Acoustics Bulletin

October 1982 Volume 7 Number 4

Special Feature

UNDERWATER ACOUSTICS

INSTITUTE OF ACOUSTICS

Material for the January issue of Acoustics Bulletin should reach Mrs F A Hill at 25 Elm Drive, St Albans, Herts AL4 0EJ, no later than Tuesday 23 November.

In case you didn't hear . . .

One or two changes and events in the world of acoustics over the past few months should not go unmentioned. First our congratulations and best wishes must go to our Immediate Past President **Brian Clarkson** and his family on their move to Swansea, where Professor Clarkson has taken up his appointment as Principal of University College of Swansea. Vice-President and Honorary Treasurer of IOA **Geoff Leventhall** is now settled at Atkins R & D, although since joining them he seems to have spent most of his time abroad, in Europe, the USA and most recently Hong Kong.

Valiant attempts at retirement have recently been made by two well-known names in the acoustics world — **Ernie Scholes** was speedily co-opted on to IOA Council on his recent retirement from BRE and is busy with the problem of a successor to the NAC; we wish him well in his (semi-) retirement. On the administrative side, **Grace Hyde** has theoretically retired from her post as ISVR Conference Secretary although she too appears to be busier than ever. Our good wishes to her and her husband when they do eventually reach their new home in Spain.

Meanwhile **Nicolet** has celebrated its 25th Anniversary. From a small group who started out working on a contract with the US Air Force to pursue the application of advanced signal processing techniques to long range radar, Nicolet has developed into one of the foremost manufacturers of high technology instruments serving acoustics workers among others. We offer them our congratulations and our thanks for their support as IOA Sponsor Members.

AIRO has recently relocated its acoustics and noise control consultancy and its electro-acoustic design services at its Hemel Hempstead laboratory; the address for all correspondence is now therefore: AIRO, Duxon's Turn, Maylands Avenue, Hemel Hempstead, Herts HP2 4SE. Tel: 0442 47146/9. □

Calls for Papers

The Meetings Committee of the Institute of Acoustics is always pleased to receive offers of contributions to any of its meetings. Contributions are particularly sought for the following:

Recreational Noise

February/March 1983
Meeting Organiser: Alan Baker
Motad International Ltd, Unit 2 Maverton Road, London E3 2JE
The Meeting will cover all aspects of recreational, DIY noise, etc

(200 word abstracts as soon as possible)

Acoustics and the Sea Bed

University of Bath, 6-7 April 1983
Meeting Organiser: Dr N G Pace
School of Physics, University of Bath, Claverton Down, Bath BA2 7AY

(200 word abstracts immediately)

Inter-Noise '83

Edinburgh, 13 - 15 July 1983
Technical Sessions Organiser: Prof J B Large
ISVR, The University, Southampton
Sessions on all aspects of noise and its control

(200 word abstracts immediately)

Sonic Emission

Late July 1983
Meeting Organiser: Dr R W B Stephens
Department of Physics, Chelsea College, Pulton Place, London SW6

(200 word abstracts as soon as possible)

Studio Design

Autumn 1983
Meeting Organiser: Mr N Spring
Sandy Brown Associates, 6 Fareham Street, London W1V 3AH

(200 word abstracts required)

Acoustics Bulletin

Advertising enquiries to:
H A Collins Ltd
37 Ruskin Road
Carshalton
Surrey SM5 3BQ
Telephone: 01-647 1393

Contributions and letters to:
Editor, IOA Bulletin
25 Elm Drive
St Albans
Herts AL4 0EJ

Books for review to:
S J Flockton
Physics Department
Chelsea College
Pulton Place
London SW6

Published by:
The Institute of Acoustics
25 Chambers Street
Edinburgh EH1 1HU
Telephone: 031 225 2143

The views expressed in Acoustics Bulletin are not necessarily the official view of the Institute, nor do individual contributions reflect the opinions of the Editor.

Single copy £4.00

Annual subscription (4 issues) £12.00

ISSN: 0308-437X

October 1982 **Volume 7** **Number 4**

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The Institute of Acoustics was formed in 1974 by the amalgamation of the Acoustics Group of the Institute of Physics and the British Acoustical Society and is now the largest organisation in the United Kingdom concerned with acoustics. The present membership is in excess of one thousand and since the beginning of 1977 it is a fully professional Institute.

The Institute has representation in practically all the major research, educational, planning and industrial establishments covering all aspects of acoustics including aerodynamic noise, environmental acoustics, architectural acoustics, audiology, building acoustics, hearing, electroacoustics, infrasonics, ultrasonics, noise, physical acoustics, speech, transportation noise, underwater acoustics and vibration.

Membership of the Institute of Acoustics

Membership of the Institute is generally open to all individuals concerned with the study or application of acoustics. There are two main categories of membership, Corporate and Non-corporate. Corporate Membership (Honorary Fellow, Fellow, Member) confers the right to attend and vote at all Institute General Meetings and to stand for election to Council; it also confers recognition of high professional standing. A brief outline of the various membership grades is given below.

Honorary Fellow (HonFIOA)

Honorary Fellowship of the Institute is conferred by Council on distinguished persons intimately connected with acoustics whom it specially desires to honour.

Fellow (FIOA)

Candidates for election to Fellow shall normally have attained the age of 35 years, have had at least seven years of responsible work in acoustics or its application, and have made a significant contribution to the science or profession of acoustics.

Member (MIOA)

Candidates for election to Member shall normally have attained the age of 25 years, must either (a) have obtained a degree or diploma acceptable to Council and have had experience of at least three years of responsible work in acoustics, or (b) possess an equivalent knowledge of acoustics and cognate subjects, have had experience for not less than seven years of responsible work in acoustics or its application, and must have been a Non-corporate member of the Institute in the class of Associate for not less than three years.

Associate

Candidates for election to the class of Associate shall have attained the age of 18 years and (a) be a graduate in acoustics or a discipline approved by Council, or (b) be a technician in a branch of acoustics approved by Council, or (c) be engaged or interested in acoustics or a related discipline.

Student

Candidates for election to the class of Student shall have attained the age of 16 years and at the time of application be a bona-fide student in acoustics or in a related subject to which acoustics forms an integral part. Normally a student shall cease to be a Student at the end of the year in which he attains the age of 25 years or after five years in the class of Student, whichever is the earlier.

Full details and membership application form are available from: The Secretary,
Institute of Acoustics
25 Chambers Street
Edinburgh EH1 1HU

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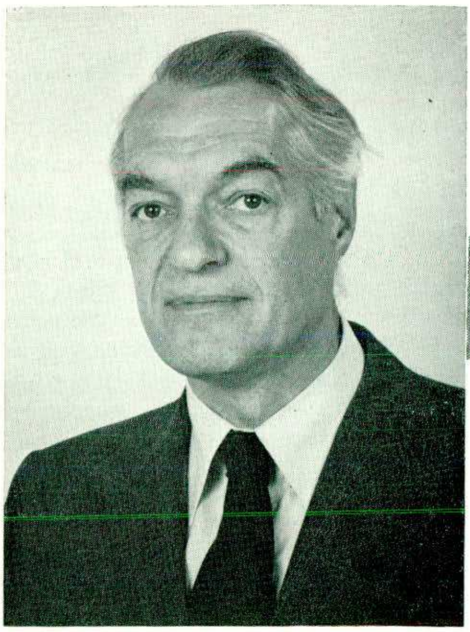


President's Letter

Dear Member,

The summer is often a time of little obvious acoustic activity, leaving aside the clatter of lawnmowers. But my reporting period really runs from May to August, and includes a Council Meeting in May. It was a pleasure to welcome Professor Berktay of the University of Bath to his first Council Meeting; and also Dr Scholes, lately of the Building Research Station, who has been co-opted for one year.

Many members will have been concerned at the demise of the Noise Advisory Council, and may therefore like to know that Council shares this concern. The United Kingdom lacks an authoritative and independent technical voice in this subject area. Thus Council has over a period been taking the lead in discussions on the desirability of setting up a new Noise Council, but it is still too early to be able to give a full report.

Now I would like to take advantage of this open letter to send my best wishes to Dr R W B Stephens. I know Council join me in doing this, and believe all members will heartily agree with the thought. We do not really need an excuse when the recipient is our first President, but in fact there are two matters. First he is now retiring from the position of Chief Examiner for the Diploma, though still keeping contact with the Diploma Examinations as with many other Institute activities. Secondly Raymond Stephens will be 80 years old on 13 October, and we hope for many happy returns.

Yours sincerely

David Weston

Acoustics in Hong Kong

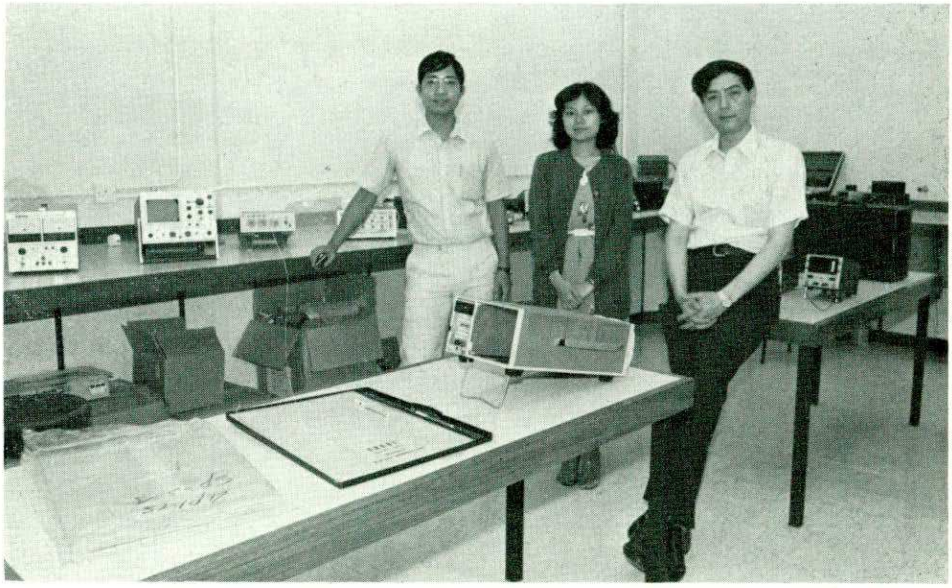
The first overseas Branch of the Institute of Acoustics is now active in Hong Kong. The Branch Chairman is Mr T K Willson of the Environmental Protection Agency, the Treasurer Mr F Mak of Hong Kong Polytechnic and the Secretary Mr D G Lees of W S Atkins and Partners Overseas.

To mark the establishment of the Hong Kong Branch we present three views of current problems and developments in acoustics in Hong Kong. We wish the Branch every success and hope it will receive the enthusiastic support enjoyed by other Branches, young and old, of the IOA.

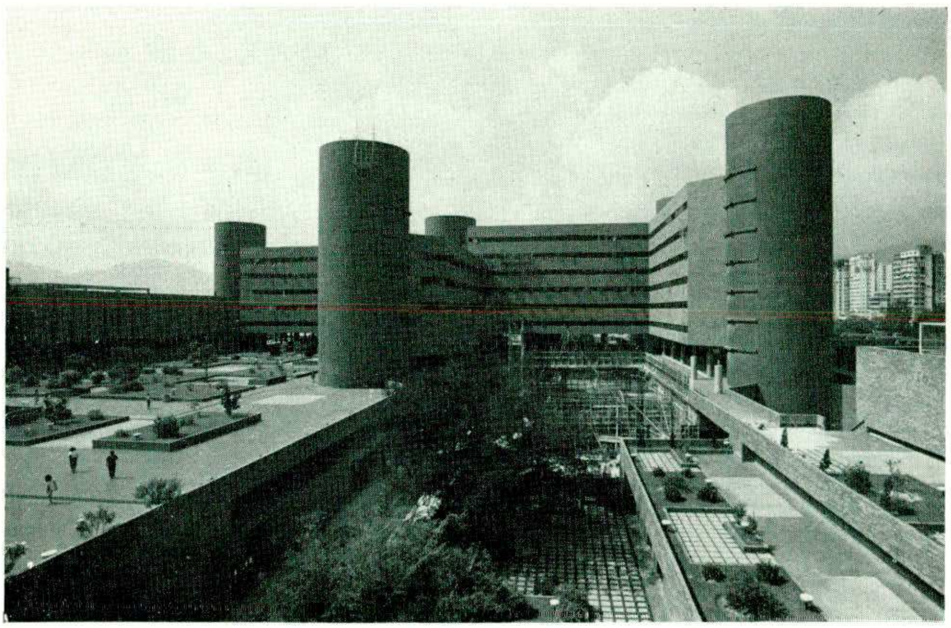
Acoustics Work in the Centre of Environmental Studies Hong Kong Polytechnic

The Centre of Environmental Studies was established in late 1979, to provide programmes of study in environmental protection appropriate to the needs of industry and the community, and to carry out research and consultancy work. It soon became obvious in late 1980 that there was a considerable need to provide education and training programmes in noise and vibration control. Indications of the level of academic achievement were that a course at technologist/practising professional standard was necessary. The Centre therefore began consultations with Council members of the Institute of Acoustics, to explore the possibility of running an Associateship programme carrying IOA recognition. With encouraging advice received, consultations within Hong Kong then began, and this led to the submission of a draft programme to the IOA for assessment. The IOA appointed an assessor to investigate acoustics facilities and staff expertise within the Polytechnic. This was followed by a visit by Dr H G Leventhall, who came as a visiting specialist to advise on the future development and resources support in the noise and vibration studies area.

At around the same time, laboratory facilities at the Centre were completed, and equipment acquisition began. To date some £30,000 have been spent on field monitoring and specialist equipment, including an FFT spectrum analyser. Equipment was purchased as additions to an existing Building Environmental Sciences Laboratory in the Building Services Engineering Department. The Mechanical and Marine Engineering Department also has a lively Engineering Dynamics Laboratory equipped with vibration studies equipment, and orientated towards the study of rigid body dynamics. Thus, the Polytechnic has good basic and advanced equipment support for acoustics and vibrations work.



Senior staff of the Centre for Environmental Studies in the newly completed Noise and Vibration Laboratory (Left to Right: Senior Lecturer Dr Daniel Lau, Administrative Assistant Miss Katherine Chu and Co-ordinator Mr Fred Mak)



Hong Kong Polytechnic — a view of the main buildings

The IOA recently gave the Centre recognition for its proposed Part-time Day-release Associateship programme. The intake level of the course is a Polytechnic Higher Diploma in an appropriate discipline, or its local or overseas equivalent. The course is of 720 hours duration, spread over two years, and approximately 35 per cent will be devoted to laboratory/field/project work. In this way, it is aimed to provide an application-orientated programme, supported by a sound core of study units which cover the fundamental and theoretical concepts. To boost staff expertise, the Centre has recruited a senior lecturer in the area, and he works closely with a team of Centre and servicing department staff.

Research is being developed at the Centre and currently two aspects are being investigated. The first is a comprehensive study of community noise in Hong Kong, and the second is low-cost applications of active noise control techniques. Discussions are being held to commence a study on industrial noise and vibration problems in Hong Kong, an area where there is little information available at present. A sizeable number of consultancy projects are also being undertaken.

Enrolment for the Associateship in Noise and Vibration Control is now in progress, and it is hoped to commence in October with between 20 and 30 students.

F Mak

IOA Treasurer Geoff Leventhall being introduced by the Associate Director of Hong Kong Polytechnic, Fred Ayscough, prior to giving his Tenth Anniversary Public Lecture on Noise Pollution — Its Effects and Control

Noise Consultancy in Hong Kong

Attention was first drawn to environmental matters in Hong Kong with the publication of an independent report in the mid 70s. This recommended the setting up of an Environmental Protection Unit to monitor and advise on Pollution Control Measures. Several changes have occurred since then.

The renamed Environmental Protection Agency is now a separate policy-making body without enforcement powers. Although it is intended to bring all enforcement actions under the 'umbrella' of the EPA, at the present moment responsibility lies with a diverse range of organisations, namely the Police, the Urban Services Department and the equivalent of the UK Health and Safety Executive.

So what is the current noise situation in Hong Kong?

The Present

Aircraft noise is common place. Hong Kong airport (Kai Tak) is built on reclaimed land on the Kowloon Peninsula. Its approach requires a high degree of pilot skill and it has one of the best safety records in the world. However the approach flightpath passes over some of the most densely populated areas of Hong Kong at heights which tend to lend credibility to apochryphal stories of aircraft landing with washing round their wheels! Night flight restrictions do apply but an airport in the centre of a city cannot help but be intrusive.

One of the main commercial links with China is by rail, particularly for supplying livestock. Recent electrification of the Kowloon to Canton Railway (KCR) has led to a quiet, efficient service.

Traffic noise is extremely prevalent in Hong Kong. Apart from one major highway, most roads pass through intensively built-up areas. Attempts to discourage the use of motor vehicles by high taxation and limited parking are offset by the public's desire to utilise the beaches and open spaces at weekends, leading to considerable congestion as public transport facilities are overwhelmed.

Lack of space necessitates elevated roads and flyovers which cause high noise levels in densely populated areas. No provision for compensation exists as in the UK, although this is currently under debate in legislative circles.

Regular helicopter links exist between Military Installations on Hong Kong Island and posts in the New Territories. A recent attempt to provide heliport landing facilities immediately adjacent to residential property was discouraged on noise grounds.

Heating, ventilation and air conditioning system noise control tends to be less common than in the UK, due to the widespread use of single unit air conditioners in individual apartments.

Roof mounted cooling towers causing noise problems are dealt with directly by the Urban Services Department. They operate a simple yet effective form of control; an excess of 5 dB(A) over the ambient whilst operating is deemed to be actionable and a prosecution is instigated.

Construction sites noise is probably the greatest source of intrusion at the moment. Currently it is controlled by hours of use restriction outside the normal working day. In brief, this means that particularly noisy activities, such as pile driving, are not permitted during evening, night-time, Sundays and public holidays. However, other noisy processes may be carried out if it can be demonstrated that the job requirements justify the issuing of a 'permit'. These normally cover a period of three months. During the daytime no controls exist.

Supplementary legislation is intended in the near future through the proposed Noise Bill encompassing all forms of noisy activity. However this is not likely to become law and enforceable before 1984.

The Future

Legislation has been passed regarding potential hearing damage. This comes into effect in November 1982 and places the responsibility on manufacturers to provide hearing protection where necessary and to ensure its use. Guidelines are given in a relevant document similar to the Department of Employment Code of Practice — 1972.

Hong Kong airport (Kai Tak) is operating at almost full capacity and plans for a new airport have been under discussion for several years. Although a decision has still to be made, the likeliest site appears to be Lantao, one of the Islands surrounding Hong Kong. Lantao itself is larger than Hong Kong Island and so would provide extensive potential building land. The provision of major bridge works connecting Lantao to the mainland would enable road and rail traffic links to be formed without hindering sea traffic. This concept itself implies much major construction work in the future. However, a 'spin-off' effect is probably of greater consequence. At the moment all buildings on the Kowloon peninsula suffer a 200 feet height restriction because of the aircraft flight path. Removal of this restriction, plus the availability of Kai Tak itself with reclaimed infill, would probably initiate a period of demolition and construction works of considerable intensity.

The Mass Transit Railway System (Hong Kong's 'Underground') continues to expand. By providing access to areas which were previously poorly served, the MTR is transforming areas of little interest into highly attractive commuter regions with community infrastructure. The increase in land values is used to subsidise the next stage of development and so the expansion increases.

As one can see, control of construction site noise and environmental planning will be very important in the future of Hong Kong.

Noise control in Hong Kong is still in its infancy. Until recently the necessary local expertise rested only with academic institutions. To establish oneself in a consultancy without the financial security that a body such as an academic institution can provide, requires a major financial commitment. Rents for office space and residential property rank amongst the highest in the world, with associated high overheads. The Hong Kong market, where rapid response and local involvement are regarded as an inarguable pre-requisite, present a challenge of the highest order to anyone contemplating the establishment of a successful consultancy in Hong Kong.

D G Lees
W S Atkins Overseas, Hong Kong

Activities of the Noise and Vibration Group of the Hong Kong Environmental Protection Agency

The Environmental Protection Agency (EPA) is a relatively new government body in Hong Kong, having been established less than two years ago. The role of the Agency is to provide a central source of expertise and scientific data on all aspects of pollution control and to assume a central co-ordinating role in the formulation and execution of government policies in this area. This work involves establishing environmental quality objectives, monitoring long-term trends in environmental quality and assessing and advising on the environmental impact of major new developments. The development of legislation is also an important activity.

The Noise and Vibration Group only began to assume its full responsibilities with the arrival of several staff in mid to late 1981. The group is headed by Terry Willson (formerly with Atkins Research and Development) who is supported at the senior level by Rob Law (formerly with an Australian EPA), Andrew Kwan (formerly with H K University) and Lex Brown (formerly with Griffiths University). In all there is a staff of sixteen in the Group which also has a well-equipped laboratory.

The work of the Group over the past twelve months has been concentrated in two main areas: the development of noise control legislation (including the acquisition of background data) and providing input to the planning process in Hong Kong.

The main thrust in the legislative area is to prepare a comprehensive Noise Control Bill which will draw together existing provisions and introduce new controls in such areas as industrial and commercial noise, construction noise, general neighbourhood noise, noise from individual products and aircraft noise.

One of the major problems in Hong Kong is undoubtedly construction noise. Development is continuous, with twenty or more large buildings or major construction works commencing each week in the urban area. The combination of high-density, high-rise living and outmoded construction practices and equipment (from a noise point of view) naturally leads to problems. Piling is a particularly bad source of annoyance and will be an early target for control. It is interesting to note that a night-time ban on piling was introduced only relatively recently!

In the field of planning, our main task has been to make the departments and staff directly responsible for planning matters more aware of noise factors and to ensure they properly take them into account in the early stages of projects or general town planning development. This is naturally a slow process but we have had some conspicuous successes, notably the acceptance of NEF 25 as the residential planning criterion for the proposed new airport.

There is much work to be done in Hong Kong but it is providing an exciting challenge to those of us who have come from more environmentally 'aware' countries. We are also learning the gentle art of compromise! □

R J S Law
Environmental Protection Agency,
Hong Kong

UNDERWATER ACOUSTICS

Acoustics tends to be an interdisciplinary subject; it has many subject divisions and these do not always have a lot in common. Thus all parts of acoustics can claim to be special, and the only reason underwater acoustics can claim to be more special than most is that it is so far removed from our everyday experience. The average person's contact is restricted to asdic pings in war films, and recordings of the song of the humpback whale. It has not been possible here even to touch on all aspects, and for example reverberation, ambient noise, scattering and many systems applications have been omitted. The articles listed below set out above all to give the flavour of underwater acoustics, and some familiar problems will appear as seen through a water-glass.

This special feature was sponsored by the Underwater Acoustics Group, organised by N G Pace of the University of Bath and of course made possible by the co-operation of the authors.

D E Weston

Sound Propagation in the Sea

D E WESTON

Admiralty Underwater Weapons Establishment

Sound propagation in the sea is often very good, and the ranges of interest are typically much longer than those in the atmosphere. Some theoretical descriptions are now quite sophisticated, ranging from ray theory through a variety of wave techniques, such as the parabolic equation, to averaging methods. Experimental measurements use explosions as well as continuously driven electrical sources, and work from a ship is costlier and less comfortable than that for land-based aerial acoustics. Knowledge of transmission level and timing and variability is central to any underwater acoustics system, and also has more direct applications.

SOUND propagation underwater obviously has a lot in common with that in the atmosphere, and it is not original to point out that they may both be regarded as starting from the wave equation. But this is also true of seismics and electromagnetics and quantum mechanics, and in many ways sound underwater is even closer to these.

Seawater as a propagation medium has a sound velocity roughly five times greater than that of air, and of course a density and wave impedance very much greater. But other influences have been more important in leading to the relatively high emphasis on understanding propagation in the sea:

- The transmission tends to be better, largely due to the much smaller attenuation, though the common occurrence of ducting also contributes.
- The better transmission leads to longer ranges where there are more complications which need to be understood, including for both deep and shallow water a variability which is at least comparable to that in air.
- There is a lack of effection competitors, visible light and microwave propagation being quite poor.
- Because of the good transmission there is a plethora of passive and active sonars and other systems calling for a quantitative understanding, much but not all of the interest being military.

Although the subject may be taken to extend up to about 1 GHz the attenuation is then very high, with very short ranges, possible for the laboratory. We will concentrate here on audio frequencies and propagation in the sea. The references have been restricted to one of the few monographs on the subject,[1] plus a more recent review.[2]

The medium

The velocity of sound varies with depth, and in deep water there is typically an important minimum somewhere near 1000 m. This can trap sound energy down to very low frequencies. An early experiment demonstrated this for the deep-water duct running from the neighbourhood of Australia, past the Cape of Good Hope and up into the NW Atlantic, the sound from a few pounds of explosive fired underwater at one end being detected quite easily at the other end.

Subsidiary surface and shallow sound channels also occur in deep water. Layering and ducting are also important in shallow coastal waters, and in suitable conditions even a detonator may be clearly heard beyond a hundred miles in range.

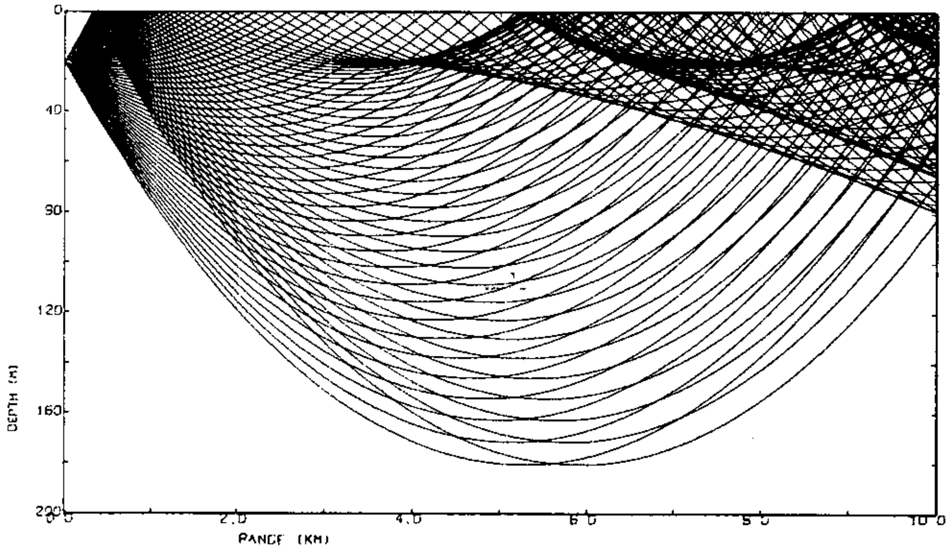


Fig 1 Ray plot for linear duct

At the upper boundary or sea surface there is a very large acoustic mismatch with the air which ensures perfect reflection at low frequencies, but the waves on the surface lead to scattering at the higher frequencies. The story is less clear-cut for the lower boundary or sea bed, and properties such as the velocities of both longitudinal and shear waves must be taken into account. The bottom can dominate the propagation at low frequencies, and for shallow depths.

Theoretical approaches

The recent theoretical emphasis has tended towards lower frequencies, wave-theoretical methods, longer ranges and velocity profiles which change with range. It will be no surprise that the current models are practicable only through use of computers.

All approaches may be considered to stem from the wave equation. This is true even for ray theory, which is still a good place to start. This is partly because the plots have an immediate impact; and partly because of the technical advantages for higher frequencies, shorter ranges and deeper water.

The example in Figure 1 is for a positive linear velocity gradient, and shows for high frequencies the surprisingly complicated structure of caustics and shadow regions.

Wave approaches increase in importance as one moves to lower frequencies, longer ranges and narrower ducts, such as those in shallow water or the surface mixed layer. Probably the best known wave method is the decomposition of the field into a number of normal modes. But the illustration in

Figure 2 was made using the parabolic equation, an approximation technique from electromagnetic theory introduced into underwater acoustics several years ago. It starts from a known solution at close range, assumes the equivalent ray paths are close to horizontal, and marches out in range using a process rather like the repeated application of Huygens' principle. It really comes into its own when the velocity profile changes with range, which is not the case in our example. In this example only two modes propagate well, and in effect they interfere to produce a very fuzzy ray. This cycles between the surface and bottom of the duct, note the intensity maximum near the surface at 9 km. Despite having the same geometry there are large differences in the propagation pictures given by Figures 1 and 2 (both were produced by D G Gleaves).

We will leave aside the many other methods of attack, such as the Fast Field Programme, and energy flux averaging procedures.

Experimental work

Theoretical models are reasonably self-consistent and well-behaved, and there is a great temptation to stay in the world of the computer, comparing this with that. The real world of measurement is much less tidy, and ship time for experiments is very costly. Although it sounds very pleasant to work in the Mediterranean or West Indies in summertime, in practice it is more likely to be the North Atlantic or North Sea in winter, with conditions hardly conducive to general well-being or to thought.

Typically the mean transmission loss would be measured using underwater explosions as sources. They are convenient to use from either ships or aircraft. They produce nice loud bangs which extend over a wide frequency range, so that by spectral analysis one may obtain quantitative results at several frequencies. Travel time measurements are also possible. One disadvantage is the complexity of the source waveform, with the initial shock wave followed by a series of pulses as the hot bubble of explosion gases expands and then collapses to a very small volume, expands and collapses again, and so on. It is also necessary to take stringent safety precautions.

An example of explosion measurements is the estimation of the bulk attenuation within the medium. Between about 100 Hz and 3 kHz the predominant mechanism involves a boron boric-acid relaxation. The early results were mainly for the North Atlantic and indicated about 0.05 dB km^{-1} at 1 kHz. Later results show an impressive dependence on pH, so that in the North Pacific the attenuation rate is about half that quoted above.

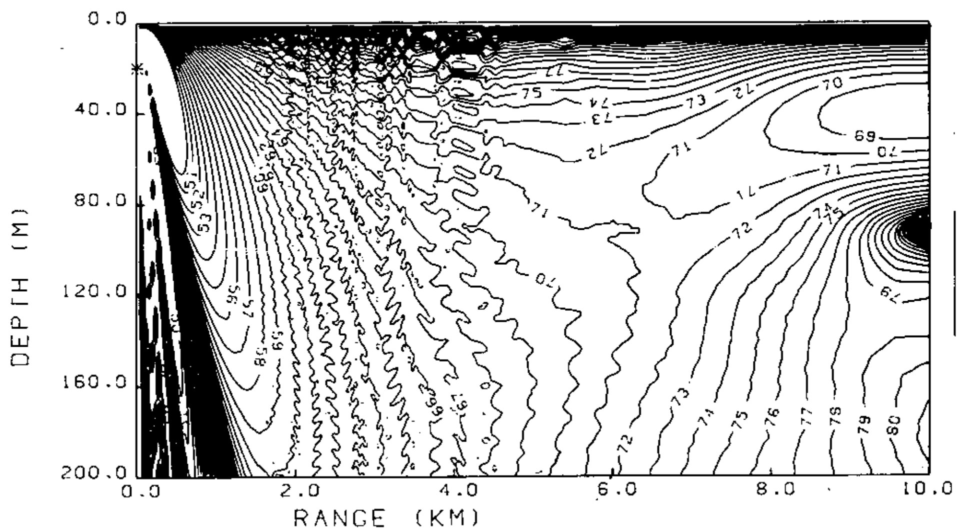


Fig 2 Parabolic equation transmission loss contours at 200 Hz for linear duct

If one is setting out to investigate variability in transmission, a subject of great current interest, one is more likely to use an electrically driven source, perhaps producing a continuous tone. The mechanisms might be piezoelectric, magnetostrictive, electromagnetic or even motor-driven. It is possible with such sources to monitor the transmission over a very long time interval, sometimes using equipment which is cabled ashore. A large number of disparate fluctuation mechanisms have been identified, with a wide range of periods. They run from surface and internal wave effects to variations caused by the seasonal changes in the structure and biological content of the water.

Uses

Knowledge of sound propagation is central to the design and development and proper operation of any underwater acoustic device or system. Thus in effect the research is largely fuelled by interest in passive and active sonar systems and in communications. Here we will merely refer to three spectacular applications which were made possible through the collaboration of the medium.[2] On passive listening: the Myojin volcanic eruptions off the Japanese coast were studied after the signals propagated right across and also reverberated right round the Pacific. On active detection: long-term sonar records of fish movement and behaviour have been made in shallow water out to several tens of miles range. On 'communications': a case of propagation half-way round the globe has already been mentioned.

A more direct use of sound propagation is the light it can shed on the character of the medium, and this has brought the Oceanographers into the story. One example concerns internal waves, ie gravity waves in the body of the water having a density layering. These produce acoustic effects with periods from a few minutes upwards, and are receiving a great deal of attention. Another is the so-called acoustic tomography, in which attempts are made to deduce the changing water structures in ocean areas a few 100 km across. This is done by making a series of acoustic 'cuts', or propagation measurements concentrating on time of flight, for different directions across the given area.

Conclusion

The field of sound propagation underwater is one encompassing a great variety of problems and of techniques. It is still a lively field with new discoveries being made, and with some real questions still unanswered.

References

1 *Ocean Acoustics: Theory and Experiment in Underwater Sound*, I Tolstoy and C S Clay, New York, McGraw Hill, 1966.

2 *Guided Acoustic waves in the Ocean*, D E Weston and P B Rowlands, Rep Prog Phys *42*, 347-387, 1979.

Nonlinear Acoustics

H O BERKTAY

School of Physics, University of Bath

The hydrodynamic equations governing the propagation of acoustic waves in fluids have been known to be nonlinear since Euler. An interesting presentation of some early attempts at analysing the effects of these nonlinearities is given by Lamb. In fact a solution by Earnshaw (1860) provides the basis for a very useful physical understanding of the distortion of a sinusoidal plane wave as it propagates in a non-viscous fluid.

To an acceptable degree of approximation, the nonlinear effects in a propagating wave may be considered to arise from the longitudinal nature of the wave as well as being influenced by the nonlinear pressure/density relationship in the medium. The overall effect is that the velocity of propagation of a particular phase of the cycle is a linear function of the particle velocity associated with that phase. Therefore, the zero-crossings of the differential pressure or particle velocity waveform (which we may assume to be initially sinusoidal) travel at the velocity of propagation, while the phases in the positive half cycle travel faster and those in the negative half cycle travel slower. The overall result is a progressive distortion of the waveform as the wave propagates. To put the magnitude of this effect into context it is worth pointing out that the distortion introduced locally (for a propagation distance comparable with the wavelength) is very small, the cumulative effect when the wave has travelled many wavelengths may well be significant.

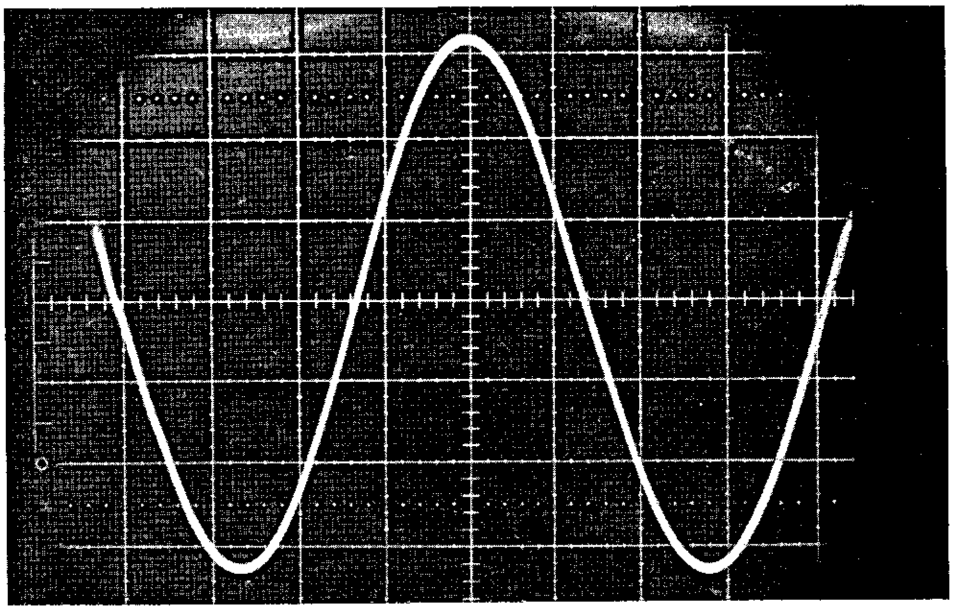


Fig 1(a)

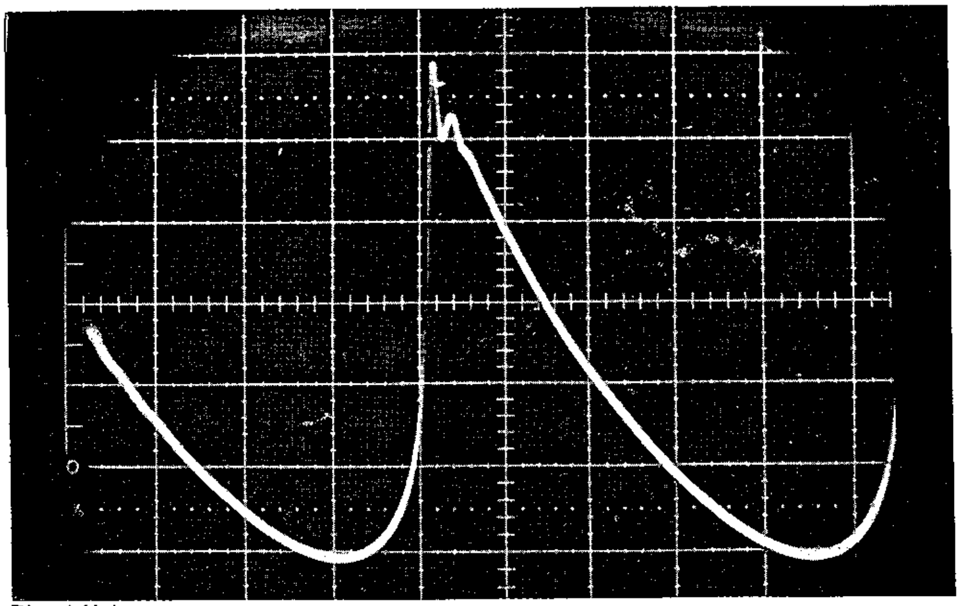


Fig 1(b)

Fig 1 Waveforms observed along the axis of a 5 cm diameter transducer at a frequency of about 1 MHz, for a transmitted intensity of 1·7 Wcm^{-2}, at different distances: (a) at 3 cm and (b) at 45 cm

As this process is continued, the waveform would resemble a sawtooth rather than retaining its sinusoidal property, becoming rich in harmonics. This is demonstrated in Figure 1, showing some results obtained in fresh water, along the axis of a 5 cm diameter transducer, resonant at about 1 MHz. The waveforms shown in Figures 1(a) and 1(b) were observed at axial distances of 3 cm and 45 cm respectively, using a PVDF film hydrophone with first resonance at about 27 MHz. The ringing seen in the waveform at 45 cm shows the presence of a significant amount of power in the 27th harmonic of the radiated frequency. Also, the waveform is seen to be non-symmetrical for the compression and dilation half cycles, whereas the explanation offered above for a plane wave would predict a symmetrical near-triangular waveform. The asymmetry of the observed waveform appears to be due to the complexity of the near-field of a transducer.

Extra attenuation of the fundamental frequency component

When considering the propagation of a finite-amplitude wave, one may think in terms of two effects working in opposition. The nonlinear 'forces' which depend on the amplitude of the acoustic pressure at a locality tend to transfer more power into the higher harmonics, while absorption in the medium tends to counteract this process.

As a consequence of transfer of power into the higher harmonics and nonlinear interactions between the various components, the amplitude of the fundamental frequency term is reduced more rapidly with range than indicated by the use of the absorption coefficient of the medium at that frequency. This extra-attenuation of the fundamental is particularly pronounced at ranges greater than the 'shock-formation' distance, ie beyond the range at which the waveform exhibits an infinite pressure gradient within the cycle.

Eventually, the pressure amplitude is reduced sufficiently for the absorption to become more significant than the nonlinear effects and the wave propagation resembles that of a wave of infinitesimal amplitude.

If the initial amplitude of the wave is increased, it is found that the pressure in the fundamental component at a sufficiently long range remains constant, the increased initial drive resulting in increased extra-attenuation. Clearly, this process limits the effective source level which can be obtained in a sonar system.

A saving grace, in practice, is that a sonar system is normally operated at ranges in the far-field of the transducer.

If the transmitted intensity from a transducer is such that the waveform distortion within its near-field is not severe, the geometrical spreading of the wave in the far-field of the projector results in the reduction with range of the pressure amplitude, and hence, of the nonlinear effects. As a consequence, the distortion of the waveform with increasing range is more gradual than in the near-field. However, even then, if the drive is sufficiently large, significant extra attenuation occurs in the far-field of a transducer. If the drive is increased still further, the waveform will go into shock within the near-field, causing more severe extra attenuation.

These effects may be seen in Figure 2 where the fundamental component of the received pressure is plotted against acoustic power for various transducers, all at a frequency of about 1 MHz. The near-field distances for the transducers are, respectively, 7 cm, 16 cm, 43 cm and 1.10 m. The straight line is included to show the 'dB per dB' slope which would be obtained in the absence of nonlinear effects.

Comparing the results shown for the same range for different transducers, we may note that for the same acoustic power the extra attenuation is increased with the area of the transducer. Also, the results at two ranges for the largest transducer indicate the increase in extra attenuation in the far-field from 1.5 m to 8.0 m. Indeed at 8.0 m, the rate of increase of the sound pressure level with transmitted power is reduced substantially.

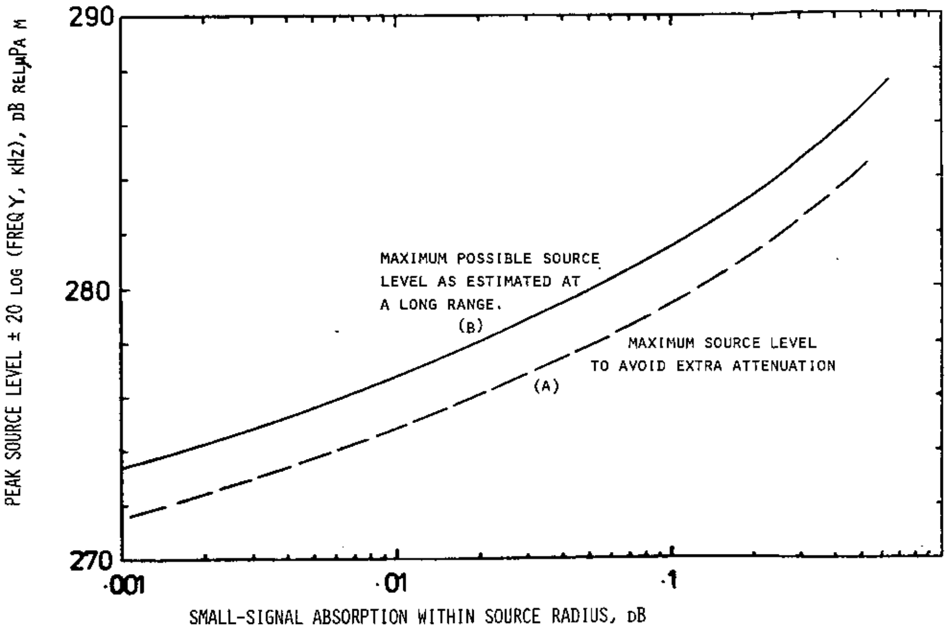


Fig 3 Effective source levels obtainable with a projector, taking into account finite-amplitude effects

A detailed study of these effects in the case of a planar transducer is very complicated. However, assuming the bulk of the waveform distortion to occur in the far-field of the transducer, we may use the solutions available for a spherical source. For this purpose, the effective source radius is of the order of the near-field distance of the transducer (ie area/wavelength). On this basis, an estimate can be obtained for the maximum permissible source level for projectors of different (simple) configurations, in order that extra attenuation effects are avoided at long ranges. A simple 'ball park' estimate (accurate to within 1 or 2 dB in many cases) may be obtained from curve (a) in Figure 3. Curve (b) in the same figure shows the maximum *effective* source level (estimated from sound level measurements made at long ranges, when the wave has reverted to 'old age') which may be obtained if the drive is increased. Abcissa is absorption within source radius in dB and curve (b) has been obtained as an approximate result in order to simplify the presentation. As can be seen, the difference between the source levels given by the curves (a) and (b) is about 2 dB. If the drive is increased beyond the 'linear' range, extra attenuation increases rapidly, while the effective source level goes up only marginally.

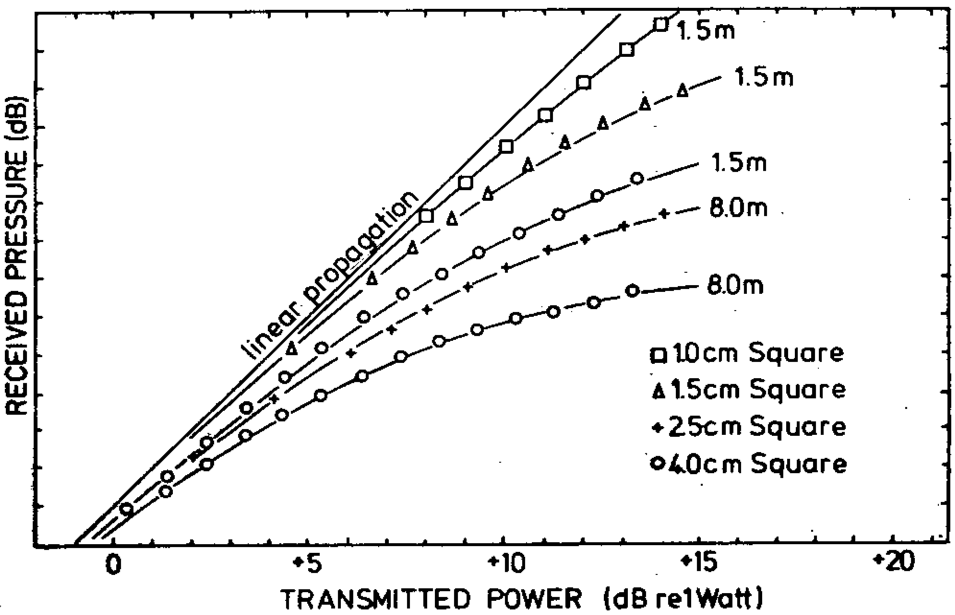


Fig 2 Variation of the fundamental component of received pressure with transmitted acoustic power at a frequency of about 1 MHz, for various transducer dimensions

A serious consequence of the extra attenuation is the distortion of the beam shape. As the intensity is high near the centre of the beam, the main lobe is compressed, resulting in the broadening of the beam. Further, as the side lobes (being at lower intensity) propagate more linearly, the side lobe discrimination is much reduced.

Thus, for sonar design it is of benefit to use the results of curve (a) as a guideline for source-level calculations.

Parametric Sources

The effects of higher-order nonlinear interactions (leading in particular to the limiting of the effective source-level obtainable from an acoustic projector) are of general significance in the realisation of sonar systems. However, what captured general interest in the field of nonlinear acoustics was Westervelt's paper on parametric sources. The principles are best illustrated by considering weak nonlinear interactions between coincident acoustic waves.

For this purpose we consider two acoustic waves each of high frequency, ω_1 and ω_2 respectively, with $(\omega_1 - \omega_2)$ being small compared with the average of the two frequencies. Wherever the two waves are coincident, they interact nonlinearly, producing interaction frequency terms, $|n\omega_1 \pm m\omega_2|$. Of particular interest is the low-frequency component corresponding to the difference frequency, $\omega_1 - \omega_2$.

It is possible to set up the differential equations for the difference frequency field, to the order of accuracy being considered, by obtaining a perturbation solution of the nonlinear wave equation. However, a physical insight into the behaviour of the difference-frequency field is obtained through the use of the source-function concept put forward by Westervelt.

A consequence of the perturbation solution (or of 'quasi-linear' approach) is that the primary field at any point may be evaluated by ignoring nonlinear effects. Interaction between the two primary waves in an elemental volume causes the generation of a wavelet at the difference-frequency which will propagate linearly. This wavelet can be ascribed to a simple source the strength of which can be calculated from a knowledge of the primary field at that point.

The conceptual simplicity of this approach may now be appreciated. The primary field calculated in the usual way is used to evaluate the volume distribution of the virtual sources at the difference frequency. Then, the difference-frequency field produced by these 'simple' sources can be written down in the form of a volume integral. In specific cases, this integral can be evaluated numerically. However, approximate closed form solutions produced for various configurations provide useful guidelines in estimating the difference-frequency field.

To simplify our considerations, we may assume that the two primary waves are launched from the same transducer. The delineation of the interaction region (and hence, of the source volume will thus be controlled by the directivity function of the transducer at the two high frequencies.

The amplitude of the source density at a point is proportional to the product of the amplitudes of the primary pressures at that point, while its phase is given by the phase difference between the two primary pressures. The situation is best depicted by considering the primary pressures and the difference-frequency source density at a point (r, θ, ϕ) in the far-field of the transducer. The primary pressures can be written in the form

$$P_{1,2} = \frac{P_{1,2}}{r} D_0(\theta, \phi) e^{-\alpha_0 r} . e^{-jk_{1,2} r}$$

Here P_1 and P_2 represent the source levels, k_1 and k_2 are the wave numbers, and (as the two frequencies are similar in magnitude) the absorption coefficient α_0 and the normalised directivity function D_0 have been used for the centre-frequency $\omega_0 = (\omega_1 + \omega_2)/2$. Then, the source density q(r, θ, ϕ) is proportional to the product $P_1.P_2^*$, the asterisk indicating the complex conjugate; ie

$$q(\vec{r}) \propto \frac{P_1 P_2}{r^2} D_0^2 (\theta, \phi)\, e^{-2\alpha_0 r} . e^{-jkr}$$

where $k = k_1 - k_2$ and is the wave number at the difference frequency.

The difference-frequency pressure at a point $\vec{R}$ can be obtained by evaluating the following volume integral:

$$P = \frac{j\omega\rho_0}{4\pi} \int\int\int \frac{q(\vec{r}) e^{-jks}}{s} d\nu$$

where ρ_0 is the density of the medium and $\vec{s} = \vec{R} - \vec{r}$. Absorption at the low frequency has been ignored. Also, for the spherical co-ordinate system assumed, with θ measured from the acoustic axis of the transducer $d\nu = r^2 \sin\theta d\theta d\phi . dr$. Note that r^2 cancels the r^{-2} dependence in the expression for $q(\vec{r})$.

Some general results obtained from the evaluation of this integral are discussed in the literature, providing methods of evaluating both the effective source level and the directivity at the difference frequency for given parameters at the primary frequencies. Good agreement between predictions and the considerable amount of experimental results already available has provided confidence in the analytical techniques used.

It is worth noting that the 'local' nonlinearity (and hence the magnitude of the source density) is very small even at high primary source levels. However, when the effect is integrated over the whole of the interaction volume, practically significant difference-frequency sound pressure levels can be obtained. This can only come about if the wavelets add substantially in a co-phasal form at the field point.

If the primary waves are confined within a narrow beam, for example, the source distribution is concentrated close to the acoustic axis of the transducer. Then the difference frequency sources resemble an end-fire line array with exponential taper, provided by the term exp $(-2\alpha_0 r)$.

This can be seen by using the expression for $q(\vec{r})$ in the volume integral. With the vector $\vec{r}$ very close to the acoustic axis for significant source densities, all the wavelets will add co-phasally at a field point along the acoustic axis as then $r + s \simeq R$ for all r. If the field-point is off-axis, a varying amount of destructive interference will be observed, producing a smaller sound pressure level.

If the field point is in the far-field of the sources, the radiation from such a continuous line end-fire array can be evaluated quite simply. An interesting result is that because of the smooth reduction of the source strength (through the exponential taper) the directivity function at the difference frequency decreases monotonically with angle, without any sidelobes. The beamwidth will be controlled by the exponential taper (which determines the effective length of the array) and by the wavelength at the difference frequency.

Thus, by a suitable choice of the primary frequencies, a relatively narrow beam of sound can be produced at a much lower frequency. As the size of the transducer is dictated by the directivity requirements at the higher frequencies, a very significant reduction can be achieved in the transducer size to produce a narrow beam of low-frequency sound by using a parametric source.

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Proceedings of The Institute of Acoustics - Abstracts

Autumn Conference

8-9 November, at the Queen's Hotel, Bournemouth

Speech Communication

A1. Glottal Losses in a Composite Model of Speech Production

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Glottal area is one aspect of laryngeal articulation in a model of speech production. Aerodynamic conditions throughout the system determine, together with vocal fold state, the form of the a c component of volume velocity of airflow through the glottis, used as the voice source (Allwood and Scully, 1982). The glottal contribution to formant bandwidths is expected to be given by:

$$BW_{g1} = \frac{c^2 A_g^2}{2\pi k U_g V_c}$$ for F1, or twice this, for any format (Fant, 1979);

where A_g = glottal area, U_g = vol vel of glottal airflow, V_c = volume of the cavity above the glottis, c=velocity of sound in the vocal tract and k=0·875.

Transglottal acoustic losses are made to vary with the d c (articulatory) component of A_g. [i]—type and [α]—type shapes of vocal tract are compared to investigate the effects of varying V_c. Realistic representation of glottis, wall and radiation losses is considered. Results are compared with those of Flanagan *et al* (1975) and of Wakita and Fant (1978).

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A2: The Target Theory of Speech Production in the Light of Mandibular Dynamics

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Stockholm University

Our aim is to review several sets of experimental facts that bear on the notion of *target* as used in current speech production theories.

In the first experiment we return to the topic of articulatory and acoustic undershoot in vowels. Is this effect associated primarily with a decrease in vowel duration whether such a decrease is brought about by destressing or by a tempo increase as argued by Lindblom (1963)? Or is its chief determinant destressing rather than increased tempo as suggested by for instance Gay (1977)? We report data on maximal mandibular displacement in vowels as a function of vowel duration. The (Swedish) speech materials were designed in such a way that stress and tempo effects were controlled separetely and with the aid of an improved method for instructing the subjects. Our results — plotted in the form of graphs with extent of displacement *vs* vowel duration — indicate that there is undershoot relative to a mandibular target as a function of decreasing vowel duration — *both* for the stress *and* for the tempo controlled samples. However there is more undershoot in the case of destressing.

In the second experiment mandibular undershoot was investigated as in the first study. Subjects were now instructed to pronounce the speech samples — which contained a single test vowel: [a] — at three levels of voice effort: soft, normal and loud. Displacement *vs* vowel duration plots were produced. They indicate duration-dependent undershoot effort for all three voice levels. However, the data for the three different efforts *cannot* be reconciled with a single underlying mandibular target since speakers tend to lower their jaws more when speaking louder.

As a general rule, does a speaker lower his jaw when pronouncing a given vowel louder? Results from articulatory modelling work (Lindblom and Sundberg, 1971) suggest that everything else being equal for some vowel configurations such as [a] a mandibular perturbation will have markedly less drastic acoustic consequences than for others say [i] or [u].

In view of this circumstance it cannot be entirely ruled out that the results obtained in the second experiment — that is the absence of a single mandibular target — reflect a vowel — specific rather than a general strategy for increasing loudness. What do speakers in fact do when they increase the loudness of different vowels?

Since an answer to that question might be of considerable interest in the context of further developing the theoretical construct of vowel target we decided to do a third experiment: *a 'natural and dynamic bite-block' experiment*. This work is now in progress. By the time of the conference we shall have data on mandible position and mouth opening, SPL values, formant pattern and identification scores for several vowels spoken in normal and loud syllables.

How do increases in loudness affect jaw and mouth openings for different vowels? Do the results indicate compensatory articulatory effects (cf bite-block speech)? In other words, although mandibular lowerings might occur is there evidence (acoustically inferred) of other articulatory gestures compensating? Or is invariance of formant pattern sacrificed for certain vowels in order to raise the SPL of the vowel (partly by increasing F_1 which is in turn achieved by lowering the mandible)? Those are some of the questions that at the time of the meeting we hope to be able to address and relate to the target theory of speech production.

A3. Temporal and Spectral Properties of Glottal Flow Pulses as a Function of Speakers, Vowel and Stress Level

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Institute of Phonetics, Nijmegen University
The Netherlands

We have designed a semi-automatic system for the reconstruction of glottal flow pulses by means of an inverse filter applied to the acoustic speech wave. The system has been carefully evaluated by comparing its output with simultaneous registrations of a number of physiological signals. The paper will start with a short presentation of the system and a formal evaluation of its performance. Next its application will be discussed in the processing of an extensive speech material, aiming at a description of glottal flow waveforms depending on the speaker, vowel type and stress level.

The data to be presented pertain to five adult male speakers, six vowels representative of both extreme and central points in the F_1 — F_2 plane that have been produced in both stressed and unstressed syllables.

A4. A Filter Bank Model of the Basilar Membrane

N Black and R Linggard
Queen's University, Belfast

The design of a physiologically based filter bank to simulate the filtering action of the middle ear and basilar membrane is described. The middle ear is represented by a fifth order digital filter, and the filter bank consists of 145, fourth-order, band-pass, digital filters. The whole system is implemented in software on a Vax mini-computer. The centre frequencies of the filters are arranged on a logarithmic scale, and their bandwidths are made proportional to the critical band at each particular frequency.

This simulation has been used to generate spectra from real speech, on which various spectral processing techniques have been tried out. These include neural models, spectral peak enhancement, and pitch detection algorithms. The paper describes several of these, and gives examples of speech spectra before and after processing.

A5. Problems of Normalising the Spectral Effects of F_0 Variations

R A W Bladon
Phonetics Laboratory, University of Oxford

An auditory theory of speaker normalisation (Bladon, Henton and Pickering 1982, following Potter and Steinberg 1950) postulates that male/female vowel differences can be normalised by means of linear displacement, by a constant Bark scale quantity, of a vowel's spectral shape in auditory space. Since male/female F_0 differences are about 1 Bark on average, they accord with this theory. More problematically, though, a harmonic component at the fundamental frequency creates marked warpings of the physical (and auditory) spectrum both by its amplitude variations and by its frequency interaction with other spectral components. However, perceptual mechanisms apparently compensate for such warpings. We attempt first to quantify these effects in production terms, and second to model the perceptual compensations.

A6. Neural Firing Model of the Basilar Membrane

R Linggard and P J McCullagh
Queen's University, Belfast

A model for the firing of neurons along the basilar membrane has been developed as an adjunct to a mechanical model of basilar membrane behaviour. The mechanical model of the basilar membrane (BM), reported previously (Linggard & McCullagh, 1981) is based on a state space solution to the one-dimensional, transmission line approximation of the basilar membrane, introduced by Peterson, and subsequently developed by Schroder and Hall. The BM is represented by 70 transmission line sections, each of which consists of a series resonant Tee network. The circuit parameters are derived from mechanical properties of the BM, and have been adjusted to fit the measured variation of resonant frequency and damping in the human cochlea.

The conversion of BM deflection to probability of neural firing is implemented using a digital version of Schroder's neural model, which takes into account adaption, satuation and spontaneous firing. This firing algorithm is applied to the outputs of each of the seventy sections, and graphs of overall neural behaviour are obtained.

Results are given for both sinewave and impulse excitation of the BM at different sound levels.

A7. Effect of Pre-emphasis on Automatic Vowel Recognition Performance

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Division of Telecommunication
University of Trondheim, Norway

Effect of pre-emphasis of the speech signal on vowel recognition performance is studied. Pre-emphasis of the speech signal is achieved by taking a first order difference of successive speech samples. Cepstral coefficients derived through linear prediction analysis of the speech signal are used as recognition parameters. A minimum distance classifier with Euclidean distance measure is used for vowel recognition. Speech data used in the present study consist of 20 ms steady-state vowel segments excised from 900/b/-vowel-/b/ utterances spoken by three speakers (two male and one female). It has been found that pre-emphasis of the speech signal deteriorates the vowel recognition performance.

Sound Intensity Measurement

B1. Practical Applications of Real-Time Sound Intensity Measurements

B Ginn
Brüel & Kjær, Denmark

The introduction of real-time analysis using digital filter techniques to process the signals from two closely spaced microphones has greatly improved the precision with which sound intensity may be measured.

This paper gives some general answers to the questions:

1 What does one measure with a sound intensity analysing system?

2 Where should one measure?

There is a brief discussion of active and reactive sound fields, of propagating waves and evanescent waves and of circulating energy. The main applications of a real-time sound intensity analysing system are presented, ie

1 Source location
  a Comparison method
  b Continuous sweep method
  c Intensity mapping
2 Determination of sound power
3 Absorption coefficients of large surfaces
4 Sound reduction index.

Practical measurements and results are presented from the following investigations:

1 Line printer
2 Motor vehicle
3 Aircraft
4 Brewery
5 Refrigeration equipment
6 Foundry

B2. Unbiased Sound Power Determination by Intensity Measurements

J C Pascal
CETIM, Senlis, France

Use of acoustic intensity meters allows the determination of acoustic power of sources where the systematic errors of measurement inherent in standardised methods are absent.

Errors of near field are cancelled by the energetic nature of the measured quantities; geometrical errors of projection are eliminated by its vectorial nature, and errors due to noisy surroundings are reduced by the conservative structure of the vectorial field. However, the finiteness of the measurement in the time and space domain (discretisation) introduces an inaccuracy of which the statistical parameters (variance) depend upon the nature of the perturbation field, the source directivity and the choice of the survey surface of measurement. The cross spectrum method directly yields estimators of the variance (phase and coherence) and it is shown that these quantities also are descriptors of the sound field on which measurements are made.

B3. Visualising Acoustic Fields by Means of Intensity Vectors

U Kristiansen
NTH, Trondheim, Norway

In studies conducted at the University of Trondheim we have experimentally and theoretically obtained two-dimensional intensity vector 'maps' of several acoustic fields. We have been using the finite difference approximation for the acoustic particle velocity. These vector maps describe the power flow directly and are therefore of great help when a fuller understanding of a noise source or a complicated acoustic field is required.

The experimental investigations include pure tone sound in the vicinity of resonators and acoustic barriers. The power flow away from a 'screaming' idling saw blade has also been measured.

The theoretical investigation has primarily been concerned with sound radiation from beams and plates vibrating in one of their natural modes. We have been especially interested in changes in the near field power flow for given mode shapes as the frequency of vibration has been changed theoretically.

B4. Intensity Measurement of Sound Absorption

P S Watkinson
ISVR, Southampton

The evaluation of the sound absorbing properties of materials and objects is important for good and reliable design of room acoustics. The rapidly developing techniques of sound intensity measurement offer the possibility of new methods for the measurement of sound absorption which may have advantages over conventional techniques.

Using an intensity meter, absorbed power can be measured over the surface of an absorber placed in a diffuse field (ie in practice in a reverberation room). From pressure measurements in the field away from the absorber the incident power may be estimated and thus an absorption coefficient calculated.

The advantages and disadvantages of this method over conventional techniques will be discussed and some results presented.

B5. Sound Intensity Measurement of Transmission Loss

F J Fahy
ISVR, Southampton

The assumptions upon which transmission loss measurement is based are reviewed. The principle of application of sound intensity measurement to the determination of transmission loss is outlined and certain theoretical and practical problems are discussed. Applications of the technique to the determination of transmission loss of panel constructions mounted between small reverberation rooms are presented and a comparison with the standard method is made.

B6. Acoustic Intensity Techniques for Transient Noise Sources

P S Watkinson
ISVR, Southampton

Techniques for the measurement of acoustic intensity due to continuous noise sources have advanced greatly over the past few years. Applying these techniques to transient noise sources yields measures of acoustic energy flux per unit area for a transient event, with the advantage of measurements *in situ*. Intensity-time graphs may prove useful in the characterisation of transient noise sources, as will the acoustic energy flux spectra, providing material for noise control.

This paper will discuss signal processing techniques and associated accuracy considerations applied to the determination of transient acoustic intensity in both the time and frequency domains. Reference will be made to the two microphone approximations, the transducers and analogue instrumentation, digital sampling and time-series analysis.

B7. Velocity Microphone for Intensity Measurements

O-H Bohr
Norwegian Electronics AS

The transmission velocity of an ultrasonic wave in air will be equal to the normal velocity of sound plus or minus the velocity of the air. A measurement of the transmission time for an ultrasonic wave to pass from a transmitter to a receiver may therefore be used to measure the air velocity or the velocity component of a sound field. The paper describes a new velocity microphone for sound intensity measurements based on this principle. The upper cutoff frequency is related to the distance between the transmitter and the receiver. The lower cutoff frequency is only determined by the time measurement circuits and the microphone may even be used down to zero Hz (DC coupled). The microphone will be used in a probe for sound intensity measurements.

Speech Communication

C1. Towards an Integrated Discriminative Network for Automatic Speech Recognition

R K Moore, D Beardsley, M J Russell and M J Tomlinson
RSRE, Malvern

Whole word pattern matching using dynamic time-warping has achieved considerable success as an algorithm for both isolated and connected word recognition. However, the performance of such an algorithm is ultimately limited by its inability to discriminate accurately between similar sounding words. The problem arises because all differences between speech patterns are treated as being equally important, hence the algorithm is particularly susceptible to confusions caused by irrelevant differences. This paper presents an alternative dynamic time-warping approach which is able to focus its attention on those parts of a speech pattern which serve to distinguish it from similar patterns. A network type data structure is derived automatically from reference speech patterns, and the separate paths through the network determine the regions where recognition takes place. Preliminary results indicate that discrimination between similar sounding words is improved, and the implications for future speech recognition algorithms are discussed.

C2. A Data-adaptive Frame Rate Technique and its use in Automatic Speech Recognition

J S Bridle and M D Brown
JSRU, Cheltenham

Data adaptive frame rate (DAFR) techniques have been used, under various names, in schemes for automatic speech recognition and low-bit-rate transmission. The basic idea is to match the representation to the non-stationary nature of speech signals by using a higher data rate when the properties of the speech signal are changing.

In automatic speech recognition using whole-word pattern matching, the advantages of DAFR include a reduction in storage and computation requirements for a given fidelity of representation of important detail. Apart from these clear implementation advantages, we argue that there should also be an improvement in speech recognition performance simply due to the extra weight given to time-varying portions of the signal (because there are relatively more frames representing them).

We present a simple algorithm for reducing an initially high frame rate, of say 200 frame/s, to a variable rate, in a way that preserves information when the spectrum is changing, but progressively reduces the rate to a minimum, of say 30 frame/s, when there is little change. This algorithm has been successfully implemented in a high-performance real-time connected word recognition equipment. We shall also present the results of some experiments on the accuracy of connected digit recognition using speech data at fixed and variable frame rates, and discuss the implications.

C3. Automatic Speech Recognition using Local Timescale Variability Information

M J Russell, R K Moore and M J Tomlinson
RSRE, Malvern

Recent work at RSRE has resulted in an algorithm for automatically measuring local timescale variability in speech. Previous experiments have demonstrated the effectiveness of this algorithm as a tool for highlighting significant temporal contrasts. This paper describes two alternative techniques for incorporating local timescale variability information into a Dynamic Time-Warping algorithm for isolated word recognition. Results are presented which show significant improvements in recognition accuracy, especially where the difference between classes is primarily due to temporal structure.

Session D

Session D is an informal workshop on Sound Intensity Measurement.

Speech Communication

E1. Sectorgrams—A New Way of Looking at Speech

R Linggard and D Rankin
Queen's University, Belfast

The traditional speech spectrogram is, perhaps, the most graphic way of presenting speech signals in a form easily assimilated by the human eye. It provides a means of looking at long segments of speech and of visualising spectral energy transitions, which are so meaningful and characteristic of speech sounds. Indeed, some research workers have even taught themselves to 'read' spectrograms with impressive accuracy. Unfortunately, spectrograms do not lend themselves readily to scientific analysis. Consisting, essentially, of black smudges on grey paper, they are meaningful to the human eye, but are otherwise not easily quantifiable. The problem is that, to view speech spectra in time, requires a three-dimensional display of the variables, frequency, amplitude and time. Creating the sequences of short-time spectra is easy enough, the difficulty is essentially one of display. An alternative method of looking at long sequences of speech spectra is to sectionalise each spectrum and display it as a SECTORGRAPH. This paper describes in detail this method of presenting the three-dimensional information in two-dimensional form.

E2. The Computer Analysis of Prosody

D Lindsay and W A Ainsworth

Department of Communication and Neuroscience, University of Keele

The acoustic correlates of the suprasegmental features of speech show great variability both between speakers and within one ideolect. One problem associated with this is the modelling of the corresponding recognition process. Any acoustic analysis of prosody must deal with the entire structural description of a phrase in order to categorise the relevant segments or groups of segments. This suggests that syntactic methods of analysis are more suitable due to the contextual nature of suprasegmentals: the traditional feature-detection and template matching methods are not appropriate here because their domain is restricted to only part of the phrase. A computer program has been written which controls an automatic analysis of speech by interpreting a set of rules constituting a description of the British English intonation system.

Working over a given corpus the program constructs a description of the pitch phenomena of the phrase; a measure of the goodness-of-fit is returned giving an indication of the applicability of the rules.

E3. Segmental Cues to Syntactic Structure

D R Scott and A Cutler
Laboratory of Experimental Psychology, University of Sussex

What kind of acoustic information do listeners use to decode the syntax of an utterance when there is no contextual information available? We will report the results of a study which examines the possible role of segmental aspects of an utterance as perceptual cues to the location of major syntactic boundries. We have chosen to look at the phonological rules of alveolar flapping and palatalisation which, in certain dialects of English (ie American English) apply across word boundaries but not across major syntactic boundaries. The experiment to be described investigates whether listeners use the presence or absence of flapping or palatalisation across a word boundary as a perceptual cue to the presence or absence of a major syntactic boundary between the two words. We also examine the relation between the use of these segmental features as syntactic markers in production and perception.

E4. Synthesis of Rhythmic Structure

S D Isard
Laboratory of Experimental Psychology, University of Sussex

One important dimension of difference among theories of segmental duration in English speech is their stand with regard to rhythm. It can be an underlying source of the observed phenomena, as in Witten's computer implementations of the ideas of Abercrombie, or a mere coincidental by-product of a set of entirely different principles, as in the system proposed by Klatt.

In an attempt to clarify the role, if any, of rhythmic principles in the organisation of English speech, we have constructed a speech synthesis by rule system in which phoneme durations can be determined according to four alternative algorithms: those published by Witten and Klatt, the first based on rhythmic feet and the second on intrinsic phoneme duration plus local syntactic environment, and ones derived from the work of Thompson, based on properties of syllables, and Cutler and Isard, based on a hierarchy of rhythmic units.

These algorithms are being subjected to tests first to determine whether they produce distinguishable styles of speech, and then for naturalness, intelligibility and other distinctive properties. In particular, preliminary results indicate that listeners perceive clearer separations between words with the rhythmic algorithms.

E5. The Use of Multi-pulse Excitation in Speech Synthesis

A P Varga and F Fallside
Cambridge University Engineering Department

One of the weaknesses of conventional L P analysis is in the excitation. The true glottal excitation is only approximated and voiced/unvoiced decisions made in the analysis are often approximate or erroneous. As a result, although moderate or low bit rates can be achieved the quality of the output speech can be low.

A significant improvement in speech quality and naturalness has been achieved by Atal and Remde (1) who introduced a method of multi-pulse excitation for low bit rate vocoders. In this the L P filter is derived in the conventional manner but a second stage of analysis is used to generate the excitation as a series of pulses during each block of speech. The method can provide high quality speech, practically indistinguishable from the original.

The method is therefore of considerable interest for the improvement of speech quality in text to speech synthesis. In such systems a syntactic analysis is usually used to generate intonation information including the excitation, eg Meli and Fallside (2). This provides either conventional impulse train excitation during voiced speech or white noise during unvoiced speech. Since the Atal and Remde multi-pulse excitation is neither of these it is necessary to relate derived excitation to multi-pulse excitation. This is the subject of the paper and preliminary results will be given in the paper for the case of synthesis by word concatenation.

1 Atal, B S and Remde, J R: A new model of lpc excitation for producing natural sounding speech at low bit rates. ICASSP '82, Paris, 1982, pp 614-617.

2 Meli, R M and Fallside, F: The modelling of F_0 contours. Ibid, pp 947-949.

E6. Adaptive Transform Coding of Speech at 0.6 kbit/s and Below

J M Rye and B C Dupree
JSRU, Cheltenham

A computer simulation of an adaptive transform coding scheme has yielded good quality output with transmission rates of 9.6 kbit/s. In transform coding, the speech is block transformed into the frequency domain and each coefficient is independently quantised. The number of bits and step sizes of the quantisers are adapted to follow the characteristics of the block of speech data. The adaption is controlled by side information, which is transmitted along with the quantised transform coefficients.

The main features of the design will be described but particular attention will be paid to the side information, which was chosen to take into account aspects both of human audio perception and of speech production. It consists of a coding of the spectral envelope and a coding of some of the fine structure present in the spectrum. The method we use takes some account of the perceptual masking of quantising noise by speech.

Audio tape recordings will be played to give an indication of the speech quality obtained from this type of coder.

E7. Speech Coding at 32 kbit/s for Use in the Switched Telephone Network

L S Moye and J A S Angus
Standard Telecommunication Laboratories Limited

There is currently a great demand for a coder which will give telephone quality speech at 32 k bits/s. For use in the Switched Telephone Network it has to be capable of transmitting voice frequency data signals and conforming to many other difficult constraints.

The paper will describe the constraints, the systems that have been proposed, their limitations and new solutions to some of these limitations.

Audio and visual material will be presented showing some of the problems that occur in the adaptive backward predictive coders that are suitable for this application, and, we hope, illustrating the solutions.

Machinery Noise Control

F1. Quietening Paper Printing Presses by Active Control

C F Ross
Topexpress Limited, Cambridge

In order to investigate the possibility of reducing the very high sound levels heard by the operators in Fleet Street newspaper press rooms a pilot study was conducted on an equivalent machine — a paperback book press at Timsons Limited.

The study, which will be described in the paper, showed that the conventional broadband active control systems did not perform as well as we hoped because of the fluctuations in the speed of the presses. An alternative scheme which was linked directly to the machine speed was more promising. The resulting noise reductions were moderate (7 dB maximum) because of unfavourable conditions but indicated that with refinement they would be likely to give the benefits required in the Fleet Street press rooms.

F2. Comparison of Least Squares Estimation and Impulse Response Techniques for Active Control of Flame Noise

P J Dines
Cambridge University Engineering Department

In order to attempt control of a system, knowledge of its characteristics is required. If knowledge is not available through theoretical considerations then observations of the system must be made.

In control of flame noise input/output methods lend themselves to the nature of the problem. However frequency response analysis relies on introducing known disturbances at the input and measuring the concomitant output. Such a method is not possible with a flame where no disturbances, nor even perturbations on normal operation, are possible. Flame sound and light emissions are stochastic processes and measurements of the flame are thus amenable to analysis by spectral analysis and system identification methods.

Because of the random nature of the flame emissions digital control techniques are suitable since many system identification algorithms produce solutions easily implemented on a digital filter. These techniques have their basis in modelling the system as an autoregressive-moving average process and the following section sets down this model. Two methods are then discussed: one, least squares estimation, which estimates the autoregressive-moving average model of a flame; the other, impulse response estimation, which models the flame simply as a moving average process.

A mechanical transfer function simulator is then used to compare the two methods and with this experience their applicability to flame sound/light emissions is discussed. Finally the current problems are highlighted and possible solutions suggested.

F3. Damping and Cancellation Devices to Reduce Punch Press Noise

G Stimpson
ISVR, Southampton

The unrestrained sudden springback of a press frame following material fracture is a source of high transient vibration levels and noise. A damping or blocking device placed in parallel with the tooling can be used to smooth the frame springback rate and lead to significant reductions of noise and vibration.

The machinery and structures group of the ISVR, in conjunction with the French research association CETIM, is at present studying the use of these devices. Our paper will review current devices and report on measurements made on a 25 tonne 'C' frame press at the ISVR and a 200 tonne straight-sided press in France.

F4. Noise Control by Energy Flow Restriction for Impact Machines

J Cuschieri
ISVR, Southampton

Most types of machine operations are of an impact nature. By equating the total energy left in the machine structure after the machine process, to the noise energy radiated by the machine, an expression is obtained which relates the radiated noise to structure parameters, like structural loss, point response at the point of impact, radiation efficiency of the structure and the force pulse shape. This expression gives the contribution that each of those structure parameters, if modified, will give to the reduction of radiated noise. The most efficient form of noise control is to restrict the flow of energy to the most efficient sound radiation part of the machine structure, that is modification of the point response and the pulse shape to create a mobility mismatch. Experiments were performed on a simple machine-type structure to verify this theoretical approach and it is shown that very high noise reduction can be obtained by energy flow restriction.

F5. An Estimation of the Noise Radiated from a Model Drop Hammer using Surface Velocity Techniques

I E Carr
ISVR, Southampton

A model drop hammer, which is an exact one-third scale replica of a 1-ton Massey Marathon drop hammer, has been built at ISVR. In order to determine the percentage contribution of each hammer component to the total noise radiated, surface velocity measurements have been taken at closely spaced intervals, using miniature accelerometers, on each component. An estimate of the noise radiated from each component, in one third octave bands and with a scaled A-weighting factor, has been calculated from the time and spaced averaged velocity^2 measurements, using radiation efficiency corrections for each component. The total radiated noise energy (scale A-weighted) has also been calculated using microphone methods. The agreement between this and the sum of the estimated energy from each component is within 0.5 dB in total, and also shows good agreement in 1/3 octave bands.

Measurements on the impactor (termed the tup) show a large amount of broadband noise energy radiated at frequencies below any tup resonance. This is attributed to acceleration noise caused by the rapid tup deceleration during a blow. The magnitude and frequency content of this broadband noise is in close agreement with that estimated from the duration and magnitude of the force pulse between the dies.

The process has been repeated on the full size hammer with similar results.

F6. Noise Radiated by Corkpaper Cutting Knives in the Production of Filter Cigarettes

J D Dornseiffen
Turmac Tobacco Company BV
The Netherlands

In the cigarette industry tipping paper from a bobbin is cut with a frequency of 2000 to 3600 pieces per minute to produce filter cigarettes.

The cutting process is in fact a squeezing process where the cork paper is pressed between a tungsten carbide knife with a top angle of 60-90° and a tungsten carbide circular drum.

The noise radiated was the result of a frequency much higher than the cutting frequency and was caused by the vibration of the knives when they come to rest just before the cutting process.

The investigation of time functions and Fourier analysis with the help of a narrow band spectrum analyser gave an answer to the question how to overcome the vibration and thus the radiated noise.

F7. Problems in Active Noise Control

Ian Roebuck
AUWE, Portland, Dorset

Now that the possibility of Active Noise Control is widely accepted, there is a danger that it will come to be regarded as a universal panacea, even when no other noise design precautions have been taken. This paper is an attempt to put Active Noise Control into perspective, as just one tool in the reduction of machinery noise, and to suggest outline 'rules' for its consideration as such.

The problems discussed, besides the inherent structure of the acoustic field under review, include: the design, provision and placement of secondary sources, and sensors to provide the data on which the control algorithms operate; the over-riding need for (and the difficulty of providing) a quantitative description of the objective of the noise control measures; the effect of time-varying propagation environments and noise sources, as well as the almost trivial one of devising control circuit hardware and algorithms.

Subjective Effects of Noise

G1. Noise Induced Sleep Disturbance

C G Rice
ISVR, Southampton

Numerous laboratory, field and social survey studies have produced information relating to noise induced sleep disturbance. Collation and comparison of this data reveals certain trends which may be formulated into a planning criterion.

Much of the information relates to transportation noise, in particular that produced by aircraft and traffic. As well as different sources producing different responses, other variables which play important rôles are age, sex, attitude, general health, habituation, bedroom location, time of occurrence during the night, and the influence of other noises when heard in combination.

The most important single factor, however, is that about 20% of the population have sleeping difficulties which appear to be totally unrelated to noise, people often wrongly reporting that their sleep disturbance is noise related. Therefore, in order to be certain that source specific noise induced sleep disturbance occurs, a general reported population response of 25% is required. This finding forms the basis of the criterion.

It is proposed that sleep disturbance will start to become significant once the outdoor night-time (2200-0700 h) L_{Aeq} exceeds 55-60 dB, providing maximum levels do not exceed 75dB (A). Levels up to 85 dB (A) may be allowed providing the number of such events does not exceed 20 per night.

G2. Effects of Moderate Noise on Human Performance

D E Broadbent
University of Oxford

Until about five years ago, laboratory tests did not usually show effects of noise on performance below levels of 95 dB (C). Recently however a number of laboratories have found such effects, by using more complex and subtle tests. These will be reviewed. Simple theories of the effects are fairly well ruled out by details of the results; the best conclusion is that noise interferes with the choice by the person of a strategy to perform the task.

G3. A Safe Sound Environment — Noise as a Contributory Factor in Industrial Accidents

P A Wilkins
ISVR, Southampton

This paper reviews the evidence to test the assertion that noise can cause accidents. Five industrial studies indicate that high noise levels may be a contributory factor, but they are not conclusive and there is no clear evidence of a causal mechanism. Possible factors include lack of attention and the masking of warning sounds. Existence of a noise-induced hearing loss or the wearing of personal ear protection could also contribute indirectly by interfering with auditory communications. The possible link between noise and industrial accidents emphasises the need to consider factors in addition to protection of hearing.

G4. Noise-Induced Tinnitus

R R A Coles
MRC Institute of Hearing Research Nottingham

Tinnitus is now receiving much more attension clinically, since at long last something can now be done to help the sufferer, even though most treatments are only palliative. The paper will review the causation, epidemiology and management of tinnitus generally, and consider noise-induced tinnitus as a special entity which also has regulatory and medico-legal implications.

G5. Hearing Conservation — What is Reasonably Practicable?

A Sinclair
British Steel Corporation, Scunthorpe

The impact of the proposed legislation on noise and hearing as it affects a large industrial organisation will be considered. Various strategies on the questions of noise reduction, personal protection and audiometry will be examined against the background of cost effectiveness, location of resources and medical requirements.

G6. The Use of Questionnaires in Industry to Derive Employee Leq

S J Karmy
Industrial Audiology Services, Odiham

Quantification of the hazard to hearing represented by industrial noise is, in theory, simple to achieve using a modern personal sound exposure meter. In practice, however, such measurements can be difficult, as large numbers of employees performing different tasks, and noise environments which vary substantially from day to day, can necessitate the deployment of large numbers of sound exposure meters over a long period of time. Both requirements are impracticable in all but the largest of industries.

This paper explores the utilisation of questionnaires to measure noise dose as an economic alternative to the large scale use of sound exposure meters. The results of such an exercise, undertaken in a manufactured workshop, are presented. Comparisons are made between questionnaire and sound exposure meter derived Leq values. The conclusion is drawn that the questionnaire technique does have a place in hearing conservation practice.

G7. Protection of Hearing at Work and the Role of the Health and Safety Executive

A R Dove
Health and Safety Executive

Inspectors of Health and Safety are increasingly involved in action to obtain noise reduction and proper use of ear protection in order to ensure that employers, employees, machine makers and others comply with general duties concerning safety and health at work imposed by the Health and Safety at Work Act 1974.

The Health and Safety Commission published, in August 1981, a consultative document proposing new legislation on protection of hearing at work. Comment on this is being reviewed before a decision is made on recommendations to be made to the Secretary of State for Employment. Future legislation might also be affected by a proposal which the European Commission is expected to make by the end of 1982 for a European Community Directive requiring Member States to harmonise legislation on protection of workers from noise.

Speech Communication

H1. Perceptual Cues to the end of Aspiration

C J Darwin and John Seton
Laboratory of Experimental Psychology, University of Sussex

Two experiments examine how the phoneme boundary between/ba/and/pa/ is influenced by the way in which voicing starts. In the first experiments the first 30 msecs of buzz excitation is played at four different levels relative to the steady-state of the vowel and with two different frequency distributions: in the Staggered conditions buzz is confined to the first formant, whereas in the Control conditions the same overall peak intensity is distributed throughout all three formants. The results clearly reject the hypothesis that aspiration is perceived to have ended when periodic excitation reaches the second and higher formants. For both the Staggered and Control Conditions sounds are heard as more voiced as the intensity of buzz excitation is increased. At the two lower intensities the spectral distribution of energy is not perceptually important, whereas at higher intensities, sounds which have buzz excitation in all three formants are heard as more voiced than those that have the same peak intensity but with periodic energy confined to the first formant. This pattern possibly reflects relative loudness. The second experiment shows that periodic excitation confined to the fundamental frequency is of little perceptual significance in indicating the end of aspiration.

H2. Acoustic Determinants of Voice Quality Features

B Cranen, R van Bezooijen and L Boves
Institute of Phonetics, Nijmegen University, The Netherlands

Perceptual ratings of voice quality features are difficult and time consuming to obtain. Furthermore data on their reliability are extremely sparse. We have obtained such ratings in two ways, viz by having trained judges apply parts of the transcription system developed by John Laver and by collecting scores on a semantic differential from large groups of students. Acoustic analysis procedures applied to the speech signals might provide an easy, reliable and fast means of obtaining similar information, provided that it can be shown that acoustic measures correspond with perceptual ratings. The purpose of the paper is to describe a number of measures based on a processing of f_0-data and long-term average spectra and to show how they relate to perceptual ratings.

H3. The Integration of Audio-Visual Speech Stimuli as a Function of Temporal Desynchronisation

A Foster
Laboratory of Experimental Psychology, University of Sussex

Visual cues can affect the perception of acoustically specified stop consonants along the place of articulation dimension. Explanations of this finding have tacitly assumed that phonetic categorisation precedes audio-visual integration (MacDonald and McGurk, 1978; Mills and Thiem, 1980). This paper reports an investigation of audio-visual onset asynchronies on the identification of syllable-initial stop consonants whose acoustic and optical components vary with regard to the place feature. Visual consonant release either preceded, lagged behind, or was synchronised with audio burst onset. The frequency of acoustically correct identifications, obtained from both naive and phonetically sophisticated subjects, decreased in the visual-lag conditions, even with lag durations as short as 5 msec. These results suggest that audio-visual speech stimuli share some common limited capacity input channel prior to phonetic categorisation. The nature of the information contributing to unified audio-visual percepts will also be discussed.

References

MacDonald and McGurk (1978). Visual influences on speech perception processes. Perception and Psychophysics, *24*, 253-257.

Mills and Thiem (1980). Auditory-visual fusions and illusions in speech perception. Linguistische Berichte.

Session I

Session I is an Informal Workshop on Machinery Noise Control

Session J

Session J is an Open Forum on administrative and standardisation aspects of noise control and hearing conservation at the workplace.

SEE Handbook

The Society of Environmental Engineers has just published its first Handbook. The Handbook contains lists of members and Sponsor Members, a cross-reference to SEE test houses, six full-length technical papers and information on the Society and its forthcoming events and publications. Contents cover the fields of vibration shock and noise, fatigue testing, reliability, contamination control and packaging. The Handbook should be a useful addition to the shelves of companies and individuals who have an interest in the field of environmental engineering. It is for sale to non-members of the Society at a cost of £10 per copy and is available from the Secretary, Society of Environmental Engineers, Owles Hall, Buntingford, Herts SG9 9PL. Tel: 0763 71209. □

Ultrasonics International 83

Ultrasonics International 83 Conference and Exhibition, sponsored by the Canadian Acoustical Association and the Journal Ultrasonics, is to be held at the University of Dalhousie, Halifax, Canada, from 12 to 14 July 1983. The conference topics include: Underwater ultrasonics, acoustic microscopy, transducer materials, calibration of transducers, defect and tissue characterisation, ultrasonics in aerospace, photoacoustic spectroscopy, acoustic emission, data handling, cavitation, ultrasonics and the Arctic, high power ultrasonics, optoacoustics, visualisation, non-linear acoustics and ultrasonic tomography. There will be a commercial exhibition of ultrasound equipment.

Accommodation is available at special rates at a nearby hotel and on the university campus in student rooms. It is hoped that the conference fee will be kept low, without any significant increase on the fee for U I 81, and some funds will be available for students and other applicants.

Authors offering papers for presentation should send abstracts of 200-300 words with one illustration, no later than 31 December 1982, to the Conference Organiser, Dr Z Novak, Butterworth Scientific Ltd, PO Box 63, Westbury House, Bury Street, Guildford, Surrey GU2 5BH, from whom further details of the Conference are available. □

Diploma in Acoustics and Noise Control 1982 Titles of Project Reports

North Staffordshire Polytechnic

The acoustic properties of the Stoke-on-Trent Film Theatre
Octave-band loudness tolerability levels: The noise exposure of two glaze sprayers in a ceramic sanitary-ware factory
Static and dynamic studies of an air support used in a screening machine
Noise emitted from coal exploration drilling rigs
The effect of mass on the performance of a loudspeaker cone

Leeds Polytechnic

An investigation into noise levels inside heavy goods vehicles
An assessment of railway noise
An investigation into water skiing and its effect on a noise-sensitive residential area

Heriot-Watt University

Investigation into the possibility of annoyance to local residents due to noise from a proposed shooting centre
Sound insulation problems in re-modernised flats
Lasswaele High School — Upgrading of the acoustics of the assembly hall
The abatement of the environmental noise complaint at BSC Imperial Tube Works at Airdrie
The measurement of the sound insulation of floors
Investigation of accelerometer response to various amplitudes of stress waves in a steel bar

Newcastle Polytechnic

Traffic noise measurement and prediction — A comparison
Enclosure of a wood-planer machine in a Tradesman's Building — A case history
A review of statutory control and practical control measures with regard to construction site noise

Cornwall Technical College

Traffic induced vibration
Hemerdon Mine Project

Tottenham College of Technology

An experience of setting-up and putting into operation a small NAZ
Survey of noise levels around Stansted Airport
Performance and evaluation of a noise dose-meter wired for sound
Incubator Noise and the Neonate
Determination of external and internal noise levels around a factory
An investigation of the sound insulation qualities of two types of partition
An investigation of NIHL within a carpentry workshop for the disabled
An investigation into different methods of real ear attenuation measurements
The concept and design of ventilator systems in noise-sensitive areas
An investigation into the sound insulation of a timber-joist party floor
Ventilation extract and air-conditioning system for a banqueting suite
Comparison of existing road traffic levels with predicted levels
The investigation of nuisance in London Borough of Tower Hamlets
An investigation into LA policies and practices in relation to planning and noise
Comparison between noise levels existing prior to construction of a relief road with the predicted level

Colchester Institute of Higher Education

Problems in the use of BS 4142 in a rural area with particular reference to an animal feed mill
A scheme to control noise from a large speculative industrial development area
Acoustical studies of the Highland Bagpipe of Scotland
Reducing the sound level of a Colchester Colt Variable Speed Lathe
An investigation into the noise problems associated with the ventilation plant at a sorting office
An investigation into possible methods of measuring SWL of large diesel engines at a factory site
An investigation into noise levels in a small typing office
The use of a dosemeter to assess the equivalent continuous noise level exposure of employed persons
Noise as it affects the rural community
The causes and effects of structure-borne noise of diesel engines

Liverpool University

Evaluation of an anechoic chamber at Liverpool Polytechnic
Propagation of gunshot noise and the effectiveness of a barrier in the reduction of noise
An investigation into the effect of surface treatment on acoustic ceiling tiles in CLASP schools
Noise from motor racing — a subjective assessment of loudness
Hearing protection for manual workers employed by the parks department of Chester City Council
An investigation into noise and vibration levels in the Liverpool Polytechnic Old Building due to passage of trains on the Mersey rail Loop Line

Derby Lonsdale College of Higher Education

Road traffic noise — a case study
Evaluation of road traffic noise
Basic criteria for auditoria design — has it worked at Derby Lonsdale College?
Noise nuisance and on-shore oil-drilling operations
Noise exposure at work and its short-term reduction
Control of noise emissions from a major civil engineering contract
An investigation of the noise problems in a small computer room
Problems of speech intelligibility in a church
Noise reduction by selection and treatment
A study of lawn-mower noise

North East Surrey College of Technology

The assessment of the noise exposure of staff of the Brighton Centre on duty at pop-music concerts
Measurement of noise production from mechanical sweepers
An investigation into a low frequency noise problem
An assessment of hovercraft noise at Dover
An investigation into noise from heat-pumps and their effects on adjacent offices
An acoustic survey of Slough Town Hall new extension (Ground Floor, North Wing)
Ventilation noise in a dwelling
Investigation of sound insulation in converted properties
The Larkfield Leisure Centre — an acoustic study
The investigation of helicopter noise for the purposes of noise certification of three helicopters for Battersea Heliport
An investigation into noise caused by a standby diesel generator
Diversion of A226 roadway via the Terrace and Milton Place, Gravesend; the assessment of the effects of increase in noise levels
To assess the implications of siting a new factory in an urban environment
A case study of noise at an industrial factory

Ray Stephens retires as Diploma Chief Examiner

Shortly before the Diploma in Acoustics was introduced five years ago Dr R W B Stephens was invited by Council to take on the responsibility of Chief Examiner. Few other people in the world were better qualified for the job. His international reputation in acoustics and considerable experience in examining at all levels made him unique. Typically despite his very busy life filled with so many activities that many men and women of half his age would have refused, Ray took up this challenge. His enthusiasm for what has been a labour of love combined with expertise has ensured the academic success of the Diploma.

Council, the Education Committee and the Examination Board extend their thanks to Ray for his work. I am sure that the many hundred students who have sat the examination are also grateful to him for making the Diploma possible. We are pleased to say that Ray has agreed to act as assistant Chief Examiner for one year.

Dr Stephens' successor as the Chief Examiner is Dr Geoff Leventhall. Again the Institute is fortunate to have obtained the services of one of the most highly qualified and experienced acousticians. Dr Leventhall's experience includes education, research and consultancy. For many years Reader in Acoustics at Chelsea College, London University, he is now Acoustics Consultant with W S Atkins. □

B J Smith

'STEVE'

We offer our warmest congratulations to Ray Stephens on the occasion of his eightieth birthday. RWBS to readers of the Bulletin, 'Steve' to friends and colleagues, Raymond William Barrow Stephens to the writers of the many citations to him, Dr Stephens is known and loved throughout the world of acoustics. His work as researcher, lecturer, examiner, author, editor and pioneer of numerous societies and groups has earned him world-wide respect and medals and awards too numerous to list here, and the esteem and affection in which he is held by his students is summed up in the extremely unusual presentation to him of the General Union Award of Imperial College Union.

It may come as something of a surprise to learn that Steve did officially 'retire' in 1970, for he has remained as busy as ever. We have reason to be grateful for his continuing hard work since Steve was instrumental in the setting up of the IOA and as well as serving as its first President was deeply involved in the development of the IOA Diploma, for which he was until very recently the Chief Examiner.

We join with Steve's many colleagues, friends and students throughout the world in wishing him many happy returns. □

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An example may illustrate this point. To obtain a conical beam of about 3 deg at 10 kHz, a transducer of about 3 metres in diameter would be required if this beam were to be realised by direct radiation at 10 kHz. The directivity index would be about 36 dB and, as a result, a respectable source level can be achieved even with the transmission of a modest amount of acoustic power. (100 watts of acoustic power would yield a peak source level of about 230 dB rel μPam.)

With a parametric source, using primary frequencies around 75 kHz, a conical beam of about 3 deg at a difference of 10 kHz can be obtained using a transducer of about 40 cm in diameter. However, a total radiated acoustic power of about 4 kW would be required to obtain an effective source level of about 215 dB rel μPam. If a higher source level is required to obtain an acceptable signal-to-noise ratio, this result can be achieved by increasing the transmitted energy rather than the source level, and using a matched filter receiver.

The overall economics of system realisation may favour a parametric source on a comparison of this kind, even though the acoustic power conversion efficiency in a parametric source may be 1 per cent or lower—a sonar source needs to be designed for required directionality and source level.

Another feature of a parametric source is its wide bandwidth capability. As the difference frequency could be much smaller than the primary frequencies, varying ω_1 and ω_2 within the bandwidth of the transducer could result in a large change in the difference frequency. This conclusion, though valid, could be misleading. Because the magnitude of the density of the virtual sources is proportional to the difference frequency, depending on the design of a parametric source, the effective source level increases with the difference frequency at a rate somewhere between the first and the second power of the latter.

Also, a parametric source can be designed (by a suitable choice of the primary beamwidth) to produce a low frequency beam the width of which varies very slowly with the difference frequency.

Thus, the main advantages of primary sources lie in the production of high resolution in space and time, using a relatively small transducer.

In this author's view, all that can be said is that when for a particular application a narrow beam, broad bandwidth signal is required at a low frequency, a solution based upon the use of a parametric source should also be evaluated to see whether it may be more cost-effective. In some specific applications, a parametric source appears to provide the only feasible solution. In other cases, any possible advantage which may accrue from the use of a parametric source is, at best, marginal.

Particular applications where a parametric source has been used in practice include narrow-beam echo sounding and high-resolution sub-bottom profiling at shallow penetration. In the latter case, penetrations up to about 20 m have been obtained.

Further reading

Lord Rayleigh's *Theory of Sound* and Horace Lamb's *The Dynamical Theory of Sound* (both Dover Publications) make interesting reading of the approach of various early scientists to the problem of nonlinearity of the wave equations.

Nonlinear Acoustics by R T Beyer (1974) is a very comprehensive book on the subject, including a host of more recent references. (This is a US Government's publication.)

Theoretical Foundations of Nonlinear Acoustics by O V Rudenko and S I Soluyan (English translation published in 1977 by Consultants Bureau, New York, a division of Plenum Publishing Corporation).

Acoustics in Fisheries Assessment

B J ROBINSON

Ministry of Agriculture, Fisheries and Food

The application of underwater acoustics to commercial fisheries has dramatically increased the catching efficiency of fishing fleets. In so doing it has made the problem of managing fish stocks more difficult as the necessary scientific data are often not available either quickly or accurately enough. This article describes attempts which are being made to turn fish detection devices into instruments capable of accurately and quickly measuring the size of fish stocks.

THE POSSIBILITY of detecting fish shoals with echo-sounders was first demonstrated in the mid 1930s. However, it was not until after the Second World War that the availability of more reliable, sensitive equipment led to their introduction on fishing vessels. Since then echo-sounders and their horizontally ranging counterparts, sonars, have dramatically increased the ability of fishing fleets to find and catch fish. Fisheries scientists have also taken advantage of these devices to study the detailed distribution and behaviour of fish populations but, although interesting, this information is of only marginal use for the management of fish stocks.

A means had to be found to turn echo-sounder outputs into estimates of fish abundance. Many early attempts were made to count fish echoes manually. However, this technique and its modern automated derivatives are only rarely applicable, because many fish shoal too densely for the echoes from single fish to be resolved. A solution to this problem was developed in Norway in the mid 1960s. This utilised volume reverberation theory which predicts that, after correction for range dependent spreading and absorption losses, the echo energy received from an aggregation of fish is proportional to their density in the insonified volume. The constant of proportionality is a function of the electrical and acoustic calibration of the equipment and of the target strength of the fish (defined as the ratio of back-scattered to incident intensity at 1 m range). Given that these parameters can be determined, several other constraints must be satisfied before fish stock estimates can be produced.

Necessary Conditions for an Acoustic Survey of a Fish Stock

An echo-sounder's ability to resolve objects close to a boundary is limited by the transmitted pulse length and the transducer beamwidth. Acoustical calibration can also only be relied upon at ranges in the far-field of the transducer. For typical acoustic survey systems these effects limit the technique to those species which spend some part of their lives more than 2-3 m off the sea bed but no shallower than 5 m beneath the sea surface. These will frequently be the pelagic (midwater) species such as mackerel, sprat, herring, anchovy or sardine, etc, although other species such as cod, which are usually found near the sea bottom in UK waters, often occur in midwater in other areas of the world.

An echo-sounder only records the presence of scatterers beneath the ship. Whilst the shape of a shoal echo on an echo-sounder display may in certain circumstances provide a clue to the fish species, this technique cannot be relied upon. The only practical method of species identification is by use of trawls. However, these are selective devices possessing differing catching efficiencies both between fish species and between different sizes of the same species. Their sampling bias is not fixed and will vary from vessel to vessel, at different towing speeds and between day and night. Attempts to divide acoustically derived biomass estimates between species on the basis of trawl data are therefore extremely difficult, especially when the fish have markedly different target strengths, as would be the case with, for example, mixed mackerel and herring.

From the foregoing it is clear that, whenever possible, attempts should be made to conduct acoustic surveys when the fish occur in single species aggregations. The high costs of research vessel time also dictate that surveys should be timed to coincide with a large portion of the fish stock occurring within a limited geographical area. Satisfying these conditions requires detailed knowledge of fish behaviour. Success has frequently been obtained by surveying over-wintering or spawning concentrations of fish, but each situation must be separately assessed as fish behaviour can vary in different parts of the world.

Before discussing calibration of acoustic systems it is instructive to consider the accuracy and precision which fisheries managers might require of the technique. It is difficult to generalise because requirements will vary with different fish stocks and levels of fishing effort. For example, a 100 per cent overestimate of a fish stock will not have serious consequences if the plan is to take only 10 per cent of the stock. However, if it were decided to take 50 per cent of the stock, such an error would have disastrous consequences. The situation is complicated by the fact that there is normally no means of verifying the estimate other than retrospectively. Independent estimates of stock size will also be subject to error or may not even be available for under-exploited or closed fisheries or for short-lived species. As a general guideline, a result accurate to within a factor of 2 (± 3 dB) on a stock estimate is the minimum precision which would be of use to a fisheries manager dealing with an under-exploited stock. At the other end of the spectrum a precision of better than ± 25 per cent (± 1 dB) is considered necessary by managers of heavily exploited North Sea stocks. These precisions must include all errors due to sampling statistics and uncertainties about acoustic propagation, fish target strengths and equipment calibration.

The problem of accurate system calibration has nearly been solved, in particular the transducer source level and receiving sensitivity can now be calibrated to better than ± 0.2 dB (± 5 per cent) either by using uncalibrated hydrophones and projectors in a reciprocity arrangement or by use of standard spherical targets made of copper or tungsten carbide. The theory of scattering from such spheres has been demonstrated to be sufficiently exact to enable calibration accuracies of ± 0.1 dB to be obtained under 'laboratory' conditions, but the practical problems of placing the target in the centre of the acoustic beam often prevent this accuracy from being realised at sea.

Fish as Acoustic Targets

Acoustic back-scattering from fish is a complex phenomenon which to date has not been satisfactorily modelled theoretically, so all fish target strengths are obtained from experimental measurements. Many fish possess air-filled swim bladders which they use for buoyancy control and it has been demonstrated that these organs are responsible for 90 - 95 per cent of the back-scattered echo intensity. Swim bladders have irregular shapes which change with fish size, sexual development and state of adaptation to the ambient pressure. Experiments performed upon dead or anaesthetised fish have also demonstrated that, at the acoustic frequencies commonly used in fisheries research (30-120 kHz), the back-scattered intensity from a fish is highly dependent upon its aspect to the incident acoustic beam, in particular in the pitch plane. Information on the behaviour of wild fish is inadequate to enable the mean aspect, or tilt angle, to be predicted during acoustic surveys; indeed, it is considered likely that this may vary between day and night and from place to place. Two experimental approaches have been adopted to study these problems further.

In the first approach a known number and weight of fish are suspended in a case at a suitable distance beneath the transducer. After a period of acclimatisation, often as long as 24 h, fish behaviour becomes less variable and measurements can then be made of the back-scattered echo intensity. Intensity fluctuations of up to ± 5 dB from one transmission to the next are typical and even 6 h running means display cyclical variations of up to ± 1 dB which are presumed to be due to differing fish behaviour stimulated by varying natural light levels. This type of experiment has enabled valuable information on the variation of target strength with fish length and submerged depth to be obtained. However, the case imposes behavioural restraints upon the fish which could bias the results.

The second approach is to attempt to measure the *in-situ* target strength of wild fish. Conceptually such an approach would remove all behavioural and physiological sources of bias. However, in order to use this technique it is necessary for the fish to be sufficiently diffuse for single fish echoes to be resolved. Under such circumstances the uncertainties of trawl sampling complicate the task of obtaining a representative sample of the insonified fish for species and size determination. In order to perform an *in-situ* measurement it is necessary to remove the effects of transducer directivity from the received fish echo. This can be done directly by using special purpose transducers which can be used to locate a fish in a known acoustic field, eg the dual-beam approach in which a fish is located in the centre of a wide beam by the ratio of echo intensity received on the wide beam to that received on a coaxially mounted narrow beam. Alternative attempts have been made to statistically remove the effects of transducer directivity from the echoes received upon a conventional single-beam transducer.

Whilst useful data have been obtained by both approaches, the problem of how to estimate the target strength of densely shoaling fish remains to be solved. If the mean tilt angle distributions were known, attempts could be made to predict the target strength from known variations with aspect, but at present these data cannot be obtained.

For some species there appears to be reasonable agreement between target strengths obtained by different techniques. It is also clear that fish target strength is not a constant but a dynamic variable. What is not clear is how much bias will result from using one (or perhaps one night and one day) target strength value for an entire acoustic survey.

One aspect of fish target strength which is arousing some interest is its variation with frequency. At low frequencies (typically 500 Hz to 2 kHz) it is known that fish with swimbladders have resonant peaks in their target strength spectra. These resonances are a function of the size of the swimbladder, which in turn is determined by fish size or species, and its adaptation to the ambient pressure at a particular depth. Experiments in the USA and in Norway have clearly demonstrated that under favourable conditions good correlations can be obtained between size estimates derived acoustically and those obtained by trawl samples. Further research is dependent upon the production of practical sized, stable equipment with adequate acoustic source levels which can be routinely deployed at sea.

In conclusion, it is evident that much work remains to be done. However, in many areas of the world considerable progress has been made and acoustic surveys have been, and are being, used to provide urgently needed data for the management of fish stocks. Some acoustic estimates of fish stock size, made under favourable conditions, have been shown retrospectively to have coefficients of variation of approximately ± 10 per cent to ± 20 per cent. Data of such precision are of considerable value to fisheries managers.

Underwater Acoustics Transducers

J R DUNN and B V SMITH

Department of Electronic and Electrical Engineering, University of Birmingham

The ability to generate and detect sound underwater certainly dates back to 1826, when the speed of sound in Lake Geneva was measured over a ten mile propagation path. A manually operated bell was used for the transmitting source and reception was made monaurally using a large ear trumpet immersed in the water. From this time and up until World War I transducer developments were slow. The carbon-button microphone was water-proofed in the 1880s and found wide use in navigation applications during the early years of this century. In 1913 Fessenden developed a piston projector, suitable for Morse-code signalling underwater, which used a reciprocating induction motor drive. It was between 40 - 50 per cent efficient and was capable of developing 2 kW of acoustic power. Subsequently the advent of two world wars and the important role played in these by the submarine inevitably boosted sonar research and hence transducer developments. Although historically numerous different transduction mechanisms have been tried only a limited number have found wide acceptance and hence this brief review will of necessity focus on these.

Transduction Mechanisms

Broadly, transducer mechanisms may be classified as either reversible or non-reversible. The former group, which are the most widely used, comprise electroacoustic techniques and involve coupling via either an electric or a magnetic field.

In particular the electric field mechanism most commonly used is the piezoelectric action of the polarised polycrystalline ceramics, such as Barium Titanate and Lead Zirconate Titanate. These were developed in the 1940s and 1950s and have replaced the naturally occurring crystals, such as Quartz and Rochelle salt, because they have the advantage of higher coupling coefficients and can be moulded into a variety of convenient shapes. They also have an electrical impedance which is much lower than that of the natural crystals. The ceramics are readily available in a variety of grades and those with low internal losses are specifically made for high power applications. The ceramic may be used either directly in some resonant mode or as the 'active' component in a composite structure. A useful version of the latter is the longitudinal sandwich (discussed later) which is the descendent of the constant-area steel—quartz—steel element developed by Langevin during World War I. A number of flexural (flextensional and flexradial) and bender composites are also used.

The magnetic field mechanism uses the magnetostrictive properties of metals such as nickel. Although transducers based on this were widely used before ceramics were fully developed they are now confined solely to applications where exceptional robustness is required. There has been some recent regeneration of interest in the possible application of the magnetostrictive properties of rare earth-iron alloys, such as terbium—holmium—iron, as compared with nickel, because of the larger inherent magnetostrain and coupling coefficient. However, it is difficult to see them replacing ceramics. One other magnetic-field type transducer which should be mentioned because of its application in the area of calibration, is the underwater 'loudspeaker' developed at the Navy Underwater Sound Reference Laboratory; it produces a useful source output over the whole of the audio range.

Non-reversible mechanisms used include explosives, various fluidic and pneumatic sources, spark sources and eddy current sources. They tend to be low frequency sources, ie in the region of 1 kHz and below, and find applications in seismic work, dynamic testing, 'throw-away' source operations and propagation studies. They generally produce shock waves and hence the radiated energy is broadband. However, certain of the hydroacoustic transducers are resonant devices.

Apart from some of the non-reversible sources and the underwater loudspeaker referred to above most of the transducers employed as underwater sources are resonant and hence wideband designs are usually multimodal in character.

Practical Designs

Simple Resonant Plates

A suitably mounted $\lambda/2$ thickness-resonant piezoelectric ceramic plate is the most commonly used technique for realising a transducer structure to operate underwater at frequencies in the region of 150 kHz and above. The main reasons for this are that circular and square piezoelectric plates in a range of sizes may be readily obtained from commercial manufacturers, and there are several easily implemented effective methods of mounting the plates, as discussed below. The plates generally used have lateral dimensions which are much larger than their thickness to avoid transverse coupling problems.

There are a number of methods of efficiently coupling the acoustic energy from the radiating face of the ceramic into the water whilst at the same time ensuring that the ceramic is protected. The simplest technique is to cover the radiating face with a low-loss layer of a material such as RTV rubber, a plastic, or an epoxy resin, whose thickness is small in wavelengths, typically less than $\lambda/10$. It is also possible to use a 'resonant' metal plate, of thickness $\lambda/2$, as the front coupling layer if extra robustness is required, but this increases the overall Q of the structure. If a low-Q design is required, a $\lambda/4$ thick layer of magnesium-loaded epoxy can be used to match more effectively the acoustic impedance of the ceramic to that of the water.

The most efficient method of backing the ceramic is with air but this is at the expense of ruggedness. Although it is possible to accommodate hydrostatic pressure variations by using pressure compensation of the rear air cavity, the ceramics are more usually bonded on to solid backing materials to provide some mechanical support. Materials such as expanded foams and various epoxy resin mixtures, are chosen for this purpose because of their relatively low acoustic impedance. However this backing layer must be of sufficient thickness to ensure that any acoustic energy radiated into it is completely absorbed. It is possible to create a low Q structure by heavily damping the back face of the ceramic with a relatively high impedance composite material, such as tungsten powder loaded-epoxy, but this is at the expense of a reduction in radiating efficiency.

Composite Structures

The combination of active piezoelectric materials and passive materials such as metals allows a much wider choice of characteristics for resonant transducers than for those of active material alone, and the most frequently used class of designs is the so-called 'tonpilz' or tapered sandwich element. This is the most suitable type for the frequency range of a few kHz to around 100 kHz, generally as individual elements with radiating faces less than a wavelength (in water) across, this being limited by the need for the head to act as a rigid piston free of spurious modes of vibration. The basic design consists of the radiating head, with minimum weight for maximum bandwidth, the piezoelectric stack with a cross-section area much less than that of the head (also for maximum bandwidth) and a tail section which is generally much heavier than the head. There is nearly always a central bolt connecting the head and the tail, whereby the whole assembly can be pre-stressed so that the bonds between the parts are always in compression even when the transducer is driven electrically at high levels of power; by this means the reliability is increased at the expense of a more complicated mechanical design.

The design procedure is based on the fact that the lengths of the separate parts (head, stack and tail) are short in terms of the wavelength of sound in the particular materials used, and therefore the head and tail can be regarded as lumped masses and the active stack as a lumped compliance. Allowance can be made for the mass of the stack by adding proportions of it to the masses of the head and the tail, and a further correction to the head mass is necessary for the reactive part of the radiation load which can be significant for isolated elements which are small in terms of the wavelength in water. The piezoelectric stack is most often made of rings with interleaving electrical contacts, the subdivision of which for a given compliance can be varied, thereby giving some freedom of choice in the electrical impedance; the total volume is independently variable to some extent, and this is a function of the power rating. The element may be mounted by the head, either with an 'O' ring seal or by a diaphragm which is effectively part of the stack with a compliant seal over the radiating face. With the head mounting, there may be additional compliant support at the tail.

Bending and Flexing Modes

Very compact resonant structures can be made by using bending modes, in which small strains in the piezoelectric material can be converted to large displacements in the same way that a bimetallic strip is used to obtain large deflections from small differences in thermal expansion. This technique has applications at frequencies of a few tens of kHz, but it is more useful at very low frequencies (below 1 kHz) where large volumetric displacements are necessary for radiating useful amounts of power from structures whose dimensions are small in wavelengths, and for which conventional sandwich elements would be very large.

Hydrophones

Transducers used solely for the reception of acoustic waves are classified as hydrophones; however, since most of the transduction mechanisms discussed above are reversible, many sources are capable of acting as sound detectors too. At frequencies below the gravest mechanical resonance of the piezoelectric element the receiving response is ideally constant, being determined by the ratio of the element compliance to the clamped electrical capacitance. Thus the hydrophone acts as a wideband receiver with a 'flat' response when operated in this region.

Spherically and cylindrically shaped piezoelectric ceramics are normally used for the basic hydrophone element because of their omnidirectional reception behaviour. They are surrounded with a thin protective layer of a material, such as rubber, whose acoustic properties are similar to those of water. A cable carries the connections to the element and is engineered to give some mechanical rigidity and support to the structure. Care is taken in the design to ensure that the element is acoustically decoupled from the cable support.

Grades of Lead Zirconate Titanate ceramic which have high receiving sensitivities are commonly used for the hydrophone element although Lithium Sulphate elements, which have a high volume-sensitivity performance, are useful in applications where a large hydrostatic pressure is to be withstood. The use of Polyvinylidene Fluoride (PVDF), a thin piezoelectric plastic film, for hydrophones, is a modern development. These are able to operate over very wide bandwidths but are less sensitive than the ceramics and are also less rugged.

Magnetostrictive Transducers

These are not commonly used for new applications now, but large numbers are still in use, particularly in the fishing fleets around the world. As mentioned above they have the advantages of robustness and requiring no watertight housing, and also the impedance level can be easily changed by varying the number of turns in the electrical winding; similarly fixed taper function can be imposed on arrays of elements. The disadvantages are the low electro-mechanical coupling and poor efficiency compared with piezoelectric transducers, and furthermore the highest useful frequency is not much above 100 kHz due to eddy current losses. The available designs are less varied because of the expense in making the tools for stamping out the laminations and the difficulties in making structures comparable to the composite assemblies with piezo-electric materials already described.

Arrays

The various transducer elements described above are often used in arrays to meet system directivity requirements. The array shapes may be cylindrical, spherical planar or conformal, and also reflectors of various shapes offer interesting potential. In large transmitting arrays, especially at low frequencies, where the element dimensions may be of the order of half a wavelength, the detrimental effect of mutual coupling is counteracted by velocity control whereby each element is forced to vibrate with a specified velocity.

Measurements

Measurements on transducers can be classified broadly under three headings: electrical, acoustic and electro-acoustic. The most important electrical measurement is of admittance (for piezoelectric transducers) or impedance (for magnetostrictive transducers); if the susceptance (or reactance) is plotted against conductance (or resistance) for a range of frequencies around a resonance, the form of the plot approximates to a circle (hence the common name of circle diagram), and from this the important parameters related to the equivalent circuit can be derived. From measurements in air and in water the radiating efficiency can be estimated. The measurement of directional response is generally taken as a purely acoustic test, in which the relative variation of sensitivity with bearing angle is either measured directly in the far-field or calculated from a set of measurements of pressure in amplitude and phase made in the near-field of a transmitting array.

Electro-acoustic measurements cover the whole area of calibration, in which the electrical response to an acoustic cause, or vice versa, is required. The absolute method, referred to as 'three transducer reciprocity calibration' is generally used for the calibration of reference transducers, which are then used for routine calibration, either by comparison or by direct transmission and reception. Numerous other methods, appropriate for particular types of transducer or ranges of frequency, are described in detail in the book by Bobber.

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Catgut at DeKalb

23 - 26 April 1982

Northern Illinois University is situated in the town of DeKalb, noted as the 'home of barbed wire', at the heart of the vast Illinois cornfields. From Friday 23rd to Monday 26th of April 1982 it was the venue of an international conference on Musical Acoustics, organised on behalf of the Catgut Acoustical Society by Professor Thomas D Rossing, which was attended by over 100 delegates from ten different countries. This gratifyingly high attendance was due in part to the foresight of the organisers in arranging the meeting immediately to precede that of the Acoustical Society of America at the McCormick Inn in Chicago some 60 miles away so that delegates were able to attend them both.

THE CATGUT ACOUSTIC SOCIETY was founded in 1963 by the late F A Saunders of Harvard in order to further research on string instruments through interaction between scientists, engineers, performers, musicologists, instrument makers and any other genuinely interested groups. By the end of 1981 the membership had grown to 806, of whom 201 were resident in 28 countries outside the USA. The society publishes a semi-annual newsletter and sponsors technical conferences from time to time: the meeting at DeKalb was the latest of these and the next will be at Stockholm in 1983. In recent years the greatest driving force behind the society has been its permanent secretary Dr Carleen Hutchins, scientist and luthier extraordinary. Research by her and other society members has led to the 'new family of fiddles' or 'violin octet'. This is a consort of scientifically scaled and acoustically balanced instruments covering almost the entire range of written music in steps of about one-half octave. At present only four full sets of the octet exist and consequently their artistic possibilities have only just begun to be explored. Delegates at DeKalb were fortunate enough to be able to examine and play some of these instruments.

Perhaps the main reason for both the popularity and the value of Catgut meetings is that members from *each* of the groups from which the society is drawn not only attend but also present papers and participate afterwards in discussions, all sessions being plenary. Since the original aims of the society were directed towards string instruments it was no surprise that some three quarters of the total of 40 or so papers presented at DeKalb were concerned with various members of the violin families and with guitars. Nevertheless, the society's official interests having long ago been extended to all musical instruments, the remaining papers covered such diverse topics as brass instruments, gongs and the English church bell.

Catgut meetings are characterised by their friendly atmosphere and by the high quality and quantity of musical and gastronomical entertainment: this meeting was no exception. Those overseas scientists who were able to arrive a day early were entertained at a banquet by the local chapter of the Sigma-Xi Society and were somewhat nonplussed at each being presented with a 'Certificate of Recognition'. Registration formalities having been completed early on the Friday afternoon and followed by a tour of the very well equipped NIU acoustics laboratory and electronic music facility, the opening lecture on *'Tone Characteristics of the Violin'* was delivered by Dr Erik Jansson of the Royal Institute of Technology in Stockholm. A buffet at the home of Tom Rossing followed and the day was rounded off with a concert of Haydn, Webern and Mendelssohn given by the NIU Graduate String Quartet.

The second day of the meeting had four technical sessions all of which were largely devoted to members of the violin families. The first session began with a review of the history of violin acoustics by the inimitable Dr Carleen Hutchins. This was followed by an absorbing lecture-demonstration by Lowell Creitz comparing the old and the new tenor violins from the performer's point of view. The second session began with a review by Professor Lothar Cremer

IOA Diploma Examination 1982

Congratulations to the following candidates who have qualified for the award of the IOA Diploma in Acoustics and Noise Control.

N E Surrey College of Technology

C F Bradford
Mrs D A Butterfield
A J Colthurst
A D M Crookenden
A R Crumbley
W Gladden
Miss P F James
J J Melville
C J Newport
P A O'Doherty
B G Olding
M J Pandya
R A Wong
M S Woods

Liverpool Polytechnic

A R Bryant
B A Chartres
C Corker
P J Crank
D C Hosker
I J Nicholls
S R Richmond

Newcastle upon Tyne Polytechnic

R M Black
P D Latimer
J Pearson

Cornwall Technical College

M E Luckett
D R Morris

Tottenham College of Technology

P P Avis
J T Brassel
R C Brown
I J Campbell
D W Coffey
P B C Colley
M R Forsdyke
Mrs S J Inwood
P R Phillips
P Pinnington
G Seal
P A Smith
G J Telfer

of the question of the duration of transients in bowed musical instruments and its relevance to acoustical quality. Erik Jansson then presented some interesting experimental results on the modes of vibration of violins obtained using speckle interferometry and inadmittance measurements. A paper by J A Moral followed in which he proposed certain acoustical quality criteria for violins related to the properties of three relatively narrow resonances at about 400, 500 and 700 Hz in the input admittance curves together with those of a much broader resonance at around 3 kHz. He reported a correlation of 0·92 between acoustical quality points based on these criteria, and subjective tonal quality ratings. The session ended with papers on the long-time average spectra of double-basses and on the relationship between the frequency response curve of a violin and its musical character. The third session of the day began with a review by Professor Gabriel Weinreich of recent research into violins at the University of Michigan. This was followed by a series of contributions concerning the selection and the properties of woods used in violin and guitar making, and finally by a paper considering whether or not the early violin makers used mineral additives in their varnish. The final technical session of the Saturday started with a paper by McIntyre *et al* in which the value of the time domain in the study of musical oscillators was considered. Iain Firth of the University of St Andrews then presented a video cassette in which he demonstrated the versatility and speed of impulse testing techniques using narrow-bound frequency analysers. These were applied to various musical instruments and especially to guitars. The results of an interesting project comparing cheap and expensive violin strings were reported by Chiang and Houtsma which, no doubt to the intense relief of string makers, showed that the expensive variety do have some advantages. The second day of the meeting concluded with lavish entertainment by the President of Northern Illinois University at his official residence after which a number of the braver delegates accepted an invitation to perform in an open rehearsal of the local Kishwaukee Orchestra.

Two technical sessions were held on the Sunday morning, the second of which was exclusively devoted to guitars. The first began with papers on electronic violins. One of the instruments described and demonstrated, due to M V Mathews of Bell Laboratories, was particularly fascinating in that it was constructed with a resonance similar to the 'formant' discovered by Sundberg in the voices of singers. A demonstration convinced the writer of the truth of the claim that this formant greatly increases the perceived liveliness of the tone. A further paper by the same author jointly with Joan Miller described the results of investigations into intonation, pitch accuracy and reproducibility, and vibrato using specially developed instrumentation capable of measuring and recording the time interval for each oscillation of a bowed string. The highlight of the morning for many of the delegates was without doubt a presentation of Chinese instruments by Professor Han Kuo-huang of NIU who described and demonstrated a variety of these including the er-hu (fiddle), san hsien (lute) and yang ch'in (dulcimer). A particularly interesting feature of the er-hu is that it exhibits a 'wolf' note which is suppressed by inserting a piece of absorbing material under the string beyond the bridge. The final paper of the session was given by Shih-yu Feng of the Chinese University of Hong Kong who reported the results of investigations into the violin-like instrument known as the pi-pa.

The session devoted to guitars began with a paper by W Bartolini who reported the results of a series of acoustical and vibration measurements on classical and flamenco guitars, guitar-like enclosures, and circular and rectangular wooden soundboards with and without bridges. This was followed by Tom Rossing who discussed the application of plate vibrations to guitars. The differences between the normal modes of plates made of isotropic and orthotropic (eg wood) materials were described and a particularly helpful graphical construction technique was presented which enables one to explain the forms of the combination modes which arise from mode mixing. The normal modes of guitar top plates both with and without bracing were then compared with those of orthotropic plates having simple geometrical shapes. Next Ove Christensen reported work on the middle frequency range in guitars, ie 400 - 800 Hz. A potentially very useful

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Leeds Polytechnic

P Broadbent	Mrs C A Moran	T P Moran

Derby Lonsdale College of Higher Education

M H Broster	K McBride	J R Shattock
N G Cooper	J Peck	J D Tildesley
D L John	S W Reynolds	G A Yates
J K Kilgannon		

Colchester Institute of Higher Education

D J Allen	L K Head	D C Walton
D J Appleby	K T Moss	R G Whitehead
A R Carruthers	C J Tubby	T J Wix
G P Goodwin		

Heriot-Watt University

R K McLaughlin	W Sherry	R Thornton
W R Purves	J R Stirling	R F Towers

North Staffordshire Polytechnic

P Buckley	P H Brassington

The following candidates obtained passes in additional Specialist Modules

S A Beard (1)	J D Lyon (1)	J J Melville (1)
K Bentley (2)	V L McGrath (1)	T J Pashen (1)
C Fudge (1)	A P Mayne (2)	P J Turner (2)

Presentation of the first 'Golden Cat' to Professor Lothar Cremer. Left to right: Prof T D Rossing, Dr C Hutchins, Prof L Cremer, Mr R E Fryxell. (Photo courtesy of Arthur Montzka.)

observation made by him was that in comparing instruments it is easier to use not the usual spectrum of acoustical energy versus frequency but rather the integrated spectrum up to a given frequency since this smooths out the irregularities in the primary spectrum. Graham Caldersmith, Australian luthier, suggested the production of a family of guitars which would consist of the standard classical guitar, a baritone tuned a fifth lower, a bass tuned an octave lower and a treble tuned a fourth higher. Experience with a prototype baritone suggests that the development of such a family is a practical proposition. The final paper of the day was given by Professor Roger Hanson who described a system to study the growth and decay of partials in a plucked string and presented data which showed that the difference between 'new' and 'old' (ie 'dead') classical guitar strings was evident in their spectral composition shortly after the pluck and in the decay rates of certain partials.

On the afternoon of this third day of the conference the delegates were treated to a visit to Wurlitzer World Headquarters, just outside DeKalb, and in particular to a spectacular recital on the 'mightiest Mighty Wurlitzer of all'. This instrument is claimed to be the world's largest theatre pipe organ. It contains nearly 5000 pipes in 69 ranks, the playing area containing five 61-note keyboards, a 32-note pedal clavier, 330 stop tablets and 66 pistons which can automatically engage different sound combinations. The most memorable part of the recital was, for many of us, the use of this enormous instrument to provide the accompaniment to a silent Laurel and Hardy movie.

There is little doubt that the highlight of the conference was the Banquet held on the Sunday evening. Entertainment was supplied initially by the NIU Gamelan Anklung Ensemble led by Professor Han Kuo-huang of the NIU Department of Music. This was followed by spontaneous 'folk' entertainment from a variety of delegates stretching from rustic England to the convict days in Australia. On a more serious note the society chose this occasion to make the first presentation ever of the award of the 'Golden Cat'. The recipient of this singular distinction was Professor Lothar Cremer.

On the final day of the meeting something of the true diversity of interests of members of the society was displayed. The opening paper by R Perrin and T Charnley reported results on the geometry of the English church bell based upon a study of original technical drawings which have survived from the last century. The main finding was that the region between shoulder and rim consists of a segment of an ellipse rather than the circular arc used in most European bells. Next Daniel Haines discussed the question of how it is possible for a pianist to produce tone variations when simple scientific arguments appear to show that this should be impossible. A computer programme modelling the vibrating piano string was described by M L Garber after which Iain Firth presented some fascinating results on the acoustics of the concert harp. Robert Shepherd reported what are believed to be the first serious measurements on the acoustics of the gamelan gong and R Causée of IRCAM described the impressive progress which has been made towards producing an accurate theory for the input impedance of brass instruments. We were then treated to a review by Robert Green of the history of the pardessus de viole, a member of the viol family which seems to have had its heyday in the period 1720 - 1770, together with a demonstration of the instrument. The session concluded with an account by E G Williams of the technique of nearfield acoustical holography and a report of results obtained when this technique was applied to guitars.

After lunch on the final day coaches were supplied to convey delegates to the ASA meeting in Chicago with a visit to Fermilab en route. This was organised with the same efficiency which was characteristic of the entire conference. Great credit is due to the organisers, and especially Professor Tom Rossing, for what was by any standards a very highly successful meeting. □

R Perrin

Appreciation

Mrs Ethel Wood

Members of the Institute will be sorry to learn of the death of Mrs Wood, the widow of 'AB' who passed away in her ninety-third year at her home in Hampton during the morning of September 6. Her health had deteriorated during the past year so that she was unable to be present at the last A B Wood award ceremony. It gave her great pleasure to be invited to attend the award of the A B Wood Medal at the Bath meeting and her attendance at subsequent ceremonies was greatly appreciated, particularly by those members associated with the Underwater Acoustics Group. □

RWBS

BRANCH AND GROUP NEWS

Yorkshire and Humberside Branch

On 22 September 1981 a meeting of those interested in forming a Yorkshire and Humberside Branch of the Institute was held at Leeds Polytechnic. The meeting resolved that a request be made to the Council of the Institute to approve the formation of a Branch. It also elected, from those present, a Steering Committee to undertake the initial planning of Branch activities prior to the formation of a properly constituted Branch Committee.

The first AGM and inaugural meeting of the Yorkshire and Humberside Branch was held at Leeds Polytechnic on 10 December. The meeting was well supported despite adverse weather conditions. John Bickerdike of Leeds Polytechnic was elected Branch Chairman; our Branch Secretary is David Marsh and the Branch Committee members represent a wide range of acoustic interests, with members from the fields of academics, consultancy, instrumentation and environmental health. In the Technical Session following the AGM, Don Baines of ICL presented a paper entitled *Implications of the proposed EEC legislation for the compulsory measurement of sound power of technical equipment*, in which he outlined the proposals by the EEC and ISO for methods of labelling technical equipment such as office, industrial and acoustic equipment with its rated sound power level. The paper proved to be very informative and well presented, provoking discussions which were carried over to the cheese and wine social held after the Technical Session. This gave members the opportunity to meet informally and get to know the other members of the newly-formed Branch.

The Branch Committee proposed a policy of holding meetings around the Region with Leeds as the geographic centre, and following that policy the March 1982 meeting was held in South Yorkshire at Rotherham, where the subject of the meeting was *Vibration indexed white finger*. The meeting was interesting and informative but unfortunately not well attended.

The third meeting of the Branch was held on 18 May 1982 at Leeds Polytechnic. This took the form of an open forum session to discuss BS 4142 and its usefulness as a measure of community response to noise. Three speakers each gave a short presentation of some 10 to 15 minutes:

1 John Bickerdike (Leeds Polytechnic) *The background to the Standard.*

2 Mike Gittins (Leeds City Council) *The European Influence on community response.*

3 Alan Hobdell (Drop Forging Research Association) *Progress towards a revision of the Standard.*

There then followed a lively and sometimes heated debate on the application of the Standard, its usefulness or otherwise, with widespread participation from those attending the meeting.

Our first meeting of 1982-83 season will have been held by the time you read this report. Sean Quinn, an engineer with West Yorkshire Metropolitan County Council, will be presenting a paper on 23 September 1982 entitled *Dealing with noise at Leeds/Bradford airport*. The paper outlines the methods used and the problems encountered in proving the NNI contours around the runway extension at Leeds/Bradford airport, and discusses the scheme of insulation being offered to residents in the area.

The major event for Yorkshire and Humberside this autumn will be its

Standards

BS 5821: 1980 Method of rating sound insulation in buildings and of building elements Amendment No 1 (AMD 3892).

Proposed for confirmation

BS 4331: Methods for assessing performance characteristics of ultrasonic flaw detection equipment

Part 2: 1972 Electrical performance.

Part 3: 1974 Guidance on the in-service monitoring of probes (excluding immersion probes).

BS Drafts for public comment

82/35955 DC Industrial hearing protectors

Part 2: Specification for ear plugs.

82/51863 DC Acoustics — Specification for threshold of hearing by air conduction as a function of age and sex for otologically normal persons (ISO/DIS 7029).

82/51864 DC Acoustics—Methods for determination of occupation noise exposure and estimation of noise-induced hearing impairment (ISO/DIS 1999).

82/52440 DC Acoustics — Laboratory tests on noise emission from appliances and equipment used in water supply installations

Part 1: Method of measurement.

International Standards

IEC 581 High fidelity audio equipment and systems, minimum performance requirements.

IEC 581-11: 1981 High fidelity systems for use in vehicles (eg motor cars). *To be implemented as dual-numbered BS.*

IEC 711: 1981 Occluded ear simulator for the measurement of earphones coupled to the ear by ear inserts.

ISO 2631 Guide for the evaluation of human exposure to whole-body vibration.

ISO 2631 Amendment No 1: 1982.

ISO 5131: 1982 Acoustics — Tractors and machinery for agriculture and forestry—measurement of noise at the operator's position — survey method.

International New Work

Electro-acoustic response of motion picture control rooms and indoor theatres. Will revise ISO 2969 to take account of room size and reverberation time (ISO/TC 36).

35 mm magnetic sound reproduction characteristics. Will specify the sound reproduction characteristics for use in conjunction with ISO 2966 (ISO/TC 36).

Recording characteristics for magnetic sound record on 16 mm motion picture films. Will revise ISO 1168 by modifying the numerical values for the recorded characteristics (ISO/TC 36). □

first one-day nationally promoted meeting to be held at Leeds Polytechnic on 18 November 1982. The meeting is called Practical implications of the revised Code of Practice for reducing the exposure of employed persons to noise. Details of the meeting can be found elsewhere in Acoustics Bulletin.

The last twelve months have been important for the Yorkshire and Humberside Branch and have seen the establishment of a further Branch of the Institute, thus giving members in the region increased participation in Institute activities.

We are looking forward to the next twelve months when we hope to have a programme of interesting meetings, covering a wide range of subject matter, for those interested in acoustics in the Yorkshire and Humberside Region. Our meetings are open to members and non-members, and the Branch Committee hope that this policy will encourage non-members to apply for membership of the Institute.

Details of all our forthcoming meetings can be found in Acoustics Bulletin as they become available. □

Brian J Anderson

Appreciation

Harry F Olson

Harry Olson passed away in April of this year at the age of 80 and just less than a year after he had been awarded the Gold Medal of the Acoustical Society of America. His initiation into acoustics following his PhD in physics was through his association with G W Stewart in work on the filtration of sound. Olson subsequently joined the research laboratory of the RCA Corporation, with whom he spent the rest of his professional life. His particular research field was concerned with acoustical problems of the sound motion picture industry. He will be known to many acousticians by his many authoritative texts, commencing with *Elements of Acoustical Engineering* in 1940 and ending with his seventh major work entitled *Modern Sound Reproduction*, which was published in 1972. His devotion to acoustics was also evident in his services to the Acoustical Society of America, serving as its President and for 20 years as Associate Editor of the Journal. □

NON-INSTITUTE MEETINGS

1982

18 November. *Does Science and Technology offer any hope for the hearing impaired in the future?* Lecture by Mr M C Martin followed by discussion. At NPL, Teddington, Middlesex. Contact: Bernard F Berry, Division of Radiation Science and Acoustics, NPL, Teddington, Middlesex TW11 0LW, who will also be glad to receive requests for notice of forthcoming events.

16 - 18 November. *8ème Colloque d'Acoustique Aéronautique.* Toulouse, France. Contact: Mme Pauzin, CERT, B P 4025, 31055 Toulouse, France.

30 November - 10 December. *International School of Physical Acoustics.* Erice, Sicily. Contact: PSE, CCSEM 91016, Erice, Trapani, Sicily.

15 - 17 December. *14th Annual Scientific Meeting of the British Medical Ultrasound Society.* Sheffield. Contact: Dr D R Naik, Department of Radiology, Northern General Hospital, Herries Road, Sheffield S5 7AU.

Notice of future non-Institute Meetings should reach the Editor at least four months before the date of the Meeting.

New Products

Submissions for inclusion in this section should be sent direct to J W Sargent, Building Research Establishment, Garston, Watford WD2 7JR.

Abbey Mark X Loudspeaker from AIRO

The Abbey Mark X loudspeaker represents a convenient solution to the long standing problem of achieving intelligible speech in reverberant spaces. The patented design was conceived by the Sound Advisory Panel to Westminster Abbey where the prototypes are in use.

Each loudspeaker column contains its own amplification and signal processing unit which precisely governs both the amplitude and phase of the signals fed to the nine individual drive units. By carefully controlling these parameters, reinforcement of the column's lower lobe and cancellation of its upper lobe is achieved such that the loudspeaker radiates a strongly downward directed sound field. This ensures that the maximum concentration of acoustic energy may be delivered to the congregation or audience whilst minimum energy is projected into the empty volume. Thus, effective speech reinforcement is obtained without an excessive reverberant contribution which so often impairs speech intelligibility in large buildings.

An optional delay unit is available to allow the output of individual pairs of loudspeaker columns to be delayed by up to 50 ms, thereby enabling the system design to accommodate the Haas effect in those applications where realism is important.

Further information from Acoustical Investigation & Research Organisation Ltd (AIRO), Duxons Turn, Maylands Avenue, Hemel Hempstead, Herts HP2 4SE. Tel: 0442 47146.

GenRad Acoustic Intensity Analysis Program

New from GenRad is an acoustic intensity analysis program, INTEN, designed for operation under DEC RT-11, in conjunction with GenRad's 2500 series analysis systems. It has two modes: the first displays the acoustic intensity function in real time as narrow band spectra and the second stores the sound intensity data for further analysis.

INTEN is available in the form of an 8-inch floppy disc.

Further details from GenRad Limited, Norreys Drive, Maidenhead, Berkshire. Tel: 0628 39181.

Nicolet Portable Digital Oscilloscope 3091

The Nicolet 3091 offers two differential inputs and the advantages of a high resolution digital storage oscilloscope in a compact portable package. Timing is crystal controlled and the maximum digitising rate is 1 MHz in both single and dual channel operation, with 12-bit dynamic range.

Buffer memory allows the 3091 to record pre-trigger as well as post-trigger data. XY, YT recorder outputs and an RS232C digital output are provided. An optional magnetic bubble cassette system for the storage of data is available. The 3091 is priced at £2750.

Further details from Nicolet Instruments Ltd, Budbrooke Road, Warwick CV34 5XH. Tel: 0926 494111.

Hearing Conservation Information from Cabot

Cabot Safety Limited, manufacturers of E-A-R foam earplugs, have launched a Total Support Package aimed at helping industry to train and motivate employees in the correct use of hearing protectors and to become more aware of the dangers of noise. A folder detailing the services and facilities available in this package is available from Cabot Safety Limited, First Avenue, Poynton, Stockport, Cheshire SK12 1YJ. Tel: 0625 878320.

B & K Integrating Sound Level Meter Model 2221

This is a low-priced instrument which meets Type 1 standards. It has four measurement functions, Leq, SEL, Max Hold 'fast' and Max Hold 'peak'.

The peak value is for linear frequency characteristic but the other values are 'A' weighted.

Price £919. Further details from Brüel & Kjær (UK) Ltd, Cross Lances Road, Hounslow TW3 2AE. Tel: 01-570 7774.

Cirrus Sound Level Indicator CRL 4.12X

Cirrus Research have redesigned their CRL 4.12 Indicator to meet the American Survey Grade ANSI Type 3. The new model CRL 4.12X has a low voltage air condenser microphone.

Further details from Cirrus Research Ltd, 1/2 York Place, Scarborough YO11 2NP. Tel: 0723 71441.

Pulsar Industrial Sound Level Meters

The Pulsar 85 series now includes the 85E2 which meets IEC 651 (BS 5969) Grade 2.

The Pulsar 83 family of sound level meters now includes the 83C series.

Model 83C meets ANSI S1.4 Type 3.

Model 83CE meets IEC 123, IEC 651 (BS 5969) Grade 3.

Model 83C2 meets IEC 651 (BS 5969) Grade 2.

Further details from Pulsar Instruments, 40-42 Westborough, Scarborough, North Yorks YO11 1UN. Tel: 0723 71351.

D J Birchall Charge Amplifier CA/04

The basic CA/04 has a flat response from 2 Hz to 40 kHz and a noise level below 0.02 pC referred to the input. It can be used for piezo-ceramic force pressure or vibration transducers and its sensitivity is immune to cable length variation. Two low impedance outputs are provided: 10 mV.g and 1 volt per FSD (0.3-100 g scaling), with a maximum output of + 12 volts. Options are available to modify the response of the basic amplifier.

Further details are available from D J Birchall Ltd, 102 Bath Road, Cheltenham, Gloucestershire GL53 7JX. Tel: 0242 518588. □

Institute of Acoustics
Meetings

1982

8 - 9 November	M	Autumn Meeting Sessions on: Speech; Subjective Effects of Noise and Vibration; Measurement of Acoustic Power and Intensity; Tyndall Medal Lecture	Bournemouth

1983

February/March	M(P)	Recreational Noise	London
6 - 7 April	UWAG	Acoustics and the Sea Bed **IOA Annual General Meeting**	Bath
21 - 22 April	HPA	Processing of Ultrasonic Signals, Analogue and Digital	Durham
May	BSA(P)	Noise Induced Hearing Loss	London
13 - 15 July	M	Inter-Noise 83	Edinburgh
Late July	M(P)	Sonic Emission	Chelsea College, London
Autumn	BAG	Studio Design	
Autumn	BAG	Local Government Noise Problems and Construction Industry Noise	

The Institute believes that one of the most important services offered to Members is the provision of a wide range of conferences. The Meetings Committee will be pleased to receive suggestions for conference topics as well as to have comments on the present Meetings Programme. Please send your views via the Secretariat in Edinburgh.

Key
M = Meetings Committee Programme
(P) = Provisional
BAG = Building Acoustics Group
HPA = Jointly with Hospital Physicists Association
BSA = Jointly with British Society of Audiology
UWAG = Underwater Acoustics Group

Further details from:
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Edinburgh EH1 1HU

Printed in England by Christchurch Printing Company Ltd., 6-8 Bridge Street, Christchurch. Dorset BH23 1EE