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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The Radio and Electronic Engineer

The Journal of the Institution of Electronic and Radio Engineers

Backing Research

RESEARCH in electronic and radio engineering, as in most other disciplines, costs money, whether it be carried out in a university laboratory, government establishment, or in an industrial research centre. Provision of support for both the manpower and the materials and facilities required should logically go together as happens in the government or industrial situation but often this does not apply in universities and polytechnics: the graduate with the bright idea which he (or she) wishes to pursue to obtain a higher degree, often has to seek separate sources of funding. First, a variety of available sources of facilities and material aid for the project itself must be explored and then funds to maintain the researcher throughout the project must be assured.

This Institution can now make a small but worthwhile contribution on this last count through the farsightedness of a former Vice-President, Leslie H. Paddle, who died in Canada three years ago. Mr. Paddle had a distinguished career in industry on both sides of the Atlantic, being for fifteen years a senior engineer with the Telephone Manufacturing Company, latterly as head of the Transmission Division at West Dulwich. Then, in 1950, he went to Toronto to look after his company's growing interests in North America until his retirement in 1966. As a founder member of the Institution, a member of its Council and subsequently as an overseas Vice-President and Chairman of the Canadian Divisional Council, Leslie Paddle was well aware of the importance of the research worker in advancing the art and science of electronic and radio engineering. In his will therefore he bequeathed $50,000 to the Institution specifically for the purpose of furthering post-graduate research in electronic or radio engineering by the establishment of a scholarship fund.

The award of the first Leslie H. Paddle Scholarship has just been announced and Mr Paddle would surely have fully approved the Trustee's decision. The award is to go to Mr Robin Alston of the Department of Electrical and Electronic Engineering at the University College of Swansea, who will be continuing the work on virtual instrumentation which formed the basis of a thesis for his master's degree.

The basic philosphy of virtual instrumentation is the replacement of dedicated hardware with a microprocessor and controlling software. The hardware is electronically configured and signals processed by the software provide the desired instrument functions and operation, the results being displayed graphically. The functions of the proposed virtual instrument include a multifunction generator, a dual-channel oscilloscope with storage, a meter for measuring several parameters, network and spectrum analysers, and a transient event recorder.

In his M.Sc. programme, Mr Alston worked closely with Wilmot Breeden Electronics (Wayne Kerr) and the company's support is promised for the continuation of the programme at Swansea. We shall thus see the coming together of diverse supporting bodies—the University College will provide facilities, an industrial organization will provide equipment and the benefit of its experience in instrumentation, and the IERE, through the Paddle Scholarship, will provide the topping-up of Mr Alston's grant from the Science and Engineering Research Council which is essential to support him during his three-year research programme.

The exciting nature of this project is surely a full justification of Leslie Paddle's benefaction in enabling the Institution effectively to back post-graduate research in electronic and radio engineering.

F.W.S.

NOMINATIONS FOR ELECTION TO COUNCIL

In accordance with Bye-Law 43 the Council's nominations for election to the 1981–82 Council were notified to Corporate Members in the June issue of the Institution's Journal.

FOR ELECTION AS PRESIDENT

Harry Edward Drew, C.B., Hon.C.G.I.A. (Fellow 1948, Member 1944) received his basic engineering training as an Apprentice in the Royal Air Force and later served at the Air Ministry Experimental Station at Bawdsey Manor. During the later war years from 1943 to 1946 he became Works Manager of the Radio Production Unit at Woolwich and then Officer in Charge of the Research Prototype Unit. After the war he moved to the Ministry of Supply HQ where he was Assistant Director of Electronics Production in 1951, and then Director in 1959. In 1964 he was appointed Director of Technical Costs and two years later he was promoted to the post of Director-General, Quality Assurance, in the then Ministry of Technology. He was made a C.B. in 1970. Following the recommendations of the Raby Committee, in September 1970 he was appointed the first Executive Officer of the newly formed Defence Quality Assurance Board, the post he held until his retirement from the Civil Service in January 1972. He was founder chairman of the European Components Quality Assurance Committee (ECQAC) from 1970 to 1975, and was instrumental in having BS 9000 recommendations accepted in Europe.

Since his retirement Mr Drew has held several directorships in industry and is currently a director of Export Packing Services (R&D) Ltd and of Quality Audit and Advisory Services Ltd; he is also an independent industrial consultant.

Mr Drew has taken an active part in Institution affairs for many years. He was a member, and subsequently Chairman, of the Membership Committee and he served for several years as a member of Council. He was a member of the Finance Committee from 1965–69 and Vice-President 1979–81. Mr Drew is an Honorary Fellow and Past President of the Institution of Industrial Managers, a Vice-President of the Institution of Works Managers, a Fellow of the Institution of Production Engineers, and a Companion of the British Institution of Management. He is also a Past Master of the Worshipful Company of Scientific Instrument Makers and in 1974 an Honorary City and Guilds Insignia Award was conferred upon him.

FOR RE-ELECTION AS VICE-PRESIDENTS

Professor James Roderick James, B.Sc., Ph.D., D.Sc., F.I.E.E. (Fellow 1975, Member 1960, Graduate 1956, age 48) is Research Professor in Electronics in the Department of Electrical and Electronic Engineering at the Royal Military College of Science.*

Prabhakar Keshava Patwardhan, M.Sc., Ph.D., F.I.E.E., F.Inst. P. (Fellow 1969, Member 1959, Graduate 1952, age 53) is a Senior Scientist at the Bhabha Atomic Research Centre; he is the Institution's National Representative in India.*

* See also September 1979 Journal

FOR ELECTION AS VICE-PRESIDENTS

Colonel William Barker (Fellow 1978, Member 1966, age 51) received his secondary and first technical education at Stockton-on-Tees while serving an apprenticeship at ICI, Billingham. 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. During National Service he became an instructor in radar and later, after a variety of Service courses, moved into the fields of guided weapons and communications. His later appointments included those of Grade 1 Staff Officer on Guided Weapons and Radar in HQ DGEME, 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 team in the Directorate of Systems Co-ordination, concerned with tri-Services rationalization.

Since leaving the Army Colonel Barker has taken up the appointment of Director of Engineering at the Services Kinema Corporation with technical responsiblity for its engineering and technical services activities worldwide including a wide variety of video equipment and audio visual aids.

Colonel Barker has been a member of Council since 1979 and he is currently chairman of the Recording Group Committee, a member of the Aerospace, Maritime and Military Systems Group Committee and of the Professional Activities Committee. He has also served on a variety of conference organizing committees and working parties.

Leonard Alfred Bonvini (Fellow 1969, Member 1963, Graduate 1958, age 49) has been with Government Communication Headquarters since 1965 where he has filled a number of posts concerned with the development and production of various specialized communications systems. After National Service spent as a radio instructor in the Royal Signals he joined the Radio Research Station (later the Appleton Laboratory) at Slough where he developed experimental techniques for propagation studies throughout the radio spectrum and was in charge of the ionospheric group at Singapore for two years.

Mr Bonvini served on the Institution's Technical Committee from 1965 to 1971 and on the Communications Group Committee from 1968 to 1972. Since 1971 he has been a member of the Papers Committee and was its chairman from 1977 to 1980.

Major-General Henry Ernest Roper, C.B., B.Sc. (Eng.), F.B.I.M. (Fellow 1978, Member 1953, age 58), joined the Royal Signals in 1942. His last two appointments were Chief Signal Officer, British Army of the Rhine, and Assistant Chief of the General Staff (Operational Requirements). Previous appointments included that of UK Director of Project Mallard. He was earlier on the Directing Staff of the Royal Military College of Science, Shrivenham, where he had gained his degree from London University and took the Technical Staff Course in Fire Direction. General Roper was appointed a C.B. in 1976. He was with Standard Telephones and Cables as Manager, Military and Public Sector, Marketing and is now with Plessey Defence Systems as Director and General Manager, Project Ptarmigan.

Derek Leslie Anthony Smith, B.Sc. (Eng.) (Fellow 1971, Member 1956, Student 1947, age 59) joined Addison Electric Co (now part of the Muirhead Group) as a Development Assistant in 1946 following service in the RAF as a Wireless Operator-Mechanic and as an Instructor. He was later with TCC and then for four years with EMI as a project engineer working on magnetic recording development; he was co-author of a paper to the Institution in 1956 on stereophonic recording and reproduction. During this period he completed part-time evening study for a London University External degree. Subsequently he went to Furzehill Laboratories Ltd, as Deputy Chief Engineer, and two years later, in 1958, moved into technical education. A number of patents and technical papers have been published by him.

Before appointment to his present position of Principal of Acton Technical College in 1970, Derek Smith held posts of increasing seniority at the Colleges of Technology at Hatfield (1958–59), West Ham (1959–60), Twickenham (1960–64) and Southall where he was from 1964 to 1968 Head of the Electrical Engineering Department and from 1968 to 1970 Vice-Principal.

Mr Smith has a fine record of service to the Institution: as an examiner for the Graduateship Examination in Electronic Measurements; as a moderator; as a member of the Education and Training Committee for eleven years, the past five as Chairman; a member for the past six years of the Professional Activities Committee; as a representative on a BSI Technical Sub-Committee, on the Joint Committee for HNC and HND in Electrical and Electronic Engineering, on the former CEI Standing Committee A, and on the present CEI Training and Experience Committee.

Group Captain James Martin Walker, MRAeS, RAF (Fellow 1981, Member 1966, Graduate 1957, Student 1956, age 46) took up his present appointment as Deputy Director of Signals 3 (Air) in the Ministry of Defence, London, in December 1977. Before joining the RAF as a National Serviceman in 1956 he was with EMI Engineering Development. In addition to further training at the RAF Technical College and RAF Staff College, he has served in a variety of communications-electronics, avionics and engineering staff posts in UK and overseas. Since 1972 he has been OC Engineering Wing, RAF

J. R. JAMES

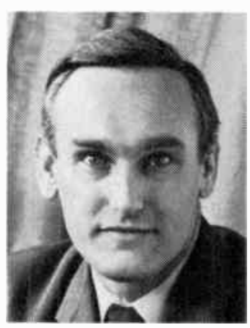
P. K. PATWARDHAN

W. BARKER

L. A. BONVINI

H. E. ROPER

D. L. A. SMITH



J. M. WALKER

Linton-on-Ouse, Chief Instructor, Electrical Engineering Wing, RAF College, Cranwell, and Officer Commanding & Commandant, No 1 Radio School, RAF Locking. Gp Capt Walker has previously served on the Council of the IERE and has served on the Membership Committee for the past six years. He has represented the IERE on the Chartered Engineer Section Board of the Engineer Registration Board since its formation in 1978.

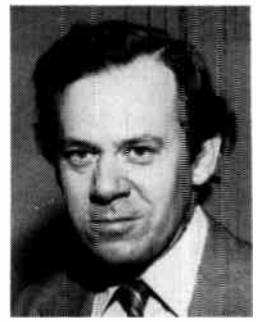
FOR RE-ELECTION AS HONORARY TREASURER

Sydney Rutherford Wilkins (Fellow 1942, Member 1935, Associate 1934, age 69) is Managing Director of Fleming Instruments Ltd. He was first elected Honorary Treasurer in 1973. (See Journal for September 1972.)

S. R. WILKINS

L. W. BARCLAY

G. A. McKENZIE



V. MALLER

FOR ELECTION AS ORDINARY MEMBERS OF COUNCIL
Class of Fellows

Leslie William Barclay, B.Sc. (Fellow 1967, Member 1960, Graduate 1955, age 48) has worked in the field of ionospheric radio wave propagation since 1956. He started his professional career in 1950 with E.K. Cole, Southend-on-Sea, initially as a student apprentice and later working in the television research laboratory. During this period he obtained a London University external degree in physics and mathematics as a result of part-time studies at Southend Municipal College and he subsequently took Higher National Certificate examinations with endorsements to gain exemption from the Institution's Graduateship Examination.

In 1956 Mr Barclay joined the Royal Society's Antarctic expedition as an Ionospheric Physicist, and before and during the International Geophysical Year he spent some two years at Halley Bay setting up and operating an ionospheric sounding station. He returned to the Radio Research Station at Slough to analyse the results and prepare a report on the work and he was awarded a Polar Medal for contribution to knowledge of the Antarctic. In 1960 he joined the Propagation Field Studies Section of the Research Division of the Marconi Company and established a prediction and consultation service for m.f. and h.f. In 1966, following re-organization of the Research Division, he was appointed chief of the Ionospheric Propagation Section. Mr Barclay joined the Directorate of Radio Technology of the Home Office in May 1977 and he is now head of Space and Propagation Branch.

For a number of years Mr Barclay has been an active member of the British Delegation to CCIR Study Groups concerned with ionospheric propagation and since 1978 has been International Chairman of Study Group 6 (Propagation in ionized media). He has written numerous papers in scientific and technical journals; these include a paper on 'Reception of BBC television sound transmissions on 41·5 Mc/s at Halley Bay, Antarctica' which was published in the Institution's Journal in January 1961. He was Guest Editor of the special issue of the journal on Ionosphere Radio Wave Propagation in January 1975. Mr Barclay has been a member of the IERE Papers Committee since 1968 and he is currently its Chairman; he has also served on the Communications Group Committee for several years.

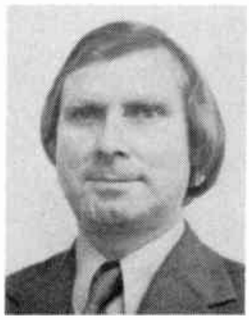
George Alexander McKenzie, B.Sc. (Fellow 1968, age 54) joined the British Broadcasting Corporation in 1943 as a Technical Assistant in the Operations and Maintenance Department (Studios). After three years National Service in the RAF as a Radar Fitter, he returned to the BBC in 1949 with whom he remained for some 10 years as a Development Engineer in the Designs Department, working mainly on sound studio apparatus and telefilm. During this period he studied part-time at the Polytechnic, Regent Street, and at the Northern Polytechnic for an external B.Sc. degree of London University which he was awarded in 1953. The next nine years Mr McKenzie spent in industry: first with Plessey as a Principal Engineer on underwater detection systems, next as Chief Development Engineer with Epsylon Industries working on closed circuit television and magnetic tape instrumentation systems, then as Chief Engineer of a Division of Elliott Automation concerned with flight recording and analysis systems, and finally, from 1966 to 1968, with Plessey Radar as Chief Systems Engineer for computer-aided radar data processing and display systems. Since 1968 Mr McKenzie has been with the Independent Broadcasting Authority as Head of the Automation and Control Section in the Experimental and Development Department. He has served on the Communications Group Committee since 1978.

Victor Andrew John Maller, M.A. (Fellow 1971, age 43) read natural sciences at Clare College, Cambridge and after graduating worked for two years on radar and guided missile control systems as a Scientific Officer in the Royal Naval Scientific Service. In 1962 he joined the then International Computers and Tabulators and is now Manager of the Research and Advanced Development Organization of ICL. Until 1971 Mr Maller worked on superconducting computer devices, integrated circuit packaging, design automation, digital magnetic recording and magneto-optic recording. In 1971 he changed his field of interest from device techniques to systems technology and in particular to associative processing where he led an inter-disciplinary research group comprising hardware, software and language specialists investigating new architectures for data management. He has been a member of the IERE Computer Group Committee since 1977. Mr Maller has on several occasions contributed papers to IERE conferences, the most recent being a joint paper at the 1973 conference on Video and Data Recording entitled 'A simplified model of the writing process in saturation magnetic recording' which was subsequently reprinted in the Journal.

Professor Kenneth Graham Nichols, B.Sc. M.Sc., (Fellow 1967, Member 1960, age 53) was appointed to a chair in electronics at the University of Southampton in April 1974 and in 1979 he was appointed head of department for a five-year period. After graduating from the University of London he held industrial and technical college appointments before going to Southampton as a lecturer in 1961; he was appointed to a readership in 1970. In 1976 he spent a year as IBM Fellow at the Hursley Park Research Laboratories. He has contributed numerous papers to this and other journals and is author or joint author of four books, the most recent, 'Theory and Practice of Microprocessors', having just been published.

Professor Nichols was a member of the Council from 1973 until 1976 and he has served on the Education and Training Committee for many years as well as on the organizing committees for national and regional conferences. A new Information Technology Group is to be formed under his chairmanship and he is now a member of the Professional Activities Committee.

K. G. NICHOLS



P. ATKINSON

R. B. MICHAELSON

FOR ELECTION AS AN ORDINARY MEMBER OF COUNCIL
Class of Members

Peter Atkinson, B.Sc. (Eng.) (Member 1962, Graduate 1961, age 48) graduated with honours in electrical engineering from Imperial College, London, in 1955 and both as a postgraduate apprentice and subsequently as an engineer, he gained industrial experience with the guided weapons division of English Electric. From 1959 to 1962 he was a Lecturer in electrical engineering at North Herts Technical College and, from 1962–64, a Senior Lecturer in control engineering at the College of Technology, Letchworth. In 1964, Mr Atkinson became a Lecturer in control engineering at Reading University, a founder member of the Department of Engineering and Cybernetics (formerly the Department of Applied Physical Sciences), and is now a Senior Lecturer in the Department of Engineering designated Course Director for the proposed new four-year enhanced degree course in Mechanical Engineering.

He is the author of two text-books, and many technical papers, for two of which he has received Institution Premiums, and he holds several patents.

Mr Atkinson is an active member of the Institution, having been Chairman of the Thames Valley Section from 1972 to 1975, and he served on the Examinations Committee and on the Academic Standards Committee for several years. He is at present Chairman of the Automation and Control Systems Group Committee and a member of the Professional Activities Committee.

FOR ELECTION AS AN ORDINARY MEMBER OF COUNCIL
Classes of Honorary Fellows and Companions

Robert Bernard Michaelson (Companion 1979, age 38) is Chairman and Managing Director of MMG Associates, an electronic and electrical product marketing business specializing in computer and data processing which he founded in 1979 at Great Malvern. Mr Michaelson's career started in medical electronics as a Junior Technician at the MRC Radiotherapeutic Research Unit at Hammersmith Hospital, London. From 1961 to 1964 he worked as a sound recording engineer, for a time on a freelance basis, and in 1964 he joined GEC Electronics, later becoming a sales engineer concerned with data links and teledata with Data Dynamics. For five years he was a Senior Sales Executive with Honeywell Information Systems and in 1976 he joined Logica, first as Sales Manager and subsequently became General and Divisional Manager of Logica Data Systems. In 1978 he formed Danwood, a computer systems programming and consultancy organization, part of whose activities he transferred to his present company.

Mr Michaelson is a Member of the British Computer Society and a Fellow of the British Institute of Management. He has been associated with several Institution Conferences and was chairman of the organizing committee for the Conference on 'The Electronic Office'; he is a member of the newly formed Information Technology Group Committee.

The 55th Annual Report of the Council of the Institution

For the year ending 31st March 1981

The Council is pleased to present the 55th Annual Report of the Institution—the 20th since its Incorporation by Royal Charter. The Annual General Meeting will be held on Thursday, 29th October 1981, at the London School of Hygiene and Tropical Medicine, commencing at 6 p.m.

INTRODUCTION

THE Institution's 55th year was overshadowed by the sudden tragic death of the President, Mr John Powell, T.D., M.Sc., on 11th January 1981. So great was his interest and enthusiasm when he took office and delivered his Presidential Address in October 1980 that it is hard, even now, to appreciate how ill he must have been at that time. And those members who are aware of the extensive programme of visits that he insisted on planning at the start of last Winter's Session can only further marvel at the courage and determination of the man. He filled the Office of President with diligence and dignity and is greatly missed. Such was his Council colleagues' affection and respect for him that they decided not to elect another President until the end of John Powell's year, but rather to ask Professor William Gosling, D.Sc., A.R.C.S., the Immediate Past President, to fill the vacancy as Acting President until the next Annual General Meeting. John Powell's obituary was published in the March 1981 issue of *The Radio and Electronic Engineer*.

Much of the work of the Council and Executive Committee during the year under report has been concerned, once again, with the politics of the profession and the aftermath of the Finniston Inquiry. Council, President and Secretary have all been active on the many facets of the debate on these matters with other Institutions and Government Departments concerned with the composition and terms of reference of the proposed British Engineering Authority. The Education and Training Committee has been similarly occupied as can be seen from the detailed account of its work set out later in this Report. All of which activity, it is hoped, will be shown to have been worthwhile by the final outcome of this acrimonious and long-drawn-out debate. It has to be said, however, that the omens were not good as the year drew to a close. It began to look as if there was little prospect of the Government's preferred solution being in any way competent to achieve the prime aim of the Finniston Report, namely, to bring about the fundamental shift in national priorities at many levels and in a wide range of different settings, which will reflect the greater acknowledgment of the crucial need of competitive manufacturing industries, and of the key role of the engineering dimension in that context, to enhance national prosperity and welfare.

But to conclude this introduction on a more practical note, members' attention is drawn particularly to the Treasurer's Report and the Annual Accounts for the year ended 31st March 1981, from which it can be seen that despite major increases in the cost of a wide range of bought-in goods and services essential for learned society work, compounded by the adverse effects of the recession on conference activity in general, the Institution managed to cope within its budget for the second year of present subscription levels. Mid-year figures having indicated quite clearly that additional subscription income would have to be generated to cover continuing inflation in the coming year, however, Council decisions to achieve this were taken at the October 1980 Meeting and will take effect in April 1981, as reported in the January 1981 issue of the Journal.

EXECUTIVE COMMITTEE

The Profession. Towards the end of the year covered by the last Annual Report, the Secretary of State for Industry published the report of the Committee of Inquiry into the Engineering Profession, and invited comment from those bodies which might be affected by any changes which could arise therefrom. Whilst the Institution's response welcomed in principle the major proposals made by the Finniston Committee, it was felt necessary to express some reservations, particularly concerning the composition of the proposed statutory 'Engineering Authority', and in the preservation of the qualifying role of the chartered engineering institutions for registration.

In the event, the Secretary of State decided that this 'Engineering Authority' should not be set up as a statutory body but should function under the authority of a Royal Charter, a first draft of which was drawn up and published by the Department of Industry. The DoI then arranged a series of meetings with organizations concerned with the profession, which continued during the year, and which resulted in a series of revised versions of the proposed Royal Charter. Progress eventually was such that the latest of these drafts (3rd March 1981), it was hoped, would be generally acceptable, provided that (a) it was agreed that to be registered as 'C.Eng.' an engineer must be in corporate membership of a chartered body, and (b) it was confirmed that a majority of the membership of the Board must be professional engineers.

A meeting under the chairmanship of the Secretary of State, attended by the Chairman of CEI, the President of the Fellowship of Engineering, the Presidents of the corporation members of the CEI and representatives for the DoI was held on 24th March 1981, which had been a constructive and useful stage in a continuing dialogue. Discussions would continue in the light of these exchanges and were still in progress as the year ended.

Appointment of an Acting President. Following the sad death of the Institution's President, Mr John Powell, on 11th January 1981, the Executive Committee was obliged to consider the constitutional issues arising, and first unanimously agreed that the Immediate Past President, Professor William Gosling, should be invited to be nominated for appointment as Acting President for the remainder of this Presidential year. Professor Gosling kindly accepted and his appointment in this capacity was subsequently endorsed by Council.

It was further decided that it would be helpful in the circumstances to appoint an additional Vice-President who was readily available in London and qualified to deal with important matters as they arose, and to attend policy meetings, etc., when Professor Gosling was not free to do so himself. Council approved this recommendation and agreed that the Institution's Secretary, Air Vice-Marshal S. M. Davidson (Vice-President 1973–74 and 1976), should be appointed as an Executive Vice-President for the remainder of the Presidential year.

The nomination of Brigadier R. W. A. Lonsdale (Vice-President) as the Institution's representative on CEI Standing Committee 'B' was approved, while visits to Local Sections and outside bodies, which Mr Powell had intended to carry out, would be undertaken by the Acting President or a Vice-President who could make himself available at the appropriate time.

Designatory Letters for Associate Members. Corporation members of CEI with a grade of membership established to accommodate Technician Engineers had supported a proposal formally put forward first by the Institution of Production Engineers that these members should be enabled to identify the nature of their discipline by the use of designatory letters: A.M.I.'X'.E. It had been expected that the required Privy Council approval for this measure would have been extended to all engineering Institutions whose Royal Charters and Bye-laws make provision for this class of membership. However, this had not been the case, hence it would be necessary to apply individually for authority to amend the Institution's Charter and Bye-laws. Council having approved that this facility should be available to Associate Members it is intended to put a formal resolution for its adoption to the next Annual General Meeting.

Overseas Affairs. Although the world-wide recession and the high value of the Pound Sterling has tended to hold down the general scale of Institution activity overseas, the Hong Kong Section has continued to make steady progress in both membership levels and quality of learned society work. Effort is still being devoted to the Committee's plan to establish a new Section in Singapore/Malaysia and new interest has been shown in the need for some form of co-ordinated Institution activity in the Republic of Ireland.

The Executive Committee is also pleased to report that the adverse financial climate has not damaged the level or rate of sale of IERE journals and publications overseas—a sure sign that these learned society products on which so much of our effort is spent are still held in high regard throughout the world.

As to the Institution's participation in the affairs of the international organizations representing the engineering profession, it is once again confirmed that our strong support of, and deep involvement in, the affairs of EUREL (Convention of National Societies of Electrical Engineers of Western Europe) has been maintained and that, through the CEI, the interests of the British electronic and radio engineer have been fully represented in the Councils of the Federation of European National Associations of Engineers (FEANI) and the Commonwealth Engineering Conference (CEC). Efforts made during the year to revive UK interest in the International Federation of Automatic Control (IFAC) have been fully supported by IERE and are to be continued in the coming year.

Scholarship Funding. It was a matter of considerable concern and disappointment to the Executive Committee that its efforts to award the first Leslie Paddle Scholarship in the year under report came to nought. Much interest was displayed in the award and several enthusiastic and technically appropriate applications were received, but none was feasible within the 1980 funding limits of the Scholarship. Attempts were made to find additional maintenance support for the most favoured candidates, without avail, due mainly to the Government restrictions on post-graduate student funding, which were being tightened even further at the critical time. The Scholarship is accordingly being offered again in 1981 at the higher level made possible by the additional income earned on the Fund's investments at the high interest levels of the past twelve months.

Finance. Last year, when we were able to report a substantial surplus of £36,456, we warned that this year's results would present a far less rosy picture. It will be seen that the accounts show a shortfall of £20,546 which follows the trend of recent years when continuing inflation inevitably catches up with us during the second year of our two-year subscription income cycle.

It is pleasing to note that despite the present economic climate which necessarily has its effect on the attendance at symposia and colloquia, the sales income figure has been held to within 3% of last year's record figure. Unfortunately, the costs associated with these activities—mainly publications printing and postage over which the Institution has no control whatever—showed an alarming increase of some £21,000 or over 17% for the year. Worth noting in this context is the expense figure of £8,000 which was an agreed loan towards the costs of launching *The Electronics Engineer* to be offset against advertising revenue. This has now been fully discharged and will not burden our expenses in future years. As a result of negotiations with the printers, we have been advised that the Journal printing costs increases for next year will be held to 7½%, effective from October 1981. Against this, however, we must expect a further increase in postal charges of between 15% and 17% during the year.

It is to the credit of the Secretariat that the administration expenses of the Institution have been kept within 15% of last year's figures despite heavy increases in several externally-provided services which have followed the market upwards and which are, of course, entirely outside our control. The additional £5,222 in Establishment expenses largely relates to costs arising within the terms of our premises rental agreement, whilst the additional £2,400 on our subscription to the CEI is a mandatory levy based on our Corporate and Associate Member strength.

The resulting £20,546 deficit for the year, whilst disappointing, still shows an excess of income over expenditure for the two-year period of nearly £16,000 and, as such, must be considered satisfactory. With the advent of the increased subscriptions, effective from 1st April 1981, and taking into account the factors outlined in this report, it is confidently expected that the figures for 1981–82 will show a substantial excess which will play its part in reducing still further our General Fund adverse balance.

PROFESSIONAL ACTIVITIES COMMITTEE

Throughout the period of the report, the economic pressures on Industry and Higher Education produced dramatic reductions in the responses to events organized as part of the Institution's programme of professional activities. The IERE was not alone in this respect, many other Learned Societies being even worse affected. However, the Professional Activities Committee was able to authorize changes in the management of events that reduced the adverse effects, the full benefits of which will be felt in the coming year.

Conference organizing committees have experienced a considerable drop in the number of papers being offered to them after the issue of a Call for Papers. This threat to the scope and standards of conferences has been countered by increasing the number of invited papers. It is proposed to hold at least one conference next year that consists entirely of invited papers. This approach allows a conference to be set up more quickly, an additional advantage in that it can be more topical.

The pattern of attendances at conferences has changed significantly in comparison with previous years. The total number of delegates at each event has dropped by 30–50%, while the proportion attending for one day only has risen markedly. The two-pronged attack on the financial returns from conferences has resulted in an increase in the amount of Institution funds placed at risk by the professional activities programme. Conference venues are now being chosen so as to minimize this risk, the use of hotels and commercial conference centres being increased with a corresponding reduction in the use of universities because of their very high cancellation and shortfall charges. One-day and two-day non-residential conferences are also being planned.

It is apparent that there is still a demand for conferences and colloquia when the topic is relevant to a potential delegate's immediate task. The Committee has therefore encouraged the extension of the Institution's professional activities into the publishing and tutorial fields. The first result of this will be the holding of a Tutorial Day immediately prior to the conference on Digital Processing of Signals in Communications to be held at Loughborough in April 1981. Initial indications are that both the tutorial day and the conference will prove to be successful events.

Conferences. The Institution held three three-day conferences during the year:

'Electronic Office' (April 1980, London Penta Hotel)
'Electromagnetic Compatibility' (September 1980, Southampton University)
'Microprocessors in Automation and Communications' (January 1981, London Penta Hotel)
and a one-day conference:
'Retraining in the Electronics Industry for the Microprocessor Age' (July 1980, London Penta Hotel)

A total of 574 delegates attended these conferences, a considerable drop compared with previous years. The implications of that fall-off, and the steps being taken to combat it, have already been discussed. The only conference to attract more than 200 delegates was that on Electromagnetic Compatibility, which also included a very successful in-house exhibition. A further EMC conference has been scheduled for September 1982.

London One-Day Events. Specialist Group Committees have continued to experience difficulties in attracting speakers for many of the colloquia that they would have liked to organize. As a result, the planned colloquia programme was severely curtailed, with only three events being held during the year. The events that were held were well attended and justified the retention of this form of professional activity within the Institution's overall programme.

Local Section Activities. During the year there were 124 Local Section meetings held, many of them being joint meetings with the IEE, IoP and others. Four colloquia were organized regionally—one by the Scottish Section, one by the Southern Section in conjunction with the Institution's Medical and Biological Electronics Specialized Group Committee, and two by the Thames Valley Section, one of these last being in association with a team from GEC Measurements Ltd. Student engineers were encouraged to present papers by the Northern Ireland Section in its annual Megaw Memorial Prize Competition and by the South Wales Section at a students' paper evening. The Kent Section Committee produced and circulated a single issue printed newsheet to stimulate the interest of local members. Reports reaching Headquarters indicated that although attendance at meetings varied considerably and some committees were concerned about the difficulties of enlisting support, most Section Officers felt that their efforts had been worthwhile and were looking forward to next year. There were no major section administration problems and the use of *The Electronics Engineer* to announce meetings has worked satisfactorily.

Representative Activities. Active support of the British Standards Institution and other external technical organizations and committees has continued throughout the year and thanks are due to all those members who have given their services to the Institution in attending meetings of these external bodies. Full details of Institution representation and committee membership are given in the Appendices to this report.

EDUCATION AND TRAINING COMMITTEE

Although the Committee continued to discharge a number of routine functions at its two-monthly meetings, the events of the year necessitated the allocation of much time and thought to considerations of the implications of the Finniston Report.

At its May meeting, the Committee approved the final drafts of the IERE submissions to the National Conference on Engineering Education and Training. These drafts were later accepted by Council, which invited Mr R. W. S. Hewitt (Training Manager, EMI Ltd., and a member of the Committee) to represent the Institution at the Conference. Several other members of the Committee also attended the Conference as delegates from other bodies and reported their impressions, in which the predominant element was one of disappointment. All shared the feeling that a golden opportunity to take a constructively critical look at engineering education in the UK had been missed: the time provided for discussion was inadequate and there were far too many prepared statements, often from entrenched positions. In this context it was noted by many who attended that in the Conference Report the recommendations on Theme 6 (Relationship with the Technician Support Base) have attached more weight to the written submissions than to the views expressed by Conference delegates.

Still in the Finniston context, the Committee considered the CEI proposals for an Engineers' Registration Council in lieu of the proposed British Engineering Authority. It thought the suggested Council likely to be more unwieldy and expensive to operate than the present CEI, noted that no positive recommendation was made in respect of the 'engine for change' to which the Finniston Report attached so much importance, and advised that the Institution should not support the proposals. Currently, members share the general concern at the time taken by Government to act on the Finniston Report's recommendations and the consequent uncertainty surrounding many matters with which it is concerned.

On the question of mergers and alliances between Institutions with similar interests as suggested by Finniston, the Committee considered draft proposals for a closer alliance with the Electronics Division of the IEE—possibly leading to eventual merger with that Institution. Most members appreciated the logic of the proposals; several, however, expressed unease about such matters as the difference in attitude of the two bodies to the academic element of an engineer's make-up and the lack of a Technician Engineer class of membership in the IEE, and urged that caution would be required if amalgamation were not to lead to abandonment of the very purposes and principles on which the Institution was founded and for which it still stands.

At its September meeting the Committee gave its customary consideration to the performance of IERE-sponsored candidates (542 in all) in the year's CEI examination. It noted the poor performance of both UK and overseas candidates in Part 1 of those examinations—in which the bogey subject is still 202 Mechanics. Although the number of candidates who passed or completed the Part 2 examination (53) was higher than in the previous year, members felt that the percentage of candidates to whom English is the natural language who fail subject 300 The Engineer in Society is so much higher than that of those who fail other subjects as to suggest that the examination is in some way unrealistic. As was noted in the previous Annual Report, the Working Group on CEI Part 2 syllabus revision has recommended that the syllabus for the paper in question should be revised, and that it should be separated from the rest of the examination and indefinite referment permitted. In view of the fact that the date for the introduction of the revised syllabus—originally to have been 1978/79—has still not been fixed, the Committee suggested to CEI that indefinite referment should be permitted immediately and retrospectively. No reply to this suggestion has yet been received. In addition to the candidates sitting the whole examination, there were 28 pre-1973 Graduate members attempting the two-subject CEI Part 2 Academic Test. Eleven of these passed, and so meet the academic requirements for transfer to the class of Member. The Institution also sponsored 7 'special candidates'—that is, persons whose qualifications it considered to justify exemption from the whole of the Part 1 examination and 2 or more subjects of Part 2. Five of these 7 candidates were successful in passing the subjects specified by the Institution.

The Committee has followed with interest the progress through the CEI machinery of proposals for the accreditation of engineering degree courses. It was pleased to note that the suggested introduction of an Honours requirement was not supported by Standing Committee 'A' and that the Educational Qualifications Committee continually stressed the need to make the accreditation procedure as simple as possible and to take care in phasing-in the introduction of the accreditation requirement to safeguard the future of students already following courses leading to awards which are currently acceptable, and to honour any undertaking given by individual Institutions in respect of courses accredited by them, even if a CEI assessor had not been involved. It had been expected that a CEI accreditation party, including an IERE assessor, would by now have visited Hong Kong, where the two Universities and the Polytechnic have requested accreditation of a number of engineering courses, including several of interest to this Institution. Unfortunately, because of unexpected organizational problems in Hong Kong, it has been necessary to postpone the visit, which it is hoped will now take place in October 1981.

In the last Annual Report, reference was made to the Committee's work on revision of the Institution's Training Regulations and the difficulty of providing the degree of flexibility in its training recommendations which the Institution believes the electronics industry needs, within the framework of the stereotyped requirements of CEI/ERB. Not until its last meeting of the Institution's year was the Committee sufficiently satisfied that a reasonable solution had been found to agree that the draft Guide to Employers, and draft Training Requirements for inclusion in the Membership Regulations, should be submitted to Council for approval. Because of the diverse needs of the great number of industries now employing electronic engineers, and the growing interdisciplinary nature of electronics, the Committee recommended that the mandatory requirements of the Training Regulations should be confined to those elements of training which are considered essential to the formation of a Chartered Electronic Engineer. Individual employers should be free to add to these, within the guidelines laid down in the proposed Employers Guide, training modules appropriate to their particular activities. The Committee hopes that at least the large organizations (both manufacturing and service) operating in the IERE's area of interest will co-operate by submitting proposed training programmes for approval—otherwise the task of assessment of the training received by applicants for membership will become unmanageable. It perhaps augurs well for the future in this respect that the Committee's first meeting of the year was held at the EMI Hayes factory where, after completing their business, members were entertained to lunch by Dr P. A. Allaway (then Chairman of CEI) and later visited the display of apprentices' work organized by the Training Department.

However, although cordial relationships with the large organizations involved in electronics and its applications are vital, and the Committee hopes to extend them, there are many small companies which cannot afford to operate comprehensive training schemes. It therefore hopes that Corporate Members will remember the Code of Conduct requirement that they should be prepared to further the education and training of aspirants to Chartered Engineer status and will offer their services as Industrial Tutors for those prospective members whose employers do not operate IERE-approved training schemes. The Committee's own remaining task in this field is concerned with the mechanics of assessment of training, particularly in the case of those applicants for membership (many of whom are from overseas) who have not undertaken organized training and are offering experience in lieu.

The Committee was not directly involved in the organization of any Conference or Colloquia during the year. It considered that, because of the cuts in educational budgets, it would be difficult to make large events devoted to educational topics financially viable, and suggested that an attempt should be made to organize smaller events on a Local Section basis. Following its report to Council on the problem of training engineers for management, the Committee was asked to investigate the possibility of arranging for its discussion at Local Section meetings, but has not yet been able to do so because of the volume of other business. It hopes both to pursue the matter and to organize a Conference on the confused state of engineering education, as part of its future programme. In this context, it invitied Mr Frank Fidgeon, Deputy Chief Officer of the Technician Education Council, to discuss the IERE attitude to TEC awards. Members explained that the Institution's attitude stemmed from the fact that TEC appeared to be under pressure from a number of sources to run before it had proved it could walk, and to take responsibility for awards of a special kind (such as the OND in Technology and the HND) before the value of its own Diplomas and Higher Diplomas had been assessed. This the Institution believes to be ill-advised and premature. It was nevertheless agreed to establish a working party to study TEC Higher Certificate and Diploma programmes relevant to electronic engineering in two particular contexts—acceptability as academic qualifications for Technician Engineers, and as replacements for current Joint Committee awards in respect of exemption from Part 1 of the CEI examination—if that examination continues. It is to be hoped that by the time of the next Annual Report, decisions will have been taken which will end the present uncertainty about the future regulation of the engineering profession and enable the Committee to give advice to enquirers which is not hedged with if's and but's.

MEMBERSHIP COMMITTEE

The strength of the Institution's membership at the close of the year under report is summarized in the normal manner in Table 1. The previous year-end figures are included and from the comparison so provided it will be seen that in a year when, due to the recession, many members may have been driven to consider all manner of personal economies, support for the Institution has clearly not been the first cause to suffer. On the contrary, for whilst the number of members lost under Bye-law 33, action for non-payment of dues, was 48 more than the previous year, the number of clear-cut resignations was down by 33%, new elections were up by 12% and the end of year total showed a net gain of 74. It is also interesting to note, once again, that the greater part of this small overall increase in membership is in the fully qualified corporate member section of the register. A further encouraging sign is substantial reduction in the rate of loss of Graduates for the first time in many years.

The Membership Committee met on twelve occasions during

Table 1. Institution Membership April 1980 to March 1981

		Additions				Deductions						
	Membership at 1.4.80	Direct Elections	Reinstatements	Transfers	Total Additions	Removals	Deaths	Resignations	Transfers	Total Deductions	Nett Gain (+) or Loss (−)	Membership at 31.3.81
Honorary Fellows	10	—	—	—	—	—	—	—	—	—	—	10
Fellows	754	5	1	18	24	—	8	4	—	12	+12	766
Members	7368	110	28	71	209	96	21	34	18	169	+40	7408
Total Corporate Membership	**8132**	**115**	**29**	**89**	**233**	**96**	**29**	**38**	**18**	**181**	**+52**	**8184**
Graduates	2620	75	16	60	151	127	2	32	69	230	−79	2541
Companions	18	—	—	—	—	—	—	—	—	—	—	18
Associates	315	14	1	—	15	11	3	4	1	19	−4	311
Associate Members	999	74	4	10	89	39	2	9	5	55	+34	1033
Students	1275	312	9	—	321	156	—	29	65	250	+71	1346
Total Non-Corporate Membership	**5227**	**475**	**30**	**70**	**576**	**333**	**7**	**74**	**140**	**554**	**+22**	**5249**
Grand Total	**13359**	**590**	**59**	**159**	**809**	**429**	**36**	**112**	**158**	**735**	**+74**	**13433**

the year and considered a total of 795 membership proposals: 563 for direct election, 173 for transfer and 59 for reinstatement. At the close of the year a further 222 proposals (70% more than last year) were being processed for the Committee's consideration, the main delaying factor being the time taken to obtain all necessary referees' reports to ensure compliance with the Institution's stringent membership regulations.

Only one new initiative was taken during the year to increase membership of the Institution. This involved direct approach by personal letter from the Secretary to all new graduates recruited by one major electronics engineering concern. The letter was accompanied by all appropriate literature on the aims and objectives of the Institution, together with membership regulations and application forms. The response to date has been disappointing and it is generally felt that little more can be done to boost membership—other than through the personal endeavours of existing IERE members—until the final outcome of the post-Finniston debate, so far as it affects engineering qualifying standards, is known.

PAPERS COMMITTEE

Variety of content has been maintained in the 1980 volume of *The Radio and Electronic Engineer*, subjects covered ranging from speech encipherment, through teletext performance, to remote sensing of the sea surface by radar. Broadly speaking, papers have been divided equally between those dealing mainly with electronic systems and those dealing with electronic devices and circuit techniques. The continuing policy of including a paper in each issue which will be of general interest to every member who likes to keep in touch with electronic developments or to read of managerial aspects relating to the industry or its history has been followed. The aim with such papers has been at the same time to include material which will not be regarded as entirely commonplace by the specialist.

Ever since the Papers Committee initiated the concept of special or 'feature' issues, the inclusion of introductory reviews which will be found both interesting and useful to those outside the field has generally been followed and the special issues published in 1980 were no exceptions. The issue on 'Applications of Charge Coupled Devices' proved to be an excellent account of this potentially very significant new technology, while in November/December the five papers on 'Remote Sensing of the Environment' have been found specially informative in describing some relatively unfamiliar applications of electronic techniques. The subject of 'Communications with Offshore Installations' was introduced in August with three papers and it is hoped to follow these during the coming months with other contributions dealing with one of the outstanding 'growth areas' and indeed challenges for the electronics industry.

In its task of obtaining papers for publication in the Journal, the Papers Committee receives 'input' from many different sources—universities, government research laboratories and industry—and in a variety of ways—direct invitation, a follow-up on a meeting or conference contribution, quite apart from what can be described without any disrespect as being 'unsolicited'. In endeavouring to provide members with 'current awareness' of electronic engineering developments, it is essential that the Committee itself should first of all be aware of new areas of work. This of course is helped by drawing on the expertise of members of the specialized group committees but during 1980 it was decided that the Committee should go out as a body to see for itself what new developments were afoot. Last summer, therefore, a short journey across Gower Street to the Electronic and Electrical Engineering Department of University College London was made by the kind invitation of the then head of department, Professor A. L. Cullen, and Professor D. E. N. Davies (a past Vice-President). Work in several of the department's specializations was demonstrated and, as a result of the useful discussions which took place with members of the department, a number of papers will appear in the Journal over the coming months.

Assessment of Papers. Last year the Committee reported that the ratio of acceptances to rejections of papers showed a significant increase: this year the balance has gone the other way although, interestingly, the number of papers returned for revision is numerically in the same order as has been the case for a number of years! Details are as follows, 1979/80 figures being given in parentheses:

Number of papers considered	136 (142)
Accepted for publication	56 (77)
Returned for revision	24 (21)
Rejected	56 (44)

As in previous years, conference papers recommended by respective organizing committees for consideration for publication are included in the figures but since revision would not be appropriate in such instances, the decisions on these papers, which represent about a third of the total papers considered, appear only under the acceptances and rejections.

Premiums. Twelve of the twenty premiums are to be awarded for papers published in the Journal during 1980. Four of these were papers first presented at conferences and two had been contributions to two of the special issues published during the year.

INSTITUTION PUBLICATIONS

Tje Radio and Electronic Engineer. Throughout the year, *The Radio and Electronic Engineer* has been able to devote a larger proportion of pages to papers because announcements to members, meetings notices, lists of elections and transfers etc., have been diverted to the fortnightly newspaper, *The Electronics Engineer*. This means that the 630 pages which comprise Volume 50 represent a high proportion of pages of papers.

The impact of increased costs, particularly for printing and postage, has to a certain extent been lessened by economies which it is believed have not been regarded by members and subscribers as deleterious to the quality of the Journal. It would however be unrealistic to expect that the further increases which are expected to fall after the end of the year under review can be similarly absorbed without either a reduction in size or quality of production or an increase in charges made for the Journal. As far as postage is concerned, the Institution is lending its support to the efforts being made through the Association of Learned and Professional Society Publishers to gain some easement in postage rates from the Post Office on grounds which include the educational nature of the Journal; early help in this direction is of course unlikely and, although whatever is achieved will be very welcome, it will probably only hold the costs of postage, and the expected increases in printing costs etc., will remain to be met.

The subscription rates for the Journal increased with effect from the beginning of 1981 and it seems probable that a modest increase will again be necessary in 1982. However it is encouraging to report that although overseas subscribers (as well as overseas members) now receive their copies by accelerated surface post, this item is one for which the Institution's contractor has been able to negotiate favourable rates appreciably below the increases that have applied to inland postings.

Journal circulation for the calendar year January to December 1980 has been maintained at only slightly below last year's figure, namely 13421 compared with 13507. One of the factors affecting the monthly average is the removal from the mailing list at the end of September of members who have not paid their subscriptions for the current year.

The general downturn in product advertising has made it impossible to obtain more than a very small amount of this kind of advertising for the Journal. However, as has been noted previously, appointments advertising which formerly featured in the Journal is now solely carried in *The Electronics Engineer*.

The Electronics Engineer. Because of the current recession in industry to which the electronics sector is not wholly immune, the amount of appointments advertising during the year has been lower than had been anticipated. This has meant that in order to balance costs and revenue realistically, the size of the issue has frequently had to be four pages instead of the planned eight. The publishing house with which the Institution and the Society of Electronic and Radio Technicians are associated in this venture, is however, confident of maintaining *The Electronics Engineer* at the level of 1980/81 and of being able to seize the opportunity to build up the publication when the present industrial climate improves.

Meanwhile, the newspaper has functioned extremely effectively in enabling members to be advised of forthcoming events in good time and often with last minute reminders or alterations—services which could not be provided cost-effectively by any other means.

Conference Proceedings. Between April 1980 and March 1981 conference proceedings were produced for four IERE-organized events, namely 'Retraining in the Electronics Industry for the Microprocessor Age', 'Electromagnetic Compatibility', 'Microprocessors in Automation and Communications' and 'Digital Processing of Signals in Communications' (held in April 1981). The total number of papers for the 1293 pages contained in these volumes was 119. In all cases substantial sales of the conference volumes have resulted subsequent to the events.

LIBRARY AND INFORMATION SERVICES

The past year has been a period of consolidation of the Library's resources, not an easy task with the increase in the price of books and the subscription charges for Journals. However, it is believed that those members using the Library have received the service which they sought whether the Librarian was able to fulfil it from 'in-house' resources or whether resources of other engineering institutions or the British Library had to be called upon.

As always, the question of new books has to weighed very carefully in the light of the money available and the likely use to be made of a particular title. Many members of the Institution are themselves authors of books and it is pleasing to record that several have been kind enough to donate copies to the Library.

ACKNOWLEDGMENTS

To complete and conclude this report, Council wishes to acknowledge with gratitude all that has been done throughout the year by all those members who give their expertise and time so enthusiastically to further the aims and objectives of the Institution both at the hub of our affairs in London and at Section level at home and overseas. The names of those engaged in regular Council and HQ Committee activity, and those who represent the IERE on outside bodies are listed in the Appendices to this report but the matter does not end there; for those lists do not include many additional members who help with local Section Committee work, on conference organizing tasks and with the refereeing of papers for presentation at meetings and for publication. Council also wishes to place on record once again its thanks, on behalf of the entire membership, for the loyal support of all members of the permanent staff who have administered the domestic and financial affairs of the Institution so cost-effectively during a year in which industrial recession and general inflation have had such a damaging influence on so many areas of our professional life.

Appendix 1

Membership of the Council and its Committees as at 31st March 1981

COUNCIL OF THE INSTITUTION

Acting President:

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

Past Presidents:

Professor W. A. Gambling, D.Sc., Ph.D., F.Eng. (*Fellow*)
D. W. Heightman (*Fellow*)
Professor W. Gosling, D.Sc., B.Sc. (*Fellow*)

Vice Presidents:

H. E. Drew, C.B., C.G.I.A. (*Fellow*)
Professor J. R. James, B.Sc., Ph.D., D.Sc. (*Fellow*)
Brigadier R. W. A. Lonsdale, C.B.E., B.Sc. (*Fellow*)
P. K. Patwardhan, M.Sc., Ph.D. (*Fellow*)
S. J. H. Stevens, B.Sc.(Eng.) (*Fellow*)

Ordinary and ex-officio Members:

Colonel W. Barker (*Fellow*)
P. V. Betts (*Member*)*
C. S. den Brinker, M.Sc. (*Fellow*)
P. O. Byrne (*Member*)*
Sir Robert Clayton, C.B.E., M.A., F.Eng., (*Fellow*)
W. R. Crooks, B.A. (*Member*)*
P. W. Day (*Member*)*
I. D. Dodd, B.Sc. (*Fellow*)*
D. J. Houliston (*Member*)*
P. J. Hulse (*Associate Member*)
Lieutenant-Commander C. J. Jackson, RN (Ret.) (*Member*)*
J. J. Jarrett (*Member*)
D. J. Kenner, B.Sc., M.Sc. (*Member*)
Henry J. Kroch, O.B.E. (*Companion*)
R. Larry (*Fellow*)
P. W. Lee (*Member*)*
C. J. Lilly (*Member*)
W. G. McConville (*Member*)*
B. Mann, M.Sc. (*Member*)
Professor C. W. Miller, D.Sc. (*Fellow*)*
C. L. Munday (*Member*)*
Major-General H. E. Roper, C.B., B.Sc.(Eng.) (*Fellow*)
D. L. A. Smith, B.Sc.(Eng.) (*Fellow*)
K. R. Thrower (*Member*)
Professor R. A. Waldron, M.A., Sc.D. (*Fellow*)*
L. Walton (*Member*)*
T. Whiteside (*Member*)*
A. Williams (*Member*)*
M. W. Wright, T.D. (*Associate*)

Honorary Treasurer:

S. R. Wilkins (*Fellow*)

Secretary:

Sinclair M. Davidson, C.B.E. (*Fellow*)

*Chairman of a Local Section in the UK

STANDING COMMITTEES OF THE COUNCIL

Executive Committee

Chairman:
Professor W. Gosling, D.Sc., B.Sc. (*Fellow*)

H. E. Drew, C.B., C.G.I.A. (*Fellow*)
D. W. Heightman (*Fellow*)
Professor J. R. James, B.Sc., Ph.D., D.Sc. (*Fellow*)
Brigadier R. W. A. Lonsdale, C.B.E., B.Sc. (*Fellow*)
Major-General H. E. Roper, C.B., B.Sc.(Eng.) (*Fellow*)
D. L. A. Smith, B.Sc.(Eng.) (*Fellow*)
S. J. H. Stevens, B.Sc.(Eng.) (*Fellow*)
S. R. Wilkins (*Fellow*)
Lieutenant-Colonel S. T. Webber, REME (*Member*)
Colonel J. Vevers, O.B.E. (*Fellow*)

Education and Training Committee

Chairman:
D. L. A. Smith, B.Sc.(Eng.) (*Fellow*)

Brigadier G. D. Clarke (*Member*)
F. Goodall, B.Sc., Ph.D. (*Member*)
K. J. Coppin, B.Sc. (*Member*)
Commander A. H. C. Fraser, B.Sc.(Eng.), RN (*Fellow*)
P. J. Gallagher, M.Sc., Ph.D. (*Member*)
B. F. Gray, B.Sc. (*Fellow*)
R. W. S. Hewitt (*Fellow*)
G. P. Heywood, B.Sc. (*Graduate*)
C. H. G. Jones (*Member*)
A. J. Kenward, B.Sc. (*Member*)
P. J. Morley (*Member*)
Professor K. G. Nichols, B.Sc., M.Sc. (*Fellow*)
W. L. Price, O.B.E., M.Sc., Ph.D. (*Fellow*)
A. C. Shotton (*Fellow*)
A. Tranter, B.Sc.(Eng.) (*Member*)
Squadron Leader P. Walters, RAF (*Member*)

Membership Committee

Chairman:
D. N. J. Cudlip (*Member*)

C. W. Brown, M.A. (*Member*)
D. A. Burgess (*Member*)
R. M. Clark (*Member*)
Commander A. C. Cowin, RN (*Member*)
Wing Commander P. J. Dunlop, RAF (Ret.) (*Fellow*)
A. N. Heightman (*Fellow*)
H. Hudson (*Member*)
Brigadier R. W. A. Lonsdale, C.B.E., B.Sc. (*Fellow*)
J. W. Morris (*Member*)
Colonel G. W. A. Pearce (*Member*)
D. G. Roberts (*Member*)
R. S. Roberts (*Fellow*)
J. B. Stephens (*Member*)
Group Captain J. M. Walker, RAF (*Fellow*)
M. M. Zepler, M.A., Dip. El. (*Member*)

Professional Activities Committee

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

N. G. V. Anslow (*Member*)
P. Atkinson, B.Sc., A.C.G.I. (*Member*)
Colonel W. Barker (*Fellow*)
Lieutenant-Colonel (Ret.) F. G. Barnes, M.A. (*Fellow*)
K. Copeland (*Member*)
A. F. Dyson, Dip. El. (*Member*)
M. H. W. Gall, M.A. (*Fellow*)
L. Hale (*Member*)
J. R. Halsall, Dip. El. (*Fellow*)
A. Hann, B.Sc. (*Fellow*)
J. J. Jarrett (*Member*)
R. Larry (*Fellow*)
Professor K. G. Nichols, B.Sc., M.Sc. (*Fellow*)
Professor P. A. Payne, Ph.D. (*Member*)
D. L. A. Smith, B.Sc.(Eng.) (*Fellow*)
J. K. Stevenson, B.Sc., Ph.D. (*Member*)
Professor D. R. Towill, D.Sc., M.Sc. (*Fellow*)
W. E. Willison (*Fellow*)

Papers Committee

Chairman:
L. W. Barclay, B.Sc. (*Fellow*)

K. F. Baker, M.Sc. (*Member*)
Professor J. D. E. Beynon, M.Sc., Ph.D. (*Fellow*)
L. A. Bonvini (*Fellow*)
W. G. Burrows, Ph.D., D.I.C. (*Member*)
M. P. Circuit, Dip. El., B.Sc. (*Member*)
R. J. Cox, B.Sc. (*Member*)
A. B. E. Ellis (*Fellow*)
K. G. Freeman, B.Sc. (*Member*)
A. E. Hilling (*Member*)
R. M. B. Jackson (*Member*)
G. G. Johnstone, B.Sc. (*Member*)
C. J. Lilly (*Member*)
E. Robinson, B.Sc., Ph.D. (*Fellow*)
A. G. Wray, M.A. (*Fellow*)

Trustees of the Institution's Benevolent Fund

Professor W. Gosling, D.Sc., B.Sc. (*Fellow*) President
S. R. Wilkins (*Fellow*) Hon. Treasurer
S. M. Davidson, C.B.E., (*Fellow*) Secretary

Aerospace, Maritime and Military Systems

Chairman:
N. G. V. Anslow (*Member*)

Colonel W. Barker (*Fellow*)
Brigadier J. F. Blake, R Sigs (*Member*)
A. Hann, B.Sc. (*Fellow*)
P. R. Hopkin (*Member*)
J. A. C. Kinnear (*Fellow*)
R. N. Lord, M.A. (*Member*)
R. B. Mitson, M.Sc. (*Member*)
C. H. Nicholson (*Fellow*)
Commander A. R. B. Norris, RN (*Associate Member*)
R. M. Trim, O.B.E. (*Fellow*)

Automation and Control Systems

Chairman:
P. Atkinson, B.Sc.(Eng.), A.C.G.I. (*Member*)

Lieutenant-Commander M. J. Ashworth, RN (*Member*)
M. S. Birkin (*Member*)
A. E. Crawford (*Fellow*)
J. R. Halsall, Dip. El. (*Fellow*)
W. F. Hilton, D.Sc. (*Fellow*)
D. J. Kenner, B.Sc., M.Sc. (*Member*)
Brigadier R. Knowles, C.B.E. (*Fellow*)
B. Mann, M.Sc. (*Member*)
J. L. Paterson, M.B.E. (*Member*)
Professor D. R. Towill, D.Sc., M.Sc. (*Fellow*)
Group Captain J. M. Walker, RAF (*Fellow*)
Professor D. R. Wilson, B.Sc., Ph.D. (*Fellow*)

Communications

Chairman:
J. J. Jarrett (*Member*)

A. R. Bailey, M.Sc., Ph.D. (*Fellow*)
L. W. Barclay, B.Sc. (*Fellow*)
A. P. Clark, M.A., Ph.D. (*Member*)
Professor J. E. Flood, D.Sc. (*Fellow*)
L. W. Germany (*Fellow*)
F. Goodall, M.Sc., Ph.D. (*Member*)
A.N. Heightman (*Fellow*)
G. R. Jessop (*Member*)
A. A. Kay (*Fellow*)
R. Larry (*Fellow*)
G. A. McKenzie, B.Sc. (*Member*)
P. L. Mothersole (*Fellow*)
R. S. Roberts (*Fellow*)
R. E. C. B. Smith (*Member*)
K. R. Thrower (*Member*)
K. E. Ward (*Member*)
M. M. Zepler, M.A., Dip. El. (*Member*)

Components and Circuits

Chairman:
J. K. Stevenson, B.Sc., Ph.D. (*Member*)

K. F. Baker, M.Sc. (*Member*)
C. R. Caine, B.Sc. (*Member*)
R. F. Mitchell, Ph.D. (*Co-opted*)
B. V. Northall, C.G.I.A. (*Member*)
C. Radcliffe (*Co-opted*)

Computer

Chairman:
Colonel W. Barker (*Fellow*)

C. E. Dixon, B.A., Dip.E.E. (*Member*)
D. B. Everett, B.Sc., Ph.D. (*Fellow*)
P. L. Hawkes, B.Sc. (*Member*)
D. T. Law (*Member*)
Professor D. W. Lewin, D.Sc., M.Sc., (*Fellow*)
V. Maller, M.A. (*Fellow*)
Wing Commander D. G. L. Packer, B.Sc., D.U.S., RAF (Ret.) (*Member*)
D. Pilgrim, B.Sc. (*Member*)
T. J. Stakemire (*Member*)
E. R. Tomlinson (*Member*)
S. E. Williamson, B.Sc., Ph.D. (*Member*)

Electronics Production Technology

Chairman:
L. Hale (*Member*)

R. Bavister (*Associate*)
J. F. Burns (*Member*)
A. F. Dyson, Dip. El. (*Member*)
R. W. Hill (*Member*)
D. G. Horan (*Member*)
R. P. Marie (*Member*)
Professor D. R. Towill, D.Sc., M.Sc. (*Fellow*)

Measurements and Instruments

Chairman:
Professor P. B. Fellgett, M.A., Ph.D. (*Fellow*)

A. E. Drake (*Co-opted*)
W. A. Evans, B.Sc., M.Sc. (*Fellow*)
E. P. Fowler, M.A. (*Co-opted*)
M. H. W. Gall, M.A. (*Fellow*)
R. F. Monger (*Member*)
J. K. Murray (*Associate*)
Professor P. A. Payne, Ph.D. (*Member*)
D. E. O'N. Waddington (*Fellow*)
P. C. F. Wolfendale (*Fellow*)

Medical and Biological Electronics

Chairman:
K. Copeland (*Member*)

J. S. Armour (*Member*)
R. Brennand (*Member*)
A. E. Hay, M.Phil. (*Member*)
Professor P. A. Payne, Ph.D. (*Member*)
L. W. Price, M.A. (*Member*)
J. R. Roberts, B.Sc., Ph.D. (*Member*)
N. C. Scott, M.Sc. (*Member*)
H. J. Terry, B.A., Ph.D. (*Member*)

Microprocessor

Chairman:
Professor K. G. Nichols, B.Sc., M.Sc. (*Fellow*)

K. F. Baker, M.Sc. (*Member*)
C. E. Dixon, B.A. (*Member*)
P. R. Hopkin (*Member*)
D. G. Horan (*Member*)
B. Mann, M.Sc. (*Member*)
D. E. O'N. Waddington (*Fellow*)
M. M. Zepler, M.A., Dip. El. (*Member*)

Recording

Chairman:
Colonel W. Barker (*Fellow*)

A. V. Davies, M.Sc. (*Fellow*)
H. D. Ford (*Member*)
A. N. Heightman (*Fellow*)
M. J. Humphries (*Member*)
R. Larry (*Fellow*)
B. K. Middleton, Ph.D. (*Member*)
B. V. Northall, C.G.I.A. (*Member*)
M. A. Perry, M.Sc. (*Fellow*)
C. E. Urban (*Graduate*)
G. White (*Member*)

Appendix 2

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

Board of CEI

Professor W. Gosling, D.Sc., B.Sc. (*Fellow*)
Professor W. A. Gambling, Ph.D., D.Sc., F.Eng. (*Fellow*) (Alternate)

Standing Committee B

J. Powell, M.Sc. (*Fellow*) (Until January 1981)
Brigadier R. W. A. Lonsdale, C.B.E., B.Sc. (*Fellow*) (Since January 1981)

Standing Committee C

S. J. H. Stevens, B.Sc.(Eng.) (*Fellow*)

CEI—CSTI Joint Affairs Committee

To be appointed

Council for Environmental Science and Engineering

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

Educational Qualifications Committee
K. J. Coppin, B.Sc. (*Member*)

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

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

Joint Qualifications Committee
Brigadier R. W. A. Lonsdale, C.B.E., 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*)

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

Cranfield Institute of Technology
Court
W. L. Price, O.B.E., M.Sc., Ph.D. (*Fellow*)

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

University of Surrey
Court
Professor W. Gosling, D.Sc., B.Sc. (*Fellow*)

University of Wales Institute of Science and Technology
Court
V. J. Phillips, Ph.D., B.Sc. (*Member*)

Barnsley College of Technology
Engineering Advisory Committee
To be appointed

Darlington College of Technology
Electrical Engineering and Science Advisory Committee
R. W. Blouet (*Member*)

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*)

Huddersfield Technical College
Engineering Advisory Committee
R. Barnes (*Member*)

Merton Technical College
Board of Governors
A. A. Kay (*Fellow*)

City of Nottingham Education Committee
Electrical Engineering Advisory Committee
F. W. Hopwood (*Member*)

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*)

South East London College
Engineering Consultative Committee
J. I. Collings (*Fellow*)

Stannington College of Further Education, Sheffield
Electrical and Telecommunications Consultative Committee
P. A. Bennett (*Fellow*)

Wakefield College of Technology and Arts
Engineering Advisory Committee
M. Holroyd, M.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.) (*Member*)
A. Tranter, B.Sc. (*Member*)

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
D. M. Pratt (*Member*)

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

Council for National Academic Awards

Electrical and Electronic Engineering Board
C. S. den Brinker, M.Sc. (*Fellow*)

London and Home Counties Regional Advisory Council for Technological Education

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

Scottish Technical Education Council (ScoTEC) Course Committee A2
P. G. Wilks, B.Sc. (*Member*)

Technician Education Council (TEC)

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

North Western Advisory Council for Further Education

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

Radio Television and Electronics Examination Board

Air Vice-Marshal S. M. Davidson, C.B.E. (*Fellow*)
W. B. K. Ellis, B.Sc. (*Member*)
N. G. Green (*Member*)

Welsh Joint Education Committee

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

West Midlands Advisory Council for Further Education

M. D. Cross, B.A. (*Member*)

Yorkshire Council for Further Education

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

Appendix 6

Members Appointed to Represent the Institution on External Bodies

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

Professor W. Gosling, D.Sc., B.Sc. (*Fellow*) (Until January 1981)
Brigadier R. W. A. Lonsdale, C.B.E., B.Sc. (*Fellow*) (Since January 1981)

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
P. L. Mothersole (*Fellow*)
R. S. Roberts (*Fellow*)
J. D. Tucker (*Fellow*)

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. Gosling, D.Sc., B.Sc. (*Fellow*)

Parliamentary and Scientific Committee

P. A. Allaway, C.B.E., D. Tech., F.Eng. (*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

F. W. Sharp (*Fellow*)

UK Automatic Control Council

P. Atkinson, B.Sc., A.C.G.I. (*Member*)
Colonel W. Barker (*Fellow*)
Professor D. R. Towill, D.Sc., 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*)

Watt Committee on Energy

M. S. Birkin (*Member*)

Appendix 7

British Standards Institution Representatives

ECL/– Electronic Components Standards Committee

Brigadier 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

Professor 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

Brigadier 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.(Eng.) (*Fellow*)

EEL/8/8 Oscilloscopes

D. M. Styles (*Member*)

EEL/23 Radio-Frequency Radiation-Induced Ignition and Detonation

Colonel F. R. Spragg, B.Sc. (*Fellow*)
D. M. Field (*Member*)

EEL/24 Electro-Acoustics

S. Kelly (*Fellow*)

EEL/24/1 Audio Engineering

S. Kelly (*Fellow*)
R. S. Roberts (*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 (*Fellow*)

EEL/25/7 Wired Distribution Systems

P. Scadeng (*Fellow*)

EEL/25/8 Reception of Sound and Television Broadcasting

P. Scadeng (*Fellow*)

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*)

MEE/10 Engineering Drawing Practice

D. J. Simmonds (*Member*)
G. Taylor (*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*)

DPS/4 Magnetic Tape and Magnetic Disc Packs

A. Pitter (*Member*)

PEL/50 Static Power Converter Equipment

M. A. Burchall (*Fellow*)

QMS/3/4 Maintenance

L. A. Bonvini (*Fellow*)
Brigadier R. W. A. Lonsdale, C.B.E., D.Sc. (*Fellow*)

Appendix 8

Award of Institution Premiums for 1980

MAIN PREMIUMS

LORD MOUNTBATTEN PREMIUM (*Value* £100)

'NICAM 3: near instantaneously companded digital transmission system for high-quality sound programmes'
C. R. Caine, A. R. English and J. W. H. O'Clarey (*British Broadcasting Corporation*)

CLERK MAXWELL PREMIUM (*Value* £100)

'Data compression techniques and applications'
Dr. G. Benelli, Professor V. Cappellini (*Institute of Electronics, Florence*) and Dr F. Lotti (*Institute of Research on Electromagnetic Waves, Florence*)

MARCONI PREMIUM (*Value* £75)

'An integrated circuit v.h.f. radio receiver'
I. A. W. Vance (*Standard Telecommunication Laboratories*)

SIR CHARLES WHEATSTONE PREMIUM (*Value* £50)

'A review of distortion and its measurement in p.c.m. telephony systems'
R. G. Rolls (*Marconi Instruments*)

CHARLES BABBAGE PREMIUM (*Value* £50)

'The choice of a recording code'
and
'A superposition based analysis of pulse-slimming techniques for digital recording'
Dr N. D. Mackintosh (*Formerly with Racal Recorders, now with Burroughs Corporation*)

GENERAL PREMIUMS

LESLIE McMICHAEL PREMIUM (*Value* £50)

'Management in a competitive environment—The experience of Tandbergs Radiofabrikk A/S'
R. McLellan (*Anglian Regional Management Centre*)

SPECIALIZED TECHNICAL PREMIUMS

LORD BRABAZON PREMIUM (*Value* £50)

'British Telecommunications trans-horizon radio links serving off-shore oil/gas production platforms'
S. J. Hill (*British Telecom*)

A. F. BULGIN PREMIUM (*Value* £50)

'Development of c.c.d. area image sensors for 625 line television pictures'
D. J. Burt (*GEC Hirst Research Centre*)

DR NORMAN PARTRIDGE PREMIUM (*Value* £50)

'Transmission of speech by adaptive sampling'
Dr. J. Dunlop and Dr. N. C. Changkakati (*University of Strathclyde*)

PAUL ADORIAN PREMIUM (*Value* £50)

'The measurement of Teletext performance over the United Kingdom television network'
L. A. Sherry and R. C. Hills (*Independent Broadcasting Authority*)

J. LANGHAM THOMPSON PREMIUM (*Value* £50)

'Systems engineering: an approach to whole system design'
Professor P. K. M'Pherson (*The City University*)

P. PERRING THOMS PREMIUM (*Value* £50)

'Wide range frequency synthesizers with improved dynamic performance'
Dr M. J. Underhill (*Philips Research Laboratories*)

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

HEINRICH HERTZ PREMIUM (*Value* £75)

Physical or mathematical aspects of electronics or radio

LORD RUTHERFORD PREMIUM (*Value* £50)

Electronics associated with nuclear physics or nuclear engineering

ARTHUR GAY PREMIUM (*Value* £50)

Production techniques in the electronics industry

SIR HENRY JACKSON PREMIUM (*Value* £50)

History of radio or electronics

ERIC ZEPLER PREMIUM (*Value* £50)

Education of electronic and radio engineers

DR V. K. ZWORYKIN PREMIUM (*Value* £50)

Medical or biological electronics

HUGH BRENNAN PREMIUM (*Value* £50)

Outstanding paper first read before any Local Section of the Institution and subsequently published in the Journal

SIR J. C. BOSE PREMIUM (*Value* £50)

Outstanding paper by an Indian scientist or engineer on any subject

ANNUAL ACCOUNTS OF THE INSTITUTION OF ELECTRONIC AND RADIO ENGINEERS

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MARCH 1981

	1981 £	**1981** £	1980 £	1980 £
INCOME (Note 2)				
Subscriptions		260,435		258,570
Entrance, Transfer and Exemption Fees		5,648		4,669
Sales:				
Institution Journal	38,924		34,765	
Other Publications and Colloquia	16,813		18,102	
		55,737		52,867
Fees Received—Symposia		62,831		79,012
Dividends and Interest Received		439		1,076
Total Income		385,090		396,194
Deduct:				
Cost of Publishing Journals				
Printing Costs	79,575		67,310	
Less: Advertising Receipts	9,694		6,253	
Less: Applied in clearance of Advance	8,000		—	
	1,694		6,253	
	77,881		61,057	
Postage	30,679		24,015	
Envelopes and Wrappers	1,623		2,454	
	110,183		87,526	
Direct Expenses relating to Symposia				
Printing of Papers	6,932		10,159	
Accommodation and Travel	25,790		25,621	
	32,722		35,780	
		142,905		123,306
		242,185		272,888
Deduct:				
Administration Expenses				
Salaries and National Insurance	127,648		111,546	
Superannuation Scheme	7,912		3,867	
Postage and Telephone	15,847		16,134	
Printing and Stationery	8,013		6,769	
Computer Service	6,556		5,293	
Travelling and Entertaining Expenses	918		1,169	
Council and Committee Expenses	4,657		3,429	
Delegate Expenses	250		104	
Bank Charges and Differences on Exchange	4,773		4,550	
Audit Fees	2,100		2,100	
Miscellaneous Expenses	1,685		1,857	
Carried forward	180,359		156,818	

The notes set out on pages 485 and 486 form an integral part of these Accounts.

	1981 £	**1981** £	1980 £	1980 £
Brought forward	180,359		156,818	
Establishment				
Rent, Rates and Insurance	40,437		37,164	
Lighting and Heating	2,026		1,703	
Office Expenses and Cleaning	5,451		6,197	
Repairs and Maintenance	3,438		1,010	
	51,352		46,074	
Divisions and Sections Operating Expenses				
Salaries, Printing, Stationery, Postage and Office Expenses	8,694		7,097	
Hire of Accommodation, Lectures and Meeting Expenses	4,019		6,493	
Travelling Expenses	738		1,666	
	13,451		15,256	
Subscriptions to the Council of Engineering Institutions	14,904		12,493	
Awards and Contributions to Other Institutions	1,080		1,162	
Depreciation (Note 4)				
Furniture, Fittings and Equipment	1,802		735	
Profit on Sale of Assets	(217)		—	
	1,585		735	
Total Expenditure		262,731		232,538
Surplus/(Deficit) for the year before Exceptional Item		(20,546)		40,350
Exceptional Item (Note 3)		—		(3,894)
Surplus/(Deficit) after Exceptional Item carried to General Fund		(£20,546)		£36,456

STATEMENT OF GENERAL FUND

	1981 £	1980 £
Adverse Balance brought forward	(51,062)	(87,518)
Surplus/(Deficit) for the Year	(20,546)	36,456
Adverse Balance at 31st March 1981	(£71,608)	(£51,062)

BALANCE SHEET AS AT 31st MARCH 1981

	1981 £	£	1980 £	£
Fixed Assets (Note 4)		71,695		66,984
Quoted Investments at Cost (Note 5) (Market Value £3,120 (1980 £4,703))		2,823		4,328
Premises Fund Investments (Note 7)		50,267		40,501
Current Assets				
Stock of Institution's Publications (Note 6)	25,878		31,787	
Income Tax recoverable	39		32	
Sundry Debtors and Prepayments	20,464		29,154	
Balance at Bank and in Hand	7,769		5,549	
	54,150		66,522	
Less: **Current Liabilities**				
Sundry Creditors and Provisions	41,718		49,120	
Net Current Assets		12,432		17,402
		£137,217		£129,215
Represented by:				
Fund Balances				
General Fund—Adverse Balance		(71,608)		(51,062)
Premises Fund Account (Note 7)		50,267		40,501
		(21,341)		(10,561)
Deferred Revenue				
Subscriptions and Receipts in advance		75,640		48,992
Short Term Borrowings				
Bank Overdraft		82,918		90,784
		£137,217		£129,215

Signed

WILLIAM GOSLING (*Acting President*)
S. R. WILKINS (*Honorary Treasurer*)
S. M. DAVIDSON (*Secretary*)

STATEMENT OF SOURCE AND APPLICATION OF FUNDS FOR THE YEAR TO 31st MARCH 1981

	1981 £	£	1980 £	£
Source of Funds				
Surplus/(Deficit) for the year after Exceptional Items		(20,546)		36,456
Add:				
Items not giving rise to the movement of funds:				
Depreciation	1,802		735	
(Profit)/Loss on disposal of Investments and Fixed Assets	(217)		—	
		1,585		735
		(18,961)		37,191
Other Sources				
Increase in Subscriptions received in advance	26,648		9,623	
Premises Fund receipts	9,766		7,672	
		36,414		17,295
Total Source of Funds		17,453		54,486
Application of Funds				
Purchase of Fixed Assets and Investments (Net)	4,791		2,602	
Amount set aside for Premises Fund Investment	9,766		7,672	
		14,557		10,274
		£2,896		£44,212
Represented by:				
Movement in Working Capital				
(Increase)/Decrease in Stocks	5,909		(14,039)	
(Increase)/Decrease in Tax recoverable	(7)		7	
(Increase)/Decrease in Debtors	8,690		(582)	
Increase/(Decrease) in Current Liabilities	(7,402)		(16,682)	
		7,190		(31,296)
Movement in Net Liquid Funds:				
Increase/(Decrease) in Bank Overdraft	(7,866)		(12,092)	
(Increase)/Decrease in Bank and Cash Balances	(2,220)		(824)	
		(10,086)		(12,916)
		£(2,896)		£(44,212)

NOTES FORMING PART OF THE ACCOUNTS FOR THE YEAR ENDED 31st MARCH 1981

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 1981, 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 for 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. Exceptional Item

As a result of limited demand for certain of the Institution's publications in the previous year, it was considered necessary to reduce these items from cost to expected realizable value. This reduction is shown as an exceptional item in the comparative figures.

4. 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. It is the policy of the Institution to maintain its Library and Furniture in such a manner that their value is not affected by the effluxion of time. Such expenditure is charged against revenue when incurred. Consequently, the Institution does not consider it necessary to provide depreciation on fixed assets other than those located overseas together with UK equipment.

Depreciation of UK equipment and overseas furniture and equipment is based on net book value at rates between 10% to 25% per annum.

	Furniture and Equipment £	*Library* £	*Total* £
Cost or Valuation			
As at 1st April 1980:			
at Cost	6,151	5,178	11,329
at Valuation	22,000	36,000	58,000
	28,151	41,178	69,329
Additions during the year at Cost	5,179	2,044	7,223
Disposal during the year	(1,409)	—	(1,409)
As at 31st March 1981	£31,921	£43,222	£75,143
at Cost	9,921	7,222	17,143
at Valuation	22,000	36,000	58,000
Depreciation			
As at 1st April 1980	2,345	—	2,345
On Disposal	(710)	—	(710)
Provision for the year	1,813	—	1,813
As at 31st March 1981	£3,448	—	£3,448
Net Book Values			
As at 31st March 1981	£28,473	£43,222	£71,695
As at 31st March 1980	£25,806	£41,178	£66,984

5. Quoted Investments

Nominal		*Cost* £
£1,000	7¾% Barnet Corporation Loan 1982/84	982
270	Inchcape & Co. Ltd.—12½% Unsecured Loan Stock 1993/98	99
£1,000	Islington Corporation—10% Redeemable Stock 1982/83	995
£166	Muirhead Limited—25p Ordinary Shares	262
£500	Stock Exchange—7¼% Mortgage Debenture Stock 1990/95	485
£1,220	5½% Treasury Stock 2008/12 (donated)	—
		£2,823

The Institution also has a residuary interest in a settlement consisting of freehold property which will be vested in the Institution at some future date. The Secretary estimates the value of this interest to be approximately £11,000 at 31st March 1981.

6. Stock of Institution's Publications

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

7. Premises Fund

Investments:	**1981** £	1980 £
Inverclyde City Council—Term Loan	43,000	—
City of Liverpool 10⅞% Bond	—	28,000
Balance at Bank	7,267	12,501
	£50,267	£40,501
Movement on Fund during year:		
Balance 1st April 1980	40,501	32,829
Add:		
Receipts during year:		
Donations	1,381	1,233
Covenanted Subscriptions	3,866	3,937
Interest received on Investment	4,519	2,502
Balance 31st March 1981	£50,267	£40,501

8. 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 1981 at the rate of exchange ruling at that date.

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

We have audited the accounts set out on pages 484 to 486 in accordance with approved Auditing Standards.

In our opinion the accounts, 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 4, give a true and fair view of the Institution's affairs at 31st March 1981 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
4th August 1981

GLADSTONE, JENKINS & CO.
Chartered Accountants

CEI Code of Conduct

The CEI Regional Affairs Committee has reported on behalf of their branch membership certain misgivings concerning the CEI Code of Conduct and the manner in which the code is seen to be observed. In essence, the disquieting aspects are the degree of consistency between the CEI code and that of individual corporation members; whether changes were required in the Code's scope and content; how the codes were applied in relation to disciplinary measures and the possible conflicts which might arise through trade union membership and contractual requirements to employers.

The Council's Executive Committee considered these points and decided to refer them back to the Standing Committee for Regional Affairs for reconsideration, discussion and the production of concrete proposals on the subject.

In order to explain the position more clearly, this article aims to outline the content of codes and rules of conduct, the way in which they are promulgated, the disciplinary action taken in cases of breaches of the codes, and the way in which codes of conduct affect the working lives of engineers and particularly their relationships with employers and trade unions.

The Content of Codes and Rules of Conduct

It is a characteristic of all professions that they require their members to conform to a code and rules of conduct, and apply sanctions against those who offend them. For many years, the Chartered engineering institutions had such codes which, although similar in content, differed somewhat in emphasis. More recently it was realised that, in order to secure full protection under industrial relations legislation, greater uniformity was needed, and CEI produced a model code on the basis of which each member institution amended its By-laws and Regulations as necessary.* On the grant of the 1978 Supplemental Charter, all Chartered Engineers became individual members of CEI, and CEI was required to frame its own code and rules of conduct and disciplinary procedures. These are based also on the original CEI model and are now contained in Regulations 1 and 2.

It can, therefore, be accepted that CEI's Code and Rules of Conduct and those of member institutions are, for all practical purposes, identical. Their content appears to conform to the general practice in other professions and to present neither difficulties in interpretation nor serious weaknesses. These codes of conduct do not attempt to cover failures of technical competence: a matter of great legal difficulty. Finniston regarded this aspect to be a serious weakness in the present codes of professional conduct.

Promulgation of Codes of Conduct

While the practice in individual institutions varies, it is normal for applicants for corporate membership to be made aware of the Rules of Conduct and to undertake to abide by them. The CEI Code has not been promulgated to individual members and legally there is no requirement to do so, since 'ignorance of the law is no defence.'

It is certainly open to question whether the arrangements for promulgating the Codes of Conduct of Institutions and of CEI are adequate.

Disciplinary Action

The number of cases of unprofessional conduct is small in relation to the number of Chartered Engineers and minimum publicity is given to these cases. Individual engineers could be forgiven for thinking that the Code has little substance since action is so seldom taken against offenders. It may be that the professional behaviour of engineers is influenced by the existence of the Code whether or not disciplinary action is a frequent event. Conversely, the position of an engineer in difficulties with his employer or trade union would be strengthened were he able to show evidence of risk of retribution for unprofessional conduct. The standing of the profession in public estimation might also be improved thereby.

In a profession in which direct personal relationships between the professional and client are rare, there will be relatively few disciplinary cases in comparison with, say, the medical profession.

Engineering institutions and CEI can fairly claim that they do take action on all cases reported to them, but such cases are minimal. Any decision that the profession should apply its disciplinary procedures more vigorously and with more publicity, must also face the problem of how the passage of information concerning suspected or prima facie offences can be improved.

The Relevance of the Code of Conduct

Many engineers, particularly those working as employees in industry, question the relevance of the professional code of conduct in their working lives. In matters of health and safety the issues are fairly clear, and, with the advent of the Health and Safety at Work Act, employers and trade unions are, at least nominally, on the side of the angels, and engineers should seldom find themselves in difficulties in this respect. However, the Code of Conduct refers to safeguarding the public interest 'in matters of safety and health *and otherwise*'. It is in the interpretation of the last phrase that engineers often voice the need for guidance. It is however, very difficult to give practical guidance on what is, and what is not, in the public interest.

It is generally held to be a characteristic of a professional that he is prepared to apply his own professional judgment to the problems that face him and to stand by the results of his action, and some would regard the publication of official guidance as infringing the professional freedom of engineers. However, many practising engineers do feel exposed, would like to look to the Code of Conduct for support, but doubt its effectiveness.

Codes of Conduct are intended to protect the interest of the public rather than those of individual members of a profession. However, its is undeniable that a well established, well understood, and strictly enforced code of conduct does strengthen the hand of individual professional people and enhances their standing in public esteem. It is, therefore, for consideration whether more guidance should be provided for Individual Members on the practical application of their Code of Conduct.

The Code of Conduct in Industrial Relations

The Industrial Relations Code of Practice framed under the 1971 Industrial Relations Act and retained under the 1974 Act, recognises the potential conflict between a professional man's responsibilities to his profession and those to his trade union. Section 21 of the Code of Practice, which was inserted largely at the insistence of CEI, reads:

> '21 Some employees have special obligations arising from membership of a profession and are liable to incur penalties if they disregard them. These may include obligations, for example, in regard to health, safety and welfare, over and above those which are shared by the community as a whole.'

Section 23 of the Code reads:

> '23 Professional associations, employers and trade unions should co-operate in preventing and resolving any

* See *The Radio and Electronic Engineer*, **42**, No. 8, pp. S127 and S128, August 1972

conflicts which may occur between obligations arising from membership of a profession and those which the professional employee owes to his employer and to his trade union if he belongs to one,'.

These sections give CEI and the Institutions the right and duty to intervene in such cases, and they do so from time to time, generally with satisfactory results. However, the number of such cases is small, and CEI can act only when asked to do so by a member. It may be that engineers are not sufficiently aware of CEI's legitimate role in these matters and for that reason do not seek the help they need. Perhaps more publicity is needed, not only for this role of CEI and the Institutions in Industrial Relations, but for specific cases.

New Underwater Sonar Surveillance System

Marconi Space and Defence Systems has designed an entirely new underwater surveillance system for the protection of harbours, naval and military establishments, ships at sea and other important potential targets, such as oil rigs and dams.

Known as the Marconi '360° Surveillance Sonar', the system is designed to provide defence against enemy threats (e.g. divers, chariots, submersibles and submarines) by detection sufficiently early to enable effective counter-measures to be carried out. During trials free-swimming divers have been detected at ranges of more than 200 metres and more substantial targets out to 1·2 km.

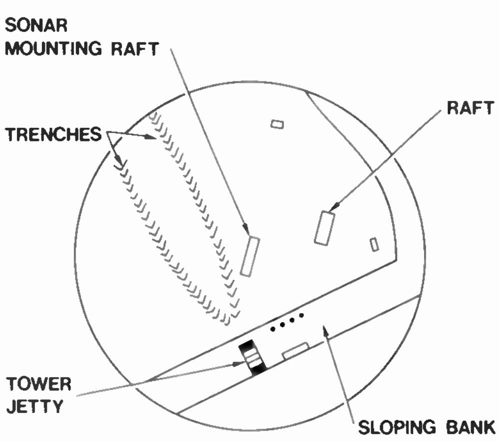
Current active sonar systems used for minehunting or anti-submarine warfare have normally operated at one sonar frequency only and employed analogue electronics, thereby limiting each equipment to one particular function.

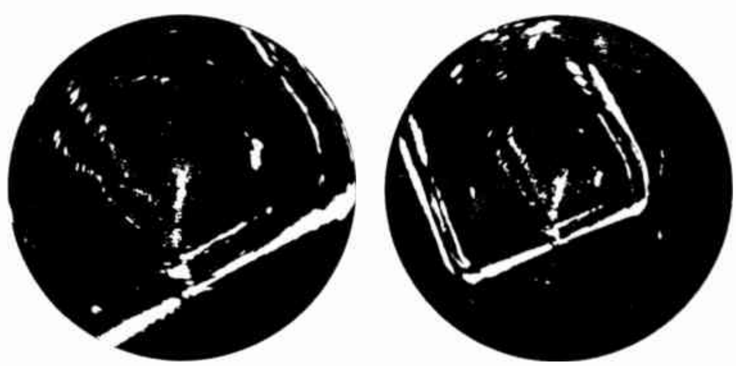
New types of transducers have been developed within Marconi for this sonar system which has been designed to be capable of operating at multiple frequencies for maximum versatility using advanced sampling techniques and digital processing together with sophisticated array geometry.

The new Marconi sonar has a 360° all-round view presented on a radar-type p.p.i. display with a fast data refresh rate accomplished by a purely electronic scan with no moving parts. On the current version surveillance range radius can be switched in steps from 9 metres radius to 1·2 kilometres radius.

One highly important use for this system will be in the protection of harbours where one or more acoustic sensors can be deployed on the sea bed at the harbour entrance. These would be connected by cable to a single trailer-mounted cabin containing all the necessary electronics, controls and displays. This system has many operational advantages; the simplicity of installation and recovery of the small sensors, combined with the trailer-mounted control centre, gives high mobility and versatility and does not require any outside involvement in order to install at top security locations.

The 360° Surveillance Sonar
above: the transducer assembly
below: typical displays





600m. diameter 1200m. diameter

Secure Tactical Radio Systems

Two leading British companies have recently announced details of their ranges of new tactical military radio transmitter-receiver equipments for network operation. Both employ frequency hopping to give a potential jammer little time to react and to achieve greater freedom from interception as well as from d.f. location.

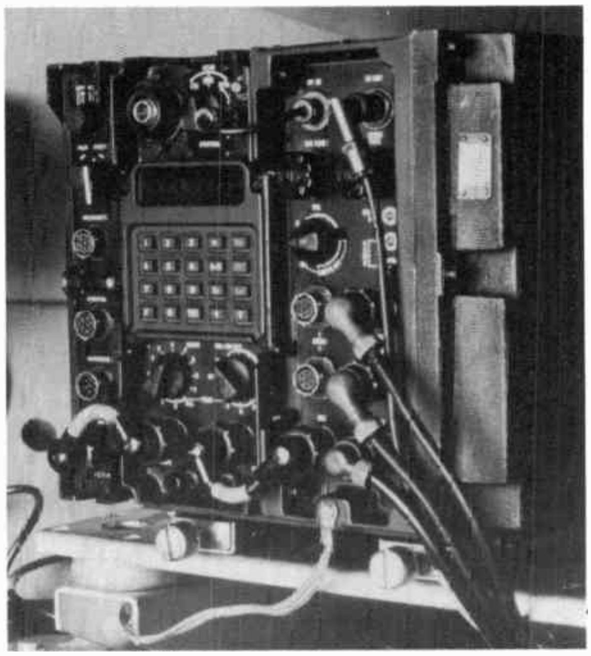
In a frequency hopping radio, a sequence generator controls the frequency of the transmitter and the random sequence of hopping is governed by a code selected by the operator. At the receiver there is an identical sequence generator which, when programmed with the same hopping code, causes the receiver frequency to hop around the spectrum in the same sequence as the transmitter. A synchronization system keeps the transmitter and receiver exactly in step with each other.

A most important aspect of a hopping system is the synchronization since the transmitter and receiver must be kept exactly in step with each other. Some of the requirements of the synchronization system are:

- Must be automatic and rapid
- Must work when signal strengths are weak
- Must be resistant to interference
- Must only operate when receiving signals from radio with same hop code
- A station must be able to join a net at any time
- The synchronization signals being passed over the link must not affect quality of speech or data being passed

Furthermore, synchronization signals must not be recognizable to the enemy and sync information is therefore passed in digital form with the speech so that the whole signal is a digital data stream and the sync cannot be recognized.

The Racal-Tacticom Jaguar-V (JAmming-GUArded Radio-VHF) is designed for 30 to 88 MHz operation and this spectrum is split into 9 hop bands each 6·4 MHz wide. The hopping is carried out in random sequence over the 256 25 kHz spaced channels in the hop band. It has manpack and low and high-power vehicle station options, modular construction being used.



The Racal-Tacticom JAGUAR-V transceiver in the vehicle station option.

The SCIMITAR family of radios introduced by the Marconi Company employ similar techniques but the hopping here is random over the whole band, i.e. 30 to 88 MHz for SCIMITAR-V. The family includes an h.f. range (SCIMITAR-H) which operates over 1·6 to 30 MHz with similar facilities and manpack and vehicular variants. There is also a pocket-sized radio (SCIMITAR-M) for the 68–88 MHz v.h.f. band (and optionally for 146–156 MHz, 420–470 MHz or other customer specified bands) and weighing less than 0·5 kg. This has 12·5 kHz channel spacing and is thus compatible with commercial f.m. high-band radio as well as with 25 kHz and 50 kHz equipment.

* A description of the JAGUAR-V equipment was given by E. Ribchester in a paper at the recent IERE Conference on Radio Receivers and Associated Systems.

The Marconi SCIMITAR-H h.f. set (left) and the SCIMITAR-V v.h.f. set (right) are seen fitted inside a Chieftain Main Battle Tank.

IERE BENEVOLENT FUND

Annual Report of the Trustees for the period 1st April 1980 to 31st March 1981

The new definitive Trust Deed for the IERE Benevolent Fund was approved by a Special General Meeting of subscribers held at 99 Gower Street, London WC1 on 22nd May 1980. Since then the Trust Deed has been formally registered with Her Majesty's Charity Commissioners and all the work needed to re-align the Fund's investments to meet the needs of the new Deed has been completed. As a result, the Fund now enjoys the full asset-protection and minimum cost investment management service provided by the office of the Official Custodian Trustee for Charities.

Some stress was laid in our last report on the need for the wider membership of the Institution to support this their own Benevolent Fund so as to ensure the maintenance of the real value of the Fund's assets against the time when, inevitably, the demands on its resources become very much heavier than they have been of late. It is with some disappointment, therefore, that we have to report no major increase in the Fund's resources from donations over the last year. Fortunately, however, interest and dividends from the Fund's assets have been maintained at a worthwhile level throughout the year.

As to calls on our resources, there has been some increase during the year from both home and abroad. In some instances, detailed case study has shown assistance to be due from statutory sources or through more appropriate and larger charitable funds: in others our own Fund has responded with emergency aid or longer term support as necessary. No deserving case has been denied caring attention and material assistance over this period; and our co-operation with other charities in those cases where joint responsibility has seemed appropriate has continued.

Once again, the Trustees would like to solicit the help of members to ensure that all known or suspected cases of colleagues in distress are brought to our attention, for it is a well-known fact that those most in need are all too often least likely to seek, on their own, the help they require to alleviate their difficulties.

ANNUAL ACCOUNTS OF THE INSTITUTION OF ELECTRONIC AND RADIO ENGINEERS BENEVOLENT FUND

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MARCH 1981

	1981 £	**1981** £	1980 £	1980 £
INCOME				
Donations		830		564
Dividends and Interest Receivable		8,230		7,102
		9,060		7,666
EXPENDITURE				
Legal and Professional Charges	210		1,065	
Grants and Donations	2,005		1,256	
Administrative Costs, Postage, Telephone and Stationery	302		250	
		2,517		2,571
		6,543		5,095
Add:				
Surplus on redemption and disposal of investments		385		378
Surplus for the year carried to Reserve Account		£6,928		£5,473

Trustees:
(*Signed*)
W. GOSLING
S. R. WILKINS
S. M. DAVIDSON

BALANCE SHEET AS AT 31st MARCH 1981

	1981 £	**1981** £	1980 £	1980 £
ASSETS				
Investments at Cost		50,319		53,537
(Market Value at 31.3.81: £85,709 (1980 £70,776))				
Short Term Deposits		27,279		18,000
Current Assets				
Bank Balances on Current Account	—		263	
Income Tax Repayment Claim	495		468	
Sundry Debtors	600		362	
Amount due from IERE	25		—	
		1,120		1,093
		78,718		72,630
Less:				
Current Liabilities				
Legal and Professional Charges payable	161		976	
Amount due to IERE	—		25	
		161		1,001
		£78,557		£71,629
Represented by:				
Reserve Account—Balance 1st April 1980		71,629		66,156
Add:				
Surplus for the year		6,298		5,473
Balance at 31st March 1981		£78,557		£71,629

SCHEDULE OF INVESTMENTS AS AT 31st MARCH 1981

Nominal £		*Cost* £
£100	Associated Electrical Industries Ltd.—6% Debenture Stock 1978/83	99
£1,000	Barnet Corporation—7¾% Loan 1982/84	982
148	Bowater Paper Corporation Ltd.—Ordinary Stock	373
170	Burmah Oil Co. Ltd.—£1 Ordinary Shares	702
£2,206.59	Corporation of London—6½% Loan 1980/82	1,800
340	Courtaulds Ltd.—25p Ordinary Shares	500
£500	Courtaulds Ltd.—7% Debenture Stock 1982/87	467
750	Currys Ltd.—Ordinary 25p Shares	1,580
914	De La Rue Co. Ltd.—Ordinary Shares 25p	764
373	English China Clays Ltd.—Ordinary Shares 25p	534
£4,853.99	3½% Funding Stock 1999/2004	1,370
£2,225	5½% Funding Stock 1982/84	1,993
£3,451.15	6% Funding Loan 1993	2,001
£2,250	6½% Funding Stock 1985/87	2,007
2,249	General Electric Co. Ltd.—25p Ordinary Shares	885
£600	General Electric Co. Ltd.—Unsecured Capital Notes 1986	—
332	Grattan Warehouses Ltd.—25p Ordinary Shares	622
£2,188.43	Greater London Corporation—9½% Loan 1980/82	2,000
£200	The Great Universal Stores Ltd.—5⅜% Redeemable Unsecured Loan Stock	106
£300	The Great Universal Stores Ltd.—8¼% Unsecured Loan Stock 1993/98	248
1,200	Henderson International Trust—now Vavasseur International Trust Units 5p	150
£150	ICI Ltd.—7¼% Unsecured Loan Stock 1986/91	148
1,124	ICI Ltd.—£1 Ordinary Stock Units	3,334
£1,000	Islington Corporation—10% Redeemable Stock 1982/3	995
817	Lonhro Ltd.—25p Ordinary Shares	755
8,822	Marks & Spencer Ltd.—25p Ordinary Shares	5,471
1,250	Plessey Co. Ltd.—50p Ordinary Stock	1,479
187	Reed Group Ltd.—Ordinary Shares of £1	454
£35	Reed Group Ltd. 10% Unsecured Loan Stock 2004/09	35
2,000	Shell Transport & Trading Co. Ltd.—Ordinary Shares of 25p	3,140
200	Tanganyika Concessions Ltd.—50p Ordinary Shares	703
928	Thorn—7% Convertible Redeemable Second Cumulative Preference Shares	891
1,330	Transport Development Ltd.—25p Ordinary Shares	743
£1,225	Treasury Loan 7¾% 1985/88	992
£1,320	Treasury Loan 8¼% 1987/90	1,006
£1,990.69	Treasury Loan 8½% 1980/82	2,000
£1,125	Treasury Loan 9% 1994	999
£3,850.67	Treasury Loan 9¼% 1983	3,500
£1,500	Tresury Loan 12% 1983	1,432
£2,180.01	Treasury Stock 13% 1990	2,200
796	Unicorn General Trust	125
937	Watts, Balke, Bearne & Co. Ltd.—Ordinary Shares 25p	437
500	Whitbread & Co. Ltd.—Ordinary 'A' Shares of 25p	297
		£50,319

AUDITORS REPORT TO THE TRUSTEES OF THE INSTITUTION OF ELECTRONIC AND RADIO ENGINEERS BENEVOLENT FUND

We have audited the accounts set out on pages 490 and 491 in accordance with approved auditing standards. In our opinion the annexed accounts show a true and fair view of the Benevolent Fund's affairs at 31st March 1981 and of the surplus for the year ended on that date, and comply with the Trust Deed dated 22nd May 1980.

50 Bloomsbury Street, London WC1B 3QY

Signed:
GLADSTONE, JENKINS & CO.
Chartered Accountants

21st August 1981

FOCUS on Safety

Safety and Reliability Society formed

The Safety and Reliability Society—which aims to draw together all those engaged in the discipline of safety and reliability and to stimulate and enhance the development and use of safety and reliability technology in the pursuit of safety, availability, profit and convenience—held its inaugural meeting at Southport at the end of last year.

The Society considers that no single institution has in the past dealt primarily with reliability engineering in its widest sense, and few have been concerned with the use of reliability assessment in safety or hazard analysis. It is setting a high professional standard for individual membership and affiliate membership for companies is available.

The President of the Society is Dr A. E. Green, FIERE, of the National Centre for Systems Reliability. The new society has planned a series of meetings during 1981/2, the formation of a branch structure throughout the UK and overseas, and the regular publication of a Journal. Further details are available from Mr B. Sayers, Safety and Reliability Society, P.O. Box 25, Cambridge Arcade, Lord Street, Southport, PR8 1AS.

Testing of Electrical Equipment

Accidents involving electricity are rare, but a high proportion of those that do occur cause death rather than injury. Electricity may start fires, indeed it is the single most frequent cause of fires in commercial and industrial premises. It is unrealistic to expect portable electrical appliances to go on working safely for an indefinite period and most industrial undertakings have a system by which the electrical safety of equipment is checked at regular intervals.

A colour video recording made by the University of London A-V Centre entitled 'Safety Screen No. 10: The Systematic Testing of Electrical Equipment' deals with the safety testing of electrical appliances with particular reference to equipment used in universities. The hazards of electricity and the defects that can arise in popular equipment are first examined, then the systems of regular testing of electrical safety in two colleges are seen in operation and their Safety Officers describe the techniques employed and the amount of effort involved. The programme concludes with advice about first aid in cases of electrical shock.

Electronic instruments etc., are not examined; the programme deals with electrical equipment which tends to be treated with familiarity that verges on contempt or at least complacency!

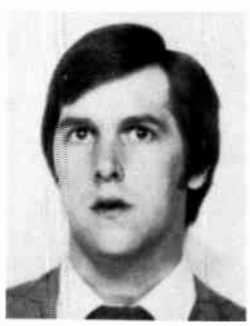
Further information regarding the programme and its hire can be obtained from The Administrative Secretary, ULAVC, 11 Bedford Square, London WC1B 3RA (Tel. 01-636 3104).

Contributors to this issue*

Richard Nicol has worked in the field of television coding since 1970 when he joined British Telecom Research as a new graduate. Early work involved the design of video analogue to digital converters and studies of techniques of data compression for the transmission of video telephone signals. He was awarded a Ph.D. for one aspect of this latter work in 1976. Since 1975 he has been head of the digital television research group where his responsibilities include the research and development of codecs for video teleconferencing, still picture transmission and the television coding aspects of Picture Prestel.

Brian Fenn received the B.Sc. degree from the City University, London in 1969, and the M.Sc. and M.Phil. degrees from Essex University in 1971 and 1975 respectively. He joined British Telecom as an apprentice in 1963, and after working on packet switching moved to the research centre in 1974, where he was involved with the operating system aspects of System X. In 1977 he joined the Visual Telecommunications Division at the research centre where he works in the digital television group.

Roger Turkington joined BTRL as an apprentice in 1968. He received his technical education at Willesden Technical College and later obtained CEI Part II in electrical engineering at Suffolk College. On completing his apprenticeship he worked on analogue CCTV systems in the Visual Communications Division. In 1978 he took up his present appointment in digital television group working on picture coding for slow scan television.



Graham Kelly is Principal Lecturer in Organizational Behaviour in the Department of Business and Management Studies at the City of Birmingham Polytechnic. He holds a Master's degree from the University of Leeds and a Ph.D. in Management Studies from the same university. His research interests include policy formulation, management development, career transitions and retirement.

*See also page 504

Brian Smithers graduated in physics at the University of London in 1955 and was subsequently awarded a Ph.D. degree for post-graduate work on electrical discharges in gases. His early training was with A. C. Cossor and the M-O Valve Company and he then joined the Electrical Research Association in 1958 to work on arc phenomena in relation to vacuum circuit-breakers. Since 1969 Dr Smithers has been with the Electronic Interference Department where he is at present a Principal Physicist.

David Bull completed an HNC course following his National Service with the RAF. After four years with Vickers Armstrong working on guided weapons development he joined ERA in 1959 to carry out research on discharges in gases. He moved to the Electromagnetic Interference Department in 1968 and is now a Principal Engineer in charge of aircraft investigations and flight programmes.

Gerry Jackson (Fellow 1978) graduated with a London University external honours degree in physics in 1945 following study at University College, Exeter. After six years in industry he joined ERA in 1952 and has worked on problems in electromagnetic interference including techniques of measurement, instrumentation and screening. He is now Manager of the Electromagnetic Interference Department and is internationally involved as a Vice Chairman of the International Special Committee on Radio Interference and Chairman of CISPR SCB (ISM equipment). He has served on Organizing Committees for IERE conferences on Electromagnetic Compatibility, being chairman for the 1980 and 1982 events.

Ron McLellan teaches Business Policy at the Anglian Regional Management Centre, and is tutor of the Centre's Advanced Management Programme M.Sc. course. He is a Chartered Engineer and obtained a M.A. in Management Studies from the Administrative Staff College, Henley and Brunel University. His management experience included periods with I.T.T. and Elliott Automation and he is currently involved in a study of business policy in Britain and Europe. The Leslie McMichael Premium for 1980 is to be awarded to him for a paper in the Journal on 'Management in a competitive environment'.

General Interest Paper

Processes for Developing New Products

RON McLELLAN, M.A., C.Eng., M.I.E.E*
and
GRAHAM KELLY, Ph.D., M.A.,†

An understanding of the processes used for developing new products can help a manager reduce the number of new product failures for his company. The authors describe three of the process patterns used by companies when developing new products and discuss the characteristics of these processes. They also discuss the influence these processes may have upon the people involved in new product development.

Introduction

Our studies of policy formulation in European companies have shown that a variety of processes are used for developing new products. We have been able to recognize several patterns of developmental processes, and three of them are described in this paper. Each of the patterns has particular characteristics that may determine its suitability for meeting a company's needs. This paper is intended to help managers understand the characteristics of these processes, and to show how the process used by their organization to develop new products can influence the performance of the people involved, and the products that emerge from the process.

It is generally agreed that the ability of companies to innovate and successfully introduce new products is crucial for their survival. The uncertainty of the demand for a company's products, the finite life of products, the increasing costs and scarcity of resources, and rapid technological change, are all threats to a company's business that can often only be countered by the introduction of successful new products.

The generation of new products challenges even the most creative new product development activity. As Randall has pointed out[1], '. . . new product development is littered with failures, and these failures occur in all markets and in all companies'.

The apparent deficiency being found in this area may seem surprising considering the wealth of advice and instruction designed to help managers with their new product development activities. However, most of the guidance provided is either prescriptive — telling the manager what he ought to do — or is descriptive — telling him about the procedures used by successful companies. Often a 'best way' is prescribed that is claimed to be suitable for all companies regardless of differences in their size, type of operation or environment. An opposite view is taken by Sounder, who has pointed out 'A variety of methods are available for managing the new product development process, although none was found to be the overall "best" one. Rather, different methods were found to be effective under different conditions.[2]' Despite such comments, it does seem that, in general, the characteristics of the alternative methods available to the manager are largely ignored.

It also seems that, as the need to introduce successful new products has increased, managers are turning towards formal processes for their generation. Parker,[3] for example, cites the case of a large company that '. . . . has recently reported that, through the adoption of a careful, systematic approach, their percentages of successful innovation has risen from 10% to 50%.' It appears that formal processes are being introduced into companies that previously relied upon intuitive innovation.

It is our contention that the selection and understanding of the process used for the generation of new products is the key to success in this area of a company's activity. The process patterns that we describe are generalized representations of extremely complex processes and should not be regarded as pure or rigidly defined, or mutually exclusive. However, we believe that they are distinguishable from each other, and that understanding these distinctions can provide insights for managers into the process used in their own organizations. It also enables them to consider and devise imaginative processes to meet their own product development needs. The processes to be described have been called Alpha, Beta and Gamma.

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† *Department of Business and Management Studies, City of Birmingham Polytechnic, Perry Barr, Birmingham B42 2SU.*

The Radio and Electronic Engineer, Vol. 51, No. 10, pp 493–496, October 1981
0033–7722/81/100493+04 $1.50

New Product Development Processes

We chose to study decentralized companies with several operating divisions. Each division was the responsibility of a divisional manager and had its own managers of finance, production, engineering, personnel and marketing. At corporate level a director was responsible for each of these functions for the whole company. Corporate management also had several staff functions to assist them — corporate planning, research and development, market research; and in some cases a new product department. While many companies are not organized in this way we suggest that the issues that the process patterns raise are relevant to the new product development process in companies with other organizational forms.

The Alpha Process

In the Alpha process pattern the company relies on new product initiatives occurring at the divisional level. These initiatives are submitted to the corporate management for approval and the allocation of the resources to develop the idea. The company may either have the idea developed by the division who originated it or by a new product unit that develops initiatives from any division.

At the divisional level, initiatives tend to emphasize the division's existing areas of operation so as to reinforce their position. Corporate management may receive a variety of ideas that reflect the interests of their divisions; thus the company's new product developments could, as a result, be diverse. Randall[4] found in his survey that most new products are derived from in-company innovations or modifications to the present products, and the Alpha process pattern would contribute to this situation.

The Beta Process

When the Beta process is used, the initiative for new products is taken at the corporate level, and not with the divisional managers. This corporate level interest might be vested in a New Product Department, Commercial Project Manager, or New Product Committee.

The corporate management may take a company-wide perspective and not be constrained by the role of any one division. Initiatives can therefore be expected to fit more neatly into the overall company operation. This contrasts with the probably constrained and insular output of divisions when the Alpha process is used. However, Randall suggests,[6] 'One of the resources that is in short supply when developing new products is really new ideas,' and if the chance of generating these ideas increases as more people are involved in the process, then the elite Beta process team may not be as fertile as the larger number of managers involved in the Alpha process. With a Beta process pattern, approval takes place at the same organizational level as that of initiative generation, and as a result may not be a very onerous process.

Once the initiative has been approved, further development may take place at either the divisional or corporate level. A division may be allocated the resources to pursue the initiative and develop the idea into a viable product, or alternatively, if the company has a new product development department, it is possible that an operating division will not be involved until the product is ready for production.

The Gamma Process

In the Gamma process the corporate and divisional level managers are expected to work together to generate new product initiatives. They arise neither solely from the divisional level, as in the Alpha process, nor solely from the corporate level, as in the Beta process. The process may be seen as the linkage between the company's divisional and corporate new product interests as shown in Fig. 1.

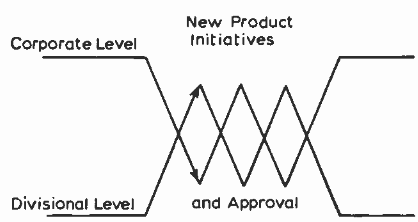

Fig. 1. Gamma process.

The process is participative and the outputs can be expected to be the result of a combination of the corporate manager's expectations for the company and the divisional managers' knowledge of their operations. This process may be the most likely to overcome Corfield's criticism that 'Too often the design of a product is developed in isolation from all other key functions'[7]. It may also reflect Holt's opinion[8] that 'A successful product innovation is the result of many people interacting . . . .' The corporate interest may be vested in a new product department, committee or manager but this may tend to dilute the effectiveness of the potential corporate involvement that the Gamma process offers. The process can be seen to contain aspects of both the Alpha and Beta processes. A high level of commitment at both divisional and corporate levels to the output of the process may well compensate for what can sometimes be a lengthy process. Finally, we should note that Sounder's study[9] suggests that '. . . . a team approach is the most effective way to manage new product development efforts', and that the Gamma process is the closest of our three patterns to such an approach.

Discussion

Information

One of the basic requirements of a new product development process is that it should provide easy access to a variety of information sources. As one would probably expect with a complex innovative process the source of ideas for new products appears to vary enormously within companies. Writers quote technical people and salesmen within organizations, and customers and competitors outside their organizations, as providers of the initial innovative thought that has led to a successful new product. This diversity of sources would suggest that the reliance on the involvement of a large number of people may be safer than banking on the ideas of the new product entrepreneur. Parker states[10] '. . . . genius is rare and thinly spread, and few companies can be expected to employ outstanding entrepreneurs.' Within organizations the nature and reliability of the information available at different managerial levels will vary. The divisional manager may be expected to have more reliable short-term information than the corporate manager; the corporate manager may be expected to have a clearer view of the long-term perspective for his organization than the operating manager. The Alpha process actively involves the divisional managers and therefore companies using this process can be expected to be knowledgeable of their current environment. Conversely, the bias of the Beta process towards the input of the corporate managers may result in companies that use this process feeling well informed about their organization's longer-term future. The Gamma process combines these two approaches to provide a blend of short and long-term information and may reveal a more realistic picture of the organization's future new product needs.

Rewards

Although an effective mechanism for collecting information may provide a valuable input for new product development there is still a need for this information to be used effectively in a well-designed, relevant process. A common intervening factor that may govern the functioning of this process is the organization's reward system. This may help or hinder the process and influence and initiatives that are generated.

In many organizations a divisional manager may be rewarded for effectively utilizing the resources of his division and this may tend to make him adopt a maintenance orientation to his activities with the result that he has little incentive to innovate in areas outside his main line of business. The speculative ideas of innovation may even be seen as threatening his ability to meet his existing targets and thereby obtain his rewards. It may not be surprising if organizations using the Alpha process, with its dependence upon the input from divisional managers, do not receive many radically new business ideas. This situation may be corrected if the reward system recognizes that divisional managers have a responsibility to develop new products, and that this may in the short term reduce their division's performance.

On the other hand, a reward system may provide such a strong motivation for a corporate manager to create new business initiatives that he pays scant attention to their effect upon the organization's existing business. An over-zealous corporate manager may even promote new ventures at the expense of current business. This could occur when the Beta formulation process is used because of its reliance upon the inputs from corporate managers. There is the need therefore, to ensure that the organization's reward system stimulates managers to meet the goals of the new product development process as well as to meet their day-to-day responsibilities. This may require a complex managerial reward system with two sets of criteria — effective maintenance of today's business and the successful development of tomorrow's.

Approval

A phase of any formulation process that should not be underestimated in terms of its effect on the behaviour and effectiveness of an organization's executives is that of approval. We have found two general patterns of approval, reflecting in the main the amount of informal communication that occurs in a particular organization. In some organizations using an Alpha process, we have found that there is a continuous discussion of ideas with more senior executives, thus making the eventual formal presentation of divisional initiatives for approval a virtual rubber-stamping operation. In other organizations, using the Alpha process, this opportunity of informal feedback may not exist and therefore the eventual presentation session may be perceived as a high risk situation, with the possibility of initiatives being totally rejected. In an organization using a Beta process, approval may be less stressful as both initiation and approval are performed by the same corporate executives. Although if this corporate responsibility is vested in a new product department or project manager and they do not remain in close contact with corporate management, then the Alpha type risk may occur. Unfortunately, the benefit of the integrated innovation and approval phases of the Beta process may be lost if the divisions are asked to implement new product developments which they have not been involved in.

In a Gamma process organization approval still resides with the corporate managers, but the divisions' involvement in the development of the new products should help them accept and implement the corporate decisions.

Whatever approval system is used, there is the possibility that it may be perceived as a hurdle that faces the participants rather than an opportunity for them to gain organizational commitment for their ideas. Managers need to be aware of the possibility that initiatives may be generated in a form that maximizes their chance of approval rather than in a way that may be seen as most appropriate for the organization. Managers proposing new product initiatives should recognize that the inhibitions and prejudices of decision makers may present barriers to the acceptance of potentially good ideas. Proposals need to be presented in a way that supports the ethos of the decisions makers rather than conflicting with it.

Conclusion

In general we find that the process used by a company to generate its new product ideas may materially affect what is ultimately developed. Where successful new product development requires the effective utilization of certain types of expertise, a process that excludes or inhibits individuals who possess this expertise may end up in a relatively impoverished state. For example, the Beta process will more or less exclude divisional level managers, eliminating their chance to influence the nature of new products introduced by the company. In contrast, in an organization with an Alpha process, the new products will, in the main, be developed by managers at divisional level who may not adopt the long term company perspective possessed by corporate management. One of the strengths of the Gamma process may be that executives from both corporate and divisional levels are involved in new product development. This may enable a larger proportion of the information and expertise available to the organization to be used in its product development process.

We also conclude that the new product development processes used by organizations may be distorted and inhibited by limitations in the rewards system used by companies. We have found, for example, that in companies using the Alpha process, divisional-level managers may be likely to adopt a maintenance orientation to their thinking. Their main concern was to maintain or consolidate their divisions' existing business activities. If rewards come from the effective maintenance of the existing activities the managers' behaviour will tend to be orientated that way. Alternatively, in an organization using a Beta process where new product development is performed mainly at corporate level and where reward may be closely linked with initiative, there may be a greater likelihood of innovative behaviour; but ideas may be generated that do not match the resources at divisional level. While the Gamma process does not ensure that a company's reward system stimulates initiatives that result in the generation of successful new products, the close involvement of divisional and corporate managers in the process may remove the inhibitions of the former and temper the excesses of the latter.

In this paper we have suggested that the nature of the process used by organizations to develop their new product ideas is a critical factor in determining the success of this activity. The design of this process deserves a level of commitment and ingenuity at least as great as that usually reserved for the design of the new products themselves.

References

1 Randall, G., 'Managing New Products', p. 5. Management Survey Report No. 47, British Institute of Management Foundation, 1980.
2 Sounder, W. E., 'Effectiveness of product development methods', *Industrial Marketing Management (USA)*, **7**, no. 5, p. 306, October 1978.
3 Parker, R. C., 'Guidelines for Product Innovation', p. 7. British Institute of Management Foundation, 1980.
4 Randall, *op. cit.*, p. 2.
5 Parker, *op. cit.*, p. 6.
6 Randall, *op. cit.*, p. 23.
7 Corfield, K. G., 'Product Design', p. 6. National Economic Development Office, March 1979.
8 Holt, K., 'Information inputs to new product planning and development,' *Research Policy*, **7**, p. 342, 1978.
9 Sounder, *op. cit.*, p. 306.
10 Parker, *op. cit.*, p. 40.

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A sequential approach to combinational logic design

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SUMMARY

The merits of a sequential approach to the design of multi-variable combinational logic circuits are discussed, and simple algorithms for computer-aided design are described. Illustrations of the method, both for completely specified and for incompletely specified logic functions, are given.

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1 Introduction

Conventional methods for the design of combinational logic circuits, at the level of basic gates, usually begin with the specification of the required function in some canonical form (e.g. sum of standard products). Simplification of the function, to economize in the use of gates, may be achieved by a graphical method (such as the Karnaugh map) if the number of variables is small. Otherwise a computer-oriented method of simplification (such as that of Quine and McCluskey) may be used. When the function is incompletely specified advantage may be taken of the 'don't care' conditions to achieve minimization. If the resulting function is sufficiently simple it might be capable of implementation as a two-level logic circuit, but when the number of variables is large the fan-in limitations of the available gates might necessitate expansion to a multi-level circuit. The use of l.s.i. modules (such as r.o.m. or p.l.a.) can greatly simplify the design of many-variable combinational logic but can also be relatively expensive.

For a symmetric function of many variables an iterative logic circuit may be appropriate, the design of the individual cell of the iterative chain then being relatively simple. Although the functional specification is in terms of combinational logic the iterative procedure implies an ordering of the variables and the design techniques parallel those used for sequential logic. Provided that multi-level implementation is acceptable, the sequential approach can be applied to any combinational function, even though the implementation is not iterative in the sense of a cascade of identical cells. Thus for a specified ordering of the variables any combinational function can be uniquely described by a sequential state transition graph or by the corresponding state transition table. The graph provides a diagrammatic description of the function which is helpful in understanding its logical structure. The state transition graph has the conceptual advantage of being independent of any particular implementation. Furthermore, being implementation-free, the graph gives a concise description of the function even when the number of variables is large, whereas other descriptions, such as the Karnaugh map, are unwieldy in these circumstances.

The 'binary decision diagram' described by Akers[1] is essentially the same as a state transition graph (it differs only in the labelling procedure for the nodes), and Akers has shown the value of this diagram in logical analysis, synthesis and test generation. Akers mentions the possibility of generalizing his diagram to take account of incompletely specified functions (don't care conditions), but does not develop this theme.

This paper describes simple computer algorithms which generate the state transition table for a combinational function specified in sum of products form. By means of standard procedures based on state

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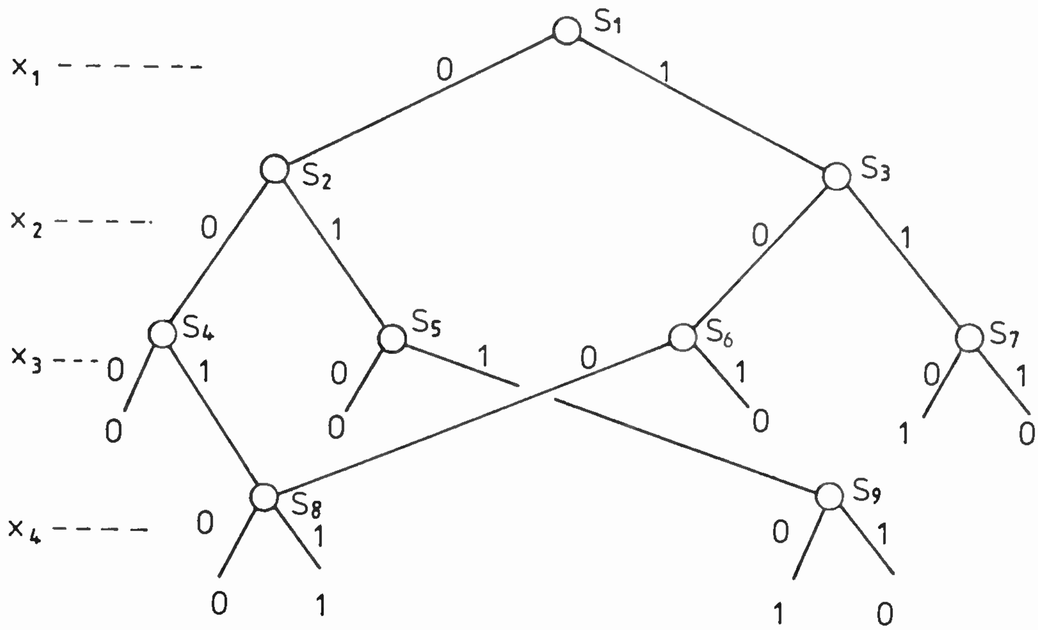

Fig. 1. State transition graph for a function of four variables.

equivalence (see, for example, Booth[2]) the table is reduced to minimum state form. For incompletely specified functions the author introduces a simple reduction procedure which, though not necessarily optimal, leads to economic implementation. In recent years much attention has been given to the development of algorithms for the efficient design of combinational logic based on multiplexers, the work of Anderson[3], Whitehead[4] and Ektare and Mital[5] being typical. The sequential approach described in this paper leads directly both to a hardware implementation based on multiplexers and to a sequential look-up table appropriate to r.o.m. storage.

2 The Sequential Approach to the Design of Combinational Logic

In this Section it will be assumed that the given combinational logic function is completely specified. Although intended to handle functions of many variables the procedure is best introduced by means of simple examples.

2.1 Example 1

Consider the state transition table shown in Table 1 which defines a particular function of four variables. The corresponding state transition graph is shown in Fig. 1. Starting from state S_1 a particular combination of the input variables x_1, x_2, x_3, x_4 defines a sequential route through the table (or graph) which terminates in one or other of the output states, 0 or 1. Thus, for example, the input sequence 1100, which corresponds to the standard product $x_1 x_2 \bar{x}_3 \bar{x}_4$, generates the state sequence s_1, s_3, s_7, 1. This indicates that the truth value of the function is 1 for this particular input combination. By examining all routes which lead to a 1 output it is easily verified that the table (or graph) defines the function (expressed in canonical form)

$$S_1\,(x_1, x_2, x_3, x_4) = x_1 x_2 \bar{x}_3 \bar{x}_4 + x_1 x_2 \bar{x}_3 x_4 + \\ + x_1 \bar{x}_2 \bar{x}_3 x_4 + \bar{x}_1 \bar{x}_2 x_3 x_4 + \bar{x}_1 x_2 x_3 \bar{x}_4$$

As is mentioned by Akers, the inverse process of deriving the graph from the sum of products representation can be achieved by iteration of the classical Shannon expansion formula. However, a different approach is used in the writer's algorithm (which ensures that the resultant graph is in minimum state form). This algorithm is described later.

Table 1

		x_i 0	1
x_1	s_1	s_2	s_3
x_2	s_2	s_4	s_5
	s_3	s_6	s_7
x_3	s_4	0	s_8
	s_5	0	s_9
	s_6	s_8	0
	s_7	1	0
x_4	s_8	0	1
	s_9	1	0

The standard techniques for reduction of a completely specified sequential machine are, of course, applicable. Thus, regarded as a sequential machine, states s_7 and s_9 are equivalent because the corresponding rows in the table are identical. At this stage however it is convenient to preserve the separate identities of s_7 and s_9 because

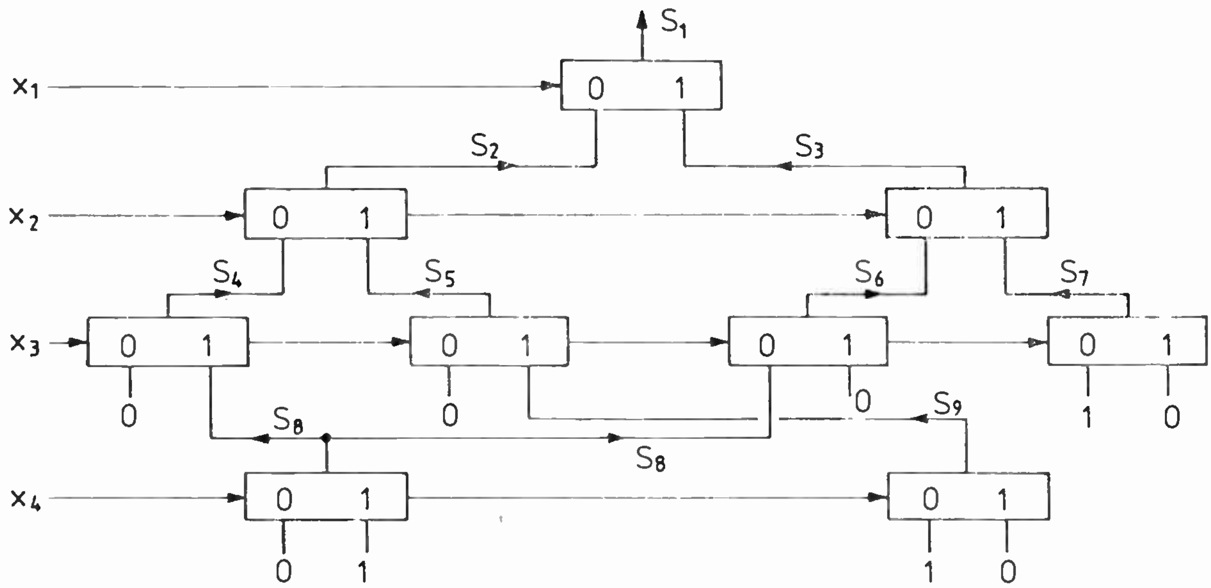

Fig. 2. Circuit for function of Fig. 1 implemented by 2-input multiplexers.

the successor states of s_7 are controlled by the variable x_3 while the successor states to s_9 are controlled by the variable x_4. This distinction is important for certain forms of implementation. It will be noted that within the blocks defined by each variable there are no equivalent states, i.e. the table is in minimal form. For a given function, and for a specified ordering of the variables, the minimal transition table is unique.

The state transition table can be implemented in a variety of ways. In particular it leads directly to a hardware implementation in terms of multiplexers and also to a firmware implementation as a look-up table in r.o.m.

2.1.1 *Hardware implementation*

The graph itself is a wiring diagram for implementation by on-off switches. Alternatively the graph can be implemented directly in terms of simple data-selector gates (2-input multiplexers). Thus, example 1 gives rise to the circuit shown in Fig. 2.

This design requires nine gates. Conventional simplification of the function (e.g. by Karnaugh map) leads to

$$s_1 = x_1.x_2.\bar{x}_3 + x_1.\bar{x}_3.x_4 + \bar{x}_1.\bar{x}_2.x_3.x_4 + \bar{x}_1.x_2.x_3.\bar{x}_4$$

which can also be implemented by nine gates (AND, OR, NOT or NAND): the two implementations have comparable cost.

2.1.2 *Firmware implementation*

The development of reliable, high-speed, low-cost sequential hardware has led to the possibility of implementing a many-variable combinational logic function by means of a simple microprocessor system. The state transition table can be stored in memory as a look-up table and a machine code program used to scan the inputs sequentially, in a cyclic manner, and to output the appropriate truth value of the function after each cycle. When used in this way the transition table represents a true sequential machine and it is not necessary to identify separately the blocks defined by the input variables. Thus in example 1, states s_7 and s_9 are equivalent and the reduced state table has only 8 rows.

2.2 Example 2

Consider the function of three variables, expressed in reduced sum of products form,

$$s_1 = x_1.\bar{x}_2 + x_2.\bar{x}_3$$

For this function, taking the variables in suffix order, the state table becomes Table 2:

Table 2

x_1	s_1	s_2	s_3
x_2	s_2	0	s_4
	s_3	1	s_4
x_3	s_4	1	0

Table 3

x_2	s_1	s_2	s_3
x_1	s_2	0	1
	s_3	s_4	s_4
x_3	s_4	1	0

The function can be implemented directly by four data-selector gates. However, if the variables are taken in the order x_2, x_1, x_3 the corresponding state table, shown in Table 3, can be implemented by only three gates because the successor state to s_3 is s_4 irrespective of the value of x_1. The appropriate cost function for an implementation by data-selector gates is therefore the number of 'switches'—a switch being a state whose successor states differ—rather than the total number of states. This example also shows that the number of switches can depend upon the ordering of the variables.

The effect of different orderings can be investigated when the number of variables is small but for functions of many variables this procedure is not normally practicable. In the writer's experience the influence of ordering on switch count is relatively small when the number of variables is large, and an arbitrary ordering enables good (not necessarily optimal) designs to be achieved quickly.

2.3 Example 3

Let a function of ten variables be defined as the sum of the ten standard products:

0 0 0 0 0 1 1 1 0 1
0 0 0 0 1 1 1 0 0 0
0 0 0 1 1 1 0 0 0 0
0 0 1 1 0 1 1 1 1 0
0 1 0 0 0 0 0 1 1 0
0 1 0 0 1 0 0 1 0 1
0 1 0 1 1 0 0 1 1 1
1 0 0 1 0 0 1 0 0 0
1 1 0 1 1 1 0 1 1 1
1 1 1 0 1 0 0 0 0 1

where 0 0 0 0 0 1 1 1 0 1 represents the product $\bar{x}_1\bar{x}_2\bar{x}_3\bar{x}_4\bar{x}_5 x_6 x_7 x_8 \bar{x}_9 x_{10}$ etc.

No two standard products differ in only one variable, hence there is no conventional simplification of the function. Because of the fan-in limitations of standard gates a conventional design results in a multi-level logic circuit with several tens of gates. The sequential approach, using the writer's computer algorithm, results in a table of 50 states, each of which is a switch. The state transition graph is virtually a wiring diagram for a design based on these 50 data-selector gates. The hardware costs of the two implementations are comparable but the design time required for the sequential approach is negligible (less than four seconds of computer time for this example).

2.4 Example 4

Suppose that a function of many variables is required to have truth value 1 whenever an even number of the variables are in the 1 state (i.e. an even parity-bit generator). Conventionally it might be decided that an iterative approach is appropriate and that the use of exclusive-OR gates rather than, say, NAND gates would result in the best design. The sequential algorithm is automatic, requiring no decisions on the part of the designer. The transition graph reveals that the structure is iterative, with two data-selector gates at each level (except for the first which has one) together performing the exclusive-OR operation.

In the above examples one block of the state transition table is associated with each of the input variables. This approach is easily modified so as to associate a pair of variables with each block (c.f. an iterative design in which a pair of variables is allocated to each cell). This results in a four-column, rather than a two-column, state transition table and automatically leads to a hardware implementation directly in terms of four-input multiplexers. Similarly a triplet of variables per block results in an eight-column table and implementation by eight-input multiplexers. In what follows however it will be assumed that one variable is assigned to each block.

3 The Computer Algorithm

In this Section the essential features of the algorithm are described. (A detailed description of the program is not given.)

Because a transition table is essentially an array of integers the storage and processing of combinational functions expressed in sequential form is readily implemented on a digital computer. Thus, for example, Table 4, corresponding to a function of 3 variables, can be stored as a 4×2 array (Table 5).

Table 4

s_1	s_2	s_3
s_2	0	s_4
s_3	1	s_4
s_4	1	0

Table 5

	0	1
1	2	3
2	0	4
3	1	4
4	1	0

Because the row and column identifiers are not explicitly stored, no confusion arises in practice from using the integer 1 to represent both the first line in the array (i.e. s_1) also the output state 1. Demarcation of the blocks associated with the individual variables need not be stored separately because this information is implicit in the array—the corresponding graph shows the level at which each variable operates. (Demarcation is shown in the example for ease of interpretation.)

Logical operations on functions are readily performed by array manipulation. Thus, the unary operation NOT simply involves the interchange of 0 and 1 in the array. Binary operations (such as AND, OR, EXOR, NAND, NOR) on two functions represented by arrays are achieved in the following manner. Firstly, and irrespective of the particular operation required, a single array is obtained from the two given arrays by a process of 'composition'. The principle is best illustrated by an example. Suppose

Table 6

1	2	3
2	0	4
3	5	1
4	1	6
5	6	6
6	1	0

Table 7

1	0	2
2	3	4
3	5	6
4	6	1
5	0	1
6	1	0

the two given arrays to be those shown in Tables 6 and 7.

These both represent functions of four variables and it is assumed that the ordering of the variables is the same for each. The composition of the two functions is the function represented by the array Table 8.

Table 8

(1, 1)	(2, 0)	(3, 2)
(2, 0)	(0, 0)	(4, 0)
(3, 2)	(5, 3)	(1, 4)
(4, 0)	(1, 0)	(6, 0)
(5, 3)	(6, 5)	(6, 6)
(1, 4)	(1, 6)	(1, 1)
(6, 0)	(1, 0)	(0, 0)
(6, 5)	(1, 0)	(0, 1)
(6, 6)	(1, 1)	(0, 0)
(1, 6)	(1, 1)	(1, 0)

Each state of the composite array is represented by a symbol of the form (a, b), where a is a state from the first of the given arrays (Table 6) and b is a state from the second (Table 7). The composite state (1, 1) identifies the first row, and its successor states (2, 0) and (3, 2) are formed by taking, in order, the successor states which appear in corresponding columns of the first row in each of the given arrays. Each distinct composite state formed in this way, other than the output states referred to later, gives rise to a new row in the composite array. The second row, corresponding to the composite state (2, 0), is obtained by composition of the second row of the first array with 0 for each column (because 0 is an output state of the given array). The composite state (3, 2) identifies the third row formed by the composition of the corresponding entries from the third row of the first array with the second row of the second array etc. The output states of the composite array are those which contain only the symbols 0 and 1, i.e. (0, 0), (0, 1), (1, 0), (1, 1). These states do not define new rows in the final array. This stage of the algorithm therefore terminates when no fresh composite states, other than output states, are generated. Again, no confusion arises from using the symbol (1, 1) both as an output state and as the starting state (s_1, s_1), because row identifiers are not explicitly stored.

The next step takes account of the particular binary operation required. For the OR operation the output states are replaced as shown in Table 9(a), simply by applying the OR operation to the bit pairs defining the composite state.

Table 9(a)—OR

(0, 0)→0
(0, 1)→1
(1, 0)→1
(1, 1)→1

Table 9(b)—AND

(0, 0)→0
(0, 1)→0
(1, 0)→0
(1, 1)→1

Similarly, Table 9 (b) shows the replacement for the AND operation. Other binary operations, if required, can be obtained by a similar procedure.

For this example suppose that the OR operation is to be performed. The composite array now has the form shown in Table 10:

Table 10

(1, 1)	(2, 0)	(3, 2)
(2, 0)	0	(4, 0)
(3, 2)	(5, 3)	(1, 4)
(4, 0)	1	(6, 0)
(5, 3)	(6, 5)	(6, 6)
(1, 4)	(1, 6)	1
(6, 0)	1	0
(6, 5)	1	1
(6, 6)	1	0
(1, 6)	1	1

The array is next reduced to minimum form. Note that (6, 5) and (1, 6) are equivalent to each other (identical rows) and that both are equivalent to 1 because the successor states are 1 in both columns. Other equivalences exist. Thus (6, 0) and (6, 6) are equivalent and hence (4, 0) and (5, 3) are equivalent etc. This reduction procedure leads to the array of Table 11:

Finally the remaining states are renumbered in accordance with row order giving Table 12:

Table 11

(1, 1)	(2, 0)	(3, 2)
(2, 0)	0	(4, 0)
(3, 2)	(4, 0)	1
(4, 0)	1	(6, 0)
(6, 0)	1	0

Table 12

1	2	3
2	0	4
3	4	1
4	1	5
5	1	0

The composition operation is commutative. The final array is independent of the order in which the given arrays are presented, save possibly for a permutation of state numberings (which has no influence on the logical properties of the array). Expressed in algebraic terms, Table 6 corresponds to the function

$$f_1 = x_1 x_2 + x_2 \bar{x}_3 + x_1 \bar{x}_4 + x_2 \bar{x}_4,$$

and Table 7 to the function

$$f_2 = x_1 x_2 \bar{x}_3 x_4 + x_1 x_2 x_3 + x_1 \bar{x}_2 \bar{x}_3 x_4 + x_1 x_3 \bar{x}_4.$$

By means of a Karnaugh map it is readily verified that $f_1 + f_2$ reduces to

$$f = x_1 x_2 + x_2 \bar{x}_3 + x_2 \bar{x}_4 + x_1 \bar{x}_4 + x_1 \bar{x}_3,$$

and this is the function which corresponds to Table 12. When the number of variables is large, conventional methods of functional composition and reduction become unwieldy, whereas the algorithm based on array operations is rapidly performed by computer and results in a concise description of the resultant function.

The data input to the program corresponds to a representation of the required combinational function in sum of products form. The products are entered one at a time and each is translated into a sequential array. Thus, for example, the standard product on four variables $x_1\bar{x}_2\bar{x}_3x_4$ is entered as 1, 0, 0, 1 and this is immediately interpreted by the program as the array shown in Table 13.

Table 13

1	0	2
2	3	0
3	4	0
4	0	1

Table 14

1	0	2
2	3	0
3	4	4
4	0	1

Clearly this array represents the function which has truth value 0, save for the particular sequence 1 0 0 1 corresponding to $x_1\bar{x}_2\bar{x}_3x_4$.

The input need not be a standard product. Thus $x_1\bar{x}_2x_4$ (again assuming four variables) is entered as 1, 0, 2, 1 where the 2 indicates the absence of a particular variable. The programme interprets this input as the array shown in Table 14.

The array which represents the complete function is obtained by successively OR'ing the array which represents the product currently input with an array which represents the cumulative sum of products, until all the products have been entered. The cumulative sum of products array is initially set at 1/0 0 (i.e. the null function). Following each OR operation the sum of products array is reduced to minimum form so as to economize in storage and processing time.

The programme embracing these principles has been written in BASIC so as to run either on a microcomputer or (for problems involving many variables) on Leicester University's Cyber computer.

4 Incompletely Specified Functions

In order to handle incompletely specified functions it is necessary to introduce, in addition to 0 and 1, a third output state to indicate the 'don't care' condition. This state is conveniently represented by -1. The composition operation on arrays is performed in the manner already described but the composite output states must now take account of the -1 possibility. The appropriate replacements for the OR and AND operations are shown in Tables 15 (a) and 15 (b) respectively.

Table 15(a)—OR	Table 15(b)—AND
$(0, 0)\to 0$	$(0, 0)\to 0$
$(0, 1)\to 1$	$(0, 1)\to 0$
$(0, -1)\to -1$	$(0, -1)\to 0$
$(1, 0)\to 1$	$(1, 0)\to 0$
$(1, 1)\to 1$	$(1, 1)\to 1$
$(1, -1)\to 1$	$(1, -1)\to -1$
$(-1, 0)\to -1$	$(-1, 0)\to 0$
$(-1, 1)\to 1$	$(-1, 1)\to -1$
$(-1, -1)\to -1$	$(-1, -1)\to -1$

The first stage of the computer algorithm for handling incompletely specified functions is essentially similar to that previously described for completely specified functions except that the input data are now in the form of a set of standard products for which the truth value of the function is 1, together with a second set for which the value is 0. (For all other standard products the truth value of the function is unspecified.) Following the entry of a product from the first set the OR operation is performed, while for an entry from the second set the AND operation is performed. The initial setting of the cumulative array is $1/-1\ -1$ rather than 1/0 0. The output of this stage of the algorithm is an array, in minimal form, with distinct output states 0, 1 and -1.

4.1 Example 5

Consider the function $s(x_1, x_2, x_3, x_4)$ for which

$s=1$ for each of the standard products

$$\begin{cases} 0\ 0\ 1\ 1 \\ 0\ 1\ 1\ 0 \\ 1\ 1\ 0\ 0 \\ 1\ 1\ 0\ 1 \end{cases}$$

$s=0$ for each of the standard products

$$\begin{cases} 0\ 0\ 0\ 0 \\ 0\ 0\ 0\ 1 \\ 0\ 1\ 0\ 1 \\ 0\ 1\ 1\ 1 \\ 1\ 0\ 1\ 1 \end{cases}$$

and s is otherwise unspecified.

The conventional approach, using a Karnaugh Map for example, gives the simplest form of the function as $s=x_1x_2\ +x_3\bar{x}_4\ +\bar{x}_1\bar{x}_2x_3$ (which can be implemented by seven NAND gates). The first stage of the sequential approach leads to the state table in Table 16.

Table 16

1	2	3
2	4	5
3	6	7
4	0	8
5	9	10
6	-1	9
7	1	-1
8	-1	1
9	-1	0
10	1	0

The 'don't care' states can now be allocated in any permissible way. Thus, the -1 states in the sixth and seventh rows could each, separately, be replaced by any one of the states in the block below or by an output state i.e. 8, 9, 10, 0 or 1. Similarly the −1 states in the eighth and ninth rows could each be replaced by 0 or 1. Ideally an allocation procedure is required which results in a reduced table having the minimum number of switches. In principle the techniques devised to minimize an incompletely specified sequential machine are available but these techniques (which involve cover algebra rather than equivalence partitions) can require the exploration of a large number of possibilities if the maximum reduction is to be achieved, (see, for example, Booth[2]). The extent of the search makes this method impracticable if the number of variables is large. The procedure adopted by the author is simple and results in a good (rather than ideal) solution in most applications. Each −1 entry is replaced by the state which appears in the other column of the same row (thus reducing the number of switches). For Example 5 this leads to Table 17.

This step is followed by reduction, using state equivalence. For this example the final table is Table 18.

Table 17

1	2	3
2	4	5
3	6	7
4	0	8
5	9	10
6	9	9
7	1	1
8	1	1
9	0	0
10	1	0

Table 18

1	2	3
2	4	5
3	0	1
4	0	1
5	0	6
6	1	0

This function can be implemented directly by 6 data-selector gates. It is of interest to note that the function obtained by the sequential approach is logically equivalent to that obtained by the conventional approach except in the truth value assigned to the 'don't care' input combination $x_1\bar{x}_2x_3\bar{x}_4$.

4.2 Example 6

Consider the function of ten variables for which

$s=1$ for each of the products

$$\left\{\begin{matrix}
0&0&0&0&0&1&1&1&0&1\\
0&0&0&0&1&1&1&0&0&0\\
0&0&0&1&1&1&0&0&0&0\\
0&0&1&1&0&1&1&1&1&0\\
0&1&0&0&0&0&0&1&1&0\\
0&1&0&0&1&0&0&1&0&1\\
0&1&0&1&1&0&0&1&1&1\\
1&0&0&1&0&0&1&0&0&0\\
1&1&0&1&1&1&0&1&1&1\\
1&1&1&0&1&0&0&0&0&1
\end{matrix}\right.$$

$s=0$ for each of the products

$$\left\{\begin{matrix}
0&0&0&0&0&0&0&1&0&1\\
0&0&0&1&0&1&0&0&0&1\\
0&0&1&0&0&1&0&1&1&1\\
0&0&1&0&1&1&1&0&1&0\\
0&1&1&0&0&0&1&0&0&0\\
0&1&1&1&1&1&0&0&1&0\\
1&0&1&0&0&0&1&1&0&0\\
1&0&1&1&1&0&1&1&1&1\\
1&1&1&1&0&1&1&1&1&0\\
0&1&0&0&1&1&1&1&1&0
\end{matrix}\right.$$

and s is otherwise unspecified.

Using the computer program for incompletely specified functions (the processing time is about 24 seconds for this example) the table obtained is shown in Table 19.

This can be built from 16 data-selector gates. (Observe that only the first six of the ten variables are relevant). For implementation in a bit-sequential manner by a microprocessor with memory it is not necessary to maintain separation of the blocks and further reduction can be achieved (states 16, 11 and 6 are equivalent and so are states 15, 13 and 9). The corresponding sequential table for storage in memory is shown in Table 20.

Table 19

1	2	3
2	4	5
3	6	7
4	8	9
5	10	0
6	1	0
7	1	11
8	12	13
9	0	1
10	14	1
11	1	0
12	15	1
13	0	1
14	1	16
15	0	1
16	1	0

Table 20

1	2	3
2	4	5
3	6	7
4	8	9
5	10	0
6	1	0
7	1	6
8	11	9
9	0	1
10	7	1
11	9	1

4 Conclusion

Any combinational logic function can be represented by a sequential state transition graph, and this graph provides a concise, implementation-free description of the function. For multivariable functions this description is superior, both in clarity and brevity, to other forms of functional description.

The state transition table is conveniently stored as an array, and logical operations on functions expressed as arrays are readily performed on a digital computer. An algorithm is described which, for a specified ordering of the variables, obtains the minimum-state transition table for a function which is completely specified in sum-of-products form. A second algorithm, appropriate to incompletely specified functions, makes use of a simple and fast reduction procedure to achieve near-optimal simplification of the table.

The transition graph leads directly to a multi-level implementation based on data-selector gates. By generalizing the procedure, so as to associate more than one variable with each level of the graph, implementation in terms of higher order multiplexers is achieved. Provided that the delays implicit in cascaded logic can be accommodated the procedure described is an effective design tool for large scale logic circuits. Where it is appropriate to evaluate a combinational logic function within a truly sequential system, under microprocessor control, the transition table can be stored in r.o.m. as a sequential look-up table.

5 References

1 Akers, S. B., 'Binary decision diagrams,' *IEEE Trans on Computers*, **C-27**, pp. 509–16, June 1978.

2 Booth, T. L., 'Sequential Machines and Automata Theory.' (Wiley, New York., 1967).

3 Anderson, J. L., 'Multiplexers double as logic circuitry,' *Electronic*, **42**, pp. 100–6, October 1969.

4 Whitehead, D. G., 'Algorithm for logic circuit synthesis by using multiplexers,' *Electronics Letters*, **13**, pp. 355–6, 1977.

5 Ektare, A. B., and Mital, D. P., 'A simple algorithm for logic design using multiplexers,' *The Radio and Electronic Engineer*, **50**, no. 7, pp. 363–6, July 1980.

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Standard Frequency and Time Service

Communication from the National Physical Laboratory

Relative Phase Readings in Microseconds NPL—Station

(Readings at 1500 UTC)

JULY 1981	MSF 60 kHz	GBR 16 kHz	Droitwich* 200 kHz	JULY 1981	MSF 60 kHz	GBR 16 kHz	Droitwich* 200 kHz
1	6·9	15·6	68·3	**17**	—	—	71·5
2	6·8	16·1	68·4	**18**	—	—	71·6
3	6·8	16·1	68·5	**19**	—	—	71·7
4	6·7	15·9	68·6	**20**	—	—	71·9
5	6·8	16·1	68·8	**21**	—	—	72·0
6	6·7	15·9	69·0	**22**	—	—	72·1
7	6·5	16·1	69·2	**23**	—	—	72·1
8	6·2	15·1	69·3	**24**	—	—	72·1
9	6·1	15·1	69·5	**25**	6·3	—	—
10	6·4	15·6	69·5	**26**	6·2	—	—
11	6·4	15·1	69·6	**27**	6·2	—	72·2
12	6·4	15·1	69·7	**28**	5·9	14·2	72·3
13	—	—	69·9	**29**	5·9	14·8	72·3
14	—	—	71.1	**30**	6·1	14·7	72·4
15	—	—	71·2	**31**	5·9	14·9	72·5
16	—	—	71·4				

Notes: (a) Relative to UTC scale (UTC_{NPL}–Station) = +10 at 1500 UT, 1st January 1977.
(b) The convention followed is that a decrease in phase reading represents an increase in frequency.
(c) 1 μs represents a frequency change of 1 part in 10^{11} per day.
*It may be assumed that the satellite stations on 200 kHz at Westerglen and Burghead will follow the day to day changes in these phase values.

UDC 621.317.332.3: 621.319.74: 677.52
Indexing Terms: Carbon fibre, Electric measurements, resistivity, Electric shielding, Electromagnetic compatibility

Radio frequency characteristics of carbon fibre composite materials

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Based on two papers presented at the IERE Conference on Electromagnetic Compatibility in Southampton in September 1980

SUMMARY

A comprehensive investigation of the r.f. properties of a range of samples of carbon fibre composite materials has been made. These samples were chosen as being representative of those which have been used or are likely to be used in aircraft construction.

This paper is in two parts, first the investigations made to determine the electrical resistance characteristics of small samples of CFC materials in the frequency range from d.c. to 300 MHz, and the second part which describes the investigation of the screening performance of larger samples in the frequency range 0·15–30 MHz for the magnetic mode and in the range 50–1000 MHz for the electric mode.

The methods of measurement which were developed during the investigation are described in detail together with the experimental results, and the conclusions include some indication of the implications of the installation of CFC panels for e.m.c. problems in aircraft.

Part 1 R.F. CHARACTERISTICS OF CARBON FIBRE COMPOSITE MATERIALS

B. W. Smithers*

1 Introduction

Carbon fibre composite (CFC) materials are increasing in use at a fairly rapid rate but their electrical characteristics have not been readily available. Electromagnetic compatibility must be achieved and the performance of metal-skinned aircraft in this respect has been generally well reported and understood. The performance of CFC will be inferior to that of metal in respect of conductivity and screening, and measurements of the basic properties are required in order to assess the limitations and the nature of remedial measures which may have to be taken.

ERA Technology was asked to examine a number of basic properties of CFC materials, including the present measurements of electrical resistance.

2 Previous Work

Measurements of low-frequency conductivity (d.c. to 1 MHz) were reported in 1977 by Scruggs and Gajda[1] for current flow parallel and perpendicular to fibre direction in a unidirectional CFC material. At the higher frequencies of this range, sample voltage was measured with an oscilloscope and current was derived from the voltage drop across a known resistor connected in series with the sample. Resistivity was shown to be constant for d.c. to 1 MHz with a value of the order 5×10^{-4} Ωm for current flow parallel to fibre direction. The method is not suitable for use at frequencies very much higher than 1 MHz as the reactance of the sample soon becomes comparable with resistance. Some more recent work by Gajda[2] indicates d.c. resistivities (unidirectional CFC with current flow parallel to fibres) of $1{\cdot}0 \times 10^{-5}$ Ωm. This value agrees more closely with values obtained by ERA than the earlier results of Scruggs and Gajda.[1]

The latter also noted that Walker and Heintz[3] found values of resistivity at 2 GHz similar to those at 1 MHz when using a CFC sample as a partition across a 50 Ω line. Using another method (strip line), however, Walker and Heintz expressed doubts about the accuracy of results above 1 GHz. In the latter case the test-sample was connected as a shunt path and treated as a lumped impedance. By introducing composite material (unidirectional) as part of the strip-line Walker and Heintz calculated resistivities of $1{\cdot}2 \times 10^{-5}$ Ωm at 1 GHz and $4{\cdot}5 \times 10^{-5}$ Ωm at 2 GHz. Some more recent work by Walker and Heintz[4] extends these measurements down to 75 MHz by using long samples (1·83 m; 6 ft). The authors suggest refinements for this technique but currently have no explanation for the manner in which conductivity decreases with frequency.

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0033–7722/81/100505+09 $1.50/0

3 Test Methods

Measurements made at ERA and described below used a Q-meter (Marconi TF1245A), to obtain the RF resistivity of small samples within the frequency range 1 MHz to 300 MHz. The Hewlett–Packard Vector Impedance Meter, Model 4815A, can measure complex impedance over the range 0·5 MHz to 108 MHz, but is limited in performance for low resistance samples.

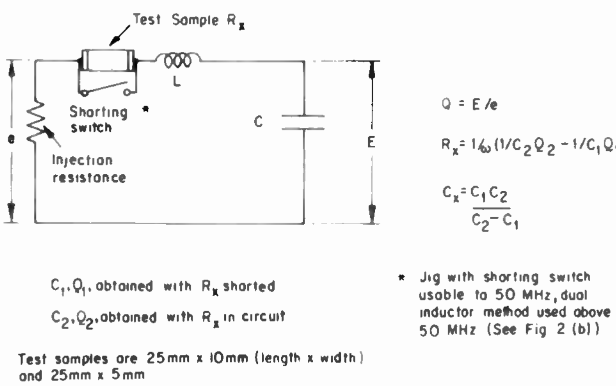


Fig. 1. Q-meter test circuit.

The measurement of r.f. resistance of low value (typical for these small CFC samples) is accomplished by including them in series connection in a resonant circuit as indicated in Fig. 1. Figure 2(a) shows the test jig used at frequencies of 50 MHz and below. At frequencies above 50 MHz and up to 300 MHz shorter connections are required and Fig. 2(b) shows a 'standard' inductor, and inductor with test sample included. Figure 3 indicates the plated areas on the samples.

In the jig of Fig. 2(a), if:

$Q_t = Q$ value obtained with the test sample shorted,
$Q_2 = Q$ value obtained with the test sample in circuit

and C_t and C_2 are the corresponding indicated values of tuning capacitance for resonance, then:

$$R_x = \frac{1}{\omega}\left[\frac{1}{C_2Q_2} - \frac{1}{C_tQ_t}\right]$$

where R_x is the required value of resistance of the test sample.

All tests were conducted at room temperature and prevailing humidity conditions.

Additionally, resistance under direct current conditions was obtained by measuring the test sample voltage drop using a digital voltmeter, and comparing this with the voltage drop across a standard resistance connected in series with the sample.

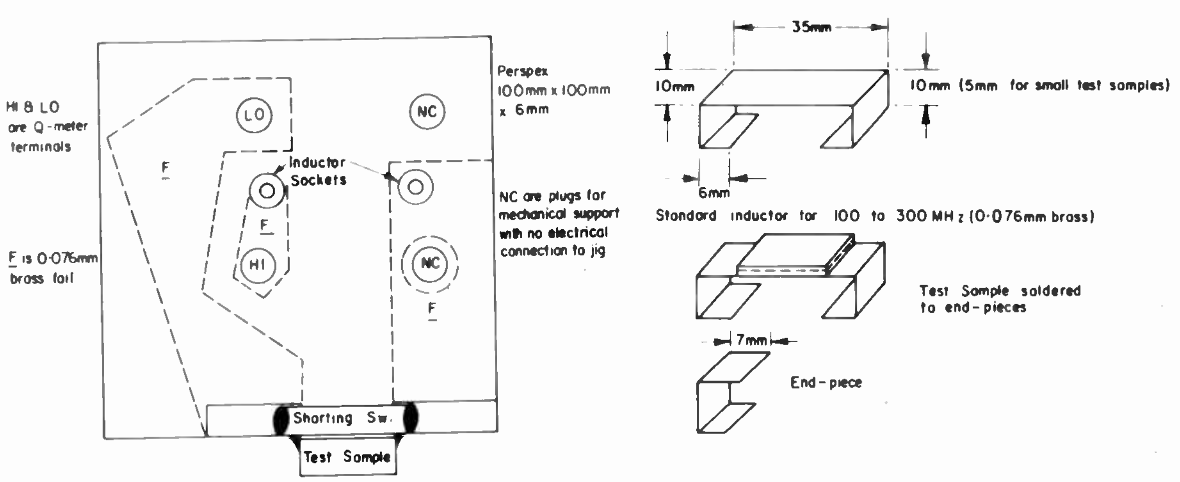
4 Origin and Structure of Test Sample Materials

Ten types of material were available, all from UK sources; structure, fibre and resin types are given in Table 1.

Table 1

Test material data

Sample	Fibre	Resin	Number of plies and lay angles, (Detailed lay-up where known)
B	—	Phenolic	16 plies; 0°, 90°
C	Super A	Code 69	10 layers of cloth; 0°, 90°
D	Super A	BSL 914C	16 plies; 0°_8, 45°_8
E	Super A	BSL 914C	16 plies; 0°_8, $\pm 45^\circ_8$
F	Super A	BSL 914C	8 plies; ±45°
G	Super A	BSL 914C	16 plies; 0°_8, $\pm 45^\circ_8$
H	Super A	BSL 914C	unidirectional; 0°, 16 plies
I	Super A	BSL 914C	40 plies; 0°, 90°, ±45° 0, 0, +45, −45, 0, 0, 90, 0, 0, +45, −45, 0, 0, 0, 0, 0, +45, −45, 0, 0, ↕ 0, 0, etc.
L	Super A	BSL 914C	16 plies; 0°_8, ±45°
P5	HM (high modulus)	Code 69	quasi-isotropic 90°, +45°, 0°, −45°, −45°, 0°, 45°, 90° 8 layers repeated 5 times



(a) Test jig, 1 to 50 MHz.

(b) Testing samples at 100 to 300 MHz.

Fig. 2.

5 Preparation of Samples

Sheets of CFC material as supplied were generally in rectangular form. Arbitrary orthogonal directions x and y were noted parallel to the sheet edges and samples were cut using a hacksaw and marked 'x' and 'y'. Additionally, samples were obtained by cutting at an angle of 45° to 'x' and 'y'. All edges were smoothed using a medium-fine grade of glass-paper and finished with fine grade carborundum paper. The 25 mm × 10 mm or 25 mm × 5 mm faces were not abraded as good adhesion and electrical contact were not required on these surfaces.

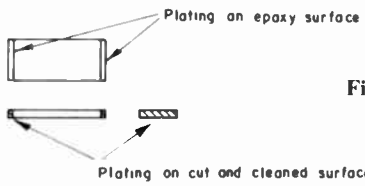


Fig. 3. Plated sample.

Samples were then wrapped in two layers of PVC adhesive tape of width 20 mm so that a 2·5 mm length at each end of the samples was exposed. The samples were then immersed in a sensitizer solution for 10 to 15 minutes, washed thoroughly and immersed in an electroless plating solution until an adequate deposit of copper was obtained. Details of this process were supplied by Plessey Research (Caswell) Limited and are to be found in the Appendix to Part 2 of this paper. The samples, Fig. 3, were washed, dried and soft soldered into the jig of Fig. 2(a), or the inductor end-pieces were soldered as required for tests at higher frequencies. Entry of current into the sample was largely at the (10 mm × thickness) or (5 mm × thickness) plated areas at the sample ends.

6 Results

6.1 Measurements on Small Samples using Q-meter

Some examples of the results obtained are shown in Figs. 4 and 5. Resistivities are generally lower for the narrower, 25 mm × 5 mm samples. This is consistent with the existence of skin effect for current flow, since in the narrower sample the loss in effective cross-sectional area will be proportionately less than in wider samples as current retreats to surfaces and edges with rise in frequency.

This change in distribution of current over the cross-section (skin effect) occurs because those parts of the cross-section which are circled by the largest number of magnetic flux lines have a greater inductance than other parts and hence a greater reactance. Those parts having the greatest reactance will carry the least current. With a flat strip, as used here, the current density is greatest at the edges, reduced at the flat surfaces and least in the centre. Hence, skin depth of current flow controls the resistance for alternating currents. From Maxwellian theory it can be shown[5,6] that current penetration depth is proportional to $f^{-\frac{1}{2}}$, and high frequency resistance is proportional to $f^{\frac{1}{2}}$ in a conductor of circular cross-section. Figures 4(b) and 5(b), where resistivity is plotted against $f^{\frac{1}{2}}$, show substantially linear relationships.

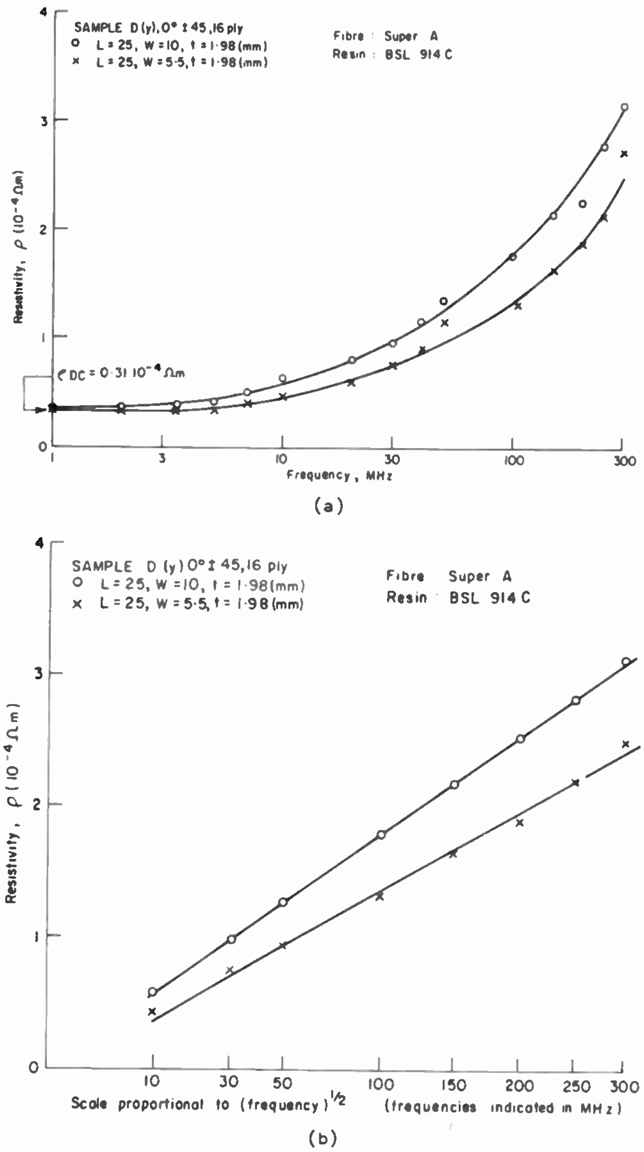


Fig. 4. Typical resistivity—frequency characteristics (Sample D).

In the case of unidirectional sample $H(y)$, Fig. 5, where the fibres are parallel to the direction of current flow, the d.c. resistivity is shown as 2·1 to 2·4 × 10^{-5} Ωm. These samples contain Super A fibres of d.c. resistivity about 1·3 × 10^{-5} Ωm. On this basis the fibre volume fraction is between 0·54 and 0·62. It has been indicated elsewhere[7] that volume fractions vary from about 0·60 to 0·65.

Table 2 shows the range of resistivities obtained at a number of frequencies, and which are characteristic of samples or panels where good contact is maintained by copper plating at the current entry and exit surfaces. It may be expected that these resistivity results will be applicable to large panels with the same aspect ratios as the samples, e.g. 1·0 m × 2·5 m panel analogous to

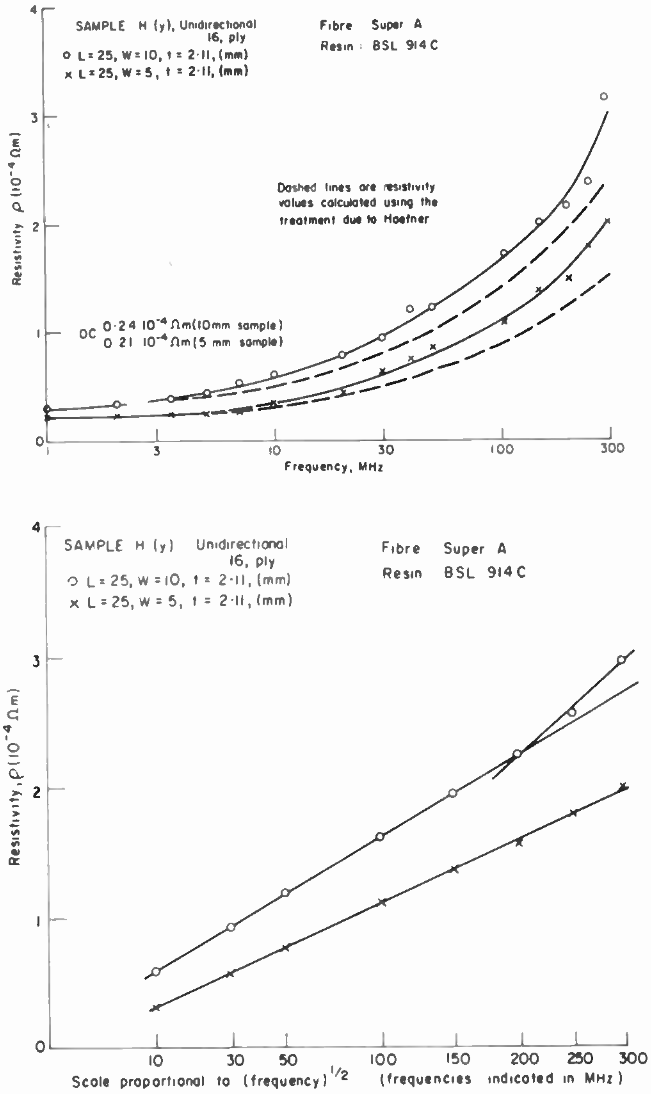


Fig. 5. Typical resistivity—frequency characteristics (Sample H).

10 mm × 25 mm samples and 0·5 m × 2·5 m panel to 5 mm × 25 mm samples.

The measurement technique was verified by measuring the resistance of a 22 mm length of Eureka resistance wire of 0·13 mm diameter from d.c. to 250 MHz and comparing these results with calculated values. Differences were negligible up to 50 MHz, but the measured value was 20% higher than calculated at 250 MHz. *Q*-meter accuracy is claimed as ±5% up to 10 MHz, rising to ±12% at 250 MHz and ±20% at 300 MHz. An assessment of overall accuracy in the determination of the resistivity of the CFC samples is difficult, but limits of ±10% up to 10 MHz, ±20% from 10 MHz to 50 MHz and ±30% from 50 MHz to 300 MHz are probably realistic. Repeatability of measurements has proved to be of a higher order, i.e. about ±5%.

Table 2

Ranges of resistivities for CFC materials

Frequency (MHz)	Ranges of resistivity all samples except unidirectional (10^{-5} Ωm)	Resistivity of unidirectional samples (10^{-5} Ωm) Parallel to lay	Perpendicular to lay
1	3 to 15	2	1100
10	5 to 15	6	1100
50	12 to 35	12	1300
100	17 to 60	16	—†
300	32 to 150	30	—†

† Measurement not possible.

7 The Calculation of R.F. Resistance of CFC Samples

A method for the calculation of the resistance of samples over a range of frequencies would be of considerable value and the measurements made on the ten types of material listed in Table 1 could provide ample validation for such procedures.

Some considerations of this nature are described elsewhere[8] and a treatment by Haefner[9] was shown to give calculated values of resistivity about 20% lower than those obtained here at 100 MHz. A method by Howe[10] for calculating the ratio R_{ac}/R_{dc} for a bundle of discrete conductors gives values quite close to those established by Haefner, indicating that skin effect in such a material will be well developed at frequencies above 10 MHz.

8 Conclusions

Resistivity data have been obtained for ten types of CFC material. In the case of unidirectional CFC, the resistivity at d.c. and low frequencies, and where main current flow is in the direction of the fibre lay, is consistent with the expected fibre volume fraction of 0·6 to 0·65.

Skin effect develops in all samples in a manner similar to that for a homogeneous isotropic material when connections to the test samples are made in the manner described. The effect can be measured by *Q*-meter or Vector Impedance Meter techniques. The *Q*-meter is usable at frequencies up to 300 MHz whereas the Vector Impedance Meter is limited to 108 MHz, and is not well suited to the low resistance of CFC samples.

Part 2 ASSESSMENT OF THE ELECTROMAGNETIC SCREENING CHARACTERISTICS OF CARBON FIBRE COMPOSITE MATERIALS

D. A. Bull and G. A. Jackson

9 Introduction

The mechanical properties of carbon fibre composite materials have been the subject of extensive investigations and are well documented and understood but the electrical properties, particularly at high frequencies, have received little attention. This part describes the investigations which were made to determine the screening effectiveness of various types of carbon fibre composite materials in the frequency range from 0·15 to 1000 MHz. The work has included the investigation of variations of screening with orientation of the material fibres relative to the incident electromagnetic field and the extent to which the material can be regarded as having an equivalent skin depth by analogy with homogeneous material.

Assessment of screening characteristics of a particular material is not an easy undertaking and examination of published reports and the literature reveals that many methods are available and that agreement between experts on the best methods is by no means unanimous.

Samples of the material were available only in single sheets of half or one metre square sizes so that fabrication of a complete enclosure was not possible. Measurements of screening effectiveness or attenuation were made by incorporating the panels as one wall or part of one wall in a high quality enclosure built from copper sheet. Particular attention was paid to sealing all the joints and seams, which were soft soldered in the copper box. All edges of the composite panels were electroless plated in order to ensure good contact and hence attenuation results dependent only on the material and not on the quality of the joints.

One of the more controversial aspects of screening theory has been the relationship between results of attenuation assessments under near and far field conditions. This investigation includes measurements in the magnetic mode made under both conditions, which showed a remarkable degree of agreement.

10 Carbon Fibre Composite Materials

Carbon fibres and filaments are not new, the patents of Edison and Swan being obtained just a century ago, but in recent years great progress has been made in the development of fibres having exceptionally high mechanical strength. The combination of these fibres and modern resins has resulted in reinforced or composite materials of superior performance. Applications include the leisure market, boat-building, automotive engineering and the aerospace industry. Recent applications of carbon fibre composites (CFC) in the aircraft industry include the AV-8B wing, the HIMAT experimental model, and both civil and military aeroplanes in the UK.

The samples that are described in this paper are representative of those that are intended to be used in future projects in the British aerospace industry.

The individual fibres have a diameter of approximately 7 μm and are generally grouped together in bundles of 10 000 filaments, forming the yarn or tow. Groups of tow are pre-impregnated with the correct amount of resin, aligned parallel to each other between sheets of non-stick material, rolled so that the filaments in adjacent tows meet, then stored in drums for ease of handling. The accepted term for the composite at this stage of production is 'pre-preg'. As stated the orientation of the tow is normally unidirectional and it is the lay-up of each ply, or layer, that gives the required mechanical strength for particular applications.

Carbon fibre composite includes the type of resin as well as the fibre and to clarify the position the results that are given in this paper refer to those composites employing XAS fibres and 914C resin. It is outside the scope of this paper to describe the curing process, i.e. the final stage of production, the techniques are documented and are noted in the references.[11]

Sample panels were normally supplied with imperfect edges as a consequence of the curing treatment, and also had, by the nature of the curing, surface resin preventing good electrical contact to the fibres. Before making any measurements the rough edges were abraded by file and glasspaper to ease the handling of what is a fairly awkward size sheet of material.

Initial measurements of the screening performance of each sample were then carried out, as described in Section 4, before removing the surface resin layer. The removal of the resin was necessary to improve the contact between the fibre ends at the edges of the sheet and one surface of the sheet and hence to the rest of the test enclosure. This was achieved by plating the edges and the area of the surface in contact with the fingerstock.

Two plating techniques were available for this purpose. Direct electroplating using acidified copper sulphate solution and a suitable plating current resulted in a coating which appeared to be good but had a poor d.c. bond to the fibres. The lesser known but more successful technique, giving a lower bond resistance and used on the samples described in the work, is that of electroless plating.

Approximately 25 mm of the resin surface was removed on all four sides of one surface of the sample under test thus exposing the carbon fibres of the first layer. Masking tape was used to protect the area immediately beside the prepared strip to avoid plating the resin surface. One of the exposed strips, including the edges, was immersed in a sensitizing solution for 10 to 15 minutes. The procedure was repeated for the remaining three sides of the sample. The sheet was then rinsed for at least 10 minutes, dried, and then each strip was immersed in an electroless plating solution until an adequate deposition of copper was obtained, taking typically 30 to 50 minutes. The plated sheet was again thoroughly washed and sparingly sprayed with WD40 to reduce oxidation.

The initial measurements to determine the screening performance were repeated and typical results are given in Section 5.

11 Screening

11.1 Definition

The purpose of screening is to provide some degree of isolation between a source of electromagnetic energy or transmitter and sensitive electronic equipment or receiver. The definition of screening ability is the ratio of the field strength in the unprotected free space situation to the corresponding value with the screen in place. The attenuation in the magnetic mode $A_H = H_1/H_2$ and in the electric mode $A_E = E_1/E_2$ where the subscripts refer to the field strength in 1—free space and 2—inside the enclosures. This definition relates to the tangential components of the field and makes no assumptions other than that adequate rejection of the component not being measured can be achieved by the measuring technique adopted. The important feature in the separation of the attenuation measurements into magnetic and electric mode values is the use of the appropriate receiving aerials. In this investigation similar loop aerials were used for both transmission and reception in the magnetic field measurements while in the electric field case scaled-down biconical aerials were used for both functions.

11.2 Techniques of Assessment

The concept of the perfect enclosure may be introduced at this stage. This is not an enclosure having infinite attenuation but one in which penetration is due to distribution transfer through the material of the screen only and not due to imperfections such as joints, seams, windows, etc. In the absence of imperfections, the field within the enclosure is less affected by local distortion and the position of internal equipment for measurements is not so critical. However, ideal conditions such as these are rarely achievable in practice and the investigation on composite panels was no exception. The techniques which were employed involved the construction of a copper box with one side replaced by the panel under test. The installation of the composite panel in the copper box inevitably results in departure from the concept of the perfect enclosure but the methods of assessment have been designed to ensure as far as possible that the attenuation of the complete structure is determined by distributed transfer through the composite panel. The incident electromagnetic field consists of separate but interrelated electric and magnetic components, complex in the near field but simple transverse E and H components in the far field. For any incident field the pattern of induced current flow in the screen is dependent on the particular component under consideration as shown in Fig. 6. (See also Ref. 2.) The

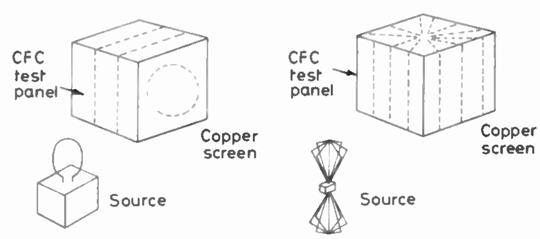


Fig. 6. (a) Induced circulating currents. (b) Induced oscillating currents.

composite panel was fitted to the copper enclosure and the transmitting aerial was orientated to ensure maximum flow of induced current in the panel.

The investigation was separated into magnetic and electric mode measurements, the former using loop aerials and extending from 0·15 to 30 MHz while the latter used biconical aerials and covered the range 50–1000 MHz. Separation into reflection and absorption losses has not been included in the investigation. However, several of the sample panels provided had a thickness of 2·0 mm which is approximately equal to the penetration depth at frequencies around 2 MHz. Thus the attenuation at low radio frequencies is generally dominated by reflection loss while at higher frequencies the effect of absorption increases rapidly and becomes dominant in the v.h.f. band and above.

12 Experimental Methods

The general experimental arrangement is shown in Fig. 7. The basis of all measurements was to set up transmitting and receiving aerials at a fixed separation distance, generally 1 m, and to obtain values of received field strength over the appropriate frequency range for a

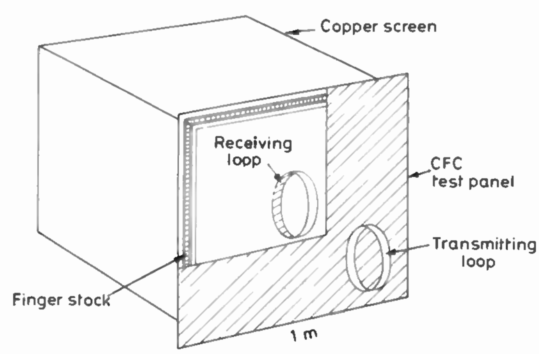


Fig. 7. Experimental arrangement.

known transmitter output. The receiving system was then installed inside the copper box with the appropriate panel in place and the measurements were repeated.

Considerable care was taken to ensure that the physical conditions, separation distance, etc., were maintained throughout the measurements.

12.1 Magnetic Mode

In the frequency range between 0·15 and 30 MHz the transmitter or power amplifier was used to energize loop aerials having a diameter of 25 cm. Similar loops were used as receiving aerials and formed part of the tuned input circuit in an amplifier which in turn was connected to an interference measuring receiver. The complete receiving installation was installed inside the copper enclosure and was battery powered. The loop aerial was tuned to resonance at each test frequency in order to achieve maximum sensitivity and was also orientated for maximum reception of signal. In practically all tests the orientation was very close to the predicted position indicating that distributed transfer was the dominant mode of propagation through the screen. Tests were performed throughout the frequency range under the following conditions: (1) free space, (2) CFC panel installed but with edges unplated, (3) panel installed with edges plated, (4) enclosure alone, open on one side.

12.2 Electric Mode

Measurements in the electric mode covered the frequency range from 50 to 1000 Hz. Considerable problems were encountered with attempts to employ rod or doublet aerials, particularly at lower frequencies, where lack of sensitivity determined the minimum frequency at which reasonable measurements could be made. Further investigations led to the development of scaled-down biconical aerials for transmission and reception which gave good coverage of the frequency range without the need for adjustment.

For reasons of operational convenience the transmitting biconical aerial was installed inside the enclosure under test and was fed through double-screened coaxial cable from the power amplifier and signal generator. The latter were installed in a similar but separate screened enclosure to ensure that no parallel propagation paths existed. The receiving biconical aerial was installed at the appropriate distance outside the enclosure under test.

Coverage of such a wide frequency range inevitably meant that resonant effects were encountered, which tended to dominate the results. Cavity resonance in the test enclosure occurred at about 230 MHz but the effects were reduced to negligible proportions by the installation of resistive damping material around the internal walls.

13 Description of Results

The results presented in this paper are representative of many others produced during the course of a very comprehensive investigation. The types of samples which were available and the fabrication techniques varied considerably but certain general patterns emerged from the results.

In Fig. 8 the attenuation in the magnetic mode is shown for frequencies between 0·15 and 30 MHz. The

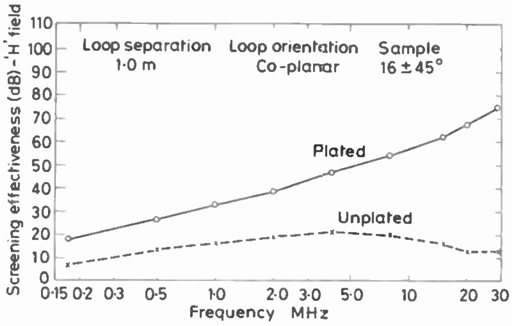


Fig. 8. Magnetic attenuation for composite panel alone, plated and unplated.

upper curve shows the attenuation for a sample with edges plated by the methods described and for which good all-round contact was maintained with the metal box. The attenuation is not large, rising directly with frequency as might be expected for a panel whose thickness, 2 mm, was approximately equal to the penetration depth at about 2 MHz. The absorption loss is estimated to be less than 10 dB at 1 MHz and probably no more than 40 dB at 30 MHz so that reflection loss largely determines the overall attenuation in the frequency range up to 30 MHz. However, the increasing attenuation at frequencies approaching 30 MHz indicates that the absorption loss is likely to become dominant in the v.h.f. band. It must be emphasized that the values of attenuation refer to the composite panel alone, allowance having been made for the contribution provided by the five-sided enclosure. The reduction in attenuation due to poor joints is well shown by the lower curve which presents the results for the same panel before plating.

Figure 9 shows the measured values of attenuation in the electric mode over the frequency range from 50 to 1000 MHz, again for the same plated and unplated

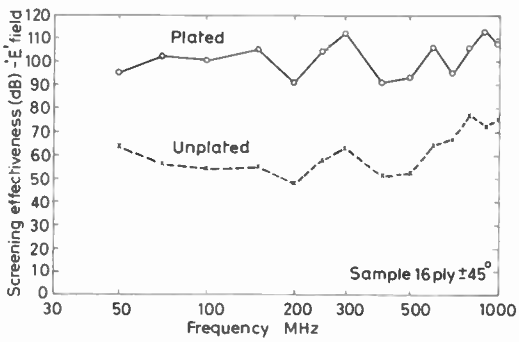


Fig. 9. Electric attenuation for panel of Fig. 8.

panel. The frequency was restricted by the inefficiency of the small biconical aerials which were used. The fluctuations in the attenuation are due to imperfections in the measuring technique rather than to variations in the sample. In particular the effect of the open sided enclosure on the small high impedance biconical aerials is much greater than on the loop aerials used for measurement of magnetic attenuation. The values around 90–100 dB are comparable with the limit of measurement as it is extremely difficult to provide this degree of isolation between the transmitting and receiving systems, so that the inherent attenuation provided by the CFC panel is probably much greater than the values shown. The most significant factor is again the deterioration in attenuation when there is poor contact between the CFC panel and the metal enclosure. The reduction shown is about 40 dB and is probably an underestimate.

Figure 10 shows the results of the measurements of attenuation in the magnetic mode for three different

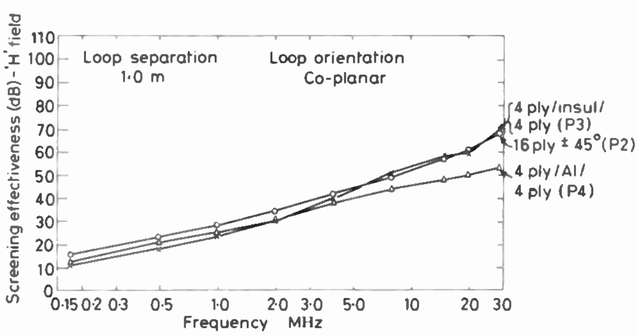


Fig. 10. Magnetic attenuation for three different panels.

samples of composite panels. One panel was conventional 16-ply CFC whereas the other two consisted of two 4-ply sheets surrounding a honeycomb in-fill of aluminium and of Hexel which is an insulating material. The mechanism of screening has not been investigated in detail but absorption loss is probably dominant at frequencies above 30 MHz while at lower frequencies attenuation is provided by multiple reflection in the complex panels. The overall result is a level of attenuation in the magnetic mode of comparable value with that provided by the 16-ply panel.

Figure 11 shows the attenuation in the magnetic mode for the same panel as used to obtain the results given in

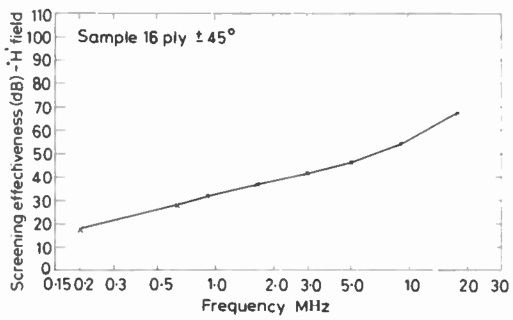


Fig. 11. Magnetic attenuation for sample of Fig. 8—far-field source.

Fig. 8 but obtained entirely under far field conditions. In the frequency range up to 1·5 MHz broadcast transmitters were used at distances of about 200 km and in the range 1·5–30 MHz a small local source was used at a distance of 200 metres which was at least one wavelength at the lowest test frequency. Comparison of the results in Fig. 8 and 11 shows close agreement.

14 Implications for E.M.C. in Aircraft

This paper does not cover aerial performance as such and thus the main implications for the achievement of electromagnetic compatibility in aircraft which have a significant part of their structures consisting of CFC panels are largely associated with the extent of penetration of transmitted power into the fuselage. It is known that operation of transmitters in the h.f. band may produce fields of some hundreds of volts per metre immediately outside an aircraft. The attenuation provided by a typical CFC panel could be as low as 20 dB so that fields of some tens of volts per metre would be encountered inside the fuselage. The disposition of the CFC panel relative to sensitive avionic equipment in the aircraft will thus be of great importance. The results of this investigation have demonstrated also the importance of bonding the CFC panel to the adjacent metallic structure. Inadequate bonding has been shown to reduce attenuation by 20–30 dB in the magnetic mode in the h.f. band. At higher frequencies the reduction in attenuation in the electric mode is much greater since the inherent capability of the CFC panels is greater than 100 dB. However, the residual attenuation even with a badly bonded panel is about 60 dB which is comparable with values obtained for aircraft with conventional fabrication.

15 Conclusions

This investigation, together with the work on resistivity described in Ref. 8, had, among its objectives the provision of information to fill a gap in current knowledge of the r.f. properties of composite materials. This paper has provided a description of the techniques of measurement of the screening attenuation for panels of CFC material. The good agreement achieved between attenuation measurements under near and far field conditions, although investigated at present only for the magnetic field, is nevertheless a good indication that consistent and repeatable results can be obtained by the techniques which have been devised.

It has been shown that CFC panels such as are presently being used in aircraft construction are inherently capable of providing high attenuation at frequencies in the v.h.f. band and above. In the h.f. band the attenuation of magnetic fields will fall approximately directly with reducing frequency and is unlikely to exceed 20 dB at frequencies below 1 MHz. The importance of bonding the CFC panels to the main structure has been clearly shown and the method of electroless plating has been demonstrated as one possibility for achieving adequate bonding.

Several aspects of the problem which still require detailed study are the attenuation in the electric mode at frequencies below 30 MHz and the performance of bonded joints between CFC panels. Further corroboration is also needed of the agreement between near and far field measurements.

16 Acknowledgments

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17 References

1 Scruggs, L. A. and Gajda, W. R., 'Low frequency conductivity of unidirectional graphite/epoxy composite samples', IEEE 19th EMC Symp. Record, August 1977, pp. 396–402.
2 Gajda, W. R., 'Measurement of the electrical properties of composite materials in the frequency range of d.c. to 30 MHz'. Phase Report RADC–TR–79–203, August 1979. (Rome Air Development Center, New York 13441.)
3 Walker, W. F. and Heintz, R. E., 'Conductivity measurements of graphite/epoxy composite laminates at UHF frequencies', IEEE 19th EMC Symp. Record, August 1977, pp. 410–413.
4 Walker, W. F. and Heintz, R. E., 'Measurement of electrical conductivity in carbon/epoxy composite material over the frequency range 75 MHz to 2·0 GHz'. Syracuse University. RADC–TD–79–255, Phase Report, October 1979.
5 Hund, A., 'Phenomena in High Frequency Systems', p. 333. (McGraw-Hill, New York, 1936).
6 Whinnery, J. R., 'Skin effect formulas', *Electronics*, 15, March 1942.
7 Whitney, J. M., 'Moisture diffusion in fibre reinforced composites'. Technical Report AFML–TR–78–48. Air Force Materials Laboratory Ohio, USA, 1978. (D of I TRC Report No. AD–AO53 561.)
8 Smithers, B. W., 'R.f. resistivity of carbon fibre composite materials'. IERE Conf. on Electromagnetic Compatibility, September 1980, pp. 183–197.
9 Haefner, S. J., 'Alternating current resistance of rectangular conductors', *Proc. IRE*, **25**, pp. 434–47, 1937.
10 Howe, G. W. O., 'The high-frequency resistance of multiply-stranded insulated wire', *Proc. Roy. Soc.*, A, 93, pp. 468–92, 1917.
11 Gill, R. M., 'Carbon Fibres in Composite Materials'. Iliffe Books, London, 1972 (published for the Plastics Institute, London SW1).
12 Miedzinski, J. 'Electromagnetic screening-theory and practice'. ERA Technical Report M/T 135, 1959.

18 Appendix: Electroless Plating of CFC Samples

Sensitizer

Add 3·5 g tin chloride to 20 ml conc. hydrochloric acid and add 5 ml of 1% palladium chloride.

Make up to 100 ml with distilled water.

The piece to be plated should be immersed at room temperature for about 5 mins, and then thoroughly rinsed (10 mins).

Note: The sensitizer can be re-used.

Plating Solution

35 g hydrated copper sulphate
170 g sodium potassium tartrate
50 g sodium hydroxide
Make up to 1 litre with distilled water.

Just prior to use, this solution should have added to it 40% formaldehyde solution in the ratio of 100 mixture : 8 formaldehyde solution. The rinsed specimen should now be placed in this mixture, and left until plated. Plating occurs best on rough surfaces (it does not adhere well to the smooth outer layer of resin). The resulting copper layer is readily soldered but overheating is to be avoided.

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Transmission techniques for picture Prestel

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Based on a paper presented at the International Broadcasting Convention (IBC 80) in Brighton in September 1980

SUMMARY

The teletext and videotex systems which are in service in the UK provide a mosaic type of graphics, permitting the display of simple pictures and diagrams. However several uses for an improved graphics facility have been identified which could benefit from still colour television pictures of normal definition and gradation. An experimental system has been developed to investigate the feasibility of such a picture option for future viewdata services. Since the available data rates are rather low for picture transmission, the application of image data compression techniques is imperative for acceptable picture update times at the receiver.

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1 Principles

The primary constraints on the implementation of a pictorial mode for viewdata are the transmission time and the amount of storage required at the receiver. A 625-line television picture, coded using 8-bit p.c.m. to provide full luminance and colour gradation, would require around 4 Mbits of storage, and take over an hour to transmit at the current Prestel transmission rate of 1200 bit/s. Whilst such storage is expensive but possible, the transmission time is clearly impractical.

The simplest method of reducing both transmit time and storage is to decrease the area and hence the number of picture elements (pels) in the picture. Instead of transmitting the full television display area in pictorial mode, part would remain in the normal alphanumeric format. The amount of storage required at the receiver and the transmit time then varies as the picture area.

By signalling the position of the insert picture with special characters in the alphanumeric data, both size, shape, and position of the picture can be varied. The result is that at the receiver the data in the normal character store effectively switch the display from alphanumeric to picture mode. The display is then returned to alphanumeric mode by an end delimiter on every picture line.

A further reduction in the data to be stored and transmitted is obtained by the application of data compression techniques to the pictorial source data.

The data compression technique first implemented was simple differential p.c.m. This technique has been widely reported in relation to the coding of composite PAL and NTSC signals for broadcast television distribution and video-teleconferencing. Since a picture viewdata system is concerned with the transmission of single television frames, there is no advantage, indeed a positive disadvantage as far as the receiver is concerned, in retaining the composite colour format. The system therefore has been arranged to encode and transmit the colour signal as separate luminance (Y) and colour difference signals (U and V). D.p.c.m. coding allows each luminance and chrominance pel to be coded by 4 bits. Thus, a colour picture insert occupying about 1/9th of the total display area takes $\sim$ 1 min at 1200 bit/s.

2 Implementation

The equipment used for the investigations was designed to act both as a prototype for demonstration and as a flexible experimental tool for development of the picture processing algorithms. The encoder comprised a 4 Mbit memory capable of storing a full-size colour picture, and a microprocessor which was used to code and format the pictures for loading into the viewdata computer. The decoder was a commercial viewdata receiver with the addition of extra storage, processing and control circuitry for the picture insert. The picture was stored at the receiver in p.c.m. form having been decoded directly off-line in a microprocessor.

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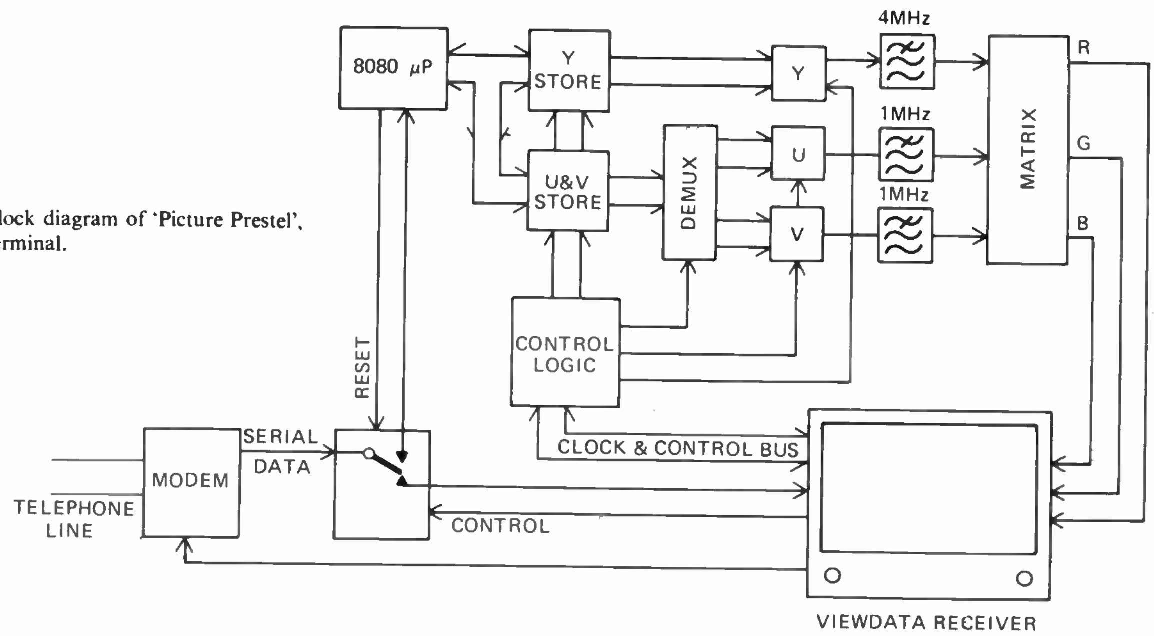

Fig. 1. Block diagram of 'Picture Prestel', terminal.

2.1 Encoding

The original picture (slide or photograph) was converted to a colour television signal by a camera or flying spot scanner. The Y component was sampled at 8 MHz and the U and V components at 2 MHz. After analogue-to-digital conversion one frame was then loaded into the frame store in p.c.m. form. The size of the picture then had to be reduced. The maximum picture area is limited by the amount of storage available at the receiver, in our case it could not exceed 16 000 luminance samples. The insert could however have a variety of shapes.

The insert can be formed either by selecting only part of the source picture, or by reducing the size of the whole picture, or both. If size reduction is required then this could be done optically, or digitally by sub-sampling the original picture. Digital size reduction was adopted as this promises to allow an information provider simpler control of his page formatting than a mechanical camera pan and zoom arrangement. To prevent aliasing caused by subsampling, a 2-dimensional filtering algorithm was used on the data in the memory before the size reduction process.

Only one field of the interlaced picture was transmitted. The Y, U and V components of this field were coded using 4-bit d.p.c.m. with prediction from the previous sample, and non-uniform quantization. In the early models the second field was obtained by repetition of the first, but better results are achieved by replacing this by an interpolation process.

A simple but effective error concealment technique was used to provide adequate resilience to channel errors. This involved the transmission of separate check-sums for the luminance and chrominance components at the end of each scan line. When an error was detected, line repetition was used to mask the horizontal streak characteristic of previous-element-prediction d.p.c.m.

Both for transmission and for storage at the computer centre, every four luminance samples were followed by one chrominance sample, U and V being transmitted on alternate lines. Each line was terminated by 8-bit words, the two error check-sums for the luminance and chrominance data and an end-of-line delimiter.

2.2 Decoding

The additional hardware used to convert a viewdata receiver to a Picture Prestel set comprised seven basic items as follows:

(i) 8080 microprocessor with r.a.m. and p.r.o.m. The r.a.m. was used for program working space, and as a television line delay for error concealment.

(ii) Picture memory—24 Kbytes of fast n.m.o.s. r.a.m.s., 16 K being used for the luminance information and 8 K for the U and V signals. These were multiplexed to allow access with the 8 MHz output clock.

(iii) TTL control logic to read data out of the picture store and format the picture shape and position correctly.

(iv) Three digital-to-analogue converters.

(v) Analogue reconstruction filters.

(vi) *YUV* to *RGB* matrix.

(vii) Clamp and mixer circuits to interface with television receiver.

The picture data (typically around 8 Kbytes) was stored in the Prestel computer as a string of data frames. a header frame provided the accompanying text and start insert codes which define the start of each picture line. Once the header page had been transmitted, a start picture character denoted the beginning of picture and caused the incoming data to be switched from the Prestel receiver to the microprocessor. At the end of the picture, the incoming data were switched back to the normal Prestel receiver so that normal alphanumeric operation could continue. The microprocessor demultiplexed and decoded the serial data into 8-bit p.c.m. words. Delays were provided for each of the three signals so that the error check could be made at the end of each line. Data were then transferred to the picture store during the television line blanking period. If an error was detected the previous line was written into store instead.

Data were read out of the picture store using a fast address register controlled by the start insert codes and end-of-line delimiters. After digital-to-analogue conversion the three signals (*YUV*) were low-pass filtered and matrixed together to give the *RGB* signals. These were then clamped and mixed with the *RGB* drives in the receiver.

The equipment was housed in a 6U 19-in rack system (which resided under the Prestel receiver). It is foreseen that without the use of custom l.s.i. the existing circuitry could be condensed onto four 6U cards. It would then be possible to incorporate the picture hardware into some existing receiver chassis.

Size and cost could be reduced by storing the picture in d.p.c.m. and using a hardware decoder. This approach was not adopted as it considerably limits the flexibility of the system for further development using alternative picture coding techniques.

3 Observations on System

The combined use of image size reduction and 4-bit d.p.c.m. reduced the amount of picture data which had to be transmitted to 67 Kilobits for an insert covering 1/9th of the total display area. At 1200 bit/s such an image takes 68 seconds to transmit and the picture builds up at the receiver from top to bottom on a line-by-line basis.

Subjectively such an update rate appears tediously slow when compared with the typical 5 seconds update time for a viewdata page. The size of the insert could be reduced still further, but it is estimated that the smallest acceptable is of the order of 70 × 90 pels, (i.e. 1/18 of the total picture area) and even this takes 35 seconds. The speed of update is more acceptable at the higher bit rates of 4·8 Kbit/s and 64 Kbit/s that are being suggested for future viewdata systems, but then likely demands for larger or higher definition pictures will present the same problems. Work has therefore continued, aimed at improving both the update time and the way in which the picture builds up at the receiver.

4 Alternative Forms of Coding

4.1 Statistical Coding

By remaining with d.p.c.m. coding a decrease in transmit time could be obtained with no loss of picture quality by the use of variable length or entropy coding techniques. These would exploit the remaining statistical redundancy of the signal after d.p.c.m. coding. The principles of entropy coding were described by Ratliff[1] at IBC 78. Essentially the technique takes account of the fact that the signal has a peaked probability distribution and allocates shorter code words to those signal conditions which occur most often. Correspondingly longer codes are allocated to the rarer signal conditions.

The disadvantage with using such codes for normal television signals is that a buffer is required at both transmitter and receiver to smooth the inherently non-uniform data rate. In addition it is possible for freak signal conditions to cause this buffer to overflow or underflow. This is not the case for picture viewdata because the frame memory at the receiver and the disk at the computer act as buffers in their own right. The non-uniform data rate manifests itself as a variable rate of picture build-up.

Measurements have been carried out on d.p.c.m.-coded pictures of the form that are likely to be used for picture viewdata using two types of variable length code, a self-synchronizing Huffman code[2] and a simple comma code. A yardstick for coding efficiency was taken as

$$\frac{\text{signal entropy}}{\text{average word length}},$$

where entropy $= \Sigma p_i \log_2 p_i$, p_i, being the probability of occurrence of condition i. The results are shown in Table 1.

Table 1.
Relative code efficiencies

Picture	Code Efficiency		
	4-bit	Comma	Huffman
1	62%	94%	96%
2	62%	94%	95%
3	60%	95%	99%
4	66%	95%	98%

It can be seen that the comma code is only marginally less efficient than the classical Huffman code, both promising a saving in data rate and hence update time of 20–30%; the comma code has the advantage of better error resilience and simplicity of implementation.

4.2 A Different Predictor

Earlier investigations[3] have shown the advantages of two-dimensional prediction, and in particular a relatively simple average of previous element and that in the line above would give similar quality with 3½ bits to the 4 bits used for previous element prediction alone. More complex two-dimensional predictors would allow further reduction to 3 bits for similar quality but error resilience would begin to suffer. In particular, error concealment by line repetition could no longer be used for two-dimensional error patterns, and forward error correction would have to be considered with sufficient complexity to handle the burst nature of errors on the telephone network.

The use of entropy coding following 3-bit d.p.c.m. would be possible for further compression, but since the number of signal conditions is that much less, a smaller percentage saving in data rate is to be expected. Measurements have shown that entropy coding with 3-bit d.p.c.m. only promises a saving of 8–10% compared with the uniform length code. The use of a non-uniform code does however more easily allow the possibility of (say) a 3½-bit quantizer, which could be a good compromise between picture quality and ease of error concealment with previous element prediction. However one complication with variable length or 3-bit coding is that storage at the computer will no longer be on the basis of an integral number of pels per 8 bit-byte which could create difficulties for file manipulation.

4.3 Transform Coding

All d.p.c.m./entropy coding arrangements still require a slow-scan form of update at the receiver. An alternative form of update is to arrange for the rapid transmission of either a very-low-definition image, or merely the outline detail of the complete picture. The picture detail and gradations would then increase with time. So unlike the d.p.c.m. case, the viewer would rapidly gain an appreciation of the picture content. In addition he could be provided with the facility of aborting the transmission if he was uninterested in the picture content, or had received sufficient detail for his needs.

The image coding technique most suited to this form of update is transform coding. Here an orthogonal, mathematical transform is performed on the image data prior to coding for transmission to produce a set of uncorrelated coefficients. The choice of the 'best' transform is dependent largely on the trade-off between its energy compaction properties and complexity of implementation. The technique takes advantage of the fact that the distribution of energy over the television spectrum is non-uniform and the aim is to select a transform that describes this distribution with the least number of coefficients. It is then possible by coefficient truncation and non-uniform quantization to reduce the data rate.

a) First image

b) Second image

c) Fourth image

d) Eighth image

Fig. 2. Gradual image build up using 8 × 1 Hadamard transform.

The technique is implemented by dividing the picture into blocks and performing the chosen transform on each. The resulting coefficients then describe the spatial detail within that block. By transmitting all the coefficients on an hierarchical rather than a block-by-block basis a gradual increase in picture resolution can be achieved. In addition, since the coefficients for each block arrive one at a time, decoding involves a simple arithmetic operation, whereas the conventional approach is to wait for all the coefficients to arrive for each block before inverse transforming. Thus the need for a complex 'fast algorithm' does not arise.

Figure 2 shows the effect of progressive picture generation using an 8×1 Walsh-Hadamard transform.[4] This is the simplest transform to implement as it merely involves additions and subtractions. Since there are 8 coefficients, there would be 8 pictures in the sequence, 4 of which are shown in Fig. 2. The rate of increase of picture quality tails off as the higher coefficients are added because most of the picture energy is in the lower part of the video spectrum.

More complex, but perhaps more attractive as far as picture viewdata is concerned is the Discrete Cosine Transform (DCT). This not only has very efficient energy compaction, but, because image build-up is essentially achieved by adding cosine waves (rather than square waves as in the Hadamard), it reduces the strong mosaic effect evident in Fig. 2. In addition the DCT facilitates the spatial filtering necessary for picture size reduction to be carried out as part of the coding operation and removes the requirement for adaptive transversal filtering. This can be achieved because the DCT is closely related to the discrete Fourier transform, where with large blocks, low-pass filtering can be implemented merely by dropping the higher coefficients. It is not quite as simple with the DCT, but Ngan and Clarke[5] suggest that truncation plus multiplication by a correction factor provides a reasonable approximation, as far as picture quality is concerned, to conventional anti-aliasing filtering.

Although transform techniques require more complex signal processing than d.p.c.m. for equivalent picture quality, the use of a microprocessor to decode directly from the incoming signal to picture storage in p.c.m. makes it a practical proposition at data rates of 1200 and 4800 bit/s. It is estimated that at 1200 bit/s, an 8080 processor could handle Hadamard transforms direct, but the addition of a hardware multiplier would be required for the DCT. At 4800 bit/s a faster 16-bit machine of the 8086 or 68000 type would be necessary.

5 Conclusions

The work reported has proved the feasibility of incorporating a picture mode into the current UK viewdata service. However, the choice of the best coding technique is by no means clear-cut. At lower transmission rates of 1·2 and 4·8 Kbit/s, a scan form of update with d.p.c.m. coding was found to produce acceptable picture quality. Transform coding techniques on the other hand offer more acceptable picture build-up, with the promise of simple software controlled picture editing at the input terminal, but at the expense of greater decoding complexity. However when decoding can be carried out using a microprocessor this need not create a problem.

For 64 Kbit/s transmission, the usefulness of transform coding perhaps becomes less attractive. Processor decoding would be difficult, unless a bipolar bit-slice approach was used, and the advantage of a progressive, over a slow scan form of update, less apparent when a d.p.c.m. 1/9th frame size insert would only take about one second to transmit. There could however be a case for 64 Kbit/s transform coding for full size and full resolution pictures which would still take about 20 seconds.

The commercial reasons for conducting this research are given by Clarke.[6] Market research indicates that the current Prestel standard is quite adequate for the public service and British Telecom has no plans to change this standard until the late 1980s. 'Picture Prestel' is seen as the main enhancement when the standard does change. It is also being offered to overseas administrations who are interested in evaluating the technology and could possibly be used for specialist business applications in the UK at an earlier date.

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7 References

1 Ratliff, P. A., 'Bit-rate reduction for high-quality digital television transmission', pp. 37–41, International Broadcasting Convention, IEE Conference Proceeding No. 166, September 1978.

2 Huffman, D. A., 'A method for the construction of minimum-redundancy codes', *Proc. IRE*, 40, pp. 1098–1101, September 1962.

3 Thompson, J. E., 'Data compression of tv signals', pp. 127–143, in 'New Directions in Signal Processing in Communications and Control' NATO Advanced Study Institute, Series E, Applied Sciences No. 12, (Nordhoff Publications, Leiden, 1975).

4 Pratt, W. K., 'Digital Image Processing' (Wiley-Interscience, New York, 1978).

5 Ngan, K. N. and Clarke, R. J., 'Lowpass filtering in the cosine transform domain', International Communications Conference, Seattle, 1980, Part 2, pp. 31.7/1–5 (IEEE, New York, 1980).

6 Clarke, K. E., 'What kind of pictures for videotext?' Viewdata 80 Conference Proceedings, London, March 1980.

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