Founded 1925
Incorporated
by Royal Charter 1961
To promote the advancement of radio, electronics and kindred subjects by the exchange of information in these branches of engineering

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Training for Yesterday—or Tomorrow?

THE Institution's Bye-laws governing admission to the classes of Fellow and Member contain identical clauses 13(c) and 14(c) which require that the applicant shall have '... undergone training for the profession of electronic or radio engineering over a period of at least 2 years, or held an appropriate position or positions for so long as Council deems sufficient to provide such training'.

At the time of the Institution's incorporation by Royal Charter in 1961, the principal active elements of radio and television transmitters and receivers—indeed of electronic equipment generally—were still thermionic valves. Capacitors, inductors and resistors were still discrete components; most interconnections were still made by means of individual wires; complete assemblies were mounted on aluminium or steel chassis and either enclosed in wood, metal or plastic, or supported by robust metal racks. It was therefore not unreasonable to require that the design or development engineer should understand—perhaps even use for a time—the skills involved in 'workshop practice'. There must, however, be many of today's newly-graduated electronic engineers—and there will be even more of tomorrow's—whose work will never entail personal involvement in any operation involving more manual dexterity than is needed to operate a pen, pencil or screwdriver, but who may well need to appreciate, if not actually possess, skills hitherto associated more with the science laboratory than the engineering workshop.

Training is expensive: no company can afford to waste its resources in manpower or money on activities which benefit neither employer nor employee. Consequently, both in the manufacturing and the service sectors of the electronics industry, the training given to the graduates whom it recruits tends to bear less and less resemblance to that proposed for professional engineers in EITB booklet No. 5. Indeed, Sir Ieuan Maddock has recently recommended that, for reasons such as this, the electronics industry should have its own Training Board. Already it is common in the industry for the period of controlled post-graduate training to be six months or even less: any further specialized training needed by individual trainees is given on an *ad hoc* basis as their career development dictates. As far as the Institution's internal affairs are concerned, the changed training pattern can be accommodated without amendment to the Bye-laws quoted. Although it has been almost traditional, when considering 'experience in lieu of training', to equate two years' experience to one year's training, the ratio is not immutable. It would be entirely within the competence of Council to rule, for example, that a year's experience in a company at the forefront of technological development was of at least as much value as a year's structured training in a less advanced organization.

Unfortunately, however, the matter does not end there. From 1st January 1980, the Institution will be required to satisfy CEI that those persons whom it nominates for registration as Chartered Engineers not only satisfy the academic requirements of Statement No. 12, but also have been trained in accordance with the provisions of Statement No. 11. The Institution's Education and Training Committee is in consequence currently engaged in the two-fold task of first ensuring that its own training requirements are appropriate to the present and future needs of the electronics industry, and second, of convincing CEI that, although traditional training methods may be appropriate for those who are accustomed to thinking in megawatts, hertz, kilometres, hours and tonnes, they are of little, if any, value to people who will be concerned with measurements in microwatts, gigahertz, microns and nanoseconds, and whose calculations seldom involve mass at all.

In considering the question of what constitutes essential training for the graduate entering the electronic engineering profession, the Education and Training Committee is in the fortunate position of being able to take into consideration the recommendations of the Electrical and Electronic Manufacturers' Education and Training Board. An interesting feature of these is that they treat education and training as a composite package—not as independent entities—and seek to achieve closer co-operation between industry and the Universities and Polytechnics in providing greater integration of training with education. Unfortunately, only the very large organizations have the resources needed to operate fully integrated comprehensive schemes of the kind envisaged by the EEMTEB, and the electronics industry contains many small but nevertheless important companies. In formulating its future training policy, therefore, the Institution is concerned not only with identifying the essential elements of training, but also with finding realistic means of collecting evidence that they have been covered by those applicants for Corporate membership whose employers do not operate structured training schemes.

Members who study the list published in each month's Journal of the names of persons recommended by the Membership Committee for admission to the Corporate classes will have noticed that a substantial proportion of these are for 'direct election'—that is, the applicants have not been previously associated with the Institution as Student or Graduate members. Often in such cases the applicant's referees are the only independent sources of information about his training, and it is recognized that there will always be cases, particularly where applicants resident overseas are concerned, in which no structured training has been received, and the Membership Committee will need to decide as best it can at what point in each applicant's career he may be considered to have met the training requirements of the Bye-laws.

The Education and Training Committee believes that it would be possible to improve the accuracy of assessment in 'grey areas', at least in cases where the applicant has previously been a Student or Graduate member, if more of our Corporate members would offer their services as counsellors to those young electronic engineers who are employed by companies which do not operate formal training schemes. The Committee is not seeking to recruit 'Training Officers, unpaid'—it merely believes that there must be, amongst the Institution's Members and Fellows, a substantial unused resource in the form of seasoned engineers, each of whom could take one or more such younger members under his wing and, by means of nothing more arduous than an occasional informal discussion, discover whether the development of his protégés was being helped or hindered by the circumstances of their employment, or if they were lacking in initiative, and offer appropriate advice.

The IERE is not, and has no wish to become, a regimented Institution; in consequence it may know less than it should about those of its members who, for one reason or another, do not take an active part in its learned society activities. It therefore wishes to extend an open invitation to all those who could devote a few hours during the year to the task of helping young engineers to find their feet—or their metier—to make their willingness to do so known either to their Local Section secretary or to Head Office.

K.J.C.

ANNOUNCEMENTS

Students and Eurocon '80

In the April 1979 issue of the Journal (page 170), details were given of Eurocon '80, the 4th European Conference on Electro-technics, which is to be held in Stuttgart, West Germany, on 24th to 28th March 1980. The conference is jointly sponsored by EUREL, of which the IERE is a member, the IEEE's Region 8, and the VDE.

At Eurocon '77, held in Venice, one of the sessions was aimed particularly at student engineers and the Organizing Committee is anxious to encourage the attendance of students at next year's conference by arranging two or more tutorial sessions. It is not intended however that there will be an extended student programme running competitively in parallel with the main programme.

Conscious of the important role which conferences nowadays play in the professional life of most engineers, the IERE Council has decided to sponsor the attendance at Eurocon '80 of two student members of the Institution who will thereby be able to benefit from the main and special programmes which are being arranged. This sponsorship will cover registration, air transport from London to Stuttgart and accommodation in university residences.

Applications are therefore invited from IERE Registered Students who are interested in being considered for sponsorship to attend this important European conference. They are asked to write to the Secretary at 99 Gower Street, without delay and in any case before 15th October, setting out briefly details of their academic studies and training to date and between now and next March, and also indicating how they believe that the proposed coverage of the conference will assist them in their future careers. The scope of the conference is outlined in the announcement referred to above.

It should perhaps be emphasized that, while the successful applicants will not be required to present a paper at the conference, they will be expected to compile, either jointly or separately, reports for publication in the Journal shortly afterwards. In this connection, the report given on Eurocon '77 which was published in the July 1977 Journal will give an idea of the required approach.

Forthcoming Meetings Bulletin

In copies of this Journal sent to members throughout the British Isles, will be found the first monthly issue of a 4-page leaflet with the above title. The leaflet replaces the information on IERE meetings previously published as an integral part of the Journal.

An added feature of this new leaflet is the inclusion of the meetings held by corresponding local sections of the Society of Electronic and Radio Technicians and SERT is similarly distributing copies of this leaflet with its Journal, *Electronic Technology*. Unless otherwise stated, all meetings of each organization are open to members of the other without further formality or restriction and irrespective of location in relation to a member's usual place of residence.

It is believed that Chartered Engineers, Technician Engineers and Technicians alike who are concerned with electronic and radio engineering will welcome the opportunities to meet and exchange opinions through common forums which this publicity for the wide range of subjects covered will provide.

BSI Engineering Drawing Practice Committee

Members will know that the Institution is regularly invited to appoint representatives to the Technical Committees of the British Standards Institution and a list of these Committees and the IERE representatives is given annually in the Appendix to the Annual Report (see this issue).

A representative is now needed to be appointed to the Engineering Drawing Practice Committee and suitably qualified members (not necessarily Chartered Engineers) who would like to be considered to fill this appointment are invited to contact Mr David Radband, IERE Technical Officer, at 99 Gower Street (Tel. 01-388 3075) for further details.

New Chartered Engineers Registered through Affiliate Members

The registration of eighteen new Chartered Engineers from three of the Council of Engineering Institutions' Affiliate Organizations was announced at a recent meeting of the Board. The Chairman of CEI, in approving and welcoming these new individual members, said:

'We at the CEI are now beginning to benefit from the provisions of our new Charter which accords Chartered Engineer status to fully qualified professional engineers from our growing number of Affiliates. I see this innovation as further strengthening the standing and influence of the CEI.'

The eighteen new Chartered Engineers are drawn from the Institution of Agricultural Engineers, the Institution of Nuclear Engineers and the Institution of Public Health Engineers.

At the same meeting, CEI admitted the following Institutions as new Affiliates:

The Association of Mining Electrical & Mechanical Engineers;

The British Institute of Non-Destructive Testing.

These elections bring the number of CEI Affiliates to nine. There are 16 Corporation Members.

Professional Engineers and Trade Unions

The second edition of 'Professional Engineers and Trade Unions', which first appeared in early 1976, was published recently. At a press conference to launch the enlarged version, several of the members of the CEI Panel on Professional Engineers and Trade Unions spoke, Mr G. A. Dummett explaining that in three years a number of developments in the trade union movement and the increased awareness and interest shown by professional engineers had led to the expansion of the book's contents.

Although the number of Trade Unions which met the CEI's criteria had not increased in the three years since the first edition, Mr Nigel Bruce pointed out that it in no way meant a stagnant situation in CEI/Trade Union discussions. Mr Bruce said that a number of meetings had been held with Trade Union representatives, and these discussions could be most important in formulating CEI's future policy on Trade Union Affairs.

As to the future, the CEI's final paragraph in 'Professional Engineers and Trade Unions' states: 'It would still be very desirable to have only one strong union open to all professional people in the private sector of industry. CEI will therefore maintain close contact with the relevant unions to use its influence in co-ordinating union policies in the interest of professional engineers, especially by encouraging amalgamation of certain unions.'

CEI Committee Appointments

At the Special Meeting of the Board of the Council of Engineering Institutions held on 11th April, the nomination of Professor L. F. Crabtree, Ph.D., F.R.Ae.S., as Chairman of the Council's Standing Committee on Education and Training in succession to Dr G. S. Brosan, B.Sc., Ph.D., F.I.Prod.E., F.I.E.E., F.I.Mech.E., was approved.

Professor Crabtree, who is the Sir George White Professor of Aeronautical Engineering at the University of Bristol, is the Immediate-Past President of the Royal Aeronautical Society.

G. J. Mortimer, C.B.E., F.Eng., is Chairman of the CEI Standing Committee on Internal Affairs. P. T. Fletcher, C.B.E., F.Eng., is Chairman of the CEI Standing Committee on External Affairs. J. Caird, C.Eng., is Chairman of the CEI Standing Committee on Regional Affairs.

Fellowship Distinction Lecture 1979

The Fellowship of Engineering's Distinction Lecture for 1979 will be delivered at 6.00 p.m. on Monday, 1st October, at the Institution of Electrical Engineers, Savoy Place, London by Monsieur Pierre Aigrain (Secrétaire d'Etat à la Recherche, Republique de France).

The title of M. Aigrain's lecture will be 'Innovative Engineering in France—Strengths and Weaknesses.'

M. Aigrain will describe the way in which innovative engineering is furthered and funded in France, the way in which his country is dealing with the impact of new technologies and how it sees future developments in these fields as related to those of its partners within Europe.

M. Aigrain will explain that the French system for the higher education of engineers involves both Ecoles d'Ingénieurs, having a highly selective and competitive entrance examination, and Universities, initially less selective, which train applied scientists and carry out most of the basic research. The strengths of the French system, including its demands for high professional and intellectual qualities from engineers, and its weaknesses, including poor contacts between research and engineering, will be analysed and possible remedies mentioned.

M. Aigrain's address will be delivered in English and will be published afterwards by the Fellowship of Engineering.

Admission to the lecture will be by ticket only, application for which should be made to:—The Secretary, Fellowship of Engineering, 2 Little Smith Street, Westminster, London SW1P 3DL.

NOMINATIONS FOR ELECTION TO COUNCIL

Brief Biographical Notes

In accordance with Bye-Law 43 the Council's nominations for election to the 1979–80 Council were notified to Corporate Members in the June issue of the Institution's Journal.

FOR ELECTION AS PRESIDENT

Professor William Gosling, B.Sc., A.R.C.S., F.I.E.E., M.Inst.P. (Fellow 1968, age 47) is a graduate of Imperial College, University of London. After taking his B.Sc. in physics in 1953 he joined De Havilland Propellers Ltd, as a junior engineer. Four years later he was designated Test Equipment Design Engineer and worked on the design of specialized electronic test systems for aircraft and missiles. In 1958 he left industry for teaching, being appointed lecturer and subsequently senior lecturer at the University College of Swansea. In 1966 he was appointed to the chair of electrical engineering and later became Head of the Department of Electronic and Electrical Engineering. In 1973 he moved to the University of Bath to take up the chair in electronics and Headship of the Electronics Group at the School of Engineering. Here he has continued his principal research interest in radio receiver techniques and he has been particularly concerned with the development of new mobile radio systems. He has contributed papers on this subject to the Institution's Journal, and in addition while at Swansea, he published papers on other subjects including instrumentation, semiconductor devices and circuits. In 1976 he was awarded the Clerk Maxwell Premium.

From 1971 to 1976 Professor Gosling was Chairman of the Professional Activities Committee and he has chaired conference organizing committees; he has also been a member of the Executive Committee. First elected a member of the Council in 1970, he served as a Vice-President from 1972 to 1975 and from 1976 to 1979.

During the past year, Professor Gosling has been an alternate representative of the Institution on the Board of CEI and he has also served on several CEI Committees. For some years he was the Institution's representative on the BSI Telecommunications Industry Standards Committee.

Professor Gosling has represented the Institution on the Convention of National Societies of Electrical Engineers of Western Europe (EUREL) since its formation and he is its President for the year 1978/79.

FOR RE-ELECTION AS VICE-PRESIDENTS

Harry Edward Drew, C.B., Hon.C.G.I.A. (Fellow 1948, Member 1944, age 69) was first Executive Officer of the Defence Quality Assurance Board from 1970 until his retirement in 1972. He is currently Chairman of Robert Stuart (London) Ltd (electroplaters) and a director of Export Packing Services (R&D) Ltd and of Quality Audit and Advisory Services Ltd; he is also an independent industrial consultant.*

Brigadier Robert William Allan Lonsdale, B.Sc., F.I.E.E. (Fellow 1971, Member 1953, age 52) is Director Quality Assurance (Technical) in the Ministry of Defence Procurement Executive.*

Samuel John Henry Stevens, B.Sc.(Eng.) (Fellow 1964, Member 1952, age 58) is Director of Aircraft Quality Assurance, Ministry of Defence Procurement Executive.*

FOR ELECTION AS VICE-PRESIDENTS

Professor James Roderick James, B.Sc., Ph.D., F.I.E.E. (Fellow 1975, Member 1960, Graduate 1956, age 46) has been a member of the academic staff of the Royal Military College of Science since 1961. He was appointed a Research Professor in Electronics in the Department of Electrical and Electronic Engineering in 1976 and co-ordinates the Electromagnetic Engineering Group within the Department, dealing mainly with specialist Ministry of Defence and industrial problems. He is a member of the Electronics Research Council's Antennas and Propagation Committee.

Professor James has published widely on research and development work in the fields of microwaves, antennas and speech processing, including papers in the Institution's Journal, for one of which he received the Heinrich Hertz Premium for 1973.

Since 1970, Professor James has taken an active part in Institution affairs, serving on the Papers Committee for eight years, including three years as its Chairman, and representing the IERE on international conference committees. He was an Ordinary Member of Council from 1972 to 1975 and he served as a Vice-President from 1975 to 1976.

* See also September 1978 Journal

H. E. Drew

R. W. Lonsdale

S. J. H. Stevens

J. R. James

P. K. Patwardhan

Prabhakar K. Patwardhan, M.Sc., Ph.D., F.I.E.E., F.Inst.P. (Fellow 1969, Member 1959, Graduate 1952, age 51) is a Senior Scientist at the Bhabha Atomic Research Centre and is head of its computing activities. He obtained his degrees at Banaras Hindu University and he has been a Member and Fellow of the Senate of the University of Bombay. Dr Patwardhan has worked for nearly thirty years in the electronics, instrumentation, data handling systems and computer hardware associated with nucleonics. Between 1962 and 1964 he was a visiting scientist to Atomic Energy of Canada, Chalk River, where he worked on one of the first on-line stored program nuclear data processing systems and also developed a special data communication link and a spectrum stabilizer. Since returning to BARC, he has initiated advance research in nuclear physics instrumentation and has participated in international conferences in Europe and America. Some of his earlier work, before going to Canada, formed the basis of a paper on scaling circuits which was published in the Institution's Journal in May 1955; he also presented a paper at the Institution's Symposium on Cold Cathode Tubes and their Applications in 1963. Altogether he has been author or joint author of nearly seventy papers in the world's literature and at conferences.

Dr Patwardhan has received National awards for his contributions in nuclear electronics, data handling systems and instrumentation. For many years he has taken an active part in the affairs of the Institution in India, serving as Chairman of the Bombay Zone and of the Indian Divisional Council. He is now the IERE National Representative in India.

John Powell, T.D., M.Sc. (Fellow 1965, Member 1969, Graduate 1953, age 55) was born and educated in Blackpool, Lancashire, and served for four years from 1942 to 1946 as a Radio Officer in the Merchant Service. He then joined Cable and Wireless Ltd as a Technician and has subsequently risen to become Engineer in Chief in 1978. During the intervening thirty-two years, he held appointments in nearly every part of the world where the company operates and in 1965 he was appointed an Assistant Engineer in Chief. Subsequent appointments were Head of Corporate Planning, Chief Engineer (Submarine Systems) and Deputy Engineer in Chief.

Mr Powell was a Vice-President of the Institution between 1976 and 1978 having joined the Council in 1972. He served on the Membership Committee from 1966 until 1976, and for 3 years was its Chairman. His other activities on behalf of the Institution include membership of the Executive Committee, of the former Technical Committee, and representation at international conferences, and he is now the Institution's representative on CEI Standing Committee B.

FOR RE-ELECTION AS HONORARY TREASURER

Sydney Rutherford Wilkins (Fellow 1942, Member 1935, Associate 1934, age 67) is Managing Director of Fleming Instruments Ltd. He was first elected Honorary Treasurer in 1973. (See Journal for September 1972.)

J. Powell

S. R. Wilkins

W. Barker

R. Larry

FOR ELECTION AS ORDINARY MEMBERS OF COUNCIL

From the Class of Fellows

Colonel William Barker (Fellow 1978, Member 1966, age 49) received his secondary and first technical education at Stockton-on-Tees while serving an electrical fitter apprenticeship at ICI, Billingham, and he subsequently obtained a Higher National Diploma in electrical engineering following full-time study at Constantine Technical College, Middlesbrough. In 1953 he entered National Service and served in the Royal Electrical and Mechanical Engineers. He remained in the Army after completing his period of National Service and his later appointments included those of Grade 1 Staff Officer on Guided Weapons and Radar in HQ DGME, Officer Commanding Telecommunications Branch REME at SRDE Christchurch, and finally, before opting for early retirement, Colonel GS in MOD Central Staffs as head of an engineering tem in the Directorate of Systems Co-ordination, concerned with tri-Services rationalization.

Since leaving the Army, Colonel Barker has been appointed Director of Engineering at the Services Kinema Corporation with technical responsibility for its engineering activities worldwide including closed-circuit television and audio-visual aids.

Colonel Barker serves on three Institution Committees at present: he is Chairman of the Computer Group Committee and a member of the Aerospace, Maritime and Military Systems Group Committee and of the Professional Activities Committee. He has also served on conference organizing committees and working parties.

Ronald Larry, M.I.E.E. (Fellow 1969, Member 1953, age 55) joined Cathodeon to work on camera tube development after wartime service in the Royal Signals. In 1951 he moved to the Planning and Installation Department of the BBC where he was closely involved in the many design and installation problems posed by the post-war expansion of the television service. He led the team responsible for designing and constructing the colour television mobile control rooms required for the start of the colour service in Britain. In 1967 he was appointed Head of General Services in the Engineering Designs Department of the BBC.

A member of Council in the period 1970 to 1973, Mr Larry has served on the Communications (formerly Television) Group Committee since 1963; he was Chairman for three years from 1970. He has been a member of the Professional Activities Committee since its inception and represents the Institution on a BSI Technical Committee.

Mr Larry has been associated with the planning of a number of the Institution's Conferences and he was Chairman of the Organizing Committee of the Video and Data Recording Conference held in July.

From the Class of Members

Commander David Kenner, B.Sc., M.Sc., RN(Ret.) (Member 1963, Graduate 1960, age 48) was born at Weymouth and obtained his Bachelor's degree at the then University College, Southampton. He entered the Royal Navy in 1952 in the instructor branch and served in HMS *Collingwood*, HMS *Thunderer* and HMS *Excellent*. He was Head of Auto Control Group at the Royal Naval Gunnery School from 1962 to 1964 and, in 1966 to 1968 while at the Royal Naval Electrical School, he carried out research, in conjunction with the City University, into the application of p.r.b.s. to the testing of systems controlling massive objects. For the next five years he was Head of Electrical Machines and Measurements at the Royal Naval Engineering College. On retiring from the Navy in 1963, Commander Kenner was appointed Vice-Principal of Redbridge Technical College and for the past three years has been Vice-Principal of Brighton Technical College.

At Brighton Technical College he has been particularly concerned with practical training of professional engineers and has devised special programmes with the Engineering Industry Training Board and the Philips Group and he has also been concerned with the application of microprocessors and with systems training for technicians.

Since 1970, Commander Kenner has been a member of the Automation and Control Systems Group Committee and he has also collaborated in the planning of several colloquia and conferences.

Brian Mann, M.Sc. (Member 1967, Graduate 1965, age 45) is a principal lecturer at Leeds Polytechnic responsible for microprocessor development and applications. He received his technical education at High Wycombe College of Technology and at the Cranfield Institute of Technology where he obtained his M.Sc. After service in the RAF, mainly at No. 2 Radio School, Yatesbury, he joined De Havilland Propellers, Hatfield, to work on instrumentation for flight trials. In 1960, he joined General Precision Systems, Aylesbury, as a project engineer on flight simulators. He was responsible for several radar, radio and navigation simulators for both military and civil projects, and before leaving the company he was a project manager. In 1969, he joined the teaching staff at Sheffield Polytechnic, moving to Leeds Polytechnic in 1972. Since then he has been responsible for much of the development work in digital electronics and microprocessors.

He is Secretary of the Institution's Yorkshire Section and a member of the Automation and Control Systems Committee.


D. Kenner


B. Mann


K. R. Thrower


P. J. Hulse


M. W. Wright

Keith Rex Thrower (Member 1967, Graduate 1965, age 44) was born and educated in London and between 1953 and 1957 he served in the Royal Air Force. He joined Racal Communications in 1957 as a junior engineer and he has remained with the company ever since. During the sixties he was principally concerned, as a Senior Engineer, with the design of frequency synthesizers and with various digital equipment. In 1969 he was appointed Technical Director of Racal Instruments, being responsible for a wide range of electronics test instrumentation. In 1974 he took over the appointment of Director of Advanced Development for the Racal Group where he is responsible for all new technological development with the Group and has a special responsibility for the application of microelectronics to new equipment. He holds a number of patents for circuit design improvements and he has contributed papers to Institution conferences. He has been a member of the Communications Group Committee since 1974 and he has also served on conference organizing committees.

From the Class of Associate Members

Philip John Hulse (Associate Member 1974, age 29) served a Craft Apprenticeship at the Royal Ordnance Factory at Radway Green and in 1972 joined the Telecommunications Branch REME as Assistant Assessment Officer in the Common Purpose Test Equipment Section of 10 Maintenance Advisory Group. In 1974 he moved on promotion to Radar Branch REME as Assistant Project Officer in the Artillery Systems Group. His present appointment is that of Workshop Manager (Electronics and Instruments) at 41 Command Workshop REME, York.

Mr Hulse was a member and latterly Honorary Secretary of the South Midland Section while working at Malvern.

From the Class of Associates

Michael Walter Wright, T.D. (Associate 1970, age 37) served an apprenticeship as an electrical technician with Ericsson Telephones (now Plessey) in Beeston, Nottingham, between 1958 and 1963 and subsequently obtained an appointment as electrical maintenance engineer. In 1964 he moved to Loughborough University of Technology to become a Senior Research Technician in the Department of Electronic and Electrical Engineering, being promoted to Chief Technician in 1974 with responsibility for computers in the Signal Analysis Centre. In January 1978 he went back into industry as an engineer with Computer Technology of Hemel Hempstead and a year later became Senior Site Engineer for CTL at British Rail's National Computing Bureau at Nottingham, the post he still holds. Mr Wright has served in the Royal Signals TAVR for 20 years and in 1968 received a Commission. His present rank is Captain and he was presented with the Territorial Decoration in July 1978. He is a member of the Committee of the East Midlands Section, one of his posts having been Programme Secretary.

General Assembly of the Engineers Registration Board

The 6th ERB General Assembly was held on 13th June at the Institute of Marine Engineers, Mark Lane, City of London.

Following the reports from the Chairmen of the three ERB Section Boards, the general discussion session ranged over a number of topics of concern to ERB member organizations.

Several speakers voiced their views on lapsed membership and suggested some time be spent in identifying the causes for registrants failing to continue their membership of institutions. It was generally felt that retention of existing members is as important, if not more so, than attracting recruits to the ERB. It is important also to convince employers of the benefits of registration of qualifications, which will have the effect of encouraging those holding necessary qualifications to join an ERB institution. The recent ERB publication, 'Registration—its value to you', was generally thought to be a useful aid with which to approach employers and personnel management, providing a personal approach was also made as a follow-up.

Other topics discussed included the status of engineers in the three recognized grades in comparison with their counterparts in the EEC, the use of designatory titles, the contribution ERB members could make in regional branch activities of institutions and the initiatives taken by the Section Boards in working with the new TEC and SCOTEC organizations. The progression from technician to TEng and CEng grades also featured among the topics of discussion.

One of the rewarding indications of the further strengthening of the ERB organizations came across in the reports of the Section Board chairmen. Since the establishment of the CEng Section Board, a degree of unanimity had been established in the co-ordinating committee which augurs well for the future. A number of speakers said how gratifying they found this spirit of co-operation and mutual support.

Dr D. F. Galloway was elected to a further term of office as Chairman of the ERB General Assembly and Mr R. W. Ladbrooke was elected Vice-Chairman.

A further report of the 6th General Assembly will appear in brochure form later this year.

Members' Appointments

CORPORATE MEMBERS

D. Dick, D.I.C. (Fellow 1970, Member 1960) has been appointed for a second term of three years as an Educational Member of the Construction Industry Training Board. Mr Dick, a past Chairman and Secretary of the Scottish Section, has been Principal of Stevenson College of Further Education, Edinburgh, since 1969.

E. G. Lamb, B.Sc. (Eng.) (Fellow 1965), who first joined the Iron and Steel Industry Training Board as an Educational Member in 1973, has been reappointed for a third period of three years. Mr Lamb is Principal of Bell College of Technology, Hamilton, Lanark.

Professor D. R. Towill, D.Sc. (Fellow 1970) of the Department of Mechanical Engineering and Engineering Production at the University of Wales Institute of Science and Technology, Cardiff, has been invited to become a member of Eta Kappa Nu, the American Honor Society for university graduates in electrical engineering. The Society is marking the 75th anniversary of its foundation by electing a few distinguished engineers from outside the US into membership.

A. Bintcliffe (Member 1965), for the past four years an engineer with the Papua New Guinea Posts and Telegraphs, has now taken up a contract in Riyadh, Saudi Arabia, as a senior Engineer with the consulting engineers, Preece, Cardew and Rider.

A. S. Harwood (Member 1965, Graduate 1962) who has been with the Independent Broadcasting Authority since 1970, has been appointed Head of the Site Evaluation Unit.

C. R. Price (Member 1970) has taken up an appointment of Senior Test Engineer with Spar Aerospace, Toronto, to work on the *Anik* series of satellites. Initially he will be spending some months working at Hughes Aircraft Corporation, Los Angeles. For the past seven years Mr Price has been with Marconi Space and Defence Systems.

Wing Cdr G. D. Ramshaw, RAF, B.Sc., D.U.S. (Member 1973) has been appointed Head of Training Advisory Cell at HQ RAF Strike Command; he was previously Officer Commanding Basic Studies Wing at No. 1 School of Technical Training RAF Halton.

Major L. A. Woods, R Signals (Member 1969, Graduate 1965) has been appointed Officer Commanding Analysis Group with the Army EMC Agency, Blandford Camp. For the past four years he held a staff post in the Procurement Executive, Ministry of Defence.

P. R. W. Webb, B.Sc. (Member 1959, Graduate 1955) who joined the Canadian Department of Industry, Trade & Commerce after retiring from the Canadian Air Force as a Squadron Leader, has been appointed Chief of the Standards & Metric Conversion Division, Office of Science and Technology.

NON-CORPORATE MEMBERS

F. O. Adophy (Graduate 1966) has been appointed Assistant Chief Engineer of the Federal Radio Corporation of Nigeria, based at Enugu. He was previously Principal Engineer with the corporation at Benin.

A. J. Shipton (Graduate 1966) has set up an independent agency organization, Parndon Electronics. He was previously UK and Scandinavia Sales Manager for General Instrument Microelectronics.

M. Jamil (Associate Member 1971) is now with the Avionics Engineering Centre of Ohio University. He was previously an Inspector in the Standards Calibration Laboratory of Saudi Arabian Airlines, Jeddah.

Obituary

The Institution has learned with regret of the deaths of the following members.

Morgan Allen (Member 1971, Graduate 1964) of Bishopbriggs, Lanarkshire, died in January 1979, aged 42 years. At one time a Technical Officer with the Post Office Engineering Department, he subsequently joined the staff of Stow College of Engineering, Glasgow as a lecturer.

Harry Norman Gant (Member 1949, Graduate 1943) died on 11th January 1979, aged 69, leaving a widow. Harry Gant served in the Royal Navy from 1934 till 1945 and soon after joined EMI Engineering Development, Hayes, as a radio and television receiver development engineer: he remained with the company until his retirement. While in the Navy, Mr Gant took the Institution's Graduateship examination and was awarded the S. R. Walker Prize in 1943; this was the award then given to the second candidate in order of merit. At the Institution's Television Engineering Convention in Cambridge in 1959, he presented a paper entitled 'Some aspects of television reception on band V'.

Captain Paul Alfred Grayson, B.Sc.(Eng.) REME (Member 1974) died recently aged 33. Captain Grayson was commissioned in 1968 after graduating at the Royal Military College of Science and at the date of his election to membership of the Institution, he was Officer Commanding No 14 Maintenance Advisory Group, attached to the Royal Small Arms Factory, Enfield. For the past year he had held an appointment at Arborfield.

Walter Philip Mansel James (Associate Member 1977) of Salisbury, Rhodesia, was killed on his way to work on 5th March 1979. Aged 35, he leaves a widow, a son and two daughters. Mr James was a Master Technician in the Rhodesian Air Force, and latterly was a Senior Instructor at the Air Force's Training School in Salisbury, teaching the T1 and T2 syllabus of the City and Guilds Telecommunication Technicians course.

Francis Finlay Kemp (Member 1973, Graduate 1968), died recently aged 35. After obtaining Higher National Certificates to gain Graduateship of the Institution, he held appointments with a number of companies in the instrumentation field as an electronics development engineer concerned generally with circuit design. From 1974 to 1978 he was a Principal Scientist with the Allen Clark Research Centre of the Plessey Company and since the end of last year he had been Assistant Engineering Manager with SGS-ATES Falkirk.

LORD MOUNTBATTEN

Members will have learned with a great sense of sorrow of the murder on 27th August of Admiral of the Fleet Earl Mountbatten of Burma, K.G., F.Eng.

A tribute to this great sailor and statesman, who was twice President of the Institution, will be given in the next issue of the Journal.

Arthur William Pearson (Associate 1963) died on 31st August 1978, aged 56, leaving a widow. He was at one time Manager of the Industrial Division of EMI Electronics, Hayes.

Reginald Douglas Trigg (Member 1947) died on 12th April 1979, aged 71, leaving a widow. Prior to his retirement in 1970, he was a Senior Lecturer in computer techniques in the Education Division of ICL and he had previously held appointments with several leading companies in the radio industry including the Marconi Company, Cinema Television, Masteradio, Murphy Radio and Philips Radio.

Oliver Victor Wadden (Member 1938, Associate 1933) died in February 1979, aged 77, leaving a widow. Following service in the Royal Air Force between 1921 and 1929, he worked as Test Engineer with the Gramophone Company at Hayes. In 1933, with a partner, he founded a radio and television business in Hounslow, Middlesex, from which he retired in 1965.

The 53rd Annual Report of the Council of the Institution

For the year ending 31st March 1979

The Council is pleased to present the 53rd Annual Report of the Institution—the 18th since Incorporation by Royal Charter. The Annual General Meeting will be held on Thursday 25th October 1979, at the London School of Hygiene and Tropical Medicine, commencing at 6 p.m.

INTRODUCTION

ALTHOUGH the work of the Institution has gone ahead apace in all its aspects throughout the year of this report an atmosphere of 'waiting for Finniston' has tended to overshadow it all. Indeed, it has often been necessary to take positive action to counter a tendency to use the uncertainty about the outcome of that inquiry as an excuse to procrastinate on some issues deserving of resolution in their own right. Perhaps, therefore, it has been fortunate for the Institution that continuing financial pressures have forced the need to take immediate decisions on a number of important long-term management problems; and that our conviction on the need, in the public and national interest, to maintain our stand on a balanced approach to qualification standards for engineers has similarly compelled us constantly to reiterate our opposition to any more specialized or elitist academic approach to this vital matter.

Both these points were, of course, fundamental to the issues discussed by the membership at the Special General Meeting held in June 1978 which led to the Bye-Law amendments which were ratified by Her Majesty's Privy Council later in the year: the first resolution being critical to the Institution's continued financial health and the second having to do with the formulation of rules for the strengthening of the membership at all levels in step with the advancement and spread of the exploitation and application of electronic engineering in the modern world. The influence of all this, and the Council's concern with wider educational issues for the profession, is reviewed in the following Standing Committee sections of this Report.

But in the midst of all this concern with things financial and—in terms of professional standards—political, the basic work of the Institution has made steady progress throughout the year. The first important step has been taken to restyle the Journal to meet better the diverse needs of the membership and our subscribers; and it is a great pity that these efforts have been made more difficult by the industrial and meteorological problems which have so often frustrated our attempts to maintain our publishing schedules this year. It is to be hoped, however, that changes in printing arrangements, including the use of newer print technology, planned for the coming year will ease these problems considerably. As to the learned society programme of conferences, colloquia and meetings it will be seen from the later report of the Professional Activities Committee that our Royal Charter remit in this regard has been met successfully both by the main Committee and its Specialized Group Committees, and by the sixteen Local Section Committees of the Institution.

On balance, therefore, the Council presents this 53rd Annual Report to the membership of the Institution confident not only that much has been achieved during the year in pursuit of our primary aim, but also that stands taken and views published and expressed in the wider policy councils of the profession throughout the year will act to the good of our members and the national interest in the longer term.

EXECUTIVE COMMITTEE

Early in the year the Council revised and extended the terms of reference of the Executive Committee to simplify and further improve the co-ordination of planning and financial management of the Institution's affairs. The changes included absorption by the Executive Committee of the responsibilities of the Finance and Overseas Affairs Committees, and the assumption of additional delegated administrative powers from the Council. These new arrangements have worked well and were particularly useful during the severe winter months when travel and industrial problems drastically restricted attendance at Institution management meetings in London.

Revision of Bye-Laws. The Committee is pleased to report the allowance by Her Majesty's Privy Council during the year of all the Bye-Law amendments approved by the membership of the Institution at the Special General Meeting held on 15th June 1978. Subsequently the Council considered and approved Executive Committee recommendations on future fee and subscription levels to take effect from 1st April 1979 and which it is hoped will allow for the progressive repair of the damage done to the Institution's general financial position by inflation over the past four years whilst maintaining the work and services of the Institution at present levels. The impact of the

Bye-Law amendments concerned with membership standards are mentioned elsewhere in this Report.

Overseas Affairs. Mention was made in the last Annual Report of the need for detailed review of arrangements for the management and support of the IERE membership in India. This work was completed by the Committee in March 1978 and Council subsequently decided to cease publication of the *Indian Proceedings* in July 1978, to close the Institution's Bangalore Office in September 1978 and to administer all the Institution's Indian affairs direct from 99 Gower Street thereafter. The need for this action was subsequently notified in detail to the Indian membership and was received with understanding tinged with some regret. No change has been made in the arrangements for IERE regional activities in India for which Dr P. K. Patwardhan (Fellow and last IERE Indian Divisional Chairman) has accepted responsibility as IERE National Representative in India. Management of the Institution's affairs in New Zealand has been stimulated by local reorganization during the year: these changes will strengthen the IERE's links with kindred national engineering bodies in New Zealand without detriment to the maintenance of such specialist IERE activity as may seem appropriate to the local divisional committee. Membership has continued to grow and mature in both Hong Kong and Singapore, the major milestone in the latter place being the election of the first Singaporean to the class of Fellow—an event which the Committee hopes will lead in the coming year to the establishment of a Singapore Section to further the work of the Institution and the interest of its members in that fast-developing area. Finally, in this context, the Committee is pleased to report the satisfactory continuance of the Institution's representative work with overseas kindred bodies and particularly with those in Europe where Professor W. Gosling (Fellow and Vice-President) was elected President of the General Assembly of National Societies of Electrical Engineers of Western Europe (EUREL) for 1978/79.

The Profession. As was mentioned in the introduction to this Report, much of the work of the Institution this year has been influenced by consideration of the future of the engineering profession and its role in the industrial life of the Nation. Whilst noting that some other bodies have seen fit to make supplementary submissions to the Finniston Inquiry Committee the IERE Council has seen no reason to amend or add to its written evidence which was reported last year and published† in May 1978. Indeed, it has been gratifying to note that during the course of the year some other bodies have, in their supplementary statements, moved towards the viewpoints expressed in the written IERE evidence on qualification standards and career development for professional engineers. It has nevertheless been necessary for the Executive Committee to devote some time to consideration of the implications of other proposals made by some other authorities for changes in professional standards and registration procedures. Most important of these in terms of Committee time and effort was the Institution of Electrical Engineers' 'Merriman' decision to raise with effect from 1982 the academic standard for entry to chartered engineer status above that generally agreed with, and now specified by, the Council of Engineering Institutions‡ for the profession as a whole. The outcome of this review by the Executive Committee, which was that no such change was at present needed or justified, was thought to be worthy of widest possible understanding by the membership and was accordingly published in *The Radio and Electronic Engineer*.§ The response to this policy statement was almost entirely favourable and included particularly strong endorsement from some senior members of the Institution and others active in higher management on the British industrial scene. In this general context of the profession and its future, Council was pleased to note at the close of the year the election of Dr. P. A. Allaway (Fellow and Past President) as Vice-Chairman of CEI for 1979.

Scholarship Funding. In early October 1978 the Council of the Institution received the sum of 50,000 Canadian dollars most generously bequeathed by the late Leslie H. Paddle (Founder Member, Fellow and Vice-President 1950–58) to found post-graduate scholarships in electronic or radio engineering for members of the Institution. Action has since been taken by the Executive Committee to establish an appropriate educational trust fund, to be known as the Leslie H. Paddle Scholarship Fund, governed by a Trust Deed to protect and administer the bequest. The official management committee of this fund, comprising the President and the Secretary of the Institution and the Chairman of the Institution's Standing Committee for Education and Training, all 'for the time being in office', will be calling for applications for the first Paddle Scholarship awards during the coming year.

Honorary Fellowships. During the course of the year under report two senior and distinguished Fellows of the Institution, John Langham Thompson (Past President) and Graham D. Clifford, C.M.G. (Secretary and Director of the Institution from 1937–1977) were elected to Honorary Fellowships, and the Executive Committee was privileged to arrange for them to sign the roll of Honorary Fellowship and receive their scrolls at a reception held in the Worshipful Company of Scientific Instrument Makers' Hall in the City of London. During this reception, which was attended by Admiral of the Fleet The Earl Mountbatten of Burma, K.G. (Honorary Fellow and Past President) and many other senior and distinguished members of the Institution, the President, Professor W. A. Gambling, presented an inscribed silver salver to Mr. Clifford on behalf of his professional colleagues and friends as a mark of their esteem, affection and gratitude for his unique contribution to the life and work of the Institution during his forty years' dedicated service as Secretary and Director.

Finance. Bearing in mind that the year under report was the third successive year at the same subscription level and that inflation has reduced the purchasing power of the currency by some 40% over that period, Council is well satisfied with the Institution's financial performance as set out in the accounts on pages 434–436.

As will be seen from the income and expenditure account, the Institution ended its year with a deficit of income over expenditure of just over £8,000. Against this must be set several items of non-recurrent expenditure, notably the expense of preparation, printing, publishing and implementing the recent

‡ CEI Statement No. 12, 1977.

† *The Radio and Electronic Engineer*, **48**, No. 5, p. 225 and 256, May 1978.

§ *The Radio and Electronic Engineer*, **49**, No 2, pp. 63 and 64, February 1977.

Bye-law amendments, and costs arising from the delayed closure of the Indian office, which together were sufficient to account for the deficit. Additionally it was considered prudent to write off some £2,000 against a now obsolete stock of Institution publications.

The total income for the year shows an increase of just under £8,000 compared with last year—an improvement largely resulting from better publication sales results.

On the expenditure side inflation brought about the inevitable increase in 'bought-in' services, notably printing, which increased by £14,000 compared with last year. It says much for the tight control on all areas of expenditure exercised by management that, notwithstanding such uncontrollable increases, the overall expenses of the Institution are within £2,000 of last year, with no diminution of the standard of services available to members.

A particular indication of the financial concern exercised by management and all members of the Institution's staff, is that the total administration cost of £150,522 is within 0·3% of last year's figure. Significant savings have also been made in the Sections' operating expenses.

Finally, mention should be made of the reduction of nearly £1,000 in bank charges, reflecting the lower average level of borrowings throughout the year that has resulted from a much improved cash flow performance.

On balance, therefore, and bearing in mind the benefits likely to be derived from the increase in subscription income announced at the last Annual General Meeting and effective from 1st April 1979, Council views the future quietly confident that provided inflation can be contained at moderate levels the Institution is now on course to an improving financial future.

PROFESSIONAL ACTIVITIES COMMITTEE

The Institution's Royal Charter leaves no room for doubt that the primary role of the IERE is the advancement of the science and practice of electronic and radio engineering, and stresses the particular importance of the exchange of information and ideas in this context. This commitment is met by the publication of original papers and survey articles in the Journal and through the Institution's programme of conferences, colloquia and meetings organized in London under the auspices of the Professional Activities Committee and by the Section Committees in the regions.

Past experience of this key aspect of the Institution's work has clearly demonstrated the need for the closest possible collaboration between the Specialized Group Committees and conference organizing committees on the one hand, and the Professional Activities Department of the Secretariat on the other, in order to ensure that all these events are adequately publicized and effectively administered. And it is for this reason that every effort has been made, and with good effect, to strengthen the manning of the department and to consolidate this essential collaboration during the period under review in this Report.

Conferences. During the year three major conferences were held:

'Electromagnetic Compatibility' (April 1978, University of Surrey)
'Radio Receivers and Associated Systems' (July 1978, University of Southampton)
'Microprocessors in Automation and Communications' (September 1978, University of Kent)

A total of 728 delegates attended these events, and of these more than 10% were from overseas. An exhibition was associated with each of these conferences. The full texts of all the papers presented at these three major conferences were published in the IERE Conference Proceedings No. 39, 40 and 41 currently on sale from the Institution's Publications Department. In addition to its own programme the Institution co-sponsored a further eight conferences, which were organized by other bodies. All of these additional events were recommended by the Professional Activities Committee and subsequently approved by the Council as being directly relevant to the roles and aims of the Institution under the terms of the Royal Charter.

Colloquia. In the period April 1978–March 1979 a programme covering 16 one-day colloquia was planned but in the event only ten of these were actually held on the planned dates: the primary reason for the deviation from plan being unexpected difficulties in the compilation of suitable programmes by the organizing committees. The ten events held were, however, very successful, attracting a total of 655 delegates. The other six events are being reprogrammed for the coming year.

London Evening Meetings. As noted in previous reports London evening meetings no longer appear to interest members. Only one of these was held during the period under review. The subject was 'The Euronet Telecommunications and Information Network' and although the meeting was extensively publicized the attendance was only 35.

Local Section Activity. Whereas much of the supporting staff work for the Institution's main professional activities programme is provided by the Secretariat, all such effort for the regional programmes other than the production of publicity material is provided by the voluntary efforts of the members of the 16 local section committees. During the year under report their hard work and enthusiasm resulted in a total of 135 events—an increase of nearly 14% on the previous year. Thirty of these events were held jointly with local branches of other engineering bodies. Three of the items in the year's local section programme are worthy of special mention: the Yorkshire Section's two-day conference 'Microprocessing '78' held at Harrogate in April 1978; the Beds and Herts Section's first one-day event 'Microprocessing—The New Science' held at Hatfield in November 1978; and the Megaw Memorial Prize Lectures—an annual event—given by final year engineering students at Queen's University Belfast, organized in March 1979 by the Northern Ireland Section.

Representative Activities. The Institution has continued throughout the year to be represented on a number of external technical organizations and committees. It has also continued its active support for the work of standardization through the efforts of those Institution members who serve on the Technical Committees of the British Standards Institution. Details of all these appointments as at the close of the year are given in Appendices 6 and 7.

EDUCATION AND TRAINING COMMITTEE

While the year's work of the Committee has been of much the same kind as that of the previous year, it has been undertaken against a background of change in many of its areas of interest. Those major changes which have affected, or are likely to affect, the overall pattern of an engineer's education and so will probably require the Committee's attention for some time to come, are the subject of later paragraphs.

However, the year also saw a more subtle change. As a consequence of amendments to CEI's Charter and Bye-Laws, responsibility for CEI policy in respect of the Chartered Engineer's education, training, and experience, has been transferred from Standing Committee A to the newly formed Chartered Engineer Section Board. While it is too early to forecast the eventual consequences of the change, the Committee has already been given reason to hope that its new 'opposite number' in the CEI structure will not attach the exaggerated importance to the academic element of the engineer's make-up which was so evident in the deliberations and decisions of its predecessor.

The Report for the year 1977/78 referred to negotiations in progress with CEI's Standing Committee A which were aimed at overcoming difficulties expected to arise as a consequence of the removal of Physics and Applied Physics from the CEI list of approved disciplines, and to criticisms made to the same Committee of the nature of the compulsory Part 2 examination paper 'The Engineer in Society'. In the autumn of 1978, as a consequence of the restructuring within CEI already mentioned, responsibility for academic matters was transferred to the Chartered Engineer Section Board. It is gratifying to be able to report that the latter body has not only agreed to receive a list of those degrees in Physics and Applied Physics which the Institution considered to be appropriate fundamental academic qualifications for its future corporate Members, but has also accepted its recommendation that a small working party should be appointed to consider whether 'The Engineer in Society' needs to be re-modelled—taking particular note of the fact that overseas candidates sitting the CEI examination outnumber UK candidates by approximately 2:1.

The number of candidates sponsored annually by this Institution for the CEI examinations having remained almost constant at around 450 since 1974 rose this year to 579. Of these, approximately one-third (mainly overseas candidates) are required to pass Part 1 before proceeding to Part 2. Where Part 2 candidates are concerned, it is noticeable that the proportion of UK extrants who attempt the examination in two groups of three subjects each is rising. Fifty-one IERE candidates passed or completed the Part 2 examination in May 1978; in addition, thirteen pre-1973 Graduate members met the academic requirements for transfer to the class of Member by passing the Part 2 Academic Test. Passes in the whole examination represented 27% of the 'possibles'—that is, those earlier sitting all six subjects or the balance outstanding from earlier attempts. The Committee awaits with interest the report of CEI Examiners and Moderators on the May 1978 examination, having noted that the percentage of passes obtained by those Institution candidates sitting subject 365 (Control System Engineering) which was 11% in 1977, shot up to 47% in 1978. Until this report can be studied it will not be possible to decide whether the dramatic improvement was due to its policy of advising IERE candidates not to sit the subject unless they are specialists in it, or to the change of Examiner and Moderator.

Reference was made in the previous Report to a joint IEE/IERE working group which was preparing recommendations for the revision of the syllabus of the Electrical/Electronic Engineering subjects in Part 2 of the CEI examination. The working group's recommendations have since been considered at a meeting between working group members and CEI Examiners and Moderators. Much interest was shown in the group's suggestion that certain papers should incorporate a 'design' section (to be separately examined), and CEI has recently sought the views of other Institutions as to whether the idea should be extended to certain subjects within their own specialist areas of engineering.

While, after careful study, the Committee reluctantly concluded that it could find no combination of studies currently available through the Open University which it could confidently submit to CEI as warranting exemption from more than 3 subjects in Part 2 of the CEI examination, it has continued to scrutinize all applications for admission as Members received from persons whose qualifications include OU degrees, and in the autumn of 1978 submitted an exemption application to CEI on behalf of a candidate whose academic record throughout it thought sufficiently outstanding to justify complete exemption. After much earnest discussion CEI agreed, and the IERE became the first CEI Institution to admit an OU graduate as a Corporate member. In March 1979 he was joined by two more whose academic record overall was considered by the Committee to merit special consideration. It should perhaps be placed on record that all three successful candidates were members of the Services, for whom studies through the Open University were the only means of supplementing their academic qualifications.

Reference has already been made in this Report to the state of flux in the field of education in general and engineering education in particular: the article on 'The Chartered Engineer's Degree' in the February issue of the Journal, beside stating the Institution's views on the academic requirements for corporate membership, hinted at problems which the Committee anticipates will arise as a result of imminent or proposed changes in the overall educational pattern. It is to be hoped that the widespread opposition to the Schools Council's proposed replacement of 'A' levels by 'N' and 'F' levels (in which CEI has recently officially joined) will lead that Council to think again. The Committee continues to watch with interest the developments taking place in respect of the Technician Education Council's new Higher Certificates and Diplomas, since the development of new TEC awards to replace the ONC and OND in Engineering, and many familiar City and Guilds awards of similar standard, is so nearly complete that for them only an 'In Memoriam' notice need now be written. Despite last minute pleas for reprieve it seems unlikely that any new intake to HNC courses will be permitted after 1980, and that this award will also soon become history. It therefore seems almost inevitable that the OND in Technology and the HND will in the end also become mere memories—but the

Committee continues to urge that, because of the rather special nature of these awards, they should be allowed to continue at least until a realistic appraisal of the worth of what TEC can offer in their place can be made.

Because, in the present circumstances, so much of the work of the Committee comes under the heading 'Education' it is easy to forget that 'Training' is also part of its remit— and that training may sometimes imply re-training. In this context the Committee has recently considered a request for assistance which is of somewhat unusual kind—despite the widespread nature of the problem to which it relates. Graduates go into industry: they are trained to perform a particular function and, having been so trained, tend to 'dig in' and, in particular, to be reluctant to move into management. Could the Institution do anything to help the electronics industry to overcome this tendency? The Committee's last act of the present year has been that of appointing a small working group to advise it on the question of whether the idea has possibilities—if the answer is in the affirmative, it will proceed to consider ways and means.

MEMBERSHIP COMMITTEE

The Membership Committee met on 12 occasions during the year and considered 859 membership proposals. Of these 529 were for direct election, 200 for transfer and 130 for reinstatement. In all 843 of these applications were accepted with the result that the membership register at the close of the year as summarized at Table 1 shows modest gains in all classes except that of Graduate Member. Here, once again, we see the debilitating effect of the closure of the gate to Chartered Engineer status to virtually all but those having qualified via the CEI examinations or by obtaining a pass degree at an approved university or polytechnic—regardless of proven posts which qualify their degree holding brethren for C.Eng. status, is now much depleted: which, as the Institution has made clear in its evidence to the Finniston enquiry, can only be to the further disadvantage of the profession in national industrial terms. But referring again to Table 1, the very worthwhile gains in Corporate Members (C.Eng.) and Associate Members (T.Eng.(CEI)) are reassuring as evidence of the profession's continued interest in, and support of, the Institution's aims and objectives and its policy of encouraging vertical integration in the profession of electronic and radio engineering as mentioned in the 1978 Presidential Address.‖ It

Table 1. Institution Membership April 1978 to March 1979

		Additions				Deductions						
	Membership at 1.4.78	Direct Elections	Reinstatements	Transfers	Total Additions	Removals	Deaths	Resignations	Transfers	Total Deductions	Nett Gain (+) or Loss (−)	Membership at 31.3.79
Honorary Fellows	10	—	—	2	2	—	1	—	—	1	+1	11
Fellows	729	4	2	16	22	—	8	4	2	14	+8	737
Members	7192	78	57	91	226	—	30	46	16	92	+134	7326
Total Corporate Membership	**7931**	**82**	**59**	**109**	**250**	**—**	**39**	**50**	**18**	**107**	**+143**	**8074**
Graduates	2840	64	44	56	164	1	3	109	82	195	−31	2809
Companions	18	1	—	—	1	—	1	—	—	1	–	18
Asssociates	319	14	4	2	20	—	1	12	2	15	+5	324
Associate Members	815	114	11	25	150	1	3	11	10	25	+125	940
Students	1055	246	12	—	258	70	—	37	80	187	+71	1126
Total Non-Corporate Membership	**5047**	**439**	**71**	**83**	**593**	**72**	**8**	**169**	**174**	**423**	**+170**	**5217**
Grand Total	**12978**	**521**	**130**	**192**	**843**	**72**	**47**	**219**	**192**	**530**	**+313**	**13291**

potential or performance in the established task of the profession as a balancing factor. And the fact that the Graduate Member loss this year is only 1/7th of that shown in last year's report does little to alleviate the Institution's concern over this matter since it probably means no more than that our reserve of high grade Graduate Members who qualified through the Institution's own examination or the HNC-plus-endorsements route to successful achievement in is to be hoped that this reassuring movement will be given a further lift in the coming year by the wider knowledge and application of the additional flexibility provided by the 1978 Bye-law amendments concerning qualifying experience, and by the publicity campaign now being mounted by CEI to high-

‖ *The Radio and Electronic Engineer*, **49**, No. 2, p. 1, January 1979.

light the advantages of registration for engineers.

The Committee's Working Party on recruitment continued its work throughout the year and has now initiated action to appoint IERE representatives in all major concentrations of electronic and radio engineering education, training and practice; to improve the Institution's promotional material, and to start presenting the Institution's mission and purpose at all appropriate exhibitions and conferences in the near future. A qualified member of the Secretariat has been appointed to co-ordinate all this work.

PAPERS COMMITTEE

An important feature in the work of the Committee during the year has been to build up the policy established in 1976 of broadening the content of the Journal. Primarily this has meant obtaining papers which are generally classified as being 'General Interest' and the success must be gauged by the fact that nearly every issue of the Journal published between April 1978 and March 1979 has contained at least one of these 'General Interest' papers. The range of subjects has been wide: 'Patent Law Reform', 'A Profile of Cossor Electronics', 'Education for Electronics Engineers in Hong Kong' and 'The Relevance of Science to Engineering'. An equally broad range of subjects is represented in the papers intended for publication later in 1979.

Added prominence has been given to the 'General Interest' papers by placing them early in the Journal which, since January 1979, has been rearranged, so that the 'News and Commentary' pages precede the part of the Journal which contains the original technical papers. The 'General Interest' papers can be regarded as bridging the early content of Institution announcements and largely ephemeral news items and the more permanent main content.

It is believed that this new policy of emphasizing the part of the Journal which is not so specialized—but not at the expense of the essential specialized material—will serve the needs of the majority of members. As has frequently been pointed out in previous Annual Reports, most papers are probably of direct immediate professional interest to only a proportion of the membership. The new concept of the Journal, which is being evolved gradually, should mean that there will be something which should be of interest to every member who takes an interest in matters which may not be concerned with his own professional role.

The practice of gathering together papers dealing with a particular theme has been followed during the year under review and several special issues were published. In June 1978 seven papers on 'Digital Processing of Signals in Communications' were selected from the volume of papers given at the conference on that subject; in July/August the theme of the Special Issue was 'Reliability'; while in January and February 1979 several of the papers from the conference on 'Electromagnetic Compatibility' were gathered together to give an account of the 'state of the art' in this subject of importance to virtually every member of the Institution. Further Special Issues are being planned for 1979/80.

Papers generally have continued to represent a wide range of subjects over the 'spectrum' of electronic and radio engineering. The perennial plea for more engineers working in industry to find the time and opportunity to contribute papers on their work must once again be made: engineering development and production techniques are probably of interest to a greater proportion of the members of the Institution than any other, if the evidence from a preliminary study of a recent questionnaire is any guide.

Assessment of Papers. The record of papers considered by the Committee during the year and the decisions shows that there was a slightly smaller number of papers and that the overall standard judged by the ratio of acceptance to rejections was not so high as in the previous year. The figures are as follows (1977/78 figures are given in parentheses):

Number of papers considered	139	(149)
Accepted for publication	59	(67)
Returned for revision	13	(24)
Rejected	67	(58)

Nearly half the papers considered had previously been published in connection with Institution conferences and the ratio of acceptance to rejection here is lower than for papers put forward for original publication. This is because a conference paper has to meet a high standard to justify what is in effect a second publication; furthermore, it is not usual to return such papers to authors for revision, any major 'surgery' of this kind being regarded as calling for a completely different paper from the initial conference version. As in previous years the proportion of papers returned to authors for revision is just about a third of those accepted as submitted or with only minor modifications.

The Committee is encouraged by comments occasionally made by authors that its criticisms are particularly constructive. In accepting these compliments the Committee is conscious of the great amount of careful work freely given by its panel of referees.

Premiums. Details of the awards which are to be made to the authors of outstanding papers published in the Journal during 1978 are given in Appendix 8. Ten Premiums are being awarded and it is interesting to note that four of the papers concerned originated from overseas.

INSTITUTION PUBLICATIONS

The Radio and Electronic Engineer. An overriding factor in the production of the Journal during the past year has been the importance of holding down costs. The practice followed in 1977 of combining issues was adopted on two occasions (January/February and July/August) and this has achieved economies in binding and postage and packing. The total number of pages published in the Journal over the year was in fact about 7% larger than in 1977, accounted for by the inclusion of more material under the heading of 'News and Commentary' as well as General Interest papers. However, the importance of the Journal in providing members with regular news of coming events must be borne in mind and it is hoped to phase out this temporary expedient as soon as possible; during 1979 it is intended that only one pair of issues will be combined (namely July/August).

Reference has been made in the report of the Papers Committee to the change in the make-up of the Journal by placing Institution news, both official and relating to meetings and members, and short technical news items in front of the technical papers. This change was made with the January 1979 issue and it is perhaps early to assess the reactions of members generally. Favourable comments have been made however and it is considered that this has been a move which will augment the value and convenience of the Journal to members.

While disappointment must again be recorded at the low level of support from industry in advertising equipment, components and services, there has been a modest improvement in the number of advertisements for appointments. These have been concerned with situations vacant in the British Isles and also overseas and indicate the role played by the British electronic and radio engineer in developing communications and other systems throughout the world.

During the latter part of 1978/79 it proved increasingly difficult to achieve timely and regular publication of the Journal by traditional methods. The effect of the extreme weather conditions and concurrent industrial relations problems on routine communications and commerce also contributed to the frustration that this persistent problem created. For these reasons and because of the need to do everything possible to hold down printing costs it was decided at the close of the year to investigate the cost-effectiveness of new printing technology in the context of further development of current plans for the future of the Journal; and it is to be hoped that new agreements now being negotiated will provide the basis for better service to members in this area of the Institution's work.

Revenue from subscriptions to the Journal and the sales of back issues and reprints continue to make a useful contribution to off-setting the growing costs of production. Subscription rates were increased with effect from January 1979 and in order to maximize this income orders are now only accepted direct from the subscriber instead of through agencies. Notwithstanding the increased subscription, *The Radio and Electronic Engineer* still compares favourably with virtually all its contemporaries.

It is hoped to achieve greater efficiency in the distribution of the Journal within the British Isles in due course by the adoption of post code sorting which should facilitate speedier handling by the Post Office and, more important, will provide a worthwhile saving in postage. The speedier systems for overseas mail offered by the Post Office are being examined to see if the transit time, now almost two months for some parts of the world, can economically be reduced.

The removal of lapsed members from the Register at the end of the year 1977/78 has naturally affected the overall circulation for the calendar year 1978; the sworn statement is 13696, compared with 14182 for 1977.

Conference Proceedings. Three sets of Conference Proceedings were produced or initiated between April 1978 to March 1979, namely 'Radio Receivers and Associated Systems', 'Microprocessors in Automation and Communications' and 'Television Measurements' (held in May 1979). These volumes contain a total of 124 papers amounting to 1179 pages. Sales of Conference Proceedings after each conference continue to provide publications revenue; the Proceedings of a conference held at the end of the previous year (Electromagnetic Compatibility, March 1978) were soon sold out and a reprint was produced in January 1979. Indeed, sales overall have reached a record level.

Association of Learned and Professional Society Publishers. The Institution continues membership of ALPSP, which provides an opportunity for useful exchange of views and experiences with similar bodies. Especially valuable has also been the co-operative publicity for the Institution's Journal and other publications at exhibitions overseas.

Problems affecting copyright and photocopying have continued to occupy the Association and its members, and the change in the law affecting copyright in the United States has led the IERE to register *The Radio and Electronic Engineer* so that fees for photocopying of papers by US organizations may in due course be remitted to the Institution.

LIBRARY AND INFORMATION SERVICES

The Library's second year in its new 'home' has confirmed the convenience and greater efficiency which result from having virtually all reference and loan material in one location. The rather smaller space available for members using the Library in person has not proved a disadvantage since the numbers involved have remained approximately constant. However, the use made of Library services, both in the loan of books and in the provision of photocopies by post and in enquiries generally, has increased as the facilities offered become better known to members.

Even though financial considerations prevent the Library from acquiring quite as many new books on expanding subject areas as it would wish, the resources which can be drawn upon, on a mutual basis from libraries of other engineering institutions, and above all from the British Library at Boston Spa, mean that it is usually possible to meet members' requirements with little delay.

ACKNOWLEDGMENTS

All learned Societies depend for their success on the general support of their membership and, more particularly, on the active participation of those members who give their time and expertise to the specialized work of society committees, working parties and external representatives activities. Our Institution is no exception to this rule. Indeed, it is probably true to say that one of the special qualities of the IERE is the active interest of the Sections in all its work and the consistent loyal support which is always forthcoming from the committees which serve the Council. To all these members who so ably and willingly contribute to the life and tasks of the Institution, and to all the staff of the Secretariat who have worked so hard throughout the year to implement our plans and to administer our affairs so cost-effectively the Council extends its grateful thanks.

The Institution's Council also wishes to record its thanks to the Royal Institution, the London School of Hygiene and Tropical Medicine and to the many universities, polytechnics, technical colleges and other such organizations for providing accommodation for the Institution's meetings and conferences; and to the editors of all technical journals and newspapers for publicizing the Institution's activities and events.

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MARCH 1979

	1979 £	1979 £	1978 £	1978 £
INCOME (Note 2)				
Subscriptions		219,742		220,910
Entrance, Transfer and Exemption Fees		3,890		2,544
Sales:				
Institution Journal	30,026		27,455	
Other Publications and Colloquia	14,184		8,300	
		44,210		35,755
Fees Received—Symposia		46,187		45,870
Dividends and Interest Received		415		1,736
Total Income		314,444		306,815
Deduct:				
EXPENDITURE				
Cost of Publishing Journal				
Printing Costs	60,824		48,020	
Less: Advertising Receipts	5,970		5,894	
	54,854		42,126	
Postage	23,304		23,489	
Envelopes and Wrappers	1,320		1,200	
	79,478		66,815	
Direct Expenses relating to Symposia				
Printing of Papers	8,327		5,095	
Accommodation and Travel	16,187		18,533	
	24,514		23,628	
		103,992		90,443
		210,452		216,372
Deduct:				
Administration Expenses				
Salaries and National Insurance	101,626		103,326	
Superannuation Scheme	4,348		5,486	
Postage and Telephone	16,327		17,214	
Printing and Stationery	7,788		5,685	
Computer Service	7,627		6,273	
Travelling and Entertaining Expenses	542		288	
Council and Committee Expenses	3,353		2,382	
Delegates' Expenses	214		263	
Bank Charges and Differences on Exchange	5,442		6,496	
Audit Fees	1,500		1,500	
Miscellaneous Expenses	1,755		1,159	
Carried forward	150,522	210,452	150,072	216,372
Brought forward	150,522	210,452	150,072	216,372
Establishment				
Rent, Rates and Insurance	34,106		31,656	
Lighting and Heating	1,583		1,428	
Office Expenses and Cleaning	6,909		7,330	
Repairs and Maintenance	1,045		1,135	
	43,643		41,549	
Divisions and Sections Operating Expenses				
Salaries, Printing, Stationery, Postage and Office Expenses	8,016		9,028	
Hire of Accommodation, Lectures and Meeting Expenses	3,674		4,710	
Travelling Expenses	502		795	
Indian Proceedings	1,002		1,431	
	13,194		15,964	
Subscriptions to the Council of Engineering Institutions	9,790		7,952	
Awards and Contributions to Other Institutions	919		1,216	
Depreciation (Note 5)				
Furniture, Fittings and Equipment	800		180	
Profit on Sale of Assets	(251)		—	
	549		180	
		218,617		216,933
Excess of Expenditure over Income for the year before Extraordinary Items		(8,165)		(561)
Extraordinary Items (Note 3)		—		(7,872)
Excess of Expenditure over Income after Extraordinary Items carried to General Fund		£(8,165)		£(8,433)

STATEMENT OF GENERAL FUND

	1979 £	1979 £	1978 £	1978 £
Adverse Balance brought forward as restated (Note 4)		79,353		110,357
Excess of Expenditure over Income for the Year		8,165		8,433
Surplus on Revaluation of Fixed Assets (Note 5)		—		(39,437)
Adverse Balance at 31st March 1979		£87,518		£79,353

BALANCE SHEET AS AT 31st MARCH 1979

	1979 £	1979 £	1978 £	1978 £
Fixed Assets (Note 5)		65,117		62,133
Quoted Investments at Cost (Note 6)		4,328		4,328
(Market Value £4,988) (1978 £4,821)				
Premises Fund Investment				
£23,000 Corporation of London 8¼% Bond repayable April 1979	23,000		—	
Balance at Bank	9,829		25,760	
		32,829		25,760
Current Assets				
Stock of Institution's Publications (Note 7)	17,748		18,723	
Income Tax recoverable	39		212	
Sundry Debtors and Prepayments	28,572		25,936	
Balances at Bank and in Hand	4,725		8,427	
		51,084		53,298
		153,358		145,519
Less:				
Current Liabilities				
Sundry Creditors and Provisions		65,802		55,114
		87,556		90,405
Add:				
General Fund Account				
Adverse Balance		87,518		79,353
		£175,074		£169,758
Represented by:				
Premises Fund Account (Note 8)		32,829		25,760
Deferred Revenue				
Subscriptions and Receipts in Advance		39,369		53,484
Short Term Borrowings				
Bank Overdraft		102,876		90,514
		£175,074		£169,758

Signed

D. W. Heightman (*President*)
S. R. Wilkins (*Hon. Treasurer*)
S. M. Davidson (*Secretary*)

STATEMENT OF SOURCE AND APPLICATION OF FUNDS FOR THE YEAR TO 31st MARCH 1979

	1979 £	1979 £	1978 £	1978 £
Source of Funds				
Excess of Expenditure over Income after Extraordinary Items		(8,165)		(8,433)
Add:				
Items not giving rise to the movement of funds:				
Depreciation	800		180	
(Profit)/Loss on disposal disposal of Investments and Fixed Assets	(251)		8,587	
Provision for deferred repairs	—		(5,000)	
		549		3,767
		(7,616)		(4,666)
Other Sources:				
Proceeds from disposal of Investments and Fixed Assets	709		23,764	
Increase in Subscriptions received in advance	—		8,179	
Increase in Premises Fund Receipts	7,069		8,539	
		7,778		40,482
Total Source of Funds		162		35,816
Application of Funds				
Purchase of Fixed Assets	4,242		7,493	
Decrease in Subscription received in advance	14,115		—	
Amount set aside for Premises Fund Investment	7,069		8,539	
		(25,426)		(16,032)
		(25,264)		19,784
Movement in Working Capital:				
(Increase)/Decrease in Stocks	975		(1,612)	
(Increase)/Decrease in Tax Recoverable	173		(26)	
Decrease in Debtors	(2,636)		(7,642)	
Increase/(Decrease) in Current Liabilities	10,688		(21,313)	
		9,200		(30,593)
		£(16,064)		£(10,809)
Movement in Net Liquid Funds:				
Increase in Bank Overdraft	12,362		3,650	
Decrease/(Increase) in Bank and Cash Balances	3,702		7,159	
		£16,064		£10,809

NOTES FORMING PART OF THE ACCOUNTS FOR THE YEAR ENDED 31st MARCH 1979

1. The accounting policies adopted by the Institution are disclosed, where appropriate, in the notes below.

2. **Income**
The accounting policies adopted by the Institution for treatment of Income are summarized as follows:
(i) *Subscriptions:* this represents amounts received by the Institution in respect of the subscription year to 31st March 1979, together with any arrears of subscriptions collected in the period. Subscriptions received in advance are carried forward as Deferred Revenue to future years.
(ii) *Journal and Publication Sales: Symposia Fees:* these represent amounts receivable in respect of Symposia programmed during the year, and for publications supplied during the year. Journal subscriptions received in advance are carried forward as Deferred Revenue to future years.
(iii) *Dividends and Interest received: Entrance, transfer and exemption fees:* these represent amounts actually received in the year.

3. Extraordinary Items

These items are made up as follows:—

	1979 £	1978 £
Net Loss on disposal of Leasehold property and sale of fixed assets	—	7,812
Net costs arising from relocation of London Office	—	4,286
Net Loss on realisation of Investments	—	774
Provision for deferred repairs	—	(5,000)
	Nil	£7,872

4. Prior Year Adjustments

The adverse balance brought forward at commencement of the year in the statement of General Fund on page 434 (and the comparative figures therefore) has been adjusted for items arising during the year, but relating to events in 1977/78 and previous years.

The details of these adjustments, together with the effect on the General Fund balance brought forward may be summarized as follows:

	1979 £	£	1978 £	£
General Fund Adverse balance brought forward as previously reported		68,169		102,558
Prior Year Adjustments:				
(a) Additional superannuation contribution relating to previous employment of an officer of the Institution during years prior to 1977/78	3,351		3,351	
(b) Correction of assessment of Journal subscriptions received in advance				
relating to 1977/78	3,385		—	
relating to prior years	4,448		4,448	
		11,184		7,797
General Fund adverse balance brought forward as re-stated		£79,353		£110,355

The comparative figures in these Accounts have been amended accordingly.

5. Fixed Assets

The United Kingdom fixed assets of the Institution were revalued by the Secretary, acting on specialist advice, on the basis of market value at 31st December 1977. The surplus so arising was dealt with in the accounts for 1977/78. Subsequent to this revaluation, the Institution does not consider it necessary to provide depreciation on fixed assets other than those located overseas together with U.K. Equipment.

Depreciation is calculated on U.K. equipment and overseas furniture and equipment at rates between 10% and 25% per annum of net book value.

	Furniture and Equipment £	*Library* £	*Total* £
Cost or Valuation			
As at 1st April 1978:			
at Cost	4,719	1,360	6,079
at Valuation	22,000	36,000	58,000
	26,719	37,360	64,079
Additions during the year at Cost	2,089	2,153	4,242
Disposals at Cost	(1,594)	—	(1,594)
As at 31st March 1979	£27,214	£39,513	£66,727
at Cost	5,214	3,513	8,727
at Valuation	22,000	36,000	58,000
Depreciation			
As at 1st April 1978	1,945	—	1,945
Provision for the year	800	—	800
On Disposals	(1,135)	—	(1,135)
As at 31st March 1979	£1,610	—	£1,610
Net Book Values			
As at 31st March 1979	£25,604	£39,513	£65,117
As at 31st March 1978	£24,774	£37,360	£62,134

6. Quoted Investments

Nominal		*Cost* £
£1,000	$7\frac{3}{4}$% Barnet Corporation Loan 1982/84	982
£270	Inchcape & Co. Ltd.—$12\frac{1}{2}$% Unsecured Loan Stock 1982/83.	99
£1,000	Islington Corporation—10% Redeemable Stock 1982/83	995
166	Muirhead Limited—25p Ordinary Shares	262
£1,000	Slough Corporation—$8\frac{3}{4}$% Redeemable Stock 1979/80	990
£521.20	Southern Rhodesia—6% Stock 1978/81	515
£500	Stock Exchange—$7\frac{1}{4}$% Mortgage Debenture Stock 1990/95	485
£1,220	$5\frac{1}{2}$% Treasury Stock 2008/12 (donated)	—
		£4,328

7. Stock of Institution's Publications

Stock of the Institution's publications is stated at the lower of cost and net realizable value.

8. Premises Fund Account

	1979 £	1978 £
Balance 1st April 1978	25,760	17,221
Add:		
Receipts during year—		
Donations	1,684	2,434
Covenanted Subscriptions	4,142	4,639
Interest received on Investment	1,243	1,466
Balance 31st March 1979	£32,829	£25,760

9. Foreign Exchange

Fixed Assets located overseas have been converted to sterling at the rate of exchange ruling when the asset was purchased.

Overseas remittances and receipts during the year have been converted into sterling at the current rates then ruling and the bank and cash balances held overseas at 31st March 1979 at the rate of exchange ruling at that date. Any resulting exchange differences have been included with Bank charges in the Income and Expenditure Account.

AUDITORS' REPORT TO THE MEMBERS OF THE INSTITUTION OF ELECTRONIC AND RADIO ENGINEERS

We have examined the accounts set out on pages 434–436 which have been prepared under the historical cost convention as amended by the valuation of certain assets by the Secretary of the Institution as described in Note 5 to the Accounts.

In our opinion the accounts give, under the basis stated above, a true and fair view of the Institution's affairs at 31st March 1979 and of the deficit and source and application of funds for the year ended on that date, and comply with the Royal Charter and Bye-Laws of the Institution.

50 Bloomsbury Street, London WC1B 3QY

21st June 1979

GLADSTONE, JENKINS & CO.

Chartered Accountants

Reading College of Technology

Board of Governors
Major-General Sir Leonard Atkinson, K.B.E., B.Sc., (*Past President*)

Southall College of Technology

Governing Body
B. S. Pover, (*Member*)

Administrative Committee
A. G. Wray, M.A. (*Fellow*)

South East London College

Engineering Consultative Committee
J. I. Collings, (*Fellow*)

East Ham Technical College

Electrical Engineering Advisory Committee
D. W. Bradfield, B.Sc., (*Member*)

Glasgow College of Technology

Advisory Board
R. D. Pittilo, B.Sc., (*Member*)

City of Gloucester College of Technology

Electrical Engineering Advisory Committee
H. V. Sims, (*Fellow*)

Darlington College of Technology

Electrical Engineering and Science Advisory Committee
R. W. Blouet, (*Member*)

Merton Technical College

Board of Governors
A. A. Kay, (*Fellow*)

City of Nottingham Education Committee

Electrical Engineering Advisory Committee
F. W. Hopwood, (*Member*)

Huddersfield Technical College

Engineering Advisory Committee
R. Barnes, (*Member*)

Stannington College of Further Education, Sheffield

Electrical and Telecommunications Consultative Committee
P. A. Bennett (*Fellow*)

University of Surrey

Court
Sir Ieuan Maddock, C.B., O.B.E., D.Sc., F.R.S., (*Past President*)

Wakefield College of Technology and Arts

Engineering Advisory Committee
M. Holroyd, M.Sc., (*Member*)

University of Wales Institute of Science and Technology

Court
V. J. Phillips, Ph.D., B.Sc., (*Member*)

Watford College of Technology

Engineering Advisory Committee
F. P. Thomson, O.B.E., (*Member*)

Widnes Technical College

Electrical and Instrument Engineering Advisory Committee
D. Chalmers, (*Fellow*)

Appendix 4

Representatives on Joint Committees for the Awards of National Certificates and Diplomas in Engineering

England and Wales

Higher National Certificates and Diplomas in Electrical and Electronic Engineering:

B. F. Gray, B.Sc., (*Fellow*) Chairman
D. L. A. Smith, B.Sc.(Eng) (*Fellow*)
A. Tranter, B.Sc., (*Member*)

Ordinary National Certificates and Diplomas in Engineering:

B. F. Gray, B.Sc.(Eng.) (*Fellow*)

Scotland

National Certificates in Electrical and Electronic Engineering:

D. S. Gordon Ph.D., B.Sc., (*Member*)
D. Dick, D.I.C., (*Fellow*)

Northern Ireland

Higher National Certificates in Electrical and Electronic Engineering:

Captain A. W. Allen, RN (Ret) (*Member*)
J. A. C. Craig, B.Sc., (*Member*)

Appendix 5

Institution Representation on other Educational Bodies

City and Guilds of London Institute

Telecommunication Advisory Committee
B. F. Gray, B.Sc., (*Fellow*)

Joint Advisory Committee for Radio, Television and Electronics
W. B. K. Ellis, B.Sc., (*Member*)

Radio Amateur Examination Advisory Committee
R. G. D. Holmes (*Fellow*)

Advisory Committee on Communication of Technical Information
F. P. Thomson, O.B.E., (*Member*)

Council for National Academic Awards

Electrical and Electronic Engineering Board
A. G. Wray, M.A., (*Fellow*) (*until October 1978*)
C. S. den Brinker, M.Sc. (*Fellow*) (*from October 1978*)

Technician Education Council (TEC)

Programme Committee A2
K. R. Thrower, (*Member*)

London and Home Counties Regional Advisory Council for Technological Education

Advisory Committee on Electrical and Electronic Engineering.
K. J. Coppin, B.Sc., (*Member*)

North Western Advisory Council for Further Education

Specialist Advisory Committee for National Education
A. G. Brown, (*Member*)

Radio Television and Electronics Examination Board

F. O. M. Bennewitz, *(Member)*
W. B. K. Ellis, B.Sc., (*Member*)
N. G. Green, (*Member*)

Scottish Technical Education Council (ScoTEC) Course Committee A2

P. G. Wilks, B.Sc., (*Member*)

Yorkshire Council for Further Education

Engineering County Advisory Committee
F. O. M. Bennewitz, M.Sc., *(Member)*

Welsh Joint Education Committee

Electrical and Electronic Engineering Courses Sub-Committee
I. D. Dodd, B.Sc., (*Member*)

Appendix 6

Members Appointed to Represent the Institution on External Bodies

Royal Society

Committee on Scientific Information
Admiral of the Fleet the Earl Mountbatten of Burma, K.G., F.R.S., (*Honorary Fellow*)

EUREL (Convention of National Societies of Electrical Engineers of Western Europe)

Professor W. Gosling, B.Sc., (*Fellow*)

British National Council for Non-Destructive Testing

A. Nemet, Dr. Ing, (*Fellow*)

British Nuclear Energy Society

R. J. Cox, B.Sc., (*Member*)

International Broadcasting Convention

Management Committee and Programme Committee
P. L. Mothersole, (*Fellow*)
R. S. Roberts, (*Fellow*)

National Council for Quality and Reliability

Brigadier R. Knowles, C.B.E., (*Fellow*)

National Electronics Council

Professor W. A. Gambling, Ph.D., D.Sc., (*Fellow)*

Watt Committee on Energy

M. S. Birkin (*Member*)

Parliamentary and Scientific Committee

Excutive Committee
P. A. Allaway, (*Fellow*)
Air Vice-Marshal S. M. Davidson, C.B.E., (*Fellow)*

British Electrotechnical Approvals Board

R. S. Roberts, (*Fellow*)

Association of Learned and Professional Society Publishers

General Assembly and Council
F. W. Sharp, (*Fellow*)

UK Automatic Control Council

P. Atkinson, B.Sc., (*Member*)
Col. W. Barker, (*Fellow*)
Professor D. R. Towill, M.Sc., (*Fellow*)

UK Liaison Committee for Sciences Allied to Medicine and Biology

J. R. Roberts, (*Graduate*)

Standing Committee of Kindred Societies

Major-General Sir Leonard Atkinson, K.B.E., B.Sc., (*Past President*)

Appendix 7

British Standards Institution Representatives

ECL/– **Electronic Components Standards Committee**
Brig. R. Knowles C.B.E. (*Fellow*)

ECL/5 **Electronic Tubes**
G. R. Jessop, (*Member*)

ECL/5/2 **Electronic Tube Performance General**
G. R. Jessop, (*Member*)

ECL/5/8 **Electro-Optical Devices**
Prof. A. Pugh, B.Sc., Ph.D., (*Fellow*)

ECL/11 **Piezo-Electric Devices for Frequency Control and Selection**
E. Kentley, (*Fellow*)

ECL/12/5 **Microwave Semiconductor Devices**
R. R. Harman, (*Member*)

ECL/12/6 **Diodes, Transistors and Related Semiconductor Devices**
G. Hennessey, (*Member*)

EEL/– **Electronic Equipment Standards Committee**
Brig. R. Knowles C.B.E. (*Fellow*)

EEL/8 **Electronic Measuring Instruments and Associated Equipment**
D. M. Styles, (*Member*)

EEL/8/7 **Electronic Instruments for Voltage Measurement**
D. L. A. Smith, B.Sc., (*Fellow*)

EEL/8/8 **Oscilloscopes**
D. M. Styles, (*Member*)

EEL/23 **Radio-Frequency Radiation-Induced Ignition and Detonation**
Col. F. R. Spragg, B.Sc., (*Fellow*) and D. M. Field, (*Member*)

EEL/24 **Electro-Acoustics**
S. Kelly, (*Fellow*)

EEL/24/1 **Audio Engineering**
S. Kelly, (*Fellow*)

EEL/24/2 **Measuring Devices**
W. V. Richings (*Fellow*)

EEL/24/3 **Ultrasonic Equipment**
W. V. Richings, (*Fellow*)

EEL/24/4 **Performance of High-Fidelity Audio Equipment**
R. S. Roberts, (*Fellow*)

EEL/25 **Radio Communication**
R. Larry, *(Fellow)*

EEL/25/1 **Radio Receiving Equipment**
R. S. Roberts, (*Fellow*)

EEL/25/4 **Aerials**
C. Hale, (*Member*)

EPC/1 **Acoustics**
W. V. Richings, (*Fellow*)

GEL/1 **Terminology**
E. H. Jones, (*Fellow*)

GEL/1/1 **Fundamental Terminology**
E. H. Jones, (*Fellow*)

GEL/1/10 **General Heavy Electrical Terminology**
E. H. Jones, (*Fellow*)

GEL/1/20 **Magnetism Terminology**
E. H. Jones, (*Fellow*)

GEL/4 **Graphical Symbols for Electrical Engineering and Telecommunication**
R. A. Ganderton, (*Member*)

GEL/6 **Reliability and Maintainability**
Brigadier R. Knowles C.B.E., (*Fellow*)

GEL/111 **Electromagnetic Interference**
M. A. Burchall, (*Fellow*)

LEL/103/–/4 **Safety**
A. J. Huelin, (*Member*)

LEL/103/–/5 **Installations**
A. J. Huelin, (*Member*)

LEL/103/2 **Electromedical Equipment**
A. J. Huelin (*Member*)

MEE/158 **Mechanical Vibration and Shock**
W. V. Richings, (*Fellow*)

MEE/158/2 **Vibration and Shock Measuring Instruments and Testing Equipment**
W. V. Richings, (*Fellow*)

MEE/158/6 **Balancing, Including Balancing Machines**
W. V. Richings, (*Fellow*)

NSS/5/6 **Audio-aids (School Music)**
M. H. Evans, (*Member*)

PEL/50 **Static Power Converter Equipments**
M. A. Burchall, *(Fellow)*

QMS/3/4 **Maintenance**
Brig R. W. A. Lonsdale, B.Sc., (*Fellow*) and L. A. Bonvini, (*Fellow*)

Appendix 8

Award of Institution Premiums for 1978

MAIN PREMIUMS

CLERK MAXWELL PREMIUM *Value £75*
'Switching phenomena in metal-insulator-n/p structures: theory, experiment and applications'
Professor J. G. Simmons and A. A. El-Badry (University of Toronto)
(Published in the May 1978 issue of the Journal)

HEINRICH HERTZ PREMIUM *Value £50*
'Design of stepped microstrip components'
G. Kompa (Endress & Hauser)
(Published in the January/February 1978 issue of the Journal)

MARCONI PREMIUM *Value £50*
'Two-bit instantaneously adaptive delta modulation for p.c.m. encoding'
F. T. Sakane and R. Steele (University of Technology, Loughborough)
(Published in the April 1978 issue of the Journal)

GENERAL PREMIUMS

LESLIE McMICHAEL PREMIUM *Value £25*
Patent law reform'
E. E. Barnard
(Published in the May 1978 issue of the Journal)

SIR J. C. BOSE PREMIUM *Value £25*
'Intelligible voice communication through adaptive delta modulation at bit-rates lower than 10 kbit/s'
T. S. Lamba and Professor M. N. Faruqui (Indian Institute of Technology)
(Published in the April 1978 issue of the Journal)

SPECIALIZED TECHNICAL PREMIUMS

LORD BRABAZON PREMIUM *Value £25*
'A broadband experimental null-steering antenna system for mobile communications'
Professor D. E. N. Davies and Mrs M. S. A. Rizk (University College, London)
(Published in the October 1978 issue of the Journal)

REDIFFUSION TELEVISION PREMIUM *Value £50*
'Assessing the circuit reliability of an h.f. sky-wave air ground link'
N. M. Maslin (Royal Aircraft Establishment, Farnborough)
(Published in the October 1978 issue of the Journal)

DR NORMAN PARTRIDGE PREMIUM *Value £25*
'Approximants in sinewave generation and synthesis'
V. Schiffer (Wandel & Goltermann) and W. A. Evans (University College of Swansea)
(Published in the March 1978 issue of the Journal)

J. LANGHAM THOMPSON PREMIUM *Value £50*
'Computer-aided design tracking systems'
Cdr M. J. Ashworth, RN (RNEC) and Professor D. R. Towill (UWIST)
(Published in the October 1978 issue of the Journal)

ARTHUR GAY PREMIUM *Value £25*
'Ageing tests on microwave integrated circuits'
W. Goedbloed (ELCOMA Eindhoven), H. Hieber (Philips, Hamburg) and A. G. van Nie (Philips Research Laboratories, Eindhoven)
(Published in the January/February 1978 issue of the Journal)

Papers of sufficiently high standard were not published within the terms of the following Premiums and they are withheld:

Charles Babbage Premium (Computers)
A. F. Bulgin Premium (Components or circuits)
Lord Rutherford Premium (Nuclear physics or engineering)
P. Perring Thoms Premium (Radio or television reception)
Sir Charles Wheatstone Premium (Instrumentation or measurement)
Dr V. K. Zworykin Premium (Medical and biological electronics)
Admiral Sir Henry Jackson Premium (History of radio or electronics)
Eric Zepler Premium (Education)
Hugh Brennan Premium (North Eastern Section Paper)
Local Sections Premium

Applicants for Election and Transfer

THE MEMBERSHIP COMMITTEE at meetings on 9th July and 7th August 1979 recommended to the Council the election and transfer of the following candidates. In accordance with Bye-law 23, the Council has directed that the names of the following candidates shall be published under the grade of membership to which election or transfer is proposed by the Council. Any communication from Corporate Members concerning the proposed elections must be addressed by letter to the Secretary within twenty-eight days after publication of these details.

July Meeting (Membership Approval List No. 261)

GREAT BRITAIN AND IRELAND

CORPORATE MEMBERS

Transfer from Member to Fellow

TURNER, Alan. *Hucknall, Nottinghamshire*

Direct Election to Fellow

WOLFENDALE, Peter Caleb F. *Milton Keynes, Bucks.*

Transfer from Graduate to Member

ASHLEY, Stephen David. *Walsall, Staffs.*
JONES, John Morlais. *Swansea.*
YOUNG, Alastair Stirling. *Edinburgh.*

Transfer from Associate to Member

EVANS, Michael John. *Christchurch, Dorset.*

Direct Election to Member

CLARKE, Donald Ian. *Reading, Berks.*
COOPER, John Yarrow. *Whitley Bay.*
COXON, Ronald John. *Hucknall, Nottinghamshire.*
JOHNSON, Malcolm Arthur. *Porthcawl, Mid Glamorgan.*
WHITTAKER, Alan Joseph. *Broadsall Hilltop, Derby.*

NON-CORPORATE MEMBERS

Direct Election to Graduate

RISHWORTH, Alan Ralph. *Esher, Surrey.*

Direct Election to Associate Member

FORD, Anna Stella T. *Wells, Somerset.*
GILL, David John. *Bath, Avon.*
MIDDLETON, John Dunbar. *Skelmorlie, Ayrshire.*
MILLAR, David Robert G. *Stevenage, Herts.*
UDOH, Sunday. *London.*

Direct Election to Student

OLDROYD, James Roland. *Harlow, Essex.*

OVERSEAS

CORPORATE MEMBERS

Transfer from Graduate to Member

McCARTHY, Frank James. *Wellington, New Zealand.*

Transfer from Student to Graduate

CHAN, Wai Ming Francis. *Hong Kong.*

Direct Election to Associate Member

BURNS, James Bernard. *Bielefeld, W. Germany.*
LIU, Yat Wing. *Hong Kong.*
OGUNKOMAIYA, Samuel O. *Kano, Nigeria.*

Direct Election to Associate

SIU, Chi Ngai. *Hong Kong.*

Direct Election to Student

ANG, Koh Leng. *Singapore.*
AU IEONG, Iu Kong. *Hong Kong.*
AU YEUNG, Yee Lung. *Kowloon, Hong Kong.*
CHAN, Kam Fai. *Kowloon, Hong Kong.*
CHAN, Sze Man. *Kowloon, Hong Kong.*
CHAN, Wai Mou. *Kowloon, Hong Kong*
CHEUNG, Wai Chung. *Kowloon, Hong Kong.*
CHEONG, Siew Khoon. *Melaka, Malaysia.*
CHEUNG, Man Sik. *Wanchai, Hong Kong.*
CHOI, Po Man Anthony. *Kowloon, Kong Kong.*
HUNG, Sing Tak Patrick. *Kowloon, Hong Kong.*
KUNG, Chi Kin. *Kennedy Town, Hong Kong.*
LAI, Chung Fai. *Kowloon, Hong Kong.*
LAM, Chiu Wah. *Kennedy Town, Hong Kong.*
LAM, Tak Ming. *Kowloon, Hong Kong.*
LAU, Kin Tong. *Hong Kong.*
LEE, Ka Yiu. *Sheung Shui, Hong Kong.*
LEE, Kwong Fai S. Kowloon, Hong Kong.
LEUNG, Kwok Hung. *Kowloon, Hong Kong.*
LIM, Jiow Yong. *Singapore.*
LUK, Wing Hong. *Kowloon, Hong Kong.*
LUNG, Wing Kwong. *Kowloon, Hong Kong.*
MAK, Chu Leung. *Kowloon, Hong Kong.*
PERERA, Bulathge A. R. *Boralesgamuwa, Sri Lanka.*
PUN, Kong Yee. *North Point, Hong Kong.*
THAN, Siew Beng. *Kuala Lumpur, Malaysia.*
THARUMALINGAM, Anton Jayarajan. *Colombo, Sri Lanka.*
WAN, Tak Wai David. *Kowloon, Hong Kong.*
WONG, Chan Shun. *Causeway Bay, Hong Kong.*
WONG, Cherk Wai. *Kowloon, Hong Kong.*
WONG, Ching Kit. *Kowloon, Hong Kong.*
WONG, Ho Ching. *Hong Kong.*
WONG, Ting Fuk. *Kowloon, Hong Kong.*
WONG, Yiu Kwan. *Kowloon, Hong Kong.*
YIU, Yu Wo. *Yuen Long, Hong Kong.*
YUEN, Weng Soon. *Singapore.*

August Meeting (Membership Approval List No. 262)

GREAT BRITAIN AND IRELAND

CORPORATE MEMBERS

Transfer from Member to Fellow

CHORLEY, Francis Kenneth. *London.*
STARK, John Wilson. *Northwood, Middlesex.*

Transfer from Graduate to Fellow

PENERY, Michael Thomas. *Shepton Mallet, Somerset.*

Transfer from Graduate to Member

TANNER, Robert. *Portsmouth, Hants.*

Direct Election to Member

GARNER, Neil. *Maidenhead, Berks.*
MUNCEY, Graham Ronald. *Horley, Surrey.*
NEAL, Robert Anthony. *North Harrow, Middlesex.*
REYNOLDS, Michael. *Chesterfield, Derbyshire.*

NON-CORPORATE MEMBERS

Direct Election to Graduate

VASSIE, Charles Kenneth. *Johnstone, Renfrewshire.*
WHITE, Kevin Paul. *Brighton, East Sussex.*

Direct Election to Associate Member

BOWYER, Mark Moncrieff. *Fareham, Hants.*
DUNN, David Kenneth. *Colgrain, Helensburgh, Dunbartonshire.*
KANE, Joseph William. *Enniscorthy, Co. Wexford.*

Direct Election to Student

BARNES, Michael Andrew Durent. *Cottingham, North Humberside.*
BLACK, George Fraser. *Hull.*
D'ROZARIO, Andrew Mervyn. *Hull.*
FAULKNER, Lawrence Samuel. *Cottingham, North Humberside.*
FINCH, Robert John. *Rotherham, South Yorkshire.*
GLOVER, Paul Martin. *Hull.*
HAIGH, Robert. *Bradford, West Yorkshire.*
HARRIS, Beverley. *Hull.*
LI, Tak Fai. *Scarborough, North Yorkshire.*
MILLER, Peter John. *Hull.*
NORONMA, Anthony Victor. *London.*
SEYMOUR, Colin Julian. *Charlbury, Oxfordshire.*
WILKINSON, Antony James. *Richmond, North Yorkshire.*
WINTER, David Edward. *Washington, Tyne & Wear.*

OVERSEAS

NON-CORPORATE MEMBERS

Transfer from Associate Member to Graduate

MBELU, Bennett Oduche. *Ikeja, Lagos, Nigeria.*

Direct Election to Graduate

LEE, Par Nan. *Singapore.*

Direct Election to Associate Member

CHAN, Shiu-Chuan Stephen. *Kowloon, Hong Kong.*
LIM, Joo Leong. *Teheran, Iran.*

Direct Election to Student

CHIN, Seong Kong. *Kuala Lumpur, Malaysia.*
CHU, Kok Onn. *Singapore.*
FONG, Kwok Cheong. *Hong Kong.*
HA, Wing Chiu Danny. *Hong Kong.*
HO, Lih Suan. *Singapore.*
KOH, Sun Yew. *Singapore*
LEE, Wah Ching. *Hong Kong.*
NG, Choon Howe. *Singapore.*
NGAI, Chee Kin. *Kuala Lumpur, Malaysia.*
RODRIGO, Viraka S.K.S. *Colombo, Sri Lanka.*
TEO, Jin Hwa. *Kelang, Selangor, Malaysia.*
TSO, Fu Keung. *North Point, Hong Kong.*
WONG, Shu To. *Kowloon, Hong Kong.*

Appendix 1

Membership of the Council and its Committees as at 31st March 1979

COUNCIL OF THE INSTITUTION

President:
D. W. Heightman, (*Fellow*)

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H.R.H. The Duke of Kent, G.C.M.G., G.C.V.O., (*Fellow*)
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I. D. Dodd B.Sc., (*Fellow*)*
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C. J. Lilly, (*Member*)
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Professor C. W. Miller, D.Sc., (*Fellow*)*
W. D. Oxenham, M.A., (*Member*)*
A. D. Patterson, B.A., (*Member*)*
P. A. S. Prance, (*Member*)*
Major-General H. E. Roper, C.B., B.Sc.(Eng)., (*Fellow*)
D. L. A. Smith, B.Sc.(Eng) (*Fellow*)
T. Thomas, (*Member*)*
Group Captain J. M. Walker, R.A.F., (*Member*)
L. C. Walters, M.A., (*Member*)*

*Chairman of a Local Section in the UK.

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S. R. Wilkins *(Fellow)*

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H. E. Drew, C.B., C.G.I.A., (*Fellow*)
Professor W. Gosling, B.Sc., (*Fellow*)
R. C. Hills, B.Sc., (*Fellow*)
Brigadier R. W. A. Lonsdale, B.Sc., (*Fellow*)
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Appendix 2

Representatives of the Institution on the Board and Committees of the Council of Engineering Institution

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Professor W. Gosling, B.Sc., (*Fellow*) (*Alternate*)

Standing Committee B

J. Powell, M.Sc., (*Fellow*)

Standing Committee C

S. J. H. Stevens, (*Fellow*)

CEI-CSTI Joint Affairs Committee

To be appointed

Council for Environmental Science and Engineering

Professor H. M. Barlow, Ph.D., F.R.S., (*Fellow*)

British National Committee on Ocean Engineering

M. J. Tucker, B.Sc., (*Member*)

Committee on Health and Safety

Colonel F. R. Spragg, B.Sc., (*Fellow*)

Engineers Registration Board

Chartered Engineers Section Board
Group Captain J. M. Walker, R.A.F., (*Member*)

Sub-committee on Training and Experience
D. L. A. Smith, B.Sc.(Eng) (*Fellow*)

Technician Engineering Section Board, Supervisory Committee and Joint Membership Committee
K. J. Coppin, B.Sc., (*Member*)

Joint Qualifications Committee
Brigadier R. W. A. Lonsdale, B.Sc., (*Fellow*) Chairman

Appendix 3

Institution Representation at Universities, Polytechnics and Colleges

University of Aston in Birmingham

Convocation
Professor D. G. Tucker, D.Sc., Ph.D, (*Fellow*)

Barnsley College of Technology

Engineering Advisory Committee
To be appointed

University of Bradford

Court
P. J. Gallagher, M.Sc., Ph.D., (*Member*)

University of Nottingham

Court
Air Vice-Marshal S. M. Davidson, C.B.E., (*Fellow*)

General Interest Paper

The Importance of Standards in Broadcasting

A. N. THIELE, B.E., F.I.E.Aust., F.I.R.E.E.Aust.

Although the author is looking mainly at the Australian scene, many of his points have relevance for broadcasting engineers everywhere and will be of interest to most engineers, if only in their capacity of viewers and listeners. This paper was originally presented at a seminar on 'The Importance of Standards in the Electrical Industry' conducted by the Electrical Development Association of N.S.W. at Sydney in June 1978. An abridged version of the paper appeared in the *ABU Technical Review*, Issue 60, January 1979.

Introduction

Many people think of engineering standards as a dull business, essential perhaps, but dull. Now anyone who has worked on standards will realize that such work, in fact, is anything but dull. It demands first of all a full understanding of the technology involved, its production in the factory and its use by the consumer, an understanding of what is on the one hand desirable and on the other technically and economically feasible. On top of that, it demands on some occasions a degree of shrewdness to look beneath the surface and judge whether the arguments being put up are for the benefit of the community as a whole or for a particular sectional interest.

Like any rule of law, standards limit freedom in some respects, in the interest of greater freedom or convenience, amenity or cost saving, for the populace at large. On the other hand, the certainty that standards provide can sometimes imply some rigidity, some resistance to change, or at least inertia against change. This is something that makers of standards are always on their guard against. It is especially a problem in a technology that is new, or undergoing rapid change, as for example in the recent history of video cassettes. Then those setting or administering standards have to tread a wary path between, on the one hand, setting standards too early and too inflexibly, thereby inhibiting further development, and on the other hand, waiting too long until a whole range of concepts has proliferated, each a little different from the other. Then either standardization becomes impossible or a multiplicity of 'standards' is legitimized that destroys much of the meaning and the advantage of standardization.

The Australian Broadcasting Commission does not set standards itself. However, we are concerned, vitally, with standards, because of our interests in the exchange of broadcasting material, both inside Australia and internationally, and because the channel of communication between our makers of programmes and our customer, the listener, includes not only the cameras, microphones and studios which are under our own control, but other important segments, the links and transmitters provided by Telecom* and most importantly, the domestic receivers, which are not. We are therefore concerned to have representatives on the various committees of the organizations responsible for standards, of which the Engineering Division of the Post and Telecommunication (P&T) Department, previously the Australian Broadcasting Control Board, sets the standards for broadcasters and the broadcasting system generally, while the Standards Association of Australia (SAA) sets the standards for consumer products.

It would be comforting to believe that standards in broadcasting are always the result of wise decisions based on sober, ordered thought. This, of course, is not always so. Standards in broadcasting, like all human attempts at order or law, represent the outcome of innumerable battles, some small, some bigger, between opposing interests. And this applies not only to the standards that have been made, but equally to the standards that have not been made, in fields where many feel that standardization should apply for the common good, but where the present state is still *laissez-faire* or even anarchy.

Engineers like to describe themselves as practical people, but in fact practicality is not really a quality of a person or of a piece of engineering. It is a simply a quality of survival. Thus Brunel's 7 foot broad railway gauge performed magnificently in its time, but it has not survived; therefore for our purposes it has not proved practical. Consider, on the other hand, the four-head videotape machine that writes and reads the video signal at high speed on a slow-moving tape by means of four tiny heads mounted around the edge of a disk. As the disk whirls, the heads scan the tape at high speed almost at right angles to its motion. This elaborate mechanical device can only be made to work by associating with it great quantities of electronics, switching, demodulating, processing and correcting the imperfect signal that comes out of it. By any standards it is a mechanical and electronic monstrosity. But practical, of course, because, at least until recently, no other method of video recording can achieve such fine results.

Television Standards

Let us consider how we are affected by standards in television broadcasting. In Australia television is on the 625-line standard used now throughout the world, apart from the 525-line system of the United States and a number of countries in the Americas and Asia, e.g. Japan, whose development was strongly influenced by the US. Apart from these, the British

After war service in the Australian Signals **Neville Thiele** graduated from Sydney University in 1951 and joined EMI Australia as a development engineer. He first worked on telemetry design, and in 1955 spent six months at Hayes, Middlesex, and in Europe and the US studying the design of television receivers. Returning to Australia he headed a team designing EMI's Australian television receivers. In 1957 he was appointed Advanced Development Engineer working on television, radio, electro-acoustics and test equipment.

In 1962 Mr Thiele joined the Australian Broadcasting Commission and was for a number of years Senior Engineer in the Federal Engineering Laboratory, responsible for design and investigation of equipment and systems for radio and television broadcasting. He was recently appointed Assistant Director Engineering N.S.W. (TV).

Mr Thiele has served on the Council and various committees of the IREE Australia, and was Deputy President in 1972. He has served on committees which advised the Australian government on standards for the introduction of colour television in 1975, and on the Standards Association of Australia's Committees on Electro-Acoustics. He has published more than twenty papers on electro-acoustics, television and filters.

* Telecom Australia is the Australian Government's telecommunications authority.

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405-line system, which was most courageous and forward-looking when it started in 1935, and the French 819-line system, which was again in its own way courageous and forward-looking in the fifties and sixties, are now obsolescent.

The field rates, that is, the rate at which the interlaced halves of the television pictures are presented, were set at the mains frequencies of 50 Hz and 60 Hz in Europe and the United States respectively. These were based on the belief, open to doubt from my experience, that mains interference would otherwise produce horizontal bars moving up or down the screen. Nevertheless, the standards were set in this manner and have had two interesting side effects.

Firstly, the region of 50 to 60 Hz is critical for the perception of flicker. As a result, television receivers on the American 60-field system can be run at much higher screen brightnesses before excessive flicker annoys the viewer.

Secondly, the standard rate for cinema projection is 24 pictures a second. Thus television projectors, telecines, in the American system need fairly elaborate equipment to produce five television frames from every four film frames, or 30 from every 24. But in the 50 field systems, the film is, quite universally, simply run faster through the projector, so that the film that was recorded at 24 frames a second is shown to the viewers at 25 frames a second, i.e. 4% faster. This avoids technical complications, but makes all movements unnaturally fast and all voice pitches unnaturally high. Four percent may not sound much but it is easily perceived. Experiments have shown that not everyone is annoyed. Nevertheless, it produces for many an unpleasant effect on voice quality and on realism generally. Besides, broadcasters thereby lose 4% air time from a given investment in film.

These are some respects in which our television standards are somewhat less than optimum, but which we have learned to accept with a more or less good grace.

Colour Television Standards

In early experiments with colour, both the Americans and the Russians flirted with frame-sequential systems, but the first really working colour came from the American NTSC system, which minimized bandwith requirements by matching the transmitted signal to known properties of the human eye and brain, and by modulating two additional but narrower bandwith signals on to two sub-carriers high in the video band, at the same frequency but in phase quadrature with each other. The intention was that this extra information could be added without any degradation of the monochrome picture. In practice, however, the definition of the monochrome viewer's picture is reduced somewhat, but this loss is offset to some extent by the improved monochrome performance of the new generation of colour equipment. And the colour viewer, of course, gains all the extra visual information and stimulation that colour brings.

But however good the equipment at the transmitting end and at receiving end, NTSC colour often suffers in its propagation through space between the transmitting and receiving aerials. In particular, ghosts on NTSC signals produce a shift of hue. An edging of foreign colour is bad enough, but with long ghosts, large areas of the received picture can be affected.

To overcome these difficulties, a French group under Henri de France tried frequency modulating the one high-frequency sub-carrier, the two colouring signals being set alternately on successive lines. To provide the two pieces of colouring information on each line at the receiver's cathode-ray tube, they provided a delay line just one line, 64 microseconds, long so that if, for example, we start with a line where the red difference signal is being sent, then during the next line, while the blue difference signal is being sent, the cathode-ray tube obtains its red difference signal by repeating the earlier red signal one line later from the delay line, then similarly the blue signal during the next line, and so on. As a result the vertical colour definition is halved, but the eye is not concerned with fine colour detail. The horizontal colour definition has been more than halved already, by bandwith limitation of the colouring signals.

However, the whole scheme depended on a delay line of considerable length being available at a feasible price, which in the late fifties, from the distance of Australia, anyway, seemed quite visionary and impractical. Of course, it is history now that the delay line *was* produced commercially and that after a number of vicissitudes requiring several modifications, the system became a working entity in France, and later was adopted in Russia and Eastern Europe. The system is of course the SECAM system, named from 'SEquenCe A Memoire', meaning that the red and blue colouring information is presented in sequence with a memory.

I believe that this development of a technically and commercially feasible delay line is a triumphant example of the way that technology, that is, technologists, their managements and their industries, can rise to a very stiff challenge if a need is truly seen, and I present it as a warning to these setting standards not to write off any scheme too easily as 'hare-brained' or 'far-fetched'.

In Germany, in the meantime, Dr Walter Bruch of Telefunken was experimenting with another new colour system, or rather one considered and passed over in the earlier NTSC investigations, in which both colouring signals are sent on each line but with the subcarrier phase of one of them reversed on alternate lines. The PAL acronym of this system stands for Phase Alternation by Line. In the original simple PAL system, phase errors on alternate lines were to be averaged out in the viewer's eye. This worked reasonably up to a point but it was soon found that larger errors could be tolerated, and the system became much more rugged, if the colouring information on each line was averaged electrically with that on its predecessor, using a SECAM delay line. By such a tortuous path we arrived at our present PAL-D or delay line PAL standard that converts false colour in ghosts simply to less colour, and has proven rugged and generally successful in practice.

Standards Converters

Thus there are in the world today three major system standards of colour television, which we can call in short form PAL-625, SECAM-625 and NTSC-525, and any program originating in one standard that needs to be seen in another must be transcoded, translated or, in the language of broadcasting, 'standards converted'.

In earlier times, the monochrome standards converters consisted virtually of picture monitors with cameras pointed at them, with some special additional circuitry. Their quality was poor and they were rather expensive. In present day standards converters, the analogue signal is coded into a train of digital pulses, and all the processing is done digitally, so that in some respects the outgoing signal is better than the signal incoming, as the noise is reduced by a digital comb filter. Then at the end, the digital signal is decoded back to analogue video at the new standards. The results are very good, little worse than, and in some ways better than the original, but the cost is enormous, leaving little change out of a quarter of a million dollars. This cost, multiplied by the number of studio centres throughout the world that handle international television, is just one of the more dramatic and obvious illustrations of the cost of non-standardization, or at least splintered standards, in television.

Contrast Gradient

However, there are far more parameters that need standardizing in television. An interesting example of strange standards, or non-standards, or even non-standards masquerading as standards, concerns the contrast gradient of the picture that is usually called 'gamma', the Greek letter γ used as the exponent of the contrast law. The brightness of the picture on the face of a cathode-ray tube, a picture tube, is controlled by the voltage between its grid and its cathode. This relationship is not linear. That is, if so many volts produces so much current, then twice as many volts will *not* produce twice as much current but rather an amount of current 2^{γ} times as great, where the exponent γ has a value variously estimated between 2·2 and 2·8. In our colour system we take the standard gamma as 2·5, so that twice as much input voltage would produce $2^{2\cdot5}$ or 5·6 times as much current.

This non-linearity is made good by a reciprocal gamma at the sending end. Thus in the camera, the relationship between the brightness on the scene and the voltage transmitted is 1/2·5 or 0·4, and if so much brightness produces so much output volts, then twice as much brightness produces $2^{0\cdot4}$ or 1·32 times the output volts. With the advent of colour this became properly specified, but for the eighteen years of monochrome before that, we followed the American specification for the transmitter that 'output varies in an inverse logarithmic relation to the brightness of the scene'. But with no number specified for the exponent (gamma), that law could be anything. With a gamma of 1, for example, the law would be linear, and so on. It is, in fact, a masterpiece of saying nothing in a highly technical manner, and a cautionary tale for all setters of standards.

Standards in Television Receivers

In Australia, and as far as I am aware everywhere else, standards in broadcasting apply to broadcasters but not in any mandatory way to manufacturers of receivers. The reasons usually given are that broadcasters have a much lower cost of equipment per listener, have supervision and much more skilled maintenance staff. Manufacturers on the other hand have to operate in a competitive market. No restrictions should be placed on a manufacturer, so the argument goes, which could put him at a competitive disadvantage. In any case, the consumer in the open market will sort the good from the bad.

Now some of these arguments are true, but some are quite fallacious. Broadcasters *are* in a better position to maintain high standards than receiver manufacturers. Because of this, a high proportion of the distortion in the Australian television standards is allotted to the receiver and only a small proportion to the broadcaster. And because of the great number of units through which a signal passes on its way through a studio and the great variety of permutations in which they can be connected, only a small fraction of this low distortion can be allotted to each unit in the studio.

But broadcasters, like manufacturers, are in competition with each other, and are under the same pressures as manufacturers to cut costs, either to ensure profits or to keep up their standard of service in spite of financial deprivation. A requirement that everyone must achieve a certain minimum standard of performance allows everyone to go ahead and do it without fear of being at a competitive disadvantage against the less scrupulous. The history of technology abounds with cases of needs, once identified, being met at a low cost, as with the SECAM and PAL delay lines.

As for the argument that we safely leave the free market to winnow the good from the bad, it hardly needs emphasis that in our present state of limited choice for a comparatively few mass-produced products, the consumer's freedom of action is limited indeed. Even then, the few manufacturers tend to mindlessly follow the leader and regiment themselves into the one fashionable groove. External design provides obvious examples, such as the universal rounded 'whale' look for motor cars and refrigerators in the fifties, followed by the 'slim line'. Or the present 'military' look for radios, or vertically-loading cassette recorders. But electronic design tends to follow fashion similarly. Advertising, secure in its own cloud-cuckoo land, is of no help to the consumer either. Thus standards carefully set and policed seem the best hope for consumer and conscientious manufacturer alike.

Yet, while a strong case can be made for standards in television receivers, one must also appreciate the considerable problems that a committee charged with such a responsibility would have to overcome, ensuring that the parameters specified are ones that really concern the consumer, setting realistic specifications, with tolerances neither too wide nor too narrow, and approving test methods that can assess some hard-to-measure parameters to an agreed accuracy. The following examples can illustrate the kind of problems involved.

Video Signal Coupling

Monochrome receivers are now only a small part of the market; nevertheless a design decision illustrates an important principle, that a feature of a receiver can be important, even though fashion says it is not. When television started in Australia twenty-two years ago, one problem that faced a designer was whether a television receiver should incorporate full d.c.-coupling of the video signal to the picture tube. Without d.c.-coupling, the blacks of the picture would not be truly black but a toneless grey. Full d.c.-coupling was not difficult to provide and the need seemed obvious enough. Yet most overseas receivers did not incorporate it. Their a.c.-coupling ensured that when a picture went to black at the studio, the receiver went a bright grey. Besides, they were hard to adjust properly. If they were adjusted for good reproduction of a low contrast scene, then all following higher-contrast scenes were over-contrasted, with staring streaky whites and blacker than blacks. My team decided for full d.c.-coupling, yet as I remember, ours was the only receiver that used it. Most other Australian receivers were a.c.-coupled, a few had partial d.c.-coupling. We were sure the advantages were obvious. The only real disadvantage was that our demand for e.h.t. current varied widely, going down to very small values on dark scenes, and up to quite high values on a nearly all-white caption, compared with the more nearly constant demand of an a.c.-coupled set. Thus in those days before the advent of cheap e.h.t. regulators, our raster size changed with picture content rather more than others did, not greatly but rather more. We obviously produced a better picture, yet in discussions with our competitors they insisted that the public preferred a.c.-coupling 'because if they didn't, the sets wouldn't sell'. Les Free, then chief engineer of TCN, gave a lecture to the IREE on 'The Importance of the D.C. Component', including a demonstration with three receivers side by side identical except for the coupling—d.c., partial, and a.c. The superiority of d.c.-coupling was clear again, yet our sales people still wanted us to conform to the prevailing fashion. We were told by our suppliers of valves that the e.h.t. current was probably higher, lowering the life of valves in the line deflection system. This again was shown to be untrue. It was a continuing battle.

Yet now with colour, all receivers are clamped to give full d.c.-coupling. Everyone agrees that it gives the best results. Around 1960 a letter to *Wireless World* asked why British receivers were not made by law to include d.c.-coupling 'as they are in Australia'. If only it were true. Even non-mandatory standards would have helped.

Colorimetry

The second example concerns the colorimetry of the picture tube, which is different in PAL countries from NTSC countries. Many Japanese receivers sold in Australia in the early days of colour used NTSC phosphors without any apparent adjustment of relative drive to the three guns. That problem seems to be decreasing now. Yet an early insistence on a standard for receivers would have saved a number of viewers from dissatisfaction.

One must confess, of course, that broadcasters are not free from fault in poor colorimetry. This has proved a most intractable problem in colour television, especially in news programmes, where films with colour differing widely not only from technical considerations but from differences in the ambient lighting, are shown one after the other. The problem is doubly severe, since a single scene with poor colour, shown between two good ones, shocks the viewer twice, on the transition into the poor scene, and on the transition out of it.

Objective Tests

One should always beware of the ploy that objective tests are not really necessary, that if a piece of television equipment, a receiver for example, produces a good picture with a good signal into it, the equipment must therefore be beyond reproach. Unfortunately, there is a feature of human perception that can be described as a 'threshold of visual impairment'. Because of this, a picture can become impaired to a considerable extent before that becomes noticeable. In the K rating method used in studios, a K factor of around 5% causes barely perceptible impairment. However, once the threshold is passed, the perceived impairment worsens rapidly. Thus if we have two equipments, each with a K factor of 5%, then when either is included alone in a circuit carrying an ideal signal, barely perceptible impairment will be seen. But if the two devices were both connected together in the one circuit, so that the K factor increased to 10%, or more likely, adding by a 1·5 power law, to 8%, the impairment would become quite noticeable. This is no academic exercise. There were several dire examples in the earlier days of television, due in one case to a combination of a particular transmitter and a particular make of receiver, and in another to a telerecorder and a telecine, whose results individually were fair but in tandem were intolerable.

Tuner Radiation

A final example of the need for and the problems of standardization in this field concerns oscillator radiation from television tuners. At present, radiation of the local oscillator signal generated in the tuner makes it impossible to use in the one area any pair of channels that are separated by approximately the Australian standard i.f. of 36·875 MHz. Present Australian frequency allocations contain several such pairs of channels. In this case a standard for tuner radiation *has* been set, corresponding to overseas practice, but it appears that a still tighter standard will be needed before the pairs of channels can be used. This would almost certainly add to the cost of every new receiver. The questions must therefore be determined: how much would it cost, and then how much more can a purchaser be reasonably asked to pay for a new receiver, to avoid polluting the r.f. spectrum, which is a common, and limited, resource for all?

Sound in Television

Before discussing standards in radio broadcasting, one must ask why the quality of sound reproduced by television receivers is not good, generally only fair. The most usual answer is that 'Sound is not so important; television is, after all, a visual medium'. Yet it is a matter of common experience that the thread of a programme can usually be followed through the sound if the picture fails, whereas the picture becomes almost meaningless if the sound fails. Some part of the blame must be laid at the door of the broadcasters. It is comparatively difficult to keep a microphone close to the performer while keeping it out of camera range. Alternatively, small lapel microphones can be used, but clipped to a lapel they cannot pick up well the upper partials of speech, and they pick up too much low frequency information from the chest. They are therefore equalized internally, in what must be a rough and ready manner, to flatten the response under 'average' conditions. And in any case poor sound can always be excused with 'Oh, well, the receivers won't do it justice anyway'.

In addition, some optical sound tracks on film, particularly the 16 mm copies usually used in Australia, are mediocre for distortion and are limited in response to around 8 kHz. But a surprising amount of film sound, particularly locally produced material, comes in fact from magnetic sound tracks of good quality.

Nevertheless, in spite of these notable exceptions, television sound, radiated through its f.m. transmitter, is generally of high quality. But the receivers, all too often, do not do the sound justice. Ineffective low-frequency response due either to inadequate baffling or to deficiencies in the loudspeaker itself, ineffective high-frequency response sometimes disguised by a peak in the mid-highs, inadequate power output, sometimes frame buzz from the intercarrier sound, all these deficiencies are met quite often, yet they can be rectified in the basic design at quite small expense if the will is there. Without minimizing the practical difficulties, these could well be a worthwhile subject for minimum standards.

Standards in Radio Broadcasting

It is tempting to think of radio broadcasting as two separate entities, first the kind of radio that provides the continuing presence, the audio wall paper, and then the other kind that often seems to be the only vehicle for surprise and delight or any continuity of intelligent content in the electronic media, the poor relation of television yet much more rewarding of attention. Yet both kinds of radio are all too often considered as one entity. They are certainly considered so at present for the purposes of standards, except for a separation into a.m. and f.m. stereo.

Nearly everyone knows that amplitude modulation (a.m.) radio is a poor quality medium for broadcasting. And in that nearly everyone is quite wrong. Given the same sort of respect as television or f.m., namely a suitable receiving aerial, a tuner with a low-noise front end and a comparatively inexpensive wide-band i.f. and a transmitter of reasonable noise performance, whose limiting amplifier affects only the top three or four dB and the odd overload, it is a good-quality medium, not superlative perhaps, but very good nevertheless, especially for metropolitan listening. Yet in spite of this, it has certainly earned over the years a reputation for very poor quality.

Limiting Amplifiers

The standards laid down for radio broadcasting stations in matters like frequency response and distortion are quite high, but in one aspect of their operation no standards are laid down at all. That concerns the use of limiting amplifiers. It is necessary in any communication channel to keep the signal levels between two extremes, and every communication channel has an upper limit beyond which the level cannot go without distress, either through an electronic amplifier distorting or through tearing an unaided voice to ribbons. At the lower end, one must not drop below the ambient noise, which in radio might be set by tape hiss or by atmospherics, or in a public meeting by the noise of air conditioning or the person in the next seat snoring. These limits are a basic and immutable fact of all communication. Failure to remember and stay within these limits is poor communication.

When a programme is being built up with sounds from a variety of sources at a variety of levels, the control of level is a vital part of audio production, for radio, television, films or disks. This is almost always done best aesthetically by a human operator, but it soon becomes obvious that even a good operator can miss occasional peaks, which cause distressing distortion or even damage. Thus there is a whole family of equipments used in broadcasting that behave broadly in a similar manner to control level automatically. They are called variously limiting amplifiers, peak limiters, compressors, Audiomaxes and constant volume amplifiers, but they all belong to the one family. Basically, they are automatic gain control amplifiers, that is, they operate on the incoming signal to keep its output amplitude comparatively constant. The difference between different members of the family lies in the degree of output constancy that they aim for and in their release times, i.e. the time they take to return to normal after a burst of high level programme has subsided. In some of the more 'sophisticated' versions, the release time is made dependent on the level, so as to make them, so their specification says, 'behave like a human operator', their final purpose being, of course, to replace the human operator largely or completely.

However, the level of intelligence that can be built into any piece of automatic equipment is much lower than that of the most stupid operator. Thus any broadcasting station using these devices has a stupid sound operator, utterly reliable of course, but utterly stupid and irresponsible as far as aesthetics are concerned. In the hands of a commercial operator whose first responsibility is to his advertisers, each of whom wants to be heard at the top of his possible voice, this becomes a potent weapon, and heavy use of limiters has become general as a result. The broadcasting standards specify no limit to the degree of limiting, but they do suggest 15 dB 'for example' in setting up one test, and that seems to be a fair average estimate of present practice on a.m. radio, though some stations use more. A 15 dB range is, of course, a 30:1 range of audio power, though perhaps a better subjective impression is given by remembering that 10 dB is said to correspond to the subjective change when one sound is 'twice as loud as' another. So 15 dB is the range when a sound grows 'twice as loud' and then grows 'half as loud again'.

Such a large volume change is quite flattened, automatically, by most Australian a.m. broadcasters. As a result, the background noise, whenever a momentary lull occurs, is 15 dB louder, often it can be heard rising inexorably, and in general the sound issues from the loudspeaker at home in a smooth even stream.

Now this is fine if all the listener asks of radio is a continuous friendly background, audio wallpaper it has been called, the medium, its mere presence not its content, being the message. However, it thereby becomes impossible to present any dynamic range, thus destroying much of the surprise, delight, even danger, the pregnant pauses that so often characterize many great artistic experiences.

Many great artistic experiences, but not all. There is an interesting parallel from earlier times. In the eighteenth century, composers were often servants in the courts of the nobility, and George-Philip Telemann for example wrote *tafelmusik*, table music, for aristocrats to eat by. Mozart too wrote *divertimenti* as background for weddings and festive occasions. Such music was essentially a kind of baroque Muzak. These pieces, not surprisingly considering the magnificent professionalism of their composers, are well suited to their purpose. Their levels are even, and thus they are not so badly affected by peak limiting.

But the big music of the nineteenth century, the Romantic Period, the great turbulent symphonies, and the great religious music of all periods, the choral pieces surging with praise of God, are horribly distorted by heavy limiting. And when the release times of the limiting devices are shorter, as they have become over the last few years, even speech of announcers or actors is made quite unnatural. With short release times the balance of level is changed and distorted within words, even within syllables. And drum beats, or peaks of clapping, punch holes in the programme. This sort of distortion, due to excessive limiting, is obvious to the ear even though the equipment meets impeccable standards of conventional total harmonic distortion measurements.

It is this that bedevils a.m. radio, not faults in the medium itself. It is a pity that there has been no will to devise standards to overcome this damage. The use of peak limiting in popular recorded music, as disks competed with each other in juke boxes, has led artists, no longer able to affect their listeners by nuances of level, to impress by sheer volume, leading them and many of their listeners to a sad and irreversible deafness that was previously the prerogative of quite small occupational groups like airline pilots or, three hundred years earlier, operators of wind- and water-mills.

For any a.m. station that still aims to give its listeners some surprise and delight, this poses the problem of how far one should control the programme to still compete with the other stations and avoid the dread accusation of 'low level', without defeating much of the point of one's effort. Compared with transmissions of continual constant volume, any transmission with reasonable nuances of level *must* have a lower average level. There is a real problem, too, even in a well-modulated programme, in how to satisfactorily manage the transition from orchestral music into a news programme.

A housewife told me once that she could always recognize an ABC programme because 'she couldn't hear it when she went out into the kitchen'. I took that as a compliment, but it wasn't meant to be, nor is it taken so by many broadcasting executives. The danger is that, from an irrational fear of 'low level', or surprise, all a.m. radio will be processed, filtered, homogenized and emasculated until it only remains fit for listeners who don't really care to listen.

That is bad enough, but another danger lies not far ahead.

Programmes are available in Australia at present, largely uncompressed, on f.m. stereo, but once commercial broadcasting begins in that medium the same pressures will tend to force f.m. as well to keep the same bland grey level—unless real efforts are made to devise suitable standards in the meantime.

Conclusion

The purpose of the paper has been to show the influence of standards on broadcasting, in particular the cost of, and the loss due to, non-standards. At times it may have seemed rather a little close to other old and perennial topics, 'What's wrong with the media?' and 'Why don't manufacturers make better receivers?' This was not its purpose, rather to present some problems which are familiar to many in the media, but not so familiar to those outside, the hope being that wider discussion, and inevitably hard bargaining, may lead to better standards, and thus to the benefit of all of us, consumers of the electronic media.

Acknowledgement

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New UK–USA telephone cable

A new £100 M telephone cable between Britain and the USA that will boost transatlantic telephone links by more than 50% has just been given international go-ahead. This undersea link, with a capacity of more than 4000 simultaneous calls, will carry phone calls, computer data and telex messages between Europe and the USA and Canada.

A new cable is now needed across the Atlantic to cater for continuing massive growth in calls between the two continents, and in particular between the USA and Britain—the world's busiest transoceanic telephone route. The demand for telephone service between the two countries has been growing by a steady 15–20% a year throughout the 1970s, and shows no sign of slackening. At present more than 20 million phone calls are made each year between the UK and the USA, and more than half go by cable.

The new system, whose manufacture will be shared between the USA, Britain and France, is due to come into service in 1983 and will run some 3400 nautical miles between Sennen Cove (Land's End) and Tuckerton, New Jersey.

Known as TAT 7, the project is the seventh in a series of telephone cables between America and Europe that date from 1956. That year the laying of TAT 1—the historic UK–USA link that was the world's first transoceanic telephone cable—saw the start of the great leap forward in global communications that these long-distance cables and satellites have made possible.

The cost of the project is being divided equally between North America and Europe. On the European side, Britain is partnered by 16 other participants and her share—22% of the total—is the largest of all those. There are seven participants in the project on the North American side, including the American Telephone and Telegraph Company which has the largest single share in the project, amounting to some 40% of the total.

The new cable will also help to maintain a balanced division of transatlantic telephone circuits between cable and satellite. At present, cables provide some 7000 telephone circuits between Europe and North America, with rather fewer provided by satellite. But the balance will swing the other way when the next generation of satellites—*Intelsat V*, with a capacity of 12,000 telephone circuits—goes into service in 1981, although only part of this capacity will serve the North Atlantic. TAT 7, therefore, is expected to restore the balance to more or less equal division between the two technologies for the mid-1980s.

Sharing the telephone 'load' in this way also improves the security and reliability of transatlantic communications. It ensures that a reasonable number of alternative paths are available in the event of a system breakdown.

Contributors to this issue

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Asrar Ul-Haq Sheikh graduated from the West Pakistan University of Engineering and Technology and subsequently obtained the degrees of M.Sc. and Ph.D. from the University of Birmingham in 1966 and 1969 respectively. He held lectureships at Universities in Pakistan, Iran and Libya between 1969 and 1975. In 1975 he returned to the University of Birmingham as a Research Fellow to work on the characterization of man-made noise. After the completion of this work in 1978 he returned to Libya and is now at the University of Garyounis, Benghazi.

After receiving an honours degree in physics at Cambridge University in 1973, **Philip Gaskell** joined the Engineering Research Department of the British Broadcasting Corporation. Here he has worked in a variety of fields ranging from the diversity reception of radio microphones to colour video analysis, but his main preoccupation has been with the development of the H and HJ surround sound systems, as well as with other aspects of acoustics. He is currently investigating programmable, digital audio techniques.

Demetra Howard graduated in electrical and electronic engineering from University College of South Wales, Cardiff, in 1974. She obtained the master's degree in microwaves and modern optics of the University of London, in 1975, and then joined the systems group of the Electronics and Electrical Engineering Department at University College London for postgraduate research in optical fibre communications. Initially she worked on the design and development of the acoustic transducers to modulate coherent light in optical fibres for use in the UCL data highway. Her research work was then extended to the study of the acousto-optic interactions in optical fibres, and several of her publications are concerned with this particular field of research. Miss Howard is now a member of the Underwater Sound Laboratory research team at Kelvin Hughes, a division of Smiths Industries, in Essex.

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Indexing Terms: Sound recording and reproduction, Stereophonic systems

System UHJ: a hierarchy of surround sound transmission systems

P. S. GASKELL, M.A.*

SUMMARY

The reproduction of sounds from all directions in the horizontal plane, commonly known as surround sound, offers new scope for greater realism of the reproduced sound and a new dimension for creative and dramatic effects. Although a large number of loudspeakers are almost certainly needed to reproduce surround sound convincingly, a worthwhile improvement may be given with just four loudspeakers in a rectangular array, i.e. quadraphony. This paper describes a hierarchical transmission system for quadraphony, System UHJ. Transmission may be by 2-, 2½-, 3- or 4-channels, the high-order channels being added to the base channels, thereby forming a hierarchy of systems. The design and development of the 4–2–4 System HJ is discussed in some detail although this paper necessarily only gives a brief account of the many facets of this involved subject.

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TERMINOLOGY

The terminology adopted in this paper is common to that of many of the references cited. Abbreviations for directions are frequently used and are defined in Fig. 1; this also shows the 16 cardinal directions. The loudspeaker positions are sometimes referred to as 'corner locations' and the span between any adjacent pair of loudspeakers as a 'quadrant'. Signals associated with a particular loudspeaker are similarly designated by the appropriate direction symbol; the origination signals are shown unprimed, whilst the decoded signals are shown primed. A list of terms and symbols is given below.

Surround sound	The reproduction of sound in two or three dimensions.
Quadraphony	The reproduction of sound from a horizontal rectangular array of loudspeakers.
Tonal quality	The subjective character of a sound in terms of its spectral content relative to that of the original sound. Considerations of distortion, image position and image width are excluded. Impairment of tonal quality may consist of, say, an excess or lack of bass, treble or a narrow band of frequencies.
l–m–n transmission system	A transmission system consisting of l input channels from which signals are encoded to m signals for transmission by or recording on m channels, and decoded for reproduction on n loudspeakers.
L_F, R_F, etc.	Quad origination signals.
L'_F, R'_F, etc.	Decoded quad signals.
L_T, R_T	Matrix encoded two-channel (stereo) signals.
f	Front (Logic control signals)
b	Back (Logic control signals)
l	Left (Logic control signals)
r	Right (Logic control signals)
$p\angle\theta$	Polar representation of vector of modulus p and argument θ degrees.

1 Introduction

The stereophonic reproduction of sound is familiar as giving an arc of sound images in front of the listener. Expanding the arc of reproduction to encompass all directions around the listener offers potentially greater realism of the original event and a new dimension for dramatic and musical effects. In any reverberant area or enclosure, sounds arrive at the listener from an infinity of directions and ideally to reproduce these sounds would

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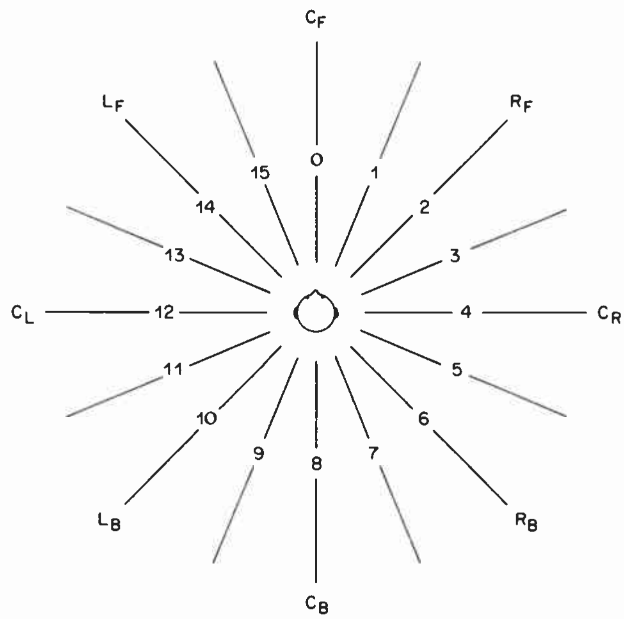

C_F centre-front, R_F right-front, C_R centre-right, R_B right-back
C_B centre-back, L_B left-back, C_L centre-left, L_F left-front

Fig. 1. Directions in the horizontal plane.

require a very large number of loudspeakers. However, the ear's spacial acuity, i.e. its ability to locate the direction of sounds, is very much less accurate than that of the eye and by using a limited number of loudspeakers, the ear can be deceived into believing that it is hearing a good approximation to the original or intended sound field. It may be shown that a minimum number of four loudspeakers are needed; when they are disposed in a square or rectangular array, the reproduction is commonly referred to as 'quadraphony'.

Ideally, to feed such an array, four recording or transmission channels are needed if full production facilities are to be maintained. Recording four signals on to tape clearly poses no serious problems, and modulation methods for recording on to disk[1] have been proposed and tried experimentally with some success. Broadcasting four signals, however, does meet with problems, particularly in Western Europe.

Proposed forms of radio-frequency transmission of four signals make use of pilot tone techniques; the third channel is carried in quadrature to the stereo difference signal[2 to 7] and the fourth channel is modulated on to a higher frequency subcarrier (e.g. 76 kHz). Use of the fourth channel could cause serious service planning problems in Europe because of signal-to-noise ratio and interference problems related to the 100 kHz spacing of Band II transmissions.[8,9] Even the third channel is not without its problems. If the third channel were transmitted at full level and bandwidth, stereo and mono service areas would be reduced, intermodulation distortion and crosstalk between the two subcarrier signals could adversely affect stereo reception on a number of commercial f.m. receivers, and noise and interference of the third signal would reduce the quadraphonic service areas even more.[8,10,11] Thus, proposals[12] have been made to bandlimit and attenuate the third signal before transmission to reduce these effects to more acceptable levels.

The BBC faces further problems peculiar to large broadcasting organizations. At present, the BBC, in common with many European broadcasters, is equipped to record, distribute and transmit stereo programmes nationwide. The cost of equipping studios and altering the distribution system for 3-channel operation would be prohibitive, particularly in view of the probable small audience who will be listening to quad, at least in the near future. The BBC turned its attention, therefore, to 2-channel quadraphonic systems.

Such transmission and recording systems have the singular advantage that they enable quadraphonic signals to be recorded on existing two-track tape recorders and stereophonic disks, and can be transmitted on the existing stereo transmission network, at minimal extra cost and without loss of service area. They make use of wide-band interchannel phase-difference in order to convey directional information of the original quadraphonic sound stage. The amount of phase must be limited judiciously in order to maintain good mono and stereo reproduction and avoid unpleasant phase-like effects in stereo or level imbalance in mono. Early commercial, 2-channel systems[12 to 15] failed to meet these requirements of mono and stereo compatibility and often also gave poor quadraphonic reproduction. The BBC therefore undertook basic research work on the properties of hearing.[16,17,18] From this was developed the Matrix H encoding system for 2-channel recording and transmission.[19] The encoding allows a variety of different types of decoder for quadraphonic reproduction and a number have been designed by the BBC.[20]

Beginning in May 1977, the Matrix H system was used as the basis for a year of experimental quadraphonic broadcasts using the existing stereo transmission network. A wide variety of programme material was produced and many programmes of 'pop' music and some drama were successful.[21] However, problems did arise with classical music broadcasts. Some orchestral works balanced in the traditional manner were noticeably degraded in stereo and although this was due partly to lack of experience in quad production and to often inadequate monitoring facilities, complaints of broad and 'phasey' images in stereo were attributable to the degree of interchannel phase introduced for centre front images. Other problems of balance were also encountered. At the same time, the designers of the Ambisonics System 45J (sponsored by the National Research Development Corporation—NRDC) acknowledged similar defects in their system which was in many ways similar to Matrix H. The BBC and NRDC decided therefore to pool their knowledge and modifications were made to both systems to arrive at a unified System HJ.

This paper gives an account of the original BBC work on the properties of hearing, the development of Matrix H and the modifications to HJ. The principles of operation of an HJ decoder are presented and the hierarchy of 2½-, 3- and 4-channel systems, using HJ as the base 2-channels is described.

2 Properties of Hearing

The work on the properties of hearing concerned two principal areas, namely, the reproduction of sounds from the normal stereo configuration of loudspeakers[17,18] and the reproduction of sounds from a square, 'quadraphonic' array of loudspeakers.[16] This Section discusses the effect of broadband interchannel phase differences on stereo reproduction.

Broadband phase affects image quality in three principal ways: impairment of tonal quality, a shift of the sound image position, and an apparent broadening of the sound image. In extreme cases, such as that of equal amplitude and anti-phase signals, a very unpleasant, even nauseous sensation can be evoked. The degree of impairment depends on the interchannel level and phase differences, the absolute levels of the signals having only a small effect. In general, the condition in which the levels of the two signals are identical is the most critical to any phase difference and as little as 20° can sometimes be detected under the most critical listening conditions. These conditions are, however, rarely encountered in practice. When the levels of the two signals differ, a greater phase-difference can be supported before it is heard. The effects are not symmetric and, for a given level difference, reversing the polarity of the phase produces a noticeably different effect. The condition where the louder channel leads in phase is the one least prone to impairment. Three zones of impairment may be defined:

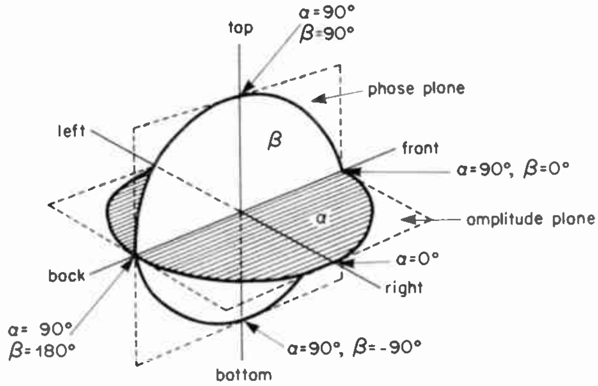

Fig. 2. Derivation of the Scheiber sphere.

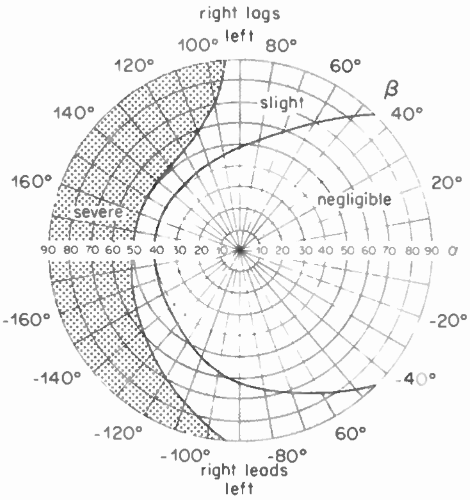

Fig. 3. Scheiber-sphere diagram (side-view, right) showing impairment zones for stereo images.

negligible impairment: imperceptible impairment of the tonal quality of the sound image but allowing a just perceptible broadening of the image.

slight impairment: perceptible impairment of the tonal quality and/or significant broadening of the image.

severe impairment: severe impairment of the tonal quality and/or extreme broadening of the image, often deemed to be unlocatable.

Clearly, there is no sharp dividing line between these zones, but it is helpful to delineate the various degrees of impairment. It is convenient to map these zones of impairment on to the surface of a sphere representing interchannel level and phase differences. Scheiber[22] first used the sphere for quadraphonic matrix design although the mapping dates back originally to Stokes.[23] The transformation is

$$\alpha = 2\tan^{-1}\left|\frac{L}{R}\right|$$

and

$$\beta = \theta_L - \theta_R$$

where α is measured anti-clockwise from the horizontal 'right' axis,

β is the angle of elevation above the horizontal plane ($-180° \leqslant \beta \leqslant 180°$)

and $\theta_L - \theta_R$ is the phase-difference between the left and right signals.

The mapping is shown pictorially in Fig. 2. The impairment zones are shown in Fig. 3 as a projection of the right half of the sphere surface (the left half is only slightly different). The impairment zones are discussed in more detail in Ref. 19.

Once familiar with the sphere, it becomes a very useful aid in designing quadraphonic encode matrices. Each matrix defines a locus (according to microphone technique) on the sphere surface and the proximity of the locus to the impairment zones gives a good indication of likely stereo performance. Other parameters of image position, sound level, mono and quad performance must of course also be taken into account.

3 Matrix HJ Encode Design

Many factors must be taken into account when designing a 2-channel quadraphonic matrix system and any final design is necessarily a compromise as the 2-channel signals must be reproduceable in quad, stereo and mono. The design philosophy adopted was that the encoded signals should not cause any noticeable impairment in stereo or mono, relative to the quality of normal stereo and mono programmes, whilst still allowing some 2-dimensional directional information to be conveyed for quadraphonic reproduction.

During programme production of 4–2–4 quadraphonic recordings or transmissions, all these modes of quad, stereo and mono are monitored and the quad is that decoded from the encoded signals. 'Ideal' decoders have yet to be invented and each decoder, for a particular encode system, has its own idiosyncrasies which can be corrected for, to some extent, during programme production. Nevertheless, with the present state of the art, the 4–2–4 quad reproduction is a fair approximation to the original and, to a first approximation, the idiosyncrasies of particular decoders may be ignored.

It is not possible to assert categorically how the sound source locations of the original quadraphonic sound field should map in stereo reproduction. One obvious mapping is to add the rear channels L_B and R_B to the corresponding front channels L_F and R_F of the original quad signals. This, however, causes images to be bunched at the left and right speakers in stereo and is not satisfactory. Some mappings of particular positions are fairly obvious. To take one example, it is reasonable to map the centre-front and centre-back positions to the centre positions in stereo. In designing the encode system, therefore, there is some latitude as to how the original quad source locations are mapped in stereo.

With these points in mind, we may draw up a set of requirements for the encoding specification and this includes the following:

(1) Centre-front and centre-back sources should map to the centre position of the stereo stage.

(2) Other positions should be distributed on either side without bunching, with the sources between L_F and R_F giving as wide a stagewidth as possible in stereo. They should also show left/right symmetry about the centre position.

(3) No source-position should cause significant impairment in stereo. However, positions in the rear stage may be allowed to cause some change in tonal quality and image broadening in order to allow quad decoding and to give 'perspective' in stereo.

(4) The encode locus should approximate as far as possible to a coplanar circle ('great circle') whose centre is also that of the sphere. This is for the purposes of decoding for quadraphonic reproduction.

(5) No source position should be reproduced in quad, stereo or mono with a level significantly different in one mode to that in another. The question of balance is more subtle than at first appears since even small level changes are often readily detectable. Within the constraint that the source levels should be approximately the same in the three modes of reproduction, small level differences between the three modes are often desirable. Thus, it is sometimes found profitable for example to have a slightly different level balance in mono than in stereo or quad.

(6) The system encode should be able to accommodate current microphone and panning techniques.

(7) The 2-channel encode should be expandable to form 3- and 4-channel transmission systems.

Some of these criteria are conflicting and any final solution must be a compromise. The detailed mathematics of the encode design are not presented here and the encode loci, as currently used by the BBC, are simply quoted.

The encode locus is determined to some extent by the particular microphone technique used. The principal categories are pair-wise panning and groups of coincident cardioid or hypercardioid microphones. The latter only contain first order azimuthal harmonic components[24] whereas the former is a somewhat artificial technique that contains many higher order components. Panning and microphone techniques form a major subject of their own and are only dealt with briefly here. (See, for example, Refs. 25 and 26.)

Pair-wise panning has long been familiar in stereo as panning a mono source according to a sin/cos law

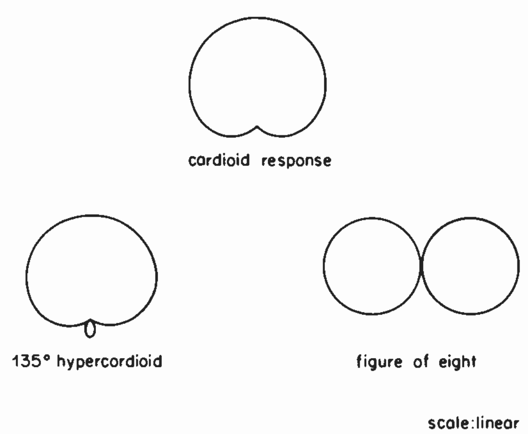

Fig. 4. Cardioid-type microphone responses.

between the left and right channels. In the limit, each of the two stereo loudspeakers may be excited individually. In the strictest sense, it is not legitimate to transpose the technique to surround sound production since it is linked intimately to the particular form of reproduction and the loudspeaker configuration.[12,26] Nevertheless, it is found to be a valuable technique in quadraphonic productions.[24] Here a mono source is panned, according to a sin/cos law, between adjacent corners thereby enabling each of the four corner loudspeakers to be excited individually (prior to any form of encoding).

Cardioid and hypercardioid microphones have a response to a source at azimuth θ of the form

$$A+\cos\theta$$

When $A = 1$ the response is cardioid and when $A = 1/\sqrt{2}$ the response is 135° hypercardioid (i.e. a null at $\theta = 135°$, see Fig. 4). A cluster of four, coincident orthogonal cardioid or hypercardioid microphones in the horizontal plane can completely define the zero and first order, horizontal azimuthal components at a point in space, i.e. an omni-directional and two orthogonal figure-of-eight components. If the four microphones are directed towards the four corners of a square L_F, R_F, L_B, R_B, the first-order azimuthal components are given by a simple addition matrix:

$$W = \tfrac{1}{2}(L_F+R_F+L_B+R_B)$$
$$= 2A \text{ (omni-directional)}$$
$$X = \tfrac{1}{2}(L_F+R_F-L_B-R_B)$$
$$= \sqrt{2}\cos\theta \text{ (forward figure-of-eight)}$$
$$Y = \tfrac{1}{2}(L_F-R_F+L_B-R_B)$$
$$= \sqrt{2}\sin\theta \text{ (sideways pointing figure-of-eight)}$$

Thus, the first-order horizontal characteristic may be fully represented by just three audio signals, unlike pair-wise panning which requires four.

A wide variety of microphone techniques is certain to be used in quadraphonic productions and, for this and other reasons, the System HJ specification for 2-channel encoding, agreed upon by the BBC and NRDC in September 1977, covers a narrow band on the Scheiber sphere as shown in Fig. 5. For pair-wise panning, the particular option currently being used by the BBC is conveniently expressed in matrix format as:

$$\begin{pmatrix} L_T \\ R_T \end{pmatrix} = \begin{pmatrix} 0{\cdot}966 \angle 2{\cdot}8° & 0{\cdot}259 \angle 67{\cdot}3° & 0{\cdot}940 \angle -27{\cdot}0° & 0{\cdot}342 \angle -103{\cdot}0° \\ 0{\cdot}259 \angle -67{\cdot}3° & 0{\cdot}966 \angle -2{\cdot}8° & 0{\cdot}342 \angle 103{\cdot}0° & 0{\cdot}940 \angle 27{\cdot}0° \end{pmatrix} \begin{pmatrix} L_F \\ R_F \\ L_B \\ R_B \end{pmatrix} \quad (1)$$

With coincident groups of four microphones, sources on the perimeter of the quad stage are correctly encoded by equation (1) if L_F, R_F, L_B, R_B are the signal feeds from four, coincident, orthogonal 135° hypercardioid microphones. Equation (1) may then also be expressed as:

$$\begin{pmatrix} L_T \\ R_T \end{pmatrix} = \begin{pmatrix} 0{\cdot}667 \angle -14{\cdot}6° & 0{\cdot}385 \angle 73{\cdot}8° & 0{\cdot}637 \angle -9{\cdot}1° \\ 0{\cdot}667 \angle 14{\cdot}6° & 0{\cdot}385 \angle -73{\cdot}8° & 0{\cdot}637 \angle -170{\cdot}9° \end{pmatrix} \begin{pmatrix} 1 \\ \cos\theta \\ \sin\theta \end{pmatrix} \quad (2)$$

where θ = source azimuth measured anti-clockwise from the centre-front position.

The loci corresponding to equations (1) and (2) are shown in Fig. 5 and it is seen that they touch at the centre-quadrant positions, i.e. C_F, C_L, C_B and C_R. If a source is panned inside the perimeter,[26] W is effectively

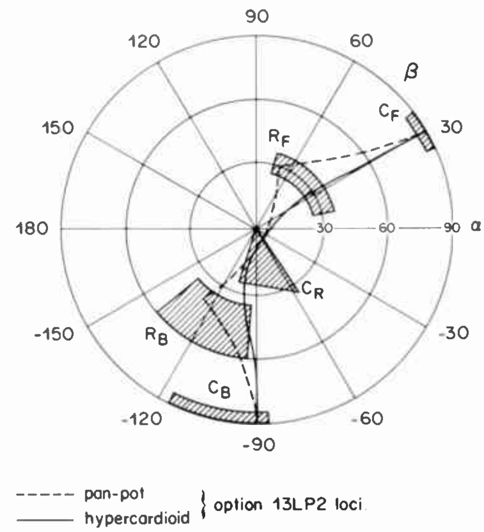

Fig. 5. System HJ tolerance zones and option 13LP2 loci.

Stage location	α	β
C_F	90 ± 5	30 ± 6
R_F	30 ± 5	45 ± 30
C_R	Bounded by points ($\alpha = 0$), ($\alpha = 25$, $\beta = -110$), ($\alpha = 35$, $\beta = -58$)	
R_B	$47{\cdot}5 \pm 12{\cdot}5$	$-117{\cdot}5 \pm 22{\cdot}5$
C_B	90 ± 5	$-102{\cdot}5 \pm 15$
L_B	$132{\cdot}5 \pm 12{\cdot}5$	$-117{\cdot}5 \pm 22{\cdot}5$
C_L	Bounded by points ($\alpha = 180$), ($\alpha = 155$, $\beta = -110$), ($\alpha = 145$, $\beta = -58$)	
L_F	150 ± 5	45 ± 30

increased and the constant term of unity in the right hand bracket in equation (2) is increased. This has the effect of 'pulling' the entire locus approximately in the $\alpha = 90°$, $\beta = -30°$ direction. The symmetry of equations (1) and (2) reflects the left/right symmetry characteric of all sensible, 2-channel encoding systems.

4 Decoding

4.1 Linear and Programme-dependent Decoding

The HJ encoding specification allows for a variety of different decoding methods. In linear decoding, the matrix by which the speaker signals are derived from the 2-channel signals is constant. For quadraphonic reproduction, the amount of separation achievable is very limited and a single corner source, for example, is reproduced with crosstalk signals to the adjacent channels typically only 3 dB down on the wanted channel. 2–4 linear decoders have been developed[27,28] that take some account of the way in which the ear localizes sounds in different frequency bands. A separate decoding matrix is then used in each of two or three frequency bands.

These decoders and the simpler wide-band decoders can give pleasant effects. If the listener is seated close to the centre of the array of loudspeakers in a room with a well-balanced acoustic, sounds will be localized reasonably well and quite a faithful reproduction of the intended surround sound field may be achieved. However, the sound field is sensitive to head movement and, even for a central listener, the images are broad and subject to movement when the listener turns his head. Thus, although a pleasant effect can be achieved, linear decoding has its drawbacks.

Another form of decoding varies the decoding matrix to give good localization of the dominant source. With such 'programme-dependent' or 'logic' decoding, it is possible to reproduce sharp stable images for a single source in quad. However, when many sources are present, complications can arise; secondary (quieter) sources can become blurred or can be pulled away from their intended position towards the dominant source; sibilants can be heard detached from the main source and by the dynamic nature of a complex programme, sources can sometimes be heard to dart disconcertingly across the stage. However, it is found that the ear is for much of the time unaware of these side-effects, depending very much on the programme material. If the programme material is prone to these effects, remedial action can sometimes be taken at the production stage. Classical music falls into this category and linear decoding is probably more suitable. 'Pop' and 'light' music, on the other hand, are probably better complemented by a programme-dependent decoder.

Another advantage of programme-dependent decoding is that a more spacious sound field is given. As a result, the listening area is not so critical and the listener has much greater freedom of movement than is possible with linear decoding. This and other properties have led BBC production staff to choose this type of decoder for balancing quad programmes in preference to linear decoding.

4.2 HJ Programme-dependent Decoder

The HJ programme-dependent decoder is based on the commercial QS decoder, designed by Sansui Electrical Company (Japan), of which fuller accounts are given in Refs. 20, 29. Figure 6 shows a block schematic of the HJ decoder. The variable matrix decoding may be expressed by the following equations:

$$
\begin{aligned}
L'_F &= [0{\cdot}924f(L_{TB}-R_{TB})+1{\cdot}307lR_{TB}]\ \underline{/0°}\\
R'_F &= [-0{\cdot}924f(L_{TB}-R_{TB})+1{\cdot}307rL_{TB}]\ \underline{/-30°}\\
L'_B &= [0{\cdot}924b(L_{TB}+R_{TB})-1{\cdot}307lR_{TB}]\ \underline{/45°}\\
R'_B &= [0{\cdot}924b(L_{TB}+R_{TB})-1{\cdot}307rR_{TB}]\ \underline{/-75°}
\end{aligned}
\qquad (3)
$$

where

$$
\begin{pmatrix} L_{TB} \\ R_{TB} \end{pmatrix} = \begin{pmatrix} 0{\cdot}917 & 0{\cdot}083 \\ 0{\cdot}083 & 0{\cdot}917 \end{pmatrix} \begin{pmatrix} L_T\ \underline{/0°} \\ R_T\ \underline{/55°} \end{pmatrix}
$$

and f, b, l, r are 'front', 'back', 'left', 'right' control signals respectively. During 'programme-dependent' operation, f, b, l, r may vary between 0 and $\sqrt{2}$ about the quiescent value of unity, for which linear operation is given. f, b, l, r are functions of the interchannel phase and level differences of the 2-channel signals after phase-tilting and blending. f and b are complementary and are a measure of the phase difference between signals $L_{Tf,b}$ and $R_{Tf,b}$ given by:

$$
\begin{pmatrix} L_{Tf,b} \\ R_{Tf,b} \end{pmatrix} = \begin{pmatrix} 0{\cdot}966 & 0{\cdot}034 \\ 0{\cdot}034 & 0{\cdot}966 \end{pmatrix} \begin{pmatrix} L_T\ \underline{/0°} \\ R_T\ \underline{/55°} \end{pmatrix}
$$

l and r are also complementary and are a measure of the level difference between signals $L_{Tl,r}$ and $R_{Tl,r}$ given by:

$$
\begin{pmatrix} L_{Tl,r} \\ R_{Tl,r} \end{pmatrix} = \begin{pmatrix} 0{\cdot}714 & 0{\cdot}286 \\ 0{\cdot}286 & 0{\cdot}714 \end{pmatrix} \begin{pmatrix} |L_T| \\ |R_T| \end{pmatrix}
$$

The control signals are frequency-dependent such that, below about 100 Hz, they assume the quiescent value of unity and the decoding is then linear. At higher frequencies, they have their full effect and improved separation for single sources is achieved.

It is seen that the 2-channel encoded signals L_T and R_T are phase-shifted and blended before further processing. The reason for phase-advancing the R_T signal by 55° is to give an encode locus which is very approximately in phase for front sources and out-of-phase for rear sources. This forms the basis of achieving high separation through the variable matrix equations. The blends

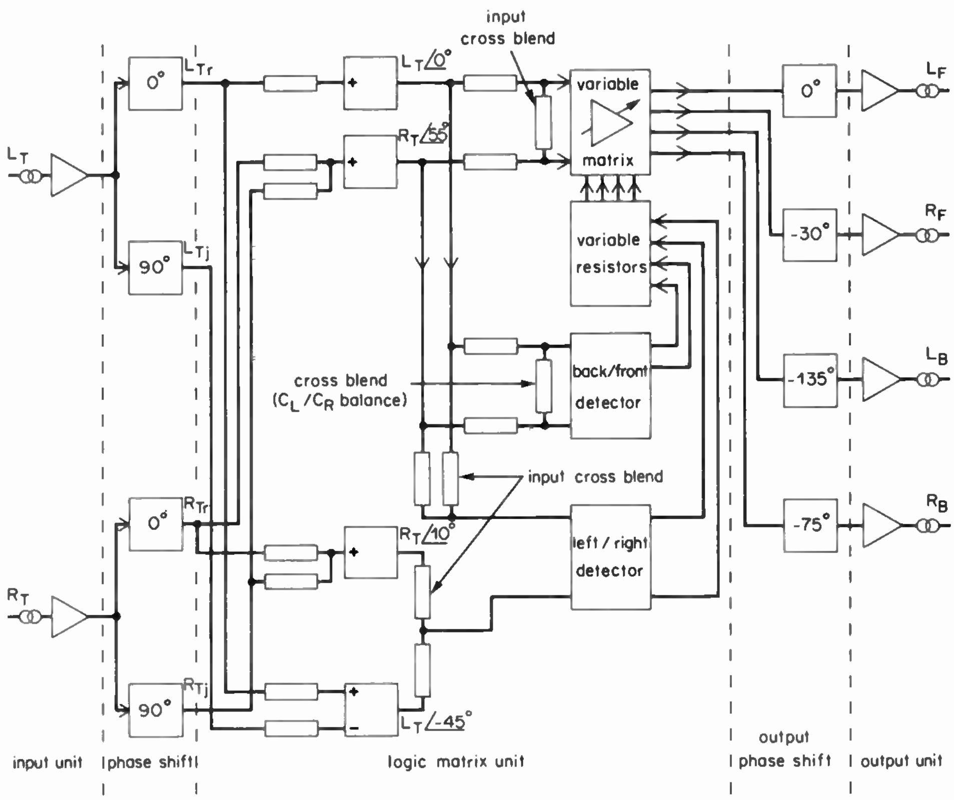

Fig. 6. Block schematic of HJ programme-dependent decoder.

introduced are in the interests of image stability and positioning.

The improved crosstalk figures that are achievable for single sources are demonstrated by Figs. 7 and 8. Figure 7 shows the crosstalk figures for single sources panned to each of eight positions using pair-wise panning, and decoded linearly according to equation (3) where f, b, l, r equal unity. Thus, the top-left corner shows that for an L_F source, the crosstalk to the R_F channel is 4 dB and to the L_B channel is 2 dB. Figure 8 shows the equivalent results for variable-matrix decoding and it is seen that, typically, crosstalk figures are improved from 3 dB to 15 dB. The results of Fig. 7 also pertain to the low frequency band of the programme-dependent decoder. When many sources

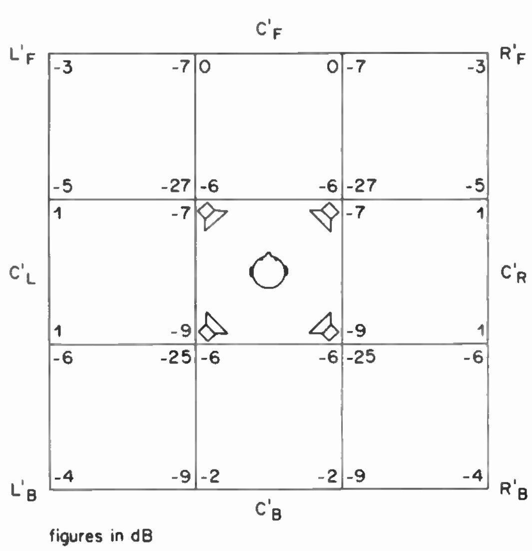

Fig. 7. Typical performance of HJ linear decoder for a single panned source.

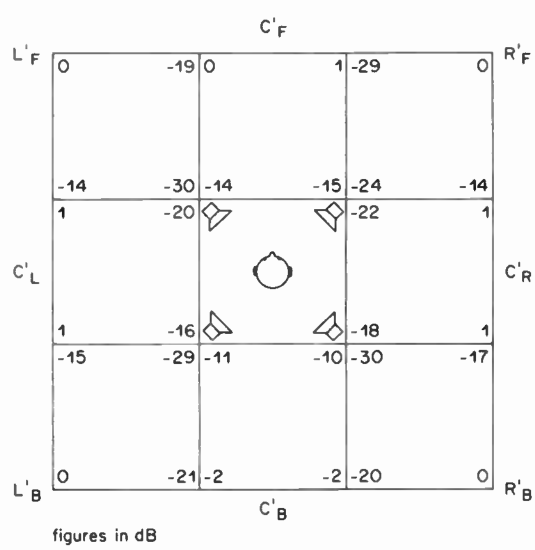

Fig. 8. Typical performance of HJ programme-dependent decoder for a single panned source of 1 kHz.

are present, the situation is much more complex since it depends on the relative levels, frequencies and positions of the various sources. The multi-source condition is therefore less amenable to analysis and greater confidence can be placed in subjective assessments.

Output phase-shifters are required primarily to limit the phase-differences between the principal channels of centre-quadrant sources. Optimum values were chosen, based on the original work on the properties of hearing related to quadraphonic reproduction.[16]

This decoder has been used in a wide variety of quad programme productions with favourable reaction from production staff. In a wide selection of tests the reproduced quad has been judged to be superior to that of any other 2-channel system. It has also won favourable comments from many European broadcasters who have assessed the system.

In the final analysis, it should be recognized that much of the surround sound directional information is lost through 2-channel encoding and the decoded reproduced sound is bound to suffer from some impairments. Those of the HJ decoders have already been mentioned. Nevertheless, the quad reproduction has been considered by many to give a worthwhile improvement over stereo reproduction.

5 Assessment of Systems

In order to assess the complete performance of a 4–2–4 quad matrix system, a wide variety of tests, mostly subjective, are needed. Many tests have been carried out by the BBC on the original Matrix H, on System HJ and on the known commercial systems SQ (CBS), QS (Sansui) and BMX (Nippon, Columbia). These tests are now described individually.

5.1 Single Source Localization Tests[30]

This is a laboratory assessment of where single sources at 16 equally distributed positions of the original quad stage are reproduced, firstly in stereo and secondly in decoded quad. Reference 30 gives a detailed description; male speech was used as the programme material as it had been found to be the most critical. Figure 1 shows the intended, original source positions and Figs. 9 and 10 show the results for the HJ system in stereo and quad respectively. The apparent image locations for each of the 16 cardinal positions are shown; the bar length drawn vertically in Fig. 9 and radially in Fig. 10 represents the image width. These tests give an indication of image distribution and of whether bunching of images is taking place in stereo or in quad. They also highlight any impairment of tonal quality or image width and anomalies such as those of double images, sibilant mislocations or phase not given by tests using noise as a test signal. This form of test is therefore very critical and often reveals characteristics of system performance not normally found by other tests. The details of the results are discussed in Section 5.6.

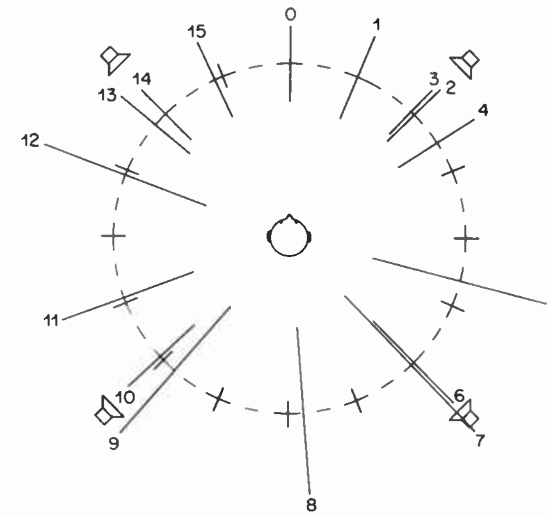

Fig. 10. Image positions—System HJ quad, pair-wise panpot.

5.2 Pre-mixed Programme Material[20, 30]

Again under laboratory conditions, programme material premixed for 4-channel transmission and reproduction was passed through the 4–2–4 codec and its performance assessed in quad and stereo. This test was somewhat restricted because no attempt was made to overcome idiosyncrasies of the system under test at the mixing stage. Nevertheless it proved worthwhile, particularly as many sources were present simul-

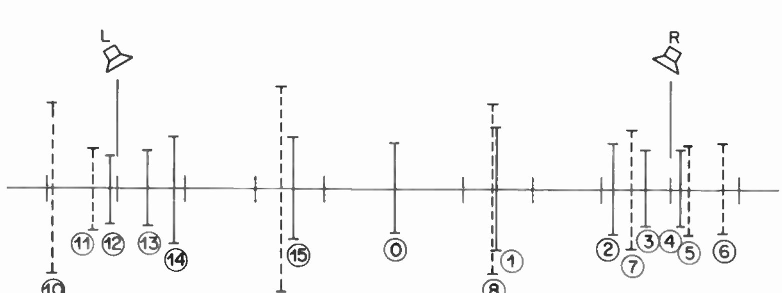

Fig. 9. Image positions—System HJ stereo, pair-wise panpot.

taneously and it was effective at exploring the deficiencies of programme-dependent decoders.

5.3 Programme Production Tests

This was perhaps the most searching test of all. A producer and sound mixer were asked to mix a quad programme from multi-track tape using an unknown 4–2–4 system or 4–4–4 system. A quad mixing desk was at their disposal and the programme was monitored in quad, stereo and mono. Many programme items were used each with a producer and sound mixer experienced with that type of programme material. They were asked to judge the quality of reproduction in all three modes and also the ease of mixing with each system. This test, therefore, optimized the performance and was highly effective at revealing the inadequacies of each system.

5.4 Listener Tests

These tests followed the programme production tests. The producers and sound mixers who had taken part in the production tests assessed the quality of the mixed-down mono, stereo and quad. Separate tests were carried out in this way because it had been found that the listener's judgement was coloured during the production tests by the fact of having mixed-down the programme and knowing how the mono, stereo and quad modes of reproduction of each system related to each other. During the listener tests, the listener was able to give his undivided attention to judging the quality of each item without bias. Indeed, many of the results of quality assessment of the listener tests differed from those of the production tests.

5.5 Broadcast Tests

In May 1977, the BBC began a year of experimental broadcasts in quadraphony using Matrix H. The broadcasts averaged about one hour per week, but in addition included almost all of the 1977 Promenade Concerts. The broadcasts proved invaluable for developing microphone and production techniques and for assessing the Matrix H system. These are intimately linked and the production technique and the matrix system are mutually dependent in achieving good results. The series of broadcasts met with success in the fields of 'pop' music and drama but impairments of some of the classical music broadcasts were noticed, as described earlier. As a result of these tests, Matrix H was modified to System HJ and the latter part of the series of broadcasts used System HJ. A second year of experimentation with the improved system is now being planned.

Just as production techniques for stereo operation took many years to develop during the 1950s, it will also take time to develop production techniques for quadraphony. There is considerable overlap of the two, but new techniques are also under test; one example is the new 'sound-field' microphone[31] which is of special interest to quadraphonic as well as stereo productions.

5.6 Results and Discussion

Of the many 2-channel quadraphonic matrix systems tested, System HJ demonstrated a consistently superior performance to that of other systems. Stereo compatibility was significantly better and was even found to be a slight improvement over the front/back blend arrangement of 'discrete' quad, in which the rear signals are added to the front signals. The quad performance using the HJ programme-dependent decoder was also preferred although it was clearly not as good as that of the 'discrete' system. Mono compatibility is less demanding than stereo and several systems, including HJ, gave good mono performance. It should be noted that many of these tests were carried out before HJ had been developed. In these instances, the BBC system examined was Matrix H, which is very similar to HJ, but gives slightly less good stereo; the mono and quad performances are largely the same.

The most important assessments are those of multi-source programmes mixed for quad. Such assessments are necessarily subjective and it is difficult therefore to give an analytical description of the system's performance. The results of the single source localization tests, however, may be more readily presented, although it should be recognized that these form only part of the overall appraisal of a system. The results for the HJ system in stereo and quad are shown in Figs. 9 and 10. Only the results of pair-wise panning are given and other microphone techniques should also be considered. For comparative purposes, the 'discrete' quad results are also shown for pair-wise panning in Fig. 11. It is seen that

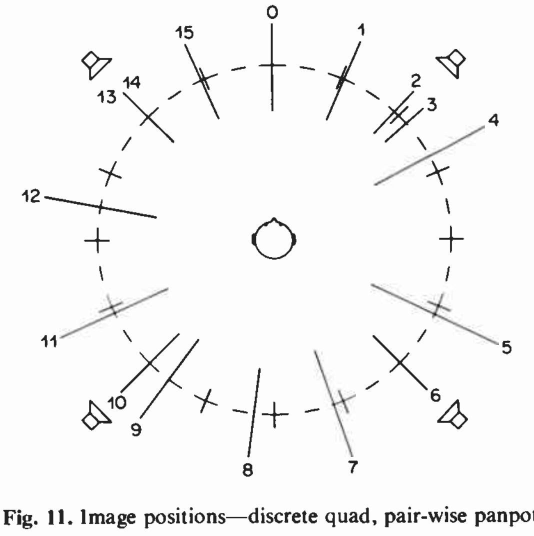

Fig. 11. Image positions—discrete quad, pair-wise panpot.

even this 4-channel system gives non-ideal results and, so far as is known, other microphone techniques (e.g. W, X, Y[26]) fail to improve matters significantly. This is a reflection of the fact that in order to give truly convincing surround-sound reproduction, more than four loudspeakers are needed, together with a matrix system commensurate with the number and disposition of loudspeakers used. From the outset, therefore, the four loudspeakers of quadraphonic reproduction limit the quality of the surround-sound possible.

6 System UHJ Transmission Hierarchy

The HJ system by design is expandable to 3- and 4-channel transmission.[32] The base two channels are unchanged and the extra channels serve to improve the surround sound reproduction. As discussed in the Introduction, the transmission of three or four channels poses several radio frequency problems. However, in the UK, the IBA (Independent Broadcasting Authority) have transmitted surround-sound broadcasts on an experimental basis using a 2½-channel version of UHJ in which the third audio channel was band-limited (about 5 kHz, low pass) and attenuated (about 7 dB) to reduce such problems.

This system is designed to be compatible in more than one sense. The base 2-channel HJ signals have the normal HJ, stereo and mono characteristics and may be decoded by any of the HJ 2-channel quadraphonic decoders as previously discussed. Those people who receive a high field strength signal, however, may decode the full 2½-channel signals for surround-sound listening free of the characteristics of 2-channel decoders. Since the third channel is attenuated at the transmission end, the receiver decoder amplifies the third channel relative to the other two. The third channel is, therefore, more susceptible to transmission noise, despite the beneficial effect of low pass bandlimiting, and a high field strength is needed. Accordingly, two zones of service area may be defined: one in which a high field strength prevails and 2½-channel surround sound, as well as the other forms of decoding, may be received with good quality, and a second area where the field strength is less strong and the 2-channel signals may be decoded for quad, stereo or mono listening.

Indications so far are that the presence of the third, band-limited and attenuated signal causes only a small (of the order of 1 dB) loss of signal level to all stereo and mono listeners. Any benefits of a 2½-channel quad service over and above the 2-channel quad services would have to be weighed against the loss to the stereo and mono listeners who will be in the majority for some time to come. Obviously, much more experimentation with the 2½-channel system will be necessary before a final choice can be made.

2½-channel UHJ surround sound transmissions provide a compatible hierarchy of decoding and listening modes; 3- and 4-channel UHJ transmissions are further steps in this hierarchy. They aim further to improve surround sound performance by whatever decoding arrangement is appropriate, not necessarily quadraphonic. The 4-channel UHJ system may also be used to transmit surround sound signals with height information.[32]

It is unlikely that the UK will be able to absorb 3- or 4-channel transmission systems into the already congested v.h.f. Band II, not at least in the near future. Similar constraints apply to other European countries, but outside Europe 3- and 4-channel systems may be accommodated. In the future, satellite transmissions at much higher transmission frequencies may also permit high-order transmissions in Europe.

7 Conclusions

This paper has given an overview of some of the considerations involved in the design of the base two channels of the HJ system, particularly as regards stereo compatibility and quadraphonic decoding. Surround sound performance is limited by the use of only four loudspeakers and is further limited by the use of only two transmission channels, which, moreover, must be mono and stereo compatible. It is felt that the HJ 2-channel system comes very close to the optimum compromise between the conflicting requirements and gives a quadraphonic performance that can add to the enjoyment of sound. Whereas the development of the 2-channel encoding specification is at an advanced stage, the field of decoder design still has considerable scope for development.

In the future, more transmission channels may become available in the UK and this would allow 3- and 4-channel transmissions of the UHJ system. This should give improved surround sound reproduction compatible with a hierarchy of decoding, ranging from mono and stereo through to full 4-channel decoding with as many loudspeakers as is desired.

8 Acknowledgments

The author is indebted for the major contributions to the development of System UHJ to engineers at BBC Research and Operational Departments and to members of the Ambisonics development team; in particular Messrs. Meares, Ratliff, Crompton, Harrison and Wright of the BBC and Gerzon of the Mathematical Institute at Oxford.

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Indexing Terms: Fibre optics, Modulation

Optical fibre acousto-optic modulators

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Based on a paper presented at a Colloquium on Component Aspects of Fibre Optic Communications held in London on 14th April 1978.

SUMMARY

Coherent light propagating within an optical fibre may be modulated by using a piezoelectric transducer to stress the fibre mechanically.

This paper discusses the design and evaluation of this type of optical modulator and compares a number of modulator designs. The paper demonstrates the relative roles of the mechanical properties of the fibre and the component parts of the transducer in determining the modulator performance and points out the differences in design philosophy between modulators employing monomode and multimode fibres. Finally, suggestions are made of ways of significantly improving modulator performance.

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1 Introduction

Mechanical stress applied to an optical fibre conveying coherent light perturbs the fibre's guiding properties and hence modulates the light. This perturbation arises from a combination of the photo-elastic effect and dimensional changes.

Research into this phenomenon at UCL has concentrated mainly on its application to data highways.[1] However, it has importance in other areas, e.g. sensors,[2] and can also be an interference mechanism[3] in conventional optical fibre systems.

In contrast to conventional optical fibre data highways, which employ intensity modulation of the optical sources, the UCL data highways employ simple piezoelectric transducers to modulate the light by mechanically stressing a short section of fibre.

An attractive feature of such a modulator is that the transducer may be clipped onto a fibre without the need to break the fibre and insert connectors or remove the outside protective coating. A series of modulators each operating at a different subcarrier frequency may be cascaded to form a multiple input f.d.m. telemetry highway. This paper discusses one particular aspect of such a highway, namely the modulators.

The general format of a modulator consists of an optical fibre and some means of introducing mechanical stress into a short length of that fibre, i.e. a transducer. The modulators may then be categorized according to the type of fibre, e.g. monomode or multimode, and, the type of transducer, e.g. 'focusing' or 'plane'. The differences between focusing and plane modulators may be appreciated by reference to Fig. 1. Plane modulators may be constructed in the clip-on form by simply providing a hinged lid to hold the fibre in place on the piezoelectric plate. Focusing modulators may also be constructed in the clip-on form by dividing the transducer into two halves which can then be placed on either side of the fibre and then clamped together.

Modulators employing monomode fibre mainly impose phase modulation[4] onto the coherent light propagating within the fibre. This modulation may be recovered using the combination of an optical hetero-dyne[5] and a p.m. receiver (Fig. 2). The transducer in this case should be designed to stress the fibre isotropically in order to give the maximum detected signal for the minimum drive power. An anisotropic stress distribution will cause the fibre to become birefrigent, resulting in polarization modulation and consequent amplitude modulation of the beat signal from the optical heterodyne.

If multimode fibre is employed, provided the multimode interference pattern possesses a moderate degree of spatial coherence, a signal may be detected by illuminating a photodetector by a section of the interference pattern (Fig. 3).

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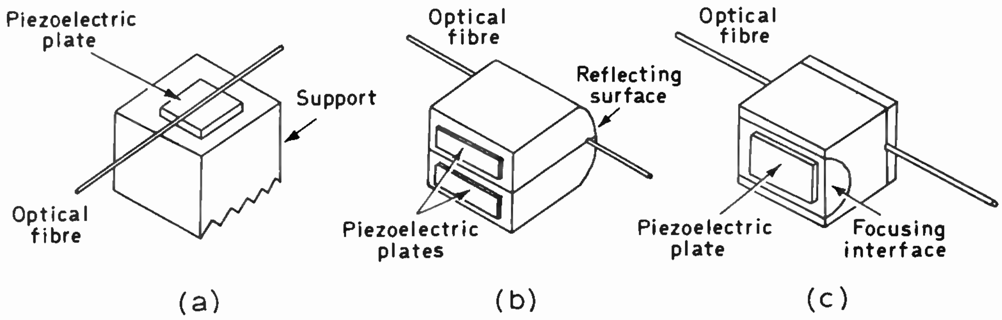


Fig. 1. (a) Plane modulator. (b) Reflector focusing modulator. (c) Lens focusing modulator.

Although the details of this detection process are still being investigated the hypothesis that the signal results from phase modulation differences between modes adequately explains most features of the phenomenon.[6,7]

Phase modulation differences between modes effectively modulate the spatial distribution of the radiated fields from the fibre in much the same way as a beam is steered in a phased antenna array. The total radiated power from the fibre is, obviously, not modulated. Hence a signal will only be produced by a photodetector if it intercepts a section of the interference pattern such that the total power falling on its surface fluctuates as the radiation pattern is modulated. In this case, then, an anisotropic stress distribution is required to maximize the phase modulation differences between modes and hence maximize the received signal.

The use of this latter detection method results in a received signal which is subject to fading and which is contaminated by intermodulation products. Fortunately, the fading may be reduced by exploiting the partial spatial coherence of the multimode interference pattern using a segmented photodetector and combining the outputs from each segment in a diversity receiver.[1]

From the above it can be appreciated that there are two fundamental parameters which affect the efficacy of a modulator: the fraction of the applied electrical power which reaches the fibre in the form of acoustic power, and the symmetry of the stress induced in the fibre. An isotropic stress distribution is desired in the case of monomode fibres and an anisotropic stress distribution in the case of multimode fibres.

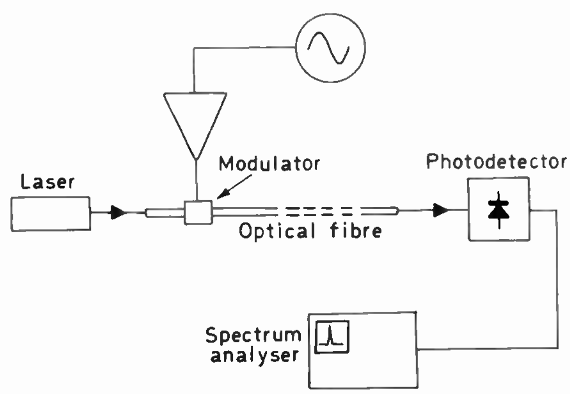
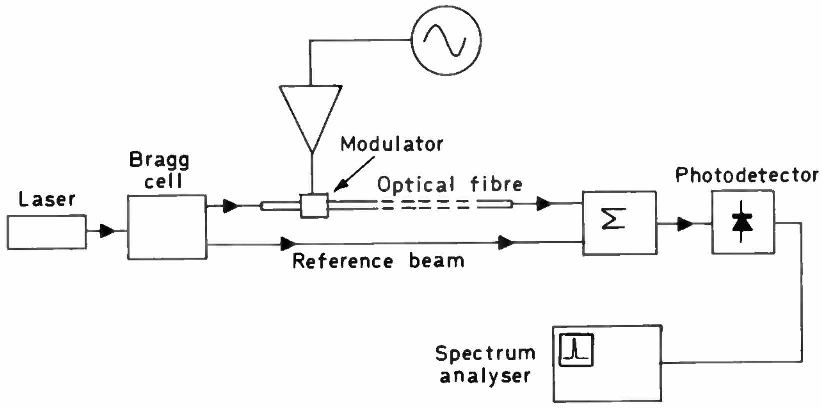


Fig. 3. Multimode fibre test system.

In order to evaluate these parameters an examination must be made of the acoustic properties of the interaction region around the fibre and also the transmission medium from the piezoelectric plate to the fibre. A detailed analysis of this region is both complex and of limited application due to experimental uncertainties in its structure. However, a number of

Fig. 2. Monomode fibre test system.



useful comparisons may be made on the basis of the approximate theory presented in the next two Sections.

2 Plane Modulators

The construction of the plane modulator is shown in Fig. 1(a). From the Figure it can be appreciated that a fundamental limit on the efficiency of this modulator is the acoustic match between the radiating plate and the fibre. To date, this interface has been effected using a grease of approximately the same acoustic impedance as the plastic jacket of the fibre. Hence an estimate of the power intercepted by the fibre can be made by assuming that the plate is radiating into a sea of grease. It is shown in reference 8 that the acoustic impedances of the load and substrate are effectively connected in series in the transducer's electrical equivalent circuit. Hence, provided there are no acoustic reflections from the boundaries of the substrate or load back to the plate, the fraction η_p of the total acoustic power intercepted by the fibre is given by:

$$\eta_p = \frac{d}{a}\frac{Z_1}{Z_1+Z_2} \tag{1}$$

where d = diameter of the fibre
a = width of the plate
Z_1 = acoustic impedance of the material surrounding the fibre
Z_2 = acoustic impedance of the substrate.

For a typical plane modulator consisting of 100 μm diameter fibre coated with a polypropylene jacket ($Z_1 = 2\times10^6$ kg m^{-2} s^{-1}) in contact with a 5 mm wide piezoelectric plate mounted on a brass substrate ($Z_2 = 40\times10^6$ kg m^{-2} s^{-1}), equation (1) gives $\eta_p \simeq 0{\cdot}1\%$.

The fraction of the electrical drive power intercepted by the fibre in the form of acoustic power is even less than this due to contact resistances, losses in the plate itself (only significant in low Q materials such as PVF_2) and the insertion loss of the electrical matching circuit. It is a fundamental fact that if it is desired to match a resonant impedance to a particular source impedance over a range of frequencies then an insertion loss must be tolerated.[9] The higher the Q of the resonant impedance the greater the insertion loss. The electrical Q of an acoustically-matched piezoelectric plate is inversely proportional to the plate's electromechanical coupling coefficient. Hence, piezoelectric plates with as high an electromechanical coupling coefficient as possible are preferred.

The above value of η_p may obviously be improved by using a substrate material with a low acoustic impedance, e.g. for an air-backed plate of the same dimensions as before, η_p is 2%. However, since the acoustic impedance of the substrate must match the acoustic impedance of the piezoelectric plate if a broadband modulator is to result, this expedient will generally result in a narrowband modulator. A broadband modulator with a value of η_p = 2% could be achieved by embedding an uncoated fibre in the substrate in the near field of the plate. The upper surface of the plate is left unloaded. However, this expedient would mean the loss of the clip-on facility.

Ideally, a plane modulator's substrate should be infinitely thick to prevent any acoustic energy radiated into it from being subsequently reflected back to the piezoelectric plate from the boundaries of the substrate. Such reflections cause Z_2 to be frequency dependent since the substrate then acts as an unterminated transmission line. For zero substrate losses, Z_2 can then vary from 0 to ∞ causing a series of maxima and minima to be formed in the modulator's frequency response. This effect could be exploited by tuning to one particular peak or, alternatively, the same transducer assembly could be used to provide a series of closely-spaced modulating frequencies. This could simplify the design for narrowband applications.

If a broadband modulator is required, a reasonable approximation to an infinite substrate can be made by using an acoustically lossy material with grooves machined at its boundaries to effectively break up any incident wavefronts.

3 Focusing Modulators

A large fraction of the acoustic power generated by the piezoelectric plate in a plane modulator is not intercepted by the fibre. The efficacy of a modulator can be improved if this power is concentrated onto the fibre by using a focusing structure to convert the plane waves from the piezoelectric plate to cylindrical waves converging onto the axis of the fibre. Two of the simplest transducer geometries capable of this function are the reflector and lens (Figs. 1(a) and (b)).

An estimate of the power reaching the fibre may be derived by assuming that the piezoelectric plate presents a plane wavefront at the lens or reflector. This is a reasonable assumption since the focusing element may easily be situated within the near field of the plate. In this case the acoustic field in the focal plane in the direction perpendicular to the fibre's axis is given by the Fourier transform of the radiating aperture.

$$A = A_0 \operatorname{sinc}\frac{\pi a y}{F\lambda} \tag{2}$$

where A_0 = amplitude at $y = 0$
F = focal length
λ = acoustic wavelength
a and y are given in Fig. 4.

The wave is still virtually plane in the direction of the fibre axis since in this direction the fibre is still in the near field of the plate as a result of the cylindrical focusing geometry.

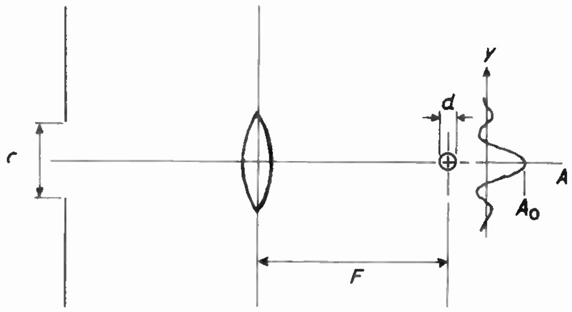


Fig. 4. Mathematical model of focusing modulators.

The fraction η_f of the total radiated acoustic power which is intercepted by an uncoated fibre embedded in the substrate at the line focus can be found by squaring and integrating equation (2)

$$\eta_f = \frac{2}{\pi}\left\{\mathrm{Si}(\theta) - \frac{1-\cos\theta}{\theta}\right\} \qquad (3)$$

where

$$\mathrm{Si}(\theta) = \int_0^\theta \frac{\sin t}{t}\,\mathrm{d}t \quad \text{and} \quad \theta = \frac{\pi a d}{F\lambda}.$$

A plot of equation (3) is given in Fig. 5. Equation (3) is an optimistic estimate since it does not account for the curvature of the fibre or the effects of aberrations.

It should be noted that the maximum *efficiency* is obtained when the fibre intercepts the whole of the central lobe of the sinc pattern, i.e. $\theta = 2\pi$ giving $\eta_f = 90\%$. A further concentration of the pattern results in the inclusion of the first sidelobes which are in antiphase with the central lobe.

A useful parameter in the evaluation of the effectiveness of focusing is the focusing gain. This is defined as the ratio of the acoustic power intercepted by a fibre at the focus to that intercepted by the fibre when placed in the substrate in the near field of the plate (i.e. the ideal plane modulator configuration). Hence the focusing gain G is given by:

$$G = \frac{a}{d}\,\eta_f. \qquad (4)$$

A typical focusing transducer employing a 5 mm wide piezoelectric plate operating at 5 MHz and a lead-aluminium lens focusing structure ($V_{Al} = 6{\cdot}3 \times 10^3$ m s^{-1}) of focal length 6 mm produces a main lobe 3 mm across and a focusing efficiency of $\eta_f = 13\%$. Hence by equation (4) the focusing gain is $G = 8$ dB.

In practice the fibre is coated by a 1 mm diameter polypropylene jacket. To account for the effect of this coating theoretically would be a difficult problem. However, the initial aim in this analysis is to establish a comparison between the performance of focusing and plane modulators. In this context, several of the geometric factors which complicate a thorough analysis are common to both configurations, i.e. the plastic and grease coatings, and so a realistic comparison may still be made. In other words, it is expected that the focusing gain calculated above is not very different from the focusing gain redefined as the ratio of the power intercepted by a coated fibre at the focus to that intercepted by a coated fibre placed in the near field of the plate.

In contrast to the plane modulator the focusing modulator's substrate should be acoustically of low loss in order that the maximum amount of acoustic power reaches the fibre. Indeed, for the previous example, the substrate loss must not exceed 8 dB if the focusing modulator is to be more efficient than the plane modulator. However, the use of a low loss substrate will result in strong internal reflections, especially from the hole provided for the fibre, which is a problem with efficient focusing modulators.

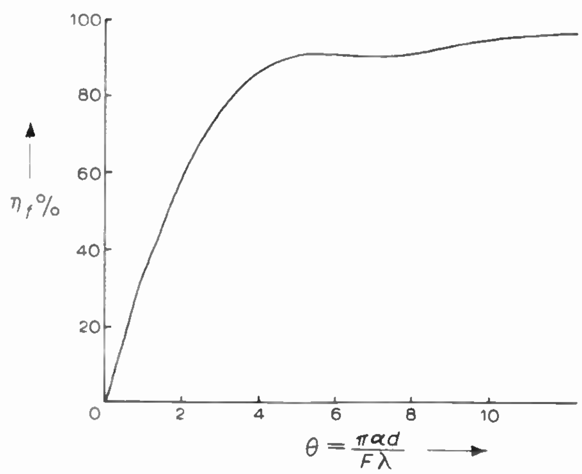


Fig. 5. Normalized focusing efficiency.

4 Evaluation of Modulators

The essential purpose of a modulator is to provide the greatest signal strength over as wide a bandwidth as possible. Hence the s.n.r. of the recovered signal and the modulator bandwidth are useful parameters in the evaluation of modulator performance.

However, before a useful comparison of modulator performance may be made on the basis of these two parameters, a number of other factors must first be taken into account.

(i) The s.n.r. of the recovered signal is directly proportional to the optical power incident on the photodetector for shot noise limited detection.

(ii) The s.n.r. of the recovered signal is directly proportional to the electrical drive power to the modulator.

(iii) The s.n.r. of the recovered signal is inversely proportional to the receiver bandwidth.

(iv) In monomode systems, the s.n.r. of the recovered signal is dependent on the heterodyning efficiency of the beams from the fibre path and the reference path.

(v) The s.n.r. of the recovered signal is highly dependent on the launch conditions at the laser end of the fibre. Typically 15 dB variations in signal strength can be found by varying the launch. In fact for some fibres it is possible to eradicate the signal altogether.

(vi) In multimode systems, the recovered signal strength is critically dependent on the photo-detector position in the output mode pattern.

(vii) The modulator performance is extremely sensitive to the exact form of the fibre's forced motion. This is itself dependent not only on the mechanical properties of the fibre but also on the form of the applied stress at the interface between the fibre and the transducer, i.e. the vibration boundary conditions of the fibre.

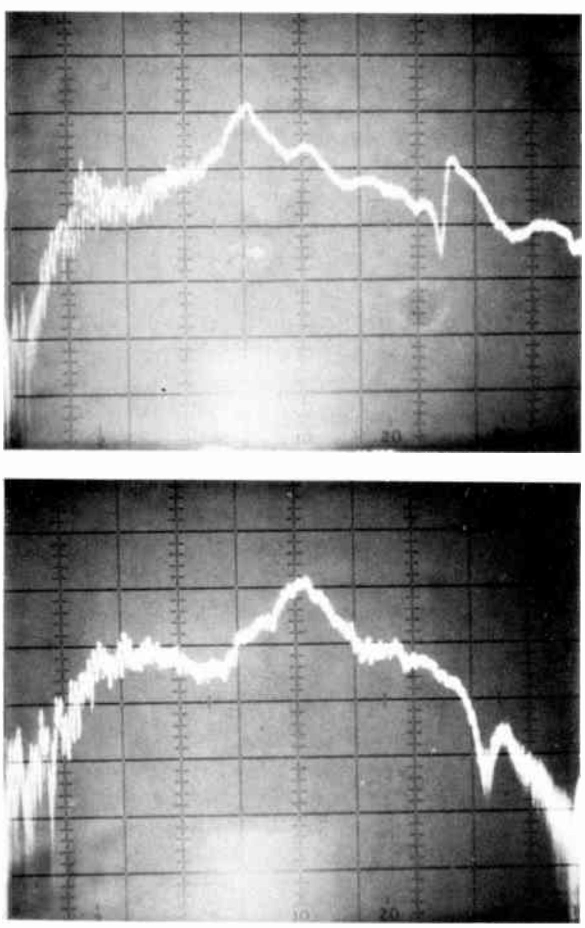


Fig. 6. Overall response of fibre and transducer. Horizontal scale: 0–50 MHz. Vertical scale: 10 dB/div. Noise level: one division from bottom of graticule. (a) 125 μm cladding diameter fibre. (b) 100 μm cladding diameter fibre.

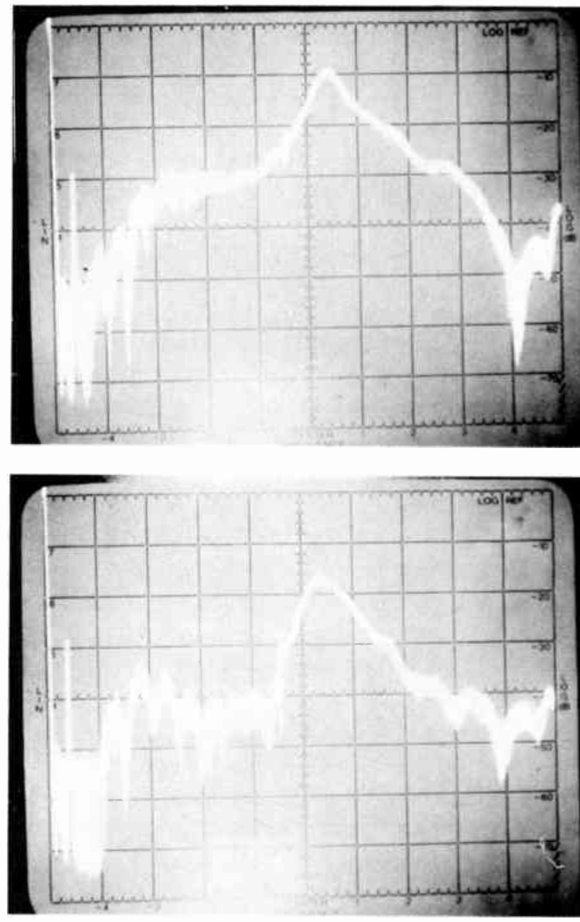


Fig. 7. Overall response of fibre and transducer with different vibration boundary conditions. (a) Horizontal scale: 0–50 MHz. Vertical scale: 10 dB/div. Noise level: two divisions from bottom of graticule. (b) Same as (a) but with fibre pressed slightly harder in place.

The sensitivity of modulator performance to the mechanical properties of the fibre is illustrated by Fig. 6, which shows the overall response of the same transducer in conjunction with two fibres of different diameters. Note the responses are completely different.

The sensitivity of modulator performance to the vibration boundary conditions of the fibre is illustrated by Fig. 7, which shows the change in the response caused by slightly changing the fibre's orientation with respect to the transducer by adjusting the pressure with which the fibre is pressed onto the transducer.

The change in the frequency response due to changing the diameter of the fibre has been attributed[10] to the acoustic waveguide properties of the fibre. It is also most likely that the sensitivity of the modulator's response to the vibration boundary conditions is also due to these acoustic waveguide properties. Both these effects are presently undergoing further investigation.

Factors (i), (ii) and (iii) listed above are easily allowed for by normalizing the s.n.r. of the recovered signal with respect to the electrical and optical powers and the receiver bandwidth. Factor (iv) may be allowed for by measuring the phase modulation index $\Delta\theta$ of the beat signal from the optical heterodyne rather than measuring the s.n.r. of the recovered signal. This modulation index may then be converted to the s.n.r. of the recovered signal, given ideal heterodyning, by using the following equation:[5]

$$\text{s.n.r.}_{\text{ideal}} = \frac{qP_0\Delta\theta^2}{4hf_0\Delta f}$$

where q = quantum efficiency of the photodetector ($\sim$0·7)
h = Planck's constant
f_0 = optical frequency
Δf = receiver bandwidth
P_0 = total optical power incident on the photodetector.

The remaining factors are difficult to quantify. However, reasonable consistency between the results presented is assured by the procedure that the signal is maximized on each occasion.

It is useful not only to compare the performance of modulators employing the same geometry with different materials but also modulators employing different geometries with the same materials. This latter comparison is effected by using the same focusing structure in both the plane and the focusing configurations. The focusing gain may then be defined as the ratio of the s.n.r. produced by the two configurations. The difference between the value of focusing gain found by this means and the theoretical value gives a rough idea of the acoustic losses and demonstrates the range of usefulness of the focusing concept.

5 Experimental Results

A large number of measurements have been made on various modulator configurations involving the use of both monomode and multimode fibres and using both PZT and 36° Y-cut $LiNbO_3$ piezoelectric plates vibrating in their thickness extensional modes. These results are summarized in Table 1.

Modulators employing 36° Y-cut $LiNbO_3$ were consistently found to offer better performance than those employing PZT. 36° Y-cut $LiNbO_3$ has the advantage of not only having a high electromechanical coupling coefficient (comparable to PZT) but also a much lower relative permittivity than PZT, making it easier to match electrically at frequencies above 10 MHz.

The use of $LiNbO_3$ allows modulators to be constructed with operating frequencies of up to 70 MHz but still employing plates vibrating in their fundamental mode. Overtone operation has been found to produce modulators of relatively lower efficiency than fundamental mode operation.

It has also been found using $LiNbO_3$ that by polishing one face of the plate at a slight angle with respect to the other, it is possible to increase considerably the bandwidth of a plane modulator without reducing its efficiency. This expedient may make the mode of vibration of the plate extremely complicated and so some of the improved performance may be due to fortuitous vibration boundary conditions. The degree of tapering to produce a certain bandwidth is undergoing further investigation. However, empirically, the difference between the half-wave resonant frequencies of the minimum and maximum thickness of the plate gives a reasonable estimate of the bandwidth.

To date, plane modulators employing this tapered piezoelectric plate technique and designed for operation at frequencies between 10 and 40 MHz have been found to give the best performance. Below 10 MHz the frequency responses of the modulators tend to exhibit closely spaced minima due to acoustic reflections from the substrate, while above 40 MHz the modulator's efficiency rapidly decreases. This result could arise from a wide range of causes including unsuitable launching of

Table 1

Typical modulator performance

Modulator	Frequency range MHz	Typical percentage bandwidth	Typical s.n.r. in 100 kHz bandwidth for 1 mW optical power and 1 W electrical drive power: Multimode dB	Monomode dB
PZT plane	<10	10	40	60
$LiNbO_3$ plane	10–40	10	50	70
	40–100	3	20	40
$LiNbO_3$ tapered plane†	20–40	50	50	70
PZT parabola focusing	<10	15	55	75
PZT lens focusing	<10	15	50	70

† The peak in the modulator's response due to the fibre's mechanical properties (see Fig. 6) is assumed to be removed by a compensating filter in the drive electronics.

the acoustic wave into the fibre, fundamental problems with the acoustic field distribution in the fibre at high frequencies, and attenuation effects in the plastic coating.

The potential of focusing modulators has been demonstrated experimentally, and focusing gains of the order of 10 dB have been achieved. However, their use is presently restricted to operating frequencies below 10 MHz for the readily-machined, substrate materials which are currently used, namely brass, lead and aluminium. Above this frequency the attenuation of the substrate exceeds the gain due to focusing. Higher frequency operation may be made possible by the use of low-loss materials such as fused silica. However, as the frequency is raised the required machining tolerances become progressively more exacting.

There still remain two further disadvantages of focusing modulators. The first, predicted earlier, is the detrimental effect of acoustic reflections from the hole provided for the fibre. The second is that the phase modulation produced using monomode fibre is greater with plane modulators than focusing modulators for the same drive power. The reasons for this rather extraordinary result are presently being investigated.

6 Conclusions

This paper has described a systematic approach to the design of the modulators used in the UCL data highway. There are still a large number of unknowns involved in their design and much room for improvement in their performance. The achievable performance of a modulator in terms of the fraction of the available acoustic power intercepted by the fibre should be of the order of 2% for a plane modulator and 30% for a focusing modulator. In practice the figures are 0·1% and 1%. The reasons for these much lower figures are the acoustic mismatch between the transducer and the plastic coating of the fibre, the acoustic loss of the coating and, in the case of focusing modulators, the acoustic loss of the substrate. Hence up to 13 dB improvement in the case of plane modulators and 15 dB improvement in the case of focusing modulators is available by employing uncoated fibres embedded in the substrate. The sensitivity of the modulator to the mechanical properties of the fibre and the fibre's orientation with respect to the transducer would also be eliminated by the same means provided the substrate was chosen to have the same acoustic impedance as the fibre. Unfortunately this expedient would result in the loss of the clip-on facility and the consequent need to use connectors.

The most promising data communications application of the clip-on modulators appears to be in low bandwidth systems where reception bandwidths of the order of 1 kHz allow detectable signals to be transmitted using electrical drive powers of the orders of microwatts to the modulators. This fact coupled with the availability of low-power-drain electronics, enables the construction of data terminals which can operate for periods of years from a single battery. Such devices will be extremely useful in hazardous or remote environments.

The data highway concept does, however, have considerable flexibility and with suitable attention to the modulator design acceptable quality colour television signals have been transmitted over a data highway employing multimode fibre.

7 Acknowledgments

The author is indebted to her supervisor, B. Culshaw and would like to thank D. E. N. Davies and T. J. Hall for useful discussions. Thanks are also due to Standard Telecommunication Laboratories for providing the optical fibres. The work was supported by the UK Ministry of Defence (ASWE).

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The characterization of impulsive noise and considerations for a noise-measuring receiver

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SUMMARY

After reviewing the ways in which impulsive noise is generated and methods by which it may be characterized, parameters suitable for an assessment of system performance are selected. Design considerations are given for equipment suitable for the measurement of these parameters and the effect of limitations in the equipment on the measured parameters is described. Methods of overcoming these limitations are discussed.

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LIST OF SYMBOLS

A	amplitude
B	bandwidth
F	noise factor
f	frequency (MHz)
G	power gain
h	amplitude of impulse response
k	Boltzmann's constant ($1{\cdot}38 \times 10^{-23}$ joules K^{-1})
N	mean noise level
N_o	output noise
S	impulse power spectral density
S_i	input signal
S_o	output signal
T_o	ambient temperature
t	time
V_{av}	average voltage
V_{rms}	root-mean-square voltage
V_d	impulsiveness ratio $= 20 \log_{10} (V_{rms}/V_{av})$
X	attenuation
τ	impulse width

1 Introduction

The performance of any communication system is dependent on the characteristics of the transmission channel, and performance can often be improved by proper exploitation of these characteristics, for example by the use of an optimum signalling technique. The important factors as far as the communication engineer is concerned are the frequency and time characteristics of the channel and the magnitude and nature of the noise. This paper is concerned with the characterization and measurement of impulsive noise, and although it arises as a result of an investigation by the authors into noise in v.h.f. mobile radio channels, there are no real restrictions and the discussion is valid over a wide range of sources and frequencies.

There are two basic reasons for a study of this kind. Firstly there is the desire to gain an understanding of the nature of the noise and methods by which it can be characterized, and secondly there is the need to be able to predict the performance of communication systems in an environment polluted by this kind of noise. At frequencies below 20 MHz, natural sources of impulsive noise dominate,[1] the major source being atmospheric noise arising from thunderstorms and similar disturbances. At v.h.f., and in urban areas the most important noise sources are the ignition systems of motor vehicles, although power lines, industrial electrical machinery and domestic equipment also contribute. This kind of impulsive interference is commonly termed man-made noise, and can be detected at frequencies up to 7 GHz.[2] Being impulsive in nature it has characteristics quite different from thermal (Gaussian) noise which can be uniquely described (in respect of its significance in communication systems) by its r.m.s. value. The

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characterization of impulsive noise is a much more involved matter.

In general terms we may consider an impulse as a transient that contains an instantaneous uniform spectrum over the frequency band for which it defined, a uniform spectrum requiring that all frequencies are present, of equal amplitude and in phase over the frequency band. Impulsive noise is the combination of successive impulses which may have random amplitudes and random time-spacings; these factors may sometimes be such that adequate separation of successive impulses is not possible.

Thermal noise can produce an annoying 'hiss' on a voice channel, but does not significantly degrade intelligibility unless its r.m.s. value is relatively high. Impulsive noise causes clicks, which, although annoying, may be tolerable. The degradation of the channel is not easily defined and is usually based on some kind of subjective assessment, although the quasi-peak measurement, which will be mentioned later, has been shown to have some correspondence with the subjective annoyance on a.m. radio and television.[3] In some senses digital transmissions are easier to deal with since the bit error rate (b.e.r.) provides a good quantitative indication of how well the communication system reproduces the transmitted information. The b.e.r. produced by thermal noise is readily established for various kinds of modulation systems and is reproduced in several textbooks. As far as impulsive noise is concerned we need to establish what methods exist for expressing the properties of the noise, and to what extent these methods provide information which is directly useful in predicting performance degradation of communication systems.

Ignition interference will be used as an example of impulsive noise in this paper, which consists essentially of two parts—a discussion of parameters suitable for the characterization of this kind of noise, and design considerations for equipment suitable for the measurement of these parameters and the effect of equipment characteristics on the measured parameters. In general it is the noise envelope which is of interest.

2 The Nature of Impulsive Noise

As an example of the manner in which impulsive noise is generated and radiated, we consider the noise from motor vehicles. Although this arises mainly from the ignition system,[4] there are also contributions from the alternator, starter motor and ancillary electrical equipment.[5] A typical vehicle ignition system is shown in Fig. 1. The sequence of events which leads to radiated interference is that initially the contact breaker points open, interrupting the flow of current in the primary of the ignition coil and inducing a voltage of about 15 kV in the secondary. Within a few milliseconds the spark plug gap breaks down and ignites the air/fuel mixture in the cylinder. The plug gap arc persists for less than a microsecond, sustaining in the secondary wiring a time varying current which is a function of the various resonances in the circuit. The primary current begins to flow again when the contact breaker points reclose to begin the sequence anew for the next cylinder.

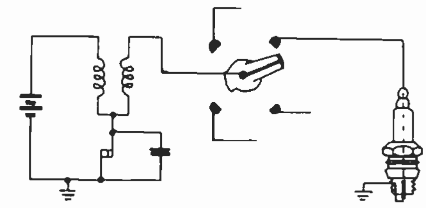

Fig. 1. Automotive ignition system.

Because of the breakdown of air gaps and the abruptness with which the various circuit capacitances charge and discharge, the currents flow in the form of impulses. The conductors carrying the currents then act as antennas and energy is radiated. The energy is spread widely over the spectrum at a level which is dependent on the radiating efficiency of the vehicle wiring and its surroundings, i.e. the engine compartment equipment, the compartment geometry, the road surface etc., at that particular frequency. The frequency characteristic is very irregular and the field in the vicinity of the vehicle varies both with frequency and the angle from which the vehicle is viewed.[5]

Successive plug firings in a particular vehicle do not yield impulses of the same amplitude, neither do successive firings of the same plug. There are variations of as much as 30 dB and because of this the noise radiated by a single vehicle varies with time. Even more important perhaps is the fact that different but similar vehicles can produce widely differing noise levels. From more than one source there is evidence that there is a small percentage of 'supernoisy' vehicles[3] which radiate noise more than 25 dB above that of the median vehicle. There appears to be no established reason for this; clearly these vehicles are major contributors to the overall noise, but whether they are inherently noisy, or just old and/or badly maintained remains unknown.

3 Characterization of Impulsive Noise

One unfortunate aspect of impulsive noise characterization is the apparent lack of any agreement among various research workers about the techniques of measurement and the relative usefulness of the parameters for characterization. The situation becomes more complex due to non-stationarity in the noise data, as any statistical model evolved may not be valid for all situations. It appears that a promising approach is to try to correlate the measured parameters with the environmental conditions under which the measurements have been carried out.

In the case of noise in urban areas, these conditions include traffic density, distance of the monitoring vehicle from the traffic flow, situation of the vehicle with respect to traffic lights etc. Once this correlation is established, then the problem of non-stationarity may be resolved and the performance of a communication system may be predictable (using certain approximations) given the general environmental conditions under which the system is operating.

3.1 Measurement Parameters

In order to provide a starting point for a discussion of suitable ways to characterize impulsive noise let us adopt a very simple physical model in which the pulses are very narrow, as shown in Fig. 2 and are described by

$$A_T(t) = \sum_{m=1}^{k} A_m \delta(t - t_m).$$

We do not lose generality by assuming positive-going pulses only, since after an impulse has passed through a band-pass filter operating at r.f. it is not possible to determine its original polarity. At the output of a band-pass filter, therefore, the waveform will be as in Fig. 3(a) with a random carrier phase, and the detected waveform will be as shown in Fig. 3(b).

We note that there may be secondary responses, these being dependent on the impulse response of the filter, and there may be overlapping, as between the third and fourth pulses.

Let us assume that we are interested in the magnitude (envelope) of the noise, and list some factors which can be measured; and which provide relevant information:

(a) mean or average voltage,
(b) peak voltage,
(c) quasi-peak voltage,
(d) r.m.s. voltage,
(e) impulsiveness ratio,
(f) amplitude probability distribution (a.p.d.),
(g) pulse height distribution (p.h.d.),
(h) noise amplitude distribution (n.a.d.),
(i) level crossing rate (l.c.r.),
(j) pulse duration distribution (p.d.d.),
(k) pulse interval distribution (p.i.d.).

The above list is not exhaustive; it illustrates that there

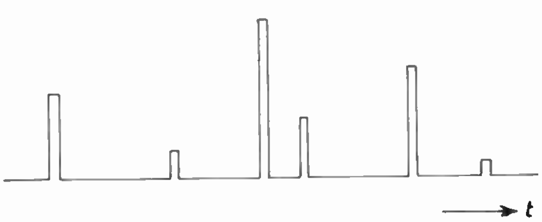

Fig. 2. Elementary model of impulsive noise.

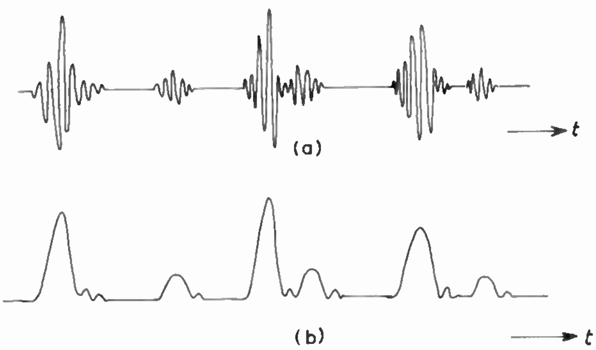

Fig. 3. Response of typical receiver to the noise of Fig. 2. (a) i.f. output, (b) detected output.

are a number of quantities that can be measured and it remains to establish the relative usefulness of these quantities for various purposes. For example, peak voltage is useful to determine whether or not a particular area or object is a source of radio noise. It is no good for characterization of ignition noise which is postulated to consist of numerous peaks of random amplitude. Impulsiveness ratio is useful in comparing the noise from two different kinds of sources, e.g. car ignitions and power lines, and may allow the conclusion that one is more or less impulsive than the other. It is used as a measure of impulsiveness at h.f. and below, and its value is used to define a certain shape a.p.d. in Ref. 6. However it is unlikely to be useful on its own as a measure of v.h.f. ignition interference because in that case the a.p.d. varies with both traffic density and traffic pattern and its shape cannot be adequately described by a single parameter. Average or mean is useful for giving a general indication of the level of background noise in any given area and allows a comparison of industrial, urban, suburban and rural regions.

The most common single parameter used for characterization is the quasi-peak value, and the use of the quasi-peak voltmeter has grown to such an extent that most Administrations now specify it as the method of measurement for regulatory levels of conducted or radiated noise. The original reason for the development of the quasi-peak meter was to try to compensate for an undesirable feature of the peak detector—that its response is insensitive to pulse rate for pulse rates greater than a few pulses per second. The specifications for quasi-peak meters to be used in different frequency ranges are contained in various CISPR publications[7, 8, 9] but essentially they have a charge time-constant much longer than that appropriate for a peak detector and a discharge time-constant much shorter, so that their response is a function not only of impulse strength, but also of impulse rate. The quasi-peak method recognizes that the noise output from a receiver has a joint probability distribution involving amplitude and time, and this is a fundamental point.

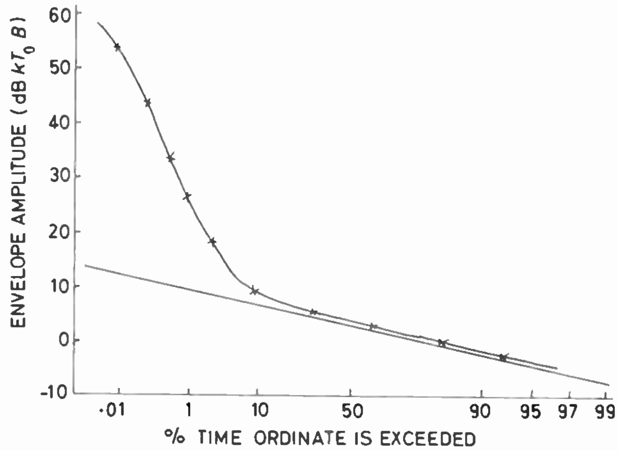

Fig. 4. Typical amplitude probability distribution.

There are two other methods of characterization which recognize time as an important factor in impulsive noise. The amplitude probability distribution is usually plotted on Rayleigh graph paper and shows the percentage of time for which the noise at the output of a receiver exceeds any particular level. The ordinate is usually expressed in dB above kT_0B, and in order to interpret a.p.d. it is necessary to know the characteristics of the receiver used to make the measurement, since bandwidth and filter response can affect the a.p.d. shape. A typical a.p.d. is shown in Fig. 4. The a.p.d. gives the 'first-order' statistics of impulsive noise, that is, it allows a determination of the overall fraction of time for which the noise exceeds any particular value. It gives no information about how this time was made up, i.e. whether the value was exceeded by one pulse, or ten, or a hundred. This kind of information is given by the noise amplitude distribution (n.a.d.).

The n.a.d. is a method of presenting impulse noise data in a form which gives a large increase in information over that provided by the quasi-peak detector. It provides a method of estimating the noise at the *input* of the receiver, rather than at the output, this estimate being independent of the bandwidth, and to a large extent the characteristics, of the equipment used to make the measurement. The n.a.d. concept also provides an empirical method[10] for determining the susceptibility of a communications receiver to impulse noise.

The information given by the n.a.d. is the number of pulses per second which exceed a given amplitude (or more exactly, contain more than a given energy). The ordinate is spectrum amplitude, expressed in μV/MHz (or dB above 1 μV/MHz), and the abscissa is pulse rate as shown in Fig. 5. There are advantages in expressing the amplitude in μV/MHz, firstly this is the unit normally found on impulse generators, and secondly since it is normalized with respect to bandwidth it allows a direct comparison with results for other bandwidths. The n.a.d. is not a probability distribution, it was originated (see Refs. 11, 12) as a means to extract information from radio noise in a form which allowed the evaluation of the effect of that noise on land mobile communication systems.

3.2 Performance Prediction

In the past, not all these parameters have been used directly for evaluating communication system performance. For example, no method seems to be available for using peak, quasi-peak, average or r.m.s. to evaluate error-rate in the presence of noise, and the use of these parameters is restricted mainly to specifying regulatory levels of noise. The impulsiveness ratio V_d can be used however and finds extensive application in some sophisticated error-rate prediction methods at h.f.[6] Noise amplitude distribution seems to be the most extensively used parameter for receiver evaluation [13–20] but unfortunately no single parameter is sufficient to provide a complete knowledge of the performance of a communication system in impulsive noise environments and this really suggests that any realistic model has to have more than two dimensions. The analysis of digital communication systems in the presence of impulsive noise in most of the literature assumes a Poisson distribution for the impulse arrival times. This implies that a second parameter which may be of some use in characterization and error rate prediction is a knowledge of the 'time of arrival' statistics. Some authors have used the amplitude probability distribution as a basis for the evaluation of communication system performance, and although the analysis may be complicated, some measure

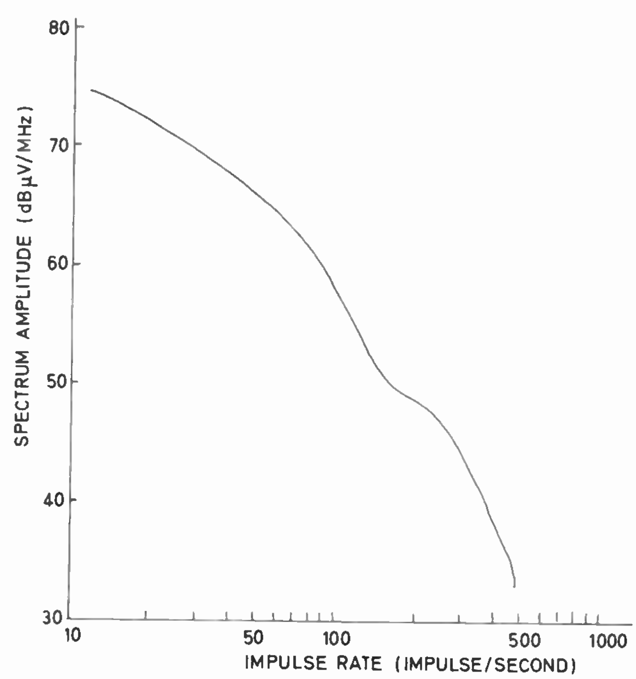

Fig. 5. Typical noise amplitude distribution.

of the noise amplitude such as a.p.d. is clearly a very important feature of noise characterization.

To gain some knowledge of the properties of noise with respect to time it is clearly of interest to measure the average rate at which the detected envelope crosses any particular level. This is known as the average crossing rate and gives information similar to that from the n.a.d. More detailed information can be obtained by measuring the pulse interval distribution, i.e. the probability that the time between crossings of a particular level will exceed a given value.

Finally, pulse-width measurements are desirable to obtain a measure of the arrival of bursts of impulses too close to be resolved by the measurement system (because of its finite bandwidth and/or its non-ideal impulse response). In general terms an output pulse-width longer than that dictated by the measuring system bandwidth indicates overlapping of impulse responses due to closely occurring impulses at the system input.

4 Measuring Equipment

Having decided the parameters that it is desirable to measure, it remains to specify the measuring equipment. Ideal measuring instruments and measuring systems have characteristics which do not influence the quantity to be measured. This ideal situation may not always be realizable, especially when the quantity is as complex as impulsive noise, and it is then important to be able to estimate the effects of the measuring equipment on the parameters to be measured. These parameters have been discussed in the previous Section and in what follows we consider the various characteristics of a measuring equipment, and their effects, so that the requirements of equipment designed to make realistic measurements can be specified. It is particularly important to consider the effects of bandwidth, sensitivity, dynamic range, impulse response and type of detector.

4.1 Bandwidth Considerations

Man-made noise occurs mainly in the form of narrow pulses a few nanoseconds wide and if it were thought necessary and desirable to produce a characterization applicable to all possible system bandwidths, a measuring system with a very wide bandwidth would be necessary. For example, it is clear that a measuring system required to maintain the shape of the input noise impulses must have a bandwidth of several tens of MHz. Such an instrument would be expensive and difficult to use, and in a congested radio spectrum the concept is totally unrealistic because coherent interference would invariably be present within the bandwidth of the instrument.

In order to make a decision about a suitable bandwidth we consider whether it is necessary to preserve the shape of the input impulses at the system output, the availability of a wideband recording facility, and the cost of data analysis. In general it seems unnecessary to preserve the input wave shape and provided the measurement bandwidth is considerably larger than the likely communication system bandwidth the noise characterization is likely to be valid. The decision therefore rests on the proposals for the likely future use of the radio spectrum and since, with the obvious exception of television, most allocations are in relatively narrow channels, a measurement bandwidth of about 100 kHz seems to be adequate. Consideration of the second and third points also leads to a similar conclusion, since wideband recording equipment is very costly and data processing time can become excessive. As an example, if we use a post-detector bandwidth of 500 kHz, it is necessary to sample and record at a rate in excess of 1 MHz. The rate at which these samples can be accepted by a computer depends on the analogue-to-digital convertor speed and the computer cycle time and although any limitations here can usually be overcome by reducing the recorder playback speed, the time taken for the computer to accept the information is then several times longer than the original recording time. When added to the computer time needed for data analysis, this can lead to excessive data processing costs.

4.2 Dynamic Range Considerations

The dynamic range required of the measurement system is probably the most difficult parameter to assess, since it depends on both the bandwidth and the centre frequency of measurement. The reasons for this are as follows.

The mean magnitude of v.h.f. man-made noise has been measured at various frequencies, and has been found to decrease as the measurement frequency is increased.[21-24] In the UK this mean level is given by

$$N = 67-28 \log f \quad (N \text{ in dB}kT_0B).$$

This value is about 10 dB lower than that measured in the USA[25] and has been confirmed in a recent study.[26] At 80 MHz, therefore, the mean level is about 13·7 dBkT_0B.

The probability that the noise will exceed 60 dBkT_0B is about 10^{-5} in the h.f. range[27] and measurements of a.p.d. made at 50 MHz using a receiver bandwidth of 10 kHz indicate a dynamic range of over 80 dB between the 0·0001 and 99 percentiles. For bandwidths greater than 10 kHz, the required dynamic range will be larger, and this can be seen as follows. The peak amplitude of the impulse response at the receiver output is proportional to the energy in the input impulse. Let S be the power spectral density of the input impulse and B_1 be the measurement system bandwidth. The power input into the system is SB_1 and if the duration of the impulse

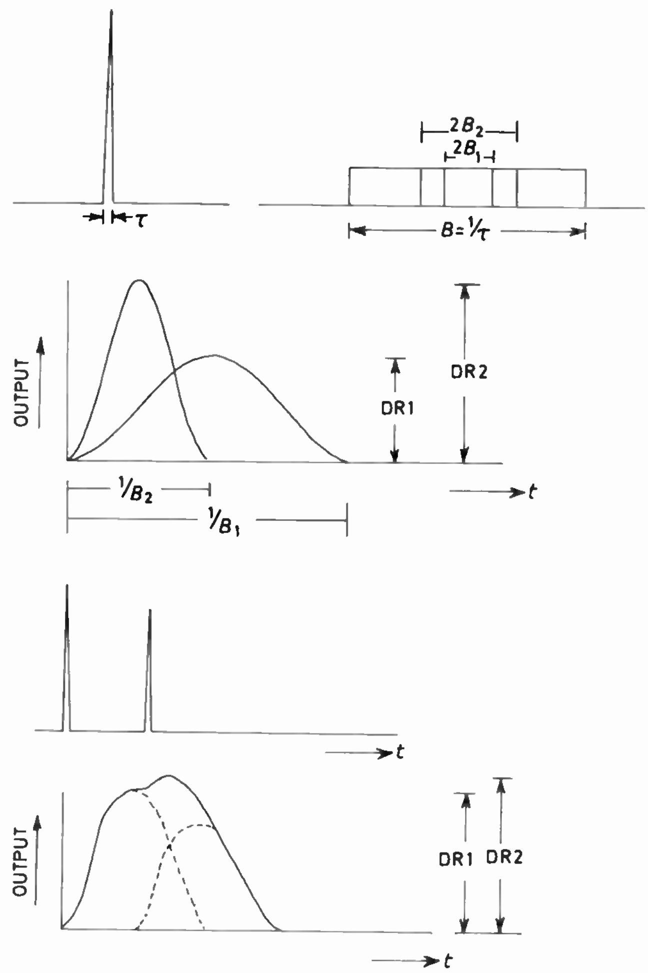

Fig. 6. The effect of system bandwidth and impulse response overlapping on the required dynamic range.

is τs, then input energy is given by $SB_1\tau$. If the system bandwidth is now increased to B_2, the input energy will be increased to $SB_2\tau$. With the same proportion the peak amplitudes of the responses will be given by (assuming that S and τ remain constant)

$$h_1 \propto \sqrt{(SB_1\tau)} \quad \text{and} \quad h_2 \propto \sqrt{(SB_2\tau)}$$

The dynamic range requirements have changed from $\sqrt{(SB_1\tau)}$ to $\sqrt{(SB_2\tau)}$ or by $10 \log B_2/B_1$ dB. This however is only an approximation since it does not take into account any change in dynamic range necessary due to the overlapping of impulse responses, an effect which increases as the bandwidth is reduced, as shown in Fig. 6. So, if the bandwidth is reduced, the full reduction in dynamic range given by the above expression cannot be realized since some allowance has to be made for the increased overlapping which is likely to occur. Considering the various points above, it seems that if it is necessary and desirable to cover the probability range 0·0001 to 99%, a dynamic range near 80 dB will be required.

4.3 Receiver Sensitivity and Noise Figure Considerations

The receiver sensitivity is a measure of the lowest signal that can be detected. However when measuring impulsive noise it is also necessary to cope with very high peaks, and the lowest detectable signal may be restricted by limitations in the dynamic range. Put another way, in a measuring system designed to cope with the highest peaks, the lower signals may be obscured by receiver noise unless the dynamic range is very wide. The problem is made worse by the fact that the amplitude of the highest peak is uncertain, but there are indications in the literature that in the bandwidths appropriate for this kind of application, a reasonable estimate of the peak level is 80 dB above kT_0B. If we are not interested in the very low levels of noise, which occur with high probability, then a very sensitive receiver is not necessary and a commercially-available receiver with a noise figure of about 10 dB and a dynamic range of 70 dB will be adequate.[28]

The receiver front-end gain should be such that its sensitivity is not degraded by local oscillator and mixer

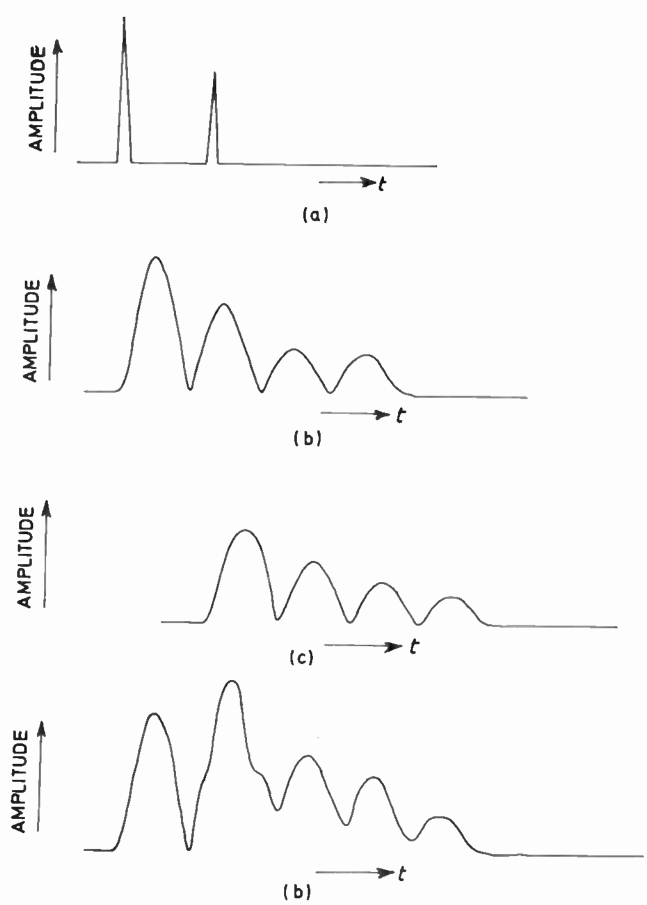

Fig. 7. The effect of time sidelobes on the ability of the system to resolve closely-spaced impulses.
(a) input impulses, (b) filter response to first impulse, (c) filter response to second impulse, (d) possible reconstructed output due to both impulses.

noise and receivers with front-end gains in excess of 20 dB are readily available. The overall gain of the receiver is dependent on the minimum detectable signal and the detector characteristics. Clearly, non-linearities in the detector should be avoided and thus the knee voltage of a detector should provide the output for the minimum detectable signal. The necessary gain can therefore be calculated, and in practice an overall pre-detector gain of about 80 dB is required.

4.4 Impulse Response Considerations

Impulse response may be the most important parameter of the impulsive noise measurement system. Limitations in the other parameters such as dynamic range and bandwidth still allow results to be obtained, but limitations in system impulse response result in fundamental modifications to the noise parameters themselves. The ideal impulse response for a measurement system is one in which there is no ringing, such as may be obtained from a Gaussian filter. The presence of ringing or time side-lobes may seriously affect the capability of the system to resolve low amplitude impulses which follow very high impulses. This is illustrated in Fig. 7. The various noise parameters are affected differently and the manner in which they are modified depends on the statistical properties of the noise. The extent to which errors occur in the measurements depends on the probability of occurrence of high amplitude impulses, and the way in which the individual parameters are affected is discussed in the following Sections.

4.4.1 *The effect of impulse response on a.p.d.*

The amplitude probability distribution (a.p.d.) is a measure of the fraction of time for which the noise exceeds any given level. If there is a time side-lobe in the impulse response, then the measured probability of exceeding lower levels will be enhanced. This arises because not only will there be a contribution from pulses at that level, but an additional contribution from the side-lobes due to high level impulses. The extent of the additional contribution may be estimated from a knowledge of the actual impulse response and the relationship between the numbers of high and low level impulses (the noise slope). As an example, consider an impulse response with a secondary response 30 dB below the main peak. If the noise slope is low, i.e. the probability of occurrence of impulses with an amplitude of, say, 60 dBkT_0B is of the same order as those with an amplitude of 30 dBkT_0B, (this is very unlikely to occur in practice) then the measured probability of exceeding 30 dBkT_0B is enhanced by a factor approaching 2, and there is significant error at the lower levels. If the noise slope is high, say the probability of exceeding 60 dBkT_0B is 0·1 of the probability of exceeding 30 dBkT_0B, then the measured probabilities at lower levels are enhanced by a much lower amount and the errors are much less. It can therefore be seen that noise slope plays an important part in determining the required impulse response, and if the noise slope is high an inferior impulse response can be tolerated.

In practice Disney and Spaulding[22] reported that the probability of impulsive noise exceeding its own r.m.s. value was 0·07, but the probability of it exceeding a value 40 dB above that level was reduced to 10^{-4}. Shepherd[27] measured the probability of v.h.f. automotive impulsive noise exceeding 25 dBkT_0B as 0·05 and of exceeding 65 dBkT_0B as 10^{-5}. We can therefore see that in practice, although the a.p.d. will be affected by impulse response, the errors caused by a time side-lobe about 30 dB or so below the main response will not be serious.

4.4.2 *The effect of impulse response on average crossing rate*

As has been pointed out above, the effect of a poor impulse response is to cause secondary impulses generated by ringing, and these are indistinguishable from genuine low-level impulses. There is therefore an increase in the crossing rates at low threshold levels, this increase depending on the crossing rate at very high levels and the number of significant time side-lobes. However, provided the increase at low levels is masked by the number of genuine impulses at these levels, the error in measurements is not significant. However the average crossing rates (a.c.r.) for high threshold levels (at the output) are not affected by the poor impulse responses, and in most cases it is the high-threshold data which is of greatest interest.

4.4.3 *Effect of impulse response on pulse width and pulse interval measurements*

Another effect of the time side-lobes present in the impulse response is to increase the measured pulse width and decrease the time interval between pulses. Again the low threshold levels are affected, but assuming a well-behaved noise slope the errors are insignificant.

5 A Practical Measuring System

A practical system for the measurement of man-made noise has been built around commercially available equipment.† The receiver has three selectable i.f. bandwidths (10 kHz, 20 kHz and 100 kHz in this case), a digital a.f.c. facility to lock the receiver to any desired centre frequency and plug-in r.f. heads to cover the frequency range 20 MHz – 1 GHz. The front-end gain

† ACL SR 209D Receiver; Philips Analog-7 tape recorder.

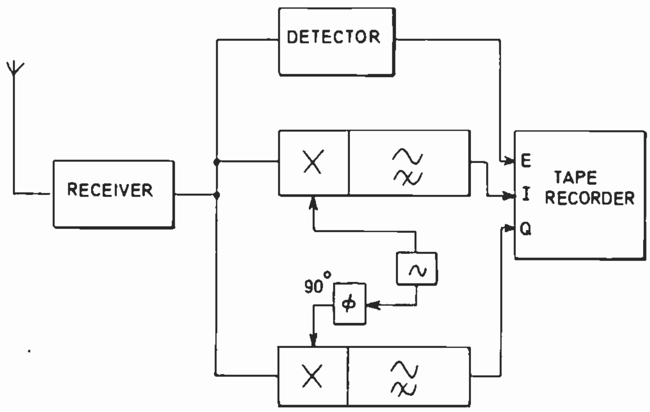

Fig. 8. Practical measurement system. E, Envelope, I, Q, Quadrature, synchronously demodulated outputs.

was typically 22 dB and the noise figure in the 80 MHz band was 4·4 dB. A block diagram of the system is shown in Fig. 8 and it can be seen that there are three recorded inputs, the envelope and two (I and Q) quadrature, synchronously demodulated inputs which can be used to derive phase information, or reconstruct the envelope. The dynamic range of the complete receiver from noise level to limiting was measured at approximately 40 dB, and this was considered to be rather low for the purpose envisaged. It was discovered that the front end dynamic range was 79 dB and that the limitation arose later in the receiver. The impulse response of the receiver was dependent on the bandwidth used but typically exhibited a secondary time side-lobe just over 30 dB below the main peak. We know that the presence of time side-lobes limits the system capability to resolve smaller amplitude impulses and this effectively limits the usable dynamic range to just over 30 dB.

As it stood, the receiver was considered to be unsatisfactory in two major respects, dynamic range and impulse response, and various methods of achieving an improvement were considered. As far as dynamic range is concerned the receiver front-end is satisfactory. In the signal-processing branches using synchronous demodulation (see Fig. 8) the dynamic range is effectively limited by that of the tape recorder, whereas in the envelope branch the impulse response is the limiting factor.

There are several ways to achieve an improvement in dynamic range, the most attractive being to insert an attenuator either between the aerial and the receiver or in the i.f. stages when measuring high-level noise, or alternatively to process the noise in two parallel branches with different gains. These alternatives are illustrated in Fig. 9. Effectively they all amount to looking at the noise data through two 'windows', the latter method having the advantage of looking through the two windows simultaneously but the disadvantage of a much larger capital cost. From an economic and technical point of view, the best method seems to be to place the attenuator in the i.f. section of the receiver. Placing it in this position is attractive because the receiver front-end has a sufficiently high dynamic range, and the use of i.f. attenuation only causes a marginal degradation in the receiver noise figure, as shown in the Appendix.

The effect of inserting an i.f. attenuator is to increase the measurement capability for high level signals, and this can be seen as follows. If an attenuator having an attenuation X (as in the Appendix) is inserted in the i.f. section of the filter (see Fig. 9(b)) then the output signal is reduced by a factor X and the input signal necessary to saturate the receiver output is therefore increased by X. However, provided the front-end gain is high the receiver noise figure is almost unaffected and the insertion of the attenuator has therefore effectively moved the *absolute* values of the signals which can be received up by an amount X without reducing the dynamic range significantly. In other words, by using a variable attenuator we can effectively slide a 'window' with a width equal to the unmodified dynamic range of the system up and down, and hence select any convenient portion of the input signal for reception. The limitation is that the inserted attenuation must not approach the value of the front-end gain otherwise the effective front-end gain is reduced with a consequent degradation in the receiver noise figure (as shown in the Appendix). Provided this limit is not approached the absolute range over which signals can be received is equal to the inherent dynamic range of the receiver plus the inserted attenuation.

Turning now to the case in point, when a receiver is subjected to impulsive noise with a dynamic range far in excess of the inherent receiver dynamic range, we look first at the situation when there is no inserted attenuation. In this case the high amplitude impulses tend to saturate the receiver and although this is not serious in itself, time sidelobes in the receiver impulse response will appear in the range being measured and can cause problems. However, if, as previously suggested, the number of pulses due to time sidelobes is swamped by the number of genuine pulses at these lower levels, measurement errors will be insignificant. For example, if a time sidelobe exists 30 dB below the mean peak of the receiver response, and at this level the impulse rate is 100 times the rate at a level 30 dB higher, the measurement error is 1%. When there is inserted attenuation the limiting factor is noise generated by those parts of the system which follow the attenuator and in the case now being considered, the most important is tape-recorder noise, which affects the lower level signals. This is overcome by arranging for the two 'windows' to overlap slightly and then ignoring information from the lower end of the upper window.

Basically the impulse response problem can only be solved by using better filters and Gaussian impulse response filters are ideal for this purpose. The point in

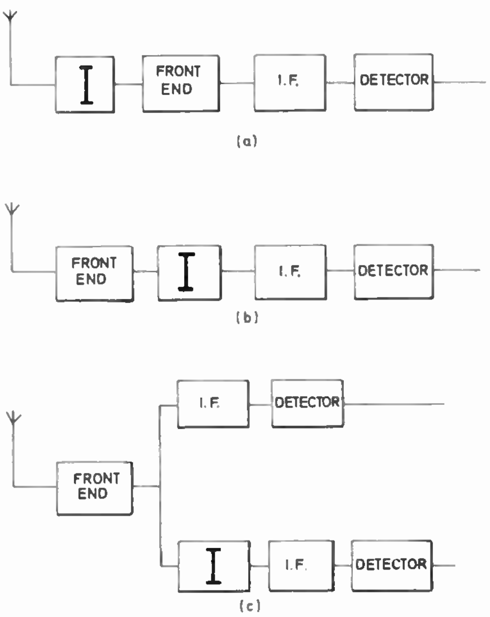

Fig. 9. Methods to improve the system dynamic range.
(a) attenuator between aerial and front-end, (b) attenuator between front-end and i.f., (c) dual i.f. system.

the system where these filters should be inserted is a matter for further consideration. The only intermediate frequency of the receiver accessible to the user is 21·4 MHz, but it is difficult to design a Gaussian filter with a centre frequency of 21·4 MHz and a narrow bandwidth. There are two possible approaches to the problem—either bring the i.f. to a value which is not higher than about ten times the required bandwidth and then use Gaussian filters, or use wider bandwidth filters at the existing i.f. and improve the impulse response at base-band. The first solution calls for a chain of i.f. sections and is therefore not attractive. The second alternative is more attractive as two quadrature channels were already constructed as shown in Fig. 8. Gaussian filters with bandwidths of 10 and 50 kHz were therefore designed in pairs for two quadrature channels. The system can be calibrated either in μV/MHz using an impulse generator or in dBkT_0B using a Gaussian noise source.

6 Conclusions

Impulsive noise occurs due to both natural and man-made sources, it occupies a large dynamic range and can be detected over a wide spectrum of frequencies. There are a variety of parameters which can be used for characterization, some of which find application in predicting system performance and others which are mainly useful in specifying regulatory levels of radiated or conducted interference.

Equipment designed to measure and record impulsive noise should have a wide dynamic range, preferably near 80 dB, a good impulse response and a bandwidth large compared to that of any likely communication system. However, if there are limitations in the measuring equipment, methods exist by which they can be overcome, so that realistic measurements can be made.

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9 Appendix: The noise figure of the measurement system when an attenuator is used.

We consider the two measurement systems shown in Figs. 9(a) and (b). The r.f. section of the receiver has a gain G_1 and a noise figure F_1, and the corresponding figures for the i.f. section are G_2 and F_2. The attenuator has an attenuation factor X, i.e. X = *power in/power out.*

Case I Attenuator following r.f. section (Fig. 9(b))

In this case the noise factor of the system is given by

$$F = F_1 + \frac{X[F_2 - 1]}{G_1}. \qquad (1)$$

If the input signal at the antenna terminals is S_i then the signal S_o at the i.f. output is

$$S_o = S_i \frac{G_1 G_2}{X} \qquad (2)$$

and the noise output N_o is given by

$$N_o = kT_oBF\frac{G_1G_2}{X} = kT_oB\frac{G_1G_2}{X}\left[F_1 + \frac{X(F_2-1)}{G_1}\right] \qquad (3)$$

The s.n.r. at this point is therefore given by

$$\frac{S_o}{N_o} = \frac{\dfrac{S_iG_1G_2}{X}}{kT_oB\dfrac{G_1G_2}{X}\left[F_1 + \dfrac{X(F_2-1)}{G_1}\right]} \qquad (4)$$

If the attenuator were absent then $X = 1$ and the s.n.r. would be

$$\frac{S_i}{kT_oB\left[F_1 + \dfrac{(F_2-1)}{G_1}\right]} \qquad (5)$$

The presence of the attenuator therefore causes a degradation in the output s.n.r. by a factor

$$\frac{\left[F_1 + \dfrac{F_2-1}{G_1}\right]}{\left[F_1 + \dfrac{X(F_2-1)}{G_1}\right]} \qquad (6)$$

which is always less than unity if $X > 1$. The amount of degradation depends upon the quantities involved, but if $G_1 \gg X$ the degradation can be very small.

Case II Attenuator preceding r.f. section (Fig. 9(a))

The signal level at the input of the receiver is reduced by an amount equal to the attenuation X, so the signal at the i.f. output is as given by (2)

$$S_o = S_i\frac{G_1G_2}{X}.$$

The output noise is given by the noise at the front end multiplied by the r.f. and i.f. gains, so

$$N_o = kT_oBFG_1G_2 = kT_oB \times \left[F_1 + \frac{(F_2-1)}{G_1}\right]G_1G_2 \qquad (7)$$

so that the output s.n.r. is

$$\frac{S_o}{N_o} = \frac{S_i\dfrac{G_1G_2}{X}}{\left[F_1 + \dfrac{(F_2-1)}{G_1}\right]G_1G_2kT_oB} \qquad (8)$$

$$= \frac{S_i\dfrac{1}{X}}{\left[F_1 + \dfrac{(F_2-1)}{G_1}\right]kT_oB}. \qquad (9)$$

Again, if the attenuator were absent the output s.n.r. would be given by (5), so it can be seen that in this case the output s.n.r. suffers a degradation equal to the attenuation.

There is therefore considerable advantage to be gained from using an attenuator after the r.f. section, provided the front end gain is high.

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