) or read on the instrument (if it is a direct reading dosimeter).

3. The weekly noise exposure of each worker ($L_{eq,40}$) is calculated as the log sum of $L_{eq,8,i}$.

4. The mean noise exposure of the whole trade (L_{Trade}) is obtained as the arithmetic mean of the $L_{eq,40,i}$ from all workers within the sample. A subsequent calculation is used to obtain the upper 95% confidence limit for the L_{Trade}.

5. The percent of workers with noise exposure higher than a given level (e.g., 85 dBA) is calculated to assess the risk of the Group, also at the upper 95% confidence limit.

The above described mathematical treatment of data involves a substantial amount of calculation. Although these calculations are not complicated, they are tedious, time consuming and prone to errors.

This is why the computer program was developed. The requirements were that the program should be menu-driven and user friendly.

2.0 THE COMPUTER PROGRAM

This program was written in Microsoft QuickBASIC 3.0 on an IBM XT running IBM DOS 3.20. Required hardware is an IBM PC/XT/AT or compatible with 256K RAM and a single 360K floppy disk drive.

2.1 Calculations Included

The program performs several calculations on noise dosimetry data, as follows:

a) A single worker's $L_{eq,T}$,

b) A single worker's $L_{eq,40}$,

c) L_{Trade} for a number of workers,

d) Upper Confidence Limit of the L_{Trade},

e) Standard deviation of $L_{eq,40}$'s for a number of workers,

f) Percentage of the population with noise exposure above 85 dBA,

g) Upper Confidence Limit of the above,

h) The median $L_{eq,40}$,

i) The modal $L_{eq,40}$, and

j) The skew of the samples.

All statistics are calculated at the 95% significance level.

Data may be entered as:

a) Dose (in percent) and start and stop times,

b) Dose (in percent) and elapsed time only,

c) $L_{eq,8}$, or

d) $L_{eq,40}$.

The program can also handle $L_{eq,40}$'s from an ASCII format dump file, which may be created using any ASCII text editor.

2.2 Installation

It is recommended that the program be installed on a computer with a hard disk. This will allow greater data file storage capacity than a floppy disk based system. Also, data access is much faster from a hard disk; therefore, the program's calculations will be performed quicker on a hard disk based computer. The following steps are recommended for the installation:

1. Create a subdirectory called NOISE under the root directory.

2. Copy NOISE.EXE from the distribution diskette to C:\NOISE\NOISE.EXE.

The program will then be executable as follows:

1. Ensure that C:\NOISE is the current default directory.

2. Type NOISE <Enter>.

For those using the program on an IBM EGA or compatible display adapter, the program may be invoked with the /e option (for Enhanced). This option allows the computer to make full use of the EGA to produce high resolution graphics in full colour. Note that this option is available only on an EGA machine. Using the /e option on a CGA or Hercules machine will cause an error.

Any files the program produces will be found in the subdirectory C:\NOISE.

2.3 Using the Program

Program structure is outlined in Figure 1. Once the program is running, the user interacts with the various screen menus to select the desired actions.

The Main Menu lists the following options:

1. Enter Noise Dosimetry Data
2. Perform Statistical Analysis
3. Quit

Each option is described in the following sections.

2.3.1 Enter Noise Dosimetry Data

Noise dosimetry data may come in one of several forms:

1. Start and stop times and the accumulated dose for that time,
2. Elapsed sampling time and the accumulated dose for that time,
3. $L_{eq,8}$'s, and
4. $L_{eq,40}$'s.

The above four data types correspond to the options in the Data Entry menu:

1. Enter Start and Stop Times
2. Enter Elapsed Time
3. Enter/Edit $L_{eq,8}$ Data Directly
4. Enter/Edit $L_{eq,40}$ Data Directly
5. Return to Main Menu

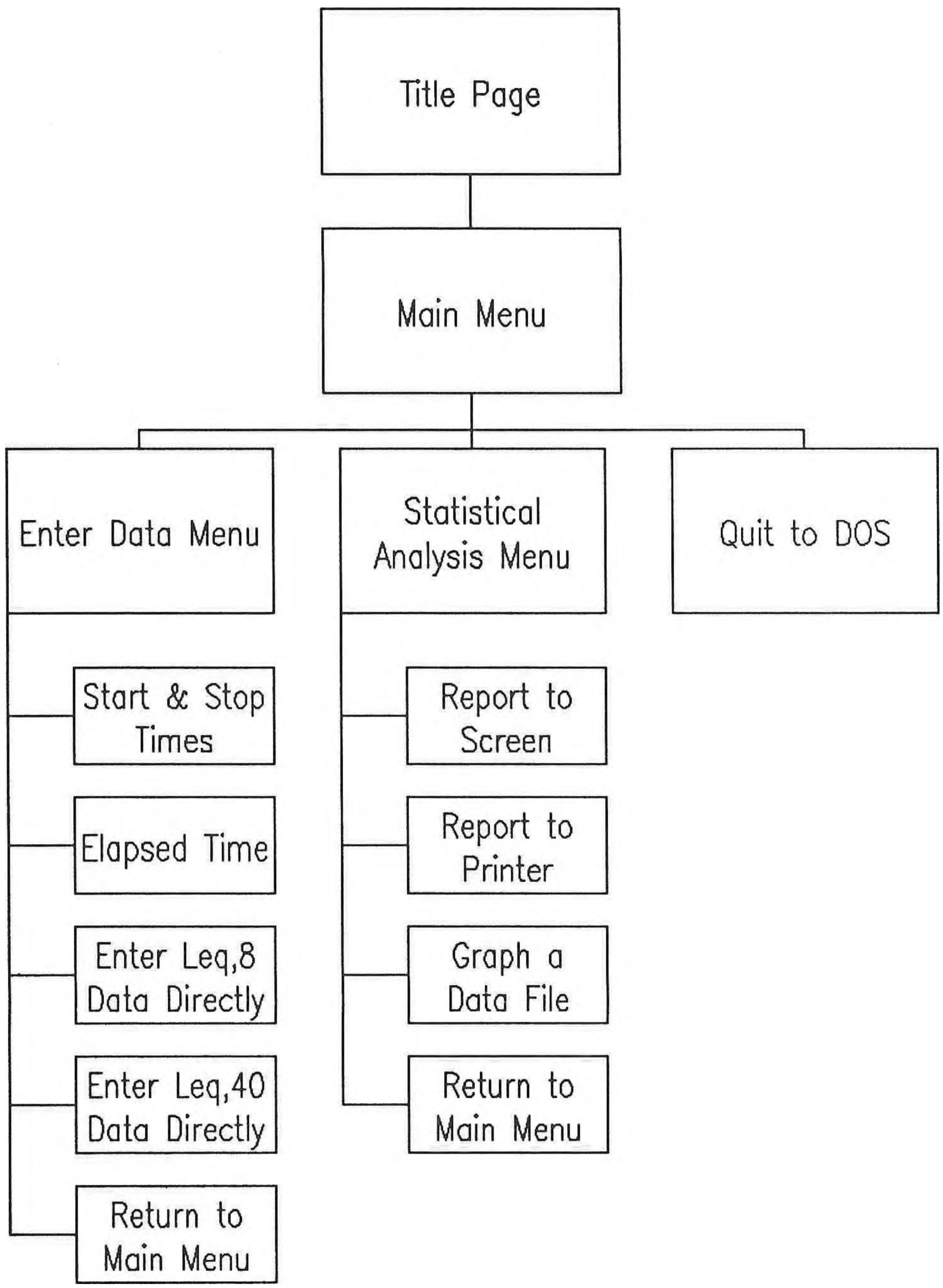
Noise dosimetry data consisting of times and doses may be referred to as raw data, since there have been no calculations performed on them. Usually, these data will be collected directly from the dosimeter.

$L_{eq,8}$ and $L_{eq,40}$ data are the results of calculations performed on raw dosimetry data, or may be obtained from previous reports.

Further calculations are usually performed on $L_{eq,40}$'s to generate the statistics (including L_{Trade}) which are included in reports.

FIGURE 1

Program Block Diagram



2.3.1.1 Entry of Raw Dosimetry Data

Entry of raw dosimetry data consists of performing the following steps:

1. Select the desired option from the menu.
2. Enter a file name for this set of data.
3. Enter the data. (Usually several sets of data are entered for each worker.)
4. Calculate the $L_{eq,40}$ for this worker, and save the data and the $L_{eq,40}$ to file.
5. Continue to the next worker, or quit when all the data have been entered.

2.3.1.2 Entry of $L_{eq,40}$ Data

The direct entry of $L_{eq,8}$ or $L_{eq,40}$ data consists of performing the following steps:

1. Select the desired option from the menu.
2. Enter a file name for this set of data.
3. Enter the $L_{eq,8}$'s of $L_{eq,40}$'s.
4. Quit when all the data have been entered.

2.3.2 Processing Data

The Statistical Analysis menu lists the following options:

1. Analyze Data
2. Graph Data
3. Return to Main Menu

The first option above, Analyze Data, calculates the statistics listed in Section 2.1.

The second option above, Graph Data, may be used to visualize the distribution of the data. Such a graph may indicate the presence of outliers or other significant information.

3.0 STATUS OF THE PROGRAM

The program has been in use in Ontario Hydro for some time. There it has proven to be a much needed, user friendly, time saving device.

The program was offered to the Canadian Standard Organization to be used as a support for the Standard. If requested, the program will be expanded further to accommodate the rest of the formulas from the rest of the Appendices.

4.0 REFERENCES

1. CAN/CSA Z107.56-M86 "Procedures for the Measurements of Occupational Noise Exposure", Canadian Standard Association, 1986.

2. Behar, A. and Plener, R. "Noise Exposure - Sampling Strategy and Risk Assessment," American Industrial Hygiene Association J.45(2):105-109, 1984.

3. Leidel, N.A., Busch, K.A. and Lynch, J.R. "Occupational Exposure Sampling Strategy Manual", NIOSH publication 77-173, Cincinnati, Ohio, USA, 1977.

THE CANADIAN ACOUSTICAL ASSOCIATION
L'ASSOCIATION CANADIENNE DE L'ACOUSTIQUE

Acoustical Week 1988 / La semaine de l'Acoustique 1988 **(3-7 Oct.)**

Newsletter from the TECHNICAL PROGRAM chairman
Lettre circulaire du président du programme technique

Abstracts should be submitted before **June 1, 1988**

Les résumés doivent être soumis avant le **1 juin 1988**

Full papers should be submitted before **August 15, 1988**

Les manuscrits devront être soumis avant le **15 août 1988**

All papers that will be approved for presentation will be published

Toutes les communications dont la présentation aura été approuvée seront publiés

The organisation of the Technical Sessions is in full swing. Here is the directory of the chairpersons to whom you should submit your papers:

Directory of Chairpersons / Annuaire des président-e-s de session

Industrial Noise and Technical program co-chairperson	Tim Kelsall Hatch Associate Ltd 21 St Clair E Toronto, Ont M4T 1L9	962-6350
Auditory Neurophysiology	Dr Robert Harrison Department of Otolaryngology Hospital for Sick Children 555 University Ave Toronto, Ont M5G 1X8	598-6535
Mechnical Vibrations	Mohan Barman Barman, Swalow Assoc. 1 Greensboro Dr. Rexdale, Ont M9W 1C8	245-7501

Hearing Conservation	Marilyn Pike MDS Health Group Ltd 100 International Blvd Etobicoke, Ont M9W 6J6	481-6312
Transportation Noise	Soren Pederson Highway Design Office Ministry of Transportation 1201 Wilson Ave, West Bldg Downsview, Ont M3M 1J8	235-3509
Environmental Noise	Leslie Kende Ministry of Environment 135 St Clair Ave W Toronto, Ont M4V 1P5	323-4458
Building Acoustics	John Hemingway Vibron Ltd 1720 Meyerside Dr Missisauga, Ont L5T 1A3	675-3983
Hearing Protection	Stan Forshaw DCIEM 1133 Sheppard Ave W P.O. Box 2000 Downsview, Ont M3M 3B9	635-2046
Clinical management of the hearing impaired	Crista Rico Mount Sinai Hospital, Room 201 55 University Ave Toronto, Ont M5G 1X5	586-5018
Legislation	Dr Shal Gewurtz Ministry of Labour 9th Floor 400 University Ave Toronto, Ont M7A 1T7	965-8710

The duration of the papers presentation has been limited to 20 minutes including any discussion. In such a way we Will have up to 8 papers per session.

Here is the intended schedule for the Technical Sessions

SCHEDULE

Session 1: Thurdsay Morning (Oct. 6)

- Auditory Neurophysiology
- Industrial Noise
- Transportation Noise
- Legislation

Session 2: Thursday Afternoon

- Mechanical vibration
- Hearing conservation
- Environmental noise

Session 3: Friday Monrning (Oct. 7)

- Building acoustics
- Hearing protection
- Clinical management of the hearing impaired

TIMING

Mornings (Oct. 6 and 7)

9.00	paper
9.20	paper
9.40	paper
10.00	coffee
10.20	paper
10.40	paper
11.00	paper
11.20	paper
11.40	paper

Afternoon (Oct. 6)

13.30	paper
13.50	paper
14.10	paper
14.30	coffee
14.50	paper
15.10	paper
15.30	paper
15.50	paper
16.10	paper

As you can see, thigs are looking great. There is a lot of enthusiasm out there and I hope that you will be able to share it with us either by present ing your paper or by attending our sesions. I will keep in touch with you, filling you with all the news.

Alberto Behar
Technical Program Chairman
Ontario Hydro
757 McKay Rd
Pickering, Ont L1W 3C8
(416) 683-7516

RESEARCH POSITION IN APPLIED PSYCHOACOUSTICS

Groupe d'acoustique de l'université de Montréal (GAUM)
Ecole d'orthophonie et d'audiologie
Université de Montréal
Montréal, Québec

GAUM is a research unit devoted to the study of the effects of noise on people, especially in the context of occupational health and safety

A full time research position will be open in July 1988. The researcher will be expected to conduct projects in acoustic warning signal perception, speech communication in noise, hearing damage risk.

Applicants should have some knowledge of French and be willing to integrate into this francophone milieu.

Candidates should sent a curriculum vitae to

Prof. Raymond Hétu
Directeur
GAUM
C.P. 6128
Montréal, Qc H3C 3J7
Tel.: (514) 343-7559

POSTE DE CHERCHEUR-E EN PSYCHOACOUSTIQUE APPLIQUEE

Groupe d'acoustique de l'université de Montréal (GAUM)
Ecole d'orthophonie et d'audiologie
Université de Montréal
Montréal, Québec

Le GAUM est un groupe de recherche dédié à l'étude des effets du bruit sur les êtres humains, en particulier dans le contexte de la santé et de la sécurité du travail

Un poste à temps complet sera ouvert à compter de juillet 1988. Le-la chercheur-e devra mener des projets concernant la perception des avertisseurs sonores, la communication verbale dans le bruit et le risque d'atteinte auditive.

Les candidat-e-s doivent faire parvenir leur curriculum vitae au

Prof. Raymond Hétu
Directeur
GAUM
C.P. 6128
Montréal, Qc H3C 3J7
Tel.: (514) 343-7559

NEWS / INFORMATIONS

Seminars and courses / Séminaires et cours

Noise Control Seminar. Offered by I.N.C.E.: computational methods for the solution of environmental noise control problems . June 18-19, 1988 West Laffayette, Ind. (Prior to NOISE-CON88). Contact I.N.C.E., P.O. Box 3206, Arlington Branch, Poughkeepsie, N.Y. 12603 [tel.: (914) 462-6719]

Speech Spectrogram Reading: an Acoustic Study of English Words and Sentences. Massachusetts Institute of Technology, July 18-22, 1988 (summer session program 6.67s). Contact Office of the Summer Session, 50 Ames, Room E19-356, Massachusetts Institute of Technology, Cambridge, MA 02139 [tel.: (617) 253-2101]

4th Spring School on Acousto-Optics and its Applications. Gdansk, Poland, 23-27 May 1989. Contact Prof. A. Sliwinski, Institute of Experimental Physics, University of Gdansk, Wita Stwosza 57, 80 952 Gdansk, Poland.

Conferences / Congrès

1988 Spring Conference - ACOUSTICS '88, University of Cambridge, U.K. (Prof. J.E. Ffowcs Williams, University of Cambridge) 5-8 April 1988

SPEECH TECH '88, New York Hilton, 1335 Avenue of the Americas, N.Y. 26-28 April 1988

New Sources & Problems in Urban Transportation Noise, Society of Chemical Industry, Belgrave Square, London (R.N. Galbraith, Sandy Brown Associates, 1 Coleridge Gardens, London NW6 3QH; tel. 01-624-6033) 23 May 1988

Acoustical Society of America , Seattle, WA , 16-20 May 1988

NVC 88 - 2nd International Noise & Vibration Control Conference (The Confernce Committee NVC88, The Trade and Technical Press Ltd, 13/15 Creek Road, East Molesley, Surrey KT8 9BE, Endgland) 9-10 June 1988

5th International Congress on Noise as a Public Health Problem, Stockholm, (Noise '88, c/o Reso Congress Service, S-11392 Stockholm, Sweden) 21-25 August 1988

7th FASE Symposium on Speech, Edinburgh, U.K. (Mrs. Cathy Mackenzie, Institute of Acoustics, 25 Chamber Street, Edinburgh, U.K.) 22-26 August 1988

INTERNOISE '88, Avignon, France (Prof. C. Carles, Conservatoire National des Arts et Métiers, 292, rue St-Martin, 75141 Paris, France) August 30th-September 1st 1988

Conference on Optical, Electrical and Acoustic Properties of Polymers, London, U.K. (Plastics and Rubber Institute, Conference Office, 11 Hobart Place, London SW1W OHL, U.K.) 5-7 September 1988

IEEE Ultrasonics Symposium, Chicago, IL (University of Illinois, Bioacoustics Research Lab., Urbana, Il 61801) 3-10 October 1988

Acoustics Week 1988, Toronto, Ontario (A. Behar, Ontario Hydro, 757 McKay Rd, Pickering, Ont. L1W 3C8; tel.: (416) 683-7516) 3-7 October 1988

2nd Joint Meeting of the Acoustical Societies of America and Japan, Honolulu, HI, 14-18 November 1988

Polmet '88, Asia and Pacific Regional Conference: Pollution in the Urban Environment, Hong Kong (Polmet '88 Secretariat, c/o Hong Kong Institution of Engineers, 9/F., Island Centre, No. 1, Great George Street, Causeway Bay, Hong Kong) 28 November - 2 December 1988

International Conference on Acoustics, Speech and Signal Processing, Glasgow, U.K. (Institue of Electrical and Electronics Engineers, Conference Coordination, 345 E 47th St., New York, NY 10017) 25-29 April 1989

New Standards / Nouvelles normes

Mechanical coupler for the measurement of bone vibrators. ANSI S3.13 - 1987. Price: $20. Contact phone: (516) 349-7800

Methods for determination of insertion loss of outdoor noise barriers . ANSI S12.8 - 1987. Price: $44. Contact the above phone number

1988 ASTM Standards Catalog, 1988 ASTM Directory of Testing Laboratories. Contact: Mrs Nolden, ASTM, 1916 Race St., Philadelphia, PA 19103; tel.: (215) 299-5594

Transcipts of ASTM Community Noise Workshop (Committee E-33) held in Bal Harbor, FL, October 27, 1987, now available.

Document

Guideline for Regulatory Control of Occupational Noise Exposure and Hearing Conservation. Part I - Model Regulation / Lignes directrices visant la règlementation de l'exposition au bruit et la protection de l'ouïe dans les milieux de travail. Partie I - Modèle de règlement.

Available upon request at / Disponible sur demande à:

Communication Directorate,

Department of National Health and Welfare,

5th floor, Brook Claxton Bldg., Ottawa, On K1A 0K9

or at / ou à:

Deirdre A. Benwell

Non-Ionizing Radiation Section

Health and Welfare Canada

Rm. 233, EHC, Tunney's Pasture

Ottawa, On K1A 0L2

From another journal in acoustics... / D'un autre périodique en acoustique...

BULLETIN D'ACOUSTIQUE

The "Bulletin d'Acoustique" is a new half-yearly scientific review published by the Applied Acoustics and Electroacoustics Department of the University of Liège. It is composed of articles describing the applied and fundamental research activities carried out by the scientific staff of this laboratory.

The subjects treated in the review are covering the following topics :

- Industrial Acoustics
- Urban Acoustics
- Rooms and Theaters'Acoustics
- Noise Control
- Electroacoustics
- Speech Signal processing

Additional information is available at the following address :

Université de Liège
Service d'Acoustique Appliquée
Sart-Tilman (Bât. B28)
B- 4000 LIEGE

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Table of Contents (second issue - june 1987)

ABSTRACTS

TEMPORARY ARRANGING OF THE PALACE 7 OF THE 'PARC DES EXPOSITIONS' OF BRUSSELS FOR THE EUROVISION SONG CONTEST 87.

by T.VO THANH

To organise the Eurovision Song Contest 87 ,the R.T.B.F. has decided to build the auditorium into the Palace 7 of the " Parc des Expositions" of Brussels. This paper describes the acoustical solutions adopted in order to insulate the auditorium from the adjoining rooms and from the outside world,to reduce the noise emitted by the technical equipment and to create an acoustics which sounds like that of a TV studio. The whole work has been planned and performed with limited means and within a very short time allowed.

THE ACCURACY OF A SIMULATION PROGRAM USING THE SOUND RAY TECHNIQUE.

by J.J.EMBRECHTS

This paper analyses the accuracy of the sound ray method developped and used in the Department of Acoustics of the University of Liège. The work begins with a short description of the technique. Three kinds of errors in the predictions of sound levels are then identified and investigated each separately : the truncation error,the statistical error and the modelisation error. It is shown that the two first kinds of errors are under operator's control whereas the third one is the most responsible for the discrepancies observed between measured and computed sound levels. In particular,the definition of absorption coefficients is drastically important.

MINUTES OF CANADIAN ACOUSTICAL ASSOCIATION ANNUAL MEETING

The meeting was called to order at 4:35 pm on October 8, 1987 at the Sandman Hotel, Pipeliner room, Calgary, Alberta. Thirty-one members were present.

(1) Introductory Remarks — Sharon Abel, President

Welcome to the meeting.

(2) Minutes of 1986 Annual Meeting — Sharon Abel

The Minutes of 1986 Annual Meeting were published in Volume 14(4) of Canadian Acoustics.

MOTION: That the Minutes of 1986 meeting be accepted as printed.

MOVED: D. Benwell SECONDED: T. Northwood CARRIED

(3) Business Arising — Sharon Abel

- Board of Directors Meeting in Toronto, November 14, 1986:

Canadian Acoustics: Raymond Hetu became Acting Editor after John Bradley asked to step down.

Prizes and Awards: Two Directors Awards (each $500.00) for best papers published by a professional and a student members of the association and three prizes for best annual meeting presentations by students (each $500.00) were approved.

- Membership to NCSES (The National Consortium of Scientific and Educational Societies): CAA has become a member and John Bradley is the liaison officer.

- INCE (International): It was agreed that Tony Embleton will be CAA representative and Hugh Jones his alternate. A report from Tony Embleton on the recent INCE meeting in Beijing China was submitted and read by David Quirt.

- NBC (National Building Code): David Quirt gave an update on activities related to the 1990 revision of this code. It seems that an STC (Sound Transmission Class) of 50 and an impact test may be included.

(4) Officers' Reports

Secretary (Moustafa Osman): Change of CAA mailing address and other secretarial activities (e.g. Renewals and issue of official receipts). Some of the free services that were offered in Ottawa cannot be maintained in Toronto (i.e. secretarial help).

The Secretary will provide JASA (Journal of the Acoustical Society of America) with an annual summary on CAA activities for publication in that journal.

ACTION: Secretary

MOTION: That the Executive Secretary be allocated a budget not exceeding $1,000.00 for the purpose of reimbursement for secretarial assistance in 1988.

MOVED: D. Benwell SECONDED: J. Hemingway CARRIED

MOTION: That the Executive Secretary be empowered to issue official receipts for annual dues.

MOVED: B. Dunn SECONDED: T. Kelsall CARRIED

MOTION: That the annual dues for members and subscribers be raised to $20.00 per annum for the two-year period January 1988 to December 1989. For the same period the student membership will remain $5.00 per annum, and the sustaining subscriptions will be the same, $100.00 per annum.

MOVED: G. Faulkner SECONDED: E. Bolstad CARRIED

(Note: The members will have a chance to vote on the 1989 dues again in 1988 at the Annual Meeting in Toronto.)

Membership (Annabel Cohen): Activities included posters, flyers and an audio visual presentation. New people have joined but others left. The total membership (approximately 400) is about the same. Other groups with interest in Acoustics will be approached.

MOTION: That the membership chairman be allocated $3,000.00 for the period January 1988 to December 1989 for the purpose of advertising of CAA activities.

MOVED: W. Sydenborgh SECONDED: B. Dunn CARRIED

Treasurer (Claudia Bulfore): Summary of financial status during 1986/1987 including major expenses and income, Status as charitable organization and need for services of an accountant. The submitted financial statement has been audited by Douglas J. Whicker - Attached.

MOTION: That the Statement of Receipts and Disbursements for the period September 1, 1986 to August 31, 1987 be accepted.

MOVED: C. Sherry SECONDED: J. Hemingway CARRIED

MOTION: That the Treasurer be allocated a budget not exceeding $500.00 per annum for the purpose of reimbursement for services of an accountant.

MOVED: R. Hetu SECONDED: C. Sherry CARRIED

Acting Editor (Raymond Hetu): Need for articles and material for publication in the journal. Possible improvements including word processing and glossy cover.

MOTION: That the editor of Canadian Acoustics be allocated a budget of $2,000.00 per issue to cover editorial costs.

MOVED: C. Sherry SECONDED: M. Hodgson CARRIED

(5) Report of Chairman for CAA 1987 Peter Vermeulen

Number of registrants was 51. Some banquet tickets were still available. Possibly a balanced budget. Some workshops were more successful than others.

(6) Report of Chairman for CAA 1988 Winston Sydenborgh

The venue has been changed from Halifax to Toronto (see below). The location will be the Loews Westbury Hotel and the date will be October 3 to 7, 1988. Special room rate has been agreed on with the hotel.

MOTION: That the Chairmen of CAA 1988 be allocated on budget of $1500.00 seed money to be used towards arrangements for the annual meeting.

MOVED: G. Faulkner SECONDED: J. Hemingway CARRIED

Meeting of ISO TC 43, TC 43 SC1 and IEC TC29 (Toronto or Ottawa) and ASTM E33 (Toronto 1988)

Dee Benwell and
Cameron Sherry

These meetings are scheduled for October 1988 in Ontario. A good opportunity to contact other international acousticians. Acoustics Week '88 will be in Toronto instead of Halifax to permit Canadian acousticians to communicate with other international experts who will attend these two meetings during the period October 3 to 14, 1988.

MOTION: That the CAA provide Dee Benwell Chairman of the Joint Hosting Committee with $5000.00 to be spent towards hosting the 1988 meeting of ISO TC 43, TC 43 SCI and IEC TC 29 in Ontario.

MOVED: T. Northwood Seconded: E. Shaw CARRIED

(7) Report of the President of the 12th ICA — Edgar Shaw

A report on 12th ICA activities and associated meetings. Some statistics on Canadian participation by area or field of specialization. An unaudited financial statement dated September 17, 1987. Thanks to all members of the 12th ICA Steering Committee. A copy of a cheque for $22,913.27 presented to the President, Sharon Abel.

The accounting services of J. Ayers were acknowledged. A token present and a certificate will be given to him.

The President of the CAA announced the creation of the post - doctoral CAA Edgar and Millicent Shaw Prize in Acoustics and other prizes on speech. Details of the award and prizes will be worked out later.

STANDING OVATION and speech from Mrs. M. Shaw.

MOTION: That the CAA Board of Directors be authorized to discharge the 12th ICA Executive Committee as soon as the Committee is able to provide the Board with an audited Financial Statement with suitable explanatory notes.

MOVED: C. Sherry SECONDED: T. Kelsall CARRIED BY ACCLAMATION

(8) CAA 1987 Directors' Awards — Sharon Abel

The winners of the 1987 Directors' Awards were:

M. Hodgson and C. Laroche. The awards were presented to M. Hodgson and to R. Hetu (on behalf of C. Laroche).

(9) Report of Nominating Committee — Cameron Sherry

The CAA officers slate was presented and accepted by the members for a one year period:

Sharon Abel	President
Moustafa Osman	Executive Secretary
Chris Andrew	Treasurer
Annabel Cohen	Membership
Raymond Hetu	Editor

Two directors positions became vacant, the departing directors are J. Leggat and P. Vermeulen. Three names were proposed by the Past President: A. Cohen, B. Dunn and A. Behar. There was no nomination from the floor. Ballots were distributed and a vote took place.

The two new directors were announced after counting the votes: A. Cohen and B. Dunn. The ballots were destroyed.

(1) Other Business

The French name of the Association should be Association Canadienne d'Acoustique. Jean G. Migneron

The change was accepted and will be implemented.

ACTION: Editor/Secretary

Long range planning for expenses and direction is needed.
John Hemingway

The President will introduce the matter in the next Board of Directors Meeting.

ACTION: President

Meeting adjourned at 6:12 pm.

Prepared by: M.M. Osman - CAA Secretary

THE CANADIAN ACOUSTICAL ASSOCIATION

L'ASSOCIATION CANADIENNE DE L'ACOUSTIQUE

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DUE FEBRUARY 15, 1988

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15 FEVRIER 1988

Check ONE Item Only / Cocher la case appropriée

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PRESIDENT / PRESIDENT

Sharon Abel (416) 586-8278
Mt. Sinai Hospital, Suite 843
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SECRETARY / SECRETAIRE

Moustafa Osman (416) 592-4988
Ontario Hydro
700 University Avenue
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Chris Andrew (403) 268-1621
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P.O. Box 2100
Calgary, Alberta, T2P 2M5

MEMBERSHIP / RECRUTEMENT

Annabel Cohen (902) 424-8888
Department of Psychology
Dalhousie University
Halifax, Nova Scotia, B3H 3J5

EDITOR / REDACTEUR

Raymond Hétu (514) 343-7559
Groupe d'acoustique
de l'université de Montréal
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