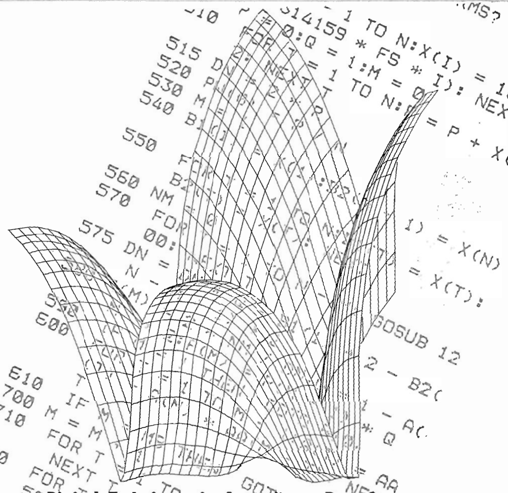
The Bulletin

AUSTRALIAN ACOUSTICAL SOCIETY

Vol. 11 No. 1 APRIL, 1983 Pages 1-48

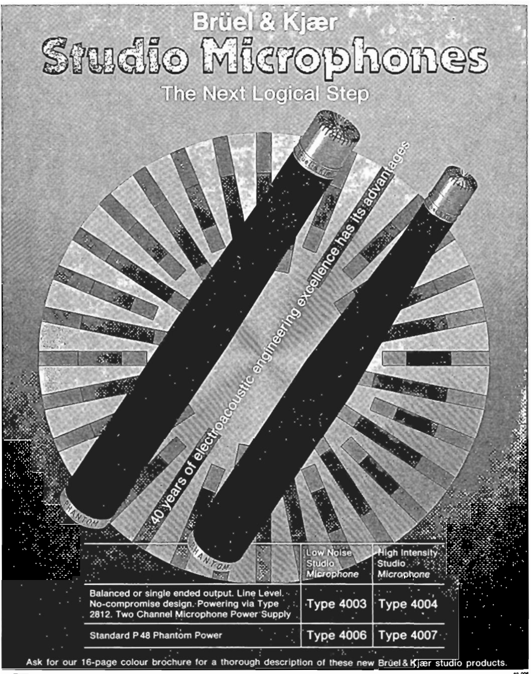


Digital Techniques in Australia — Part 2

Robert Harris

Speech Waveforms in Cerebral Palsy

Janis van Doorn



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BULLETIN OF THE AUSTRALIAN ACOUSTICAL SOCIETY

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EDITORIAL

As a supplement to this issue of the Bulletin the latest edition of the Directory is included, thanks mainly to the guiding hand of Michael Kateifides. The order of the areas of interest of members remains almost the same as for the previous Directory but higher percentages of interest have been expressed this time. For instance, the Big Three categories are (previous voting in brackets): **Noise** 87% (58%), **Architectural and Building Acoustics** 62% (44%), **Measurements and Instrumentation** 49% (33%). Close behind is Shock and Vibration 42% (29%), then Physiological and Psychological 25% (18%), Speech Communication/Transduction 19% (12%), and with less than 15% — Physical Acoustics, Aeroacoustics, Music, Bioacoustics, Ultrasonics and Underwater Sound.

While these figures are a useful guide in planning future issues of the Bulletin (and as a guide to possible attendance at technical meetings) it is not possible to keep the proportion of contributions to a similar scale. Without going into all the reasons, most members with interests in the first three categories appear to be too busy to write articles for the Bulletin, whereas contributions keep coming in from some of the "minor" categories. Of course, that is the way in which a less popular field can generate greater interest and maybe score better next time around. And what do we do with the innovator who carves out a new, promising area of acoustics for him/herself and only generates an initial vote of one?

In passing, we note that, at the time of printing the Directory, there were 18 sustaining members, no fellows and no student members in South Australia. Aren't random facts fascinating?

In this issue we continue our policy of printing short reports as well as the longer technical articles. Included is a report on an acoustical project undertaken by a group of **high school students** with no previous experience in acoustics. We hope that the appearance of this report may inspire members in other educational institutions to send a similar account of activities of their own students.

There are two longer articles in this issue. **Jan van Doorn** describes an important application of digital speech analysis to the study of the speech of patients suffering from cerebral palsy. Jan successfully completed a Ph.D. at the University of New South Wales in 1982 on this topic and is now a lecturer in the Department of Biological Sciences at Cumberland College of Health Sciences in Sydney.

Bob Harris continues his longer/longest article on Digital Techniques in Acoustics. The concluding part will be printed in the next issue. The programmes given in the Appendices will run quite happily on a pocket computer.

The pattern shown on the cover could well be mistaken for a computer simulation of the Sydney Opera House. In fact it is a simulation of the pressure variations in a rectangular room caused by a resonant mode.

HOWARD POLLARD.

FROM THE PRESIDENT

Having recently returned from overseas, where I was fortunate to attend meetings of acoustical societies in France, Britain, Canada and the United States, I am very pleased to find that the Australian Acoustical Society is continuing to flourish. I would like particularly to welcome our new Sustaining Members as well as thanking all of our existing Sustaining Members for their continued support.

At the **Council Meeting** held in December the delays which sometimes occur between the receipt of an application for membership and the admission of the applicant to the Society were again discussed. The procedure is a lengthy one, since, in order to ensure uniformity throughout the Society, an application is first considered by the appropriate Divisional Membership Grading Committee which makes a recommendation to the Divisional Committee. A recommendation is then forwarded to the Council's Standing Committee on Membership which in turn makes a recommendation to Council. If any queries are raised regarding eligibility for the particular grade requested, further delays may occur. In this latter respect I would again like to remind members of their responsibility to the Society when acting as Proposers for applicants for membership; only when they are satisfied that the applicant has the required qualifications and experience for the grade requested should they agree to act (the Membership Information sheet is helpful in this area).

In order to admit applicants for the grade of Member, Affiliate and Student as soon as possible to the Society, *Council has now decided that they will be admitted initially at the grade of Subscriber.* The Federal Registrar has been empowered to admit such an applicant, on the receipt of the application from a Division, and, since it is only necessary for a person to demonstrate a genuine interest in the objects and activities of the Society, this should be a relatively quick procedure. Thus, whilst the application for admission to Member, Affiliate or Student grade is processed, the applicant will become a member of the Society and receive all the normal benefits.

ANITA LAWRENCE.

AUSTRALIAN NEWS

VICTORIA DIVISION

Technical Meetings:

October 21, 1982 —

"THE LOUDSPEAKER/ROOM INTERFACE" presented by **Gerald Riley** of Riley, Barden and Kirkhope Pty. Ltd. Mr. Riley presented a talk on some important characteristics of loudspeakers and also discussed the main acoustical factors of listening rooms and how these affect the perceived performance. The fundamental equations which define the behaviour of an idealised piston loudspeaker were presented and were developed to define the power radiation, directional characteristics and on-axis frequency response. Mr. Riley showed that in the normal listening room the low frequency response is limited in quality by the room modes, while at other frequencies the room absorption plays an important role in the relative intensity of the direct to reverberent sound. To complete the talk, Mr. Riley and Dr. Jim Menadue, also of Riley, Barden and Kirkhope, measured the **axial frequency response of a loudspeaker** in situ using a gating method. This result was then compared with the combined response of the loudspeaker and room.

November 26, 1982 —

"VISIT TO THE ANSETT TEST CELL". A large number of members of the Division and guests turned out for the tour of **Ansett's aircraft test facilities** at Melbourne Airport. The tour commenced with a brief introductory talk on the work being carried out by the Ansett group and this was followed by an inspection of the large aircraft hanger used for the maintenance of the current fleet of aircraft where members were given the opportunity to closely inspect noise abatement equipment fitted to jet aircraft engines. The next part of the tour was of the huge hangar recently built by Ansett to carry out maintenance on the soon to be introduced wide-bodied Boeing 767.

The highlight of the evening was, however, the inspection of the **new jet engine test cell.** Of particular interest to most was the design of the sliding doors. These not only enabled the engines to be brought in and out of the cell, but as they also incorporated large turning vanes, doubled as part of the airway to the sound absorbing splitters as well. After a short drive to the ASTROJET CENTRE, the tour recommenced with an opportunity to look at the **flight simulator** at close hand. The same building also housed flight training equipment including full scale mockups of the passenger cabin areas and computer interfaced pilot control systems. The tour finished with a short film on the capabilities of the new Boeing 767 aircraft. Afterwards, many members took the opportunity to dine at the nearby Top Air Restaurant and to discuss the year's work. Our thanks go to **Bob Lam** for organising the visit and to **Derryn Elliot, Ian Deal** and **Ray Boak** of ANSETT who were our guides and informatively answered any questions.

Programme for 1983:

March 16 — Tour of the National Acoustics Laboratories.

June 7 — Tour of GTV9.

July 19/27 — 11th I.C.A., Paris.

August 17 — "New Parliament House" — L. Challis, Victoria Division AGM.

October 6 — Tour of the Research and Development Facility.

November 25 — A.A.S. Symposium and A.G.M., Melbourne.

JIM FOWLER.

NOTES FROM COUNCIL

There have been two meetings of Council since the last issue of the Bulletin — on Sunday, 12th December, 1982, in Sydney and on Friday and Saturday, 25th-26th February, in Tanunda, South Australia. The following items considered by Council are published for the information of members:

- A programme of exchanging journals with other acoustical societies has been initiated and is being administered through the Editor-in-Chief of the Bulletin.
- The Australian Acoustical Society has recently joined the Science Centre Foundation, based in Sydney.
- Council has obtained advice from the Society's solicitors and accountants regarding the implications of the new Companies Code. It is also concerned with longer-term financial planning so that the Society's assets may be deployed in the best interests of the aims and objects of the Society and its members.
- The resignation of **Paul Dubout** from his position as Chairman of the Council Standing Committee on Membership (on health grounds) was accepted with regret. Council was pleased to learn that Paul will continue to act as Society Archivist. **Ken Cook** has taken over the Chairmanship vacated by Paul Dubout.
- Concern continues about the future of government acoustic laboratories such as the Experimental Building Station at Ryde, N.S.W., and the C.S.I.R.O. Division of Building Research, Highett, Victoria. A report will be prepared on the needs for acoustic research and testing facilities in Australia and forwarded to the relevant Ministers.
- A new, accelerated membership admission procedure has been adopted, in an attempt to avoid the long delays which sometimes occur. All new applicants will be admitted initially as Subscribers by the Federal Registrar, on receipt of the application from the Divisional Committee. Those applying for Member, Affiliate or Student grade will then be considered for grade transfer by the Divisional Membership Grading Sub-Committees

and the application will be dealt with in the normal way.

• A new document *"Guidelines for Admission and Grading of Members"* is published with this issue of the Bulletin and will be available, on request, from Divisional Secretaries. This document sets out clearly the educational qualifications and experience required for membership of the Society in the various grades. It is hoped that all members will read it carefully and that they will follow these guidelines when proposing new applicants for membership. A new application form and information sheet will be issued soon.

• Council has also agreed on a procedure for elevating Members to the grade of Fellow. This procedure is also published with this issue of the Bulletin.

• Finally, **membership certificates** for Fellows, Members, Affiliates and Sustaining Members are being prepared and will be sent to all members in these grades over the next month or so.

Anita Lawrence, President.

AIRCRAFT NOISE SYMPOSIUM

A symposium titled Aircraft Noise to the Year 2000 was held by the N.S.W. Division on Saturday, 11th December, 1982 at the N.S.W. Institute of Technology. Some 85 registrants attended the Symposium and an Exhibition of Acoustic products. The invited speaker was Mr. **Noel A. Peart,** Manager, Noise Technology Division of Boeing Aircraft Company, Seattle, Washington, who delivered an interesting and informative lecture on the progress of noise reduction in aircraft design. Mr. Peart and the eight other speakers were available for a concluding panel discussion on the general topic of aircraft noise, which generated some lively debate. Copies of the Symposium Abstracts are available from the Bulletin at $5.00 each. The Contents page is reproduced below:

J. I. DUNLOP.

AUSTRALIAN RESEARCH INSTITUTE

Resulting from the initiative of a number of corporations and organisations who desire to support scientific and industrial research programmes in Australia the Australian Research Institute has been established.

It is acknowledged that there is existing opportunity to support many areas of research, however, the establishment of an institute to invite applications from individual researchers appears most desirable in that it will attract applications from the broadest possible base and encourage individual endeavour.

The Australian Research Institute is an independent, non-profit organisation, established to promote and assist scientific and industrial research in Australia.

The organisation is governed by a Council of nominees from corporations, professional and other bodies who, through a Research Board, allocate funds for individual or joint research effort.

Applications for research grants are invited by public advertisement and are accepted from individuals or groups of individuals who are able to demonstrate the establishment or proposed establishment of a research programme leading to greater understanding and knowledge. The Institute does not provide physical facilities for the undertaking of research programmes but rather is a supportive organisation distributing grants and maintaining recipient liaison.

Enquiries should be directed to: Dr. Noel King, Director, Australian Research Institute, Suite 204, 720 George St., SYDNEY 2000. Tel. (02) 211-1472.

NEW RESEARCH PROJECT ON NOISE AND VIBRATION GENERATION IN ROLLING ELEMENT BEARINGS AT THE UNIVERSITY OF W.A.

Dr. Gwidon Stachowiak of Imperial College of Science and Technology, London, has recently accepted a University Research Fellowship in Mechanical Engineering at the University of Western Australia. He will be working closely with **Professor B. J. Stone** and **Dr. M. P. Norton** on a research project on the mechanisms of noise and vibration generation in roller contact bearings. Some of the specific aims of the project are:

(i) To investigate experimentally noise and vibration in rolling element bearings under different surface finish conditions.

(ii) To investigate experimentally influence of the cage (material and design) on noise and vibration generation.

(iii) To establish an analytical model of the noise and vibration generation mechanism, based on surface topography.

(iv) To utilise the results obtained to develop a simple and cost-effective machine condition monitoring technique for rolling element bearings.

AUSTRALIAN CENTRE FOR PUBLICATIONS ACQUIRED FOR DEVELOPMENT

"Shortage of current written materials was one of the major impediments to teaching and the advancement of research in the developing countries" said **Mr. Les Johnson,** newly appointed President of the Australian Centre for Publications Acquired for

Development. A group of non-governmental organisations and professional associations have announced the formation of a new voluntary organisation which will aim to promote development initially in neighbouring countries through providing them greater access to books and journals. The organisation will be known as **ACPAD** or the Australian Centre for Publications Acquired for Development.

As a first step an **Interim Council** has been formed and Mr. Les Johnson, former Administrator of Papua New Guinea and Director-General of the Australian Development Assistance Agency, appointed its President. The Interim Council decided to seek association with the Australian Universities' International Development Program (AUIDP), which is providing initial financial support for the Centre.

Mr. Johnson said that the written word could be a powerful tool in the development process. There was available in Australia a great resource of materials such as books, journals and associated library materials which were sources of valuable and current scientific and general information that could be used by developing countries to aid their own development processes. This included, for example, publications from scientific bodies which were prepared to make available, free of charge, back copies of its publications to developing country libraries and institutions offering information services, provided that an effective arrangement for their distribution could be set up. ACPAD aimed to provide a distribution mechanism that would identify and respond to developing country requirements for such materials.

It was expected that other professional associations, libraries and interested groups and individuals would wish to participate in the new scheme. **Further information** can be obtained from the Executive Officer, P.O. Box 35, Monaro Crescent, Red Hill, A.C.T. 2603.

AMENDMENTS TO ARTICLES OF ASSOCIATION OF THE AUSTRALIAN ACOUSTICAL SOCIETY

The following special resolutions were passed at the Annual General Meeting of the Society on 19th September, 1981.

1. The definition of Special Resolution in **Article 1** be amended to read:
   ' "Special Resolution" shall mean a resolution of the Society, Council or Division Committee passed in accordance with the provisions of Article 120.'

Article 120 be amended to read:

"A resolution passed by a majority of not less than three-fourths of the members of the Society, Council or a Division Committee voting in person or by proxy at a General Meeting of the Society or a meeting of the Council or such Committee of which not less than twenty-one days' notice in writing has been given to every member of the Society or Council or such Committee specifying the intention to propose the resolution as a Special Resolution has been duly given shall be a Special Resolution. The provisions as to quorum hereinbefore contained shall apply to any such meeting."

2. Amend **Article 104** as follows:
   Delete — "Five members present in person included amongst whom shall be two representatives at least of each of the two Divisions of the Society (subject always to future alterations under this Article if more than two Divisions are established) shall form a quorum of the Council."
   "Five members present in person included amongst whom shall be one representative at least of each of the four Divisions of the Society (subject always to future alterations under this Article if more than four Divisions are established) shall form a quorum of the Council."
3. Amend **Article 74** by deleting "twenty-one" and adding "eighteen".
4. Replace **Article 12** with the following:
   "The number of Honorary Members shall not at any time exceed fifteen (15) or 3% of the Corporate Membership, whichever is the greater."
5. Replace **Article 14** with the following:
   "It shall not be permissible for a Member of the Society to apply for the grade of Fellow. Unless otherwise provided by these Articles a Fellow shall be entitled to vote at any General Meeting of the Society and at any General Meeting of the Division of which he is a member."
6. Amend the following Articles as indicated:
   Article 56 — Delete "30th day of June" and add "30th day of September" wherever appearing in Article 56.
   Article 57 — Delete "30th day of September" and add "31st day of December" wherever appearing in Article 57.
   Article 65 (2) — Delete "31st day of March" and add "30th day of June" wherever appearing in Article 65 (2).
   Article 103 (g) — Delete "30th day of June" and add "30th day of September" wherever appearing in Article 103 (g).

GRAPHICS 1983

First Australasian Conference on Computer Graphics
31 August - 2 September, 1983
N.S.W. Institute of Technology, Sydney.

This is the first conference of the Australasian Computer Graphics Association. It is held in association with the Institution of Engineers, Australia conference *Computers and Engineering.* It is co-sponsored by the New South Wales Institute of Technology, the Association for Computer Aided Design — ACADS and the Institution of Engineers, Australia.

CONFERENCE SCOPE

Computer graphics cuts across almost all application areas of computer usage. This Conference aims to consider aspects of development, implementation and operation of computer graphics systems from the point of view of hardware and software design, user interfaces and maintenance and management issues.

The Conference will include the following areas: Computer-aided design, Business and management graphics, Numerical control, Medicine, Personal computers, Research, Computer-assisted learning, etc.

Enquiries:
The Conference Manager,
First Australasian Conference on Computer Graphics,
The Institution of Engineers, Australia
11 National Circuit,
BARTON, A.C.T. 2600

SOUNDS OF SIMON AND GARFUNKEL IN COURT

The Equity Court in Sydney spent three days during January considering whether to grant an injunction sought by the Sydney City Council to stop two outdoor concerts by Simon and Garfunkel at the Sydney Sports Ground.

The council claimed that if the concerts proceeded, council resolutions passed in 1980 and 1981 prohibiting outdoor, night "rock" concerts in the Moore Park area would be violated and that residents in the area, upset by previous concerts, would be inconvenienced by noise pollution and crowd behaviour.

The promoters claimed that Simon and Garfunkel were not a "rock" duo and that the Sydney Cricket and Sportsground Trust had allowed the concerts to be held at its venue.

During the hearing before Justice Rogers, video recordings of the Simon and Garfunkel reunion concert in New York's Central Park in 1982 were played and, by way of contrast, a concert by KISS in America. The Sydney Morning Herald for 19 January, 1983 commented: 'There was no foot-tapping, only the promoters moved in rhythm. The legal fraternity remained rock solid. "The loudest part of it all was the clapping and cheering", the judge said after the Simon and Garfunkel tape. He stopped the first song of the KISS video midway.'

A Sydney Morning Herald feature writer had the following to say under the heading: **Song and Dance.** 'Probably the best free entertainment to be had in Sydney at the moment is at the Equity Court of N.S.W., 12th floor, Supreme Court Building, Queens Square. That's where the Sydney City Council is trying to persuade Justice Andrew Rogers to ban next month's Simon and Garfunkel concerts planned for the Sydney Sports Ground. Yesterday the court watched a videotape of Simon and Garfunkel singing Mrs. Robinson, Homeward Bound, America, Kodachrome, and Scarborough Fair. At this point Justice Rogers felt he had heard enough, but the barrister for the concert promoters, Brian Rayment, said enthusiastically that Justice Rogers really must hear them doing Wake Up Little Suzie and Sounds Of Silence.

While these songs were being found on the tape, the court was treated to a video of the American flash-in-the-pan rock group called KISS (not to be confused with the European theatre troupe now performing in Sydney). No one could make out the name of the first song KISS were performing, but in any case, Justice Rogers called a halt halfway through it. He asked, a little plaintively, if he would be hearing any Neil Diamond. He was also amused by a City Council document which said that any concert which used electronically amplified instruments was automatically a rock concert. He asked whether this meant that if

"Oh no", he said, "Why pay good money for tickets when we can hear the concert in the comfort of our own home"!

Luciano Pavarotti used such instruments, he was a rock performer. The City Council's representative said yes. The show continues at 10 a.m. today, and it's open to the public.'

In finding for the promoters, Justice Rogers sought undertakings from them and stated that, if these undertakings were breached, court action would result. The promoters' undertakings include: The employment of an acoustical consultant to monitor noise levels; the erection of a six-metre high, 16mm. particle board barrier on the north-eastern side of the stage; two of the speakers will be not more than 10 metres high and all others six metres or below; that a limiter-compressor be incorporated into the sound system to limit speaker input and that noise be kept below 70 to 75 decibels if a southerly or south-westerly wind of more than .5 knots was blowing at specified points in the Moore Park residential area.

In commenting on the concert itself, the Sydney Morning Herald for 5 February, 1983 reported:

'Council staff with noise-monitoring equipment were on duty at several locations around the grounds last night.

But the Cross family who live right on Moore Park Road, opposite the Showground, were actually disappointed they couldn't hear more.

"We were going to take chairs outside to listen," said Margaret Cross. "But we can't hear a single thing." Inside, all you could hear was their television and that traffic again.

"If we were going to complain about the noise from over there, it'd be when the cricket is on. That's much noisier, but then we'd never complain about that because we love cricket."

In Oatley Road, a City Council engineer was lurking on a balcony, behind a tall tree.

At that time, in that street, you couldn't hear a thing and a couple of doors up from him, a middle-aged visitor was quite disappointed. "We'd been hoping to get a free concert," he said. "But we can't hear a thing and Simon and Garfunkel are such a nice group, aren't they?"

By 7.50 in Moore Park Road, you could hear faint whistling and distant cheers. You could also hear a few birds, voices from the local pub, someone's stereo — and traffic.'

The sound system for this outdoor concert was designed by **Peter Knowland and Associates.** Full use was made of the directional properties of the loudspeaker units which were carefully located so as to irradiate the audience with minimum spillage into the surrounding residential areas. The tone of the subsequent newspaper comments suggests that the design of the sound system was eminently successful. P.S. No court action was necessary against the promoters.

METROSONICS INSTRUMENTS

BWD INSTRUMENTS PTY. LTD. proudly announce that they are now the sole and exclusive distributor of the Metrosonics range of Environmental Noise Measuring Instrumentation.

BWD are a long established Australian manufacturer of high quality electronic test instrumentation well placed to service the requirements of the Noise Measurement Industry.

A recently released Noise Dosimeter is described under New Products.

For further details, contact:
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Miles Street, Mulgrave, Vic. 3170
P.O. Box 325, Springvale, Vic. 3171
Phone: (03) 561 2888
Telex: 35115
Cable: "Oscope"

BWD Instruments Pty. Ltd.
10 Euston Street
Rydalmere, N.S.W. 2116
Phone: (02) 684 1800

Plants that click when they are thirsty

An Australian scientist has found that drought-stricken plants make noises when they are thirsty. The noises are clicking sounds which are caused by the vibration of the tiny water pipelines inside the plants.

Professor John Milburn of the University of New England at Armidale in New South Wales listens to the sounds with a miniature microphone placed in the stems of the plants. He says that the technique could provide breeders with a means of measuring the drought-resistance of new types of plants. It could also help farmers when they are selecting varieties of seeds to grow in arid areas.

Professor Milburn started his experiments with the caster bean plant and plans to eavesdrop on most of the crops grown in Australia.

(New South Wales Business Review No. 10, June/July 1981)

AUSTRALIAN STANDARD — AUDIOMETERS

The Standards Association of Australia has published a new edition of its standard dealing with audiometers used in the measurement of hearing loss.

AS 2586, which supersedes AS Z43.1 and AS 1591.6, was revised as a consequence of changes which occurred in the corresponding IEC standard.

This standard provides for the requirements of five types of audiometers — type 1, 2, 3, 4, and 5, based on the type of test signal they generate, pure tone or speech, or both, and according to the mode of operation, their complexity or range of functions they test, e.g. diagnostic, screening, free-field. Use of audiometers to this standard will assist in the correct measurement of hearing loss for various purposes including hearing conservation, fitting of hearing aids, etc.

Copies of AS 2586 can be purchased from any SAA office at a cost of $8.80 plus a $1.50 postage and handling charge.

PURGING NOISE

Included in the annual merit awards of the Association of Consulting Engineers Australia was an award to **Louis A. Challis & Associates Pty. Ltd.** for their work on the Huntly Steam Purge Silencer, New Zealand. During the commissioning of power station boilers, the purging operation releases extremely high noise energy whose intensity is deafening not only for those in the immediate vicinity, but more significantly at more distant locations as far as many kilometres.

The new Huntly Power Station in New Zealand has been sited on the opposite side of the Waikato River from the township of Huntly. New Zealand Electricity faced a dilemma because of the problem of silencing the purge process not only for the protection of the workers at the station but equally for the peace and amenity of the people in the township across the river. The design developed by Louis A. Challis & Associates allowed the purge cycle to take place without the people in the township being aware of the purging process. The judges considered this a fine engineering solution to what would otherwise have been a most serious environmental problem.

* * *

UPWARD AND ONWARD

Professor **Neville Fletcher,** one of our Consulting Editors, has been appointed to the position of Director of the Institute of Physical Sciences, CSIRO, Canberra. The Institute of Physical Sciences is one of five research institutes within CSIRO and encompasses ten research divisions together with the Australian Numerical Meteorology Research Centre. The Institute is responsible for conducting scientific and technological research in the physical, chemical and mathematical sciences and aims to meet the needs of Australian industry as well as leading to increased understanding of the physical environment.

Neville has previously worked in the CSIRO Division of Radiophysics from 1956 to 1960. In 1960 he transferred to the University of New England and in 1963 was appointed to a Personal Chair in Physics. He has since been Head of the School of Physics, Dean of the Faculty of Science, Chairman of the Professorial Board and a Pro-Vice Chancellor. For some years he was a member of the Australian Research Grants Committee and is currently President of the Australian Institute of Physics and Secretary (Physical Sciences) of the Australian Academy of Sciences. Despite all his commitments, he has found the time and energy to produce a steady stream of research publications in both solid state physics and acoustics.

We wish Neville well in his new position and hope that somehow among the rarefactions of his new administrative world there may still arise the occasional acoustical condensation.

* * *

RETURN TO PORT JACKSON

Two underwater acousticians returned from the U.S.A. to the Royal Australian Navy Research Laboratory (RANRL) in December. They are Drs **David Wyllie** and **Marshall Hall.** David, who has previously worked with sonar systems at the Defence Research Centre Salisbury in South Australia, has spent the last three years as an assistant to the Counsellor for Defence Science at the Australian Embassy in Washington DC. Marshall has spent 18 months working on mathematical aspects of underwater acoustics at the Naval Ocean Systems Centre (NOSC) in San Diego. This posting was in exchange for an 11-month stay at RANRL by David Gordon, a Mathematical Acoustician from NOSC.

* * *

MARION IN TRANSIT

Our Managing Editor, **Marion Burgess,** and her husband Mike, who works at RANRL, have departed for England for a stay of 18 months. Marion is taking 12 months study leave from University of N.S.W. and the remainder of the time as special leave. The Bulletin team will probably stagger from one crisis to another in her absence. We will miss her cool, efficient way of handling our business matters.

* * *

NEW MEMBERS

It gives us great pleasure to welcome as **Sustaining Members** the following bodies: Sound Attenuators Australia, Stramit Industries Ltd., Pitstock Pty. Ltd., BWD Instruments Pty. Ltd. and the Association of Australian Acoustical Consultants.

We also wish to welcome the following new members recently elected to the Society:

N.S.W.: E. J. Anchich, member — C. J. Butler, subscriber — H. F. Johnson, member.

VIC.: D. J. Sanderson, subscriber.

S.A.: P. J. Brook, member — L. H. Zetlein, subscriber.

Q.: P. J. Fishburn, subscriber.

Transfers: G. R. Wild from South Australia to New South Wales — D. Tuck from Victoria to South Australia.

Resignations: The following members have resigned: R. J. Gayler, South Australia — A. L. Ratcliff, South Australia.

* * *

R.B.K. ACOUSTICS PTY. LTD.

Following the **retirement of Gerald Riley** from Riley, Barden, and Kirkhope Pty. Ltd. the company has changed its name to R.B.K. Acoustics Pty. Ltd. The Directors now are Dr. Ron Barden M.A.A.S., Mr. James Kirkhope M.A.A.S. and Dr. Sam Richardson. Readers may note that Sam Richardson is a potential candidate for membership in the Society.

* * *

DAY DESIGN PTY. LTD.

Athol Day M.A.A.S. has established his consulting acoustical and mechanical engineering practice at 2 Tate Place, Lugarno, N.S.W. 2210.

* * *

BOB WEIR JOINS S.A.A.

No, S.A.A. in this instance does not stand for Standards Association of Australia, but Sound Attenuators Australia. **Bob Weir,** once a member of the Victoria Division prior to incorporation, has moved from Dunn Air Conditioning to Sound Attenuators Australia and is re-entering the acoustical field.

* * *

AN AMALGAMATION

Noise Abatement Products Pty. Ltd. and BTR Silentflo Pty. Ltd. have amalgamated under the name NAP Silentflo Pty. Ltd. and are operating from 21 Browns Road, Clayton, Victoria.

NEW BOSS FOR THE E.P.A.

Andrew Hede M.A.A.S. formerly Head of the Socio-Acoustic Research Section of the National Acoustic Laboratories is now Head of the Noise Control Branch of the Environment Protection Authority Victoria. Strictly speaking, Andrew's title is Chief Noise Control Officer. Many members may have heard Andrew being interviewed by Terry Lane on the ABC in late February. Terry observed the title of Chief Noise Control Officer, and commented that the title conjures up the picture of not just a chief, but all the Indians as well.

* * *

A SOUND HOBBY

From Peter Anderson M.A.A.S. in Queensland I have received a clipping from The Brisbane Telegraph with the heading Sound Hobby. The item in the Telegraph concerns **Will Tonisson** an audiologist, who is currently working on his PhD research into the problems confronting deaf children.

The results of his speech research appear to suggest that the reasons one deaf child develops language while others do not are related to the speed at which the child's brain can unscramble distorted messages. "The speed at which the brain processes messages varies enormously in all people, but doesn't constitute intelligence," he said. "Deaf children who develop good speech have highly developed processing abilities and could be identified at an early age."

And what has this to do with a sound hobby? Music is his hobby; and Will has recently released his first country and western record. The songs, "Once I'm Over You" and "I Love You Country Music Man", are his own compositions. They were written on his Camira property amid the ducks, geese and children, far away from the academic trappings of the university.

* * *

OCCUPATION HEALTH COURSE

From Mrs. Margaret Czako of the Department of Adult Education, University of Sydney, we have received a press release describing the 15th course on **Occupational Health for Industry.** The course is a five day non live-in full-time course covering all aspects of occupational health in industry, including the recognition and evaluation of noise hazards. The closing date for enrolment is April 9 and further information can be obtained from Mrs. Margaret Czako at Sydney 692 3177.

* * *

MORE PEOPLE

More people should be mentioned in the Peoples Column and your columnist reminds you of the need for readers to forward to me items for this column. Items should be forwarded to Graeme E. Harding & Associates Pty. Ltd., 22a Liddiard Street, Hawthorn, Victoria, 3122.

GRAEME HARDING.

INTERNATIONAL NEWS

INTERNATIONAL INSTITUTE OF NOISE CONTROL ENGINEERING

The following change of address for the Secretary General has been noted:

The Secretary General
International Institute of Noise Control Engineering
Celestijnenlaan 200 D
B-3030 HEVERLEE-LEUVEN
BELGIUM.

Request for Research Items:

The International Institute of Noise Control Engineering (I/INCE) was founded in 1974 as an organisation dedicated to the application of noise control technology for the benefit of the public. It provides leadership through the organisation of international conferences and seminars on noise control engineering, especially the INTER-NOISE series of conferences. I/INCE also seeks to develop interdisciplinary contacts between Noise Control Engineering and other related fields of work, and promotes international co-operation in research on noise control. I/INCE has twenty member societies in seventeen countries spread over five continents.

As part of its responsibility to promote co-operation in research, I/INCE publishes a **newsletter** which contains news items of international interest. **One of the objectives of the newsletter is to publish a survey of research in noise control in progress in laboratories throughout the world.** These items will appear in a "Research" column of the newsletter. Individuals working in noise control research are encouraged to send such items to the newsletter. It is not necessary to provide details of the results of the research; the scope and subject matter are sufficient. Information should be sent to Dr. A. Cops, Editor, I/INCE Newsletter, Celestijnenlaan 200D, B-3030 Heverlee, Belgium. Information on other I/INCE activities may be obtained from the I/INCE General Secretariat at the same address.

FOURTH INTERNATIONAL CONGRESS OF THE INTERNATIONAL COMMISSION ON BIOLOGICAL EFFECTS OF NOISE

"Noise as a Public Health Problem"

21-25 June, 1983. TURIN (Italy).

Structure of the Congress

The work of the Congress will be conducted in seven sessions. These will be composed of the members of the respective International Noise Teams, together with their invited speakers. The Team thus formed will examine the following topics:

(a) Review of the literature published since the Freiburg Congress,
(b) Scientific papers,
(c) Discussion,
(d) Proposals for a scientific programme in the light of the needs brought out by the papers and during the discussion,
(e) Elaboration of a programme for future scientific activity.

Australian members of the Teams include:
Norm Carter (Team 1: Noise-induced Hearing Loss).
Ray Piesse (Team 2: Noise and Communication).
Further details available from:
Professor G. Rossi, Programme and Planning Chairman, Head, Department of Audiology, 3, via Genova - 10126 TORINO (Italy).

STOCKHOLM MUSIC ACOUSTICS CONFERENCE SMAC 1983

28 JULY to 1 AUGUST, 1983

SMAC 83 is a joint meeting of the CATGUT ACOUSTICAL SOCIETY and the INTERNATIONAL ASSOCIATION OF EXPERIMENTAL RESEARCH IN SINGING. It is organised by the Music Acoustics Committee of the Royal Swedish Academy of Music, with support from the Dept. of Speech Communication and Music Acoustics (head: Gunnar Fant) at the Royal Institute of Technology (KTH) and from the Swedish Acoustical Society. The conference will be held at KTH in the centre of Stockholm.

MAJOR TOPICS. The main topics of SMAC 83 will be ACOUSTICS OF STRINGED INSTRUMENTS and SINGING. The main themes are planned to be
(1) Voice-source/breathing interaction in singing,
(2) Voice-source/vocal-tract interaction in singing, and
(3) Optimising measurement of physical instrument properties: How and What?

SOCIAL PROGRAMME. A series of events is planned for the evenings, including: A concert of winning pieces from a composition contest for the New Violin Octet — an opera performance at the authentic 18th century opera house at Drottningholm — a reception at the Stockholm Town Hall.

Also planned are a MATES' PROGRAMME and a KIDS' PROGRAMME.

SMAC 83 is timed to synchronise with the 11th ICA, which will be held in Paris, 19-27 July, 1983 and the 10th International Congress on Phonetic Sciences, Utrecht, 1-6 August, 1983.

Further information may be obtained from:
SMAC 1983, Dept. of Speech Communication and Music Acoustics, KTH, S-100 44, STOCKHOLM 70, SWEDEN.

CATGUT ACOUSTICAL SOCIETY

20th Birthday

The Catgut Acoustical Society, Inc., with headquarters in Montclair, New Jersey, is one of the more active acoustical societies, with a current membership of 841 including 209 members in 29 countries other than the U.S.A. The Society was officially started with 20 charter members in 1963 as an outgrowth of a small group who shared in violin research with Professor F. A. Saunders during the 1950's. From a starting budget of $165 there is now an annual expense budget of over $20,000, which is met by subscriptions, contributions and income from publications.

The **main categories** in which the Society functions are:

1. Dissemination of information on musical acoustics, violin making, music and related areas.
2. Basic research — active collaboration is maintained among research workers in musical acoustics in Australia, Canada, China, Europe, Great Britain, Hong Kong, India, Japan, Scandinavia, South America, U.S.A. Seven International Technical Symposia have been held, including one in Wollongong at the time of 10 ICA.
3. Applied research — design and construction of the VIOLIN OCTET — continuing development of acoustical testing for improving conventional instruments.
4. Musical development — new compositions and arrangements for the Violin Octet.

5. Education in violin making and testing.

The Catgut Acoustical Society NEWSLETTER which started more or less as a bulletin for members, has become a respected refereed archival journal known throughout the world. A strong effort has been made to keep the NEWSLETTER and the activities of the Society on a broad spectrum relating to interests in music, musicians, violin makers as well as those interested in acoustics.

The current annual subscription is $20.00. **Enquiries** and payment may be made to: Mr. Rex P. Thompson, 10 Rothesay Avenue, HAZELWOOD PARK, South Australia 5066.

FRENCH GOVERNMENT SCIENTIFIC AND PROFESSIONAL SCHOLARSHIPS

The French Government is offering a limited number of scholarships to enable Australians working in scientific and professional fields to visit France for three to six months in the period January to December 1984 to further their experience through observation and participation.

Benefits: (a) Monthly allowance of around 2400FF,
(b) Economy class air travel from France to Australia,
(c) Book allowance,
(d) Registration fees,
(e) Internal travel.

Note: Travel to France from Australia is not provided.

Conditions: Applicants must be: Australian citizens, at least 25 years of age as at 1st January in year of tenure, possess appropriate academic or professional qualifications, have practised a profession for at least two years, have some knowledge of French and present a detailed programme including advice of acceptance from a French institution.

Closing date: 31st May, 1983.

Further information and application forms are available from:

The Secretary,
Department of Education,
(French Government Scientific and Professional Scholarships),
P.O. Box 826
WODEN, A.C.T. 2606

• 11th ICA

The 11th Congress will be held in Paris (Hotel SOFITEL, Paris, July 19-27, 1983. The venue for the opening session will be the main theatre at the Sorbonne, in Paris. GALF (a group of French speaking acousticians), will be wholly responsible for the organisation of the Congress.

The Congress will deal with every aspect of acoustics and will be heralded by three smaller "Satellite" Symposia, held in:

MARSEILLE: July 12-13 on active sound absorption and acoustic feedback control;

LYONS: July 15-16 on acoustic radiations from vibrating structures;

TOULOUSE: Also July 15-16 on oral communication.

Details: 11th ICA, Secretariat, SOCFI, 7 rue Michel-Ange, F.75016 PARIS.

SEVENTH NEW ZEALAND ACOUSTICAL SOCIETY CONFERENCE

THE UNIVERSITY OF CANTERBURY, CHRISTCHURCH, NEW ZEALAND

THURSDAY AND FRIDAY, 7 and 8 JULY, 1983

Call for Papers

This Conference is organised every two years to promote communication in acoustics with particular reference to work being carried out in New Zealand. An important objective is to stimulate interchange between research workers, engineers, architects and planners.

Papers will be selected for presentation upon review of an abstract not exceeding 100 words. **The closing date for receipt of abstracts is 30 April, 1983** and the address is: Professor D. C. Stevenson, Mechanical Engineering Department, University of Canterbury, Private Bag, Christchurch.

In New Zealand and many overseas countries, environmental noise and its effect on people is being neglected. It is suggested that **the theme of the Conference be concerned with all aspects of both indoor and outdoor environmental nois**e in an attempt to bring to the attention of people and politicians, both the short and long term detrimental effects. However, intending contributors are invited to present **papers on any subject in acoustics** as the Conference will be organised into sections. If you think you can make a contribution, however short, please send a summary. It is hoped to organise panel sessions to discuss particular subject areas if sufficient interest is shown. It is not intended to publish proceedings of the Conference but it would be desirable if a printed paper was available as arrangements could be made during the Conference to obtain copies at cost for participants who would like one.

An initial estimate for the cost of the Conference, including morning and afternoon teas, is $25.00.

For further information, write to:

Professor D. C. Stevenson
Chairman, Organising Committee,
Department of Mechanical Engineering,
University of Canterbury,
Private Bag, CHRISTCHURCH.

Future Events

AUSTRALIA

1983

July

Environmental Engineering Conference
Details: The Conference Manager, The Institution of Engineers, Australia, 11 National Circuit, BARTON, A.C.T. 2600.

August 31-September 2, SYDNEY

First Australasian Conference on Computer Graphics
Details: The Conference Manager, First Australasian Conference on Computer Graphics, The Institute of Engineers, Australia, 11 National Circuit, BARTON, A.C.T. 2600.

September 19-22, BRISBANE

Second National Local Government Engineering Conference. Topics include Traffic Control, Structures, Soil Mechanics, Coastal Protection, Water Supply & Sewerage, Urban Planning, Environment Management, Computer Systems, etc.
Details: The Conference Manager, Conference on Local Government Engineering 1983, The Institution of Engineers, Australia, 11 National Circuit, BARTON, A.C.T. 2600.

INTERNATIONAL

1983

May 9-13, CINCINNATI, U.S.A.

Meeting of the Acoustical Society of America.
Chairman: Horst Hehmann, 119 Glenmary, CINCINNATI, OH 45220.

June 21-25, TURIN, ITALY

Fourth International Congress of the International Commission on Biological Effects of Noise
"Noise as a Public Health Problem".
Details: Professor G. Rossi, Program and Planning Chairman, Head, Department of Audiology, 3, via Genova - 10126 TORINO (ITALY).

July 7, 8, CHRISTCHURCH, N.Z.

7th New Zealand Acoustical Society Conference, University of Canterbury, Christchurch.
Details: Professor D. C. Stevenson, Mechanical Engineering Department, University of Canterbury, Private Bag, CHRISTCHURCH, NEW ZEALAND.

July 11-24, COLGATE UNIVERSITY, U.S.A.

Summer Computer Music Workshop. The workshop will be held at the Colgate Computer Music Studio using the Digital Music Systems DMX-1000 real time signal processor. Participants will have individual studio time with programming assistance.
Details: Dexter Morrill, Computer Music Studio, Colgate University, Hamilton, NY 13346.

July 12-14, SURREY, U.K.

Ultrasonics International '83.
Details: Z. Novak, IPC Science & Technology Press, P.O. Box 63, Guildford, SURREY GU2 5BH, U.K.

July 13-15, EDINBURGH

Internoise 83.
Secretariat: Institute of Acoustics, 25 Chambers Street, EDINBURGH EH1 1HU.

July 13-15, DELFT, NETHERLANDS

Joint IUTAM/ICA Symposium on Mechanics of Hearing Processes.
Organiser: Dr. Max Viergever, Department of Mathematics and Informatics, Delft University of Technology, P.O. Box 356, 2600 AJ DELFT.

July 19-27, PARIS, FRANCE

11th ICA—International Congress on Acoustics.
Satellite Symposia:
July 12-13, MARSEILLE, Active Sound Absorption and Acoustic Feedback Control.
July 15-16, LYON, Acoustic Radiations from Vibrating Structures.
July 15-16, TOULOUSE, Oral Communication.
Details: Secretariat SOCFI, 7 rue Michel-Ange, F.75016 PARIS.

July 28-August 1, STOCKHOLM, SWEDEN

Music Acoustics Conference.
Principal themes of the conference will be acoustics of stringed instruments and singing.
Details: Stockholm Music Acoustic Conference 1983, C/o Dept. of Speech Communication KTH, S-100 44 STOCKHOLM 70.

August 1-6, UTRECHT, NETHERLANDS

10th International Congress on Phonetic Sciences.
Contact: Organizing Secretariat, C/o QLT Convention Services, Keizeasgracht 792 1017, EC AMSTERDAM.

August 1-6, TOKYO, JAPAN

4th World Congress of Phoneticians.
Contact: Secretariat, Phonetic Society of Japan, 12-13 Daita-2, Setegaya, TOKYO-55.

September 4-7, LONDON

4th Conference of the British Society of Audiology.
Details: above society, M. C. Martin, The Secretary, 105 Gower Street, LONDON WC1E 6AH.

September, PARIS

Information Processing Congress.
Contact: M. Hermieu, 6 Place de Valois, F 75001 Paris.

October, HIGH TATRA, CZECHOSLOVAKIA

22nd Acoustical Conference on Electroacoustics and Signal Processing.
Preliminary Information: Acoustical Commission of Czechosl. Academy of Science, Secr. Dr. I. Januska, Provaznicka 8, 11000 PRAGUE 1.

November 7-11, SAN DIEGO

Meeting of the Acoustical Society of America.
Chairman: Robert S. Gales, Code 5152, Naval Ocean Systems Centre, SAN DIEGO, CALIFORNIA 92152.

1984

May 7-11, NORFOLK, VIRGINIA

Meeting of the Acoustical Society of America.
Chairman: Harvey H. Hubbard, Acoustics and Noise Reduction Div., NASA Langley Research Center, Langley Station, Mail Stop 462, HAMPTON, VIRGINIA 23665.

August 21-24, SANDEFJORD, NORWAY

FASE 84 — 4th Congress of the Federation of Acoustical Societies of Europe.
Topic: Solving todays noise problems — technological and political aspects; Planning with respect to environmental noise; Acoustics in Condition Diagnosis.
Secretariat: FASE 84, Secr. Gen. J. Tro, ELAB, N-7034 TRONDHEIM-NTH, NORWAY.

October 8-12, MINNEAPOLIS

Meeting of the Acoustical Society of America.
Chairman: W. Dixon Ward, Hearing Research Laboratory, University of Minnesota, 2630 University Ave., S.E. MINNEAPOLIS, MINNESOTA 55414.

October, HIGH TATRA, CZECHOSLOVAKIA

23rd Acoustical Conference on Speech and Music in Environment.
Secretariat: House of Technology, Ing. L. Goralikova, Skultetyho Street, 881 30 BRATISLAVA.

December, HONOLULU, U.S.A.

Internoise 84.

1985

September 18-20, MUNCHEN, GERMANY

Organised by VDI MUNCHEN.
Internoise 85.

1986

TORONTO, CANADA

12th ICA Congress (International Commission on Acoustics).

Speech Waveforms in Cerebral Palsy —An Acoustic Analysis

Janis L. van Doorn
Department of Biological Sciences
Cumberland College of Health Sciences, East Street, Lidcombe, N.S.W.

ABSTRACT: The advent of the digital computer has seen a surge in the use of digital techniques in speech processing, a surge which has been aided by significant advances in the understanding of the acoustics of speech production. Applications of these techniques have been made in areas such as speaker identification and verification systems, and in speech training aids, but to date there has been little interest in the area of cerebral palsied speech. Features of cerebral palsied speech have traditionally been assessed by perceptual means, and so analysis of cerebral palsied speech by a popular digital method called linear prediction has provided some objective measures of acoustic features to complement the perceptual ones. In particular, a spectral analysis using linear prediction was made to estimate the first three resonant frequencies of the vocal tract during continuous speech. Comparison of the time trajectories of these resonances with similar trajectories from fluent speech revealed that resonance transitions in cerebral palsied speech showed some anomalous patterns, were generally over a lower range of frequencies, of longer duration, and showed slower rates of change than the transitions for fluent speech. Conjecture was then made on possible interpretations of these differences in terms of articulatory function.

1. INTRODUCTION

"Cerebral palsy" is the term which is used as a collective description of conditions where there are disorders of the body's motor functions — non-progressive disorders which have been caused by damage to the central nervous system either before, during, or shortly after birth. Cerebral palsy does not refer to disorders such as mental retardation and perceptual and behavioural disorders which may also occur when there has been damage to the central nervous system. It is, however, possible that cerebral palsy may be accompanied by these other disorders.

The motor disorders of cerebral palsy can affect the function of the muscles involved in the production of speech just as they affect the postural muscles. The effect of motor disorders on speech in cerebral palsy is widely varied, from no effect at all through to complete inhibition of speech. Speech production involves the interrelation of respiratory, laryngeal, and articulatory (lips, tongue and jaw) musculature, and any of these areas may be affected in cerebral palsy. A significant proportion of the cerebral palsied population have unintelligible or barely intelligible speech because of disorders in the articulatory muscles, and it is in this area that the research work reported in this article has been concentrated.

The movement of the articulators (lips, tongue and jaw) during speech causes the shape of the vocal tract to change, and this in turn alters the resonance properties of the tract, resulting in the production of different speech sounds. Analysis of the speech waveform which enables the resonant frequencies of the vocal tract during continuous speech to be determined has the potential to provide information about the corresponding articulator movements. However, the "acoustic-mapping" between resonant frequencies and articulator positions during continuous speech is extremely complex, and a great deal of research will be required if it is going to be possible to interpret acoustic data obtained from waveform analysis in terms of the corresponding articulatory movements.

This concept of acoustic-mapping would be a particularly useful one in the area of assessment of articulatory disorders in cerebral palsy. Until now, such assessment has relied solely on perceptual judgment of trained clinicians, and if waveform analysis were able to provide

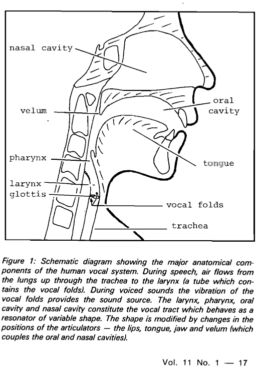

Figure 1: Schematic diagram showing the major anatomical components of the human vocal system. During speech, air flows from the lungs up through the trachea to the larynx (a tube which contains the vocal folds). During voiced sounds the vibration of the vocal folds provides the sound source. The larynx, pharynx, oral cavity and nasal cavity constitute the vocal tract which behaves as a resonator of variable shape. The shape is modified by changes in the positions of the articulators — the lips, tongue, jaw and velum (which couples the oral and nasal cavities).

information about articulatory movements and positions, then resources would be available to assist clinicians by providing a non-invasive and convenient tool for the identification and treatment of speech disorders: a tool which is less subjective than the current perceptual analysis, and yet one which could then be linked to the physiological aspects of speech.

The complex time-dependent nature of the speech waveforms makes its analysis a difficult problem, and it was not until the advent of the sound spectrograph in 1946 that large amounts of speech data could be analysed relatively efficiently. The sound spectrograph has continued to play an extensive role in speech research, even though it has limitations in terms of the type of analysis which can be performed, and in the resolution and range of its display. The advent of high speed digital computers has seen a surge in available speech processing techniques, a surge which has been aided by significant advances in the understanding of the acoustics of speech production (Fant, 1960). An overview of some of the available methods has been presented in Flanagan (1972) and Schafer and Rabiner (1975).

Most of the digital speech processing techniques have as their basis a linear source-filter model for the production of speech: among these is the linear prediction model which has become predominant in both the analysis and synthesis of speech using digital computers. The application of linear prediction of speech to the analysis of handicapped speech has until now been limited to deaf speech, and so the analysis of cerebral palsied speech by this method is a novel approach to the identification of some of the acoustic characteristics of cerebral palsied speech.

2. THE PHYSICS OF SPEECH PRODUCTION

The Physiological Speech Mechanism

Human speech can be considered as an acoustical pressure wave produced by the voluntary physiological movements of the anatomical components which constitute the speech mechanism. These components can be considered as a power supply (lungs), an oscillator (vocal folds), and a resonator (the vocal tract consisting of pharyngeal, oral, and nasal cavities) (see Figure 1). A complex interrelation between these components allows a range of sounds to be produced by the vocal system; sounds which are then organised into structured speech (see Figure 2).

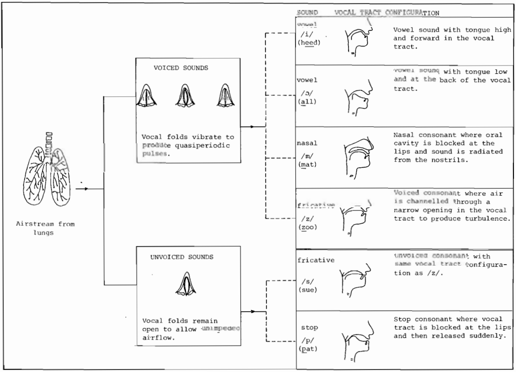

Figure 2: Production of various speech sounds. For voiced sounds, the primary sound source is provided by the vibrating vocal folds. For vowel sounds these quasiperiodic pulses of air are modified by the resonance properties of the pharynx and the oral cavity. For nasal sounds, the nasal cavity is coupled to the oral cavity. For voiced fricatives (e.g. /z/) there is a secondary sound source when air is channelled through a narrow opening in the vocal tract to produce a turbulent flow. For unvoiced sounds, there is no sound produced by the vocal folds, but there is a source in the vocal tract, such as a constriction at some point in the vocal tract (e.g. /s/), or an occlusion which is released suddenly (e.g. /p/).

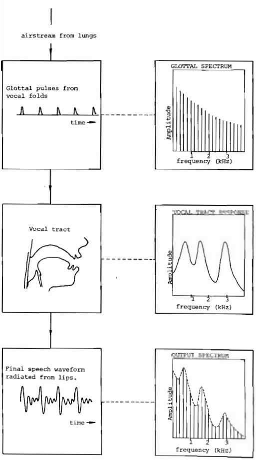

Figure 3: Idealised spectral representation of the production of a voiced sound. The quasiperiodic pulses from the vocal folds have a spectrum which consists of a fundamental frequency (the voice pitch frequency) and its harmonics, which have decreasing amplitude with increasing frequency (approximately 12 dB/octave). The vocal tract frequency response curve has several resonant frequencies (usually three or four below 4 kHz) which causes the source spectrum to be modified so that the harmonics in the vicinity of the resonant frequencies of the vocal tract are predominant in the output speech spectrum.

Spectral Properties of the Acoustic Speech Waveform

The speech mechanism can be treated as a source-filter system, where the source of sound is produced by the interaction of an airstream with the glottis, or with a constriction or occlusion in the vocal tract; or both; and this sound source is then filtered acoustically by the resonance properties of the vocal tract (comprising oral, pharyngeal, and possibly nasal cavities). It is pertinent, then, to consider the spectral properties of this sound source-filter system for the various speech sounds.

The final spectrum of the speech sound at the lips (and perhaps nostrils) is a combination of the source and filter characteristics of the sound system at a particular time. The individual source spectra, the frequency response characteristics of the vocal tract, and the final combination of these two to produce various sound spectra is illustrated in Figure 3.

Models of Speech Production

Successful models of speech production have been developed which assume a linear system consisting of a sound source and a filter which produce an output speech wave. The properties of the source and the filter are assumed to be constant for short time intervals during the production of speech sounds. The linear system can be represented by the simplified diagram shown in Figure 4.

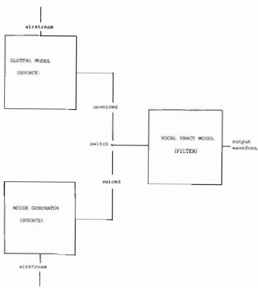

Figure 4: Representation of the vocal system as a source — filter system where the source is either provided by vibration of the vocal folds, or by a noise generator, and the filter is provided by the resonating cavities of the vocal tract.

Various models to represent both the source and the filter systems have been developed. Detailed descriptions of these models can be found in Fant (1960), Flanagan (1972) and Rabiner & Schafer (1978). Models of the source are based on either an acoustic mathematical treatment, or an equivalent transmission line analogue treatment. Models of the filter system (vocal tract) can be divided into several categories: (1) models which make a direct acoustic analysis of sound waves in the vocal tract, (2) models which use a transmission line analogue of the acoustic properties of the vocal tract, and (3) "terminal analogue" models where the vocal tract is represented by a system which has spectral characteristics which are controlled by a set of parameters which are in some way related to the process of speech production, but do not directly represent the physics of speech production. Various digital models of speech production come into this last category, including the application of the linear prediction model to speech — a model which has been particularly successful in analysis and synthesis of speech, and the model which was used to carry out the speech processing in this project.

3. THE LINEAR PREDICTION MODEL OF SPEECH

Linear prediction techniques in the area of speech processing have become widely used since their introduction in 1970. Since that time there have been numerous reports in the literature illustrating applications of linear prediction coding of speech. These applications include pitch detection and measurement, spectral analysis, vocoders, speaker verification systems, speaker identification systems and speech training aids for the deaf.

Fundamentally, the linear prediction model of speech assumes that in a digitised speech signal, a single sample can be estimated as a weighted linear combination of a certain number of immediately preceding samples; i.e.

$$s'_n = \sum_{k=1}^{p} a_k s_{n-k},$$

where s_n is the *n*th speech sample, s'_n is the estimated value, a_k ($k = 1, \ldots, p$) are the weights and p is the number of past samples.

This linear prediction formulation of the speech waveform is equivalent to treating the composite effects of the glottal excitation (source), vocal tract shape (filter) and lip radiation as an all-pole filter with transfer function

$$H(z) = G \Big/ (1 - \sum_{k=1}^{p} a_k z^{-k}),$$

where G is the gain of the filter.

In other words, the speech waveform is modelled as the output of a linear all-pole filter.

The all-pole filter model for speech production is closely allied to the speech synthesis model where speech is modelled as the output of a linear time-varying system excited either by quasiperiodic pulses (for voiced speech) or a noise source (for unvoiced speech). The all-pole model is an accurate representation of non-nasal, voiced sounds, although for other sounds, such as nasals (e.g. /n/, /m/) and fricatives (e.g. /s/, /f/), the transfer function should also contain zeros as well as poles, and so the all-pole model is not as accurate for these sounds.

POLES AND ZEROS

In z-transform notation, the transfer function of a linear system can be represented by

$$L(z) = A(z)/B(z)$$

where A(z) and B(z) are polynomials in z. The roots of the polynomial A(z) are referred to as the **zeros** of L(z), while the roots of B(z) are referred to as the **poles** of L(z), that is, when B(z) = 0, L(z) tends to infinity.

The occurrence of poles is related to the resonant frequencies of the system.

Analysis of speech using the linear prediction model then becomes a problem in estimating a set of coefficients a_k that gives optimal spectral estimates of the speech signal. Each segment of speech for which a_k is calculated must be short enough that the filter parameters can be considered to remain unchanged (usually 10–20 ms). The optimal estimate of a_k is found by using a least squares technique to minimise the total squared error E between the actual and the estimated speech signal for the duration of the analysis segment. E is given by

$$E = \sum_n (s_n - s'_n)^2 = \sum_n (s_n - \sum_{k=1}^{p} a_k s_{n-k})^2$$

Putting $\partial E/\partial a_k = 0$ for $k = 1, \ldots, p$ leads to a set of p equations in p unknowns which can be solved for a_k, $k = 1, \ldots, p$. The calculated parameters a_k can be used in a variety of ways to estimate speech characteristics such as the reflection coefficients of the vocal tract, the resonant frequencies of the vocal tract, and the vocal tract area function, depending on the particular speech processing application required.

In the generalised approach to linear prediction described above, the exact range of summation of the total squared error, and the definition of the signal s_n in that range have not been specified. Two major methods of linear prediction analysis have been derived from different specifications of the summation range, and the definition of the waveform segment s_n. These methods have become known as the autocorrelation method and the covariance method (see Figure 5).

LINEAR PREDICTION MODEL FOR SPEECH

$$s'_n = \sum_{k=1}^{p} a_k s_{n-k}$$

$$\text{Error } E = \sum_n (s_n - s'_n)^2$$

To estimate coefficients a_k solve $\partial E/\partial a_k = 0$ for $k = 1, \ldots, p$

Covariance Method	*Autocorrelation Method*
Range of summation of signal s_n: $0 \le n \le N-1$	Range of summation of signal s_n: $-\infty < n < \infty$
Definition of signal s_n does not require special definition outside the range $-p \le n \le N-1$	Definition of signal $s_n = \begin{cases} s_n w_n & 0 \le n \le N-1 \\ 0 & \text{otherwise} \end{cases}$
$\partial E/\partial a_k = 0$ leads to solving $\phi_{i0} = \sum_{k=1}^{p} a_k \phi_{ik}$ where $\phi_{ik} = \sum_{n=0}^{N-1} s_{n-i} s_{n-k}$	$\partial E/\partial a_k = 0$ leads to solving $R_i = \sum_{k=1}^{p} a_k R_{i-k}$ where $R_i = \sum_{n=i}^{N-1-\lvert i \rvert} s_n s_{n+\lvert i \rvert}$

Figure 5: Comparison of the two main formulations of linear prediction analysis of speech known as the autocorrelation method and the covariance method. Both methods stem from the same basic model whereby a sample from the digitised speech signal is approximated by a linear weighted sum of a number of previous samples. The weights are estimated by a least squares technique which minimises the total error signal over the analysis frame (usually 10-20 ms in length). The methods differ in the range of summation of the signal, and its definition over the analysis frame, leading to slightly different estimates for the weights.

Apart from the different formulations of the general method, there are other computational details which must be assessed for any particular application of speech processing — the sampling rate for digitisation of the speech signal, the necessity for pre-emphasis of the signal, the duration, shape and position of the analysis frames within the digitised speech signal, and the order of the linear predictor filter. The decisions about all of these factors are necessarily empirical to a large degree, and can be made on the basis of information gleaned from the literature and, where necessary, by experimental comparisons of different conditions.

4. ANALYSIS OF CEREBRAL PALSIED SPEECH

The acoustic analysis of cerebral palsied speech reported here actually constitutes part of a larger project where the relationship between the acoustic speech waveform and simultaneously recorded electromyographic signals from speech articulator muscles is to be investigated for cerebral palsied speech.

The aim of this particular study of acoustic features of the speech waveform is to establish comparative differences in the acoustic speech signals for fluent and cerebral palsied speakers, concentrating on features which are significantly affected by the movements of the speech articulators, so that these acoustic features can eventually be related to the electromyographic signals recorded during articulator movements involved in speech.

In particular, the values of the resonant frequencies of the vocal tract (referred to as formants) depend on the shape of the vocal tract, which in turn is determined by the relative positions of the articulators (lips, tongue and jaw). Hence, these resonant frequencies are significantly altered by movements of the articulators. During continuous speech, the positions of the articulators are continuously changing in a complex way, and so too are the frequency values of the formants of the vocal tract. Using linear prediction analysis it is possible to construct a time trajectory of the formant frequencies during continuous speech.

From speech studies it has been found that the first three formants are primarily responsible for the intelligibility of voiced speech, and in view of any future practical application of this research to aid the intelligibility of cerebral palsied speech, the project was concentrated on a linear prediction analysis of speech which provided the trajectories of the first three formants during a test sentence* where a large range of articulator movement was required.

Formant trajectory studies

Formant trajectories are a reflection of the dynamic nature of the speech waveforms during continuous speech. In this particular study it was evident from inspection of the formant trajectories for the first three formants of the test sentence that there were certain transitional features in the first and second formant trajectories which were consistently present at particular instances in the sentence for all of the fluent subjects (Figure 6). These formant transitions were investigated

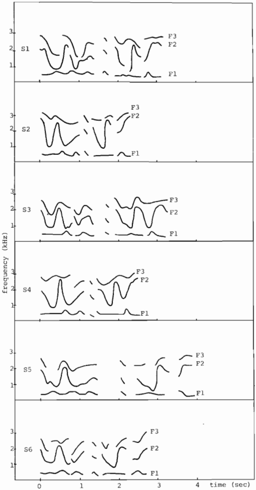

Figure 6: Smoothed contours showing the time trajectories of the first three vocal tract resonances (labelled F1, F2, F3) during a single utterance of the sentence "Do all the old rogues abjure weird ladies?" for six fluent subjects (S1 to S6). Similar transitional features (especially in F1 and F2 contours) corresponding to particular phonetic features in the sentence are found to be present for each subject.

in detail, and compared with the corresponding transitions in the formant trajectories for the cerebral palsied speakers, using the following criteria: (1) the formant pattern during the transitions (i.e. whether the formant frequencies were rising or descending, and the interrelationship between the first and second formants), and, provided that the transitions for the cerebral palsied speakers had similar patterns to the fluent patterns, (2) the durations of the transitions, (3) the frequency range of the transitions, and (4) the maximum rate of change of the formant frequency during each transition.

These criteria were chosen because there is some evidence that each of them is related in a complex way

* The test sentence used was, "Do all the old rogues abjure weird ladies?".

to the dynamic movements of the articulators during continuous speech (Stevens and House (1956), Stevens, House and Paul (1967), Ohman (1967)): the formant pattern appears to be an indicator of the correct movements of the articulators, the duration of the transitions would appear to be an indication of the time taken for the articulators to move from one position to another, the frequency range of the formant transition could be interpreted in terms of the range of tongue movement (in both the inferior-superior and anterior-posterior dimensions), and the maximum rate of frequency change during a transition appears to be an indicator of the relative velocity of the articular movements. These relationships are tenuous, complex, and have not been fully investigated, although many speech researchers consider that an understanding of these dynamic acoustic-relationships would be a highly significant step in helping to unravel some of the mysteries of the production and perception of speech.

Results of formant trajectory studies

From this investigation, the most frequently occurring abnormal acoustic effects found in the speech of cerebral palsied speakers, and possible physiological interpretations can be summarised as follows.

The formant patterns for cerebral palsied subjects for some of the transitions deviated from the patterns seen for all of the fluent subjects. Each cerebral palsied subject had individual anomalies in their individual patterns, and remarkably, for any one subject, these anomalies were generally reproducible over several repetitions of the test sentence. These anomalous patterns could be considered as manifestations of consistently incorrect articulatory movements in cerebral palsied speech.

For those transitions which had patterns similar to the fluent patterns, measurements showed that

(1) the durations of the transitions for cerebral palsied speakers were generally longer than the durations for fluent speakers, and this could probably be linked to slow articulatory movements from one position to another.
(2) the frequency ranges of the transitions were reduced for the cerebral palsied subjects when compared with the fluent subjects, and this appears to be associated with a reduced range of tongue movement (especially anterior-posterior movements), and
(3) the maximum rates of frequency change during transitions for cerebral palsied subjects were reduced when compared with the fluent speaker rates, which is probably a reflection of reduced rates of articulatory movements (Figure 7).

It is interesting to surmise on the perceptual effects of the acoustic abnormalities. It would seem that the inappropriate transition patterns found in cerebral palsied speech would be perceived as incorrect sounds. Increased duration and slower rates of frequency change during transitions can also produce perception of incorrect sounds (Liberman, DeLattre, Gerstman and Cooper, 1956). Hence, the long durations and the slow rates of transitions found here could well have a significant effect on the intelligibility of cerebral palsied speech, in addition to incorrect sounds produced by incorrect articulatory placement.

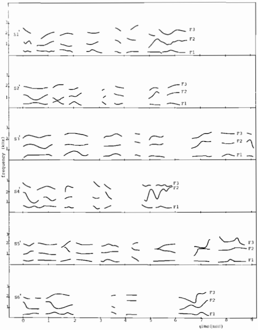

Figure 7: Smoothed contours showing the time trajectories of the first three vocal tract resonances (labelled F1, F2, F3) during a single utterance of the sentence "Do all the old rogues abjure weird ladies?" for six cerebral palsied subjects (S1' to S6'). A slower speech rate than for fluent speech is clearly evident. Anomalous or omitted transitional features are present for some subjects and slower frequency transitions over a smaller frequency range were also measured.

5. FUTURE DIRECTIONS

Both the analysis technique developed for this project, and the results of the analysis have provided a basis for further research. Firstly, in relation to the linear predictive analysis of speech, it would be possible to pursue a theoretical line of research to develop an improved model for speech production which more closely represents physiological features, taking into account such factors as losses in the vocal tract, and zeros in the transfer function associated with the glottal source and with coupling to the nasal tract; and indeed continued work in this general area of speech research has been suggested from several quarters (e.g. Markel and Gray, (1976), Flanagan, (1972), Rabiner and Schafer, (1978). Another area of research related to analysis techniques which could prove useful, particularly in clinical application, is the development of real-time linear prediction analysis of speech using microprocessors, which would require an optimal compromise between the accuracy of the analysis and its computational efficiency. The recent rapid development of technological research into the use of microprocessors in human-to-machine communication has opened the possibility of accurate real-time linear prediction analysis and synthesis systems which could be used in clinical applications.

For example, the recent development of improved speech analysis techniques means that these techniques could be applied to dysarthric speech in cerebral palsy, to assist in the assessment of specific disorders, a task which is presently reliant almost solely upon perceptual judgments of trained specialists. It will still be necessary to establish the importance of specific objective acoustic measures in relation to their role in speech perception, because it is the lack of intelligibility resulting from speech disorders which leads to communication difficulties in cerebral palsy, and so it is important to know what acoustic features play a significant part in speech intelligibility. Speech synthesis makes[7] such an investigation viable because artificial means can be used to alter various acoustic parameters, and hence the effects of these alterations on intelligiblity can be observed.

Secondly, with regard to the results obtained from this study, a natural extension of the project (which was designed into the initial experiment) is the correlation of formant contours for the test sentence with the electromyographic signals which were simultaneously recorded from fourteen lip, tongue, and jaw muscles, so that information can be gathered about the effect which individual muscles have on each of the formants during continuous speech, thus providing a data bank for dynamic articulatory-acoustic mapping for both fluent and cerebral palsied speech, using electromyographic activity as an indicator of articulator movements. The correlation of electromyographic and acoustic data could well lead into areas of research on the aetiology of disorders in cerebral palsied speech. Several researchers have already developed thoughts on possible causes of motor dysfunction in the speech musculature in cerebral palsy (e.g. Kent and Netsell (1978); Harris (1976)) and information gained from the correlation of electromyographic activity and acoustic features should shed further light in this direction of research. Following from this, any study of physiological disorders, such as those found in cerebral palsy, must enhance the understanding of normal physiological function, and this applies equally to speech as to other functions. Consequently, a study of disorders in cerebral palsied speech and their causes may well enlighten us on some of the mysteries of motor commands and their eventual conversion to a continuous speech waveform in normal connected speech.

Not only have the results of this project opened up possibilities for a continuation of fundamental research, but they have also indicated possible applications to clinical uses and communication aids in cerebral palsy. For instance, if an articulatory-acoustic map could be developed it would enable interpretation of acoustic data in terms of articulatory disorders, which would be of assistance in speech therapy, and could also be useful in the form of a visual display which represents in some way articulatory parameters which may require adjustment for the correct articulation of sounds and words.

As previously mentioned, the powerful analysis tool of linear prediction lends itself to the possibility of real-time on-line analysis of speech in a microprocessor environment. This opens up numerous application ideas, ranging from a modest home training device for speech improvement, where speech sounds can be analysed, and a representation of the vocal tract (such as the area function) displayed visually, and compared with the required sounds, which could be generated both as an audio signal and as a visual display, through to ambitious ideas such as a speech translator for cerebral palsied people who have barely intelligible speech. Some of the findings from this comparative study of formant trajectories during continuous speech could provide the basis for development of a sound translation map for individual cerebral palsied speakers.

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Digital Techniques in Acoustics

Part 2: Analysis of Stored Data

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ABSTRACT: The most common techniques that can be used to analyse sampled and digitised data are surveyed and several computer programs supplied to illustrate how the techniques can be implemented.

1. INTRODUCTION

Analog signals have been sampled, digitised, and stored with the Nyquist criterion being satisfied (sampling frequency is at least twice the highest frequency present in the signals) and the number of binary digits employed sufficient to give the required accuracy. To extract further information from the stored data, various calculations are carried out using discrete formulations of mathematical parameters. The quantities calculated for a single variable can be a simply computed parameter such as the mean value or a parameter such as the power spectral density. When two or more different signals are being studied it is often desired to know the nature of the relationship between the signals and this can be realised by a calculation of either the cross-correlogram or the cross-spectrum which leads to a calculation of the transfer function.

There are many types of calculation that can be carried out on stored data so only those which are considered the most customary techniques will be considered. There will also be a limited discussion of new techniques under development. Some computer programs written in the BASIC language which can be implemented on a microcomputer are included as appendices so that the reader can become familiar with how a discrete formulation is transposed into a useable program.

For the statistical parameters to be useable, two requirements should be met; that the signal be stationary (statistical properties of a sample of a signal at one time be unchanged by a shift in the time origin) and ergodic (signal observed be not dependant on its beginning). The ergodicity requirements may be relaxed, however, the signal should be stationary or the sample interval chosen so that the signal may be considered stationary over the interval (sometimes referred to as the quasi-stationary approach).

2. PARAMETERS FOR ONE VARIABLE

2.1 Mean Value

The mean or average value is simply obtained by adding together all the values and dividing by the number of values. If the values are x_i where $i = 1, 2, 3 \ldots N$, and $\bar{x}$ denotes the mean, then

$$\bar{x} = (1/N) \Sigma x_i \quad (1)$$

where the summation over i is from 1 to N.

If a sequence of data points has a non-zero mean, this is often subtracted before any further computations are carried out. The computer program in Appendix I shows how the mean is calculated.

The calculation of the mean value can be used as a first test for stationarity since the mean value for a stationary signal does not depend on when a sample is taken, so that

$$\Sigma x_i = \Sigma x_{i+M} \quad (2)$$

where the summation over i is from 1 to N.

The mean defined by equation (1) is a time average. However, due to computer storage requirements, the maximum value for N may be limited, so an alternative is computing many different values for the mean and then averaging these results (ensemble averaging). Ensemble and time averaging are equivalent for signals which are stationary and ergodic.

2.2 Variance and Standard Deviation

The extent to which a signal fluctuates can be expressed by the variance which is the averaged squared deviation about the mean value. If there is no correction for the mean then the mean square is calculated. The square root of the variance is the standard deviation and is the same as the rms (root mean square) value for a signal with zero mean. If σ is the standard deviation, and σ^2 is the variance, then

$$\sigma^2 = [1/(N-1)] \Sigma (x_i - \bar{x})^2 \quad (3)$$

where the summation over i is from 1 to N, and $N-1$ is used instead of N because one degree of freedom has been lost. (For N large one can neglect the -1). The variance is a measure of the total energy associated with variations about the mean value.

The next level to test the stationarity of a signal is with respect to the variance. Since the variance involves the squaring of the values it is referred to in statistical parlance as a second-order moment, so that if the variance is independent of the choice of time origin, the time series can be called stationary to the second-order. The computer program in Appendix I shows how the variance is calculated.

2.3 Kurtosis

The mean is the first-order moment and the variance is the second-order moment. An n-order moment can be defined as

$$(1/N) \Sigma (x_i - \bar{x})^n \qquad (4)$$

where the summation over i is from 1 to N.

A parameter based on the fourth-order moment (n = 4), which has been shown to be important in the assessment of mechanical integrity, is the kurtosis which has a value of 4 for most normal distributions and a value different when a loss of mechanical integrity resulting in mechanical impacts occurs. The kurtosis is defined as the fourth-order moment normalised by the second-order moment:

$$[\Sigma (x_i - \bar{x})^4] / [\Sigma (x_i - \bar{x})^2]^2 \qquad (5)$$

A computer program to calculate the kurtosis is included in Appendix I.

2.4 Probability Density Function

Further details on the nature of a signal can be ascertained by computing the probability density function (pdf) which allows the probability that a variable lie between two limits to be determined from an area under a graph. A typical pdf graph is shown in Figure 1, and the probability that x lies between x_1 and x_2 is given by the shaded area under the

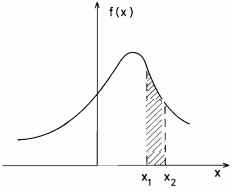

Fig. 1. Typical probability density function graph.

graph. Once the pdf f(x) is known, then the mean and mean square can be simply computed by integration

$$\bar{x} = \int x f(x) dx \qquad (6)$$

$$\text{mean square} = \int x^2 f(x) dx \qquad (7)$$

where the limits of the integrations are from $-\infty$ to $+\infty$. The construction of the pdf from digitised data is simply a sorting of the values into amplitude levels and then counting how many values occur at a specific amplitude. The computer program of Appendix I provides a method of computing the pdf.

2.5 Autocorrelation

The autocorrelation expresses the relationships within a signal in the time domain by multiplying a delayed version of the signal with itself and then averaging (integrating) for different values of the delay. If τ is the delay and T is the averaging time, then the autocorrelation is given by

$$R_{xx}(\tau) = (1/T) \int x(t) x(t+\tau) dt, \qquad (8)$$

where the integration is from 0 to T.

A correlogram is useful in ascertaining whether a deterministic signal such as a sine wave is buried in random noise since the sine wave continues to relate to itself for increasing values of the delay while the noise does not. The autocorrelation can therefore be used as a basis for signal recovery. The autocorrelation can also be the starting point for the calculation of the power spectral density.

The discrete version of equation (8) when $\triangle t$ is the time between samples, is

$$R_{xx}(i\triangle t) = [1/(N-1)] \Sigma x_j x_{j+i} \qquad (9)$$

where the summation over j is from 1 to N − i and i takes values from 0 up to a suitable maximum so that the value of N − i is not so small that the accuracy suffers. The value of the autocorrelation for no lag is the mean square, i.e. $R_{xx}(0) = |x_i^2|_{av}$.

2.6 Power Spectral Density

Often a more meaningful description of a time signal is in the frequency domain so that the amount of energy in different frequency bands can be determined. The parameter employed is the power spectral density which is constructed so that the energy between two frequencies is the appropriate area under the power spectral density versus frequency graph. There are three main ways of computing the power spectral density.

2.6.1 Blackman-Tukey Method

The earliest method of computing the power spectral density is to use the fact that it is the Fourier transform of the autocorrelation. If $S_{xx}(\omega)$ is the power spectral density where $\omega = 2\pi$.frequency, and i is the square root of -1, then

$$S_{xx}(\omega) = \int R_{xx}(\tau) \exp(-i\omega\tau)\, d\tau \qquad (10)$$

Now, since $R_{xx}(\tau)$ is symmetrical about $\tau = 0$, only the real part of the complex exponential need be considered, and if the maximum value of τ is T, equation (10) becomes

$$S_{xx}(\omega) = 2\int_0^T R_{xx}(\tau)\cos(\omega\tau)\, d\tau \qquad (11)$$

where the integration is from 0 to T and the value of the frequency cannot exceed the Nyquist frequency. The autocorrelation and power spectral density for broad band noise passed through a tuned circuit are shown in Figure 2. The discrete form of equation (11) is

$$S_{xx}(j\triangle\omega) = \Sigma R_{xx}(i\triangle\tau)\cos(2\pi ij/N) \qquad (12)$$

where $\triangle\omega = 2\pi/(N\triangle\tau)$.

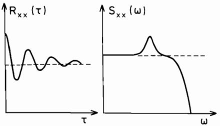

Fig. 2 Autocorrelation ($R_{xx}(\tau)$) and power spectral density ($S_{xx}(\omega)$) for white noise passed through a tuned filter.

A problem can arise if the autocorrelation does not go to zero for the largest values of the lag since equations (11) and (12) assume that the function being transformed is zero at the extremities. The application of a weighting function to ensure a zero value, will modify the results while overcoming the effects of a discontinuity at the extremes of the correlogram. A compromise situation is the end result and a further discussion on this subject is included in the section on the direct use of the Fourier transform.

2.6.2 Direct Fourier Transform

The Fourier transform of a signal can be used to compute directly the power spectral density. If x(t) is the signal and X(iω) the Fourier transform; then

$$X(i\omega) = \int x(t) \exp(-i\omega t)\, dt \qquad (13)$$

where the integration is usually carried out from $-\infty$ to $+\infty$, however, since the integration is usually only for a time interval T, this will be indicated by a suffix. The power spectral density is then given by:

$$S_{xx}(\omega) = (1/2T)\, X_T(i\omega) X_T^*(i\omega) \qquad (14)$$

where * refers to the complex conjugate.

The discrete form of equation (13), to calculate the discrete Fourier transform (DFT) using the fact that $\exp(i\theta) = \cos\theta + i\sin\theta$, is

$$\begin{aligned} \text{Real}\,[X_j] &= (1/N)\,\Sigma\, x_i \cos(2\pi ij/N) \\ \text{Imag}\,[X_j] &= (-1/N)\,\Sigma\, x_i \sin(2\pi ij/N) \end{aligned} \qquad (15)$$

where the summation over i is from 1 to N and j ranges from 1, 2 . . . N/2.

As mentioned in the previous section, since one is dealing with finite length time samples there arise certain problems when carrying out Fourier transforms due to discontinuities at the boundaries of the sample interval, and to overcome this some "window-carpentry" is required. Since there is still argument about the optimum form of this "carpentry", the simplest procedure which is usually quite effective will be described. The Hanning window is a simple averaging procedure, where if a_N^H represents the Nth coefficient after Hanning and a_N before, then

$$a_N^H = 0.25a_{N-1} + 0.5a_N + 0.25a_{N+1} \qquad (16)$$

The length of a time slice taken for analysis is usually limited by the available storage for data, so to improve the statistics many time slices can be taken and the results of the analyses are averaged (ensemble averaging).

A limitation on all techniques used for computing the power spectral density for a sample of a signal is that the frequency resolution (the smallest separation of two different frequencies that can be identified) depends on the total length of the sample used (the longer the sample the better the resolution), which can pose a serious restriction for transient signals.

The calculations required for the Fourier transform of a signal are time consuming because of the large number of sine and cosine functions that have to be evaluated. Appendix II shows how a DFT is calculated. Several simple techniques can be used to speed up the calculations, such as using a precalculated look-up table for the trigonometric functions, or building up the trigonometric functions by using the expressions for the sums of angles. However, the trigonometric functions have certain properties which have been used to develop a fast technique for calculating Fourier transforms. Special dedicated processing units employing the FFT algorithms have been constructed and are used in modern spectrum analysers.

A simple description of how an FFT algorithm is developed follows. The discrete Fourier transform can be written as

$$X_T = \Sigma\, x_k \exp(-2\pi irk/N) \qquad (17)$$

where the summation over k is from 0 to $N-1$; the values of r range from 0 to N/2, and the properties of the complex exponential have been invoked. For notational convenience put

$$W = \exp(-2\pi i/N)$$

Then equation (17) becomes

$$X_r = \Sigma\, x_k W^{rk} \qquad (18)$$

The calculation of all X_r requires around N^2 operations. The time samples, x_k, can be subdivided into two series of N/2 samples as odd and even values of k, so that

$$y_k = x_{2k}$$
$$z_k = x_{2k+1} \qquad (19)$$

where $k = 0, 1, 2, \ldots N/2-1$.

Each of the two series in equation (19) will have its own Fourier transform

$$Y_r = \Sigma\, y_k W^{2rk}$$
$$Z_r = \Sigma\, z_k W^{2rk} \qquad (20)$$

where the summation over k is from 0 to $N/2-1$. The Fourier transform of the original series can now be written as

$$X_r = \Sigma\,(y_k W^{2rk} + z_k W^{2r(k+1)})$$
$$= Y_r + Z_r W^{2r} \qquad (21)$$

Thus, the DFT of a sequence x_k of N points can be constructed from the DFT of two sequences of N/2 points. Each of these two sequences can also be further broken down until a sequence of 1 point is left whose Fourier transform is that point. The FFT needs around 10,000 operations to transform 1024 points while the ordinary DFT needs around 1,000,000 operations.

(To be continued)

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APPENDIX I

BASIC program to compute mean, standard deviation, kurtosis and probability density function.

```
10  REM STATS PACKAGE
40  REM DATA IN X(*)
60  INPUT "NO.OF POINTS";N
70  DIM X(N),P(100)
80  FOR I=1 TO N
90  PRINT "POINT NO.";I
100 INPUT "VALUE";X(I)
110 NEXT I
120 REM COMPUTE MEAN
130 M=0; V=0; K=0
140 FOR I=1 TO N
150 M=M+X(I)
160 NEXT I
170 M=M/N
180 PRINT "MEAN IS";M
190 REM COMPUTE SD
200 REM AND KURTOSIS
210 FOR I=1 TO N
220 Z=X(I)-M
230 V=V+Z*Z
240 K=K+Z*Z*Z*Z
250 NEXT I
260 K=K/(V*V)
270 V=V/(N-1)
280 SD=SQR(V)
290 PRINT "STANDARD DEV.";SD
300 PRINT "KURTOSIS";K
310 REM COMPUTE PDF
320 REM GET MAX. VALUE
330 MV=0
340 FOR I=1 TO N
350 Z=ABS (X(I))
360 IF Z<MV GOTO 380
370 MV=Z
380 NEXT I
390 REM SUB. INTO 100 INTS.
400 SF=50/MV
410 FOR I=1 TO 100
420 P(I)=0
430 NEXT I
440 FOR I=1 TO N
450 OV=INT(SF*X(I)+0.5)+50
460 P(OV)=P(OV)+1
470 NEXT I
480 PRINT "PDF VALUES"
490 FOR I=0 TO 100
500 PRINT "ORD. NO.";I; "VALUE";P(I)
510 NEXT I
520 END
```

APPENDIX II

BASIC computer program to calculate power spectral density via the discrete Fourier transform.

```
10  REM PSD CALCULATION
20  REM INPUT IN X(*)
30  REM PSD IN S(*)
40  INPUT "NO. OF POINTS";N
50  N2=N/2
60  DIM X(N),S(N2)
65  GOTO 500
70  FC=6.2832/N
80  FOR I=1 TO N2
90  IV=0:IR=0
100 FOR J=1 TO N
110 IV=IV+X(J)*SIN(FC*I*J)
120 IR=IR+X(J)*COS(FC*I*J)
130 NEXT J
140 S(I)=IV*IV+IR*IR
145 S(I)=S(I)/N
150 NEXT I
160 PRINT "VALUES OF PSD"
170 FOR I=1 TO N2
180 PRINT "STEP";I"VALUE";S(I)
190 NEXT I
200 END
500 REM GET DATA
510 FOR I=1 TO N
520 INPUT X(I)
530 NEXT I
540 RETURN
```

AUSTRALIAN ACOUSTICAL SOCIETY

Incorporated in New South Wales

GUIDELINES FOR ADMISSION AND GRADING OF MEMBERS

These grading gates are intended to provide a measure of uniformity of consideration of applications from prospective members.

In this, as in all other documents of the Society, member with the lower case m means all members of the Society in all grades; and Member with the upper case M means those members of the Society in the grade Member.

Article 16 provides for a variety of gates for admission to Membership. Gates MA, MB, etc. correspond to Articles 16 (a), 16 (b), etc.

These gates are a guide only to the assessment of applicants; they are not a simple checklist.

Admission to the grade Member is open to people working in all fields of acoustics, such as bioacoustics, electro-acoustics, auditorium acoustics, physical acoustics, musical acoustics, speech communication, ultrasonics, noise control, vibration, etc.

The fundamental requirement is an understanding and working experience in acoustics as assessed by the Society independent of any recognition or non-recognition by the applicant's employer or other bodies.

The applicant's application form with attachments and any written testimony of the applicant's proposers should be aimed at conveying to the Council Standing Committee on Membership the information necessary for it to assess the applicant's understanding and working experience in acoustics.

Regardless through which gate Members are admitted, the admission requirement is the same, the successful applicants should all be assessed as having the understanding and ability to work in, and follow developments in their field of acoustics at an adequate level of competence.

In the details below the following interpretations should be made:—

(i) Actively engaged in the science or practice of acoustics means working in acoustics at what can be assessed by the Council Standing Committee on Membership as at an adequate professional level.

One criteria which could be used is to judge whether the employer of the applicant would be at such a loss if the employee left that the employer would need to advertise for the services of a person eligible for admission to the Society in the grade Member.

Applicants should show that they are keeping abreast of their field of acoustics by:—

(a) attendance at technical meetings of the Society: and/or

(b) subscribing to and reading acoustical journals and periodicals: and/or

(c) doing research or development in their chosen field: and/or

(d) attending symposia and conferences on acoustics: and/or

(e) working in a field where the work itself provides a source of information feed back.

(ii) Engaged for 2 (4, or 5) years means a total assessed time of 2 (4, or 5) years discounting time spent on work of a non-acoustical nature. Thus an elapsed time of 4 (8, or 10) years may be required if only 50% of the applicant's time is spent working in acoustics after allowing for other work.

Time spent in postgraduate studies in acoustics may be assessed for the equivalent time in the same way as any other postgraduate work experience.

(iii) Recognised educational qualifications means a degree or diploma (comprising the equivalent of at least 3 years fulltime study) appropriate to the field of work of the applicant.

Applicants must submit evidence of all degrees or diplomas claimed.

Gate MA

Requirements for Admission to the grade Member

(i) Applicants must show they are interested in the objects and activities of the Society.

(ii) Applicants must show that at the time of their election they are actively engaged in the science or practice of acoustics at a professional level.

(iii) Applicants must show that they have recognised educational qualifications.

(iv) Applicants must show that they have been actively engaged in the science or practice of acoustics at a professional level for not less than 2 years.

Gate MB

Requirements for Admission to the grade Member

(i) Applicants must show they are interested in the objects and activities of the Society.

(ii) Applicants must show that they have been actively interested, or actively engaged in the science or practice of acoustics at a professional level for a total period of not less than 2 years.

(iii) Applicants must show that they have recognised educational qualifications.

(iv) Applicants are admitted to this grade although they are at the time of their election not actively engaged in the science or practice of acoustics if it is in the interest of the Society that they be elected.

Gate MC

Requirements for Admission to the grade Member

(i) Applicants must show they are interested in the objects and activities of the Society.

(ii) Applicants must show that at the time of their election they are actively engaged in the science or practice of acoustics at a professional level.

(iii) Applicants shall submit for examination a thesis on a topic agreed to by the Divisional Committee. The thesis should be of final year undergraduate standard.

(iv) Applicants must show that they have been actively engaged in the science or practice of acoustics at a professional level for not less than 4 years.

Gate MD

Requirements for Admission to the grade Member

(i) Applicants must show they are interested in the objects and activities of the Society.

(ii) Applicants must show that at the time of their election they are actively engaged in the science or practice of acoustics at a professional level.

(iii) Applicants must show that notwithstanding their lack of recognised educational qualifications they are suitable for election as a Member by reason of their verified practical or theoretical experience in the field of acoustics.

(iv) Applicants must show that they have been actively engaged in the science or practice of acoustics at a professional level for not less than 5 years.

GATES AA AND AB — REQUIREMENTS FOR THE GRADE AFFILIATE

This grade is awarded in recognition of the proficiency of technicians working in acoustics. It is open to all people who make routine acoustical measurements as, for example, in audiometry, or who make routine selections of equipment according to established procedures or similar.

Gate AA

Requirements for Admission as an Affiliate

(i) Applicants must show they are interested in the objects and activities of the Society.

(ii) Applicants must show evidence of satisfactory completion of an appropriate certificate course or other appropriate post secondary qualification.

(iii) Applicants must show they are engaged in the science or practice of acoustics at technician level; and have so been for not less than 2 years.

Gate AB

Requirements for Admission as an Affiliate

(i) Applicants must show they are interested in the objects and activities of the Society.

(ii) Applicants must show they are engaged in the science or practice of acoustics at technician level; and have so been for not less than 5 years.

GATE SU — REQUIREMENTS FOR THE GRADE SUBSCRIBER

Applicants must show they are interested in the objects and activities of the Society.

GATE ST — REQUIREMENTS FOR THE GRADE STUDENT

This grade is allocated to students in post-secondary educational establishments. After graduation Student members may remain in this grade whilst gaining their experience. But in no case may a member remain in this grade for more than 10 years.

(i) Applicants must show they are interested in the objects and activities of the Society.

(ii) Applicants must show they are enrolled in an accredited educational institution, OR that they intend to gain experience for qualification as an Affiliate or Member.

SUSTAINING MEMBERS

Sustaining membership is conferred in recognition of the contribution made by the sustaining member.

The essentials are:

(i) The contribution precedes the conferring of Sustaining Membership.

(ii) The contribution may be financial or otherwise.

(iii) The contribution may be to the Society, or towards its objects or activities.

(iv) Sustaining Membership is conferred for a time determined by the Council which may typically be for a year.

(v) Sustaining members may be companies, partnerships, organisations, societies, corporations or persons; if a person they shall not otherwise be a member of the Society.

Authorised by 30th Council Meeting, 26 February, 1983.

REQUIREMENTS FOR ELEVATION TO THE GRADE FELLOW

SPONSORSHIP OF FELLOWS

As Members cannot apply for elevation to Fellowship the administrative processes are different from other membership grades.

(a) Each division's Membership Grading Committee will examine the Members in its Division every two years to see if any Member's work, ability, or service to the Society, warrants elevation of that Member to Fellowship, and shall seek a sponsor for such Member. Alternatively, any Member or Fellow may sponsor a Member for elevation.

(b) The sponsor shall prepare a recommendation for elevation to Fellowship of the Member he or she is sponsoring.

(c) The recommendation should be prepared without the candidate's knowledge; and shall be a comprehensive history of the applicant. As a guide the supporting information should include the following:—

- (i) Education, including all degrees and awarding institutions
- (ii) Positions held
- (iii) Major professional achievements and awards
- (iv) Contributions to acoustics, including inventions and patents
- (v) Publications including the initial and final page numbers for each publication. Please indicate also whether the publication is an article, letter, abstract, chapter in a book, etc.
- (vi) Service to the Society.

(d) The sponsor should prepare and submit with the supporting information a brief citation for the nominee. If the nominee is advanced to Fellowship, the citation will be published in the Bulletin.

(e) At least two supporting letters for the nominee are required. These letters should come from Fellows or Members of the Society and *must be requested by the sponsor.* Those writing supporting letters should be asked for suggestions regarding the proposed citation, and should include support for the citation in their letters.

(f) Of the three letters required (one from the sponsor and two from other Fellows or Members) not more than one should be from a Fellow or Member employed by the organisation which employs the candidate.

(g) The original sponsoring letter and accompanying material and the letters of support should be sent to the General Secretary who will forward the Recommendation For Fellowship to the Council Standing Committee on Membership.

(h) The Council Standing Committee on Membership shall determine whether the nomination is acceptable. Elevation is then made after Council ratifies its Standing Committee's determination.

CRITERIA FOR ELEVATION TO THE GRADE FELLOW

The awarding of Fellowship should be considered exclusively a recognition of achievement such as might be attained by from 10% to 20% of the Society membership. This should be measured in terms of contribution to the advancement of acoustics in the broadest sense including conspicuous service to the Society. The recognition of achievement should be based solely on high standards of quality and merit; it should not be subjected to arbitrary formula as to quantity of activity or the percentage of persons warranting election to Fellowship.

The following criteria are but a guide:—

(a) That the nominee has been a Member of the Society for not less than five years, and has been interested in the objects and activities of the Society for the same period.

(b) That the nominee has for at least ten years been actively engaged in the science, practice, teaching, research or development of acoustics.

(c) That the nominee has made a sustained and outstanding contribution to acoustics and/or the Society; for example the nominee has advanced the understanding or appreciation of acoustics in the community, or has advanced the science or practice of acoustics, or has advanced the use of acoustics in industry or the community, or has given outstanding service to the Society, or similar.

(d) The position or standing of the nominee and his work, relative to others in the same field. For example, if the nominee works in engineering acoustics, his position or standing relative to others in the same field; if he is a designer of architectural acoustical products the position or standing of his designs relative to others in the same field.

It should be noted that serving members of Council and of the Council Standing Committee on Membership are ineligible for sponsorship.

Restoration of the Sydney Town Hall Organ

Howard Pollard

(1) A Brief Report

The large pipe organ in Sydney Town Hall was designed by Dr. Arthur Hill and built in London by W. Hill & Son in 1886-89. The opening recital was given in 1890 by the visiting English organist W. T. Best. The re-opening recital was given by Robert Ampt and the ABC Sinfonia on 11th December, 1982. The Sydney Town Hall organ is the largest **pneumatic action** organ in the world and is considered to be one of the finest concert organs available. The Sydney organ and the Cavaillé-Coll organ in St. Sulpice, Paris are the only large romantic instruments still surviving in their original state. Following years of complaint over the state of the organ, a committee of organists and organ builders was set up in 1964 to report to the City Council on the state of the organ and to recommend appropriate action. This investigation was supported by an independent scientific survey conducted by Dr. Howard Pollard and Roy Caddy in which action response times, acoustic delay times and pipe spectra were measured.

The final recommendation was that *the organ be restored to its original state* including the restoration of the original pneumatic action and the removal of later 'improvements' to the mechanism. This was an important decision as most old organs with pneumatic action have been converted to electric action, often with unsatisfactory results both from the players' viewpoint and the side effects that electric action has on the tone quality. Keyboard performers still prefer to relay their digital instructions via solid levers or columns of air rather than to play on a set of switches.

The manual note *action* is unusual in that it operates on a vacuum system set at approximately 10in. negative water pressure (organs were invented long before SI units). The stops and combination pistons are worked with the more usual positive pressure system. Hill's pneumatic system is very reliable and is considered to be ideal for the size of building and the prevailing climatic conditions, although the latter has recently been standardised by the installation of air conditioning in the Town Hall.

Restoration of the organ has been skilfully carried out by **Roger H. Pogson Pty. Ltd.** Under Roger Pogson's guidance, the work has included the restoration of the original double-rise bellows, the complete reconditioning of all wind chests and the reconditioning of the console, the latter work involving the removal of many layers of dark varnish before the original natural wood finish was revealed. In the course of the restoration a number of anomalies and unsatisfactory features were found, the most serious being the poor construction of the under-actions for the wind chests, which according to Mr. Pogson 'appear to have been built by first year apprentices without supervision'. New matching under-actions had to be designed for a number of the wind chests.

The *pipework* was found to be generally in good condition, again, with a number of inconsistencies and damage that had accumulated over the years. Apparently, pipes had been moved around between the different ranks as speech problems occurred, this being especially evident in some of the reed ranks. Eventually, all the pipework was restored to its original place and condition, including the return of a Trumpet 8' to the Swell organ and a Vox Humana 8' to the Choir organ.

During 1939 the pitch of the organ was lowered by about two-thirds of a semitone. The method used to alter the reed pipes was rather disastrous resulting in a loss of power and a deterioration of tone. Mr. Pogson has now restored all the reed pipes to their former brilliance. Altogether, the restoration of this fine instrument, which took about ten years, is an outstanding success story, as may be inferred from the following article by the present City Organist. For further details concerning the restoration work, a comprehensive article by David Kinsela may be consulted in the Journal of the British Institute of Organ Studies, Vol. 2, 1978.

(2) An Organist's Perspective

Robert Ampt
Sydney City Organist

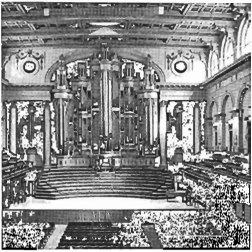
Between 1972 and 1982 the historic organ in the Sydney Town Hall was restored. For the organist the most immediate impact of the restoration is felt at the console. Over the past decades the woodwork of the console has been darkened through repeated coats of stain and oil in order to achieve a match with the colour of the surrounding stage floor—dark red/brown. In returning the woodwork to its original light finish, the restorers of the organ—**Roger H. Pogson Pty. Ltd. of Sydney**—have provided the organist with a very bright and pleasant working situation.

Details of the *console restoration* offer further delight to the player. All stop knobs have, where necessary, been either repaired (no more first-quarter moons) or replaced, with closely matched lettering adorning the new stop knobs. Even the missing Octave Oboe 4' on the Solo has been replaced, thus bringing to a close one small chapter of the organ's folk-lore which, for many years, maintained that the missing knob had been purloined one school speech day by a mischievous Miss St. Trinian. And joy of all joys, all stop names can now be read from the normal seated position; hand-stands and neck-twists being no longer necessary to bring the names onto an apparent horizontal plane.

Still at the console, the keys of the five keyboards have been levelled so that the player's fingers can now speed over five sleek freeways rather than through the pre-restoration pot holes which gave some notes deep touch and others shallow touch. More than this, the restoration has actually turned the instrument into a five manual organ again by making the lowest keyboard, the Choir, fully operational once more. Problems with this keyboard had developed as the three largest pipes in the case, situated immediately above the console, began to sag. With gentle persistence, the combined weight of these giant pipes (estimated to be about 4½ tonnes) began to grind the console, and hence the mechanism of the lowest keyboard, into the floor of the stage. With the resultant alignment problems, this mechanism required frequent repairs, and the nature of some of these repairs throws a very positive light on the strength and durability of the rubber band. The pipes have now been jacked up and secured, and the Choir action restored.

The instrument's sixth keyboard, that played by the feet, is completely new. It is at least the second new pedal board to be fitted to the organ, the others having worn out. The new pedal board is of Pogson's own radiating/concave design, and in this respect differs from the original straight board.

But the sound of the organ is, of course, the organ itself, and here the restoration effected a dramatic change, improving the brightness, volume and attack of the tone. But the last sound to become operable again was that of the famous pedal stop — the Contra Trombone 64'. With vibrations induced by the movements of a brass "reed" the length and width of an adult's forearm, the number of cycles of the lowest note can almost be counted with the naked ear. A glass window set into the boot of this pipe offers a fascinating glimpse of the production of sound. The immensely deep tones of this stop provide an additional thrilling dimension below the Full Organ. Alone, the sound of these pipes has something in common with a motorcycle, and Kenneth Robins of The Bulletin described it, perhaps a shade too enthusiastically, as "hardly musical, but . . . probably apocryphal". *To the writer's knowledge this is the only acoustic 64' stop in existence which is in operational condition, thus making it a truly unique feature of the organ.*



Taken as a whole the restoration has reproduced the original bright tone of 1890. Pipes have been cleaned, wind pressures restored and the tops of many small pipes reopened. This last act was made necessary by the method used in 1939 to lower the pitch of the organ, when the tops of many small pipes were partially closed using an inverted cone tuner. The reopened pipes, again speaking at full volume, have been transposed and fitted with tuning slides. The brighter tone has greatly increased the clarity and hence the musical worth of the instrument, and this fact alone is sufficient justification for the restoration.

The saying: "The best stop on an organ is a good building", is a glorious jumble of fact and fiction. While the acoustical properties of a room in no way effect the physical attributes or the tonal qualities of an organ, they do colour the listener's perception of that organ's tone, and what is heard is what counts. The Sydney Town Hall is a large, reverberant space, and one which, in general terms, is flattering to organ tone. However, in 1964 large expanses of the side and rear walls were covered with acoustic tiles in order to control and improve the hall's acoustic. At the same time appraisals of the organ's tone altered alarmingly, for after the mid-1960's, critics of the instrument loudly condemned the dullness of tone. It could well be that the tiles absorb a disproportionately high percentage of the upper frequencies, thus robbing the organ of some of its sheen and clarity, particularly towards the back of the hall.

So although the restoration of the instrument has now been completed, perhaps the restoration of the instrument's tone is yet to be awaited. Possibly an updated treatment of the hall is required: one which would marginally increase the reverberation time and the proportion of upper frequencies, while at the same time offering facilities for the clear understanding of the spoken word.

The restoration of the organ has been a mighty success, and the Pogson firm and a succession of City Councils are all to be congratulated. But perhaps there is yet one final step to be taken with regard to the hall itself, and if this can be proved to be the case, then musicians and acousticians might conceivably be the first to come together to initiate this step.

Audio wallpaper; sound in the round!

My vidauditory friend Daedalus reckons that spinning-disc or moving tape sound recordings are very old fashioned. These days with laser scanning there is no need to bother with moving parts at all; you might just as well hold the record still and scan the laser beam spirally in along the groove, reading its modulation by photodiode. But Daedalus then had a much brighter idea. When radiation hits a surface, some is absorbed and turned to heat — which of course warms up and expands the air immediately around the point of impact. A dark surface absorbs more radiation than a light one, so a laser beam scanned along a track of varying shade would produce a variation in air expansion from moment to moment depending on the darkness of the point it was passing. And a time variation in air expansion is, simply, sound!

So Daedalus is inventing his splendidly simple **audio wallpaper.** It is densely printed with optical soundtracks encoded as variations in shade. "Pop", "classical," "romantic," etc. versions will be available, but since for a 10μm spot size the average living-room wall could carry two months of continuous playing an "all tastes" compilation may well suffice. Each hour-long programme will be folded zig-zag into its own 10-cm square patch, and will be played from across the room by a unit steering the laser beam at the right speed along this track. As the conversion of light to heat is 100% efficient and totally linear, a 200-mW laser should produce adequately thunderous hi-fi.

Stereo would be elegantly provided by directing two lasers in synchronism at separate right and left channels printed on opposite ends of the wall. An intense laser beam can burn a black mark on white paper, so such a beam, carrying an audio modulation and tracked along a suitable surface, would burn an optical soundtrack in it, which it could later replay using a much reduced beam intensity. So enthusiasts will be able to pasteup audio wallpaper to receive their own material. The whole technique could also be used for public address audio hoardings, and audio roadsigns to be swept by lasers on the passing cars.

—From New Scientist.

Student Project:

The promotion and publishing of science amongst the potential and uncommitted students is a serious business for the many competing educational institutions and disciplines. Summer schools, science competitions, lectures and demonstrations are all useful means of achieving this end. The University of New South Wales is no exception to these activities and each year conducts a Science School for High School pupils during which groups of students work for one week on a short research oriented project. These projects are of interest in their demonstration of scientific principles, and the results in general will confirm existing knowledge and in some instances may reveal anomalies or new insights into the subject. The following is a summary of one such project related to acoustics.

* * *

Some Characteristics of Traffic Noise

John Dunlop (Supervisor), H. Merrit, G. Patis, M. Souvannovang, J. Watford

School of Physics
University of New South Wales

INTRODUCTION

The urban noise environment is dominated by traffic noise which is difficult to measure and to quantify. This is partly due to the wide variety of traffic situations — free flowing, stop, start, etc. — and of types of traffic vehicles — cars, trucks, motorcycles, etc. Traffic noise is statistical in character and most systems of quantifying it make use of simple statistical parameters. The most common single number values for example are L_{10} — that noise level exceeded 10% of the time — L_{50} and L_{90}, and predictions or extrapolations of measurements are made usually assuming that the statistical characteristics of traffic noise fits a *normal distribution*.

Another characteristic of traffic is that it flows along a one-dimensional path and the noise may assume the properties of line source noise as distinct from point source noise, the most prevalent condition in other noise measurements. One property of line sources, that sound levels fall off by 3dB per doubling of distance from the source, is often used to predict the noise levels at different distances from a traffic noise source.

The *aim of the project* was to examine these basic characteristics of traffic noise by making measurements in a simple situation.

EXPERIMENTAL METHODS

Sound pressure levels generated by a free flowing traffic stream were measured at various distances from the roadway of a major six-lane suburban road (South Dowling St.) adjacent to a flat grassed park. Visual readings (by untrained observers) of the A weighted SPL were noted at 10 second intervals for 20 min. periods using a B & K 2206 sound level meter set on fast response. Measurements were made on two consecutive week days between 10 and 11 a.m. at distances of 8, 16, 32 and 64 m. from the near kerb.

The results of the sound pressure level measurements were plotted as cumulative frequency distributions on normal probability paper as shown in Fig. 1. This method of presentation permits an easy check of the "normality" of the statistical distribution of noise levels, a normal distribution being represented by a straight line.

The traffic flow was also measured by counting the number of passing vehicles in 30 sec. intervals over a 20 min. period. These results were also plotted on normal probability paper.

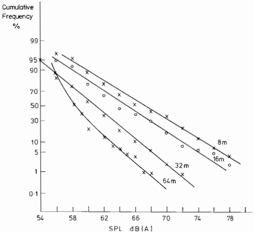


Fig. 1. Cumulative frequency distributions of traffic noise measurements at distances of 8, 16, 32 and 64 m from roadway, plotted on Cumulative Normal Probability paper.

DISCUSSION

The cumulative frequency plots of noise levels at 8, 16 and 32m. from the roadway, as shown in Fig. 1, indicated by their linearity that the distribution of noise levels is close to being a Normal or Gaussian distribution, which is consistent with earlier workers (Alexander et al., 1975). (Chi-square goodness of fit tests supported this at the 75% level of significance).

The distribution of noise levels at 64m. however exhibits some deviation from linearity (Fig. 1) when plotted on probability paper and this was attributed to the effects of background noise levels intruding into the traffic noise distribution. The background noise was estimated at 51 dB(A) on the basis of measurements taken in the centre of the park.

The reduction in noise level with distance from the roadway is illustrated in Fig. 2. In this graph the L_{50} levels obtained from Fig. 1 have been used and the distance plotted is that from the noise measurement point to the centre of the second nearest traffic lane. The graph in Fig. 2 indicates a fall off rate for L_{50} levels of about 3.6 dB per doubling of distance which suggests that the traffic approximates to a line source, this value being consistent with values reported previously, e.g. 4.3 dB by Wegner and Don (1981) and 3.3 dB by Delaney (1972). There is also a reduction in the variance of the traffic noise level distribution with distance as is indicated by the slopes of the graphs in Fig. 1. The traffic flow was estimated to contain 5% heavy commercial vehicles and the count results indicated that the flow distribution from 30 sec. interval samples was very close to being a normal distribution (with mean of 18 cars per 30 sec. interval, standard deviation 3) being significant at the 95% level in a chi-square goodness of fit test.

CONCLUSION

The results of measurements by untrained observers (high school pupils) were consistent with previous established work, confirming the general tenure that the statistics of traffic noise (free flowing) fit those of a normal distribution and that the traffic stream approximates to a line source in its emission characteristics.

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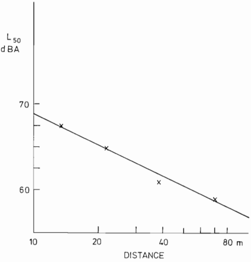


Fig. 2. Plot of measured L_{50} noise levels at various distances from roadway.

Some Highlights of an Overseas Special Studies Program

Anita Lawrence
Graduate School of the Built Environment, University of New South Wales.

I divided my five months' study leave approximately equally between Western Europe and North America, the first few weeks being devoted to a rather hectic series of visits in France, Belgium, the Netherlands, Germany and Denmark just prior to the commencement of the European summer vacation period.

Europe

In Paris I had the honour to address members of the **French Acoustical Society** on "Acoustics in Australia" and I later spoke with Dr. JEAN MATTEI and Dr. PAUL FRANCOIS who are both involved in the organisation of the 11th ICA in July and who were most interested to hear of some of our experiences in Sydney in 1980. Community noise studies and building acoustics research and practice appear to be thriving in continental Europe and I was impressed with the facilities and expertise available in universities, government institutes and private consultancies. Room acoustics studies are also in progress in several centres — the most famous of these being in **Gottingen,** headed by Professor MANFRED SCHROEDER. Professor Schroeder was enthusiastic about a possible new method of measuring the acoustical characteristics of an auditorium during an actual performance, with an audience present.

U.K.

Unfortunately, the situation in the United Kingdom was a depressing contrast to that in the continent, due to government funding cuts which were having a serious effect on well-known acoustic research centres and universities. Such centres take many years to establish — to obtain the physical facilities and expert researchers and yet they can be destroyed very quickly as their staff dissipate through early retirement, alternative employment, etc. When the economic situation improves I anticipate there will be a shortage of younger acousticians to take up the work again.

In spite of the gloom and despondency in Britain's academia and research establishments, about 80 delegates attended the **Institute of Acoustics Conference** in Edinburgh, held at the University of Edinburgh, the venue for Internoise this year. The topic was Auditorium Acoustics and Electroacoustics and 28 papers were presented over three days. Professor C. A. TAYLOR of Cardiff University gave a very interesting invited lecture-demonstration on the physics of the interaction between player, instrument and acoustic environment. Professor BRIAN DAY presented a Memorial Address in honour of Dr. Vilhelm Jordan (naturally the Sydney Opera House was mentioned) and Dr. MIKE BARRON described the new concert hall in Wellington, New Zealand. I presented an invited paper on "Soundlines and Sightlines" on a rather practical note!

Canada

Next I crossed the Atlantic to spend two most enjoyable and interesting months with the **National Research Council of Canada** in Ottawa. There are two acoustic groups at NRC — one, in the Division of Physics is headed by Dr. EDGAR SHAW with the able support of Dr. TONY EMBLETON and Dr. JOE PIERCY amongst others. The second group is in the Division of Building Research and is now headed by Dr. ALF WARNOCK (since Dr. Tom Northwood's retirement). NRC has many interesting acoustic projects under way. I was particularly interested in the sound propagation studies which have produced some cohesive theoretical reasons for the variations in noise levels from distant sources (which confirm what many of us have long suspected — that the prediction of noise levels at a distance out of doors is a hazardous occupation). In **Building Research,** the acoustics laboratory has been automated and computerised. Because of the ability to carry out very large numbers of repetitive measurements, relatively painlessly, some disturbing fluctuations in decaying sound fields have been revealed. Again, it is something to be expected in an auditorium, but not in a very well designed 'diffuse' reverberation chamber. Back to the Fogg Auditorium, Professor Sabine!

Whilst in Canada I was fortunate to be able to attend part of the annual **"Acoustics Week"** in Toronto. This was organised by the Canadian Acoustical Association in conjunction with the Ontario Ministry of the Environment. The first two days were given over to seminars and tutorials — partly acting as training sessions for noise control officers. The remainder of the week included a Symposium and Society meeting. The CAA is already gearing up for the **12th ICA in Toronto in 1986,** and I had a distinct sense of déjà vue remembering the years leading up to the 10th ICA in Sydney! About 60 papers were presented in two parallel sessions and one highlight of the meeting was a "walk-through" the new **Roy Thomson Hall,** with TED SCHULTZ of Bolt, Beranek and Newman, the acoustic consultants, as guide. This was followed by a concert given by the Toronto Symphony Orchestra. The Toronto hall is one of four new concert halls, including Melbourne's, recently designed by B.B. & N. As President of the Australian Acoustical Society, I was invited to address the CAA Banquet — this time on some of my impressions of acoustics in Europe.

U.S.A.

My final major acoustical activity was to attend the 104th Meeting of the **Acoustical Society of America** in Orlando, Florida (the city of Walt Disney's new Epcot and the Kennedy Space Centre — which fortuitously launched a manned Space Shuttle whilst we were there). Over 500 abstracts appeared in the programme and the papers were presented in up to nine parallel sessions over four days. (I sometimes wonder why we all make such a fuss about organising an ICA once every three years, since the ASA run two meetings of similar size every year, the main difference being that most of the participants come from North America, rather than worldwide). I was a little disappointed to find the Architectural Acoustics sessions were chiefly devoted to auditorium design and there was not much interest in noise control in buildings; community noise was covered in sessions on Noise, however. The demise of the Office of Noise Control of the US EPA and the restriction of the acoustic work at the National Bureau of Standards caused concern to acousticians working in these areas.

As KEN ELDRED pointed out, although many states and local authorities will attempt to meet some of the needs for noise control, it is important that measurement procedures, noise scales, etc. are standardised "if the result is to be nonchaotic".

In conclusion, I would like to express my appreciation of the opportunity provided to me by the University of New South Wales in granting me leave to undertake a Special Studies Programme. Particularly as we live in a rather isolated corner of the world it is extremely important that we are able, from time to time, to see at firsthand what is happening overseas (rather than reading about it months later in a journal), and to be able to develop and maintain contacts with overseas acousticians working in the same fields. To this end, I hope that as many AAS members as possible will endeavour to attend both **Internoise 83** in Edinburgh and the **11th ICA** in Paris, in July, so as to maintain contacts with the International acoustics community which were fostered by the 10th ICA in Sydney.

A Visit to San Diego

Marshall Hall

Royal Australian Navy Research Laboratory

Accompanied by my wife and family, I returned in December from an 18-month exchange posting at the **Naval Ocean Systems Center (NOSC)** in San Diego, California. Having worked in underwater acoustics since 1967, the posting was an opportunity to meet most of the leading practitioners in the field, and also to work closely with a few of them over a meaningful length of time.

Called the Navy Electronics Laboratory when it was established during World War II, and later the Naval Undersea Centre, NOSC has been a centre of excellence in environmental underwater acoustics over the past two decades. During the past several years however the U.S. Navy has been reducing and rationalising its environmental research programmes, and this has entailed NOSC in gradually pulling out of the field. There are, however, two eminent workers still there, (**Melvin Pedersen** and **Homer Bucker**), but when they retire NOSC will be out of the environmental acoustics game.

Mel Pedersen has been doing research in underwater acoustics for around 30 years and has been a Fellow of the Acoustical Society of America (ASA) for over 10 years. His major contributions have been to analyse in detail the strengths and weaknesses of ray theory; and to pioneer the application, without approximations, of normal-mode theory. For many years he was pushing against the boundaries of the ability of large computers to do the sums that are required. For the past 20 years Mel has been assisted by **David F. Gordon,** a fellow mathematician who has concentrated on developing the computer programmes and has also investigated several aspects of its application. David became a Fellow of ASA in 1981. He visited the Royal Australian Navy Research Laboratory (RANRL) on an exchange posting from October 1977 to September 1978. During that visit he looked at applying his computer programme (which is valid for any stratified medium providing its boundaries are smooth) to the case of sound transmission in the ocean when the surface is rough. This is a topic of considerable interest in underwater acoustics, although a rigorous solution has not yet been found.

Mel is also assisted by another computer programmer, R. (Fell) Hosmer, who is also an old hand at the game.

By the time I arrived at NOSC in June 1981 Mel and David's interests had returned to problems with a smooth boundary, such as, how to incorporate bottom reflectivity into their programme; or to what extent the deep water profile can be neglected when transmission within the near-surface ocean mixed-layer is being considered. These problems are also of interest to RANRL (or any agency which aims to develop a comprehensive understanding of underwater acoustics), and so it was with relish that I began work on topics that were of immediate interest to people who had been leading figures in the field over a significant period of time.

One of the benefits of working close to a specialist is that some of his enthusiasm inevitably rubs off. My office was a couple of doors down the corridor from Mel's, and with his booming voice it was not difficult to pick up snatches of his telephone conversations. The subject of these would usually be normal-mode theory! With the familiar technical phrases wafting down the corridor, coming from a person who is on the "pay cap" for U.S. civil servants, it is easy to feel that normal modes must be an important subject and that I should get right onto it!

Another valuable impression I received from working with Mel, and also through seeing what Homer Bucker was at, is that a competent scientist can keep at his technical work right through his career and find it satisfying, while enjoying the respect of others in the field and in the laboratory; and not losing out substantially in terms of salary. This indicated to me that in the U.S. at least, competent and productive scientists are held in high regard even though they eschew the usual temptations to become administrators.

At a more tangible level, I obtained a lot of benefit from direct discussions with Mel and David, and also with the many other acousticians I was able to meet during my stay in the U.S. Most of these discussions took place at meetings of ASA, of which I attended three. ASA is a huge body by Australian standards, and each of its bi-annual meetings is divided into several specialist programmes, of which underwater acoustics is one. These sessions would usually have an audience of at least 30, whereas in Australia there are only a handful of underwater acousticians altogether!

The "output" of my visit can be summarised as follows:

(i) Lectures at meetings of ASA:

a. "Comparisons of measured volume backscattering strengths with predictions based on mid-water trawls" *(Miami, Nov. 1981).

b. "Shallow-water propagation: the role of the Branch-Line Integral in the Pedersen-Gordon model" (Chicago, April 1982).

c. "Application of two-variable Taylor series to the ray theory of propagation in a stratified medium".

d. "Sound propagation in a surface duct: can the deep water profile be neglected?"

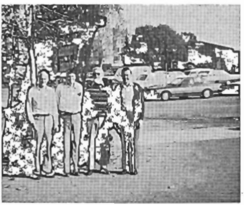
(c. and d. both in Orlando, November 1982).

(ii) Published papers (in the Journal of ASA):

a. M. Hall: "Normal mode theory: the role of the Branch Line Integral in Pedersen-Gordon type models" (December 1982).

b. M. Hall, D. F. Gordon, and D. White: "Improved methods for determining eigenfunctions in multi-layered normal-mode problems" (January 1983).

* Based on earlier work at RANRL.



Left to right: David F. Gordon, R. Fell. Hosmer, Melvin A. Pedersen and Marshall Hall.

(The "Hungry Hunter" is a restaurant where the division I was attached to held its 1982 Christmas party.)

Experiment on the Pitch of Complex Tones

Tim Dabbs and Howard Pollard
Department of Applied Physics,
University of New South Wales,
Sydney, Australia

In one of the regular first-year experiments for science and engineering students, some experience in acoustical analysis is obtained by analysing a number of taped noises using a one-third octave filter set and a wave analyser. To add a little variety to this staple diet, it was decided to offer the student a set of synthesised sounds which would involve the student in both a listening test and some analysis. A number of complex tones were produced by additive synthesis on an Apple II computer in which the partial tones all bore simple relations to each other. In Table I are shown the chosen components (consisting of a number of harmonics with or without the fundamental) for seven test sounds with their relative amplitudes.

For complex tones it is well known[1] that the ear assigns a pitch to the complex tone that may or may not coincide with the lowest frequency present. The so-called missing fundamental occurs when there is no frequency present in the signal corresponding to that of the estimated pitch. For instance, test sound 7 consists of harmonics 3, 4, and 5 of a fictitious fundamental. Even though the fundamental is not physically present there is little difficulty in perceiving such a sound and assigning it as the pitch of the complex tone. A number of theories have been developed for this phenomenon, three of which are summarised in Plomp.[1] All assume that a preliminary frequency analysis of the sound occurs in the cochlea followed by further neural processing that "computes" the fundamental of the series of tones and designates this as the pitch.

In the experiment, the test sound is played simultaneously with the output of a frequency generator. The frequency of the generator is slowly varied until the student estimates that the two sounds have the same pitch. The student then analyses each sound with the aid of a wave analyser and compares the resulting frequencies with the estimated pitches. At this stage many expressions of disbelief have been observed.

COMMENTS ON STUDENTS' RESULTS

For sounds 1 - 4 and 6, the fundamental was easily recognised by over 90% of the students. Sounds 5 and 7 were found to be confusing with sound 5 more so than sound 7. However, after much deliberation, the pitch was assigned by about 70% of the students. The remaining 30% were unable to assign any frequency as the pitch. For the latter students a further test was staged. The frequency generator was turned off and the students were asked to hum the note they thought they were hearing. The test sound was now turned off and the frequency generator turned on and matched with the hummed note. In all cases using this procedure the correct pitch was found. As an additional comment, all students thought that the various test sounds had different tone qualities.

Table I. Components of complex test sounds.

	Components of test sound (Hz)	Relative amplitude	Perceived fundamental (Hz)	Partial number relative to perceived fundamental
1	250	100	250	1
2	250	50	250	1
	500	30		2
	750	20		3
3	500	67	250	2
	750	33		3
4	500	50	500	1
	1000	30		2
	1500	20		3
5	1250	50	250	5
	1500	30		6
	1750	20		7
6	500	67	500	1
	1000	33		2
7	750	50	250	3
	1000	30		4
	1250	20		5

[1] R. Plomp, *Aspects of Tone Sensation* (Academic, London 1976).

(Reproduced with permission from American Journal of Physics, Vol. 50, p. 855, 1982.)

ABSTRACTS OF INTEREST

PRACTICALLY PERFECT PITCH

Gregory R. Lockhead and Robert Byrd,
Department of Psychology, Duke University, Durham, North Carolina 27706.

J. Acoust. Soc. Am. **70**, 387, Aug. 1981.

People who can identify piano notes with essentially no errors (perfect pitch) are much less capable in identifying musical notes produced by sine waves. Thus, frequency is not the only information these people use to identify musical notes; piano notes are complex waveforms or patterns, sine waves are not complex. Musically trained people who do not have perfect pitch ability have considerable difficulty identifying either sine waves or piano notes. As well as this quantitative difference, these two groups of musicians also differ qualitatively. The people in both groups are about equally able to judge octave levels, but people with perfect pitch are excellent in identifying the particular note, e.g., E, independent of its octave, while people without perfect pitch ability are not.

COMPARISON OF AIRCRAFT AND GROUND VEHICLE NOISE LEVELS IN FRONT AND BACKYARDS OF RESIDENCES

Jose C. Ortega and Karl D. Kryter.

J. Acoust. Soc. Am. **71** (1), 216, Jan. 1982.

Investigation of aircraft overflight and ground vehicle noise around a general aviation airport provided the opportunity to measure the frontyard to backyard noise reduction afforded by residential structures for these two types of noise sources. The measured average noise reduction for two residences using passing street vehicles as noise sources was found to be 17 and 21 dBA. For aircraft overflights using identical measurement instrumentation and microphone locations, as were used for the street traffic noise, the average measured noise reduction (i.e., difference between frontyard and backyard noise levels) was found to be 0.2 and 0.4 dBA. The results of the measurements show that acoustical factors around residences are such as to generally cause substantial frontyard to backyard noise reduction for street traffic noise, but not for the noise from aircraft overflights.

ABSTRACTS OF INTEREST

THE ECONOMICS OF INDUSTRIAL NOISE CONTROL IN AUSTRALIA

D. C. Gibson and M. P. Norton,
C.S.I.R.O., Highett.

Noise Control Engineering, p. 126, May-June 1981.

Important sources of industrial noise and the level of exposure of workers to noise in Australian industry are examined. The magnitude of the noise problem is estimated in terms of its social and economic consequences. The annual cost of meeting workers' compensation claims for hearing impairment is found to be marginally more than the equivalent cost of mounting hearing protection programmes. Noise reduction costs per worker are greater than compensation costs per worker; therefore, in the absence of restrictions on operation, there is no apparent financial incentive for Australian industry to reduce its noise.

PRIMARY AUDITORY NEURONS: NONLINEAR RESPONSES ALTERED WITHOUT CHANGES IN SHARP TUNING

Donald Robertson and Brian M. Johnstone,
Department of Physiology, University of W.A.,
Nedlands, W.A. 6009.

J. Acoust. Soc. Am. **69**, 1096, Apr. 1981.

Two-tone suppression as well as distortion product responses in mammalian auditory neurons were altered by exposure to short, high intensity tones in the frequency region of the suppressing or primary tones. These changes occurred without significant alteration of the single neurons' tuning curves. The findings support the notion that two-tone suppression and distortion product responses are a function of the integrity of cochlear regions remote from the final transduction site.

SPECTRAL ANALYSIS OF IMPULSE NOISE FOR HEARING CONSERVATION PURPOSES

Guy O. Stevin
Laboratory for Acoustics, Technical Service of the Army, STFT/CT Quartier Housiau, B-1801, Brussels, Belgium

J. Acoust. Soc. Am. **72,** 1845 (1982)

Damage-risk criteria for impulse noise does not presently take the spectrum of the impulse into account; however, it is known that the human auditory system is spectrally tuned. The present paper advocates the extension to impulse noise of the noise dose concept which is widely used for continuous noise. This approach is based upon **sound exposure** instead of sound pressure. An A-weighting filter or an octave band analysis can then be used to take the spectral content of the impulses into account. The equipment needed for applying these procedures for impulse noise is an integrating sound level meter or a digital Fourier processor. Generalized spectral methods have been evaluated by means of an impulse simulation applied to a mathematical model of the human hearing mechanism. The results of this simulation agree with the most recent experiments on impulse noise and fully support the proposed rating methods. This conclusion must be emphasized as it leads the derivation of a uniform procedure for predicting loudness and damage risk for hearing which is applicable for continuous noise as well as for impulse noise.

A NEW CRITERION FOR THE DISTRIBUTION OF NORMAL ROOM MODES

Oscar J. Bonello, Solidyne S.R.L., Buenos Aires, Argentina.

J. Audio Eng. Soc. **29,** 597, Sept. 1981.

A new criterion is proposed for the best distribution of normal room modes, with the objective of improving the acoustics of recording and broadcasting studios. A new system is analyzed for controlling isolated room modes to obtain rooms free of sound colouring. Applications are described, and the criterion is compared with others. A simple computer programme performs the calculations.

Microphone Calibration at NML

The **National Measurement Laboratory** has just completed a series of measurements to determine the on-axis sensitivity of a group of three one-inch freefield microphones (B & K type 4145) over the frequency range 40 Hz to 20 kHz. The measurments were made in accordance with I.E.C. Publication 327/1971 (closed-coupler reciprocity) at the low-frequency end of the band and with I.E.C. Publication 486/1974 (free-field reciprocity) at the high-frequency end, but their unique feature is that the free-field measurements were pushed down to 316 Hz where the difference between free-field and pressure sensitivity is negligible.

Free-field measurement at 316 Hz is not an activity to be undertaken lightly. The laws of Physics decree that the signal available to the receiving microphone will be proportional to the frequency squared, so that it will be 1000 times smaller at 316 Hz than it was at 10 kHz. Moreover, the acoustic and electrical noise backgrounds both tend to rise as frequency falls, so that the transition from easy to impossible is very rapid indeed. It is symptomatic that the I.E.C. tables of corrections stop at 1.25 kHz.

The measurements were made in N.M.L.'s *new anechoic chamber* which has a working space roughly 2.5 metre cube, lined on all faces to a depth of 600mm. with bonded textile fibre blankets (acrylic and acetate) in 4 gradations of density. Impedance tube measurements show a 99% energy absorption at normal incidence down to 125 Hz.

The internal consistency of the free-field results is within 0.1 dB over practically the whole band. Whilst consistency is necessary, though not sufficient, to guarantee accuracy, the high-frequency results fuse very convincingly with the coupler measurements which various intercomparisons have assured us are likely to be within 0.05 dB of the truth. It is expected that a detailed report of these results will be published in due course.

Dennis Gibbings.

Transmission of underwater images by acoustic waves

The Societé Thomson-CSF (Paris, France) has demonstrated the continuous transmission, with acoustic waves, of TV images that were being filmed at a depth of 1000m. The demonstration was held on Castillon Lake in the southern range of the French Alps.

According to Thomson, the technique will have applications in many fields, particularly the oil industry, to monitor underwater structures by means of remote controlled vehicles or manned submarines. Thomson claimed that its system can cope with a much higher data rate than previous systems.

The **acoustic transmission technique** used is similar to that used in space exploration systems. The signals from the camera below are decoded and stored to allow display on a TV screen with a continuous sequence of still images. A directive acoustic receiver is used to reduce noise and reverberation. Along with high-capacity transmission, the system also provides for transmitting remote-control signals to the underwater station.

Possible future applications include the transmission of images and other data, such as telemetry information, between a submerged craft and several surface ships, between surface ships and submarines, or between submarines and submerged equipment.

—From J. Acoust. Soc. Am. 71, 1614 (1982)

Bionic Ear — Nearing completion

The 'bionic ear' will soon be a reality for millions of nerve-deaf people throughout the world.

It was developed by the **University of Melbourne** in conjunction with a Sydney based firm, TELECTRONICS PTY. LTD., part of the Nucleus group of companies, which is well known for its expertise in implantable prothesis.

Recognising the high social and economic benefits of the implantable hearing prosthesis the Department of Science and Technology agreed to fund further research and development, and it is now expected that the device will be available by the mid-1980s.

The device is based on the principle of electronically receiving, processing and coding sounds in a similar manner to that which occurs naturally in the nerve fibres of people with normal hearing.

A coded signal is sent by an externally worn transmitter to a miniature receiver-stimulator implanted behind the ear. The receiver-stimulator converts the signals to electrical impulses which are conducted to the inner ear where the nerve fibres are stimulated electrically to enable the nerve-deaf to recognise speech and other sounds.

During the first phase of the project, Melbourne University implanted a prototype receiver into several patients, conducted clinical tests and evaluated the effectiveness of the device.

The second phase saw the University complete a portable prototype of a speech processor unit and a basic rehabilitation package suitable for immediate use and later development.

A biological test programme provided preliminary results which can be used as a basis for agreeing to a full clinical trial programme with health authorities.

During that phase of the project the consultancy firm PRICE WATERHOUSE ASSOCIATES prepared a commercial plan for the manufacture and marketing of the device.

The next phase of the project involves the full commercial development of the 'ear' which is being undertaken by the Nucleus group of companies.

As well as the obvious benefits the 'bionic ear' will bring to the deaf, its commercial development will provide important economic benefits. With the aid of just over $3 million in federal funding, the development of the bionic ear will create employment and export benefits with an estimated potential world market of $500 million.

Australian industry will have gained an expertise which could be extended to other implantable neural prosthetic devices; and the development of a major prosthetic implant industry could make Australia the world leader in the industrial and engineering applications of such medical developments.

—(The Australian Physicist, Dec. 1982)

Beef grading by ultrasound

A proposed method for grading beef quality uses ultrasonic inspection. In the method, the grade of beef carcasses is determined by analysis of the ultrasonic A-scan signatures from the marbling within the muscle. Since the reflections from within the muscle are determined primarily by the fat/muscle interface, the richness of such reflections is a direct indication of the degree of marbling and quality. The method is intended to replace the present subjective method of sight and feel of individual USDA graders and ultimately to yield both the grade and yield of live cattle.

Though no work has been done on live animals, tests on butchered-beef specimens indicate a definite trend between ultrasonic signatures and grade. The reflection content is seen to be greater for the better grades: i.e., prime is richer in reflections than the other grades, and reflection content of standard is poorer than the other grades.

The area studied was about 1in. (2.54cm.) below the surface of the steak. The external fat was trimmed off and the transducer aimed in the direction shown in Fig. 1. The electronics were gated so that the picture displayed covers the range of 20-70mm. from the transducer. The reflection content or the density of moderate-amplitude reflections is an indication of the fine structure of a specimen.

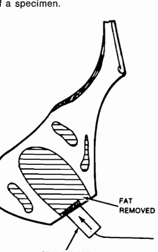


Fig. 1. The ultrasonic transducer is positioned and oriented on the meat to measure the marbling and quality. The fat has been removed so that the signal attenuation is reduced.

As the sound wave propagates through fluid and soft tissues of the body, about 0.01%-1% of the energy is reflected back toward the transducer at each interface. If the interface is approximately perpendicular to the transducer, a strong specular reflection is received, and the distance of the interface from the transducer can be measured with an A-scan instrument.

In the feasibility experiments performed, a 2.25 MHz unfocused ultrasonic transducer of 0.5in. (1.27cm.) diameter and moderate damping was used to transmit and receive direct and specular reflections from different tissue areas of marbled beef. The 2.25-MHz ultrasonic bursts were 20 mW in power and lasted about 1 μs. A wideband receiver without a rectifying detector was used in order not to reduce the information content of the signal.

The method was developed by P. M. Gammell of Caltech for NASA's Jet Propulsion Laboratory, Pasadena, CA.

—From J. Acoust. Soc. Am. 71, 1612 (1982)

Electronic Ear is hard of hearing

For hundreds of years, the standard treatment for hearing problems has been to turn up the volume. Great grand-pa's ear trumpet and today's electronic hearing aid merely amplify sound. But unfortunately, the most common auditory deficiency of the elderly, *presbycusis*, seems to involve difficulties of tuning as well as volume. Anyone who listens to the radio knows that if a frequency isn't tuned in, increasing the volume won't make the music any clearer.

But **Gordon Bienvenue,** an American audiology researcher, is working on a new approach to the problem — he has programmed a computer to have "hearing losses" that specifically involve tuning.

Bienvenue estimates that "almost everyone in our society suffers from some form of presbycusis by old age." To those stricken, speech sounds at best fuzzy, and at worst unintelligible. He believes that the tuning problems are caused by physical damage to hair cells — structures with hairlike projections — inside the conchshaped cochlea of the inner ear. A relatively small number of these seem to be the vital tuning components. Over part of the cochlea's inner surface, the critical cells are arranged in soldierly ranks. As an incoming sound wave travels along the cochlea's spiral tube, it builds to a certain height and abruptly falls, like a wave breaking at the seashore. Specific-frequency waves always break at the same spot, confining their excitatory influence to a narrow band.

The human hearing system groups millions of sounds into such bands, sorting them by frequency. Under normal circumstances people detect no difference between sounds in the same band, thus limiting the information-storage capacity need for hearing.

Through the effects of age, however, or from stress, excessive noise and injury to the ear, the cochlear hair cells may become damaged. If enough of these hair cells malfunction, the bands widen and overlap, causing the brain to misanalyse incoming frequencies. Presbycusis will then result.

To study this disorder better, Bienvenue created his **computer model,** in which simulated hair cells can be "turned off" to mimic damage to their cochlear counterparts. Programmed in this way, the computer *recreates the symptoms of old-age hearing loss.*

Potential applications of Bienvenue's research are widespread. Presbycusis has always been difficult to diagnose. But the system provides a definitive test: the computer takes a normal sentence and processes it to sound as it would to a person with the disorder. Then, both it and the original sentence are played for a test subject. Individuals with normal hearing can easily tell the difference. But to someone with presbycusis the two sentences are indistinguishable: the ears improperly tune the normal sentence.

Bienvenue now wants to develop a computer programme that will modify incoming sounds to fit the wider frequency bands of the afflicted. The device would actually retune sounds, not just provide amplification. "This will really be a hearing aid," says Bienvenue. "We'll be able to correct hearing in the way glasses have restored vision for years."

—(Omega Science Digest, Jan.-Feb. 1983)

New Products

METROSONICS db-307 PERSONAL DOSIMETER AND INTEGRATING SOUND LEVEL METER

The db-307 is a sophisticated computer-based instrument, scaled down to be held in hand or slipped into a shirt pocket. It permits accurate field measurements of all common noise descriptors. By combining the functions of a Digital Integrating/Averaging Sound Level Meter and a Personal Noise Dosimeter in a single instrument, IT ELIMINATES HAVING TO CARRY SEVERAL INSTRUMENTS TO A MEASUREMENT SITE.

Designed for:

Industrial Hygienists
Community Noise Abatement Officers
Product Test Engineers
Acoustical Consultants

who may need any or all of these instruments:

Dosimeter
Sound Level Meter (including max-hold and peak-hold meter)
L_{eq} Meter

The following **measurements** may be made:

dB(A)
L_{max}
L_{pk}
L_{OSHA} L_{DOD} L_{eq}
Noise Dose
Projected 8-hour Noise Dose
Test Duration
L_{ex} 40

For further details, contact:

BWD Instruments Pty. Ltd.,
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Telex: 35115
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BRUEL and KJAER AUDIO TEST STATION

Hearing Aid Response Tests

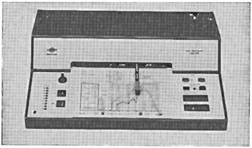
B & K are pleased to announce the release of the Audio Test Station Type 2118.

The Test Station is primarily intended for use with the Anechoic Test Chamber Type 4222 and is especially designed for swept frequency response measurements on hearing aids in accordance with ANSI S.22 1976 and IEC 118 (new revision).

The 2118 supersedes the earlier Audio Test Station Type 2116 and is a highly versatile desk-top instrument containing a stepped frequency sine generator, a signal analyser and a pen recorder for automatically documenting results. In addition to frequency response measurements, both harmonic and intermodulation distortion measurements can be carried out. A fully automatic pushkey activated control sequence makes the 2118 an exceedingly easy instrument to operate.

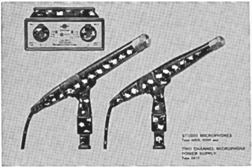
The overall frequency range of the Audio Test Station is from 100 Hz to 10 kHz and signal levels ranging from 60 to 140 dB SPL can be handled. A special feature of the instrument is a digital memory capable of storing a compression curve for maintaining a constant sound pressure level during measurements. Also fixed test frequencies of 1 kHz, 1.6 kHz and 2.5 kHz may be chosen as recommended by ANSI and IEC.

As standard the Type 2118 is equipped with a ½-inch Condenser Microphone Type 4134 and Type 2642 Preamplifier Type 2642 combination, which for interfacing hearing aids and other test items, may be fitted with a wide range of optional adaptors and couplers.



BRUEL and KJAER STUDIO MICROPHONES TYPES 4003, 4004, 4006, 4007 AND TWO CHANNEL MICROPHONE POWER SUPPLY TYPE 2812

With more than twenty-five years experience in the development and manufacture of precision measurement microphones, Bruel & Kjaer has developed a range of four omnidirectional condenser microphones specifically intended for professional studio use. Designated Types 4003/4006 and 4004/4007, two basic microphone designs are offered: Types 4003 and 4006 are acoustically identical, low-noise (15dB(A)) microphones which differ only in the method of powering. Type 4006 is powered from the standard P48 Phantom system while Type 4003 is powered by B & K Power Supply Type 2812, the advantage being a high ("line-level") balanced, transformerless output. Types 4004 and 4007 are also acoustically identical and are intended for applications requiring a very high-level handling capability (<1% THD at 148dB) and extended frequency and phase responses. Type 4007 is Phantom powered while Type 4004 is powered via Power Supply Type 2812. Each microphone undergoes a thorough quality control procedure and is supplied with a calibration chart.



These studio microphones have been designed with particular emphasis on the ability to render a balanced and clean sound image, free from tonal colouration both on- and off-axis. The on-axis response of Types 4003/06 ranges from 20 Hz to 20 kHz ± 2 dB with a very smooth high-frequency roll off. Smaller diameter Types 4004/07 have an on-axis response from 20 Hz to 40 kHz ± 2 dB. Owing to the relatively small cartridge diameters they retain omnidirectivity at high frequencies.

The microphones are prepolarised condenser microphones utilising a fixed charge carrying layer which is deposited on the microphone backplate. For dimensional and long-term stability and to ensure a robust construction the cartridge, protection grid and main body housing are manufactured from carefully selected, corrosion resistant materials. The supplied calibration chart contains the individually measured on-axis frequency response, sensitivity and equivalent noise level of the microphone.

INSULATION TECHNICAL GUIDE

CSR's Bradford Insulation is Australia's only manufacturer of a complete range of Fibreglass and Rockwool insulation.

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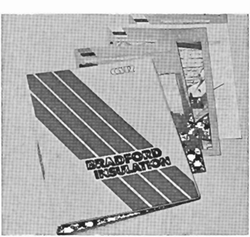
The new Bradford Insulation literature is available from the Bradford Insulation Group, CSR Limited, 4 O'Connell Street, Sydney, or Bradford Insulation's sales offices in each State.

Enquiries: H. Anderson, (02) 237 5682.



DUAL CHANNEL SIGNAL ANALYSERS BY B & K

The analysers types 2032 and 2034 are ideally suited for acoustic measurements such as noise source location, transmission path characterisation and sound intensity. Both analysers feature 801-line resolution, built-in digital zoom and noise/sine generator, direct connection to microphones, plus built-in computation of sound intensity. The 2034 is the standard version with a real time speed of 800 Hz in two-channel operation. The 2032 is functionally identical but has six times the computing speed (5 kHz real time speed—10 kHz in single channel operation), hence making it ideally suited for acoustic applications.

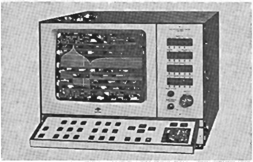
Calibration of the analysers may be made directly in acoustic units such as Pascal, and dB references may be chosen at will, permitting calibration to any value, such as 20 μPa or 1 pW/m^2. Virtually all Bruel & Kajer condensor microphones (including pre-polarised types) can be powered directly from the 2304 and 2302.

The measurement of high-Q resonances, such as room modes, is made easy by the built-in **zoom facilities,** which make it possible to zoom up to 16384 times anywhere in the 0 to 25,6 kHz frequency span, thus giving optimal signal to noise ratio, and avoiding excitation of out-of-band resonances and non-linearities.

The built-in Hilbert transform makes it possible to compute the envelope of the impulse response, giving what is known as the Energy Time Curve from Time Delay Spectrometry. This gives a powerful tool for locating reflections as well as viewing them on a logarithmic amplitude scale, giving much greater dynamic range than on a traditional linear y scale. The Hilbert transform also provides complex signals for all time functions, and auto and cross correlation functions.

Built-in functions include sound intensity (A-weighted or linear), frequency response, cross correlation, impulse response, auto spectrum, cross spectrum, autocorrelation, coherence, non-coherent output, coherent output, cepstrum, and liftered spectrum.

Frequency response functions may be stored for subsequent equalisation of new data, thus making it possible to correct for gain and phase errors in the measurement chain, or, for example, to deconvolve the inpulse response of a loudspeaker.



The **sound intensity function** does not require programming, and displays the data directly on a bipolar (positive flow points up, negative flow points down) display. Display ranges of 10, 20, 40, 80 or 160 dB are available, as well as linear. The built-in cursors may be used to read the intensity in any desired frequency band. In addition, the ambient pressure and temperature, as well as microphone spacing may be entered, for automatic correction for these parameters.

Virtually all functions can be displayed in one of the **six formats:** real, imaginary, imaginary vs. real (Nyquist), magnitude, phase, and log. magnitude vs. phase (Nichols). The auto and cross correlation functions as well as the impulse response may also be shown in complex form thanks to the built-in Hilbert transform.

X and Y scaling and units may be either linear or logarithmic, and any user-defined scaling factor may be used. Extensive cursor facilities allow highlighting of harmonics, sidebands, frequency bands, and provide for the measurement of power in a band, relative power, relative frequency, relative time (time delay), relative level, harmonic number, etc. A phase compensation function allows readout of the group delay of any part of the frequency range, and permits a simple form of phase unwrapping.

For speech analysis, or echo determination, the **cepstrum** is included along with the liftered spectrum which is often used for formant tracking in speech analysis.

Ease of use was one of the main design criteria for the 2034 and the 2032. Therefore, virtually all text on screen is in plain, unabbreviated English, and selection of functions is made by a self-explanatory menu. Frequently used set-ups can be stored in 20 non-volatile memories for later use. Automatic scaling of the display, as well as automatic attenuator setting is provided. The user is free to select any display function or post-processing both during and after the measurement, as well as on stored data.

Interface to external mass storage (such as Digital Cassette Recorder Type 7400), high-speed hard copy (Graphics Recorder Type 2313), or computers is provided by the IEC (IEEE) interface bus. Additional outputs are provided for XY recorder Type 2308 as well as video hard copy units.

Further details available from:

Bruel and Kajer Aust. Pty. Ltd., P.O. Box 120, Concord N.S.W. 2137. Tel.: (02) 736-1755.

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NEW PUBLICATIONS

A HANDBOOK OF PUBLIC SPEAKING FOR SCIENTISTS AND ENGINEERS

Peter Kenny
Adam Hilger, 1982, A$11.00
Available from: D.A. Book Depot Pty. Ltd., 11-13 Station St., VIC. 3132

Contents: The speaker, his material, his audience. Preparation of material, the text. Sections on order, style, length, preparing notes, practising, an example of speech preparation. Preliminaries and actual presentation. Speaking with limited or no preparation: reading and speaking from a full text, speaking at short notice, impromptu speaking. Effective use of visual aids, i.e. chalkboards, overhead projector, etc. Methods of improving technique: confidence, stance, breathing, presentation, etc. Speaking at/chairing technical conferences/committee meetings, addressing small groups, informal meetings.

THE ACOUSTICS OF STRINGED MUSICAL INSTRUMENTS

Proceedings of the Wollongong Co-operative Workshop, 5-8 July, 1980.
Published by the University of Wollongong, 1982, 289 pp., A$15.00.
Edited by Abe Segal.

This neatly produced book contains 16 papers on a variety of topics including acoustical and constructional problems relating to the violin, guitar, clavichord, etc. by authors from eight different countries.

Copies may be obtained from:
The Department of Physics, University of Wollongong, P.O. Box 1144, Wollongong, N.S.W. 2500. Payment should be made to "Wollongong String Workshop".

INTER-NOISE 81 and 82 PROCEEDINGS

Practice of Noise Control Engineering was the theme of INTER-NOISE 81, sponsored by the International Institute of Noise Control Engineering. The two-volume set of proceedings contains 250 technical papers and 1143 printed pages.

Copies may be ordered from the Netherlands Acoustical Society, Postbus 162, 2600AD DELFT, Netherlands, at a cost of US$60.00 which includes surface postage and handling. US$25.00 extra is required if the books are sent by air.

The theme of INTER-NOISE 82 was Noise Control: Ten Years Later. The two-volume set of proceedings contains 190 technical papers and 944 pages. Copies may be ordered from Noise Control Foundation, P.O. Box 3469, Arlington Branch, Poughkeepsie, N.Y. 12603, U.S.A. at a cost of US$55.00 which includes surface postage and handling. US$25.00 extra is required if the books are sent by air.

PRINCIPLES AND APPLICATION OF ROOM ACOUSTICS

L. Cremer and H. A. Muller (translated by T. J. Schultz).
Applied Science Publishers Ltd., Ripple Road, BARKING, ESSEX IG 11 OSA, England, 1982.
Volume 1: Geometrical, Statistical and Psychological Room Acoustics, 651 pp., £47.50 including surface posting.
Volume 2: Wave Theoretical Room Acoustics, 433 pp., £35.50 including surface postage.

COMMUNITY NOISE RATING

T. J. Schultz
Applied Science Publishers Ltd., Ripple Road, BARKING, ESSEX IG 11 OSA, England, 1982, 384 pp., £37.50 including surface postage.

PROCEEDINGS OF THE FASE/DAGA '82 CONGRESS

The volume presents 13 review and 270 contributed papers comprising 1300 pages on a wide variety of topics in modern acoustics.

The cost is US$35.00 or DM 88 payable to the account of DPG-GmbH, account no. 025 6925 at the Deutsche Bank Bonn (BLZ 380 700 59). Mail to: DPG-GmbH, Hauptstrasse 5, D-5340 Bad Honnef (FRG).

SOUND INTENSITY

S. Gade
B & K Technical Review.

Issue No. 3 — 1982 featured Part I Theory in which the theoretical concept of sound intensity was described and the different principles of signal processing were outlined.

Issue No. 4 — 1932 featured Part II Instrumentation and Applications.

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C. AUTHOR INDEX

The symbols following each author's name refer to volume and issue, e.g. V1/2 refers to volume 1, issue no. 2. Entries in *italics* refer to technical reports.

PUBLICATIONS by AUSTRALIANS

We are indebted to Marion Burgess of U.N.S.W. and Anne Quill of RANRL for making regular journal checks and to Toni Benton of U.N.S.W. for arranging the references for publication.

Within each year references are arranged alphabetically by first author.

1981

Measurements of Acoustic Volume Backscattering in the Indian and Southern Oceans
M. Hall
RANRL, Rushcutters Bay, Sydney
Aust. J. Mar. Freshwater Res. **32** (6), 855-876 (1981)

Noise Characteristics of a Pulsed Jet
R. J. Hooker, R. H. Rumble
Dept. Mech. Eng., University of Qld.
Noise Control Engineering, **17** (3), 113-119 (1981)

Development of a Digital Acoustic Wave-Height Recorder
A. A. Johnson, J. E. Hinwood and G. T. Lleonart
Dept. Mech. Eng., Monash University, Vic.
Fifth Aust. Conf. on Coastal and Ocean Eng. 164-165 (1981)

Application of Stochastic Waveguide Propagation Model of Ocean Acoustics
G. R. Sutton
N.S.W. Institute of Technology
J. Mathematical Physics, **22** (12), 2974-2976 (1981)

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Ultrasonic Absorption Studies of Human Blood
A. F. Collings and N. Bajenov
CSIRO Division of Applied Physics, Sydney
Aust. Physicist **19,** 149-151 (1982)

The Barrier Attenuation of Garden Fences
C. G. Don and J. G. Wegner
Caulfield Institute of Technology, Vic.
Appl. Acoust. **15,** 429 (1982)

Robust Adaptive Array Antennas
R. J. Evans, K. Z. Ahmed
Dept. Elect. and Comp. Eng., University of Newcastle, N.S.W.
J. Acoust. Soc. Am. **71** (2), 384-394 (1982)

Axisymmetric Wave Propagation on a Conical Shell
N. H. Fletcher
Dept. of Physics, University of New England, N.S.W.
J. Acoust. Soc. Am. **72,** 250-4 (1982)

Acoustic Admittance of Air-Driven Reed Generators
N. Fletcher, R. Silk, L. Douglas
Dept. Physics, University of New England, N.S.W.
Acustica, **50** (2), 155-159 (1982)

Acoustical Characterisation of Flute Head Joints
N. H. Fletcher, W. J. Strong and R. K. Silk*
Dept. of Phys., University of New England, N.S.W.
**Brigham Young University, Provo, Utah*
J. Acoust. Soc. Am. **71,** 1255-1260 (1982)

Effect of Air Cavity on the Annular Drum
H. P. W. Gottlieb
School of Science, Griffith University, Qld.
J. Acoust. Soc. Am. **71** (4), 1025-1027 (1982)

An Exploratory Study into the Prediction of Low Frequency Traffic Noise
G. H. Hollingsworth
Main Roads Department, Qld.
Applied Acoustics, **15** (2), 79-96 (1982)

High-level Impulsive Noise Source
L. C. Kenna
National Acoustic Laboratory, N.S.W.
J. Acoust. Soc. Am. **71** (2), 483-486 (1982)

A Tristimulus Method for the Specification of Musical Timbre
*H. F. Pollard and E. V. Jansson**
School of Physics, University of N.S.W.
**Dept. of Speech Communication and Music Acoustics, Royal Institute of Technology, Stockholm*
Acustica **51,** 162-171 (1982)

A Spectrum Analyser for Acoustic Emission
I. G. Scott
Aeronautical Research Labs., Melbourne
Rept. No. ARL-MAT-TM-382 (1982)

Placement Equalisation of Microphones in Small Rooms
P. Terts
33 Falcon Road, Claremont, W.A.
J. Acoust. Soc. Am. **71** (2), 503-505 (1982)

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(b) Long articles which may take the form of a discussion, review, tutorial or technical paper. A referee's report will be sought for the latter

Forthcoming closing dates for the receipt of these articles are as follows:

Vol. 11, No. 2 — Long articles: May 13
Short articles: June 17

Vol. 11, No. 3 — Long articles: September 16
Short articles: October 14

Contributions should be sent directly to the Chief Editor. Manuscripts should be typed with double spacing and should have ample side margins.

Articles should include a title, author's name, address and organisation (if applicable), and, in the case of long articles, be accompanied by an abstract of approximately 200 words.

The *body of the text* should be divided into numbered sections and preferably contain frequent subheadings, which greatly assist the reader in following the development of the paper. Any standard system of referencing is acceptable.

To assist the printer, footnotes should be avoided. Instead, place additional material in brackets or include in reference section. Equations, tables and figures should be numbered sequentially. A list of captions for figures should be supplied on a separate sheet. It is recommended that captions give a complete explanation for each figure, thus obviating the need to refer to the text for identifying details.

Drawings and **photographs** may be prepared to any convenient size and will normally be reduced proportionally to single column width. Authors are requested to plan the proportions of diagrams so that they will fit preferably into a single column width. Drawings may be supplied with or without lettering. If lettering is added, please allow for the proportional reduction in size and thickness that will be necessary. In general, typed lettering is unsatisfactory.

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