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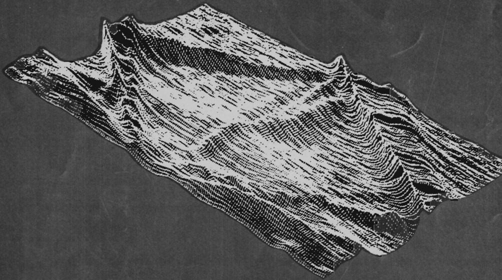

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Australian Acoustical Society

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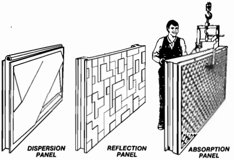
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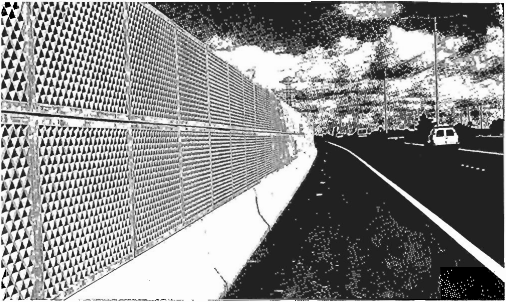

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COVER :

The image reproduced on the cover shows a frequency-wavenumber power spectrum for underwater acoustic data obtained from an experimental line array of hydrophones. Rather than applying conventional spatial filtering methods, the spectrum is calculated using an adaptive beamforming technique that maximizes the array gain thereby reducing the spatial leakage, improving the spatial resolution and enhancing the superdirectivity of the array. Readily identifiable features are the array's self-noise propagating fore and aft along the array and the tow vessel's radiated noise; direct path propagation and boundary reflections (multipaths) are present. Also, spatial aliasing is evident and occurs because the underwater acoustic pressure field is spatially undersampled at the higher frequencies. The image is submitted by Brian Ferguson, Gary Speechley and Lionel Criswick of the Australian Defence Science and Technology Organisation.

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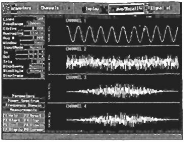

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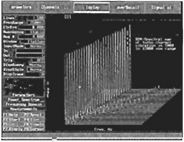

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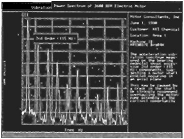

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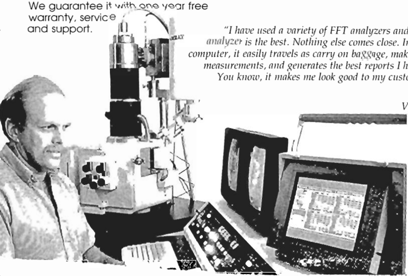

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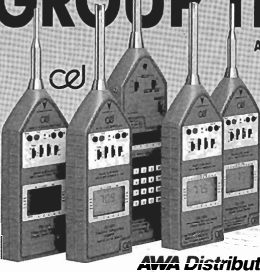

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FROM THE PRESIDENT

Council has elected me President again, which means that either 1992 went well or there was no one else around. Indeed 1992 did go well financially as well as technically. As a consequence, the Federal levy on Divisions has been reduced significantly, and so Divisions will be in a healthier position.

The 1992 Annual General Meeting had the longest list of business items of recent times. Five special matters of business were considered.

The most significant concerned a proposal to adopt a Code of Ethics. During 1992 a draft code had been circulated to Divisions and published in Acoustics Australia, with invitations to comment. A revised code, incorporating as best as possible the comment received, was included in the A.G.M. business papers. The meeting approved the proposal, 57 to 3. Hence the Code of Ethics, as it appeared in the A.G.M. papers, comes into effect immediately.

A proposal to amend the Articles of Association in such a way as to simplify the procedure for appointing a General Secretary was carried without dissent.

Council had decided in 1991, when funds were 'a bit tight', to seek the views of Society members on a proposal to join the Australian Foundation for Science. We receive many requests to join various groups and bodies, all of these of course involving payment of subscription fees. The background to this proposal was set out in detail in the business papers. The proposal was carried 39 to 22.

Two further resolutions, instructing Council to prepare changes to the Articles of Association, were carried. One is to set the Annual Subscription for a bone fide student at $20.00, with some consequential changes, and the other is to change the title of Affiliate grade to Associate grade. Refer back to your A.G.M. papers for more detail.

There were two other informal but nonetheless vital items of business. Glowing and well-deserved tributes were paid to Howard Pollard and Ray Piesse. Ray has resigned from the position of Acting General Secretary, having tried unsuccessfully to leave the position of General Secretary twelve months ago. Howard is relinquishing the position of Chief Editor for Acoustics Australia after the April issue is 'put to bed'. Both Ray and Howard have given long and dedicated service, and the Society is deeply indebted to them. Warm votes of appreciation were carried with sustained acclamation.

Robert J Hooker

EDITORIAL

This issue is my final one as Chief Editor. For nearly 12 years it has been a matter of great interest and satisfaction for me to spearhead the efforts of an enthusiastic team of editors and assistants in our endeavour to develop a quality journal for the Society. It is time now to hand over the reins to a new editorial team in Canberra which includes Neville Fletcher as Chief Editor, Marion Burgess, Joseph Lai and Leigh Kenna.

I would like to make special mention of the willing and efficient contributions made by Marion Burgess who has been Associate Editor throughout my term of office. Also, the skill and advice of Fred and Scott Williams of Cronulla Printing Company has been a major factor over the years in maintaining the quality and style of the journal.

Judging by the articles submitted to Acoustics Australia in recent years the state of acoustics in Australia is decidedly healthy. A good sign is the increasing number of unsolicited articles now received. The same phenomenon is beginning to appear with the advertising which has been very quiet for a number of years. A steady increase in the number of advertisers will bring the day closer when Acoustics Australia will become self-supporting.

In conclusion, may I wish the new team every success in their continuing efforts to advance the cause of acoustics.

Howard Pollard

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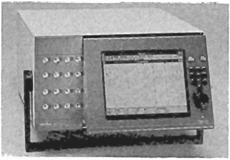

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An Introduction To Cohen's Class Of Time-Frequency Distributions

M.J.Harrap and Z.L.Zhuang
Acoustics and Vibration Centre
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Australian Defence Force Academy

Abstract: Time-frequency distributions describe the evolution of a signal's energy in both frequency and time. This paper describes one generic class of time frequency distribution known as Cohen's Class. Better known members of this class include the Spectrogram and Wigner Distributions. Several distributions in this class are compared. The relationship between the properties of these distributions and the shape of their Kernel functions is explained. A portion of a speech waveform is used to illustrate the performance of these distributions.

1. INTRODUCTION

A time-frequency distribution describes the evolution of a signal's energy in both frequency and time. Perhaps the most common time-frequency representation is a musical score (Figure 1), in which frequency (pitch) is represented by the vertical position of notes on a staff and time (duration) is given by the symbol used to represent the notes, (quavers, minims etc.). The loudness (signal amplitude) of a given passage is usually described by a combination of symbols and Italian annotations above and below the staff.

Figure 1. An early time-frequency representation - a music score for the piano by Mozart.

Time-frequency distributions find application in the analysis of signals whose frequency content is time varying, i.e. (statistically) non-stationary signals. The transient sound pressure due to an impulsive noise source is an example of a non-stationary signal, as is the sound generated by an overflying aircraft measured by a ground observer.

Whereas a simple frequency (spectral) analysis will show the way in which the energy content of a signal is distributed in frequency, a time-frequency analysis shows how the frequency spectrum evolves in time. Applications of time frequency analysis include speech recognition (spectrograph), sonar (sonargraph), seismology and vibration analysis.

The spectrogram (or Short Time Fourier Transform[1]) is a commonly used method of time frequency analysis. Other methods include Wavelet Transforms[2] and parametric techniques such as ARMA modelling with time dependent coefficients[3].

This article will consider the application of a generic class of Time-Frequency Distributions to the analysis of non-stationary signals.The generic equation describing this class of distributions is attributed to Cohen[4]. Accordingly, this is referred to as 'Cohen's Class' in this article. First the concept of time-frequency analysis will be discussed and then the physical basis and desirable features of time frequency distributions will be reviewed. The performances of three distributions in analysing a voiced speech signal are then compared.

2. THE TIME-FREQUENCY CONCEPT

To illustrate the concept of a time frequency distribution, consider the 'chirp' signal shown in Figure 2a. This is simply a sinusoid whose frequency is increased linearly with time. The energy spectral density of this signal (Figure 2b) shows that its energy is spread over a range of frequencies as expected. Although the energy spectrum shows the *overall* energy content of the signal at a given frequency, it does not reveal the variation of the signal's frequency content with time. We can solve this problem by slicing the signal into a series of segments. The ends of each segment are then tapered using an appropriate time window to reduce spectral 'leakage' in the frequency domain and finally the energy spectra of the individual segments are arranged in time-order to form a spectrogram (Figure 2c).

The spectrogram is not perfect in that it shows the signal's energy is spread over a broad peak of width ~50 Hz at each of the times shown in Figure 2c. Ideally this peak should have zero width (an impulse function) showing energy exists at only a single frequency at any instant. The broadness of the peaks shown in Figure 2c cannot be attributed to the frequency resolution of the calculation method, Discrete Fourier Transform (DFT), which in this case is of order 10 Hz. Instead, this effect is caused by the variation of the signal's frequency *during* each of the time-slices. This problem cannot be overcome by reducing the length of each time-slice because this in turn reduces the frequency resolution of the calculated energy spectra. (The frequency resolution of the DFT varies inversely with the record length.)

The spectrogram is but one member of Cohen's class of time frequency distributions. We shall see that other members of this class allow us to make different sorts of trade-offs between resolution in time and frequency and distortion-like energy terms known as 'interference'. This general class of distributions is now discussed.

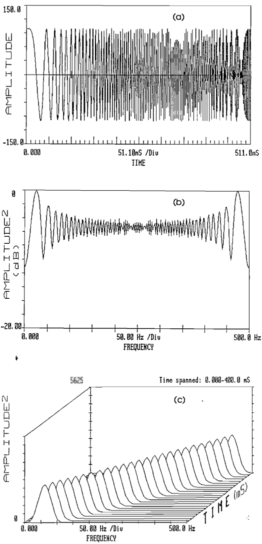


Figure 2. (a) The chirp signal - a sinusoid with linearly increasing frequency in time. Start frequency 0 Hz: end frequency 500 Hz; sampling rate 1 kHz.
(b) Chirp energy spectrum. 512 point DFT, rectangular window.
(c) Spectrograph - DFT's of thirty-two Hanning-weighted segments of the chirp signal. Each 128 ms segment overlaps its predecessor by 112ms. DFT's are arranged in time order.

3. COHEN'S CLASS OF TIME-FREQUENCY DISTRIBUTIONS

The mathematical formulation of a generic class of time frequency distributions was first identified by Cohen in 1966 and is described in reference 4. The spectrogram and Wigner Ville Distribution[5-I] are the better known members of this class and both can be derived from Cohen's generic formulation.

Cohen's generic equation can be re-written in a form in which the time-frequency distribution $C_X(t,\omega,\phi)$ of a signal $x(t)$ at time t and frequency ω is expressed as the Fourier Transform (F) of a weighted and time localized auto-correlation-like function, $R(\tau)$:

$$C_X(t,\omega,\phi) = F(R(\tau)), \qquad (1)$$

where $$R(\tau) = \int_{-\infty}^{\infty} x\left(t' + \frac{\tau}{2}\right).x^*\left(t' - \frac{\tau}{2}\right).\phi\left((t-t'),\tau\right)\,dt'.$$

The Kernel function $\phi(t',\tau)$ is a function of the dummy time variable t' and time lag variable τ. The correlation function $R(\tau)$ is formed by convolving the kernel with the 'instantaneous correlation'

$$x\left(t' + \frac{\tau}{2}\right)x^*\left(t' - \frac{\tau}{2}\right)$$

(see Figure 3).

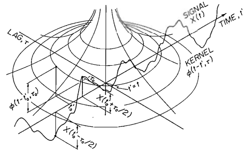


Figure 3. Construction of the correlation function $R(\tau)$ *from the signal* $x(t)$ *and kernel function* $\phi(t',\tau)$*. The kernel function* $\phi(t',\tau)$ *centred on* $t' = t$ *serves to localize and weight the correlation function. At each lag* τ*, the function* $R(\tau)$ *is formed by integrating the product of the kernel function* $\phi(t',\tau)$ *and the instantaneous correlation.* $x\left(t'+\frac{\tau}{2}\right)x^*\left(t'-\frac{\tau}{2}\right)$ *The kernel effectively weights the integral of the instantaneous correlation according to its cross section at the lag of interest.*

By repeating this convolution for a range of time lags $-\infty \le \tau \le \infty$, we build up a picture of the time localized correlation function $R(\tau)$. We then Fourier Transform this function to convert it into an energy spectrum[13] . This calculation is repeated at each time of interest. In this way, a series of energy spectra are produced. These spectra are then arranged in time order to form a time-frequency distribution.

The kernel function clearly plays a key role in determining the properties of the time frequency distribution. In the next section, the properties of three time frequency distributions are related to the shapes of their kernels.

4. KEY FEATURES OF TIME-FREQUENCY DISTRIBUTIONS.

In an excellent paper[5-II] Claasen and Mecklenbrauker discuss nine desirable properties of time frequency distributions. Each of these properties is shown to constrain the kernel function in a different way. It is also shown that no one kernel function can satisfy all of these constraints simultaneously. For this reason, there is no 'best' distribution. Instead different distributions will have their forte in different circumstances and we must choose the distribution appropriate to the task in hand. This is akin to the choice of a time window function in Fourier analysis.

In this section several key properties of time frequency distributions are discussed and three distributions are compared - the Spectrogram, Wigner Distribution and a 'Cone-Kernel' Distribution. We shall conclude this section with a discussion of unwanted interference terms that may appear in time-frequency distributions due to the inherent non-linearity of the generic equation (1).

4.1. Properties

Five desirable properties of Time-Frequency Distributions are now discussed. The corresponding constraints placed on kernel functions are given where possible. These constraints have been derived by the authors and are based on an equivalent set of constraints presented by Claasen and Mecklenbrauker[5-II]· (The latter relate to kernel functions in the time-frequency domain rather than the time-lag domain.) The kernel constraints derived by the authors of this article are illustrated in Figure 4c.

Property P1 - Distribution frequency integrals: If a distribution genuinely shows the development of signal's instantaneous energy spectrum with time, we would expect its integral at a particular time over all frequencies should give the signal's instantaneous energy $|x(t)|^2$.
Constraint: *Kernel is an impulse function* $\delta(t',\tau)$ *at the origin.*

Property P2 - Distribution time integral: By symmetry with property P1, we would expect the integral of the distribution at a particular frequency ω over all time would equate to the signal's energy spectrum $|X(\omega)|^2$ at that frequency. This is consistent with the concept that at a given frequency, the distribution should show the time variation of the energy in the signal at that frequency.
Constraint: *Any section through Kernel normal to the lag axis* τ *must have unit area.*

Property P3 - Distribution type: In addition to the above properties we would expect an energy distribution to be real valued rather than complex valued, given that 'energy' in the sense used here ($|x(t)|^2$) is necessarily real valued and positive (see P5).
Constraint: *Kernel real and even in time t' and lag* τ.

Property P4. Finite time support: It is desirable that a distribution should be zero from the instant the signal $x(t)$ falls to zero and at all times before its first commences. A corresponding property known as finite frequency support is also desirable.
Constraint: *Kernel must be zero where* $|t'| > |\tau/2|$.

Property P5. Positivity: The final property we shall consider is that an energy distribution should always be positive. However, it has been shown[5-II] that the distributions of Cohen's class cannot be positive over the entire time frequency plane *and* satisfy the properties P1 and P2 described above. Cohen has described another generic class of distributions [6] which are not constrained in this way.

4.2 The Spectrogram, Wigner and Cone Kernels

The kernel functions corresponding to the Spectrogram, Wigner and a Cone-Kernel Distribution are shown in the Figures 4a, 4b and 4c respectively.

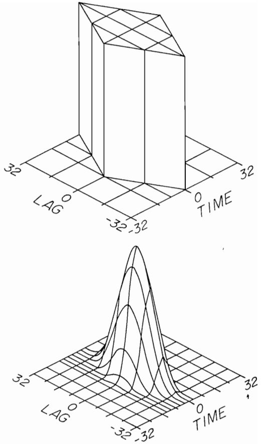


Figure 4a. Spectrogram Kernels. These Kernels give rise to time frequency distributions which are equivalent to Spectrograms calculated using a sliding Rectangular Window (upper) and a sliding Hanning Window (lower).

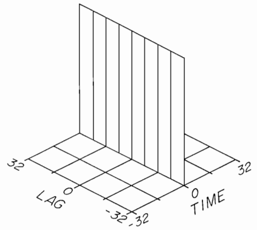


Figure 4b. Wigner Kernel - a line of impulse functions.

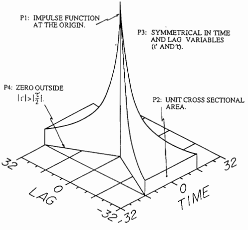


Figure 4c. Cone Kernel [7]. The height of this Kernel varies as the inverse of the lag. The geometrical constraints corresponding to the properties P1-P4 are shown.

Table 1 summarizes the properties of the three distributions being considered here. An important difference between these distributions is that the Spectrogram always leads to *positive* distributions whereas the others don't. Although this is a desirable property in terms of the interpretation of the spectrogram, it is at the expense of other desirable properties including finite time support (P4) which in some applications may be more desirable than positivity.

TABLE 1. Properties of Distributions calculated using three Kernel functions.

	PROPERTY				
	P1	**P2**	**P3**	**P4**	**P5**
SPECTROGRAM	NO	NO	YES	NO	YES
WIGNER	YES	YES	YES	YES	NO
CONE KERNEL	YES	YES	YES	YES	NO

4.3. Interference Terms.

We shall conclude this section with a brief discussion of a problem known as 'interference'. This occurs with many of the distributions in Cohen's class and describes by-products of the calculation technique which appear in the resulting time frequency distribution. Interference terms are the result of the signal product term $x\left(t'+\frac{\tau}{2}\right)x^*\left(t'-\frac{\tau}{2}\right)$ in Cohen's generic equation (1). The shape and magnitude of interference terms depend on both the distribution of the signal's energy in time and frequency and also on the particular kernel function used to calculate the distribution. For example, consider a signal consisting of the sum of two constant frequency harmonic components $x(t) = e^{jw_1t} + {}^{jw_2t}$, (where $j=\sqrt{-1}$). The time-frequency distribution satisfying all five of the properties described above is simply $C_x(t,\omega,\phi) = \delta(\omega_1) + \delta(\omega_2)$, ie., two rows of time invariant impulses in the time-frequency plane as shown in Figure 5a. The results produced by the Wigner and Cone Kernel distributions are shown in Figures 5b and 5c respectively. In the case of the Wigner distribution, the interference is in the form of a third line of impulse functions, parallel to and midway between the lines $\delta(\omega_1)$ and $\delta(\omega_2)$. The magnitude of the third impulse line oscillates sinusoidally with time in the time frequency plane with an angular frequency $2\pi(\omega_1-\omega_2)$ rad/s

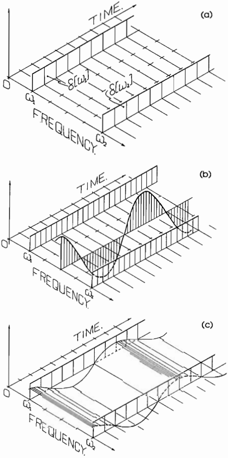


Figure 5. Time-frequency distributions of a signal consisting of the two harmonic components $x(t) = e^{jw_1t} + {}^{jw_2t}$ (a) Expected Distribution (b) Wigner Distribution (c) Cone Kernel Distribution.

In the case of the Cone Kernel, the authors have shown the interference takes the shape of a corrugated sheet lying between the lines $\delta(\omega_1)$ and $\delta(\omega_2)$, (Figure 5c). The size of the sheet's corrugations (peak to peak) is inversely proportional to the difference $\omega_1-\omega_2$. Its rate of oscillation with time in the time-frequency plane is equal to $2\pi(\omega_1-\omega_2)$ rad/s. In other words, as the frequencies ω_1 and ω_2 of the two harmonic components $e^{jw_1t} + {}^{jw_2t}$ in the signal become closer, the magnitude of the interference term increases and it oscillates more slowly. Similar interference patterns are generated between the broadband instantaneous spectra generated by signals containing two impulse functions. It is interesting to note that the Cone Kernel effectively *spreads out* the interference produced by the Wigner Kernel in the time frequency plane. Furthermore, interference exhibits both positive and negative terms in the time-frequency plane.

This example illustrates the link between Kernel design and interference suppression. Several recent studies[8,9] consider this relationship in more detail. Other methods for removing interference involve the smoothing of distributions in the time-frequency plane. In fact, it can be shown[5-II] that the spectrogram (which does not exhibit the type of interference described above), is nothing more than a Wigner Distribution *smoothed* in time and frequency.

5. EXAMPLE - SPEECH WAVEFORM

Figure 6a shows a portion of a digital recording of the word 'that-u' spoken by a male. The 102.4 ms portion of the signal shown corresponds to the vowel 'a'. We would expect a *voiced* speech waveform such as this to show resonances of the vocal tract (formant frequencies) being periodically excited by 'puffs' of air exiting the vocal chords. The periodic nature of the vocal tract excitation is evident from figure 6a which shows excitation occurs approximately every 8 ms. By analysing a single 8 ms segment of this signal, we can get some idea of the likely vocal tract resonances (figure 6b).

The Spectrogram, Wigner distribution and Cone Kernel distributions have been used to analyse this signal and the resulting time frequency-distributions are shown in Figures 6c to 6f. To suppress very low frequency interference terms caused by the interplay between the signal's positive and negative frequency components, the negative frequency components were removed prior to the Wigner and Cone Kernel analysis. This form of the signal is known as the *analytic* signal[10], and the Wigner distribution of an analytic signal is known as the 'Wigner-Ville' distribution. In this example, the Wigner and Cone Kernel Distributions were numerically approximated using software written in 'C' on an NEC 386/20 computer. Fourier transforms were calculated using the Fast Fourier transform (FFT). The spectrogram was evaluated using the commercial signal analysis package 'Hypersignal'. The time step between spectral estimates in the time-frequency plane was 0.8 ms in all cases.

Both 'broadband' and 'narrowband' spectrograms have been calculated with frequency resolutions of approximately 450 Hz (Figure 6c) and 120 Hz (Figure 6d) respectively. The broadband spectrogram shows a periodic excitation of three frequency bands approximately every 8 ms. These bands broadly correspond to the vocal tract resonances (Figure 6b) which are being periodically excited by the individual puffs of air leaving the vocal cords. The narrowband spectrogram does not clearly show the periodic excitation of the vocal tract due to its reduced resolution in time. However, its superior frequency resolution better defines the vocal tract resonances. The appearance of individual lines within each broad resonance band (Figure 6d) is a consequence of the length of the sliding window used to create the narrowband spectrogram. Unlike the shorter 3.2 ms broadband window, the 12.8 ms narrowband window captures the response of the vocal tract to more than excitation. This leads to the periodic modulation of the spectral magnitude with frequency shown in Figure 6d. The fact that the spacing between the individual lines within each resonance band is roughly 125 Hz (which is the inverse of the excitation repetition period (8 ms)) supports the above explanation. Furthermore, the line spacing remained fixed when the analysis was carried out with 25.6 ms time segments which implies the lines are not caused by side-lobes of the Hanning window.

The Cone Kernel distribution (Figure 6e) shows both the individual frequency bands associated with each of the three formant resonances *and* the periodic excitation of these resonances. However, in interpreting Figure 6e, the reader should be mindful of the likely effects of interference described earlier in this article. For example, we would expect to find interference between each of the broadly spaced vocal tract resonances. Therefore, some contribution to the repetitious vertical bands between the formant resonances will be the result of interference. As a quick check, we might expect interference between the 600 Hz and 1500 Hz vocal tract resonances to be in the form of a corrugated sheet lying between these bands as in Figure 5c. The wavelength of the corrugations would then be $(1500 \text{ Hz} - 600 \text{ Hz})^{-1} = 1.1$ms which is almost an order of magnitude less than the period of the excitation shown. More detailed analysis of the likely effects of interference is beyond the scope of this article. However, this initial check at least shows that the repetitious vertical bands in Figure 6e are not simply the peaks and valleys of an interference sheet lying between the 600 Hz and 1500 Hz vocal tract resonances. This is supported by the results of the broadband spectrogram (Figure 6c).

The effect of interference is even more dramatically illustrated in the Wigner-Ville distribution shown in Figure 6f. Unlike the narrowband spectrogram and the Cone Kernel distributions, the Wigner distribution shows a third horizontal band at approximately 1 kHz mid-way between the two vocal resonances at 500Hz and 1.5kHz. This additional band corresponds to the strong interference term expected of the Wigner distribution in this situation (Figure 5b). Another feature of the Wigner Distribution is illustrated by this example - the Wigner Distribution appears 'noisy'. This is because the Wigner Kernel leads to a correlation function R(t) that is highly localised in time and does not benefit from the time averaging provided by the breadth of the other Kernels.

6. CONCLUSIONS

Time-frequency analysis is a powerful tool with the ability to analyse non-stationary signals. The formulation of Cohen's class of distributions has been described. The desirable features of time frequency distributions in this class have been related to the corresponding constraints on their kernel functions.

Three time frequency distributions in this class have been compared and used to analyse a speech signal. This analysis illustrated the use of broadband and narrowband spectrograms to separately examine the distribution of the signal's energy in time and frequency respectively. The Cone Kernel was able to achieve a good balance between resolution in frequency and time whilst not appearing to be unduly affected by interference in this particular case. The Wigner distribution proved unsuitable for this application in that the results it produced appeared noisy and strongly affected by interference. However, the Wigner distribution is known to perform very well with certain other types of signals which illustrates the point that the choice of distribution for a given application requires a good understanding of the strengths and weaknesses of the various kernels.

Further general reading on the subject of time-frequency analysis may be found in references 11 and 12.

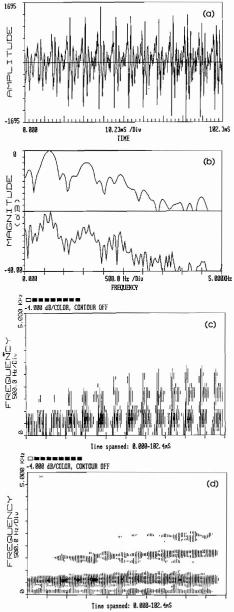
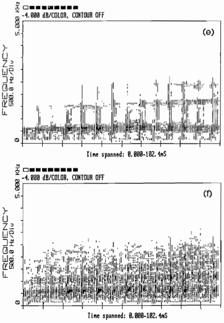


Figure 6. (a) Voiced 'a' from the utterance 'that-u'. Sampling rate 10 kHz. (b).Magnitude spectra of a single 7.9ms segment (upper trace) and three consecutive 7.9ms segments (lower trace) of the signal shown in Figure 6a. In the upper trace, two broad resonances at 600 Hz and 1.5kHz are evident along with a number of narrower peaks. The lower trace shows the periodic modulation of the upper spectrum due to the presence of the two repetitions (echoes) of the initial 7.9ms segment. 256pt.FFTs; Hanning window. (c) Broadband Spectrogram. 32 point sliding Hanning window; 64 point FFT. (d) Narrowband Spectrogram. 128 point sliding Hanning window; 256 pt. FFT. (e) Cone Kernel Distribution. 128 point Kernel ; 256 point FFT. (f) Wigner-Ville Distribution. 128 point Kernel ; 256 pt. FFT.



7. REFERENCES

1. Oppenheim, A.V., 'Applications of Digital Signal Processing', Prentice Hall, 1978.
2. Kronland-Martinet, R., Morlet,J. and Grossman, A., 'Analysis of sound patterns through Wavelet Transforms', Int. J. of Pattern Recognition and Artificial Intelligence, Special Issue on Expert Systems and Pattern Analysis, Vol.**1**, **2**. World Scientific Publishing Co.,97-126.
3. Qui, L, 'Techniques for Time Varying Signal Analysis', PhD thesis, University of Queensland, Nov., 1991.
4. Cohen, L., 'Time-frequency Distributions - A Review', Proc. IEEE, Vol.**77**, No.7, July 1989.
5. Claasen, T.A.C.M. and Mecklenbrauker, W.F.G., 'The Wigner Distribution - A Tool for Time Frequency Signal Analysis - Parts I & III', Phillips Journal of Research, Vol.**35**, No.6, 1980.
6. Cohen, L. and Posch, T., 'Positive Time-frequency Distribution Functions', IEEE Transactions on Acoustics, Speech and Signal Processing', Vol. ASSP **33**, No.1, Feb.1985.
7. Williams, W.J. and Jeong, J., 'Reduced Interference Time-frequency Distributions', Proc. of ISSPA 90, Signal Processing Theories, Implementations and Applications, Gold Coast, Australia, August, 1990.
8. Zhao,Y., Atlas, L.E. and Marks, R.J. 'The Use of Cone-Shaped Kernels for Generalized Time-frequency Representations of Nonstationary Signals', IEEE Transactions on Acoustics Speech and Signal Processing, Vol.**38**, No.7, July 1990.
9. Choi, H. and Williams, W.J., 'Improved Time-frequency Representation of Multicomponent Signals using Exponential Kernels', IEEE Transactions on Acoustics, Speech and Signal Processing, Vol. **37**, No.6, June 1989.
10. Randall, R.B., 'Frequency Analysis', Bruel and Kjaer, 3rd ed. September 1987, pp.62-70.
11. Priestly, M.B.,'Non-Linear and Non-Stationary Time Series Analysis', Academic Press, London, 1988.
12. Boashash, B. (Ed.), 'Time-Frequency Signal Analysis - Methods and Applications', Longman Cheshire, Australia,1992.
13. This is analogous to the calculation of the power spectral density of a stationary random process in which we Fourier Transform the process' auto-correlation function.

ACTIVITIES REPORT

Underwater Acoustics Activities at ADFA

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In 1986, the Australian Defence Force Academy (ADFA) replaced the RAAF Academy, Pt Cook, the Royal Military College, Duntroon and the RAN Naval College, Jervis Bay, as the single centre for tertiary education for officer cadets of all three armed services. Since that time, the University College, established in the Academy grounds by the University of New South Wales, has been responsible for conducting courses of study and research. Given the naval connection, it is hardly surprising that underwater acoustics appears on the list of specialist courses.

The Department of Physics provides second year and third year units entitled *marine acoustics and optics 2* and *3*. These units double as physics electives and as components of the oceanography course offered by the Department of Geography and Oceanography. In addition, Maritime Engineering students currently take the level 2 unit as part of their final year of study. The underwater acoustics section of the units treats the acoustic wave equation, spherical waves, transmission loss, sound channels, transducer physics, beam formation and phase steering, sidescan-, multiple beam- and doppler-sonar, sonar equations, ocean acoustic tomography and marine seismic surveying. A parallel laboratory course is provided for oceanography students taking the units. Acoustics experiments deal with sound attenuation and the fast fourier transformation of acoustic "signatures" and employ both pulsed and continuous wave methods to determine the speed of sound in gases (static and flowing) and water. Figure 1 shows a commercial, small vessel echo-sounder whose transducer has been mounted in a vertical tube of water. A storage oscilloscope is used to monitor the reduction in echo delay as the transducer is lowered into the water. An interactive, acoustic ray-tracing computer program developed by the author and Steve James (also of the Department of Physics) has proved popular with the students because of its "user-friendliness" and clear graphical presentation of results. The computer program is used in conjunction with a laboratory script which introduces concepts and develops useful formulae as they are required. In particular, the student is introduced to the *underwater sound channel* (Figure 2) and the *surface sound channel*.

The Department of Electrical Engineering offers a fourth year elective unit entitled *underwater acoustics*. An emphasis on beamforming and signal interpretation reflects that department's research interests in real time signal processing using digital signal processing chips (for which underwater acoustics represents just one application) and in theoretical aspects of passive sonar beam formation and noise cancellation. Honours and higher degree projects are offered in both these fields.

In addition to these regular lecture courses, a short course on the *basics of underwater acoustics* was held at the academy on 15 - 16 May of 1991. This course was sponsored by the Materials Research Laboratory (MRL) of the Defence Science and Technology Organisation (DSTO) and organised by the University College's Acoustics and Vibration Centre.

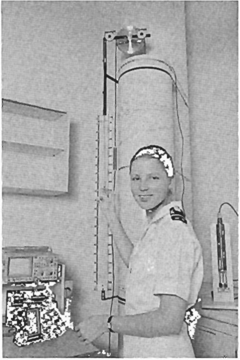

Figure 1. Midshipman Michele Miller monitors the pulse signals of a commercial echo-sounder whose transducer is mounted in a vertical tube of water.

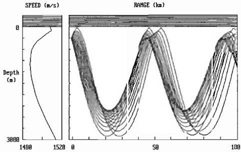

Figure 2. Underwater sound channel screen display gener-ated for an acoustic beam projected horizontally from a depth of 300 m with an angular width of 15°. The sound speed profile is shown to the left of the screen.

Lecturers for the course were drawn from senior staff from the Underwater Systems Division and the Materials Division of MRL, the Naval Engineering Services of the Department of Defence and from the University College. The course attracted a total of 76 participants from various organisations within Defence, government organisations and private industry. In response to the course's enthusiastic reception, it will be offered again at about the same time this article appears (November 9 - 10, 1992).

EXCELLENCE IN ACOUSTICS AWARDS - 1992

NSW Division ran the biennial Excellence In Acoustics Awards again during 1992. Inaugurated in 1988, the Awards are made for works in the fields of Acoustics and Vibration which are of outstanding merit. The works have to be carried out either in design, study or execution in New South Wales. The 1992 Awards were sponsored by CSR Hebel, who were also the Sponsors for the previous Awards made in 1990, and new Sponsors Kell & Rigby Acoustics.

Seven entries were received in 1992 and these were judged, in each category, by panels comprising both acousticians and persons whose primary technical expertise lies outside acoustics. Awards would only be made to any particular entrant if the judges' consensus was that the entry was indeed of an excellent standard. All seven entries were of high standard, but the judges' consensus was clear. Four Awards were made as follows:-

Acoustic Design

Environmental Noise Control – *The ENCO Power Pak, an acoustic enclosure for diesel generators.*
Renzo Tonin & Associates – *Acoustic design of 2nd Military band practice facility at Victoria Barracks, Sydney.*

Acoustic Report, Systems and Procedures

VIPAC – *Noise impact study of Kingsford Smith Airport 3rd Runway, Sydney.*
Wilkinson Murray – *Noise investigation of Western Section of North-Western Transport Corridor, Sydney.*

Announcement and presentation of the Awards was made at a well attended dinner at the Wharf Restaurant overlooking Sydney Harbour on Wednesday 9 December 1992. Stephen Samuels, the Chairman of the Excellence In Acoustics Awards Subcommittee, presented the Awards with the assistance of John Klune, from CSR Hebel, for Category 1, and Malcolm Bergmann, from Kell & Rigby Acoustics, for Category 2. Accepting the framed Awards certificates were Ram Krishnaswamy and Bob Blackhall of Environmental Noise Control, Matthew Palavidis of Renzo Tonin & Associates, Les Husin of VIPAC and Barry Murray of Wilkinson Murray.

The Excellence In Acoustics Awards are proving most successful in fulfilling the Society's objective of promoting and stimulating the pursuit of excellence in the fields of acoustics and vibration. Sincere thanks are also offered to all participants, sponsors and to the organising committee.

FOOTNOTE: Federal Council took the decision at its November 1992 Meetings that henceforth, the Excellence Awards would be run on a national basis. The first such will be in 1994 with the timetable set so that the presentations will take place during the Annual Conference. In that year the Conference will be held somewhere in NSW.

Category 1. Bob Blackhall and Ram Krishnaswamy of Environmental Noise Control.

Category 1. Matthew Palavidis of Renzo Tonin & Associates Certificate presented by John Klune of CSR Hebel

Category 2. Les Huson of Vipac. Certificate presented by Malcolm Bergman of Kell and Rigby Interiors.

Category 2. Barry Murray of Wilkinson Murray. Certificate presented by Malcolm Bergmann of Kell and Rigby Interiors.

R & D In Underwater Acoustic Arrays

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Abstract: The construction of the Collin's class submarine in Australia has resulted in research into both array design and measurement techniques. This report surveys current Research and Development being applied to the design of acoustic arrays in Australia which are related to this and other Defence acquisitions. The measurement techniques and facilities developed as a consequence of this programme have a potential wider benefit for underwater acoustic Research projects in Australia.

1. INTRODUCTION

A number of developments in underwater acoustic arrays in Australia are associated with the Collin's class submarine currently under construction. This has resulted in research with the aim of:

a. Developing arrays for installation on the submarine, and
b. Developing test facilities to measure the performance of the arrays produced,

The primary mode of operation of all submarine arrays is passive and a typical submarine sonar suite for detection of radiated shipping noise comprises ,

a. a bow mounted sonar to provide accurate bearing information at medium ranges
b. a distributed array to provide passive range information and
c. a flank array and a towed array to provide long range detection.

2. HULL MOUNTED ARRAYS

With the exception of the flank array these passive arrays for the Collin's class submarine are being produced by GEC Marconi systems in Sydney (GMS). While the bow array and distributed array have been based on overseas designs the development to produce arrays suitable for installation on the submarine has required detailed modelling of the array performance and research to develop suitable test facilities.

This has resulted in the implementation of a large array test facility capable of measuring the far-field beam pattern and sensitivities for both individual staves and arrays weighing up to ten tonnes. Due to the logistics of providing a floating crane with the lift capacity required to handle the arrays it was convenient to locate the facility on Sydney Harbour on a barge, extended by a floating bridge moored on Sugarloaf Bay. This resulted in an acoustic environment that is less than ideal and required the development of new test methods to satisfy the stringent measurement requirements.

The constraints on the system are:

a. The propagation time between transducers may vary due to mechanical movement and fluctuations in the velocity of sound in the water.
b. The presence of surface reflections with a fluctuation in their arrival times due to surface motion requires a gated measurement to remove the surface echo.
c. The depth of the Harbour of 25 metres in conjunction with measurement ranges in the order of 75 metres requires short gating periods in the order of 2 ms.
d. A high ambient ambient noise associated with local boating activity is present.

In this environment it is required to optimise the frequency resolution while maintaining measurement accuracies better than 1 dB in amplitude and 1 degree in relative phase accuracy.

Because of the fluctuation in the propagation time it was found that by using pulsed tone burst measurements an order of magnitude improvement in phase accuracy could be achieved relative to that realised by broadband and correlation methods. The phase information was extracted from the tone burst data by processing the analytic signal formed from the received pulse. The accuracy of the technique is such that the correlation in the fluctuations in the propagation path associated with inhomogeneities in the water can be accurately measured across the array.

The effect of gating inherent in a tone burst measurement is to convolve the true frequency response with a frequency window which is related to the envelope of the transmitted tone burst. The degradation in the measured data is minimised by choosing a tone burst envelope which produces a frequency window which is as narrow as possible to minimise the smoothing in the frequency domain while maintaining sidelobes at a level sufficient to prevent leakage from high spectral regions associated with transducer resonances. This is realised by using a family of tone bursts which yield Kayser Bessel windows in the frequency domain after processing. The sidelobe levels of these windows may be selected to match the transducer under test.

To enhance the signal to noise of the tone burst measurements the received data may be filtered before gating. As the filter bandwidth is reduced to improve the noise rejection the extent of the filter impulse response in the time domain increases. As this impulse response is convolved with the received tone burst this constrains the length of the tone burst which may be transmitted to realise any given gating period. This results in an optimum matching of the transmitted pulse and receiving filter which maximise the signal to noise ratio of the measurement while realising the required frequency window and gating.

The signal processing outlined above is implemented under the PROCUBE analysis software which generates and transmits the test pulses, simultaneously acquires the data for up to 128 hydrophone channels, processes the received signal to extract the amplitude and phase response of the channels and beams at each bearing, and rotates the array to generate the beampatterns for each frequency.

3. TOWED ARRAY DEVELOPMENTS

The towed array for the Collin's class submarine is based on the Kariwara technology developed by the Defence Science and Technology Organisation. This towed array differs from towed arrays currently in service overseas in that it is a solid fill array rather than fluid fill and is of a much smaller diameter than is commonly used. These characteristics result in a rugged array which is capable of being winched onto a submarine. The technology is being commercialised by GEC Marconi Systems who are producing arrays for the Collin's class submarine and other applications.

This development involves ongoing R&D both for the production of components and techniques to manufacture the arrays and to quantify the array self noise mechanisms which influence the acoustic performance.

The array self noise is produced by two mechanisms which are:

a. The turbulent boundary layer flow noise and

b. The vibration which propagates along the array from the tow point.

The flow noise at the array may be represented as a two dimensional frequency wavenumber spectrum. This may be visualised as a frequency spectrum of acoustic waves. At each frequency there is a set of waves, each of which propagates with a different velocity. As the acoustic signals at the array all have apparent propagation velocities greater than or equal to that of sound in water it is possible to reduce the array self noise without reducing the signals of interest by filtering out the low velocity components of the flow noise. In principle this is readily achieved by the array beamforming however due to the extremely wide range of wavenumbers present in the flow noise the number of hydrophones and processing channels required would be in the order of 10^5 to 10^6. This necessitates a more elegant design to provide a cost effective solution.

The techniques used to achieve this are to design the mechanical structure of the array to filter high wavenumber waves propagating from the external flow noise to the internal hydrophone elements. This provides a spatial antialiasing filter. The internal waves may then be sampled by groups of hydrophone elements which should be designed to pass wavenumbers in the acoustic space while rejecting wavenumbers outside this space. The outputs of these hydrophone groups may then be processed by the sonar beamformer.

The vibration induced noise is translated into acoustic noise by excitation of internal structures in the array which may act as pistons driving pressure waves or by constriction of tubing in the array structure which directly induces an internal pressure. The nature of the vibration induced noise differs from that of the flow noise in that only discrete wavenumbers are present. These wavenumbers are associated with the velocities of waves propagating in various array structures. Similar design techniques are available to reduce the vibration noise as are used for the flow noise. In addition it is possible to utilise symmetry in the position of hydrophone elements to cancel some vibration induced waves which are generated with opposite polarity.

To validate design concepts prior to production of full arrays, land based test facilities are used to measure both the vibration sensitivity and flow noise of sample array sections. These facilities which were initially developed by DSTO are now operated by Australian Defence Industries.

The vibration testing is carried out in a water filled trench about 100 metres long at DSTO Salisbury. One end of the array section is driven by a shaker and the acceleration sensitivity is measured between hydrophones in the array and externally mounted accelerometers. Reflections from the end of the array sections require gating similar to that used for the large array test facility. A difference in the facilities is that the propagation paths are stable in the vibration facility which enables broadband correlation techniques to be used to measure the impulse response. Rejection of echoes may be implemented by applying conventional gating techniques. Advanced spectral estimation methods are also used in the analysis of the vibration data which synthesise the spectrum by estimating the parameters in a model of the waves propagating in the array. This avoids the low frequency limits imposed by conventional gating techniques.

The flow noise is measured in a tow facility in a reservoir in the Barossa Valley. A winch on the shore is used to tow array sections behind a catamaran over a range of speeds. To remove possible vibration contamination from the tow source accelerometers at the ends of the array section are used to remove components in the measured spectra which are correlated with the vibration in the array. As with the large array test facility the signal processing required for the analysis is implemented using the PROCUBE software.

4. OTHER R & D ACTIVITIES

In addition to the array development for the Collin's class submarine Australia has had a long research programme to develop arrays for sonobuoys. This has resulted in the production of the Barra sonobuoy and research is continuing to develop improved arrays for future sonobuoys.

At higher frequencies arrays for research relevant to minehunting applications are being developed by GMS.

Closely related to the fundamental array research is the extensive research into signal processing for arrays which has been carried out by DSTO Salisbury, DSTO Sydney and more recently by GMS. An important outcome of this research is the ability to design the array and signal processing as a system. This is a significant advance from previous approaches in which arrays were designed to mechanically reduce self noise sources prior to the application of conventional beamforming. With a systems approach it is possible to use a balance between mechanical methods and and adaptive signal processing methods to reject the noise in an optimal manner.

⁂

MCG GREAT SOUTHERN STAND

In order to cater for increasing spectator demand, particularly Australian Football League Finals and World Series Cricket one-day games, the Melbourne Cricket Ground Trustees decided to replace the old Southern Stand, build in 1936-7, with the 47,850 capacity Great Southern Stand.

This has increased the ground's capacity to 105,000 and, as an extra bonus, most patrons will now be seated, although the Trustees bowed to tradition and retained standing room capacity for 4,000 to cater for the more 'die-hard' spectators.

For such a venue, acoustics and sound fidelity are important, and accordingly, engineering consultants for the project, Connell Wagner Rankine & Hill commissioned VIPAC to model three tendered sound systems.

VIPAC used the EASE (Electro Acoustical Simulator for Engineers) software program to simulate the sound distribution uniformity and frequency response across the stadium, and a system proposed by Neilson Electronic Systems Pty. Ltd. of Hawthorn East (Melbourne) was recommended.

The Master Cluster consists of a mixture of twenty-one high and low frequency constant directivity horns and thirty-one DH1A high-frequency drivers, all developed by Electro-Voice of Buchanan, Michigan, U.S.A. The use of a single cluster array emanating from one point to serve such as extensive area is believed to be unique.

The system is programmable – controlled by a PA-422 digital control interface, configured for simple operation by non-technical personnel who can select any of up to nine operating modes, or nine memories of EQ and gain settings in each of the four main areas zones.

After commissioning, extraordinarily - even Sound Pressure Levels (SPL's) around the seating areas were noted, typically of ±2dB tolerance, and only 8dB higher directly under the array than to the furthest 'throw', which is 250 metres to the rear of the existing Western Stand.

(From Vipac News)

ACTIVITIES REPORT

Underwater Acoustics Activities at the Australian Maritime College

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1. INTRODUCTION

The Australian Maritime College (AMC) is a directly-funded Commonwealth Government College established in 1980 to provide maritime and maritime related education and training for Australia. There are presently three schools, Engineering, Fisheries and Nautical Studies spread over the two campuses at Newnham in Launceston and Beauty Point 50 kms north of Launceston on the Tamar River.

College facilities relevant to the underwater acoustics area include several vessels particularly the fisheries vessels, Bluefin and Reviresco, the 13m hydrographic survey launch, Pinduro, an 11m x 5m x 2.5m deep flume tank, a 60m ship model towing tank and the Survival Centre pool. The Bluefin sonar equipment includes a Simrad SQ4 scanning sonar. The Reviresco will be used for sea trials of mine sweeping equipment as part of a research and development program being carried out by the College Company, AMC Search Ltd, for the Royal Australian Navy. The Survival Centre pool has a 12.5m x 5m x 4.2m deep section at one end, with an overhead crane and a derrick covering part of the area, which make this facility very useful for acoustic experimentation.

Courses range in level from certificate to four-year Bachelor of Engineering (BEng) degrees in Maritime Engineering and Naval Architecture with a Master of Applied Science in Fisheries being offered for the first time this year.

2. DEVELOPMENT OF THE UNDERWATER ACOUSTICS AREA

In 1989 a marine acoustics subject was run as a third year option in the BEng program. This is mainly a first course in underwater acoustics with a treatment of noise and vibration generation and transmission in ships, and an introduction to noise design in ships and methods of estimation and control.

Partly to support this subject a 4m x 3m x 2m deep tank, together with instrumentation supplied and commissioned by GEC Marconi Ltd was installed at the Newnham Campus. The BEng students use this facility to carry out such experiments as transducer directivity, hydrophone calibration and target strength measurement. The lower frequency limit of the tank, using the gated signal (pulse) technique is approximately 20 kHz. The 'random noise' method can be used, for calibrating hydrophones for example, well below this frequency with the aid of an FFT analyser. A range of projectors, hydrophones and amplifiers are used, with the upper hydrophone frequency of operation being around 370 kHz presently, with power amplifiers available to work well above this figure.

Several BEng students have chosen to do their 200 hour fourth year projects in the underwater acoustics area, particularly the Department of Defence (DoD) sponsored students. These are either Royal Australian Navy officers who come to the AMC via HMAS Cerberus to study the last two years of the BEng program or DoD engineer cadets sponsored by the Navy Office, Canberra. An outline of student projects undertaken in 1990/1991 follows:

1. A 38 kHz 8-element broadside amplitude-shaded array was designed, built and tested. The design, aimed at minimising the level of the side-lobes was based on a classic paper by Dolph [1]. The array can be used to demonstrate the various beam patterns which result from different element driving configurations.
2. Scaled experiments were carried out to measure the simulated normal mode pressure distribution in shallow water. The results were compared with some of those given by Wood [2] and with results predicted by a two-layer normal mode computer program [3].
3. An 850mm microbend loss fibre optic acoustic sensor similar to that described by Vensarkar [4] was designed, built and tested.

The underwater acoustics projects undertaken by BEng students this year are the development of a non-resonant (<20 kHz) projector and experimentation with the School of Fisheries Digital Echo Integrator. The latter project entails the interfacing of this equipment with an echo sounder and the measurement of the acoustic density of targets and the comparison of these results with theoretical and measured target strength values.

A total of twenty-six people attended the College's Underwater Acoustics short courses in 1991.

3. RESEARCH

It is intended that the work on the fibre-optic acoustic sensor be continued as a research project. As a result of sabbatical leave spend by the author at the DSTO Maritime Systems division in Salisbury in July 1991 the DSTO Materials Research Laboratory (MRL) Maritime Operations Division is supporting research at the AMC into the physical limits and design of parametric and truncated parametric arrays suitable for underwater measurement of the acoustic properties of sample underwater panels. This research is aimed at improving the performance of the DSTO truncated parametric array, which is used for reflectivity and transmissibility measurements up to a frequency of 100 kHz. A two-year research agreement between the DSTO MRL and the AMC has enabled a full-time research assistant to be employed on this project.

A parametric source consists of a directional transducer driven at two frequencies near transducer resonance forming a dual-frequency primary beam. Because of the non linear propagation properties of water, sum and difference frequencies and harmonics are produced. The difference frequency is the lowest frequency component and the primary beam acts as an end-fire array of sources at the difference frequency. It is possible to generate highly directional difference frequency beams which are almost sidelobe free. This beam is ideal for measuring, for example, the transmissibility of plates thus avoiding the diffraction problems that occur in this measurement with the less directive beams that result when using a conventional source at the same frequency as the difference frequency. The parametric array was first described by Westervelt [5].

The DSTO have built a projector for the AMC research project which resonates at approximately 1 MHz. A medium frequency radio transmitter has been modified to drive this projector. The College Company, AMC Search Ltd, has contributed approximately $7000 towards the cost of this research in 1992 in addition to the DSTO MRL support.

3. THE FUTURE

The College is hoping to offer higher engineering and science degrees by research in 1994. The College is a partner in the recently approved Australian Maritime Engineering Cooperative Research Centre with the University of NSW, Monash University and Curtin University as core academic partners. Industrial partners with an interest in underwater acoustics include the DSTO MRL and Thomson Sintra Pacific Pty. Ltd. A propeller testing tunnel is proposed as one facility to be installed at the AMC in the early stages of the CRC development. At present no such facility exists in Australia.

REFERENCES

1. C L Dolph: Current Distribution of Broadside Arrays which Optimises the Relationship between Beam Width and Side-lobe Level, Proc. Inst. Radio Eng. 34: 335 (June 1946).
2. A B Wood: Model Experiments on Sound Propagation in Shallow Seas, J Acoust. Soc. Am. Vol. 31, No. 9, Sept. 1959.
3. D D Ellis: MORM2L: An Interactive Computer Program for Acoustic Normal Mode Calculations for the Pekeris Model, Defence Research Establishment Atlantic Technical Memorandum 80/K, Dec. 1980.
4. A M Vengsarkar, K A Murphy, T A Tran, R O Claus: Microbend Loss Fiber Optic Direction and Amplitude Sensors for Underwater Applications, J Acoust. Soc. Am. Vol. 88, No. 1, July 1990.
5. P J Westervelt: Parametric Acoustic Array, J. Acoust. Soc. Am. Vol. 35, No. 4, 1963.

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ACTIVITIES REPORT

Remote Sensing With Underwater Acoustics

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1. INTRODUCTION

The term *remote sensing* describes well most applications of underwater sound. Passive and active techniques aim to provide information about distant targets and have many analogs, notably in airborne and satellite remote sensing and with systems using electromagnetic waves. Acoustic remote sensing in the sea is receiving enhanced attention in biological, geological and, increasingly, in physical oceanography. In some cases the physics upon which new techniques depend has been understood for some time, but the advent of economical improvements in technology, notably in signal processing, has only recently made such new developments feasible. A key development in biological applications is the emergence of improved quantitative capability in relating acoustic backscatter to water column biomass. In geological applications, major emphases are observable to enhance coverage of the sea floor and to assess sea floor properties. The use of acoustics as a sensing tool for physical oceanography has expanded dramatically over recent years, with doppler, tomographic and time-of-flight techniques emerging. Notable amongst the latter is the global scale experiment described by Forbes [1992].

Three programs underway at Curtin University illustrate aspects of these developments.

2. TARGET STRENGTH ESTIMATION

The acoustic target strength of sound scatterers in the sea, a measure of the backscatter they provide, depends on sound wavelength and scatterer morphology and constitution. Such target strength values are central to the use of acoustic techniques to estimate oceanic biomass and underly the technique of echo integration, widely used for this purpose. The population of Antarctic krill, *Euphausia superba,* is the subject of international concern and the focus of a sustained biomass assessment program involving echo integration. Over recent years the assessment of krill target strength has been given high priority in several countries because uncertainty in this parameter translates to substantial uncertainties in assessed biomass and hence perceptions of sustainable fishing yields. Curtin's Centre for Marine Science and Technology (CMST) has undertaken the task of making an accurate assessment of krill target strength as a contribution to the biological assessment program of the Australian Antarctic Division. The work began with the creation of a Monte Carlo simulation of the formation of acoustic backscatter from krill, and of a signal processing method designed to retrieve target strength values from the statistics of an ensemble of echoes. Such ensembles are provided when a ship-based sounding system encounters a krill aggregation (Penrose et al.[1984], Palumbo et al. [in-press]).

The modelling phase yielded an efficient processing method and an understanding of the uncertainties in estimated target strength expected to arise from fluctuations in parameters such as target length, attitude in the beam, intertarget spacing and system calibration. This method was then applied to an experiment in which populations of krill were insonified in a large refrigerated test tank built at the Kingston laboratories of the Antarctic Division. The krill moved freely in the tank, which was periodically insonified at 120 kHz, a widely used frequency in Antarctic biomass estimation. Echoes from krill entering the sound beam were automatically recorded and processed using the previously evaluated processing method. Four populations of krill were measured in this way during 1989/90 and a suite of target strength values derived (Figure 1).

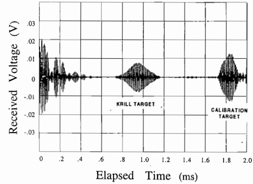

Figure 1. Representative 120 kHz signal record acquired during tank based measurements of krill backscatter. The record shows the transmitter ring-down, a krill target echo and an echo from a calibration sphere.

Tank techniques offer considerable advantages in such work, primarily because the target population can be closely defined. Such techniques, however, may influence target behaviour to an extent difficult to quantify; a key example is that of target orientation to the vertical which can strongly influence the magnitude of near vertical backscatter. These concerns call for a measuring capability which can operate efficiently at sea. The CMST equipment and signal processing system was accordingly deployed from *Aurora Australis* during a marine science voyage carried out January-March 1991 in the vicinity of Prydz Bay, Antarctica. In this work, a 120 kHz transducer was deployed from a towed body behind the ship and echo records were collected as the vessel traversed a variety of targets including krill and ice crystals found at depth in a large lens of supercooled water occupying much of the bay (Penrose et al. [in press]). The krill target strength values derived from this field data compare well with the earlier tank results for targets of similar size and provide a significantly improved value for this ecologically important parameter.

3. SEA FLOOR ROUGHNESS ASSESSMENT

The physics of wave interactions with rough surfaces is of continuing interest in many research areas. The scattering of sound from the sea floor is one such area and an extensive literature on the measurement and modelling of such interactions exists. Approaches to modelling and interpretation include those based on the Helmholtz equation and its derivatives and Monte Carlo techniques. Depending on sound frequency and hence penetration, the sea floor may be modelled as a single scattering surface or an assembly of surfaces. For comparatively high frequency sound, where a single scattering surface approximation is applicable, workers in the field such as Stanton [1984] and Reut et al. [1985] have shown that it is possible to extract information on sea floor roughness from the backscattered signal envelope.

Following this approach, and as an extension to earlier CMST work (Penrose et al.[1984]), the project now underway aims to develop a sea going PC based data acquisition and processing system interfaced to standard side scan sonar equipment. The project aim is to enable real-time roughness categorisation to proceed during side scan sonar surveys. The project has four stages comprising tank based measurements from stylised model surfaces, numerical modelling of the scattering process, jetty based field trials and the development of a sea going operational system. Sea going trials will use roughness estimates based on underwater stereophotography to evaluate the system performance.

The first stage of the tank work is complete and an associated numerical model has provided favourable comparison with experimental data. Figure 2 shows a modelled backscatter signal from a laboratory test surface and a fitted echo envelope. Analysis of the echo structure yields information on surface roughness. Two jetty based experimental programs have been carried out, in Fremantle harbour and at HMAS Stirling in Cockburn Sound. These have provided a limited range of sea floor roughness variation and further field evaluation will require vessel based trials. Diver surveys of suitable sites are now proceeding and the instrumentation and software development needed for full field operation is nearing completion. This will include the incorporation of Global Positioning System navigational data together with sonar data and roughness estimates in a form suitable for use with existing Geographical Information Systems.

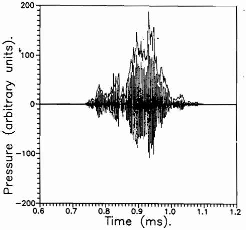

Figure 2. Modelled backscattered acoustic echo and fitted echo envelope from a sinusoidal surface, corresponding to experimental tank information.

4. ACOUSTIC THERMOMETRY

The speed of sound in the sea is a function of temperature, salinity and pressure. For most conditions, temperature induced fluctuations in sound speed dominate. Thus measurements of the time of flight of an acoustic pulse between two points can be used as an estimate of the effect of temperature on sound speed integrated along the transmission path and hence as a measure of temperature. Long range transmission applications are represented by the account of Forbes [1992]. In an initial project undertaken within CMST, a short range (14m) transmission experiment has been completed using a 300 kHz underwater position fixing system developed at CMST (Duncan et al.[1987]) In this experiment the time taken for an acoustic pulse to travel in both directions between a transmitter/receiver and a transponder horizontally separated by 14m was recorded over a 40 minute period. Both acoustic units were located in water of approximately 4m depth within the cooling water outfall plume emerging from a power station on the coast of Cockburn Sound, Western Australia. The outfall provided a turbulent plume of warmed water with a temperature signature sufficient to provide a usable time of flight variation to suit the equipment deployed. Figure 3 shows some of the results obtained. A major temperature signature, equivalent to approximately 1°C change in temperature over the entire sound path corresponding to approximately 60 µs change in time flight is seen, with higher frequency noise, in excess of system noise, also present. This proof of concept experiment has shown the practicability of short range acoustic thermometry under such conditions. Improvement in timing resolution and the deployment of an array of transponders would provide enhanced temperature resolution and permit estimates of the scale lengths of the plume temperature microstructure. The provision of each-way time measurement capability would give along beam current estimates and, for a suitable transponder geometry, measures of system vorticity at selected scale lengths.

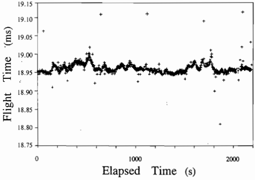

Figure 3. Round trip flight time vs elapsed time for 300 kHz acoustic pulse over a 14 metre path.

5. CONCLUSIONS

Work at CMST Curtin illustrates several aspects of wider activity in acoustic remote sensing in the ocean. The widespread and increasing use of quantitative acoustic techniques in marine biomass estimation has led to a focus on issues such as calibration techniques and accurate target strength estimation for key species. In related developments, acoustic imaging techniques for sea floor visualisation are improving and techniques emerging to provide quantitative information on bottom properties. In physical oceanography, systems yielding information integrated over acoustic travel paths are among many new developments. Such space-integrating techniques will, for some experimental regimes, revolutionise the quality of field data available to the oceanographic community.

ACKNOWLEDGEMENTS

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REFERENCES

Duncan,A.J.(1987), "A diver operated acoustic surveying system", Proceedings of the Annual Conference of the Australian Acoustical Society, Hobart.

Forbes AMG, (1992), "Ocean Acoustic Thermometry - the Heard Island Feasibility test, 1991" Acous Aust **20**, 87-90

Palumbo,D., Penrose,J.D. and White,B.A.(in-press), "Target strength estimation from echo ensembles", J. Acoust. Soc. Am.

Penrose,J.D., White,B.A., Palumbo,D., Wells,J.B. and Collins,L.B. (1984), "Monte Carlo modelling of scattering in underwater acoustics", Bulletin Aust. Acoust. Soc., **12** 39-45.

Penrose,J.D., Conde,M. and Pauly,T.J. (in-press). "Acoustic detection of ice crystals in Antarctic waters", J. Geophys. Res.

Reut,Z., Pace,N.G. and Heaton,M.J.P.(1985). "Statistical properties of side scan sonar signals and the computer classification of seabeds", Proc. Inst. Acoust., **7**(3), 102-107.

Stanton,T.K.(1984). "Sonar estimates of seafloor microroughness", J.Acoust. Soc. Am. **75**, 809-818.

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A Case History

Condition Monitoring is a proven method for reducing maintenance costs. Benefits include reduced material and labour costs, minimised catastrophic failures and production downtime.

VIPAC has been performing Condition Monitoring using vibration analysis for almost twenty years and considers the operational benefits of an effective vibration monitoring programme are considerable.

Finite Element Modelling

On a mill at the Kidston gold mine, North Queensland, excessive vibration of the bearing support pedestal and building resulted from a torsional resonant frequency falling close to a multiple of pinion speed. Wearing of the pinion teeth was increasing harmonic excitation and increasing vibration levels over many months had been observed. Strain Gauge Torque Telemetry measurements confirmed the presence of a fluctuating torque at 50% of the drive torque. Monitoring of the DC motor current revealed an AC component at the same frequency induced by the fluctuating torsional displacement. Finite Element Modelling was used to model the system and test the selection of a new coupling. The end result was the replacement of the original steel flex coupling with a rubber element coupling. This coupling was built in Germany to VIPAC specifications and was fitted with specially-designed high damping rubber. The resonant frequency was altered but, more importantly, the damping of the system suppressed the response of the system. The new coupling was successful in dramatically improving the running condition.

VIPAC considers the most important benefit of Condition Monitoring is the marked reduction in maintenance costs which can be attained. It is generally agreed in the industry that cost savings of 25-40% are readily achievable, even after incorporating the cost of the analysis service, and making no allowance for increased production

(from VIPAC News)

The Instantaneous Sound Intensity in Two-Dimensional Sound Fields — A Finite Element Approach

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Abstract: The acoustic finite element approach is employed for the calculation of the instantaneous sound intensity vectors in a two-dimensional sound field. The sound pressure distribution is first calculated via the acoustic finite element method. The sound particle velocities are then solved for each element from the linearised Euler's equation, and are used to derive the active sound intensity and the reactive sound intensity through a decomposition approach. It is demonstrated that the instantaneous sound intensity vector can be calculated by retaining the time dependence factor. It is also found that the sign, or direction, of the reactive sound intensity vector can be specified in different ways, provided that the instantaneous sound intensity is defined accordingly. An example is provided to simulate sound propagation in a two-dimensional duct with rigid walls, excited by a point monopole source with constant particle velocity. The results of the active sound intensity field agree well with those given by Fahy [2]. The calculated reactive sound intensity field is very much related to the contour lines of the sound pressure levels, as expected. Two circulatory patterns were observed in the active sound intensity field, each corresponding to a zero pressure point in the sound field. These two circulatory patterns, however, were hardly visible in the instantaneous sound intensity field. It is suggested that the instantaneous sound intensity should be used in complement with the time-averaged active and reactive sound intensities in cases where the acoustic energy transfer is vitally important, e.g. the active noise control for a pure-tone sound field.

1. INTRODUCTION

The basic concept of sound intensity was established in the early 1940s [1]. But is was not until recently that it received such a warm embrace by the communities of acousticians and engineers [2]. The application of sound intensity measurement covers many engineering fields, e.g. noise source identification [3], determination of transmission loss in buildings [4] and analysis of sound radiation [5]. The conventional sound intensity, i.e. the active sound intensity, is a time-averaged quantity which describes the net energy transfer per unit area of the cross-section normal to the direction of intensity propagation during a time period. It does not, however, reflect the acoustic energy flux within the sound field. It is therefore necessary to consider the instantaneous sound intensity which combines the active and reactive sound intensities. Clearly the instantaneous sound intensity has not been fully investigated or thoroughly understood. Analytical difficulties, before anything else, are to blame for the lack of effort towards discovering the phenomena of the instantaneous sound intensity in sound fields of different natures. In general practice the complexity of the sound field geometry and/or the boundary conditions make it difficult, or even impossible to derive an analytical solution to the governing wave equation. In such cases numerical techniques are always the only alternative. The finite element method, characterised by its robustness and versatility, was chosen for the present investigation.

The acoustic finite element method, pioneered by Arlett and Zienkiewicz [6] and subsequently improved and explored by others, as discussed in Ref. [7], has proved to be a powerful numerical tool in analysing the acoustical performance of complex cavities [8], radiation from vibrating structures [9], etc. The application of the finite element method for the study of the instantaneous sound intensity field, however, has not been reported. The fast development of computer technology has contributed substantially to the ever increasing popularity and capabilities of the acoustic finite element. The two-dimensional finite element formulation employed in the present paper was first reported in Ref. [10], in which an absorptive road barrier and an automotive induction duct were studied as examples. It is extended here for the study of the instantaneous sound intensity fields.

2. FINITE ELEMENT FORMULATION

The Helmholtz equation covers a wide range of physical phenomena and, like other differential equations, can be formulated for a finite element solution. The original equation is given as

$$\frac{\partial}{\partial x}\left(k_x\frac{\partial\phi}{\partial x}\right)+\frac{\partial}{\partial y}\left(k_y\frac{\partial\phi}{\partial y}\right)+\frac{\partial}{\partial z}\left(k_z\frac{\partial\phi}{\partial z}\right)+\lambda^2\phi=0 \tag{1}$$

with Dirichlet and Neumann type boundary conditions [12].

For the time harmonic acoustic wave propagation in a homogeneous medium in the absence of mean flow, the equation is reduced to the form

$$\nabla^2 p + \left(\frac{\omega}{c}\right)^2 p = 0 \tag{2}$$

where p is the sound pressure; ∇^2 is the Laplacian operator, i.e.

$$\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2};$$

ω is the frequency of osclilation; and c is the speed of sound in the medium.

The Galerkin formulation of the above equation was obtained in [10] and is included here for the sake of completeness.

The three-node triangular element was chosen for the formulation. It was assumed that the field parameter considered, i.e. the sound pressure varies linearly within the element. The interpolation function p_e is represented by

$$p_e = c_1 + c_2 x + c_3 y \tag{3}$$

where c_1, c_2 and c_3 are constants.

The sound field within the element can then be expressed in terms of the interpolation function and the node pressure values, i.e.

$$p_e = [N][P] = \begin{bmatrix} m_{11} + m_{21}x + m_{31}y \\ m_{12} + m_{22}x + m_{32}y \\ m_{13} + m_{23}x + m_{33}y \end{bmatrix}^T \begin{Bmatrix} p_i \\ p_j \\ p_k \end{Bmatrix} \tag{4}$$

where p_i, p_j and p_k are sound pressures at the three nodes.

The Galerkin method was applied and the following equation was obtained:

$$\int_A [N]^T \left[\frac{\partial^2 p_e}{\partial x^2} + \frac{\partial^2 p_e}{\partial x^2} + +k^2 p_e\right] dA = 0 \tag{5}$$

where $k = \omega / c$ is the wave number and the superscript T denotes the transpose.

To allow for the incorporation of the Neumann boundary condition, the integration by parts was performed. This produced the following equation

$$(k^2[M] + [K])\{p\} = \{f\} \tag{6}$$

The element matrices for each element is found from

$$\begin{aligned} [M]_e &= -\int_A k^2 \{N\}^T \{N\} dA \\ &= -\frac{k^2 A}{12} \begin{bmatrix} 2 & 1 & 1 \\ 1 & 2 & 1 \\ 1 & 1 & 2 \end{bmatrix} \end{aligned} \tag{7}$$

$$\begin{aligned} [K]_e &= \int_A \left(\frac{\partial N^T}{\partial x}\frac{\partial N}{\partial x} + \frac{\partial N^T}{\partial y}\frac{\partial N}{\partial y}\right) dA \\ &= A \begin{bmatrix} k_{11} & k_{12} & k_{13} \\ k_{21} & k_{22} & k_{23} \\ k_{31} & k_{32} & k_{33} \end{bmatrix} \end{aligned} \tag{8}$$

where $k_{ln} = m_{2l}m_{2n} + m_{3l}m_{3n}, (l, n = 1, 3)$.

The vector $\{f\}$ on the right side of equation (6) relates to the excitation terms which can be evaluated from

$$\{f\} = \int_L \{N\}^T \frac{\partial p_e}{\partial n} dl \tag{9}$$

For a velocity source coinciding with the leg ij of an element, the length integral renders

$$\{f\}_v = -jk\rho c \frac{L_{ij} U_{ij}}{2} \begin{bmatrix} 1 \\ 1 \\ 0 \end{bmatrix} \tag{10}$$

For a dissipative surface occupying the leg ij of the element, the length integral is given by

$$\{f\}_s = -jk \frac{L_{ij} R_{ij}}{6} \begin{bmatrix} 2 & 1 & 0 \\ 1 & 2 & 0 \\ 0 & 0 & 0 \end{bmatrix} \tag{11}$$

Thus the global matrices can be assembled from the element matrices and the equation solved for the sound pressures at all the nodal points in the sound field of interest. The calculated pressure distribution will be used to evaluate the instantaneous sound intensity in the next section.

3. SOUND INTENSITY CALCULATION

Sound intensity components can be calculated directly from the finite element acoustic pressure results. By solving Eq. (6) we can obtain all the information of the sound pressure distribution inside a particular sound field. Both the amplitude and phasor of the sound pressure are known. The particle velocity can then be calculated for harmonic excitation by employing the linearised Euler's equation, i.e.

$$u = \frac{j}{k\rho c} \nabla p = \frac{j}{k\rho c} [\nabla N] \{p\}_e \tag{12}$$

In the following discussion we will restrict the derivation within the scope of the finite element formulation developed in the previous section. Due to the assumption of linear distribution of sound pressure in each element, the resultant sound particle velocity components remain constant within the element.

The spatial differentiation of Eq. (4) with respect to x and y yields

$$\frac{\partial p}{\partial x} = m_{21}p_i + m_{22}p_j + m_{23}p_k \tag{13}$$

$$\frac{\partial p}{\partial y} = m_{31}p_i + m_{32}p_j + m_{33}p_k \tag{14}$$

The particle velocity components within the element are given by

$$u_x = \frac{j}{k\rho c} \frac{\partial p}{\partial x} \tag{15}$$

$$u_y = \frac{j}{k\rho c} \frac{\partial p}{\partial y} \tag{16}$$

where the j denotes the imaginary unity.

The sound pressure within an element, in terms of shape function, is given by Eq. (4). The sound pressure at the mid-point of the triangular element, for a special case, is found from

$$p = \frac{1}{3}(p_i + p_j + p_k).$$

The particle velocity components at this mid-point are derived from Eqs. (15-16). The particle velocity components, u_x and u_y are then decomposed into two orthogonal parts, respectively. The first part is in phase (or out of phase) with the sound pressure at the mid-point, i.e. u_{xa} and u_{ya}. The second part is in quadrature with that pressure, u_{xr} and u_{yr}.

Based on the pure-tone sinusoidal excitation, the active and the reactive sound intensity components are calculated using the following formulae

$$I_{xa} = \frac{1}{2} u_{xa} |p_{mid}| \tag{17}$$

$$I_{ya} = \frac{1}{2} u_{ya} |p_{mid}| \tag{18}$$

and

$$I_{xr} = \frac{1}{2} u_{xr} |p_{mid}| \tag{19}$$

$$I_{yr} = \frac{1}{2} u_{yr} |p_{mid}| \tag{20}$$

where $|p_{mid}|$ is the modulus of p_{mid}, i.e. the amplitude of the sound pressure at the mid-point of the element.

The instantaneous sound intensity at the mid-point of the element is given by

$$\tilde{I} = 2\vec{I_a} \cos^2(\omega t + \theta_p) - 2\vec{I_r} \cos(\omega t + \theta_p) \sin(\omega t + \theta_p) \tag{21}$$

where $\vec{I_a}$ is the active sound intensity vector; $\vec{I_r}$ is the reactive sound intensity vector; and θ_p is the phasor of p_{mid}.

It can be shown that the decomposition can be performed with either the pressure or the particle velocity as the reference without the instantaneous sound intensity results being affected. While the active sound intensity remains unchanged, the reactive sound intensity changes its sign. It is suggested that the sign of the reactive sound intensity is not important provided that the expression for the instantaneous sound intensity is accordingly defined.

Eq. (21) is not the same as the expression given by Jacobsen [13]. This is because of the difference in the definition of the instantaneous particle velocity. Considering that ωt rotates in counter-clockwise direction, we can write the instantaneous sound particle velocity as

$$\tilde{u}(t) = \vec{u}_a \cos \omega t - \vec{u}_r \sin \omega t \tag{22}$$

which is different from Jacobsen's expression

$$\tilde{u}(t) = \vec{u}_a \cos \omega t + \vec{u}_r \sin \omega t$$

in Ref. [13].

The sound pressure at the mid-point of the triangular cross-section was chosen for the derivation throughout the section. The calculation of sound intensities at other locations within the element can be performed in the same manner except that the sound pressure should be evaluated via the interpolation function introduced in the finite element formulation. In the case of non-linear interpolation functions, as is the case with higher order elements, the sound particle velocities are not constant within the element and therefore should be calculated through the interpolation functions in a similar manner.

4. AN EXAMPLE

The example discussed below was studied by Fahy [2] who used the modal summation method to derive the mean intensity distributions in an infinitely long two-dimensional duct when excited by a point monopole source. Such a calculation is, however, very computationally inefficient and only applicable to simple sound fields. Some modifications were made to facilitate the application of finite element modelling for this case. As shown in Fig. 1, only the right half of the duct was chosen as the computation region because of symmetry of the sound field. The point source at the bottom of the duct was approximated by a half circle whose diameter was much less than the width of the duct. It was found that a ratio of 1/100 gave reasonably good results. There is no need to impose the boundary condition of the hard walls of the duct in the calculation as it is inherently included in the Galerkin formulation of the finite element method. The infinitely long duct was replaced with a ρc termination 3 meters from the monopole source, as can be seen in Fig. 2.

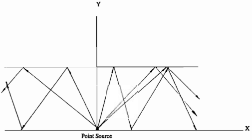

Figure 1. Two-dimensional sound field produced by a point monopole source between two hard walls of infinite length

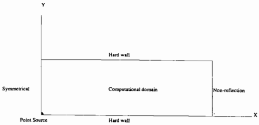

Figure 2. Finite element model of the two-dimensional field shown in Fig.3

The finite element results of sound intensities at the frequency of 165 Hz, calculated from Eqs. (17-20), are shown in Fig. 3. The arrows are scaled proportional to $\sqrt{I}$. The circulatory patterns can be seen in the active sound intensity field in Fig. 3(a). This phenomenon has been studied by some researchers, e.g. Mann et al [14]. It is considered as the direct result of the rotationality of the active sound intensity field. Each circular centre corresponds to a vortex point where the pressure, active and reactive sound intensities are zero. While the formation and the existence of these circulatory patterns in the active sound intensity field are elusive and frequency depen-

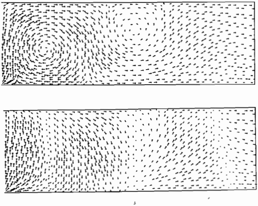

Figure 3. The finite element results of sound intensities. Above: The active sound intensity. Below: The reactive sound intensity.

dent, the authors tend to agree that they are the product of the interaction among different acoustic modes. It is found that the circulatory patterns can not be found in the active sound intensity field at frequencies far below the cut-off frequency of the lowest non-propagating mode for the two dimensional sound field considered here, i.e. 170 Hz. In the neighbourhood of this cut-off frequency, however, these circulatory patterns are evident. The divergence of the active sound intensity is zero anywhere in the sound field, as mentioned in [13,14]. There are no sources or sinks of acoustic energy; the active sound intensity field is, in a mathematical sense, solenoidal. On the other hand, the most distinct feature of the reactive sound intensity is that the vectors are always towards the direction normal to the sound pressure contour lines. It has been stated that the reactive sound intensity field is indeed irrotational, i.e. curl-free. This feature can be identified in Fig. 3(b).

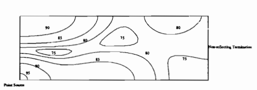

Figure 4. The contours of the sound pressure levels. $p_{ref} = 2.0 \times 10^{-5}$ Pa.

The information that can be drawn from Fig. (3) is, nevertheless, still not sufficient enough to render a constructive suggestion as to how one can make better use of the active and reactive sound intensities. In fact, even the definition of the reactive sound intensity seems arbitrary. In the present paper the reactive sound intensity is defined from the concept of the reactive particle velocity — the particle velocity component 90^o *ahead* of the sound pressure being positive. The instantaneous sound intensity, based on Eq. (21), is valid only for this definition of the reactive sound intensity. Apart from that, there are still other things which are not very well understood. One would hope that further investigation would bring a clearer picture of the complex sound intensity field.

In Fig. 3(a) it can be seen that in the region near the non-reflecting termination the plane wave mode is dominant. From the calculated sound pressure results, shown in Fig. 4, we can see that the two circulatory patterns in Fig. 3(a) correspond to the two troughs in the pressure distribution in the duct. This is expected because at the centre of the circulatory pattern both pressure and the active sound intensity are zero. The reactive sound intensity, on the other hand, shows a different pattern. In the region near the source the reactive sound intensity is very large as compared with the active sound intensity in the same region. The minima of the reactive sound intensity can also be related to the sound pressure troughs in Fig. 4. Near the non-reflecting termination, the reactive sound intensity is small and, as expected, pointing to the direction parallel to the surface. In the left region of the reactive sound intensity field, as shown in Fig. 3, one can see that the vectors in the upper and lower parts are nearly opposite in directions. It is suspected that this is caused by the reflected waves from the hard boundary on the top. In the right region of the reactive sound intensity field this symmetrical pattern disappears. Overall, there are three "sources" in the reactive sound intensity field, corresponding to the three pressure minima in Fig. 4. Apart from the "sink" relating to the real source at the lower-left corner, there are two additional "sinks", corresponding to the two pressure maxima in Fig. 4. While the "sink" above the monopole source could be caused by the reflective boundary on the top, the other "sink" on the right is difficult to interpret.

Figs. 5(1-8) are the vector plots of the instantaneous sound intensities as calculated from Eq. (21). The same scale for the arrow length was used. A time interval of 1/16 of the time period of the sound pressure was chosen. We can see that the instantaneous sound intensity in the near field displays a rather reactive feature — the instantaneous sound intensity vectors change directions after half a period. While in the region near the non-reflecting termination the active sound intensity dominates the pattern. It can be seen that the instantaneous sound intensity does not change direction near the termination during the whole period.

The two circulatory patterns of the active sound intensity, seen in Fig. 3, can not be identified most of the time as a result of combination of the active and reactive sound intensities in the time history. The most interesting phenomenon to notice in Fig. 5 is that the instantaneous sound intensity patterns differ greatly from that of the active sound intensity. This is not surprising as the active sound intensity is but a time-averaged quantity which does not reflect the real nature of acoustic energy flow. In the field close to a non-reflective boundary the instantaneous sound intensity does not change direction in general. For the sound field considered in the present paper, the reactive sound intensity has a far greater effect upon the instantaneous sound intensity field than the active sound intensity.

Overall, the results of the active sound intensity agree well with the analytical results given by Fahy [2] and the results of the reactive and instantaneous sound intensities give a clear picture as to how sound energy flow behaves in a seemingly simple two-dimensional sound field. It is expected that the approach developed will be integrated with computer animation to provide a better insight into the mechanism by which the acoustic energy is radiated, transferred and absorbed in various sound fields.

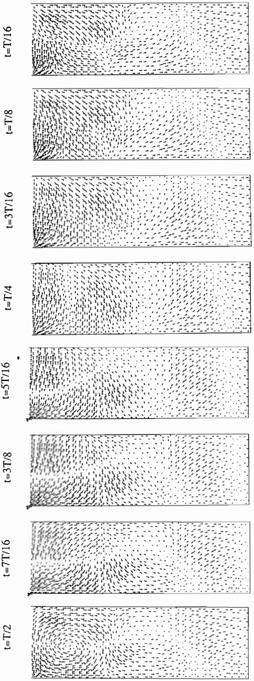

Figure 5. The instantaneous sound intensities. Time interval= T/16.

5. CONCLUSIONS

The numerical evaluation of the instantaneous sound intensity of two-dimensional sound fields was made possible by employing the acoustic finite element approach. The decomposition of the sound particle velocity has proved to be practical for the post-processing of the finite element results to calculate the active and reactive sound intensities. The formulae for the instantaneous sound particle velocity and the instantaneous sound intensity have been derived. Only a simple example was considered in the present paper, the formulation developed, however, can be extended to handle general three-dimensional sound fields. The effects of mean flow and temperature gradients in the sound field can be accommodated by the finite element method. The present paper serves only as a demonstration of the approach developed. Further research should focus on the application of the approach in general acoustic and noise control situations.

ACKNOWLEDGMENTS

The authors would like to thank Dr. Nick Stokes of the Division of Mathematics, Commonwealth Scientific and Industrial Research Organisation (CSIRO) of Australia, for providing the mesh generating routine employed in this investigation. The junior author (QHZ) would also like to acknowledge the financial support from both the Australian International Development Assistance Bureau (AIDAB) and Monash University in the forms of OPRS and MGS scholarships.

REFERENCES

1. Wolff, I. and Massa, F., Direct measurement of sound density and sound energy flux in a complex sound field, *J. Acoust. Soc. Am.* **3**, 317–318 (1932)
2. Fahy, F.J., *Sound Intensity*, Elsevier 1989, p.74, Fig. (4.12)
3. Alfredson, R.J., A new technique for noise source identification on a multi-cylinder automotive engine, *Proc. Noise-Con 77* New York 1977, pp.307–318
4. Cops, A. and Minten, M., Comparative study between the sound intensity method and the conventional two-room method to calculate sound transmission loss of wall structures, *Noise Control Engineering* **2**, 104–111 (1984)
5. Pascal, J.C., Practical measurement of radiation efficiency using the two microphone method, *Proc. Inter-Noise '84* New York 1984, pp.1115–1120
6. Arlett P.L. and Zienkiewicz O.C., Application of finite element elements to the solution of Helmholtz's equation, *Proc. IEE* (12) 115 1968, 1762–1766.
7. Fyfe, Ken R., Coyette J-P G., and van Vooren, P.A., Acoustic and elasto-acoustic analysis using finite element and boundary element methods, *Sound and Vibration* **25**(12), 16–22 (1991)
8. Craggs, A., The use of simple three-dimensional acoustic finite elements for determining the natural modes and frequencies of complex shaped enclosures, *J. Acoust. Soc. Am.* **23**, 331–339 (1972)
9. Kaizer, A.J.M., and Leeuwestein, A., Calculation of the sound radiation of a nonrigid loudspeaker diaphragm using the finite-element method, *J. Audio Eng. Soc.* **36**(7/8), 539–551 (1988)
10. Alfredson, R.J., The finite element method for the solution of the Helmholtz equation in the presence of dissipative surfaces, *Proc. 6th Int. Conf. on Finite Element Methods* Sydney, Australia, 1991, pp.625–631

11. Lamancusa, J.S., Acoustic finite element modelling using commercial structural analysis program, *Noise Control Engineering J.* **30**(2), 65–71 (1988)
12. Rao, S.S., *The Finite Element Method in Engineering*, 2nd edition, Pergamon 1989, p.605
13. Jacobsen, F.A., A note on instantaneous and time-averaged active and reactive sound intensity, *J. Sound Vib.* **147**(3), 489–496 (1991)
14. Adin Mann, I., Tichy, J. and Romano, A.I., Instantaneous and time-averaged energy transfer in acoustic fields, *J. Acoust. Soc. Am.* **82**, 17–30 (1987)

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Swedish Action Plan Against Noise

In Sweden noise has been placed on the political map. Recently cabinet appointed a special Commissioner to work out an integrated plan of action against noise in Sweden, the proposal to be presented before 1 July 1993. It is the view of the Government that noise pollution should be reduced and that each sector concerned should implement noise control measures commensurate with its responsibility for the environmental impact of its activities.

Noise pollution is an international problem and has lasting effects. In a large number of sociological surveys carried out in various countries noise is ranked as one of the most intrusive environmental factors in both work and housing environments. Hearing defects due to noise are irreversible. And there is no prospect in the near future of replacing today's noisy machines by quiet ones.

In Sweden, the responsibility for noise control measures rests with various authorities, e.g. the National Environmental Protection Agency, the National Board of Housing, Building and Planning, the National Road Administration, the National Road Safety Office and the National Board of Occupational Safety and Health. These authorities have issued directions, instructions, guidelines and recommendations relating to noise.

Reduction of noise at source
It is generally most cost effective to deal with noise at source. This applies both to industrial machinery and many consumer products. This question is dealt with in the European Community Directive relating to Machinery (89/392/EEC, OJ no. 183/89) which requires noise information to be declared on all machinery, from household mixers to excavators, that emits levels exceeding 70 dBA at a distance of 1 metre. As of 1993 these requirements will be applied throughout the EC, and Swedish exports to the EC will have to comply with them.

Research and education
There is at present a lack of acoustically trained personnel. This is due to the interdisciplinary nature of acoustics, which requires a knowledge of subjects that are all taught at Swedish institutes of technology, but which are spread out over different study courses. Both research and development and education have been neglected in this area.

Terms of reference
The Action Plan should include proposals in the following areas: noise suppression at source, the external environment, work environments, housing environments, leisure environments and research and education. The aim of the plan should be to reduce the number of people who are exposed to noise disturbance. It should be directed at concrete measures with a realistic prospect of implementation. It should also include preventative measures.

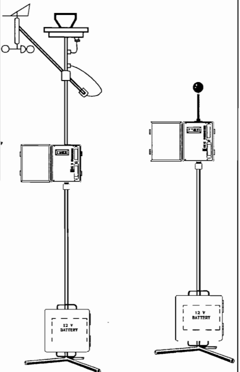
It is important that the problem of noise be taken into account in municipal planning and in environmental programmes. Greater importance must be attached to physical planning as an instrument of environmental policy. Municipalities should be involved in the integrated Action Plan against Noise, and existing planning expertise should be made available to help them in this work.

The investigator should also propose measures to promote the development of housing with adequate sound insulation, taking into account the proposals for simplification of the rules governing housing construction set forth in the report on Government support for the financing of housing.

The Action Plan should also include an analysis of the need of research and development in the field of acoustics and noise suppression with a view to ensuring a sufficient supply of acoustics expertise for industry and the public sector.

One of the investigator's priorities must be to submit detailed cost estimates, including estimates of the cost to the national economy of achieving the goals and implementing the measures proposed by the investigation, as well as proposals as to financing. The investigator should also indicate the social rate of return that may be expected as a result of reducing noise pollution.

Interested parties are invited to submit reports, publications, and ideas to the Commissioner, Tor Kihlman, Department of Applied Acoustics, Chalmers University of Technology, Goteborg, Sweden.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NEWS... NOTES... PEOPLE... BOOKS... PRODUCTS

1992 AAS Conference

With the theme 'Practical Noise Solutions' it was held from Nov 25 to 27 at the 'Old Ballarat Village' conference centre. While the proceedings began on Wednesday with the AAS Council meeting and an opening dinner, they were officially opened on the Thursday morning by the Mayor of Ballarat, **James Coghlan**, and **Graeme Harding's** interesting and colourful address on "The good, the bad and the beautiful of noise control". Then, during the remainder of Thursday, and the Friday morning followed the delivery of 24 varied technical papers by 32 authors. These were available in a nicely bound volume (Available from Publications Officer, Australian Acoustical Society, 15 Taylors Rd, Dural NSW 2158). The conference was concluded with the announcement of **Dr Kerry Byrne** as recipient of the President's prize for his notable paper on 'The Development of Acoustic Volume Velocity Sources', and the Friday barbecue lunch.

While in most respects the Conference was eminently successful, one disappointing feature was a lower than hoped for attendance, particularly of delegates from the home state of Victoria, the total attendance being 74 delegates (NSW 36, Vic 25, Qld 7, WA 4, NZ 1, Hong Kong 1). By contrast, a gratifying number of acoustical firms took the opportunity to mount useful and well-prepared displays of their products, from the best currently available acoustical materials to the latest in measuring instruments.

AAS ANNUAL CONFERENCE - 1993

This will be held 9 - 10 November in Adelaide with the theme **Progress in Acoustics, Noise & Vibration**. The Grand Prix will be held in Adelaide immediately preceding the conference so, for those who are interested, there will be the opportunity to listen to some rather loud sounds.

Abstracts for papers should be submitted by 5 April 1993.

Further information:
AAS Conference, Dept Mech Eng,
University Adelaide, GPO Box 498,
Adelaide 5001,
Tel: (08) 43 9331,
Fax: (08) 224 0464

Mech 94

The theme of this conference is Resource Engineering and it will be held in Perth, 15-19 May 1994. One of the four conferences comprising Mech 94 will be the tri-annual Vibration and Noise Conference. Abstracts should be submitted by 16 April 1993 with the draft paper by 31 August 1993 and camera ready copy paper by 22 December 1993. Expression of interest forms are available from the organisers.

Further information: Convention Manager,Mech 94, AE Conventions, Engineering House, 11 National Circuit, Barton, ACT 2600, Tel: (06) 270 6530, Fax: (06) 273 2918

Rylander Returns

In Nov 1992, the WA Division hosted a special breakfast meeting at which Ragnar Rylander, Professor in Environmental Medicine at Gothenburg University, Sweden, gave an interesting presentation on road traffic noise planning. His studies have shown that annoyance is more closely related to the maximum noise level of the noisiest vehicle than to Leq, and further that an increase in the number of heavy vehicles causes an increase in annoyance up to a break point, above which the level of annoyance remains constant for a constant maximum noise level. This constant level of annoyance also increases with maximum noise level.

This leads to a planning concept for roads whereby the level of annoyance can be controlled by limiting the maximum noise level of the traffic , by barriers, setbacks or vehicle restrictions. In the longer term, this approach would lead to lower noise level limits for vehicles.

Further information can be obtained from Prof Rylander at Gothenburg University, Box 33031, S 400 33, Gothenburg,Sweden.

Bionic Ear

The Victorian Division's final technical meeting and end-of-year function for 1992 was a visit on Nov 13 to the Australian Bionic Ear and Hearing Research Institute, East Melbourne for a demonstration by **Prof Graeme Clark**, and **Messrs Andrew Vandali** and **Richard Vanhoesel** of their work. Hearing help by bionic ear is possible in case of cochlea damage through an inner ear implant used to directly excite the basilar membrane nerve endings by sound impulses relayed to it via a microphone and electronic processor. In spite of limited finance, considerable progress has been achieved in developing this bionic ear which Prof Clark and his assisting staff then described in further detail.

New Journal

Agreement has been reached between seven of the acoustical societies of Europe to commence publication of Acta Acoustica. This journal will seek to publish scientific and engineering papers in any branch of acoustics, noise and vibration. Acta Acoustica will be published six times a year commencing in mid 1993.

Further information: Institute of Acoustics, PO Box 320, St Albans, Herts, AL1 1PZ, UK Tel: int + 727 48195, Fax: int + 727 50553

Break Noise

The Advisory Committee on Vehicle Emissions and Noise (ACVEN) is a national body with representation from transport and environment agencies at a Federal and State/Territory level, plus advisors from Federal energy, industry and health agencies. Where required, the Committee establishes expert working groups, with wider representation, to address specific issues.

ACVEN is aware of growing community concern over the adverse impact of heavy vehicle compression break noise in residential areas - particularly at night. ACVEN representatives were actively involved in the management of a consultant's report commissioned by Austroads into the problem. Austroads is the body representing all the road authorities around Australia.

The report recommends that a new ADR be developed to address the problem in new vehicles and it also makes a number of recommendations for in-service controls. The report's recommendations are expected to be considered by Austroads and it is anticipated that they will be forwarded to the National Road Transport Commission. The Commission is then likely to formally ask ACVEN to act on the report.

SEA

Prof **Nick Lalor** from Institute of Sound and Vibration, University of Southampton and acknowledged expert on Statistical Energy Analysis (SEA) will be visiting the Eastern States in July 1993. During his visit he will be presenting seminars on SEA and its applications.

Further information: Acoustics & Vibration Centre, ADFA, Canberrra, ACT 2600 Tel (06) 268 8241, Fax (06) 268 8276

Award for AAS Member

Dr Dean Patterson has been honoured as 1992 National Professional Engineer of the Year. He is Associate Dean of the School of Engineering, Mathematics and Physics at the Northern Territory University and member of the South Australian Division of the AAS.

Moves

Dr Rob Bullen has recently joined Mitchell McCotter as a Senior Engineer. **Nell Gross** returned to Australia and to Wilkinson Murray in Sydney after spending some time in UK and Europe.

Hearing Rehabilitation Conference

This International Conference will be held at Macquarie University, Sydney from 14 to 18 July. The theme is "Bridging the Hearing Gap" and it will have a strong emphasis on issues of prevention and noise management. Two of the principal speakers will be **Mr Alan Dove** from the Noise Policy Section, Health and Safety Executive, London and **Dr Ross Coles** from the MRC Institute of Hearing Research, University of Nottingham.

Further Information: ICHR Secretariat, GPO Box 128, Sydney, NSW 2001. Tel:9)2) 262 2277, Fax: (02) 262 2323

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NEW MEMBERS

We welcome the following new members whose gradings have now been approved.

South Australia
Subscriber
Mr B Martin
Member
Mr I D M Hillock

Victoria
Member
Mr S Camp (Malaysia)

Books...

MODERN METHODS IN ANALYTICAL ACOUSTICS - Lecture Notes

D.G. Crighton, A.P. Dowling, J.E.Ffowcs Williams, M. Heckl & F.G. Leppington

Springer Verlag, 1992, pp738, soft cover, ISBN 3 540 19737 0.
Australian Distributors: DA Books, PO Box163, Mitcham, Vic 3132. Tel (03) 873 4411, Fax (03) 873 5679. Price A$84.50

This book is a collection of lectures first given 25 years ago to the Admiralty (U.K.) with special emphasis on analytical techniques relevant to sonar. Since then, the lecture notes have been evolved and expanded to cover a wide range of mathematical techniques for applications in advanced research on unsteady mechanical problems encountered in aeroacoustics and underwater acoustics.

The book consists of over 700 pages divided into 26 Chapters which are grouped under 3 themes (parts). Part I deals with the 'Classical Techniques of Wave Analysis' in which 10 topics have been treated. Naturally complex variable theory and generalized functions are covered first before Fourier transforms are introduced. There is also a small section on wavelet transform which has recently attracted much attention. Some methods for asymptotic evaluation of integrals, methods based on Wiener-Hopf technique for solving linear partial differential equations, the method of matched asymptotic expansions and the method of multiple scales have been adequately described and supplemented with useful examples. The last three Chapters (8,9 and 10) in this part are of particular interest to engineers as they introduce the method of statistical energy analysis (SEA), highlight the importance of considering mean energy and momentum effects in acoustics problems and describe the use of numerical methods primarily finite element and boundary element methods.

In Part II under the theme of "The Generation of Unsteady Fields", there are 7 chapters. Various noise source mechanisms including Lighthill's theory of aerodynamic sound are explained in Chapters 11 and 12. Combustion noise is treated in Chapter 13 as part of thermoacoustic sources and instabilities. It is interesting to read here how the combustion process can be altered by the sound waves it generates, thereby generating even more sound. The effects of motion on acoustic sources are described in Chapter 14 with examples on supersonic sound source. Some time and frequency characteristics of propeller and helicopter noise are given in Chapter 15. Chapter 16 is particularly interesting for underwater acoustics as it primarily deals with flow noise, that is noise due to turbulent boundary layers. The effect of coupling between a fluid and a structure, known as the 'fluid loading' effect is described in Chapter 17.

Part III deals with 'Wave Modification' by various means in nine Chapters. The methods for describing the effects of scattering and diffraction are given in Chapters 18 and 19 which is then followed by resonators in Chapter 20. The hydrodynamic and acoustic behaviour in bubbly liquids is introduced in Chapter 21. The effects of reverberation in room acoustics and underwater acoustics and the use of sound absorbers are fairly well explained in Chapter 22. The importance of the discovery of inverse spectral transform and soliton in the last 25 years to nonlinear physics is highlighted in Chapter 23 which are then followed by Chapter 24 on nonlinear acoustics and Chapter 25 on the applications of chaotic dynamics to acoustics. This part is appropriately concluded with a Chapter 26 on anti-sound, believed to be a revolutionary noise control technology of the nineties.

Despite the fact these lecture notes are written by five different authors, the book is fairly coherent and conforms quite well under the central theme of "Modern Methods in Analytical Acoustics". There are good cross references between Chapters in the book. The topics have been well organised and follow a logical sequence. While quite a number of topics covered in this book can be written into a book in their own right and, therefore, cannot be treated in great depth, the presentation of the basic concept is very clear. There are also sufficient references provided to allow the reader to pursue further topics of their own interest. All five authors of the book are leading world experts in their field and it is a pleasure to read about their interpretation of basic concepts and applications of these concepts.

This book is an excellent collection of mathematical techniques that are important in acoustics and is very well written. The authors should be congratulated for their efforts and for the insights they convey to their readers. Personally I have found it very useful to be able to consult a variety of methods in one book. I would certainly recommend this book to postgraduate students and researchers that require the use of analytical techniques. Practising acousticians and engineers in noise control may find the book too mathematical. However, it is certainly a book that should be ordered for every engineering and physics library.

Joseph Lai

Joseph Lai is an Associate Professor in the Department of Aerospace and Mechanical Enginering at the Australian Defence Force Academy, Canberra. He is Director of the Acoustics and Vibration Centre and has undertaken considerable research in the areas of fluid dynamics and acoustics.

NOISE CONTROL IN BUILDINGS

Randall McMullan

BSP Professional Books, 1991, pp.147, soft cover, ISBN 0-632-02717-7, Aust. Distributor: Blackwell Scientific Publications, 54 University St., Carlton, Vic. 3053. Price A$37.95

Randall McMullan is a construction physicist with experience in lecturing and consulting. In the Introduction he states that this book "will help put your efforts, or your money, into constructions which are more effective against noise". This statement establishes that the book is aimed at the competent handyman or professional builder who needs to understand more about construction for noise control in residential buildings.

The book is divided into 4 Sections. Part One provides simple descriptions of acoustic principles and terminology. A few well chosen diagrams and a complete lack of mathematical symbols and equations make this part easy to read. Part Two builds upon the concepts introduced in Part One and gives practical details of common forms of construction. The significance of each element in the construction, in terms of its contribution to the overall noise reduction, is summarised. The constructions are primarily aimed at satisfying the UK Building Regulations for party walls and floors. There are some valuable chapters on remedial work for walls, floors and ceilings but only a small amount on vibrations and machinery noise.

The details, usually found in the early chapters of acoustics textbooks, are left to Part Three "Technical Reference". It is here that the mathematical symbols and equations appear. While the concepts are still presented in a clear manner, it is in this section that there are limitations. For example the concept of "ideal reverberation times" for spaces depending on volume and purpose is included with a brief table of suitable reverberation times for four types of room. However there is no explanation of the reason for suitable reverberation times for rooms used for speech being shorter than for the same room size used for music. Elsewhere the equation for determination of the sound transmission loss for a composite construction is given but the graphical method, which may be easier for the target reader to use, is not presented. The complete lack of a reference list or bibliography could be annoying for the reader who wished to learn a little more about any of the topics mentioned.

The final part, headed "Product File" comprises manufacturer's installation sketches for a number of commercial products. These refer to UK products, however similar products would be available from Australian manufacturers. In the ten pages allocated for this part of the book, only a limited range of products can be presented.

This book is well presented, easy to read and would be valuable for those who wish to know more about constructions for noise control. I feel its main benefit is that no special knowledge is required before commencing to read the book. Those who receive enquiries from the general public and small builders may find it useful to refer the enquirer to the book, thus saving considerable time explaining the basic principles. The lack of sufficient detail and of suitable references would limit the use of the book for professional acousticians.

Marion Burgess

Marion Burgess is a research officer in the Acoustics and Vibration Centre at the Australian Defence Force Academy, Canberra. She has had considerable experience in teaching building acoustics in an academic environment.

New Products...

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The CRL 236A Data Logging Sound Level Meter is a successor to the CRL 236. It includes all the features of the 236 plus vastly increased memory capability, real time clock and improved data transfer software. A specialist 5 millisec short Leq for impulsive noise is available in the variant CRL 236AF. The stored data from the 236A can be downloaded to a MS DOS compatible computer with no deterioration of data quality and any required index can be determined.

Further information: Davidson, 17 Roberna St, Moorabbin, Vic 3189, Tel: (03) 555 7277 Fax: (03) 555 7956

INTAQ
Accelerometers

INTAQ International has introduced a range of accelerometers using a piezo electric polymer (PVDF) as the sensing element. The manufacturing process for these accelerometers is much simpler than for other types of accelerometers and high performance is available at considerably reduced costs. PVDF accelerometers withstand rough treatment, have excellent linearity, a wide dynamic range and are equipped with internal buffer amplifiers so operation with long cables is possible. A special feature is the very high mechanical to electric conversion factor (typically 20 times that for ceramics) with the result that these accelerometers have low mass for their sensitivity.

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The **ACH03-03** is a seismic accelerometer in a stainless steel case, weighs 80 gm and has sensitivity of 1000 mV/g over the range 0.01 to 800 Hz. It is particularly applicable in mining, civil engineering, vehicle movements and low sped servo systems.

The **ACH05-04** is a 4 mA constant current supply unit which has been optimised for use in areas such as machine condition monitoring. It has a sensitivity of 100 mV/g in the range 0.2 to 15kHz. The rugged construction and isolated connections make the device ideal for operating in industrial environments.

The **ACH01-06** is a general purpose ruggedised version of the ACH01-07. It is housed on an electrically isolated stainless steel case and has a sensitivity of 10 mV/g in the range 3 to 20,000 Hz.

Further information: INTAQ International, 9th floor Kyle House, 27-31 Macquarie Place, Sydney, 2000, Tel: (02) 252 4055, Fax (02) 252 4064

ARL
Options for Loggers

Two more optional accessories for the EL 015 range of noise loggers have been recently released. The FPU 001 Field Programmer Unit is a low cost hand held device for in-the-field interrogation and control of the EL 015 noise logger. The unit comprises a 16 character liquid crystal display and a number of control keys. Connection is via the EL 015 port and exisiting users only require a free software upgrade to use the device.

The ALI 001 Audio line Drive Interface permits the audio signal measured by the EL 015 to be transmitted on a cable of 1-2 km in length. A communication link can be incorporated in the cabling which permits access to the current measured noise levels and the recent noise statistics.

Further information: ARL, 169A Pacific Highway, Hornsby NSW
Tel: (02) 482 2866 Fax: (02) 476 4198

NAP
Soundwave

NAP Silentflo has introduced a high performance metal based acoustic lining for ceilings and walls. SOUNDWAVE is designed for acoustic treatment of highly reverberant rooms and chambers where noise reduction and an improved intelligibility of speech and sound is required. Due to its unique profile, it provides significant performance advantages over traditional flat absorptive wall linings. The strength and durability of Soundwave makes it particularly suitable for use in a much wider range of applications than has been previously available , eg indoor sporting activities, industrial workshops, plant rooms etc.

Further information: NAP Silentflo, 58 Buckland St, Clayton Vic 3168,
Tel: (03) 562 9600, Fax (03) 562 9793

N & VMS
Signal Conditioning Amplifier

The CA 10 Signal Conditioning Amplifier combines extensive signal conditioning features and transducer interfacing capability. It is compatible with a wide range of transducers.

Further information: Noise and Vibrations Measurement Systems, PO Box 8197, Stirling St, Perth, WA 6849, Tel: (09) 227 6349, Fax: (09) 227 6342

Publications Received

Journals

Acoustics Bulletin Vol 17, No 4 1992 Contents include "Voice Source and Acoustic Measures in Singing"

Acoustics Bulletin Vol 17, No 5 1992 Issue published for distribution at Euronoise 92, comprises a number of papers detailing noise control policies and issues from both the UK and the EC

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Acoustics Bulletin Vol 17, No 6 1992 Special issue on acoustics in medicine.

* * *

Anales Otorrinolaringologicos V19 No5 1992 (Summaries in English)

* * *

Applied Acoustics V38 No 1 1993 Articles on Equivalent SPL, Musical Horns, Equivalent Level in Traffic Noise, Balance Measure between Choir and Orchestra, Noise Water Supply Installations.

* * *

Australian J of Audiology V14 No 2 1992

* * *

Canadian Acoustics V20 No 3 1992 Includes Proceedings of Acoustics Week 1992 V20 No 4 1992

Chinese J of Acoustics (in English) V11 No 4 1992

* * *

J Aust Assoc Mus Instr Makers V11 No 4 1992

* * *

J Catgut Acoustical Society V2 No 2 (Ser 11) 1992

* * *

Shock & Vibration Digest V24 No 12 1992 (Includes article on "Seismic Performance of Low-rise Wood Buildings" by L A Soltis & R H Falk

V25 No 1 1993 (Includes article On "Measuring Vibration for Machinery Monitoring & Diagnostics" by A el-Shafel) Nos 2,3 1993

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REPORTS

Quarterly Progress & Status Report No 2-3 1992 Royal Institute of Technology, Stockholm

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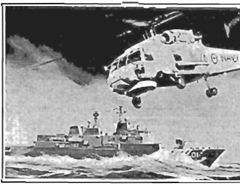
ENCO GAINS RECOGNITION

Environmental Noise Control Pty. Ltd. now two years old, has good reason to celebrate.

Having won an Australian Design Award for the "ENCO Powerpak" in January 92 the company forged ahead to win contracts for OPTUS and Tomago.

The Company's aim to be No. 1 in the Noise Control Industry was realised, when German Diesel Engineering company MTU Australia searched the Country high and low and zeroed in on Enco's manufacturing arm Roy Mammone Pty. Ltd. to manufacture Acoustic Enclosures for the Blohm & Voss designed ANZAC Frigates manufactured at Transfield Amecon's Williamstown facility.

The Acoustic Enclosures are for the main propulsion engines and four power generators. This contract is for nine Frigates, lasting nine years. ENCO Engineers will be responsible for Contract Management and Quality Assurance for the period of the contract.



Anzac Frigate

December brought a further laurel for "ENCO" in the form of "Excellence in Acoustics Award 1992, for design, development and manufacture of "ENCO Powerpak" that had earlier won an Australian Design Award.

Report on 49th and 50th Council Meetings

The 49th and 50th Council meetings were held in Ballarat, Victoria on 25 and 27 November 1992. Preparatory work for both meetings was undertaken by Ray Piesse, Acting General Secretary. The President, Prof Bob Hooker, acknowledged Ray's continued work as Acting General Secretary during 1992 and conveyed to him the appreciation of Council.

The Chief Editor, Acoustics Australia, Dr Howard Pollard, advised Council of his intention to resign later this year. Plans for this role are well in hand and will be announced in due course.

Ken Cook, Chairman of the Council Standing Committee on Membership (CSCM), reported that 24 membership gradings were made in the 12 month period. The Committee comprising Ken Cook, Bill Davern and John Davy was re-elected.

The Registrar, Ray Piesse, reported a net increase of 2 members over the year. The number of elevations to Member grade (14) was substantially less than in the previous year (25). Current membership of Divisions is as follows -

New South Wales	171
Victoria	117
Queensland	46
South Australia	34
Western Australia	45
TOTAL	413

Prof. Anita Lawrence reported on Internoise '92 held in Toronto, Canada. She also attended the INCE Board Meeting at which two technical committees were proposed, namely "Upper Noise Limits in Working Environments (85 or 90 dB(A) and 3 or 5 dB(A) trading)" and "Noise Emission of Flowing Traffic (the effect of the lowering of permissible emission levels for individual vehicles over the last 15 years)". Bruce Gibson-Wilde from James Cook University and Anita Lawrence are the Society's representatives on these technical committees.

Council has been able to reduce the levy on Divisions to 50% of subscriptions compared with the recent 90%. Society ties and scarves are not selling well. Victoria and Western Australia still have considerable stocks for sale.

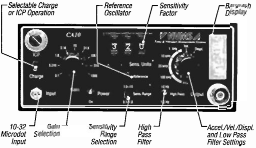
The Acoustical Society of Korea has published a WESTPRAC Newsletter. Although these were sent by our colleagues from Korea in mid 1992, they have only recently arrived at Science Centre and have now been distributed to Division Secretaries.

A National Awards Scheme similar to the excellence in Acoustics Awards developed by New South Wales is to be considered by the next Council meeting.

Marion Burgess, the FASTS liaison officer, recommended that AAS appoint a Competency Based Standards (CBS) representative to deal with CBS matters which, with the advent of competency based training nationally, could impinge on the acoustics profession. The issue of the setting of competency standards by professions is on the national training agenda and is becoming important as the first step in the development of training curricula.

The 1993 Conference is to be held in Glenelg, South Australia, immediately following the Grand Prix. The 51st and 52nd Council Meetings will be held at that time.

Noela Eddington
General Secretary


Selectable Charge or ICP Operation
Reference Oscillator
Sensitivity Factor
Bargraph Display
CA10
10-32 Microdot Input
Gain Selection
Sensitivity Range Selection
High Pass Filter
Accel./Vel./Displ. and Low Pass Filter Settings

ACOUSTICS AUSTRALIA INFORMATION

GENERAL BUSINESS

*** Advertising *A A Subscriptions**

Mrs Leigh Wallbank
PO Box 579, CRONULLA 2230
Tel: (02) 528 4362
Fax: (02) 523 9637

ARTICLES & REPORTS NEWS, BOOK REVIEWS NEW PRODUCTS

The Editor
Acoustics Australia
Acoustics & Vibration Centre
ADFA
CANBERRA ACT 2600
Tel: (06) 268 8241
Fax: (06) 268 8276

PRINTING, ARTWORK

Scott Williams
16 Cronulla Plaza
CRONULLA 2230
Tel: (02) 523 5954
Fax: (02) 523 9637

AA SUBSCRIPTION RATES 1993

	Aust	Overseas
1 year	A$42	A$54
2 year	A$71	A$95
3 year	A$95	A$131

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All enquiries to: Mrs Leigh Wallbank
Tel (02) 528 4362 Fax (02) 523 9637

SOCIETY ENQUIRIES

*** Notification of change of address**

*** Payment of annual subscription**

General Secretary
AAS– Science Centre Foundation
Private Bag 1, Darlinghurst 2010
Tel (02) 331 6920 Fax: (02) 331 7296

Enquiries regarding membership and sustaining membership should be directed to the appropriate State Division Secretary as under:

AAS - NSW Division
Science Centre Foundation
Private Bag 1, DARLINGHURST 2010
Sec: Mr S Connolly
Tel: (02) 922 4199 Fax: (02) 923 1462

AAS - SA Division
C/–Department of Mech Eng
University of Adelaide
GPO Box 498, ADELAIDE 5001
Sec: Mr A C Zander
Tel: (08) 228 5698 Fax: (08) 224 0464

AAS - Queensland Division
C/– Ron Rumble Pty Ltd
27 Station St,
INDOOROOPILLY 4169
Sec: Mr R H Rumble
Tel: (07) 378 9211

AAS–W A Division
PO Box 1090
WEST PERTH 6872
Sec: Mr R L Langford
Tel: (09) 367 6200

AAS - Victoria Division
PO Box 417 Market St PO
MELBOURNE 3000
Sec: Mr C Senese
Tel: (03) 794 0677
Fax: (03) 794 5188

SOCIETY SUBSCRIPTION RATES

From 1 APRIL 1992 membership subscriptions will be as follows:

Fellow and Member	$85
Affiliate and Subscriber	$68
Student	$50

ANNUAL CONFERENCE

Copies of past conference proceedings may be ordered from:

Publications Officer
Australian Acoustical Society
15 Taylors Road, DURAL 2158

ADVERTISER INDEX

Diary ...

CONFERENCES and SEMINARS

- Indicates an Australian Activity

1993

April 27-28, BRISBANE
• NATIONAL SEMINAR NOISE MANAGEMENT IN THE WORKPLACE
Details: Presented by the National Acoustics Laboratories in association with Worksafe Australia. Enquiries to Julie Barrow Tel (02) 412 6928

May 2-5, WILLIAMSBURG
NOISE-CON 93
Noise Control in Aeroacoustics
Details: Noise Con 93,David Stephens, Mail Stop 426, NASA Langley Research Centre, Hampton, Virginia, 23665-5225; tel (804) 864-3640

May 10-13, TRAVERSE CITY
NOISE & VIBRATION CONFERENCE
Details: Society Automotive Engineers, Communications& Meetings, Warrendale, PA 15096, USA

May 31-June 3, ST PETERSBURG
NOISE 93
International Noise and Vibration Control Conference

Details: ^{c}/Malcolm Crocker, Mech Eng, 210 Ross Hall, Auburn University, Auburn, AL 36849-3501, USA

June 25-27, IOWA
INTERNATIONAL HEARING AID CONFERENCE
Details: University Iowa Conference Centre, Memorial Union, Iowa City, IA 52242, USA

June 26 - July 2, BERGEN
13th INTERNATIONAL SYMPOSIUM ON NONLINEAR ACOUSTICS
Details: Prof Halvor Hobaek, Dept Physics, University Bergen, Allegt 55, Bergen, Norway 5007, Tel 0475 21 27 87, Fax 0475 31 83 34

July 6-8, VIENNA
ULTRASONICS INTERNATIONAL 93
Details: U193 Meetings management, Straight Mile House, Tilford Rd, Rushmoor, Farnham, Surrey GU10 2EP, UK

July 6-9, NICE
NOISE & MAN
6th International Congress on Noise as a Public Health Problem
Details: Noise & Man 93, INRETS LEN, Case 24, F 69675, Bron Cedex, France

July 7-9, PARIS
PUMP NOISE AND VIBRATION
Details: Pump Noise & Vibration, SHF, 199 rue de Grenelle, 75007 Paris, France.

July 14-18, SYDNEY
• INTERNATIONAL CONFERENCE ON HEARING REHABILITATION
Details: Hearing Rehabb. Conf Secretariat, GPO Box 128, Sydney, NSW 2001; tel (02) 262 2277, fax (02) 262 2323

July 28 - Aug 1, STOCKHOLM
STOCKHOLM MUSIC ACOUSTIC CONFERENCE
Details: SMAC 93, KTH, Box 70014, S 10044, Stockholm, Sweden; tel (468) 7907873, fax (468) 7907854, email smac93@spech.kth.se

August 24-26, LEUVEN
INTER-NOISE 93
People Versus Noise
Details: INTER-NOISE 93, TI-K VIV, Desguinlei 214, B-2018 Antwerpen, Belgium, Tel (03) 216 09 96 Fax (03) 216 06 89

August 31-September 2, SENLIS
4th CONFERENCE ON INTENSITY TECHNIQUES
Structural Intensity and Vibrational Energy Flow
Details: CETIM, BP 67, 60304, Senlis, France Tel (33) 44 58 34 15 Fax (33) 44 58 34 00

August 30-September 1, LEUVEN
INTERNATIONAL SEMINAR ON MODAL ANALYSIS
Details: ISMA, TI-K VIV, Desguinlei 214, B-2018 Antwerpen, Belgium,Tel (32) 16 28 66 11 Fax (32) 16 22 23 45

September 15-17, BUCAREST
10th FASE
Details: Comm. d'Acoust. de L'Acad Roumaine, Calea Victoriei 125, 71 102 Bucarest, Romania

September 19-22, CARDIFF
7th International Symposium in Audiological Medicine
Details: Dr D Stephens, Welsh Hearing Institute, University Hospital of Wales, Cardiff CF4 4XW

October 4-8, DENVER
Meeting Acoustical Society of America
Details: Acoustical Society of America, 500 Sunnyside Boulevard, Woodbury, NY 11797, USA, Tel: (516) 576 2360, Fax: (516) 349 7669

November 9-10, ADELAIDE
• AAS ANNUAL CONFERENCE
Progress in Acoustics Noise and Vibration Control
Details: AAS Conference, Dept Mech Eng, niversity Adelaide, GPO Box 498, Adelaide 5001, Tel: (08) 43 9331, (08) 207 2177, Fax: (08) 224 0464

December 6-10, PERTH
• INTERNATIONAL CONGRESS ON MODELLING AND SIMULATION
Modelling Change in Environmental and Socioeconomic Systems
Details: Anthony Jakeman, CRES, ANU, GPO Box 4 Canberra ACT 2601 ; tel (06) 249 4742, fax (06) 249 0757, email tony@cres.anu.edu.au

1994

February 27 - March 3, AMSTERDAM
96th AES
Details: Sec, AES Europe Office, Zevenbunderslaan 142/9, B-1190 Brussels, Belgium

May 15-19, PERTH
• MECH 94 - Resource Engineering including tri-annual Australian Vibration and Noise Conference
Details: Convention manager,Mech 94, AE Conventions, Engineering House, 11 national ircuit, Barton, ACT 2600, Tel: (06) 270 6530, Fax: (06) 273 2918

June 5-9, CAMBRIDGE
Meeting Acoustical Society of America
Details: Acoustical Society of America, 500 Sunnyside Boulevard, Woodbury, NY 11797, USA

July 18-21, SOUTHAMPTON
5TH International Conference on RECENT ADVANCES IN STRUCTURAL DYNAMICS
Details: ISVR Conference Secretariat, The University, Southampton, SO9 5NH, England.

August 23-25, SEOUL
WESTPRAC V
Details: Dr Il-Whan Cha, Yonsei University, Seoul, Korea

August 29-31, YOKOHAMA
INTERNOISE 94
Details: Yoiti Suzuki, Sone Lab, Riec, Tohoku Univ. 2-1-1 Katahira, Aoba-Ku, Sendai, 980 Japan. Tel 81 22 266 4966, Fax 81 22 263 9848, 81 22 224 7889 email: in94@riec.tohoku.ac.jp

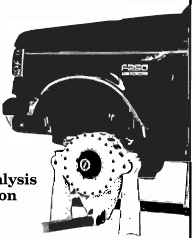
COURSES

In accordance with the recognition of the importance of continuing education, details on course held in Australia are included in this section at no charge. Additional details can be given in an advertiement at normal rates.

1993

CANBERRA
6 - 8 JULY - BASICS OF STATISTICAL ENERGY ANALYSIS
main presenter: Prof Nick Lalor, ISVR, University of Southampton
Details: Acoustics and Vibration Centre, Aust. Defence Force Acdemy, Canberra, ACT 2600. Tel (06) 268 8241 Fax (06) 268 8276

LAUNCESTON
28 JUNE - 2 JULY - UNDERWATER ACOUSTICS
Guest lectureres: Dr Allan Carpenter and Mr Graham Mountford from Aust Sonar Systems.
Details: Short Course Administrator, NC Search, PO Box 986, Launceston, 7250 Tel (003) 26 0703, Fax (003) 26 3790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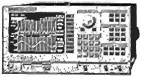

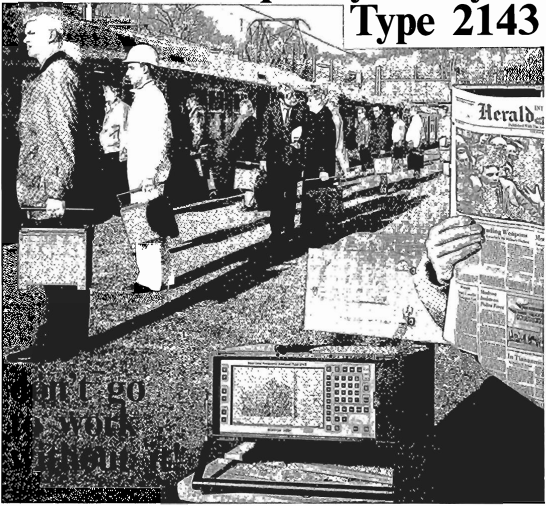
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