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

Volume 49 No. 5 May 1979

The Radio and Electronic Engineer

The Journal of the Institution of Electronic and Radio Engineers

Accolades for Excellence

RECOGNITION of merit by some form of annual adjudication and a subsequent award is nowadays a widespread custom of many organizations, both national and international, governmental and otherwise. In science and technology there are respectively the Nobel Prizes and the relatively new MacRobert Awards, details of which have been frequently reported in this Journal. But both these are generally made to individuals, and it is interesting to consider, particularly at this time of year when the lists have just been published, two groups of awards made to British industry. These are The Queen's Awards for Export and Technology (originally instituted in 1965 as The Queen's Awards to Industry) and the Design Council Awards (founded in their present form in 1967).

The balance between 'Export Achievement' and 'Technological Achievement' in The Queen's Awards is always heavily weighted towards export; this year 19 of the 121 awards were for technological achievement and included marine radar, computer control of multi-interactive processors, liquid crystals, an electronic digital micrometer, a radioimmunoassay counter, and h.f. communications receivers. Ten organizations were involved in these six electronics achievements' and represented enterprising collaborative efforts between industry, and government and university research laboratories.

Export achievement on the part of nine electronics companies was recognized—rather a disappointingly low number. Bearing in mind that a firm has to make application for consideration and that the overall 'pass rate' was about 1 in 13 (about 1 in 15 for 1978), the standard is obviously set high, although a total of 1640 applications, if indicative of industry's own view of the merits of its activities, is perhaps rather over-modest. In the electronics industry the implication seems only too clear that the innovative spirit outstrips the selling ability, surely a familiar complaint in Britain and one which The Queen's Awards were introduced to help cure. Selling overseas still is *not* the strong suit of the British electronics industry although there are of course praiseworthy and famous exceptions, apart from those honoured this year.

In most years electronic engineering companies feature prominently in the Design Council's Awards which are now given for Engineering Products and Engineering Components. In the six in the first category there were a phototypesetter using a laser, a new flying spot telecine and a digital voltmeter, while in the components category an ingenious but mechanically simple linear displacement transducer using magnetic field variation was recognized.

It is probably fair to say that the prestige attaching to both The Queen's Awards and the Design Council Awards is regarded with more respect by the holder, his employees and his competitors, perhaps contenders successful or unsuccessful themselves, than by the potential customer. And yet why should not the customer attach just as much weight to such independent assessment of excellence as does the general public, or at least the more value-conscious part of it, to consumer product assessments?

We have only to think of the regard paid to 'Best Buys' and 'Seals of Approval', not to mention the avid perusal of guides listing, for instance, recommended hotels, restaurants or public houses. Unless the technological awards can gain comparable informed acceptance by the engineering customer, their avowed purpose is not being fully met: mutual admiration is hardly enough.

F. W. S.

CEI News

Individual Members Elected to CEI Executive Committee

The continuance of the practice of delegating wide powers to the CEI's Executive Committee was approved at the Special Meeting of the Board on 10th April. Immediately following that meeting, the Individual Members met to elect six of their number to serve on the Executive Committee where they will join the CEI Officers and the members elected by the six groups of Corporation Members.

The following are those who were elected by the Individual Members:—

Dr. R. J. Clayton, C.B.E., F.I.E.E., F.I.E.R.E., F.R.Ae.S.

Dr. H. P. Jost, C.B.E., F.I.Prod.E., F.I.Mech.E.

Brigadier T. B. Palmer, M.I.Mech.E.

D. A. H. Roberts, M.I.Gas.E.

J. D. Sampson, F.I.Mech.E., F.I.Mar.E.

E. H. Wakefield, F.I.C.E.

The groupings of Corporation Members referred to above are as follows:—

(1) Aeronautical/Mechanical/Production
(2) Civil/Municipal/Structural
(3) Electrical/Electronic and Radio
(4) Marine/Naval Architects
(5) Mining/Mining and Metallurgy/Metallurgists
(6) Chemical/Energy/Gas

New Chairman for CEI Standing Committee

At the Special Meeting of the Board of CEI on 10th April, the nomination of Professor L. F. Crabtree, Ph.D., F.R.Ae.S., as Chairman of the Council's Standing Committee on Education and Training in succession to Dr. G. S. Brosan, B.Sc., Ph.D., F.I.Prod.E., F.I.E.E., F.I.Mech.E., was approved.

Professor Crabtree, who is the Sir George White Professor of Aeronautical Engineering at the University of Bristol, is currently President of the Royal Aeronautical Society. He represents the Society upon the CEI Board and has been a member of the Standing Committee which he will now chair.

CEI Rejects N and F Examination Proposals

The Council of Engineering Institutions and the Egineers Registration Board have welcomed the statement by the Secretary of State for Education to the effect that the Government has no intention at the present time of abolishing 'A' level examinations. The CEI's 1,000-word report rejects the proposals of the Schools Council for the replacement of the 'A' level examination by N and F systems. IERE misgivings were voiced in the February Journal in discussing 'The Chartered Engineer's Degree'.

In its report the CEI argues that the present system is universally understood and is well balanced in that it can produce the right number of qualified entrants for the places available in higher education. The Schools Council's proposals, it is contended, could upset the equilibrium by producing sixth form classes having wider, more diffused and more shallow curricula — without additional funds from government to implement the changes. This might well lead to the reduction in entry standards for young people proceeding to higher education and a greater failure rate on degree courses. The CEI warns that engineering degree courses would have to be seriously amended and lengthened to compensate for the lack of basic ground work in appropriate subjects in schools. Clearly this would make an engineering career less attractive to the very people who should be encouraged to enter the profession.

The report argues that the 'A' level system should be extended, improved and made more efficient in terms of the time involved by developing core material in a syllabus making long-term study of engineering sciences more effective. More realistic coverage should be achieved by reducing and rationalizing the number of 'A' level syllabuses in given disciplines. The CEI also recommends the introduction of a subject in humanities to the existing 'A' level subjects which would have the effect of formalizing the work presently done by most sixth formers and thus making the N and F examination proposal irrevelant.

Finally the CEI's opinion that 'change-for-change's-sake' does not provide any solution to the problem is emphasized. CEI shares the view of other professional bodies that no change in the common examination system at 18-plus is acceptable if it results in any lowering of academic standards reflected in the intellectual abilities of entrants to a professional career.

CEI Notice

Call for nominations for the CEI Board

The Board of CEI is now calling for nominations from Chartered Engineers to fill the six places on the Board which will become vacant at the conclusion of the 1980 Annual General Meeting.

Nomination forms are available from the Secretary of CEI, 2 Little Smith Street, London SW1P 3DL, and will give details of the nomination procedure but briefly nominations must be supported by fifteen chartered engineers and forms must be received at CEI by 12 noon on 2nd October 1979 at the latest.

The following elected Board Members will be retiring but all are eligible for re-election if nominated:

Miss E. G. Dodd, <u>FIMechE</u>, FIEE	Brigadier T. B. Palmer, <u>MIMechE</u>
Dr. K. W. A. Guy, <u>MIChemE</u>	Mr. D. A. H. Roberts, <u>MIGasE</u>
Mr. P. T. Houldcroft, <u>FIM</u>, MIMM	Mr. E. H. Wakefield, <u>FICE</u>, FIHE

The Institution with which each retiring Board Member was identified for the purposes of the 1979 election is underlined. Nominations need not, however, be confined to members of these Institutions. Any Chartered Engineer may be nominated with the sole exception of one who is a member of the Institution of Electrical Engineers only. The elected membership of the CEI Board will continue to include two members who are uniquely identified with the IEE and this is the maximum allowed by the By-laws.

Notice to all Corporate Members of the Institution of Electronic and Radio Engineers

NOMINATIONS FOR ELECTION TO THE 1979-80 COUNCIL OF THE INSTITUTION

In accordance with Bye-law 49, the Council has nominated the following members for election at the Annual General Meeting to be held on Thursday, 25th October, 1979.

President

For Election: Professor W. Gosling, A.R.C.S., B.Sc.

Vice-Presidents

Under Bye-law 46, all Vice-Presidents retire each year but may be re-elected provided they do not serve thereby for more than three years in succession.

For Re-election: H. E. Drew, C.B.; Brigadier R. W. A. Lonsdale, B.Sc.; S. J. H. Stevens, B.Sc.(Eng.).

For Election: Professor J. R. James, Ph.D.; P. K. Patwardhan, M.Sc., Ph.D.; J. Powell, B.Sc., M.Sc.

Honorary Treasurer

For Re-election: S. R. Wilkins

Ordinary Members of Council

Under Bye-law 48, Ordinary Members of Council are elected for three years and may not hold office for more than three years in succession.

Fellows

The following must retire: L. A. Bonvini; L. F. Mathews, O.B.E.

For Election: Colonel W. Barker; R. Larry

Members

The following must retire: N. G. V. Anslow; K. Copeland; Group Captain J. M. Walker, RAF

For Election: Instr. Cdr. D. J. Kenner, B.Sc., M.Sc., RN(Ret.); B. Mann, M.Sc.; K. R. Thrower

Associate Member

The following must retire: Lieutenant-Commander J. Domican, RN

For Election: P. J. Hulse

Associate

The following must retire: T. D. Ibbotson

For Election: M. W. Wright

The remaining members of Council will continue to serve in accordance with the period of office laid down in Bye-law 48.

Within twenty-eight days after the publication of the names of the persons nominated by the Council for the vacancies about to occur any ten or more Corporate Members may nominate any one other duly qualified person to fill any of these vacancies by causing to be delivered to the Secretary a nomination in writing signed by them together with the written consent of the person nominated undertaking to accept office if elected, but each nominator shall be debarred from nominating any other person for the same vacancy (Bye-law 50).

By Order of the Council
S. M. DAVIDSON
Secretary

15th May 1979

Members' Appointments

CORPORATE MEMBERS

F. Oakes (Fellow 1969, Member 1954) has accepted a Partnership in Cremer and Warner, Consulting Engineers and Scientists. Following some eighteen years with Thorn Electrical Industries during which time his appointments included those of Chief Engineer of the Ferguson Electrical Division, and Director and General Manager of Thorn Electronics (Laboratories), Mr Oakes joined Cremer and Warner as an Associate in 1971 being mainly concerned with building up the Partnership's noise and vibration control section. For several years Mr Oakes served on the Institution's Technical Committee, subsequently the Professional Activities Committee, and he was chairman of the Management Techniques Group Committee.

J. D. Corrie (Member 1977) has rejoined the Signal and Mining Division of the Westinghouse Brake & Signal Company as a Senior Executive Engineer. For the pas four years he was with Nuclear Enterprises as a Project Engineer.

D. J. Cousins (Member 1973, Graduate 1962) who joined Sunstrand Aviation, Rockford, Illinois in 1972 is now Section Manager for Test Equipment Design. Before going to the company as a Project Engineer in 1966 he was for several years an Assistant Engineer in the test equipment design department of the Valve Division of Standard Telephone and Cables, Paignton.

M. J. Dash (Member 1976, Graduate 1970) has re-joined British Aerospace Dynamics Group as a member of the Rapier Project Management Team. He has just completed five years at NATO Headquarters, Brussels as Senior Systems Analyst in the EMC Section of the Allied Radio Frequency Agency.

S. J. Morris, B.Sc. (Member 1977, Graduate 1973) has taken up an appointment as a Principal Scientist in the Microelectronics Division of the Plessey Company's Allen Clark Research Centre, at Caswell, Towcester. From 1972 until the beginning of this year he was a Medical Physicist, initially at the University Hospital of Wales, Cardiff, and since 1977 at the Royal Devon and Exeter Hospital.

While working in Cardiff Mr Morris was Secretary/Treasurer of the Institution's South Wales Section.

Sqdn Ldr P. B. Murphy, RAF (Member 1973) has completed a two-year appointment as Officer Commanding Electrical Engineering Squadron, RAF St Mawgan and has moved to a staff appointment at the Procurement Executive of the Ministry of Defence in the *Nimrod* AEW Project Office.

J. A. O'Doherty, B.Sc. (Member 1977, Graduate 1975) who has been a lecturer in the Department of Electrical and Electronic Engineering at Southall College of Technology for the past five years, has been appointed Lecturer in Electronics at Bailbrook College, Bath, part of the IAL Group.

Sqn Ldr R. S. Proctor, B.Sc., RAF (Member 1975, Graduate 1971) has taken up an appointment in the Ministry of Defence Procurement Executive. He was previously a Flight Commander on the VC 10 Line Servicing Squadron at RAF Brize Norton.

W. A. M. Ramsbotham (Member 1952) is currently employed by the Crown Agents as a Project Manager in Nigeria. He has previously held similar posts in Laos and Malaysia in the latter as Chief Engineer with the Department of Broadcasting and Information, Jesselton, North Borneo.

W. E. Rodwell, M.B.E. (Member 1972, Graduate 1966) has taken up the appointment of Manager for Cable and Wireless (West Indies) in Antigua. He previously held a similar appointment in the Republic of Maldives following two years at the Head Office of the Company in its Corporate Development Unit.

Major J. M. Sweetman, B.Sc., R.Sigs (Member 1973, Graduate 1966) has relinquished his post as a Squadron Commander of a *Bruin* Communications Centre in 22 Signal Regiment in BAOR and has returned to the United Kingdom to take up an appointment as a Grade 2 (Weapons) Staff Officer in the Project *Wavell* Military team attached to the Procurement Executive of the Ministry of Defence.

J. W. Southgate (Member 1968, Associate 1962) has moved from Crow of Reading Ltd, where he had been Marketing Manager since 1976, and has taken up the post of Senior Engineer (VTR) with Thames Television, Teddington, Middlesex.

Lt Col B. Southwell, REME (Ret.) (Member 1967, Graduate 1960) is now Quality Assurance Director with Racal-BCC, Wembley. Before his retirement from the Army in October 1977, Colonel Southwell was Principal Quality Officer in the Electrical Quality Assurance Directorate.

D. E. G. Stark (Member 1968, Graduate 1963) has been promoted to Deputy Divisional Manager of the Automation and Controls Division of Westinghouse Brake & Signal Company. He has been with the company since 1964 and was formerly Engineering Manager of the Division.

A. Troughear (Member 1972, Graduate 1966) has recently been appointed Group Engineer in charge of telecommunications in the newly formed Northern Transmission District in the C.E.G.B. North Western Region on a 1st Engineer grading. He was previously a 2nd Engineer with the C.E.G.B. North Western Region as District Telecommunications Engineer in the Preston District.

Tse Chun-Cheong, B.Sc. (Eng.) (Member 1977) has been appointed Industrial Training Officer (Electronics) with the Labour Department of the Hong Kong Government. Previously Product Engineering Manager with Fairchild Semiconductor (HK), Mr Tse has recently been elected a Member of the Institution of Production Engineers.

Sqn Ldr R. L. Wilson, RAF (Member 1973, Graduate 1969) is now Senior Engineering Officer No. 92 Squadron stationed at RAF Wildenrath. He was previously Regional Communications Officer, HQ Southern Maritime Area Region, RAF Mount Batten.

A. R. T. Witchell, D.L.C.Eng. (Member 1970, Graduate 1955) is now Technical Supervisor with Radiall Microwave Components, Farnborough, Hants.

Lt Cdr R. J. Wright, RN (Member 1973, Graduate 1970) has been appointed Ship Systems Readiness Officer at Maritime Command Headquarters of the Canadian Armed Forces, Halifax, Nova Scotia. For the past 2 years he has been Weapons Electrical Engineer Officer in HMS *Eskimo*.

NON-CORPORATE MEMBERS

K. Ariyaratnam (Graduate 1976) has been posted as Regional Telecommunication Engineer (Anuradhapura) with the Posts and Telecommunications Department of Sri Lanka. He joined the Department in 1976 after completing his studies for a degree in electrical engineering (electronics) at the Indian Institute of Technology, Madras.

R. J. Horne, M.Sc. (Graduate 1968), who joined Magnavox Research Laboratories, Torrance, California, as a Systems Design Engineer in 1974, is now Engineering Manager of the Ocean Systems Group.

Flg Off K. A. Munson, B.Sc., RAF (Graduate 1976) is now Station Electrical Engineer at RAF Digby.

R. A. Norling (Graduate 1978) has taken up the post of Bio Engineer Grade II at Rumiallah Hospital, Doha, Qatar. After obtaining the

Associateship in Electrical and Electronic Engineering of Glamorgan Polytechnic in 1973, he worked as a Medical Physics Technician at the University Hospital of Wales, Cardiff.

J. Davison (Associate Member 1976) has been appointed an Associate of the practice of A. J. Ramsay & Partners, consulting engineers of Billingham, Cleveland. Before joining the practice a year ago he held appointments with companies in the North East specializing in industrial instrumentation.

P. M. Thorp (Graduate 1967) who has been with Burroughs Business Machines in Canada since 1977, is now Manager of Product Engineering at the Company's main peripheral equipment manufacturing plant.

O. A. Uche (Graduate 1978) returned to Nigeria in October 1978 following some five years gaining experience with British companies and obtaining the College Diploma of Twickenham College of Technology and he is now Electrical/Electronics Engineer with the Nigerian Petroleum Refining Company, Port Harcourt.

R. B. Light (Associate Member 1973, Associate 1958) is now Technical Services Manager with International Aeradio. He joined IAL in 1950 following service in the RAF, and he has held appointments in Mediterranean and Arabian Gulf areas.

J. J. Mizzi (Associate Member 1975), formerly a lecturer in the Education Department of the Government of Malta, recently joined Paddington College, London, as a Lecturer I in electronics, radio and television.

M. Obinkwo, B.Sc.(Eng.) (Associate Member 1973) has successfully completed a degree course in electronic engineering at the University of Essex and has returned to Nigeria to take up an appointment with the Department of Posts and Telecommunications as an Engineer Grade II.

B. R. Sudbury (Associate Member 1973, Associate 1969) has joined Redifon System Simulation as Senior Project Manager.

A. T. Sampanthar (Associate 1977) has been appointed Acting Superintendent in the Electrical Section of the Ceylon Cement Corporation, Kankesanthurai, Sri Lanka. He joined the company as a technical trainee in 1970 and subsequently held posts as foreman in the Instrument Section.

A. Olaoya (Associate Member 1974) has been appointed Assistant Chief Technologist with the Nigerian Airports Authority, Murtala Muhammed Airport, Lagos. He was previously Technical Manager of Electronics Instrumentation, Ibadan.

M. E. G. Willcocks (Associate 1975) has been appointed Director of Engineering of the Audio Mobile Division of the Advent Corporation in Santa Ana, California. After going to the United States in 1977 he continued the consultancy business which he had started in 1973 when he relinquished the appointment of Chief Engineer with Sinclair Radionics, Cambridge.

Obituary

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

Edward Adams (Member 1973, Graduate 1968) died on 3rd January, 1979, aged 56 years. He is survived by a widow and two sons.

Born and educated in Paisley, Renfrewshire, Mr Adams served during the war in the RAF and on demobilization worked for two years at a Government Communications Centre in Fife. A period of serious illness lasting five years interrupted his career until 1956 when he joined a firm of electrical contractors as an estimator. From 1957 to 1960 he was with IBM(UK) as a computer test engineer and product engineer and he was then appointed Senior Computer Engineer in charge of the Ferranti Pegasus Installation at the University of Southampton. During this period he obtained the Higher National Certificate in Electrical Engineering which qualified him for Graduateship of the Institution.

In 1969 Edward Adams entered technical education, being appointed a Lecturer in electrical engineering at the James Watt College, Greenock, Renfrewshire, where he remained until his death.

William Robert Bitcheno (Member 1943) died on 1st October 1978, aged 70 years, leaving a widow.

Mr Bitcheno obtained his early technical training at the Electrical Training College, Holloway, London, and after nearly two years as a ship's radio officer with Radio Holland, he joined the Marconi Company in 1930. During the pre-war years he gained wide experience on both marine and airborne communications and from 1936 to 1940 was engineer in charge of the Marconi Depôt at Glasgow Airport. During the war years he held a variety of appointments, at one time being attached to RAF Bomber Command as a Special Liaison Engineer.

He continued to be involved in airborne electronics after the war and in 1954 took up a post in the Aviation Department of the Canadian Marconi Company with whom he remained until his retirement in 1970 when he returned to live in Devon.

Robert Alan Boulton (Member 1963, Graduate 1958) died on 20th December, 1978, at the age of 51 years. He leaves a widow.

After initial technical training at Liverpool Technical College, Mr Boulton served with REME from 1947 until 1958. For the last five years of his Army career he was attached to the Royal Radar Establishment, Malvern, and during this period he completed his technical qualifications by obtaining a Higher National Certificate in electronic engineering at the RRE College of Electronics. In 1958 he joined the Automatic Telephone and Electrical Company, Liverpool and was in charge of a team commissioning a section of a large data handling project, and he subsequently held appointments with the Plessey Company in Essex and Surrey.

Alan Terrell Davies (Member 1968, Graduate 1963) died on 10th November 1978, aged 43 years, leaving a widow.

Following training at Marconi Training School, Hamble, Mr Davies was for three years a Marine Radar Officer (deep sea) in charge of operation and maintenance of radio and radar equipment. He then spent two years National Service in the RAF as a Radar Fitter (Instruments) Corporal, and on return to civilian life in 1959 became a Radar Development Engineer with Decca Radar.

In 1961 Alan Davies joined the National Physical Laboratory as an Assistant Experimental Officer, remaining with the Laboratory until his death. While working in the Autonomics Division he contributed a paper to the Institution's Journal on transmission of digital information using infra-red radiation.

Olawole Fatimilehin (Member 1972, Graduate 1968) died on 24th November 1978, aged 40 years, leaving a widow.

Mr Fatimilehin was Managing Director of Mofat Engineering Company, Lagos, which he joined in 1974 following fourteen years with Nigerian Posts and Telegraphs. In 1964 he came to the United Kingdom and following study at West Ham College of Technology received the degree of B.Sc.(Eng.) in electrical engineering. In 1966 he was awarded the M.Sc. (electronics) degree by the Queen's University of Belfast and for the next two years worked with the British Post Office, gaining experience on operation of earth satellite ground stations. On returning to Nigeria he was responsible for setting up the management for the running of the Nigerian Satellite Earth Station and associated microwave links. Later he was concerned with establishing a laboratory for development, research and standardization of testing and measuring devices.

Applicants for Election and Transfer

THE MEMBERSHIP COMMITTEE at its meeting on 3rd April 1979 recommended to the Council the election and transfer of the following candidates. In accordance with Bye-law 23, the Council has directed that the names of the following candidates shall be published under the grade of membership to which election or transfer is proposed by the Council. Any communication from Corporate Members concerning the proposed elections must be addressed by letter to the Secretary within twenty-eight days after publication of these details.

April Meeting (Membership Approval List No. 257)

GREAT BRITAIN AND IRELAND

CORPORATE MEMBERS

Transfer from Member to Fellow

GIBBONS, Donald Elvin Gordon. *Thornton Heath, Surrey.*

Transfer from Graduate to Member

GREENLAND, John. *Farnborough, Hants.*
FIELD-RICHARDS, Hugh Sherwood. *Malvern, Worcs.*

Direct Election to Member

JOYNSON, Roy Herbert. *Liverpool.*
NICE, Edward George. *Murton, Co. Durham.*
SMIALOWSKI, Hemryk. *Staines, Middlesex.*
VERMA, Mahendra Kumar. *London.*
WILLIAMS, Derfel Llewelyn. *London.*

NON-CORPORATE MEMBERS

Transfer from Student to Graduate

ADRANI, Victor Tunde. *Loughborough, Leics.*
EVANS, Graham Arthur. *Chilwell, Nottingham.*
TAN, Kia Tong. *Manchester.*

Direct Election to Graduate

TRIGWELL, Steven. *Thornton Heath, Surrey.*

Direct Election to Associate Member

GULLIFORD, Julian David. *Uckfield, Sussex.*

Direct Election to Student

AMMANN, Max James. *Dublin.*
DEVEY, Gary Alan. *Filton, Avon.*
KIRK, Steven Alan. *Leicester.*
OSAGHAE, George N. *Liverpool.*
UDOUSORO, Christopher J. *Middlesbrough, Cleveland.*

OVERSEAS

CORPORATE MEMBERS

Transfer from Graduate to Member

ABBOUD, Mohamed Ibrahim. *Abu Dhabi, UAE.*
BRICKELL, Christopher Gavin. *Auckland, New Zealand.*
OGUNSOLA, Kehinde Olaitan. *Ibadan, Nigeria.*

Direct Election to Member

AAL, Mohamed Abdel. *Khartoum, Sudan.*
THARMASUTHAN, Ariyanayagam. *Colombo, Sri Lanka.*

NON-CORPORATE MEMBERS

Transfer from Student to Graduate

CHAN, Cho Chun. *Kuala Lumpur, Malaysia.*
CHIU, Kin Fai. *Hong Kong.*
WONG, Yang Tze. *Hong Kong.*

Direct Election to Associate Member

FOO, Lam Kwan. *Singapore.*
HO, Meng Ann. *Singapore.*

Direct Election to Student

CHAN, Bing Kwan. *Hong Kong.*
CHAN, Chun Chuen. *Hong Kong.*
CHAN, Ching Wah. *Hong Kong.*
CHAN, Duk Lung. *Hong Kong.*
CHAN, Pak Ming Daniel. *Hong Kong.*
CHEUNG, Kin Wai Kenneth. *Hong Kong.*
CHEUNG, Por. *Hong Kong.*
CHEUNG, Shun Wah. *Hong Kong.*
CHIN, Yu Keung. *Hong Kong.*
CHIU, Kan Kay Alfred. *Hong Kong.*
CHIU, Peter Ping Kuen. *Hong Kong.*
CHU, Lee Wai. *Hong Kong.*
CHUNG, Ping Yee. *Hong Kong.*
FUNG, Kwok Wing. *Hong Kong.*
HO, Chi Ngai. *Hong Kong.*
HO, Hin Wai. *Hong Kong.*
HO, Siew Weng. *Singapore.*
HONG, Koon Wah. *Hong Kong.*
KWAN, Wan. *Hong Kong.*
LAM, Fu Wing. *Hong Kong.*
LAM, Kee Chok. *Hong Kong.*
LAM, Wing Leung. *Hong Kong.*
LEE, Moon Tong. *Hong Kong.*
LEE, Shui Sum S. *Hong Kong.*
LEE, Wai Ming. *Hong Kong.*
LEUNG, Chung Kwong. *Hong Kong.*
LEUNG, Hing Ming. *Hong Kong.*
LEUNG, Wing Kai. *Hong Kong.*
LI, Cheong Ming. *Hong Kong.*
LI, Ka Chun. *Hong Kong.*
LIU, Kam Kwong. *Hong Kong.*
LO, Siu Kuen. *Hong Kong.*
LUK, Wing Chuen. *Hong Kong.*
MA, Si Tak Stephen. *Hong Kong.*
MAK, Shee Ting. *Hong Kong.*
NG, Chow Por Andrew. *Hong Kong.*
SEOW, Hock Beng. *Singapore.*
SEUNG, Chung Ming. *Hong Kong.*
SO, Cheuk Wah. *Hong Kong.*
SUEN, Chiu Keung. *Hong Kong.*
TO, Wan Sang. *Hong Kong.*
TSE, Tak Chi. *Hong Kong.*
TSUI, Chung Hong. *Hong Kong.*
TSUI, Chi Shing. *Hong Kong.*
WAN, Ho Sang. *Hong Kong.*
WONG, Chi Bun Frankie. *Hong Kong.*
WONG, Chor Chung. *Hong Kong.*
WONG, Kwok Kee. *Hong Kong.*
WONG, Kwok Wah. *Hong Kong.*
YAN, Hung Kong. *Hong Kong.*
YU, Man Lung. *Hong Kong.*

Meetings in London during June

Two meetings have been arranged by the IERE for June, both to be held at the Royal Institution, Albemarle Street, London W1. Details are as follows:

Tuesday, 5th June, 2 p.m.

Colloquium on ' Microwave Techniques for the Amateur '

- 'Simple techniques for optimizing receivers'—Dr Charles Suckling
- 'High gain Yagi antennae'—Michael Walters
- '10 GHz narrow band technique for troposcatter'—Julian Dannaway

Tuesday, 12th June, 10.30 a.m.

Colloquium on ' Peripheral Components for Microprocessors '

- 'Five-volt-only memories for microprocessors'—P. F. Mayes
- 'Serial I/O and direct memory access devices for the Z80 family of microprocessors'—P. Pittman
- 'L.S.I communication interfaces for microprocessors'—A. Danbury
- 'Peripheral interface devices for microprocessors'—A. Nagase
- 'Interfacing keyboards to microprocessors'—A. Lowe
- 'Floppy disk controllers and interfaces'—A. Piper

Registration details for both the above meetings may be obtained from the Professional Activities Secretariat, IERE, 99 Gower Street, London WC1E 6AZ (Tel. 01-388 3071).

Periodicals received by the Library

The following are the principal journals at present received regularly in the Institution's Library. Current issues can not be borrowed but certain back copies can be sent on loan to members in the United Kingdom for limited periods. Normally it is most satisfactory if the intending borrower can specify the title and/or pages of the paper or article of interest and a photocopy can then be supplied for retention at a charge of 10p per page.

ABU Technical Review
A.E.U. Elektronik
Atom
Audio
Audiovisual

Bell System Technical Journal
Bell Laboratories Record
BKSTS Journal
BSI News

Cables & Transmission
Cable Television Engineering
Canadian Electronics Engineering
Communication & Broadcasting
Computer Bulletin
Computer (IEEE)
Computer & Control Abstracts
Computer Journal
Control & Instrumentation
Control Engineering
Current Papers in Physics
Current Papers in Electrical & Electronic Engineering

EBU Review
Electrical Communication (ITT)
Electrical & Electronics Engineering Abstracts
Electronic Technology (SERT)
Electronics International
Electronic Engineering
Electronic Information & Planning (India)
Electronics Letters
Electronics & Power
Electronics Times
Electronics Weekly
Elektro
Elteknik
Engineering
Engineering Designer
Engineering Journal (Journal of the Engineering Institute of Canada)
Engineers Australia (Journal of the Institution of Engineers, Australia)
Ericsson Review
E & R Trading Service Sheets

Fujitsu Scientific & Technical Journal

G.E.C. Journal of Science & Technology

Hewlett Packard Journal

IBA Technical Review
IEEE Journal of Oceanic Engineering
IEEE Journal of Quantum Electronics
IEEE Journal of Solid State Circuits
IEEE Spectrum
IEEE Transactions on:
- Acoustics, Speech & Signal Processing
- Antennas & Propagation
- Automatic Control
- Bio-medical Engineering
- Broadcasting
- Circuits & Systems
- Communications
- Computers
- Consumer Electronics
- Education
- Electrical Insulation
- Electromagnetic Compatibility
- Engineering Management
- Geoscience Electronics
- Industry Applications
- Industrial Electronics & Control Instrumentation
- Information Theory
- Instrumentation & Measurement
- Magnetics
- Manufacturing & Technology
- Microwave Theory & Techniques
- Nuclear Science
- Parts, Hybrids & Packaging
- Plasma Science
- Power Apparatus & Systems
- Professional Communication
- Reliability
- Software Engineering
- Sonics & Ultrasonics
- Systems Man & Cybernetics
- Vehicular Technology

I.S.I. Bulletin
Information & Control
Institution of Engineers, Australia. Mechanical & Chemical Engineering Transactions
Institution of Engineers, Australia. Electrical Engineering Transactions
International Journal of Electronics

Journal of the Acoustical Society of America
Journal of the Franklin Institute
Journal of the Institution of Electronic & Telecommunications Engineers, India
Journal of the Radio Research Laboratories Tokyo—Japan
Journal of Physics E: Scientific Instruments
Journal of Scientific & Industrial Research (New Delhi)
Journal of the Society of Motion Pictures & Television Engineers
Journal of the Society for Underwater Technology

Marconi Review
Measurement & Control
Medical & Biological Engineering
Microelectronics & Reliability

N.E.C. Research & Development (Japan)
N.H.K. Laboratories Notes (Japan)
N.H.K. Technical Monographs
N.T.B. Journal of Information Processing
N.R.D.C. Bulletein (National Research Development Corporation)
N.T.Z.
New Electronics
New Scientist

Offshore Engineer
Onde Electrique
Optics & Laser Technology

Philips Technical Review
Post Office Electrical Engineers Journal
Post Office Telecommunications Journal
Proceedings of the IEE
Proceedings of the IEEE
Proceedings of the IREE (Monitor)

Production Engineer
Public Address
Physics Bulletin

Q.S.T.

R & D Abstracts
R.C.A. Engineer
R.C.A. Review
Radiobranchen (Rateksa)
Radio Communication

Radio Engineering & Electronic Physics
Radio Science
Radio Services (India)
Radio Times of India
Review of Scientific Instruments
Revue Technique (Thomson-Houston)
Royal Television Society Bulletin

Short Wave Magazine
Systems Technology

Telecommunications Journal (ITU)
Telephony
Television

U.R.S.I. Bulletin
Ultrasonics

Wireless World

Sector-scanning Sonar for Ocean Engineering

A new, small, high-definition sector-scanning systems Hydrosearch Mini Sonar developed by Marconi Space and Defence Systems Limited is being used by Hunting Surveys Ltd to provide real-time hydrographic survey pictures with wider, faster and more complete coverage than any comparable system. In successful trials conducted in the North Sea last year, the Hydrosearch Mini-Sonar system was used for pipeline surveying and was operated continuously for periods up to twelve hours at speeds up to 5 knots. This system provides a pipeline/sea bed accuracy of 20 centimetres.

Underwater features are shown to a high degree of accuracy and are presented in pictorial form on a cathode-ray tube display. The wide swept path with high resolution in both range and bearing makes Mini-Sonar ideal for many applications in underwater location and inspection, and the small size of the new equipment makes it suitable for use on survey vessels of all sizes, in manned or unmanned submersibles or on platforms or rigs. Yet another feature of this versatile sonar system is the ability of the transducer array to operate efficiently in depths of water up to 600 metres.

The Hydrosearch Mini-Sonar is a within-pulse-sector scanning sonar. It is a development derived from the Hydrosearch sonar designed for H.M. Hydrographer and currently undergoing trials on board H.M.S. *Bulldog*. Of modular construction, and able to work in two modes, forward scan and vertical scan, the sonar insonifies a sector of the sea bed, and within an angle of 30° the receiver scans the angle, using a narrow beam of one degree, 7500 times per second.

Six basic modules make up the system—a transducer array, two sonar electronics modules, power supply unit, display-controller assembly and the cathode-ray tube display itself. The standard display is a conventional XY configuration with a long persistence tube and the display area is 21·6 cm by 16·5 cm.

A basic standard Hydrosearch Mini-Sonar permits selection of four ranges with a maximum of 160 m and a range resolution of 0·5 m. By using a somewhat improved display this figure can be reduced to 0·2 m. The bearing scan is 30° and 1° resolution.

Standard Frequency Transmissions

(Communication from the National Physical Laboratory).

Relative Phase Readings in Microseconds
NPL—Station
(Readings at 1500 UTC)

March 1979	MSF 60 kHz	GBR 16 kHz	Droitwich 200 kHz
1	1·1	4·2	31·1
2	0·9	4·9	30·0
3	1·0	4·3	28·8
4	0·8	3·9	27·8
5	0·8	3·5	26·6
6	0·8	3·7	25·3
7	0·7	3·7	24·1
8	0·5	3·7	23·0
9	0·7	—	21·6
10	0·8	—	20·5
11	0·7	—	19·5
12	0·7	—	18·0
13	0·1	—	16·9
14	0·2	3·7	15·8
15	0·2	3·9	14·7
16	0·0	3·9	13·4
17	0·6	4·4	12·2
18	0·4	4·0	11·1
19	0·4	3·9	10·2
20	0·2	3·8	10·4
21	0·6	3·5	10·5
22	0·6	3·8	10·7
23	0·4	3·8	10·9
24	−0·2	3·8	11·1
25	0·4	3·5	11·3
26	0·5	5·9	11·5
27	0·0	3·3	11·8
28	0·5	3·3	12·0
29	0·3	3·2	12·3
30	0·2	3·7	12·5
31	0·3	3·7	12·6

Notes: (a) Relative to UTC scale (UTC_{NPL}−Station) = +10 at 1500 UTC. 1st January 1977.
(b) The convention followed is that a decrease in phase reading represents an increase in frequency.
(c) Phase differences may be converted to frequency differences by using the fact that 1 μs represents a frequency change of 1 part in 10^{11} per day.

Letters to the Editor

From: **C.W. Andrews, B.Sc., D.C.Ae., M.Sc., C.Eng., M.I.E.E., M.I.E.R.E., M.R.Ae.S.**

P.L. Needham, Ph.D.

Professor D. Lewin, M.Sc., D.Sc., C.Eng. F.I.E.E., F.I.E.R.E.

T. Lomas, E.R.D., Dip.E.E., C.Eng., M.I.E.E., M.I.E.R.E.

The Chartered Engineer's Degree

I read with interest your policy statement in the February issue of the Journal on 'The Chartered Engineer's Degree: Ordinary, Honours or "Enhanced" '.*

I would submit that much confusion exists with regard to the nature and content of enhanced degree courses even amongst those who should, or could, be better informed. Currently (March 1979) I am aware of only one enhanced engineering degree course which might be described as for 'Electrical Engineers' although many of the other courses have an electrical, electronic, control and computing content.

The enhanced (or enriched) degrees were originally conceived to improve the quality of trained manpower entering manufacturing industry. The interpretation placed on the method of improving the quality has led to a wide variety of 'enhancements' but it is generally accepted that enhancement may include:

- Higher entry qualifications
- Greater technical content covered at a greater pace than conventional courses
- Longer courses
- Better motivated students
- Different teaching and/or learning methods especially in the final years
- Better integration both between traditional subjects and between the course and industrial training
- Additional, non-traditional subject material

It is the last feature which seems to have caused most eyebrows to be raised. What is added? What should be added? What is traditional?

Most of the course announcements have indicated the inclusion of management subjects. We, in the public sector of higher education, view this 'development' with some amusement. The more flexible departmental structure of Polytechnics has long enabled most, if not all, engineering courses to have a management content varying from 5 to 15%. It is easy to fall into the semantic trap of defining what is meant by management subjects in a way which suits a variety of purposes. An inexhaustive list of discipline areas often included under such a subject heading is:

Economics	Business Decision Making
Law	Finance and Accounting
Organisational Behaviour	Management Control
Industrial Relations	Marketing
Health and Safety	Purchasing
Communication Studies	Language Studies

Many of the course announcements have indicated a greater integration with industry, achieved in a variety of ways. Whilst the Polytechnics do not have the sole prerogative of running sandwich courses, they have been very fully developed and their products very well received by industry. Integration is, in general, highly developed.

Those of us who develop courses do not do so lightly, wantonly or without the authority of the Department of Education and Science. Such authority is rarely if ever granted unless appropriate consultation has occurred with industry and unless the market for the product has been effectively researched.

It is probable that I am the only Chartered Engineer, who is a member of the Institution of Electronic and Radio Engineers, who has led the planning of an enhanced engineering degree, and it is with some annoyance that I find that the course for which I am responsible is described as 'extended in order to provide time for the students to be initiated into management and other non-technical problems'. The enhanced degree course at Sheffield City Polytechnic, a B.Sc.(Hons) in Manufacturing Systems Engineering is an unusual thin sandwich of four years and one term duration. The eleven academic terms provide 22% longer time in college than on conventional four-year sandwich courses, whilst the so-called management subject elements, referred to above, constitute only 16% of the course. The engineering subject content is thus greater than on conventional courses but the educational experience has been broadened, the *ab-initio* development in this form being supported and encouraged by leading industrialists.

It is our view that early exposure (and initiation) into management and non-technical problems is vital if the engineer of the 1980s is to play his proper role in the revitalisation of British Industry. I must stress again, these enhanced courses are honours degrees in *ENGINEERING* +. If depth is the sole criterion of excellence or further depth is required, taught Master's programmes and/or research programmes are still available.

C.W. Andrews
Sub Dean,
Faculty of Engineering

Sheffield City Polytechnic,
Pond Street,
Sheffield S1 1WB.
22nd March 1979

The Relevance of Science to Engineering

I read Professor Lewin's article, 'The relevance of science to engineering — a reappraisal' , with great interest, particularly because he found it appropriate to base his views in part on the writings of a philosopher of science. Since Professor Lewin said he did not want to enter into philosophical arguments, I would like simply to record a disagreement with an aspect of Popper's views shared by many philosophers and then to pursue a point in connection with Professor Lewin's application of Popper's views.

The point of disagreement concerns Hume's problem of induction which Popper claims to have circumvented. The process of induction described by Professor Lewin is often more precisely referred to as enumerative induction — i.e. inferring general statements from particular cases. However, Hume's problem applies to any form of induction (i.e. non-fallacious arguments not deductively valid), and this would include Popper's own procedure of selecting bolder, more informative hypotheses.

It is not reasonable to criticize Popper for not solving a problem no one else has been able to solve, and this is not the point I want to pursue. Rather, it concerns the impression Professor Lewin gives that engineering is to be contrasted with 'pure science', the latter supposedly proceeding along orthodox Baconian lines. This is misleading because Popper was concerned to provide a clear demarcation between science

*. *The Radio and Electronic Engineer*, **49**, No. 2, pp. 63-4, February 1979.

. *The Radio and Electronic Engineer*, **49**, No. 3, pp. 119-24, March 1979.

and other activities, but did not himself draw any distinction between pure and applied science. His attack on Bacon's method of enumerative induction is aimed equally at the application of this methodology to pure and applied science, and I don't believe Popper would want to draw any such distinction by the application of his own methodology. Thus, whilst this position does support Professor Lewin's conclusion that 'it would be a dangerous misnomer to classify engineering as applied science', and that engineers are not somehow 'impure scientists', it argues against the contrast Professor Lewin suggests by picturing 'pure scientists' as second-rate problem-solvers. Indeed, if Professor Lewin is right in his views about how the approach to the teaching of engineering should be modified, and in his characterization of Nuffield science as Baconian, then the same criticism is applicable to the teaching of what is traditionally regarded as pure science. And if we look at the history of science we find that the problem-solving approach recommended by Professor Lewin has always been used by the purest of scientists. There has always been the question of appreciating and defining the problem situation, and the clarity with which this has been achieved is the hall-mark of the great scientists of the past.

I do not wish to undermine the nice distinction Professor Lewin makes between problem situations based upon open and closed systems in the sense of thermodynamics. But as I've tried to indicate, one of his theses is of considerably greater scope. The upshot of this is that the most artificial of distinctions is that underlying the two-tier system of pure and impure scientists. But this would apply as much to the one Professor Lewin would instigate as the one he opposes. Such two-tier systems would have no place in an approach to the teaching of science as a whole which took serious account of the problems scientists actually faced when their discoveries were made.

P.L. Needham

Department of Humanities,
North Staffordshire Polytechnic,
Beaconside, Stafford ST18 0AD.
26th March 1979

Science is a Puzzle

Dr. Needham is quite correct in drawing from my paper a conclusion which I only had the courage to hint at in passing! Namely that my criticism of teaching engineering as an applied science (because of its orthodox Baconian approach) is also applicable to the education of the 'pure scientist'. However, I would not dare go as far as suggesting that the teaching methods employed by our Universities to educate scientists produce 'second rate problem solvers' (but see later!). Certainly many of the major contributors to science, including Einstein, Medawar, Monod to name but a few, have acknowledged and employed the Popperian problem solving approach. However, these have been the exception rather than the rule and all have caused major revolutions to take place in their subjects—truly great scientists who have had the courage to question authority. Science teaching in the main concentrates on the established theory, laws and techniques of a subject area (called a *paradigm* by Kuhn*). Consequently the scientist's training will normally consist of solving standard problems, performing standard experiments and in generally acquiring the skills and methods of empirical science. Moreover, workers in a particular field will justify and develop the paradigm by fact gathering and experimentation working within a well defined problem area dictated by the paradigm. Thus 'normal science' (as defined by Kuhn) is not directed towards major substantive innovations but is more concerned with improving the match between the paradigm and the natural world.

Kuhn also makes the point that the scientific community in following a paradigm tends to choose research problems which can be assumed to have answers (a deterministic or closed-system approach). Normal scientific research then is concerned with puzzles (engendered by the paradigm) and scientists are trained primarily as puzzle solvers—note that there is always a presumed answer to a puzzle and the solutions need not be of world shattering importance. (Note also the resemblance here to examination papers set in science subjects!)

A crisis situation comes about in normal science when experiment and experience can no longer support the current paradigm. At this point a revolution takes place and a new paradigm comes to power. As would be expected there is considerable opposition and reluctance on the part of the establishment to accepting any change in the prevailing system. It can be shown historically that this attitude has often resulted in impeding the path of true scientific progress. It is my contention that revolutions take place when scientists step back and consider what constitutes the real problem—the Popperian principle.

Thus, though the scientist is in general educated to consolidate and establish an existing paradigm through a process of essentially puzzle-solving activities, the innovative engineer must be able to solve real practical problems as they exist and if necessary go beyond the bounds of existing theory. Thus the philosophy and attitudes of mind essential to the creative engineer stands in strong contrast to those of the 'normal scientist'.

But what of science itself, surely one may say (and Dr Needham has) that these attitudes of mind are also essential to the truly creative scientist. Obviously the answer must be yes and herein lies the criticism of conventional science education. Unfortunately in practice the Baconian approach tends to be predominant and the wider problem-solving philosophy of Popper given scant attention. In my view there is a place for both in the science curricula, with the overall philosophy being that of Popper. In the same context I would certainly not advocate that the open-system approach should supplant the classical closed-system model, simply that the power and limitations of the two approaches be recognized and understood.

It is also relevant to consider the social sciences in the light of our argument; sociology, for instance, is often criticized as a science because it has no paradigm. Consequently workers in this field, say in psychology, have tended to emulate (in order to appear respectable) the established sciences by pursuing the Baconian principles. Thus *hard* psychology has become accepted whilst *soft* psychology, employing essentially the Popper philosophy, tends to be *ultra vires* (perhaps to the detriment of understanding the real problems of human behaviour).

I am grateful to Dr. Needham for raising these points which has allowed me to develop my arguments further. I am also sure he would be delighted that in so doing I have enlisted the aid of yet another philosopher of science!

Brunel University. Douglas Lewin
Uxbridge.

12th April 1979

*T. S. Kuhn, 'The Structure of Scientific Revolutions'. 2nd ed. (University of Chicago Press, 1970).

Academics or Entrepreneurs?

I would support most strongly Professor Bell's suggestion* that some basic economic or business training be included in undergraduate curricula. I do not even share his doubt that all engineering students be put through this programme as I would argue that, as engineering is essentially concerned with the provision and maintenance of technological goods and services where they are wanted, when they are wanted and at acceptable cost, graduates who lack formal training in other than the technical aspects of engineering are less than adequately trained for industries' needs.

The argument one hears when this proposal is made is that the syllabus is over full already and there is therefore no room for these other subjects. I would suggest, in reply to this, that those responsible for university syllabuses might ask themselves whether they do not concentrate too much on technology which is, almost by definition, out of date by the time it reaches university curricula. I am very conscious of this having spent many grinding hours in the evening as a student studying valve theory whilst during the daylight hours I was earning my keep in an engineering laboratory working on semi-conductor devices which, at that time, were not yet in the syllabus.

If, as I am suggesting, university courses were to spend a little less time on technology which, if it is not out of date already, will be by the time the undergraduate reaches industry, and a little more on fundamentals and complement this with economic and business studies the product would be, I believe, a more broadly educated graduate potentially better fitted to the needs of industry.

21 Clarence Road,
St. Albans, Herts. AL1 4NP.

T. LOMAS

4th April 1979

* *The Radio and Electronic Engineer*, **49**, no. 3, p.116, March 1979.

First in-orbit anniversary for Meteosat

The European Space Agency meteorological satellite, *Meteosat 1*, has already completed its first year in orbit. Launched on 23rd November, 1977, it reached its geostationary position at 0 degree longitude over the Gulf of Guinea on 7th December, 1977 and started sending its first Earth images in the visible and in the infra-red on 9th and 11th December, 1977 respectively. This first year in orbit has shown the excellent performance of all satellite equipment, with the three spacecraft missions – imaging, dissemination, data collection – perfectly fulfilled.

During this year, the ground facilities set up at the European Space Operations Center (ESOC) in Darmstadt have progressively reached operational status for the reception, processing, archiving and dissemination of the satellite meteorological data. The system is now ready to meet all requirements of the first Global Atmosphere Research Programme (GARP) experiment which started on 1st December, 1978. Besides providing every half-hour high quality images of the Earth in the visible and in the infra-red, *Meteosat* also rebroadcasts at present some 300 formats per day, in analogue or digital form, towards primary and secondary data users stations (PDUS and SDUS). Furthermore, a number of experiments has been conducted during the year with data collection platforms (DCP). They have demonstrated the high quality of the links between *Meteosat* and mobile platforms.

One of the prime objectives of the *Meteosat* system besides the acquistion and the dissemination of images is to yield directly usable meteorological products, such as wind speeds, cloud altitudes, sea surface temperatures, etc. The intrinsic quality of *Meteosat* images should lead to the extraction of high grade products. The results obtained so far are at least comparable to those from the other geostationary satellites participating in GARP.

Finally, the use of the water vapour channel, one of the exclusive *Meteosat* features, is considered by the meteorological community as a substantial progress towards refining interpretation techniques.

The users of Meteosat *disseminated data*

At the last count, 9 PDUS (Primary Data Users Stations) and 73 SDUS (Secondary Data Users Stations) were in operation within the *Meteosat* coverage zone. During the present calendar year, a further dozen SDUS are to be commissioned and 8 PDUS are being planned.

About 10 SDUS have been put together by non-professional people as a hobby. All these stations can receive data coming from three geostationary satellites, since *Meteosat* also serves as a dissemination relay for image data from the American satellites *GEOS East* stationed over the Atlantic and *GEOS I* stationed over the Indian Ocean; these data are relayed by the French Space Meteorology Center in Lannion at the average rate of 40 formats per day.

Data collection platform (DCP) users

Twenty DCPs are already operational, 10 are in the process of being commissioned and more than 100 are being planned. The present uses are very diversified and deal with terrestrial DCPs (snow status or water level monitoring, for instance), as well as floating DCPs (like the VEMNO buoy developed for the Ministry of Research and Technology of the Federal Republic of Germany) or even airborne DCPs (ASDAR system). Large DCP projects are at various planning stages in Greenlana, Saudi Arabia and in the Sahel countries (Applhymet project).

The continuity of the Meteosat *system*

Two spacecraft, identical to the *Meteosat* satellite now in orbit are under construction; one of them will be launched in June 1980 by the European *ARIANE* launcher during its third development flight. The nominal lifetime of a *Meteosat*-type satellite is 3 years, and system continuity is thus provided until 1983.

The European Space Agency and a number of European National Meteorological Services are at present discussing the possibility to set up an operational system based on *Meteosat* and starting around 1983. This represents a decisive step forward in insuring a continuous *Meteosat* service.

British manufacturers directly involved in ground equipment for *Meteosat* are: British Aerospace Dynamics Group (receiving stations), Plessey Radar (receiving stations and DCPs), Muirhead Data Communications (image displays) and McMichael Radio (DCPs).

Two New Instruments

Microprocessor-controlled Signal Analyser

A microprocessor-based calculator has been developed by Datalab for use with its DL Micro 4 Signal Analysis System. The method adopted for programming and controlling the microprocessor, the DL 417, is stated to be unique. Hitherto there were two possible methods. The keypad method, generally used for calculators, which assigns separate functions to separate buttons, is inexpensive and easy to use. It is, however, limited by the number of buttons which can reasonably be accommodated in a keypad, and the functions cannot readily be altered. The minicomputer approach gives great flexibility and adaptability since it allows the operator to write new programs as required, but is complex and expensive and needs a trained operator. Datalab has evolved a compromise approach for the DL 417 which avoids the costly complexity of the minicomputer method whilst allowing the module to be used for a wide range of signal averaging and waveform analysis problems well beyond the capability of a reasonably sized keypad.

The existing DL Micro 4 system is a modular instrument with a data highway connecting one of a range of signal analysis modules to a timer unit, a large digital memory and a display controller. This arrangement has already made the DL Micro 4 one of the most versatile signal processors in production. The addition of the off-line data manipulation capabilities of the DL 417 has greatly enhanced its usefulness.

The microprocessor in DL 417 is furnished with a number of resident programs which are either functions, i.e. arithmetic (+, −, ×, ÷) or trigonometric (sin, cos, tan) operations, square root, etc., or routines, i.e. Mean, Standard Deviation, Integration, Fast Fourier Transform, etc. By means of a high-level user-oriented language, two or more standard functions can be combined into an expression which will perform an operation on data from a selected channel. Use of the same language allows expressions and routines to be combined into a statement so that the various operations will be carried out automatically in sequence. The 'user definable' (u.d.) facility make provision for such statements to be stored so that they can be recalled subsequently by simple instructions. It is therefore unnecessary to rewrite a statement in detail each time it is required.

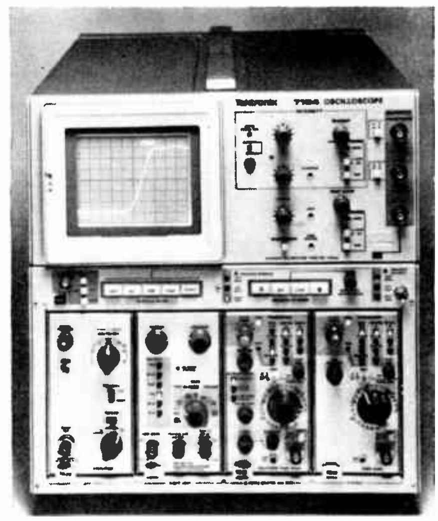
The analogue waveforms and alphanumeric characters are displayed on an external c.r.t. Interesting regions of the waveforms can be selected for intensification, expansion and manipulation. The display can be divided into two or four separate channels, each of which can be sub-divided further for processing purposes. To this anologue display the DL 417 adds alphanumeric information, two lines of which are used to display all the instructions entered by the user. The controls for the display functions and recall of u.d.s. are on the front panel which also has provision for connection of a keyboard which is used for entering instructions. This keyboard may be either a small hand-held unit or a full alphanumeric terminal.

The combination of the DL 417 waveform calculator with the on-line capability of the DL Micro 4 produces a very versatile waveform analysis system. This has a wide range of applications in such fields as kinetic and spectrol chemistry, electrical and mechanical engineering, physics, biomedical research and pharmacology, when signal averaging, correlation, point process analysis or waveform characterisation are required.

General-purpose 1 GHz Oscilloscope

A new high-performance general-purpose 1 GHz oscilloscope has been introduced by Tektronix. The Model 7104 incorporates the latest technology in integrated circuits, cathode-ray tubes and interconnection systems to set what are claimed to be new standards in oscilloscope performance, notably a photographic writing speed of 20 cm/ns, a rise-time of less than 350 ps, a horizontal (X–Y) bandwidth of d.c. to 350 MHz, calibrated sweep speeds of up to 200 ps per division, and a vertical sensitivity down to 10 mV per division.

Several important technological advances have been incorporated in this 1 GHz oscilloscope. Among the major new developments are advances in cathode-ray-tube design, including a distributed horizontal deflection system, a meshless scan expansion lens and a microchannel-plate electron multiplier.



Tektronix Model 7104 1GHz oscilloscope

The microchannel plate also solves the problem of 'blooming' that occurs in conventional oscilloscopes when the beam intensity is set high to observe a pulse combining a short rise-time with a low repetition rate. The microchannel plate (essentially a secondary-emission device behind the cathode-ray tube) effectively limits the waveform brightness just to the point at which the plate's electron amplifier becomes saturated. A limited-viewing-time feature helps preserve the life of the tube.

The interconnection system, particularly the connection between planar striplines and printed-circuit boards or hybrid substrates, uses a 'sandwich' of a plastic frame, an elastomer with contacts and a metal plate. The plate provides heat sinking and connects the back-side ground planes, and the elastomer contacts bridge the gap between the printed circuit and hybrid striplines. The top of the sandwich is the plastic frame, which holds the elastomer, provides contact force and aids alignment.

The vertical sensitivity and other high performance characteristics of the 7104 are the result of a new integrated-circuit process developed by Tektronix which combines extremely shallow diffusions with ion implantation to make transistors with usable gain up to 6·5 GHz operation.

According to the manufacturers, users of the Tektronix Model 7104 will be able to observe very high-speed single-event pulses in real time without resorting to cumbersome photographic techniques. This results from the fact that the brightness of the 7104 display is about two orders of magnitude greater than that of conventional high-speed cathode-ray tubes. In addition, timing measurements can be made directly on the cathode-ray tube down to a resolution of 20 ps (one-tenth of a division at 200 ps per division).

TXE2—The British Post Office's medium-sized electronic exchange

The number of electronic telephone exchanges in Britain will double during the next 5 years, said Mr. Peter Benton, the Post Office's Managing Director for Telecommunications, when he opened the 1,000th electronic exchange—a TXE2—at Hagley, near Stourbridge, recently.

The Hagley exchange is one of the larger TXE2s to have been installed. It serves nearly 4,000 customers initially and can be extended to cater for up to 7,000. It was supplied by Plessey Communications at a cost of £400,000 to replace a 44-year-old electromechanical exchange as part of the Post Office's exchange modernization programme.

Since the opening of the first production TXE2 electronic exchange—at Ambergate, Derbyshire, in 1966—the Post Office has spent £160M on providing these exchanges, giving a more efficient and reliable service to some 1,300,000 customers. It plans to spend more than £150M on this system over the next 5 years, bringing a further 650 new TXE2 exchanges into service during this period. By 1984, nearly 3 million customers will be served by TXE2 electronic exchanges.

The Post Office also has a rapidly expanding programme of large electronic exchanges for densely populated areas; these are the type known as TXE4. It is spending over £800M on more than 300 new exchanges of this type during the next 5 years.

Already, there are 17 TXE4 exchanges in operation, providing an improved telephone service for about 100,000 customers. By 1984, the total of these exchanges should have grown to 350, serving more than 4 million customers. Five years from now, 11 million telephone customers will be served by modern exchange systems of all kinds, including crossbar. This figure represents 50% of all telephone users.

Introducing TXE2 in 1966 marked the first major step in modernizing local exchanges to give improved service. This improvement resulted in part from the system's second attempt facility—an unsuccessful call is re-routed automatically with no noticeable delay and without the caller having to re-dial.

Customers have benefited from the introduction of TXE2 exchanges by:

- fewer call failures because of the automatic repeat attempt feature
- fewer faults affecting service
- lower maintenance costs which help to keep charges to a minimum
- better connections because of improved transmission through the hermetically-sealed reed relay switches.

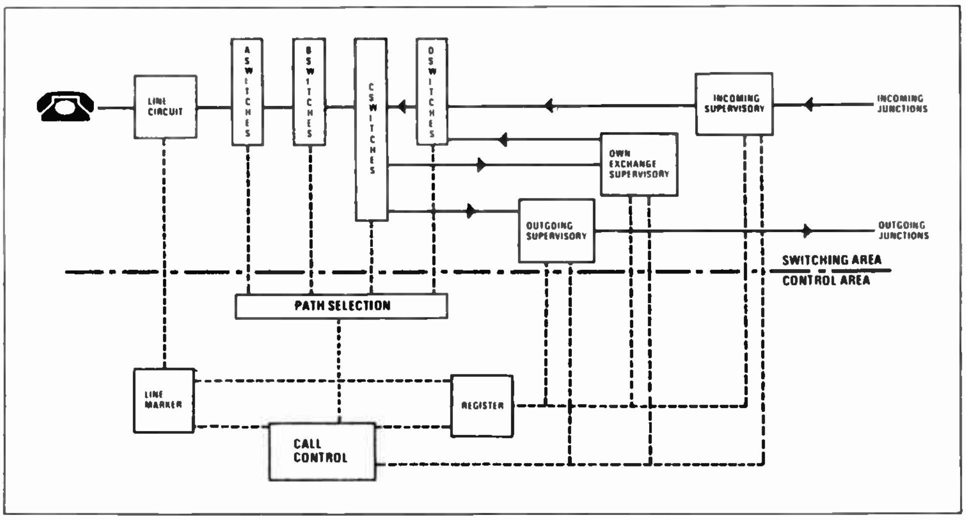
The exchange at Hagley is the latest variant of TXE2—designated Mark 3—which has evolved from selected developments designed to increase system capacity and simplify dialling procedures. Its basic system configuration and operation differs in only relatively minor ways from the earlier versions—confirming the quality of the original design and its suitability for comparatively trouble-free operation in the British network, serving rural and low-density suburban communities.

The system is suitable for applications serving from 400 to 7,000 customers. If the upper limit is exceeded during the exchange's lifetime, a second unit may be started, doubling the maximum capacity.

A TXE2 exchange is usually connected to the nation's main telephone network through a nearby large local exchange, which acts as a 'parent'. Long-distance calls to and from the TXE2 would therefore be routed through the parent exchange, travelling between the two on a junction circuit.

It is a straightforward two-wire analogue space-division switching system: each call is connected over an electrical path through the exchange that is maintained for the exclusive use of that call throughout its duration. Speech paths are switched using reed relays, while call set-up and control involves solid state devices in addition.

The accompanying block diagram illustrates the basic system configuration. There are four stages of switching, known as the A, B, C and D switches. The first three only are involved in switching calls to other exchanges over the outgoing junction circuits, although all four are used



Block diagram of a TXE2 exchange

in the reverse situation, handling incoming calls for customers on the exchange. Own-exchange calls, between customers on the same exchange, involve seven switching stages, following the path A-B-C-D-C-B-A.

Part of the control system—supervisories, path selection and call control—is basically the same for any TXE2. Appropriate sections are duplicated to provide continuity of service in the event of equipment faults. The number of switches, registers and line markers will vary with the number of customers served and the calling rate.

Equipment function may be outlined as follows:

Line circuits	To detect and advise call control of the presence of calling signals and to indicate the state of the line (free, busy or spare) to call control when required.
Switches (A, B, C, D)	To interconnect customers and equipment as explained later.
Supervisories	To control calls after they have been set up, to provide ringing tones and call charging signals and to provide exchange power to customers' telephones to enable them to transmit speech.
Registers	To provide signalling tones as required, to detect dialled digits, to advise call control of digits dialled and, with call control, to determine action required.
Other control equipment	To control the setting up of calls, including the selection of paths through the switching network.

Lifting the telephone handset from its cradle generates a calling signal which is detected by the line circuit associated with that customer's line. The line circuit signals call control that a customer wishes to make a call. Call control's reaction is first to check—via the line marker—that the customer is permitted to make calls. It then selects a register and a supervisory (generally a supervisory associated with an outgoing junction) and from the line circuit sets up an electrical path through the A, B and C switches and supervisory to the register. This then returns dialling tone to the customer ~~who~~ can then go ahead and dial the call.

Under normal circumstances, the above sequence of events occurs within 50 ms. Most customers would not have been aware of any delay between picking up the phone and hearing dial tone.

Once dial tone is returned to the customer, call control is released to deal with the next call. For simplicity, call control has been designed to handle one call at a time, but is able to handle calls at 70 ms intervals—equivalent to more than 12,000 calls an hour. This is more than adequate for normal TXE2 applications; the 3,800 customers on Hagley exchange are expected to generate some 5,000 calls in the busiest hour of the day.

By the time the customer starts to dial, his telephone is linked through the line circuit and A, B and C switches to an outgoing supervisory and from there to the register. The first digit dialled indicates whether it is an own-exchange call (to another customer on the same exchange) or whether it has to be routed to the parent exchange. If it is the latter, the register is released to deal with the next call and the dialling signals are passed through the supervisory to the outgoing junction and thence to distant exchange.

Should the first digit indicate an own-exchange call, the outgoing supervisory is released and another path is set up from the line circuit to the register, through the own-exchange supervisory. This change of supervisory normally takes 50 ms and occurs in the interval between dialled digits.

When the remaining digits dialled have been received by the register, the line circuit of the required customer is tested by call control via the line marker to check whether the line is free (i.e. not already engaged on another call). If the line is free, and the customer permitted to receive calls, a path is set up by call control from the own-exchange supervisory through the D, C, B and A switches to the called customer and the register is released. The supervisory sends ringing current down the line to ring the bell in the called-customer's phone and returns ringing tone to the calling customer. This continues until the called customer answers. Should the called line be busy, engaged tone is returned for a limited period from the register.

A call from another exchange arrives on an incoming supervisory and will be handled in a manner similar to that of setting up the second stage of an own-exchange call. If at any stage during call set-up through the switching area a fault is encountered, the system will automatically make a repeat attempt using an alternative path.

Coaxial cable testing

Using a technique known as c.w. burst—the first time that this has been done commercially—Decca Radar claim a significant advance in the field of high performance land cable testing. The C.W. Burst Test Set developed by the Company's Instrument Division enables regularity return loss and returned power in discrete successive 10 MHz bands to be measured in one 50 second sweep over the frequency band 10-50 MHz, and it is economically attractive for both routine testing of drum lengths of cable in the factory and for the assessment of installed cables. A further very important feature is the ability to record the forward echo characteristics of cables over the swept frequency band 20-500 MHz.

The theory of the c.w. burst method is complicated, but in short this method consists of modulating a swept carrier wave and introducing a time delay which allows the reflections due to cable impedance irregularities to be recorded as a function of frequency, whilst rejecting returned echoes from the hybrid bridge, test leads, cable connexions and cable terminations. This eliminates the errors usually associated with conventional swept frequency techniques.

The C.W. Burst Test Set is compact, robust and easily transportable. Important parameters have push button control for ease of operation, and the extreme stability of the equipment allows the use of pre-calibrated chart paper.

New and Revised British Standards

Copies of British Standards may be obtained from BSI Sales Department, 101 Pentonville Road, London N1 9ND.

PERFORMANCE OF TELEVISION SETS

BSI has published an important new document of particular interest to television manufacturers and service engineers. It represents the first stage of a major revision of BS 3549 **Methods of measuring and expressing the performance of television receivers,** which is being extended to include appropriate requirements for colour television. (The earlier edition was restricted to recommendations for monochrome receivers.)

Part 1 is entitled **General considerations and electrical measurements other than those at audio-frequencies,** (£12.20) and chapters deal with General notes on measurements, Geometrical properties of the picture, Synchronizing quality, Sensitivity, Selectivity and response to undesired signals, Fidelity, and Compatibility with audio-visual recording equipment.

Methods of measuring the electrical, acoustic and optical properties described in this Standard apply more particularly to monochrome and colour television receivers designed for use with sound systems approved by the International Radio Consultative Committee (CCIR), due regard being given to national transmission standards. The aim is to enable performance of the complete receiver to be assessed with minimum effort and without separate consideration of individual components.

The specification of limiting values of the various quantities for acceptable performance is not a function of the Standard. It is neither mandatory nor limiting since a choice of measurements is available in each particular case and, if necessary, additional measurements can be made. The suggested measurements are, of course, subject to future improvement in line with developing techniques.

Part 1 is identical with the corresponding part of IEC Publication 107-1. Later parts of the Standard will comprise: Part 2 — Audio-frequency measurements; Part 3 — Colorimetric and photometric measurements; Part 4 — Additional measurements.

BALLASTS FOR FLUORESCENT LAMPS

BS 5717 Transistorized ballasts for fluorescent lamps (£6.40) just published by the British Standards Institution, is identical with IEC 458 (including amendment No 1). It specifies performance requirements, safety requirements and type tests for transistorized ballasts for use on d.c. supplies not exceeding 250V, associated with fluorescent lamps with pre-heated cathodes operated without a starter switch, and complying with BS 1853.

SAFETY REQUIREMENTS FOR MEDICAL ELECTRICAL EQUIPMENT

The publication by the British Standards Institution of **BS 5724 Safety of medical electrical equipment Part 1 General requirements** (£14.00) represents an important step towards the production of a new generation of standards. It embodies the state of the art for medical electrical equipment which will be internationally acceptable.

Requirements for the design and manufacture of safe electrical equipment for use in the home and at work are widely known, but the conditions under which medical electrical equipment is used are not encountered in other areas. For example, equipment may frequently be connected to unconscious or anaesthetized patients, and a subject may be connected to more than one piece of mains-operated equipment. Furthermore, the risk of electrical shock may be increased because the patient's skin resistance has been lowered deliberately, or because transducers or electrodes are in direct contact with internal organs. Another risk is where sensitive equipment detecting bio-electric signals is used in combination with relatively high power equipment.

Nor is shock the only hazard presented by medical electrical equipment; failure of a temperature device may expose the patient to the risk of burns or other injuries, equipment used in the presence of flammable anaesthetics presents a fire hazard, and life support equipment may be subject to mechanical or electrical failure.

A standard for medical electrical equipment is clearly needed, and has to be accepted internationally, harmonizing with the safety requirements of importing countries. The issue of BS 5724 Part 1 is a result of BSI's participation in the work of the International Electro-technical Commission (IEC) and reflects a standard agreed within that body. It deals with terminology, marking, documentation, electrical and mechanical safety, requirements for equipment used with flammable anaesthetics, and with constructional requirements. Tests for compliance by measurement or checks by inspection are included.

Some of the material in the Standard breaks new ground; for example, a fresh approach is made to the problem of defining acceptable limits for leakage current, including that which may flow through the patient, and limits are now specified both for normal operation and for single fault conditions. The allowable leakage current figures and the test methods specified are the result of considerable work, taking into account a computer search of the literature and experimental evidence including the results of measurements on the hearts of humans as well as animals in real-life situations.

The new Standard is thus more than just a guide for those concerned with design and testing of equipment—its general requirements form the basis for a comprehensive range of standards for specific items for medical equipment.

Over the next two years, the DHSS safety code for electromedical equipment (HTM8) will be phased out and authorities will be advised to purchase equipment complying with BS 5724.

METAL CORROSION

One of the most troublesome and complex corrosion problems encountered in industry stems from the interaction of different metals and alloys in close contact. Valuable advice on the subject is now available in the form of PD 6484 **Commentary on corrosion at bimetallic contacts and its alleviation** (£6.40) recently published by the British Standards Institution.

PD 6484 provides guidance on the likely behaviour of metallic couples subject to normal environmental exposure. The first part of the Standard deals with the conditions which lead to bimetallic corrosion, and makes recommendations for its prevention. The second part consists of annotated tables covering various combinations of metals, and rates their likely performance in three atmospheric and two immersed environments. Evidence is not available for every possible combination, this fact being stated where relevant.

The document is based on an earlier HMSO publication intended for Service designers. In view of the importance of the subject, however, the original text has been extensively revised and updated by BSI for the benefit of everyone concerned with the use of metals.

General Interest Paper

Total Engineering: Control during product development

J. G. COTTRELL, F.I.W.M., C.Eng., F.I.E.R.E.

The development of new products has always been fraught with the problems associated with achieving a design suitable for volume production capable of yielding consistent performance results without the need for constant technical or engineering supervision or adjustment. The achievement of this goal has become progressively more difficult as both products and technology have become increasingly complex and systems have become larger and more sophisticated. Methods and disciplines for achieving satisfactory designs are discussed and compared with past practices. Recommendations are given for the organization and control of the development process and their application to the engineering of major new products.

Introduction

During recent years the production of new products incorporating the latest electronics technology has greatly accentuated the problems of design for efficient and economic manufacture. This is because modern design practice involves much higher penalties in both cost and time when corrective modifications have to be incorporated into serial production equipments.

Much more disciplined evaluation and proving of design is therefore required to verify producibility as well as performance before final release to production. A revised approach to development, industrial engineering and design for manufacture is necessary. More effective industrial engineering inputs to the early and not just the later design phases are required and closer relationships between industrial and product development engineering throughout all stages becomes essential. Technical cost estimates must be progressively established to ensure that the eventual product cost is compatible with market price requirements.

In short, the use of modern technology, e.g. hybrid circuitry, l.s.i. multi-layer and through-hole plated assemblies, etc., makes it essential to undertake producibility studies and methods engineering as an integral part of the development process and at all stages of design. The Engineering Function must accept the responsibility for not only instructing production on 'What' to make but also 'How' to make. Methods, processes and inspection procedures have, therefore, to be devised and proved as part of the overall development programme. The control and management of development programmes must be strengthened and accompanied by formalization of performance evaluation, including independent assessments of prototypes at appropriate stages.

John Cottrell (Fellow 1959, Member 1955, Graduate 1950) is Director, Marine & Submarine Systems, of Standard Telephones and Cables, based in London. He joined the Company in 1974 as Executive Assistant to the Managing Director, becoming General Manager of the Submarine Systems Division in 1975. He was appointed to his present position earlier this year and is now responsible for the Company's businesses in Telephone Cables, Hydrospace, Optical Systems, Marine Radio and Submarine Systems. For the previous 25 years Mr Cottrell was with the Plessey Company; in 1971 he was appointed Divisional Managing Director of Communications and Marine Systems and he subsequently became Director of Projects on the Company's Corporate staff. From 1959 to 1964 Mr Cottrell served on the Institution's Programme and Papers Committee and he took a leading part in the formation in 1964 of the East Anglian Section as its first Honorary Secretary, later serving as Chairman from 1968 to 1970.

The same complexities also emphasize the importance of early technical cost estimating of both the proposed design and the manufacturing processes to establish the probable product cost in production. Thus the acceptability of the design can be measured against the market requirement and any necessary cost reduction targets set. Subsequently the estimates should be up-dated at each engineering stage to ensure continued compliance. Alternatively, if the cost levels required for marketability cannot be met, then Management will have the opportunity to revise or cancel the project before too much engineering expense is incurred. In this way the achievement of the right balance between product performance and production cost is more likely to be achieved.

This concept has been dubbed 'Total Engineering'.

The Traditional Approach and Why It is No Longer Relevant

Prior to the mid-60s most electronic equipment designs involved straightforward and well-established engineering practice. Components were discrete and easily changed. Metal work was simple and mainly consisted of individual pieceparts easily assembled and not difficult to alter if modifications were required. Most equipments were relatively large and changes could be made very quickly at only minor expense. The active elements were valves, thermionic devices and/or transistors or diodes. All of these too, were easy to change in the event of modification, whether occasioned by new performance requirements or simply through design errors coming to light during the early stage of production.

Designing equipment to suit production depended heavily upon the development engineer being experienced in what the production departments could handle and the machinery that might be available to manufacture mechanical parts together with industrial engineering inputs from the Production Department on a part-time basis. The latter activity generally resulted in advice to widen the tolerances, to provide larger radii on corners of press parts, requests for cheaper or more easily worked material, the re-routing of cable forms, better clearances for nuts and bolts, improved accessibility for soldering irons and so on.

Traditionally, the draughtsmen and mechanical engineers would have been trained through apprenticeships and have worked in model shops and machine shops, thus understanding at first hand the production process and able to apply their practical knowledge to the design of new equipment. Similarly, most of the more senior engineers would have seen numerous products through from development into production and possess comprehensive experience of what could be tolerated in production and what could not.

0033–7722/79/050226+04 $1.40

During the past ten years a remarkable revolution in technology has occurred, such that dependence on these procedures is no longer sufficient to ensure that the design which emerges from a development programme is suitable for manufacture in quantity. The most significant changes are the following.

(1) New technology involving complex components and assemblies, frequently special to requirements, have evolved. These cannot be readily changed other than at considerable expense: not only in financial terms, but also with a very significant time penalty. No longer can modifications be introduced overnight or through a weekend—many weeks are often involved whilst sub-systems re-design is undertaken with consequent delays to the overall product. Hence the requirements for such components and assemblies, as well as for the complete equipment of which they form part, must be correct before main production is initiated.

(2) Equipments are becoming more sophisticated and complex with the project cycle, from the start of development to full production, becoming longer and longer. Two significant outcomes have resulted:

(a) The growth in equipment size and cost has produced a tendency to rely on fewer prototypes than in the past. When large systems are involved only one model may be built even though substantial production is expected. This cost-saving policy during development often causes skimped evaluation and corner-cutting engineering. The money saving is invariably offset many times by the consequent excess costs during the early production stages.

(b) The average engineer and designer has less and less experience of seeing projects through from inception to full design approval. Engineers who have changed jobs every two or three years may never have seen any project through into full production with all the pains, experience and learning which results.

Recognition of the true and total development costs before work is authorized would sometimes result in reversal of the intent to proceed.

(3) The growth in research and development activity during the past 20 years has produced increasing numbers of engineers and development personnel who have not experienced the traditional process of apprenticeships, practical training and the other activities which ensure that the development work is carried out with a thorough knowledge of production capabilities and limitations.

The majority of draughtsmen come direct from Drawing School whilst really good mechanical design engineers are now few and far between. Electronic engineers originate in universities and a decreasing number through apprenticeships and Higher National Certificates or their equivalent.

(4) The electronics content of equipment has grown enormously over the past decade with a corresponding decrease in the mechanics, although that remaining is still vital. Nevertheless, few industrial engineers possess real understanding of electronics and its associated manufacturing problems. Dependence on the design department for this expertise is, therefore, much greater than in the past.

The net result of these evolutionary changes is that, increasingly, equipment emerges from development laboratories inadequately engineered for production and to designs more difficult to put right subsequently. Hence the need for a new approach.

The second major factor which must be recognized is that, although the complexity of the designs has increased and much greater performance is expected, little progress has been achieved in changing and improving the development process itself. Development Cost Planning and Project Management have appeared and contribute significantly to better control of time and money. But they do not, in themselves, improve the adequacy of the design work or its evaluation. Other steps are necessary for this purpose and should be introduced into development programmes on a formalized basis.

Development work is normally carried out in stages including conception and design, cost studies, feasibility studies, breadboard design, initial prototypes followed by engineered models for internal and field trials. However, frequently, there is no formal release from one stage to the next. Even where there is, as often as not it is confined to the engineering department and without any formal reports of the state of the design and the outstanding problems and inherent risks in the remainder of the programme. Work between the stages often overlaps and the design is not frozen at appropriate points in the programme for strict evaluation purposes. Prototypes tend to be all different, and a final model of the exact design which is to be released for production is never made.

It is a strange paradox that whereas the evaluation, i.e. Quality Assurance, of production-made equipment is carried out independently, in most organizations this does not happen to the engineering—the designer acts judge and jury of his own efforts.

Frequently large projects are injected into engineering laboratories without prior examination of organizational requirements. As a result the department tends to grow like topsy without a real professional management determination of how the work should be structured and controlled or the team organized for optimum efficiency.

The Modern Method

There are three steps that must be taken:

(1) Industrial engineering integrated into the development process.

(2) Disciplined control through stage-by-stage release procedure.

(3) Independent evaluation coupled to overall policy control by a Board of Management.

Each of these changes can, in themselves, be effective for improving control but all three taken together will provide a major step function towards total control at all stages. Consider each factor in turn.

Industrial Engineering

In simple terms it is that the development of the assembly and test methods, processes, and if necessary, manufacturing machines, is all carried out in addition to the development of the design itself, as part of the engineering process. Secondly, this total responsibility, traditionally split between the Engineering and Production Functions, must now become part of the total concern of the Chief Engineer of the business concerned. Thus the term 'Chief' comes into its own, covering all aspects of engineering a basic design into a product which can be manufactured and whose design does embody fully proven engineering and processes suitable for manufacturing use. This does not mean that problems will not be encountered in production since, inevitably, there will still be difficulties with tooling, operator training and changes to components through obsolescence but the major variable, namely, inadequate producibility of the design, should be greatly reduced or eliminated.

For this change to be effective, there are a number of important points which must be followed. Briefly, they are:

(a) The development programme must be constructed so that an adequate number of prototype equipments are produced at each of the appropriate stages. These prototype equipments are the vehicles by which the design and the assembly methods and processes are to be proved. Hence

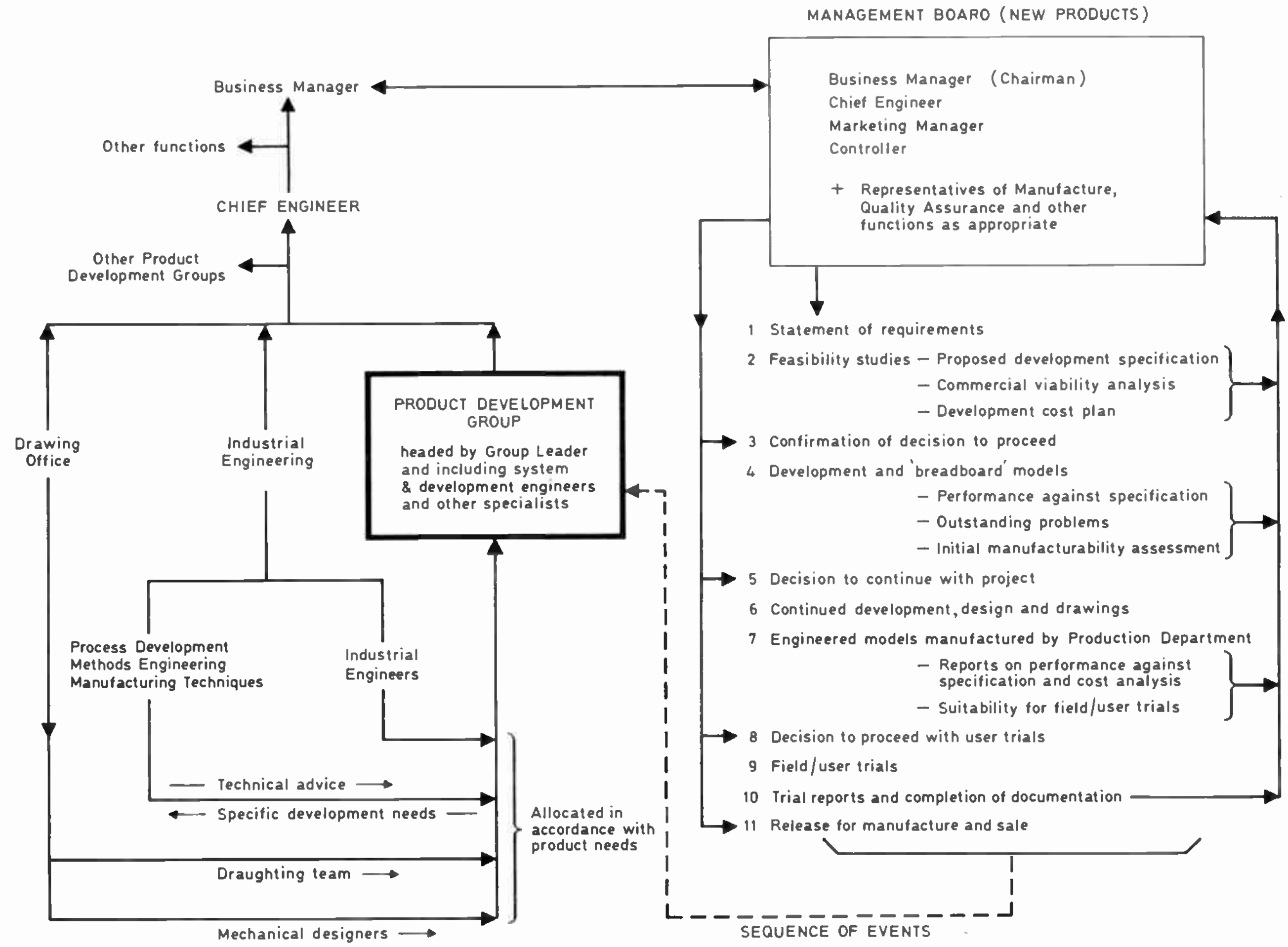


Fig. 1. Outline structure for engineering organization and management control of new product development.

they must be constructed in the production department which will eventually manufacture the équipment or, alternatively, in a Prototype Shop under the control of that Production Department and subject to all the disciplines associated with normal manufacture.

(b) An acceptance by the business of the necessity to include in the Development Cost Plan provision for the additional costs of fully developing the manufacturing methods and processes prior to initiation of actual manufacturing programmes.

(c) The total development estimates must also include the costs of carrying out industrial engineering as part of the development process. The production documentation emerging from the Engineering Department must, therefore, now include the following:

Production drawings
Test specifications
Process layouts
Test schedules
Test gear plan
One set of proven production test equipment
Bills of material
Fault-finding guides
Sets of production samples
Piecepart issue list
Equipment family tree.

Previously, only the production drawings, test specifications and perhaps a bill of material would have been provided. Unless the foregoing points are accepted and totally incorporated into the programme there is no point in proceeding along the lines indicated. Industrial engineering cannot be carried out as part of the engineering process unless substantial changes are made to the traditional pattern of development.

Implementation of this policy involves the transfer of responsibility for industrial engineering as it applies to new products into the business development organization but with certain specific functions remaining under manufacturing control. The activities in the latter category will normally include facility planning, work study, planned and sales estimating, tool design and shopfloor trouble shooting.

These activities should remain as part of the Production Function comprising of an industrial engineering unit reporting to the Manufacturing Department although with functional responsibility to the Chief Industrial Engineer.

All other industrial engineering activities must now be considered as part of the total engineering function, namely,

(1) Production engineering
(2) Process development engineering
(3) Ergonomics
(4) Skills analysis
(5) Value engineering
(6) Test and inspection planning
(7) Jig, tool and test gear design.

The introduction of these engineering skills and disciplines into the existing engineering department must be such that total integration must be achieved. To this end the day-to-day work of the industrial engineer must be as a full member of the task team working on the development project.

For this reason an industrial engineering manager must be appointed reporting to the Technical Manager of the business and functionally responsible for the provision of a complete industrial engineering service. The line responsibility for the individual industrial engineers will be via task team leaders on each project, as with draughtsmen and development engineers.

In addition to the functional responsibility for all industrial engineering skills, the industrial engineering manager will have direct line responsibiiity for a process development group. This group will design, develop and evaluate new manufacturing processes in response to the general changes in technology emerging over the years and to the specific needs of new products.

The output from this group will be assembly and process standards in which will be set out in detail the new process, the tools and fixtures necessary, standard times and quality measurement methods.

Disciplined Control

The first and obvious step must be the establishment of a clear and totally definitive development specification. The second is the establishment of the successive stages of the development programme. The third must be the establishment of the technical and financial criteria by which the development process is to be judged as complete and satisfactory at *each* stage.

Stage by stage control must also ensure that:

(1) Stages are not allowed to overlap.

(2) Shortcomings against the objectives at any stage are cured before the next is initiated.

(3) Approval of the results of each stage involve commercial and technical functions and with general management involvement in the final decision making go/no-go process.

(4) Programmes do not proceed without full engineer manning since otherwise the engineering will be inadequately carried out particularly if tight time-scales are involved.

(5) Changes to specification may only be introduced by Management Decision and with full prior adjustment of time and money, where necessary, to the programme.

Unless these requirements are implemented with discipline then meeting programmes and specifications will be more a matter of chance than management.

Independent Evaluation

Once the prototype stages are reached, the performance evaluation required to establish that the acceptance criteria for each stage have been met should be carried out by an independent team of technicians. Ideally, this team will consist of personnel who have not been involved in the design process. Thus, the evaluation will not only gauge the acceptability of the equipment, but also provide an objective assessment of the adequacy of the test specifications, methods and procedures. This independent evaluation should be carried out under the control of senior Quality Assurance personnel.

The results of this work should be subject to the approval, or otherwise, of a Board of Management comprising marketing, manufacture and engineering representatives. Their task would be to decide whether the product is fully suitable for meeting the market requirement in all respects, to be satisfied that any variations from the original performance specification are acceptable or whether or not additional engineering work must follow, and finally to gauge whether, on the basis of the results, the performance is adequate within the stated tolerances for consistently meeting the ultimate test requirements in manufacture.

The judgements to be exercised on the results can have a serious impact on the product performance and timing of ultimate product launch on the market. It is, therefore, considered essential that variations, particularly to specifications and/or programme, be authorized as Business Decisions.

Conclusions

The practical application of all these principles must always be adjusted in line with the nature of the product and the technology involved. These factors will influence the relative importance of the disciplines described. They will also vary according to the nature of the manufacturing methods.

In the process industry, for example, the total integration of performance design and industrial engineering is vital. Finalizing a design has to be an iterative process which can only be accomplished by prototype manufacture on the production plant. On the other hand electronic digital hardware requires rigid, disciplined, stage-by-stage control as first priority. However, all the procedures described will contribute to a successful outcome and it is only weighting the application of them appropriately which requires selection in each and every project.

The proposed methods of management control, disciplines and engineering organization are summarized in Fig. 1. The structure and sequence of events will inevitably vary from project to project: that shown here is only intended to illustrate a typical situation for the purpose of highlighting recognition of the need for specific breakpoints in the programme to allow management decisions to be made.

Other Reading

This paper was not intended to discuss the many other aspects of New Product creation, e.g. Development Cost Planning, Project Management, Critical Path Scheduling etc. However, some useful references to these important related subjects are:

'Project Planning and Control—Simplified Critical Path Analysis', D. C. Robertson (Iliffe, London, 1967).

'Profitable Selection and Control of Research and Development Projects', Industrial Education International Ltd., 110 Strand, London WC2.

'Value Analysis', W. L. Gage (McGraw-Hill, New York, 1967).

Contributors to this issue

Richard den Dulk received engineering degrees in electrical engineering from the Haags Polytechnische Instituut, The Hague, in 1969 and from the Hogere Technische Avond-School, Rotterdam, in 1971. In 1978 he received the M.Sc. degree in electronics from the Delft University of Technology. In 1964 he joined the Department of Electrical Engineering of Delft University, where he worked on h.f. communication receivers, v.h.f. receivers and automatic tracking systems for meteorological satellites. Since 1974 Mr den Dulk has been a mentor for students, who are working on the application of digital circuits in frequency synthesizers. His present research interests are mainly concerned with phase detection, irregular signals and phase-locked loops.

Durk van Willigen finished his studies at the Delft University of Technology in 1963 and since 1964 he has been a member of the scientific staff of the University. In recent years he has been working on frequency synthesizers for receivers, tracking and scan-conversion systems for meteorological satellites, and digital receivers for LORAN-C navigation applications.

Franz Demmelmeier received the Ing.(grad.) degree in 1968 from the Polytechnikum of Munich and the Dipl.Ing. degree in 1973 from the Technical University of Munich. For the next four years he held an appointment as Scientific Assistant at the Lehrstuhl für Prozessrechner, Technical University of Munich, and in February last year was appointed Akademischer Rat at the Lehrstuhl für Prozessrechner. His research interests are signal processing, iterative arrays in which field he is working towards the Dr. Ing. degree, and multimicroprocessor computer-systems.

Professor William Gosling (Fellow 1968), has been Head of the Electronics Group at the School of Engineering at the University of Bath since 1974. He was previously at the University College of Swansea for some 16 years and was Professor of Electrical Engineering and Head of the Department of Electronic and Electrical Engineering from 1966 to 1973. He has contributed numerous papers to the Journal on a variety of subjects including instrumentation, semiconductor devices and circuits, and radio receiver techniques, being awarded the Clerk Maxwell Premium for 1976. Professor Gosling was Chairman of the Professional Activities Committee from 1971 to 1976 and he serves currently on the Executive Committee. He was first elected a member of the Council in 1970 and has been a Vice President from 1972 to 1975 and since 1976; he is now President-elect of the Institution for 1979/80. He has served on various CEI Committees and is now an alternate representative of the Institution on the Board. He represents the IERE on EUREL and was recently elected President for 1978/79.

Joseph McGeehan received the B.Eng. and Ph.D. degrees in electrical engineering from the University of Liverpool in 1967 and 1972 respectively. From 1970 to 1972 he held the position of Senior Scientist at the Allen Clark Research Centre, Plessey Co. Ltd., where he was primarily concerned with research into solid-state microwave devices and their applications. In September 1972, Dr McGeehan was appointed Lecturer in the School of Electrical Engineering at the University of Bath, and he currently conducting research in mobile communications.

Peter Holland graduated from the University of Bath in 1976 with an honours degree in electrical engineering. During his course he obtained industrial experience with Marconi Elliott Avionics, Rochester. After working with the mobile radio research project at the University funded by the Wolfson Foundation, he has remained to pursue postgraduate work in mobile data systems as an SRC CASE student in association with Philips Research Laboratories.

UDC 621.376.24: 621.396.621.029.62: 621.396.931

Indexing Terms: Radio systems, mobile, Radio receivers, Modulation, single sideband

Receivers for the Wolfson single-sideband v.h.f. land mobile radio system

W. GOSLING, B.Sc., A.R.C.S., C.Eng., F.I.E.E., F.I.E.R.E.,*

J. P. McGEEHAN, B.Eng., Ph.D.*

and

P. G. HOLLAND, B.Sc.*

Based on a paper presented at the Conference on Radio Receivers and Associated Systems held at Southampton on 11th to 13th July 1978.

SUMMARY

Both the reduction of spectrum width of a s.s.b. transmission and its lower spectrum pollution, due to the absence or diminution of a carrier component, make this mode of modulation attractive for future use in land mobile radio. Outstanding problems are frequency stability and a.g.c. The latter cannot be of the 'hang' type used at h.f. In the Wolfson system a low amplitude audio tone transmitted at the centre of the audio pass-band is used for both a.g.c. and a.f.c. A hierarchy of receivers, from simple, manually clarified to sophisticated, fully automatic types, is described, to meet the needs of varied users. The proposed system appears to have several advantages over other contenders.

* *School of Electrical Engineering, University of Bath, Claverton Down, Bath BA2 7AY.*

1 Introduction

Further growth in the use of civil land mobile radio will depend critically on the more effective use of the radio frequency spectrum, particularly in the v.h.f. and u.h.f. bands.[1] Many techniques can contribute to this improved utilization—better operational methods like the use of dynamic channel assignment,[2] increased use of data transmission with its relatively low redundancy, and diversity techniques in reception and transmission[3,4] will all play a part. Not least significant, however, could be a change of modulation system from f.m. or a.m. to another which utilizes the spectrum more efficiently, for a given grade of service.

It is not difficult to show that of all the currently available modes of modulation, only single sideband permits information transfer at a rate which approximates to the Shannon limit:[5] all others are worse, and some very much worse (notably f.m. in all its forms and full-carrier a.m.). This simple analysis only considers performance with white noise in the channel as the medium impairment, and is therefore by no means beyond challenge, nevertheless it does imply that the case for s.s.b. at v.h.f., and even u.h.f., in the civil land mobile service must be carefully considered.

Thanks to a substantial grant from the Wolfson Foundation, it has been possible to initiate a study at the University of Bath aimed at determining the feasibility of the use of this mode of modulation in the private mobile radio service and evaluating the practicability of its commercial exploitation. This paper will review the system aspects and indicate typical resulting receiver designs.

The programme, in general terms, consists of the construction of transmitters and receivers for v.h.f. s.s.b. working, with u.h.f. equipment to follow at a later date. The equipment is then being used in an extensive series of laboratory and field trials to determine how a private mobile radio system would behave in everyday use, based on this mode of modulation. In particular, the likely practical improvement in spectrum utilization will be evaluated.

To be viable in the market place it was felt essential that the Wolfson s.s.b.v.h.f. system should have operator characteristics in no way inferior to those of present 12·5 kHz narrowband f.m. or a.m. systems, and better if possible. An essential decision at the very beginning of system evaluation was the channel width for which operation was to be designed. It was felt that a strong case could be made out for 5 kHz channels, as the narrowest which present-day technology would probably permit and this, therefore, was the channel width adopted. The advantages of simply splitting present 12·5 kHz channels, from an administrative point of view, might lead instead to the decision to standardize on a 6·25 kHz channel width; however equipment designed for a 5 kHz channel would not be embarrassed by such a choice.

At the same time a full audio frequency response

0033–7722/79/050231+05 $1.50

(300 Hz to at least 3 kHz) was also an important design aim, as was the ability to use all the commoner present-day 'add-on' facilities, as used with n.b.f.m. and a.m. 12·5 kHz equipments. Among these would be data modems, overlay paging, sub-audio tone muting, selective calling, and so on.

2 Problems of V.H.F. S.S.B.

In earlier studies a number of problems have been identified which prevent the present use of s.s.b. at v.h.f.[6,7] These may briefly be summarized as follows (starting with the most intractable).

2.1 Frequency Offset

With suppressed carrier s.s.b. systems the carrier component used for product demodulation is generated in the receiver and may therefore differ in frequency slightly from the true carrier frequency value. This small frequency offset appears as an equal frequency translation (either up or down) in each Fourier component of the receiver audio output, with consequent loss of naturalness of speech, and even loss of intelligibility if the offset is large. Whilst it is true that speech remains reasonably intelligible with offsets up to ± 150 Hz, the naturalness is entirely lost for offsets exceeding ± 50 Hz. Speaker recognition may also be impaired. Thus for speech transmission an offset not exceeding ± 25 Hz appears a reasonable goal. For some applications, e.g. sub-audio tone muting, where tones are selected by narrow band-pass filters, even greater frequency accuracy is essential. By contrast the frequency stability of a crystal oscillator in a land mobile equipment is usually taken as ± 5 parts in 10^6 or ± 500 Hz at 100 MHz. Most future equipments will be synthesized and therefore a better temperature-compensated crystal oscillator may be used as the standard (since only one will be required). Even so, the cost of such oscillators climbs rapidly if better than ± 1 part in 10^6 (± 100 Hz at 100 MHz) stability is specified. The all-digital temperature-compensated oscillator may yield a breakthrough here,[8] but the economics of this approach are not yet clear.

2.2 Automatic Gain Control

Like a.m. related systems, s.s.b. requires good a.g.c. to overcome signal fading. In mobile use fade rates (at v.h.f.) as high as 1000 dB/second are sometimes encountered and fade depths in excess of 30 dB are common, thus good a.g.c. is particularly important. A.m. systems have a constant amplitude reference in the carrier component, thus a.g.c. is designed to monitor the carrier level and keep it constant, so far as possible. Well designed, it yields nearly constant audio output levels.

Suppressed carrier s.s.b. cannot operate in the same way. If the a.g.c. voltage is simply derived from the mean signal amplitude (as with a.m.) it tends to compress the audio signal but, worse, gives maximum receiver gain in between words, when the received signal vanishes. The audible effect is to fill the inter-word gaps with loud receiver noise which is very fatiguing for operators. Co-channel interference, even at a low level, is also emphasized by the gain increase between words. In h.f. practice the effect is overcome by using 'hang' a.g.c., in which the gain is held at a low level for a fixed time interval after the signal disappears. This is not suitable for use at v.h.f., where fading is much more rapid, and also behaves unsatisfactorily in the presence of impulsive noise.

2.3 Impulsive Noise

The predominant type of noise in the land mobile environment is not white but impulsive, derived principally from ignition systems of petrol engines. The effect of impulsive noise on s.s.b. at v.h.f. is a matter of considerable interest. It has been claimed that the effect is more severe[6] than for a.m. and n.b.f.m., to the extent that s.s.b. might be considered hardly useable. Certainly if 'hang' a.g.c. is used this will be so, since each impulse will trigger the receiver into low gain for a fixed, quite long, interval. However, other users report impulsive noise as being little different in its effect from that in 12·5 kHz a.m. and n.b.f.m. systems, presumably using receivers without 'hang' a.g.c. Our own preliminary experiments[9] confirmed the view that impulsive noise would not present a more severe problem with s.s.b. than other narrow band modulation systems. Clippers or blankers in the receiver give a worthwhile improvement, as in a.m. systems.[10]

2.4 Transmitters

The s.s.b. transmitters used at h.f. generate the s.s.b. signal at low level, with linear amplification up to transmitted power level. Such transmitters have many disadvantages. They are relatively inefficient in conversion of d.c. to r.f.: figures as low as 15% are not uncommon. Noise from low-level stages is amplified by the linear amplifier, whilst non-linearities in the amplifier result in substantial spurious emission from the transmitter, typically as little as 40 dB below the wanted signal. Although it has been claimed that mobile a.m. and f.m. transmitters give rise to equal or worse spurious adjacent channel emission in 6·25 kHz channelling,[11] clearly a substantial improvement in s.s.b. transmitter performance, both in respect of better power efficiency and lower spurious emission, would greatly enhance the utility of a v.h.f.s.s.b. private mobile radio system. Such a development in transmitter technology has now been successfully achieved, and is described elsewhere.[12,13] This depends on a radically new transmitter configuration, with the s.s.b. signal amplified in polar coordinate form, and the use of power f.e.t.s in the output stages.

3 The Wolfson S.S.B. V.H.F. System

The Wolfson s.s.b. v.h.f. system was developed to overcome these problems. An early decision was that it appeared essential to transmit an additional signal, with the suppressed carrier single sideband, which could act as both a frequency and an amplitude reference, to assist the frequency stability and a.g.c. problems.

The most conventional solution would be the transmission of a diminished (pilot) carrier component. This has three important disadvantages: first, because it is situated to one side of the s.s.b. spectrum the pilot carrier is particularly vulnerable to adjacent channel interference; secondly, the use of pilot carrier for a.g.c. may be unsatisfactory when the coherence bandwidth of fading is particularly low;[14] and thirdly, a component at the carrier frequency, which is to one side of the s.s.b. spectrum, in conjunction with transmitter non-linearities, gives rise to a spurious 'ghost' sideband in the adjacent channel.

For these reasons it was decided to locate a pilot tone at the centre of the speech spectrum. The frequency chosen is 1·667 kHz (=5/3 kHz). In the transmitter speech processing circuits, a band-stop filter produces a gap in the speech spectrum 350 Hz wide (to −3 dB points) centred on the tone frequency and tone energy is then added at a level −16 dB relative to peak speech power. In the receiver, the tone is suppressed in the audio output by means of a band-stop filter, thus rendering it inaudible.

The advantages of a mid-band pilot tone are relative immunity to adjacent channel effects, no more than about 1·5 kHz difference in frequency between the pilot and any sideband, and the addition of coherent energy near the centre of channel gives rise to very little spurious emission in the adjacent channels, despite residual transmitter non-linearities. It has a further advantage in respect of automatic frequency control. However, to explain this in detail a further aspect of the Wolfson system will need to be described: the use of a hierarchy of possible levels of equipment sophistication.

4 Equipment Hierarchy

It is characteristic of a.m. and f.m. mobile radio equipment that it is available in a range of different degrees of sophistication and cost. At the simplest, low-power single-channel equipments without special facilities give excellent low cost service for the less critical, whilst much more sophisticated synthesized equipment may be preferred by public service users. The same principle is retained in the Wolfson system: both relatively cheap and simple equipments and relatively more expensive and complex realizations are possible. This applies to both transmitters and receivers, but in what follows attention will be concentrated on receiver technology. In particular, problems of a.f.c. and a.g.c. will be reviewed in the light of this design principle.

4.1 Frequency Control

To overcome frequency drift in the receivers some kind of frequency control, using the pilot tone, is required. Design assumes drift of ± 1 part in 10^6 in the local oscillator and thus a control range of ± 200 Hz is required for v.h.f. use. The simplest arrangement uses a manual clarifier: the standard oscillator is 'pulled' slightly in frequency using a manual control, which may be conveniently mounted on the microphone. Such manual clarifiers are standard practice on h.f. s.s.b. equipments. Their use demands some skill, since correct adjustment depends on judging the 'naturalness' of the voice as heard. In the Wolfson system manual adjustment of the clarifier is much easier and demands no skill: it is simply adjusted until the audible continuous tone is 'tuned' into the null of the audio band stop filter, when it becomes inaudible. An accuracy of setting of ± 25 Hz is attained by unskilled operators without practice. This is the system to be used in the cheapest receivers, and is surprisingly easy to use.

For more sophisticated receivers the pilot tone is used for automatic frequency control. In the most complex receivers this is achieved by phase locking the pilot tone to 1·667 kHz signal generated by counting down from the receiver frequency standard. The phase of the component of the received signal near the tone frequency is compared with the internal 1·667 kHz source and the error voltage (after low-pass filtering and amplification) controls the frequency of the receiver's first frequency-changer oscillator. When lock is achieved the residual frequency error is a small fraction of 1 Hz. Best results are achieved with a derived rate rejection (d.r.r.) phase lock system[15] which gives ± 200 Hz lock-in range yet is much more resistant than a conventional phase-locked loop to pulling off-lock by modulation once lock has been achieved.

A receiver of this kind will give very precise reproduction of the transmitted signal frequencies and is thus suitable for use with sub-audio tones, selective calling and other ancillaries. Superior audio frequency response, resulting from the use of post-demodulator amplitude equalizers, is also facilitated.

Obviously receivers to a standard between those described—having a.f.c. of a less sophisticated kind—are also possible.

4.2 A.G.C. and Muting

The simplest receivers have envelope-derived a.g.c. with 'fast up-slow down' characteristics identical with that used in a.m. receivers. There is some speech compression, but this is not particularly objectionable, and inter-word pauses are filled by pilot tone (which is suppressed by the audio band-stop filter) and thus are heard as silent at the audio output. Muting is conventional, the mute opening when a sufficient a.g.c. voltage is developed.

Slightly more sophisticated are receivers which derive the a.g.c. voltage entirely from the pilot tone, which is passed through a band-pass filter, to select it from the audio output, before rectification. Using this technique

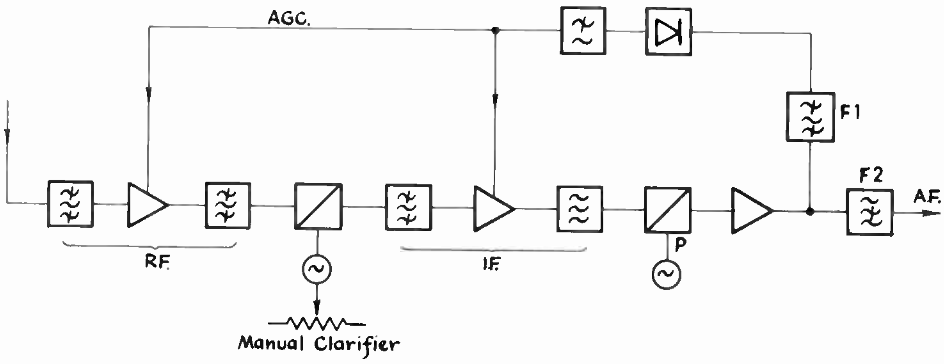


Fig. 1. Simple manually clarified receiver. A double superhet. receiver may also be used, particularly at u.h.f.
P: product demodulator; F1: tone band-pass filters; F2: tone-band-stop filter.
(In practice, F1 and F2 are combined as a single active filter.)

speech compression is avoided, but it can only be applied to receivers having some form of a.f.c.

Still more sophisticated receivers use forward-feeding a.g.c., embodying an audio time delay. Fully described elsewhere[16] this provides extremely effective a.g.c., especially to combat fast fading. It will therefore be particularly important when the use of the system is extended to the u.h.f. bands. Sophisticated receivers, which are likely to embody high-grade a.f.c., can use any of the forms of muting (open, noise, sub-audio tone) in use in existing mobile radio equipments, a.m. oı f.m.

4.3 Typical Receivers

A typical receiver of the simplest possible kind is shown, in block diagram form, in Fig. 1. The receiver uses a manual clarifier and envelope a.g.c. It thus differs from an a.m. receiver virtually only in the incorporation of an active audio band-stop filter to suppress the pilot tone. A single superheterodyne configuration is shown, in contrast to the double superheterodyne extensively used in mobile radio practice. This is because a product demodulator can operate at a much lower power level than a diode, hence less i.f. gain is required and double conversion is not needed.

The block diagram of a receiver near the upper extreme of complexity is shown in Fig. 2. This receiver incorporates both forward and backward-feeding pilot-tone a.g.c., and a phase locked a.f.c. system using a long d.r.r. loop. Matched with a transmitter of comparable quality, it can give speech communication in 5 kHz channels superior to that frequently achieved with a.m. or n.b.f.m. in 12·5 kHz channels.

5 Discussion

By incorporating a low-power pilot tone near the centre of the audio pass-band most of the problems in use of s.s.b. at v.h.f. can be overcome. The tone is suppressed in the receiver by a band-stop filter and it is well known that the consequent 'hole' in the a.f. spectrum has negligible effect on speech intelligibility.[17] The range of receiver technologies applicable, from the simple to the complex, means that the quality of service given can be

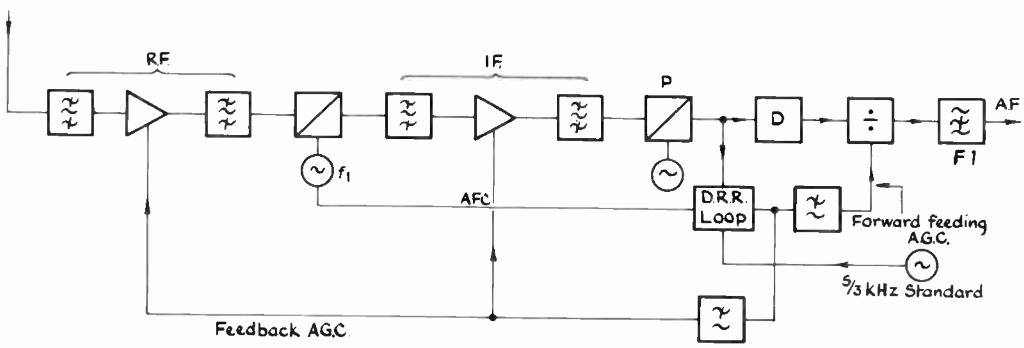


Fig. 2. More sophisticated Wolfson receiver.
P: product demodulator; D: time delay (c.c.d. or bucket brigade); F1: tone band-stop filter. All local oscillator frequencies derived from a synthesizer (not shown) with a.f.c. of the frequency standard. This produces a significant change only in f_1.

tailored to the needs of the user and to the depth of his purse. The most sophisticated equipments can be used with all the ancillary systems commonplace in present-day private mobile radio practice (except d.p.s.k. data transmission: the Wolfson s.s.b. v.h.f. system functions best with f.s.k. data).

It is clear that 6·25 or 5 kHz channelled s.s.b. private mobile radio is feasible at v.h.f. using the Wolfson system. What is not yet known, but must be established by the research at present in progress, is whether the field characteristics are such as to make a general change to this system desirable. The economics of the system also merit investigation, but superficially appear promising. Transmitter peak powers can be reduced about 9 dB relative to a.m. or n.b.f.m., and the mean power is even lower, by a substantial factor, since little power is radiated in the inter-word intervals. Thus the s.s.b. transmitter is likely to be lower in cost than an a.m. or f.m. transmitter for a comparable coverage area, will be more compact and will have less substantial heat sinks. The receiver ought to be similar in cost to an a.m. or f.m. synthesized receiver of comparable quality. However, the frequency standard used with the synthesizer will have to be of a temperature compensated type. This is the only immediately obvious cost penalty for adoption of s.s.b.

6 Conclusions

Although the use of s.s.b. at v.h.f. in the land mobile radio service has not yet been fully established, significant progress towards that goal has been made. Its ultimate adoption is beginning to look distinctly possible.

Sometimes it is argued that 5 kHz channelling is undesirable because it will preclude the ultimate adoption of digital speech transmission. The rapid development in low bit-rate speech digitization at the present time, made possible by l.s.i. and v.l.s.i. technology, render it probable that speech digitizers operating at two or three kilobits/second will be cheaply available within a few years. Using f.s.k. modems, digital speech will then be easily transmissible through the proposed Wolfson s.s.b. system.

This paper has concentrated on s.s.b. as a means of working in narrow channels. It can offset spectrum congestion in another way also, which in the event is likely to prove just as important. Because the carrier component of an a.m. or n.b.f.m. system is replaced by a pilot some 16 dB smaller (in the present system) all intermodulation effects due to carrier interactions are reduced by at least 38 dB, and hence are much less significant. Since sideband intermodulation products can, anyway, only be transient and are on average much smaller than calculations based on peak power, due to the high peak-mean ratio of speech, these too are much less serious than present-day carrier interactions. Thus the whole intermodulation problem becomes more tractable if all users convert to s.s.b. This would be true even if the need to reduce channel widths did not exist.

7 Acknowledgment

We are grateful to the Wolfson Foundation for financial support which made the work described possible.

8 References

1 Pannell, W., 'A Study of the Future Spectrum Requirements for Private Mobile Radio in the UK', Pye Telecommunications Ltd, Cambridge, 1976.

2 Craine, J. F., 'Automatic control of mobile equipment for dynamic channelling systems', Conference on Civil Land Mobile Radio, November 1975. (IERE Conference Proceedings No. 33.)

3 Parsons, J. D. and Ratcliff, P. A., 'Diversity reception for v.h.f. mobile radio', *The Radio and Electronic Engineer*, **43**, pp. 317–24, May 1973.

4 Gosling, W., Martin, J. D., Holbeche, R. J. and Allen, G., 'Sideband diversity: a new application of diversity particularly suited to land mobile radio', *The Radio and Electronic Engineer*, **48**, no.3, pp. 133-9, March 1978.

5 Taub, H. and Schilling, D. L., 'Principles of Communication Systems', p. 454 *et seq.* (McGraw-Hill, New York, 1971).

6 Beusing, R. T., 'Modulation methods and channel separation in the land mobile service', *IEEE Trans. on Vehicular Technology*, VT-**19**, p. 187, May 1970.

7 'Minimum channel separation and optimum systems of modulation for land mobile systems between 25 and 50 MHz', CCIR Document XII/72E, 1968.

8 Warwick, G. A., Gosling, W. and Prescott, A. J., 'A digital technique for temperature compensation of crystal oscillators', Conference on Radio Receivers and Associated Systems, 1978. (IERE Conference Proceedings No. 40.)

9 Gosling, W. and Weston, D., 'A quasisynchronous v.h.f. s.s.b. system', Conference on Civil Land Mobile Radio, November 1975. (IERE Conference Proceedings No. 33.)

10 Martin, J. D., 'Clipping and blanking in an a.m. receiver', to be published.

11 Hett, A., 'Adjacent channel performance of f.m., a.m. and s.s.b. at v.h.f.', Communications '78 Conference. (IEE Conference Publication No. 162.)

12 Petrovic, V. and Gosling, W., 'A high efficiency v.h.f. s.s.b. transmitter', Conference on Civil Land Mobile Radio, November 1975. (IERE Conference Proceedings No. 33.)

13 Petrovic, V. and Gosling, W., 'The polar-loop transmitter', Electronics Letters, **15**, No. 10, 10th May 1979, pp. 286–88.

14 Jakes, W. C., 'Microwave Mobile Communications', p. 207 (Wiley, New York, 1974).

15 McGeehan, J. P., 'Technique for improving the pull-in characteristics of phase-locked loops', *Proc. Instn Elect. Engrs*, **123**, pp. 761–4, August 1976.

16 Rawling, A. J., McGeehan, J. P. and Gosling, W., 'Forward feeding a.g.c. with extended signal delays', Conference on Radio Receivers and Associated Systems, 1978. (IERE Conference Proceedings No. 40.)

17 Hill, P. C. J., 'Simultaneous subliminal signalling in conventional sound circuits', *BBC Engineering*, No. 90, pp. 14–25, May 1972.

Manuscript received by the Institution on 28th February 1978.
(Paper No. 1876/Comm 180)

UDC 620.11: 621.397: 681.32

Indexing Terms: Computerized instrumentation, Inspection, Image sensors, Teletext applications

Display of component profiles from microprocessor-based recognition systems using a Teletext-encoded display

Professor ALAN PUGH, B.Sc., Ph.D., C.Eng., F.I.E.R.E., M.I.E.E.,*

and

CLIVE LOUGHLIN, B.Sc.†

Based on a paper presented at the Conference on Microprocessors in Automation and Communications held at Canterbury from 19th to 22nd September 1978.

SUMMARY

Teletext as a communication medium has aroused considerable interest amongst those appreciating the virtues of television display and the power of universal interactive information handling. This paper outlines a powerful use of teletext which has, hitherto, been ignored. The shape of component profiles, when encoded into Teletext graphics characters, offers profound advantages in applications of visual sensory feedback for component orientation prior to automatic handling.

* *Department of Electronic Engineering, University of Hull, Hull HU6 7RX.*

† *Department of Electrical and Electronic Engineering, University of Nottingham, University Park, Nottingham NG7 2RD.*

1 Introduction

Over recent years, research at the University of Nottingham has been directed towards the evolution of visual determination of component part orientation. The implication of this approach is that methods of mechanical selection of orientation manifested in devices such as 'bowl feeders' might be replaced by a self-programmable, visually interactive, orientation device capable of immediate application to a wide variety of component parts. The mechanical tooling of the traditional bowl feeder is then replaced with a software alternative through the medium of a microprocessing computer; the component orientation being determined by the successive application of a number of simple algorithms.[1,2,3]

The system used consists of a line-scan camera which is continuously scanning a vertical slit at the side of a conveyor belt. The schematic arrangement is shown in Fig. 1. The output from the 128-element photodiode array is used to build up a picture silhouette of objects as they move past this slit, a maximum of 128 scans being made after the object first enters the field of view. The information from the camera is processed so that only the location of picture elements on the edge of the silhouette are retained in memory. The resulting picture is then displayed on a 128×128 dot storage display unit. The outline of the component of Fig. 2 is illustrated in Fig. 3.

The reason for only displaying points on the edge of the component is to reduce the memory storage required from 16K bits to a size which depends on the complexity of the object but which in practice reduces to slightly more than 256, 8-bit bytes.

Investigations are currently in progress to replace the storage display unit (s.d.u.) with a cheaper, more versatile

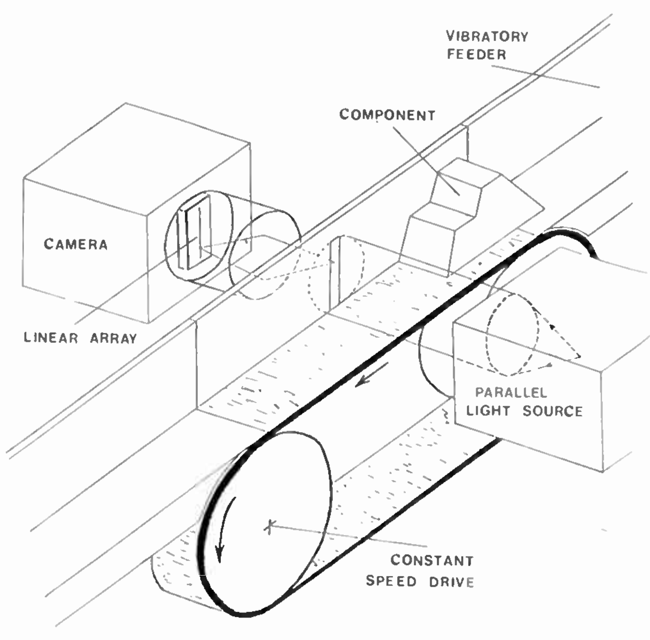


Fig. 1. Schematic arrangement of component recognition system.

0033–7722/79/050236+05 $1.50

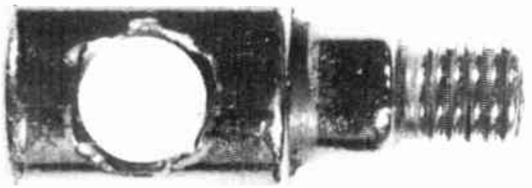


Fig. 2. Bicycle brake adjuster lug. (By courtesy of T. I. Raleigh Ltd, Nottingham.)

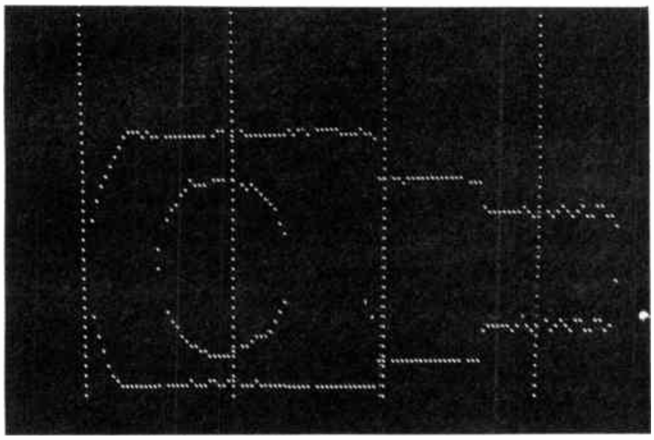


Fig. 3. Outline of brake adjuster lug.

alternative which will be (arguably) more acceptable to human beings. These requirements are coupled to a long term research policy for the empirical determination of the lowest picture resolution compatible with positive and reliable identification of components.

2 The Use of a Teletext Encoded Display

An exciting possibility is under investigation to display the component profile on a conventional colour television receiver and to define the shape by the use of a series of Teletext graphics characters. The already well-established Teletext standard for the display of alphanumeric and graphic characters is currently being used by the B.B.C., I.B.A. and the Post Office in their Ceefax, Oracle and Prestel transmissions. An example of the combined use of alphanumerics and graphics is shown in the familiar weather map illustrated in Fig. 4. This demonstrates how graphic characters can be used to provide a low resolution representation of a shape (in this case the British Isles) which is nevertheless readily acceptable and adequate for positive recognition. Advantage has been taken of the ready availability of modules for Teletext decoding (for example, Texas Instruments TIFAX) to decode and store the Teletext characters. It is a natural step to derive Teletext graphics characters directly from the original scan of the component profile. The present system of processing the data from the line-scan camera to store only the points corresponding to the edge of the profile, is replaced by a dedicated slave

Fig. 4. CEEFAX weather map page.

microprocessor which processes all the data from the camera to produce a real time stream of ASCII graphics characters containing 6 picture cells where each cell is composed of 9 picture elements according to Fig. 5. The data leaving the ASCII camera contain a completely linear and symmetrical representation of the scene viewed by the camera. These data are used by the main processor for the purpose of comparison and recognition so that no distortion is introduced at this part of the process.

When the data representing these equally divided graphic cells are interpreted by the Teletext encoder module, the transformation of the 6×9, 6-bit picture cell to the 7×10, 6-bit cell occurs which introduces an aspect ratio distortion of only 4·76%. This does not prove

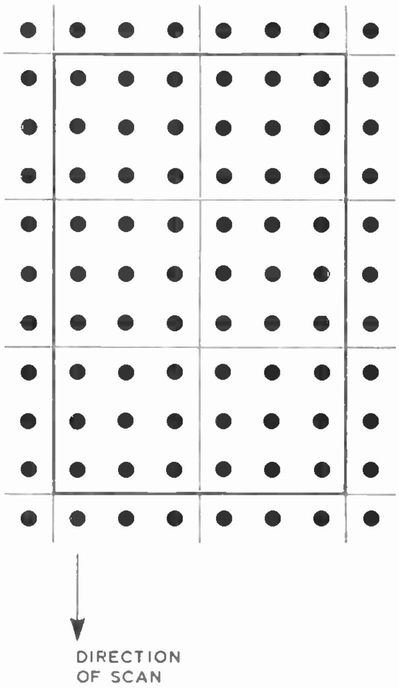


Fig. 5. Division of picture elements into equal graphic cells.

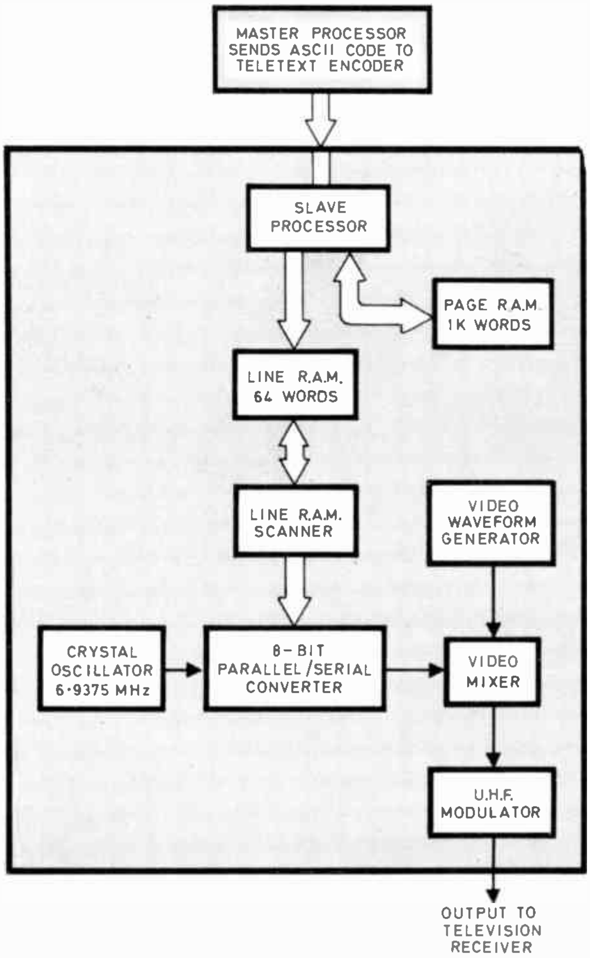
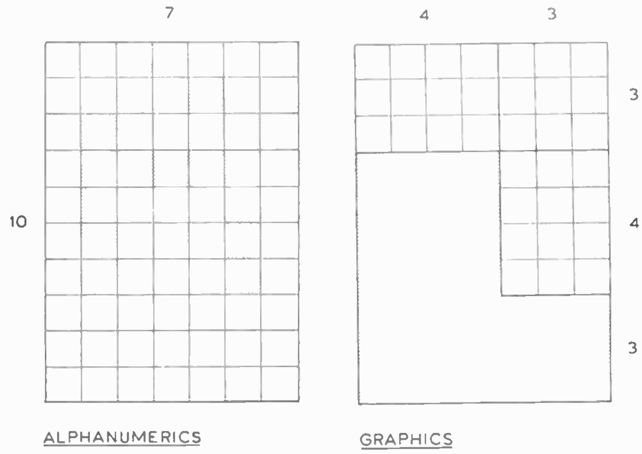


Fig. 6. Block diagram of Teletext encoder.



(a) (b)

Fig. 7. Format of Teletext characters (as in Texas TIFAX decoder).

confusing to the human operator if indeed it is noticed at all, and further, maintains an overall simplicity which is implicit in the proposals under discussion.

3 Interface Considerations

In order that the Teletext system can be used in this way, it is necessary to incorporate an electronic interface between the component recognition microprocessing facility and the Teletext decoding module. This interface is, in effect, a Teletext encoder which accepts ASCII coded 8-bit words from the main microprocessor, converts them into a serial data stream at a rate of 6·9375 Mbits/s, inserts the necessary clock run-in, framing and row identification codes which are required by the Teletext decoder and also superimposes these signals on a 625-line video waveform.

The interface is realized by the use of a dedicated microprocessor which acts as a 'slave' to the main microprocessing facility. The microprocessor used is the Intel 8085 and in addition to the standard complementary integrated circuits (8155, 8755) for input/output and program storage, an additional 1K of random access memory is used for storing the data for the displayed page. The Teletext encoder has been programmed to work in the simplest mode but more complex programs would offer page and roll modes as well as 'intelligent' functions such as graph plotting, bar charts, etc. within the limits of the Teletext system. A schematic diagram of the interface is shown in Fig. 6.

The resulting Teletext display comprises 24 rows of 40 characters; each character being composed of 7×10 picture elements which in the case of graphics characters represents 6 picture cells as defined in Fig. 7.

4 The Virtues of a Teletext Encoded Display

The decision to use the Teletext standard was made with regard to the benefits of using an already well-established standard for the display of alphanumerics and graphics; also by using mass produced items it is hoped that a more cost-effective solution is possible.

The unit cost of a Teletext module (for large quantities) is at present around £75 whilst the projected price for 1980 is as low at £30 at present day prices. The reduction in cost is influenced by the expected increase in sales of television receivers equipped for Teletext decoding. This entry into the consumer market will yield the added advantage that the public will already be accustomed to seeing Teletext displays in the home environment so their acceptance on the shop floor and into industry in general should be quite natural. It is apparent that the application of a Teletext encoded display is by no means limited to areas concerned with component recognition. It can also be applied to any area where the display requirements can be fulfilled by alphanumerics and low resolution (80×69 cell) graphic display.

5 Display Format

Every character cell is composed of 7×10 picture points which are used for the display of both alphanumerics (Fig. 7(a)) and, when divided into a 6-bit field, graphics (Fig. 7(b)). Reference has already been made to the fact that the 6 cells of the graphics character are not

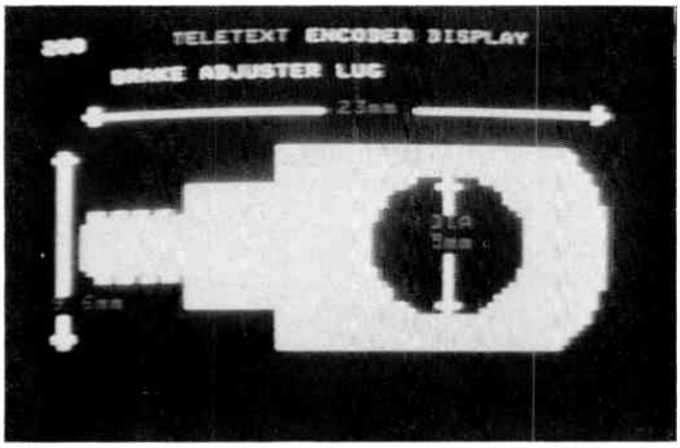


Fig. 8. Teletext profile of brake adjuster lug.

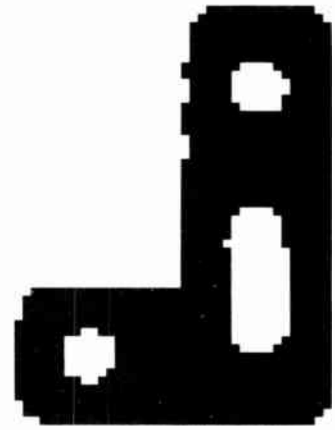


Fig. 10. 'Hard copy' of angle bracket used as a test component which illustrates the available resolution of Teletext.

all of the same size. Examples of profiles displayed through the medium of Teletext are illustrated in Fig. 8. The profile of Fig. 8 can be compared with the original component part illustrated in Fig. 2. There is no doubt that sufficient picture information is retained within the Teletext display to determine component orientation. Indeed, it is possible to use the encoded display to test for gross defects such as omission of a perforation (hole) which is the kind of defect so common during mass-produced component manufacture.

An interesting alternative to visual representation is by an ASCII character array where the graphics characters are interpreted as alphanumeric hexadecimal characters. The profile of Fig. 8 represented in this way is illustrated in Fig. 9. The picture profile remains recognizable in the alphanumeric medium although this is not the main objective. The implication here is that components can be quantified in terms of a character array directly from the drawing board. The array size is quite manageable for human encoding as an alternative to machine encoding.

6 Concluding Remarks

The method of profile capture in use at present is a standard industrial television camera whose output is encoded into the Teletext format but restricted to 32 columns by 21 rows, as this gives a 64×63 picture element display which has proved to very convenient.

20	20	20	20	2C	20	20	20	20	20	7F	7F	7F	7F	7F	7F	7F	7F	7F	7F	7F	7F	BC	20
20	20	20	20	2C	20	70	7D	70	70	7F	7F	7F	7F	7F	7F	7F	7F	7F	7F	7F	7F	B5	20
20	20	20	20	2C	EA	7F	7F	7F	7F	7F	7F	7F	7F	7F	A7	20	23	3F	7F	7F	7F	FD	20
F8	FD	FD	FD	FD	FE	7F	7F	7F	7F	7F	7F	7F	7F	25	20	20	20	A2	7F	7F	7F	7F	20
7F	7F	7F	7F	7F	7F	7F	7F	7F	7F	7F	7F	7F	7F	20	20	20	20	20	6B	7F	7F	7F	20
7F	7F	7F	7F	7F	7F	7F	7F	7F	7F	7F	7F	7F	7F	20	20	20	20	20	EA	7F	7F	7F	20
7F	7F	7F	7F	7F	7F	7F	7F	7F	7F	7F	7F	7F	7F	34	20	20	20	20	FE	7F	7F	7F	20
A2	A7	BF	AB	AB	6B	7F	7F	7F	7F	7F	7F	7F	7F	FD	20	20	20	E0	7F	7F	7F	7F	20
20	20	20	20	20	2A	7F	7F	7F	7F	7F	7F	7F	7F	7F	F4	70	70	FE	7F	7F	7F	37	20
20	20	20	20	20	20	20	20	20	20	7F	7F	7F	7F	7F	7F	7F	7F	7F	7F	7F	7F	35	20
20	20	20	20	2C	20	20	20	20	20	A2	23	23	23	23	23	23	23	23	23	23	23	A1	20

Fig. 9. Hexadecimal numeric array for brake adjuster lug.

The magnitude of the numbers used are always within the range of either 16 or 8-bit binary numbers, and so can be handled easily by the registers or register pairs within the microprocessor. The total amount of data involved is small and the majority of the recognition process is based on the sixteen 8-bit numbers which define the segment histograms. This leads to a very fast recognition process which, although not optimized to date, is expected to take about 100 ms. Recognition of individual components is independent of orientation or position within the field of view. The angular rotation, with respect to the stored mask, can be ascertained almost invariably to better than 10° and nearer 3° in the majority of cases.

Although in its infancy, the results obtained so far justify the hopes originally entertained for low resolution industrial component recognition. For example, the recognition system has been able to discriminate without failure the shape of eight components, these being the alphanumerics A, B, C, 1, 2, 3 from a child's spelling set and two versions of the bracket shown in Fig. 10.

It is the intention of this paper to introduce the idea of expanded use of Teletext encoded displays primarily into industry. The implications are fascinating and the early results at Nottingham show a great deal of promise when associated with our work of visual orientation of component parts. The application of Teletext in this way has been predicted[5] but no publication referring to specific application has been identified. Further details of the progress to date have been reported elsewhere.[6,7]

7 Acknowledgments

This work is now being supported by the Science Research Council, Swindon, England, under Grant No. GR/A80266.

8 References

1 Pugh, A. and Waddon, K., 'The prospects of sensory arrays and microprocessing computers in manufacturing industry', *The Radio and Electronic Engineer*, 47, no. 8/9, pp. 377–84, August/September 1977.

2 Pugh, A., Waddon, K. and Heginbotham, W. B., 'A micro-processor-controlled photo-diode sensor for the detection of gross defects', 3rd International Conference on Automated Inspection and Product Control (Sponsored by International Fluidics Services Ltd., Bedford, England), Nottingham, April 1978, pp. 299–312.

3 Waddon, K., Pugh, A. and Heginbotham, W. B., 'A visually interactive method to determine the transportation speed of component parts', *Electronics Letters*, 13, No. 3, pp. 86–88, 3rd February 1977.

4 'Broadcast Teletext Specification', published by the British Broadcasting Corporation, Independent Broadcasting Authority and the British Radio Equipment Manufacturers' Association, September 1976.

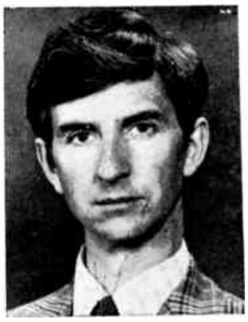
5 Burkitt, A., 'Home data on trial', *Electronic Engineering*, **47**, No. 571, pp. 56–57, September 1975.

6 Loughlin, C. and Pugh, A., 'Recognition and Orientation of Component Profiles through the Medium of Teletext Graphics', 9th International Symposium and Exposition on Industrial Robots, sponsored by the Society of Manufacturing Engineers and the Robot Institute of America, Washington, D.C., March 1979.

7 Loughlin, C. and Pugh, A., 'Recognition and Orientation of Component Profiles within the Low Resolution of Teletext Graphics', Robots '79 Conference, sponsored by the British Robot Association, Nottingham, March 1979.

Manuscript first received by the Institution on 30th May 1978 and in final form on 12th March 1978.
(Paper No. 1877/ACS 79)

The Authors



Professor Alan Pugh (Fellow 1970, Member 1965) graduated from the University College of South Wales, Cardiff, in 1957 and held appointments with the BBC and Rolls-Royce and Associates Ltd. From 1961 to 1978 he was one of the academic staff at the University of Nottingham latterly as Senior Lecturer in Electronic Engineering. Dr Pugh was a visiting Professor at the University of Waterloo, Canada, for the whole of 1972 and his work on advanced robot techniques has gained him an international reputation through papers both published and read at conferences in many parts of the world; he is UK national coordinator for the International Symposia on Industrial Robots. In 1978 he was appointed Head of the Department of Electronic Engineering at the University of Hull. He is a member of the IERE Papers Committee and of the Components and Circuits Group Committee and a year ago was appointed Chairman of the latter.

Clive Loughlin received his B.Sc. in electronic engineering from Nottingham University in 1977, where he is currently investigating methods for the low resolution recognition of component profiles. He has previously worked for two years for the Fulmer Research Institute, Buckinghamshire, where he was involved in the life testing of mercury ion engines and field emission thrusters for the European Space Research Organization.

UDC 621.396.621.54.029.55
Indexing Terms: Radio receivers, Oscillators, variable frequency

Application of the loose-locked oscillator in a professional short-wave receiver

RICHARD C. DEN DULK, B.Sc., M.Sc.*
and
DURK VAN WILLIGEN*

SUMMARY
A description is given of the design and implementation of a loose-locked oscillator (l.l.o.) tuning system with 1 Hz stepsize in a commercial communication receiver. A single tuning knob controls the tuning speed according to a non-linear joystick principle, not generally used in this application.
To estimate the established quality of the l.l.o. a comparison is made with a conventional synthesizer. The digital control facilities of the tuning system provide a conversion to convenient operation combined with good stability, which makes the receiver applicable to both fixed frequency and variable frequency communication links.

* *Department of Electrical Engineering, Delft University of Technology, Mekelweg 4, 2628 C D Delft, The Netherlands.*

The Radio and Electronic Engineer, Vol. 49, No. 5, pp. 241–249, May 1979

1 Introduction

High-frequency communication receivers are being increasingly used because short wave is a relatively cheap medium for all sorts of small bandwidth, long distance communication.

The characteristic construction of a contemporary short wave receiver consists of a low-pass filter at the input; a mixer, which converts the signal to a first i.f. of about 70 MHz; and a local oscillator, which consequently covers a frequency range of 70–100 MHz (see Fig. 1). The first i.f. signal is then down-converted via a crystal filter to a suitable second i.f. for further signal processing.

If we restrict ourselves to the tuning mechanism of a receiver, there are many methods for realizing the first local oscillator. The choice of a local oscillator depends on the user requirements concerning stability, tuning accuracy and controllability.

When users operate on a limited number of fixed frequencies, a decimal synthesizer has many advantages. But, if they often search for a transmission in a restricted frequency range, a non-continuously tunable synthesizer is very clumsy to operate because, especially around frequencies with many zeroes or nines, one has to control several decade knobs. In this kind of communication a synthesizer with a free-running interpolation oscillator is often used.

Such a design always contains a compromise between the requirements of stability and accuracy and the requirements of convenient continuous tuning, because long-term stability of the interpolation oscillator is influenced by temperature, ageing, etc.

A digitally-controllable synthesizer which has a small adjustable step and which is controlled by an up-down counter closely approximates continuous tuning. Then the tuning process corresponds to the supply of count pulses, each giving a small frequency alteration. The total number of count pulses defines the frequency change, while the tuning speed is determined by the pulse rate.

For manual tuning a non-linear characteristic is required, because the tuning speed can be subdivided into two cases.

In the first case one wants to tune rapidly without listening to reach a frequency band which is up to several MHz higher or lower. The operator's attention is directed mainly to the three most significant digits of the display.

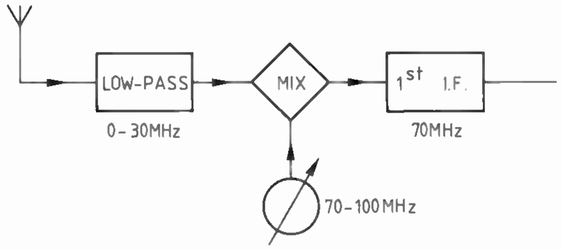


Fig. 1. Design principle of current communication receivers.

0033–7722/79/050241+09 $1.50

In the second case, the normal tuning process concerns actual reception. Now the maximum tuning speed is related to the bandwidth and amounts to 20 kHz/s for a communication receiver. The smallest tuning speed is 2 Hz/s.

The tuning pulses are generated at a rate which is controlled by means of the joystick principle, i.e. the deviation of a stick or knob determines the tuning speed, and the direction of the deviation determines whether the frequency becomes higher or lower. A spring holds the tuning knob in the mid-position. In this position no pulses are supplied and the frequency of the local oscillator will not change. Experiments have proved that operators feel comfortable about this joystick type control with tuning speeds following the 1–2–5 sequence.

Time lag during the tuning process is inadmissible. Therefore, the acquisition time of the synthesizer has to be very short. Generally, this creates additional requirements for the synthesizer. In the case of a synthesizer following the single-loop principle, it is well known that a short acquisition time together with a small frequency increment is impossible. Obtaining such a combination leads, consequently, to complicated multiple loop design which is relatively costly and intricate.

A synthesizer with a loose-locked interpolation oscillator,[1] however, is simple and the loose-locked oscillator appears to be integratable to a high degree.

The purpose of the investigations to be described is to show how this tuning system can combine the convenience of continuous tuning with the accuracy and stability of a synthesizer and can give facilities for both fixed frequency and variable frequency communication links. The utilization of integratable designs and the implementation possibilities in existing receiver constructions are handled as important investigation restrictions.

2 Loose-locked Oscillator Principle

As shown in Fig. 2, schematically the loose-locked oscillator (l.l.o.) consists of a rate multiplier (r.m.), a frequency difference detector, a v.c.o. and a v.c.o. interface. The rate multiplier signal acts as an input parameter of the loop and has to maintain the v.c.o. frequency.

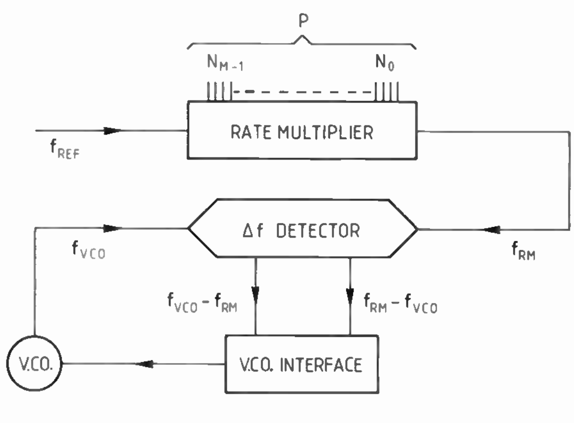


Fig. 2. Basic block diagram of a loose-locked oscillator.

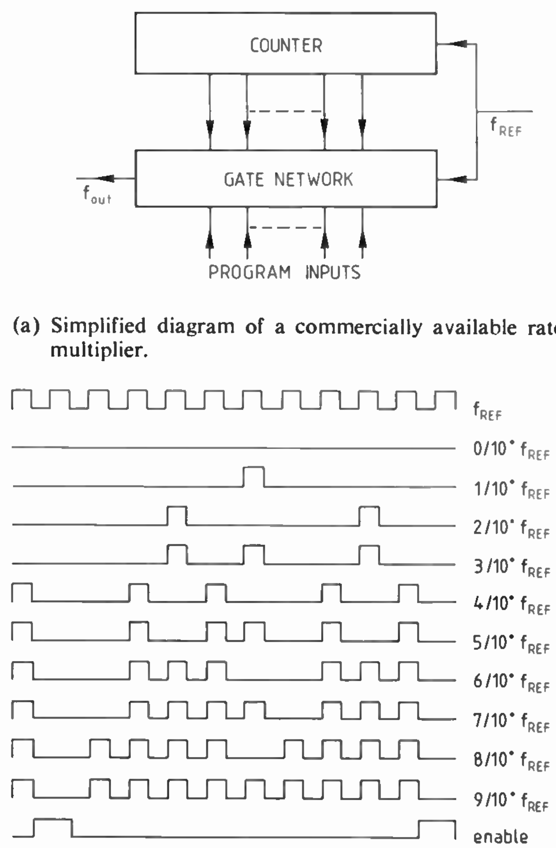
2.1 Rate Multiplier

In a rate multiplier a reference frequency is keyed in such a way that the output frequency, averaged over a relatively long time, is a programmable fraction of the reference frequency. If this fraction is a base 2 number, one talks of a binary rate multiplier (b.r.m.). The output frequency of a decimal rate multiplier (d.r.m.) is related to the number 10.

Principally the commercially available rate multipliers are constructed of a counter and a gate network, which are both fed by the reference frequency (see Fig. 3(a)) Under the influence of the counter's state and the programmed input value, the gate network determines which periods of the reference frequency have to be gated out. The counter of a b.r.m. has a binary count sequence, and a d.r.m. has a counter with a count cycle of ten, i.e. out of each ten reference frequency periods, a programmable number has been gated out. (Fig. 3(b).)

The averaged output frequency of one decade of a decimal rate multiplier can be expressed by

$$\overline{f_{\mathrm{DRM}}} = \frac{N}{10} \times f_{\mathrm{ref}},$$



(a) Simplified diagram of a commercially available rate multiplier.

(b) Waveforms of a one-decade decimal rate multiplier.

Fig. 3

in which $N = D\times 2^3 + C\times 2^2 + B\times 2^1 + A\times 2^0$ for decimal zero to nine inclusive. Therefore, $\overline{f_{\mathrm{DRM}}} = \{0, 0{\cdot}1, 0{\cdot}2, \ldots, 0{\cdot}9\}\times f_{\mathrm{ref}}$ (see Fig. 3(b)).

If rate multipliers are cascaded, it actually means that the counters are cascaded, but the outputs of the gate networks are summed. The averaged output frequency of M cascaded decimal rate multipliers amounts to

$$\overline{f_{\mathrm{DRMs}}} = \frac{P}{10^M}\times f_{\mathrm{ref}},$$

in which

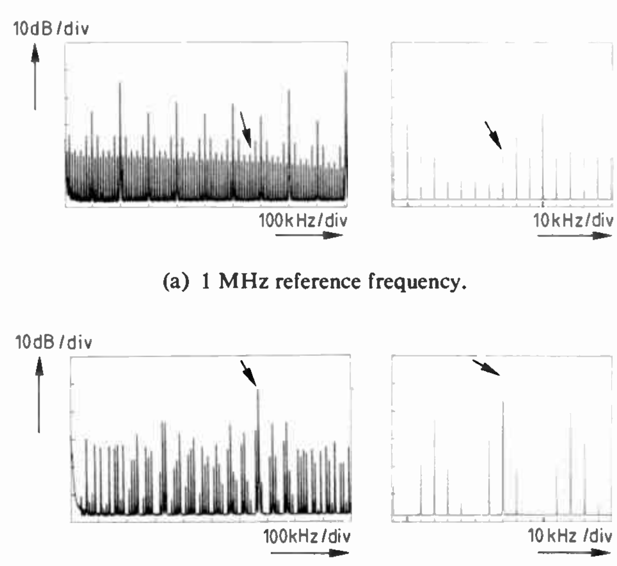
$$P = N_{M-1}\times 10^{M-1} + N_{M-2}\times 10^{M-2} + \ldots + N_0\times 10^0.$$

In other words, the averaged output frequency is a fraction of the reference frequency, with M significant digits.

2.1.1 Irregularity

In the previous text, the averaged output frequency has been referred to, because, inherent in the operation of the rate multiplier, the momentary period time of the output signal is always a whole number of periods of the input signal. The minimum required averaging time T_{av} is equal to $10^M/f_{\mathrm{ref}}$.

The irregularity of the rate multiplier signal within the time interval $T_{\mathrm{av}} = 10^M/f_{\mathrm{ref}}$ demonstrates itself in the frequency domain by the presence of sidebands on distances equal to the smallest adjustable frequency step $\Delta f = f_{\mathrm{ref}}/10^M$. The sideband amplitudes depend on the programmed rate, and as shown in Fig. 4(a) they can have a considerably larger magnitude than the desired frequency.



(a) 1 MHz reference frequency.

(b) 5 MHz reference frequency and the output divided by 5. (Arrows indicate the wanted frequency.)

Fig. 4. Frequency spectra of a 2 decade rate multiplier signal with $\bar{f} = (67/100)f_{\mathrm{REF}}$.

This property of the rate multiplier signal precludes its use as a direct signal source for a local oscillator. The irregularity can be conceived of as phase modulation with a relative low frequency and therefore it is not possible to clean up the rate multiplier signal with a phase locked loop. However, it is possible to use the signal in a frequency locked loop, provided the loop responds exclusively to the average frequency. This makes special demands on the frequency difference detector.

2.2 Δf Detector

The frequency difference detector is not allowed to respond to the momentary value of the frequency, but has to average the frequency. In the case of a desired smallest programmable step of 1 Hz and a reference frequency of 1 MHz, six decades are necessary. Then the averaging time T_{av} is equal to 1 s. Generally, in a closed loop this time results in an inadmissibly large acquisition time.

Another way of approaching the problem is to consider the irregularity to be caused by phase-jitter. Then the detector has to average the peak-peak value of the phase-jitter, which can be realized with a detector that measures the accumulated phase difference between the input signals.

A frequency difference can be interpreted as a net accumulated phase difference over a definite time interval. Two signals with unequal frequencies ω_1 and ω_2 can be conceived of as two signals with an equal frequency ω_1, of which one has a time dependent phase $\phi(t)$.

Suppose the signals are

$$A = \sin(\omega_1 t) \quad \text{and} \quad B = \sin(\omega_2 t + \phi_2)$$

Signal B can be rewritten as

$$B = \sin(\omega_1 t + (\omega_2 - \omega_1)t + \phi_2)$$

in which the term $(\omega_2 - \omega_1)$ is the actual frequency difference $\Delta\omega$. Because of the definition of frequency $\omega = \mathrm{d}\phi/\mathrm{d}t$, the second part of the argument can be conceived of as the time dependent phase

$$\phi(t) = \int_{t_1}^{t_2} \Delta\omega\, \mathrm{d}t + \phi_2.$$

Then signal B can be written as $B = \sin(\omega_1 t + \phi(t))$. With a fixed frequency difference, $\phi(t)$ has a constant slope of $(\omega_2 - \omega_1)$. In case of an irregular signal B this slope is polluted with the phase jitter.

A detector, which only responds to the overflow of predetermined boundaries of $\phi(t)$, has an averaging time which is inversely proportional to the frequency difference. Large differences are quickly detected. But, for very small frequency differences ($\Delta f \ll f_{\mathrm{ref}}/10^M$), the detection time is much longer than T_{av}, and the phase jitter is absorbed by the space between the net accumulated phase boundaries.

A detector, which follows the above-mentioned principle in steps of 360°, can be realized with an up-down counter. This counter acts as a frequency difference detector if the exceeding of an upper of lower boundary generates a signal that resets the detector one step of 360°. These reset signals give the exact frequency difference provided that the sign of the difference remains the same and that both input signals are regular.

If the difference changes its sign, the first reset signal does not represent the actual frequency difference, because the net accumulated phase first has to pass through the dead band before the other boundary is exceeded. The detector then generates a reset signal if there is a consolidated net amount of accumulated phase difference. These reset signals are converted to an incrementing or decrementing signal for the voltage-controlled oscillator by means of a bi-directional switched current source with hold capacitor.

2.3 Loop Properties

By means of the reset signal of the detector, the v.c.o. is controlled discontinuously. In other words, the loop is only closed at certain moments depending on the value of the net accumulated phase difference. With a small v.c.o. frequency drift and a fixed programmed value of the rate multiplier, the loop is closed occasionally. This explains the name 'loose-locked loop'. So the v.c.o. is modulated with a rate equal to the drift. Sidebands are spaced close to the averaged frequency and their magnitude decreases quickly.[1]

Reviewing the characteristics of the l.l.o., we see that it represents an adequate way of meeting the demands of a local oscillator tuning system. The utilization of a rate multiplier gives rise to a very high resolution. The rate multiplier signal responds directly to a digital adjustment, and it has the same long-term stability as the reference frequency. The voltage-controlled oscillator adds its own short-term stability, which is reasonably good, to the loop. Because the phase/frequency detector has a dead phase band, control in the loop takes place occasionally, and the poor short-term stability of the rate multiplier's signal is not present in the output signal of the v.c.o.

The loop is easy to apply to existing systems, which will be explained in the following Section.

3 L.L.O. Application in the Philips RO 150

3.1 Original Construction

The Philips communication receiver type RO 150 is a double superheterodyne with a first intermediate frequency of 71·6 MHz and is suitable for the frequency range 0·2–30 MHz.[2] The coarse tuning of the frequency takes place in 100 kHz steps; searching is made possible by means of an interpolation oscillator over a frequency range of 100 kHz with some over-range.

For the indication of the received frequency use is made of a built-in frequency counter for the interpolation range. The three most significant digits are directly controlled by the decade switches of the coarse synthesizer.

The interpolation oscillator, which is taken into a sum loop of the coarse synthesizer, is controlled by a ten-turn potentiometer. The adjusted frequency can be stabilized by a so-called count/lock system: after each count cycle of the frequency counter, the content of the three least significant digits is compared with the previous contents, which has been stored in a digital memory. If deviations occur, they are corrected by a separate control input of the v.c.o.

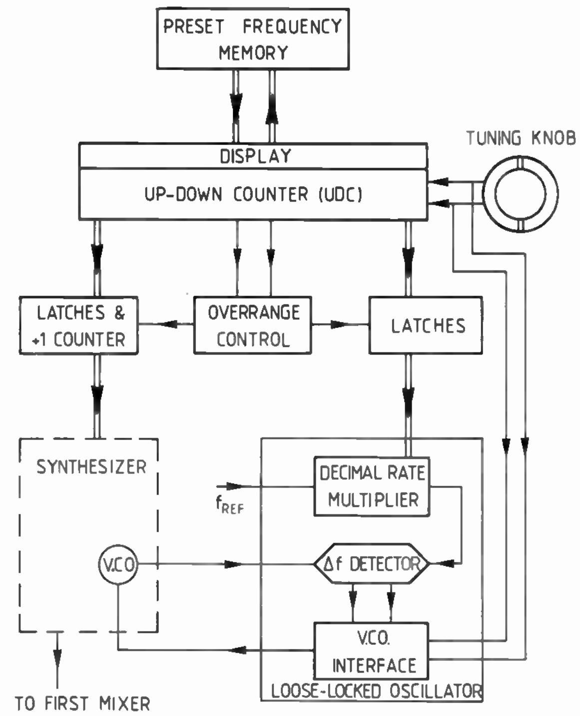


Fig. 5. Schematic diagram of the tuning system.

3.2 Continuous Tuning over the Entire Range

The loose-locked oscillator is implemented simply by including the existing v.c.o. The 100 kHz coarse synthesizer is maintained and is controlled together with the l.l.o. by means of an up-down counter. Continuous tuning with only one knob can be realized by supplying count pulses to the up-down counter. A numerical display is connected directly to this counter. At the same time a preset frequency memory can be joined to the controlling up-down counter. The total tuning system is shown in Fig. 5.

3.3 Block Diagram

The part of the diagram in Fig. 5 enclosed by dotted lines is already present in the receiver. The v.c.o. covers a frequency range of 480–600 kHz. By means of the rate multiplier, average frequencies are generated from 579999 Hz up to 599999 Hz, which are compared with the frequency of the v.c.o. The rate multiplier is programmed by the five least significant digits of the up-down counter. The remaining three digits control the coarse synthesizer in 100 kHz steps.

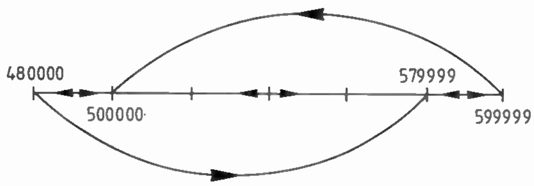


Fig. 6. Over-range break points of the interpolation oscillator with hysteresis.

When the contents of the up-down counter reach the upper limit of the interpolation range, the coarse synthesizer has to be switched 100 kHz higher and the l.l.o. has to be set 100 kHz lower; the reverse is also true. To avoid repeated switching during searching for a frequency near either limit of the interpolation range, the l.l.o. has an over-range with hysteresis. In Fig. 6 the switching points are shown schematically. A bow represents a 100 kHz step of the l.l.o. and an opposite 100 kHz step of the coarse synthesizer. The control of the most significant digit of the rate multiplier has been combined with the 100 kHz digit of the coarse synthesizer in the block named 'over-range control'.

3.4 Realization of the L.L.O.

3.4.1 *Rate multiplier*

The rate multiplier is constructed with six SN 74167's, which are clocked with a reference frequency of 5 MHz. The output frequency is divided by 5. This results in a smaller irregularity than is obtained by using a reference frequency of 1 MHz without division. The resolution is the same with both methods and amounts to 1 Hz.

As shown in Fig. 4(b), the sidebands are indeed still found on distances equal to the smallest programmable step, but the magnitude of the desired frequency component has been increased considerably, compared to the values of Fig. 4(a) in which the signal is not divided.

3.4.2 *Accumulated phase/frequency difference detector*

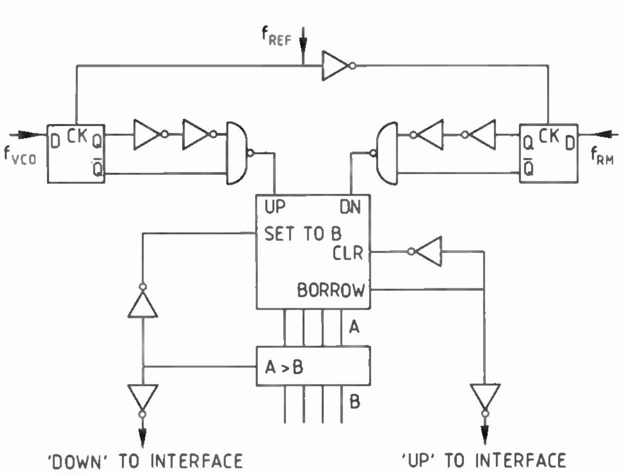


Fig. 7. Accumulated phase/frequency difference detector.

As explained in Section 2.2, the detector measures a consolidated net phase difference which represents a frequency difference. The detector is realized with a reversible counter, which is fed with pulses on the up and down input, as shown in Fig. 7. The v.c.o. signal is supplied to the up input and the signal of the rate multiplier is connected to the down input of the counter via an anti-coincidence circuit.

So the state of the reversible counter represents the net accumulated phase difference in steps of 360°. If the contents exceed an upper boundary, which is determined by the number B, the counter is set back by the comparator signal. This states that the frequency of the v.c.o. is too high, because the net accumulated phase is positive. Or in other words, within a certain time interval, the number of up-pulses should have been larger than the number of down-pulses. The reverse is the case, if the contents of the up-down counter pass the lower limit (zero).

Because a pulse is generated only if the upper or lower limit is exceeded, the intermediate states of the counter belong to the dead phase band and are used to average the phase jitter or to absorb the irregularity.

In Ref. 1 the irregularity of a waveform is defined as the excess states of a detector to absorb the phase jitter. In contrast to Ref. 3 our measurements have shown that one decade of commercially available rate multiplier needs a detector with four states. Therefore, the maximum irregularity of the signals in Fig. 3(b) is equal to 2, because two regular waveforms need two states. Also, our measurements have shown that the output signal of six cascaded decimal rate multipliers needs two basic and eight excess states. By the division by 5 the excess states can be reduced to two. In this case the total number of detector states amounts to four.

3.4.3 *V.c.o. interface*

The detector's output pulse repetition time is approximately inversely proportional to the frequency difference. If each output pulse corrects the frequency of the v.c.o. by a value which is smaller than or equal to the least significant step of the rate multiplier's frequency, overshoot in the loop will never occur.

To convert the detector's frequency difference pulses to an incrementing or decrementing control voltage for the v.c.o., a capacitor is charged or discharged by means of in time and magnitude defined current pulses, following $\Delta V = \Delta I . \Delta t / C$. This single correction is allowed because the detector detects any phase and/or frequency difference.

As already mentioned, the dead band does not mean that the detector is insensible to a certain frequency difference. Depending on the beginning condition of the counter and the sign of the frequency difference, detection takes place after a time period in which minimally 360° and maximally 3 × 360° of the phase difference is accumulated. A frequency difference of 0·1 Hz can be thought of as a phase speed of 36°/s, which is detected after minimally 10 s and maximally 30 s.

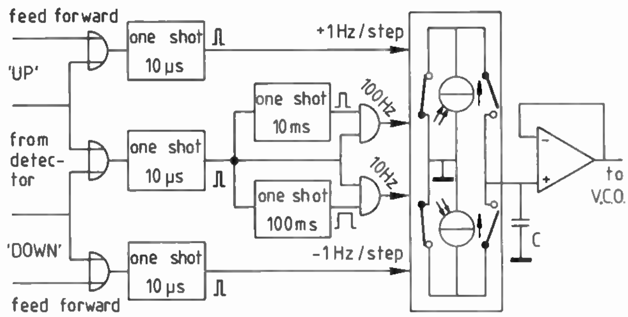


Fig. 8. Interface for detector pulses to v.c.o. control voltage conversions equivalent to 100, 10 and 1 Hz/pulse.

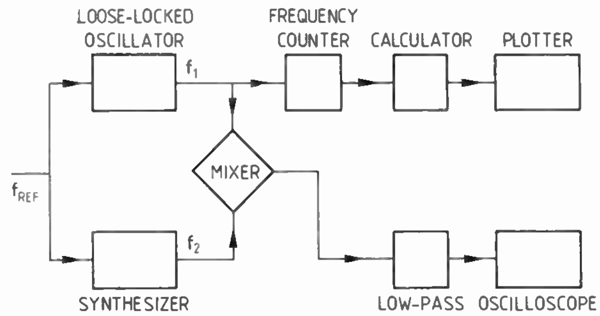


Fig. 9. Measurement set-up for obtaining photographs and histograms of stability.

If the detector stays at one phase boundary, a frequency difference of f Hz will be detected after $1/f$ seconds. Correcting the v.c.o. with 1 Hz, the remaining difference amounts to $f-1$ Hz. This is detected after $1/(f-1)$ s. So the total time needed to correct a difference of f Hz with 1 Hz/step to within 1 Hz of the desired frequency amounts to[1]

$$\frac{1}{f}+\frac{1}{f-1}+\frac{1}{f-2}+\ldots+\tfrac{1}{3}+\tfrac{1}{2}\approx \ln(f)+1/(2f)-0{\cdot}4.$$

In the case of an initial error of 100 Hz, this value amounts to 4·2 s, and a difference of 100 kHz delivers 11 s. The corrections, however, do not need to be restricted to 1 Hz per pulse, because if the momentary error value is not exceeded, corrections can be made with larger gain in the loop.

In the design, a choice has been made to correct with 10 Hz steps, if the difference is between 10 and 100 Hz and with 100 Hz steps, if the frequency difference is greater than 100 Hz. As shown in Fig. 8 this is realized by comparing the repetition time of the output pulses of the detector and the time generated by 2 retriggerable monostable multivibrators.

The step response is much shorter now. The loop is always within 10 Hz of the programmed frequency in less than 300 ms. This time is of the same order of magnitude as the acquisition time of the coarse synthesizer, and so fast enough for this application.

However, during continuous tuning there still remains a time lag in the feedback system. Because of the quantized nature of the correction signal the time lag can be easily removed by applying feed forward control. The tuning pulses (1 Hz/step) are supplied to both the controlling up-down counter and the v.c.o. interface. This results in a negligible time lag, and the loop corrects only the accumulated errors.

3.4.4 *Frequency stability and purity*

Due to correction pulses the magnitude and rate of the v.c.o. frequency steps determine the total amount of undesired sidebands. A constant linear v.c.o. frequency drift of 2 Hz/s causes a semi-periodic correction signal which will generate no visible or audible sidebands.[1]

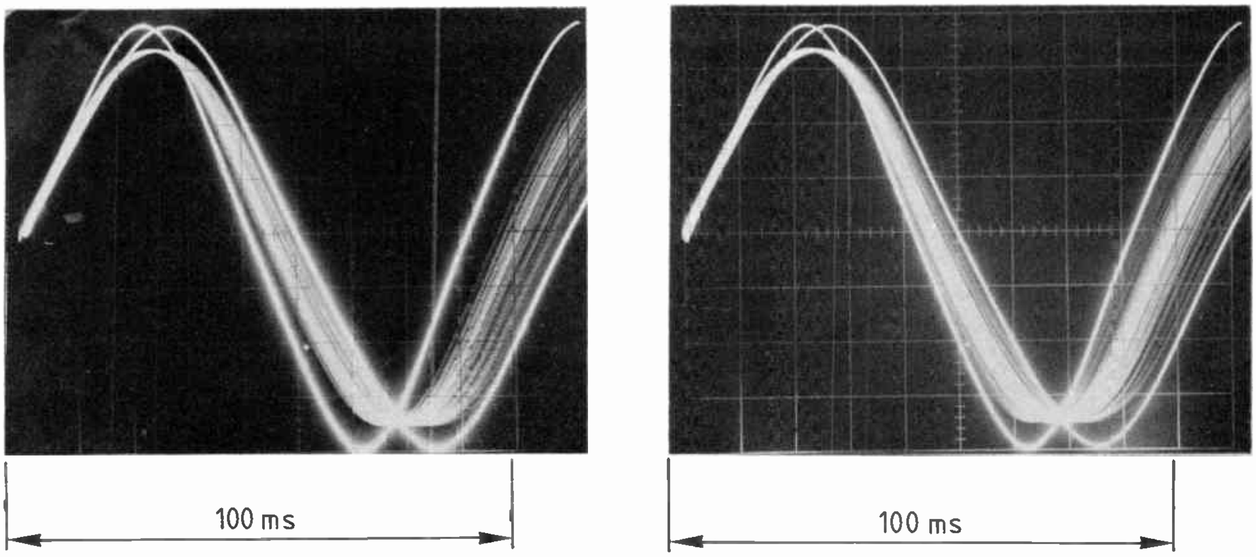
To estimate the quality of local oscillators generally the following aspects have been specified:

(1) Frequency stability
(2) Short-term stability/phase jitter
(3) In-band noise and spurious signals
(4) Out-of-band noise and spurious signals.

To get insight into the established frequency stability of the loose-locked oscillator, two methods are applied with regard to the warm-up period and the stationary state. Figure 9 shows the simple and generally applicable measurement set-up for recording photographically the output frequency density of a frequency source. The l.l.o. and the reference synthesizer are adjusted in such a manner that the frequency difference amounts to 10 Hz. The mixer's output signal is via a low-pass filter connected to an oscilloscope. After calibration of the time-base, the oscilloscope is triggered on the zero crossings of the difference signal, and one period of this signal is displayed on the screen. Then the choice of the down-converted frequency determines the averaging time and the measurement resolution.

If the camera shutter is opened for a certain time, one can get a photograph like the ones in Fig. 10. The grey band shows that during the measurement period no frequencies occur, which deviate more than 1 Hz from the desired value. The whitening in the band shows also that the frequencies are reasonably distributed round the programmed value.

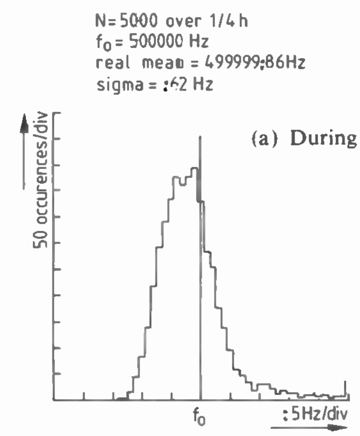
This fact is affirmed by the result of a second, more exact measurement. This consists of making a histogram of the measurement results of a frequency counter by a computer. Figure 11 shows the results of 5000 frequency measurements during a period of 15 minutes. The duration of each measurement is 100 ms, so these results are comparable with the photographs. The histograms show, like the photographs that during the warm-up period the mean value is lower than the desired value. This is caused by the drift of the v.c.o. and the opposite correction of the loop.



(a) During a 2-minute warm-up period.

(b) After a 1-hour warm-up period, 350 single-shot traces over a 2-minute period.

Fig. 10. Converted l.l.o. output frequency density between 9 and 11 Hz.



(a) During a 15-minute warm-up period.

(b) After a 1-hour warm-up period.

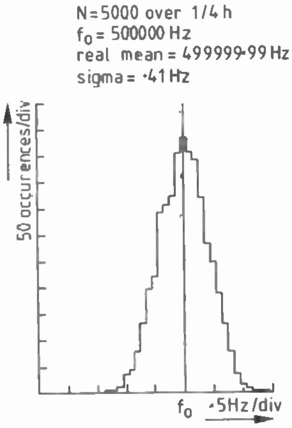


Fig. 11. Real frequency density histograms over a 15-minute period. 5000 frequency samples, each averaged over 100 ms, are divided into 50 classes of 0·1 Hz width.

To determine the short-term instabilities mentioned under (2), (3) and (4) the fact has to be taken into consideration that the correction pulses cause frequency jumps, the repetition rate of which depends on both the short-term stability of the v.c.o. and the time dependence of the irregularity of the rate multiplier signal. A spectral plot assumes a frequency spectrum that is continuously available during the measurement time.

However, a comparison is made of the noise and spurious spectra of the l.l.o. and a conventional laboratory synthesizer (Schlumberger type FS 30). Figures 12(a) and (b) show that, except for the hum components due to the prototype character of the l.l.o., there are slight differences. Details are given in Figs. 12(c) and (d). In Fig. 12(c) there are no sideband components visible which are caused by the correction signal.

As already mentioned a frequency spectrum gives partial information. This is supplemented by Fig. 13 in which the measured probability density of the time intervals between the correction pulses is shown. It is clear that because the density is centred on 2–3 seconds, the undesired sideband components are situated on about $\frac{1}{2}$–$\frac{1}{3}$ Hz distances; consequently these are not visible in the spectra of the loose-locked oscillator. It should be mentioned that the probability density and consequently the sideband distance is dependent on the v.c.o. quality. For a very stable v.c.o. the density shifts to the right, and an unstable v.c.o. gives a density centred on high repetition rates.

A further comparison of the l.l.o. and a conventional synthesizer with respect to the frequency stability is illustrated in Fig. 14. Here frequency histograms of the two frequency sources are made with different horizontal

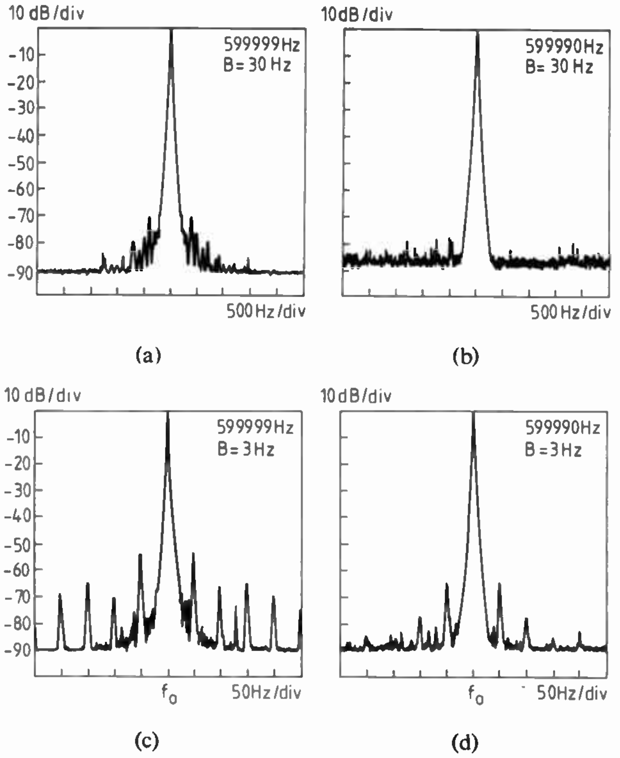
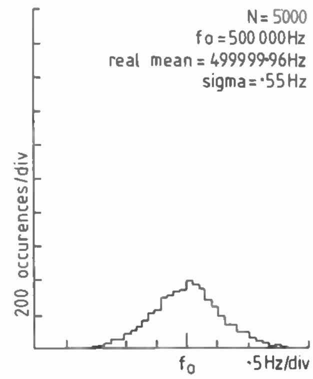
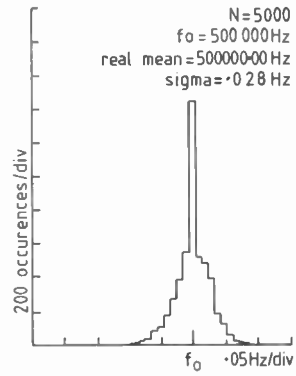


Fig. 12. Frequency spectra (a) and (c) loose-locked oscillator. (b) and (d) synthesizer Schlumberger type FS30.



(a) 50 classes of 0·1 Hz width for the l.l.o.



(b) 50 classes of 0·01 Hz width for the synthesizer.

Fig. 14. Frequency density histograms of the l.l.o. and a conventional synthesizer.

resolutions. From these histograms an important conclusion can be made with respect to the applicability of the l.l.o. The frequency density histogram of a conventional laboratory synthesizer shows a pronounced peak. The synthesizer generates the exact desired frequency more often than does the l.l.o. However, the standard deviation (σ) of the frequency density of the l.l.o. is only a factor of twenty higher. Each of these properties can play its role for a specific application. As shown before the l.l.o. is attractive for receiver purposes.

4 Digital Control Facilities

Digital control of the loose-locked oscillator increases the operating capabilities of the receiver.

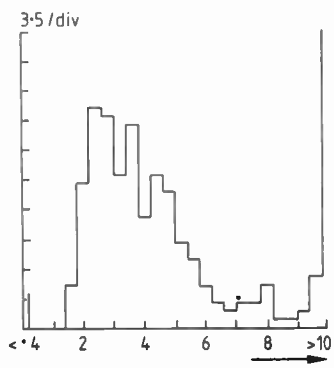


Fig. 13. Histogram of 250 measurements of the repetition time of the correction pulses in the l.l.o.

In the description of the tuning process the control of the local oscillator is carried out by means of an eight digit up-down counter. This digital control is characteristic for the loose locked oscillator, and makes continuous (manual) and channelized tuning easily possible. The various operating facilities, however, require some memory and control. It is beyond the scope of this paper to describe the ergonomic aspects of the various operating facilities, but the convenience of working without pencil and paper is found to be of vital importance. Figure 15 shows the modified receiver in which the continuous and channelized tuning facilities are realized in hardware. Easy manipulation is possible for all memory positions without interrupting reception.

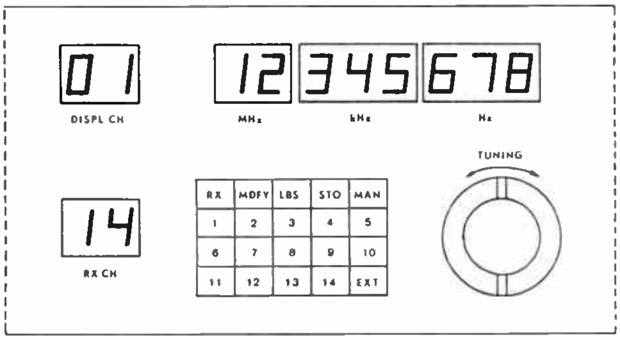
Digital control of the loose locked oscillator makes microprocessor application attractive when the software controls the operating facilities which can be expanded extensively.

5 Conclusion

The loose-locked oscillator offers the combination of the long-term frequency stability of a reference frequency and the generally good short-term stability of a voltage controlled oscillator. Further it is possible to obtain a very high resolution.

The utilization of a loose-locked oscillator in a local

(a) A front view of the receiver



(b) Part of the front panel showing keyboard, tuning knob and displays

Fig. 15. The modified communication receiver.

oscillator of a communication receiver makes the operation easy because of the instantaneous digital control with feed-forward, by which negligible lag is obtained. As shown, the l.l.o. can be implemented simply in existing receivers.

Combined with a memory for preset frequencies, the system offers a quasi-continuous tuning with stability almost equal to that of a synthesizer which makes it attractive for application in general-purpose h.f. communication receivers.

The key to the realized tuning system, the loose-locked oscillator, has some restrictions in its applicability to higher frequencies. Further investigation of the realization methods and system design parameters are necessary to extend the versatility of applications. The realization of suitable rate multipliers in particular can result in better performances.

6 Acknowledgments

The authors are indebted to Mr J. W. van Otterloo and Mr W. Verveer for their valuable experimental assistance. The fruitful discussions and the encouragement of Mr J. Noordanus and others from Philips Telecommunicatie Industrie, Huizen, are also gratefully acknowledged.

7 References

1 Regenbogen, L. K., 'A loose-locked oscillator', *The Radio and Electronic Engineer*, **48**, no. 3, pp. 127–32, March 1978.

2 Aarts, J. P. A., 'The professional communications receiver RO 150', *Philips Telecom. Rev.*, **30**, no. 4, pp. 147–55, November 1972.

3 Stringer, D. V., 'A modern loose locked digital frequency synthesizer', *Marconi Review*, 37, no. 195, pp. 181–208, 1974.

Manuscript first received by the Institution on 11th July 1977, in revised form on 26th September 1978 and in final form on 15th January 1979
(*Paper No. 1878/Comm 181*)

UDC 621.374: 681.325.57
Indexing Terms: Computers, multiplying

A fast multiplier module

FRANZ DEMMELMEIER,
Ing.(grad), Dipl.Ing.*

SUMMARY

An iterative pipeline carry save array multiplier module (PCAMM) is proposed which has a constant throughput rate for every number of data bits.
Data in 2's complement form are processed directly according to the Robertson algorithm. The PCAMM was realized in ECL-technology for 6-bit data with a throughput rate of 35×10^6 multiplications per second.
Multipliers of this kind are the heart of the 12-bit arithmetic unit of a fast signal processor which has been developed at Technical University of Munich.

* *Technical University of Munich, Lehrstuhl für Prozessrechner, Franz Josef Strasse 38, 8000 München 40.*

1 Introduction

In digital signal processing the significance of real time increases as do the requirements of the arithmetic capability of a signal processor. Data, in the form of data arrays, have to be processed according to algorithms such as FFT, inverse FFT, digital filtering, correlation and so on. The graphs of these algorithms have structures without any data dependent branches and the sequence of arithmetic operations to be executed is the same for every data set.[1] An efficient control processor together with appropriate memory structures produces a continuous data stream for the arithmetic unit.

The capability of a signal processor is determined by the number of arithmetic operations executed in a time interval, the throughput rate, and not by the execution time of a single instruction like multiplication for instance.

All relevant algorithms mentioned above have the feature of forming sum-of-products,[1] so that the efficiency of the arithmetic unit is therefore determined by the throughput rate of the multiplier used. Possible ways to increase the efficiency are parallelism of the arithmetic unit, pipelining and application of the carry-save principle as structural improvements and using fast logic families (Schottky-TTL, ECL) as technological improvements.

In case of parallelism the structure of the arithmetic unit is fixed by the relevant algorithms. A possible structure essentially consisting of four multipliers and several adders has been described.[2]

1.1 Pipelining

Pipelining means dividing a complex operation into independent suboperations. The suboperations are executed in substages separated by registers (pipeline registers). In every substage is a different data set. To increase the throughput rate by pipelining it is necessary to execute the suboperation in less time than necessary for the total operation.[3,4,5]

1.2 Carry-Save Principle

The partial product addition in multiplication can be speeded up by use of carry-save adders (CSA) having a diagonally rippling carry.[6,7,8] Figure 1 shows the addition of four terms A, B, C, D by CSAs. A CSA cell has three inputs and two outputs (full adder). In the first level of addition the terms A, B and C are put to the inputs. The results are sum vector S′ and carry vector C′. These two vectors together with the third term D are processed in the second adder stage. The resulting vectors S″ and C″ have to be added by an adder with horizontally rippling carry (carry propagate adder CPA, carry look ahead adder CLA) to produce the final result E.

1.3 Iterative Array Multiplier Module

To realize multipliers for binary numbers iterative arrays are excellently suited.[9] Such an iterative array multiplier can, for example, process numbers in 2's complement form.[10] Jayashri and Basu have described

0033–7722/79/050250+05 $1.50

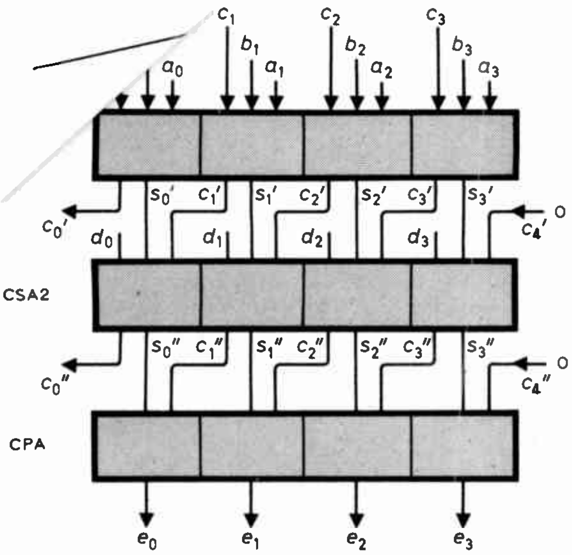


Fig. 1. Addition of A, B, C and D with two carry save adders (CSA 1, CSA 2) and one carry propagate adder (CPA).

two arrays for multiplication of signed binary numbers.[11]

To meet the different requirements of the number of data bits an array multiplier has to be realized as a module for a certain number of data bits. Placing these modules in rows and columns results in a multiplier for an increased data word. The modules can be connected in pipeline mode.

In the following a modular pipeline multiplier is described whose throughput rate is independent of the number of data bits. This multiplier is heart of the arithmetic unit of an extremely fast signal processor developed at the Technical University of Munich.[2]

2 Iterative Pipeline Carry Save Array Multiplier Module

The iterative pipeline carry save array multiplier module (PCAMM) consists of the iterative carry save array multiplier module (CAMM) and the pipeline register (Fig. 3). The CAMM is composed of switched adder/subtractor cells,[12–15] Fig. 2(a) showing one of these cells. The iterative connection scheme produces the carry save structure of the module. The carry output C_{out} is connected to the carry input C_{in} of the corresponding cell of the row below (Fig. 3). A carry propagates diagonally across the array.

The lower significant part of the product $s_6 \ldots s_{10}$ proceeds as one operand at the sum outputs of the right edge cells, and the higher significant part proceeds as the sum vector $s_0 \ldots s_5$ and carry vector $c_1 \ldots c_5$ at the lower edge of the array (Fig. 3).

To receive a result in the same number representation as the input operands the sum and carry vector must be added still in a CPA.

2.1 Number Representation

Multiplicand X and multiplier Y are represented in 2's complement form:

$$X = x_0 + \sum_{i=1}^{n-1} x_i 2^{-i} \quad x_i = 0 \text{ or } 1. \tag{1}$$

$$Y = y_0 + \sum_{i=1}^{n-1} y_i 2^{-i} \quad y_i = 0 \text{ or } 1. \tag{2}$$

A carry coming from the most significant bit position of an array row (representing an adder or subtractor respectively for the partial product and the multiplicand) has no significance in further computation. Therefore carry inputs C_{in} of the array's left edge cells are not connected.

2.2 Robertson Algorithm

The multiplication follows Robertson's algorithm (Robertson's first method):[10,11,16]

$$\left.\begin{aligned} &P_i = \tfrac{1}{2}(P_{i-1} + X : y_{n-i}) \\ &P_0 = 0,\ i = 1 \ \ldots \ (n-1) \\ &P_n = X \,.\, Y = P_{n-1} - X : y_0 \\ &P_i = i\text{th partial product, } X,\ Y \\ &\qquad \text{defined by (1), (2)} \end{aligned}\right\} \tag{3}$$

It has been shown elsewhere[10] that in an array like that in Fig. 3 using Robertson's algorithm the sign generation of the partial product needs correction signals. Very simple correction cells generate the partial product signs in the CAMM (Fig. 3, inset): when a negative sign caused by the sign extension at the A-input of a left edge cell should have no influence, another addition (caused by the correction cell) at the unused carry input C_{in} produces a zero at the sum output. The resulting carry output signal is not used.[10] Another correction is necessary when a subtraction takes place in the last row (eqn. (3)). The cells produce the 1's complement of the multiplicand (via the B input, Fig. 2(a)). Completion of the 2's complement already occurs in the first row via the unused inputs of cell 01 (Fig. 3(a)). Because of the used number representation, a correction via cell 00 is not possible.

Correction of the partial product sign is unnecessary, when the least significant bit of multiplier $Y(y_5)$ always is a 1. A realization in which this fact has been taken into consideration is investigated by Mengele.[17]

2.3 Modularity

The structure of an iterative array is very well suited for l.s.i.; for practical application however it is also necessary to have l.s.i. modules to realize multipliers for variable number of data bits. The CAMMs can be arranged two-dimensionally to produce a multiplier for a new word format. The new multiplier can be considered as a

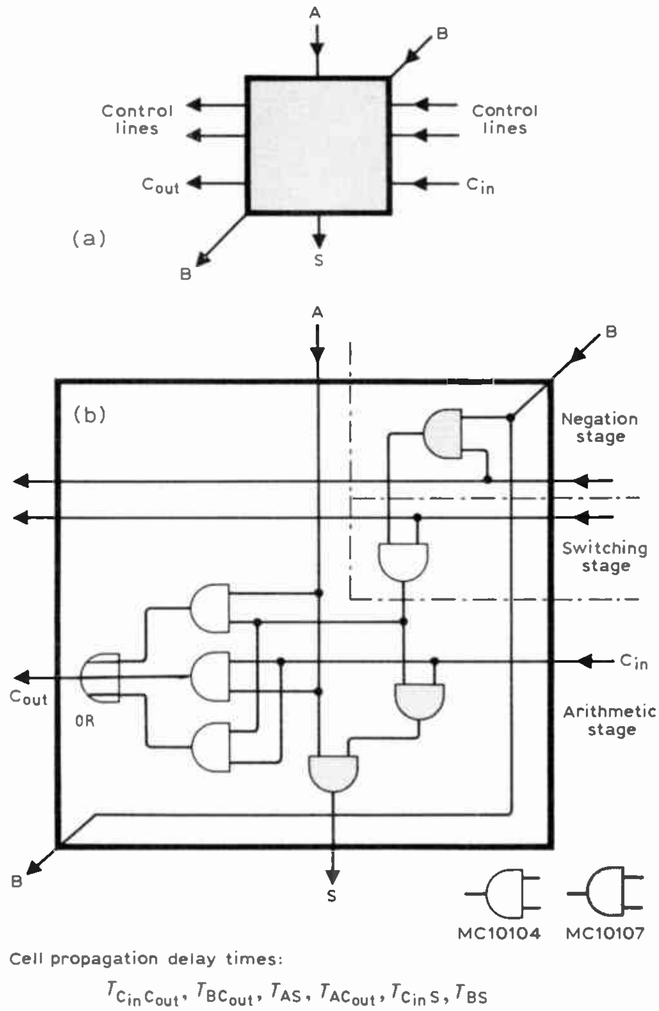


Fig. 2. The cell.
(a) Block diagram.
(b) Detailed circuit and delay times.

'macro array' with CAMMs or PCAMMs. An example of such a macro array is given in Fig. 5.

2.4 Completion to a Full Multiplier

To complete a CAMM or a PCAMM to make a full multiplier the sum and carry vector of the higher significant-product have to be added in a CPA. Using PCAMMs the multiplier works in pipeline mode. The multiplication is divided in two parts, the carry save multiplication and the carry propagate addition. Figure 4(a) shows the arrangement for a two-level pipeline multiplication. The registers for the multiplicand X and the multiplier Y provide the PCAMM with the input data. The results of the first stage $s_0 \ldots s_{10}$ and $c_1 \ldots c_5$ are clocked into the pipeline registers. $s_0 \ldots s_5$ and $c_1 \ldots c_5$ are added in the second stage, while $s_6 \ldots s_{10}$ passes the second stage without any processing. The product $X \cdot Y$ is clocked into the pipeline register (result register) of the second stage.

The CPA is a one-dimensional iterative array with the same cells as the multiplier array. The carry output C_{out} of the one cell is connected to the carry input C_{in} of the left neighbouring cell (Fig. 4(b)).

2.5 Multiplication Time

The processing time of the first pipeline stage is determined by the worst case path of the PCAMM, marked in Fig. 3.[17] In cell 00 the input signal x_0 has to propagate across the negation- and switching stage (initialization time) and the arithmetic stage (Fig. 2(b)). In the following cells only the arithmetic stages delay the signal.

The total processing time computes according to the formulas (4) and (5) when the cells are realized as in

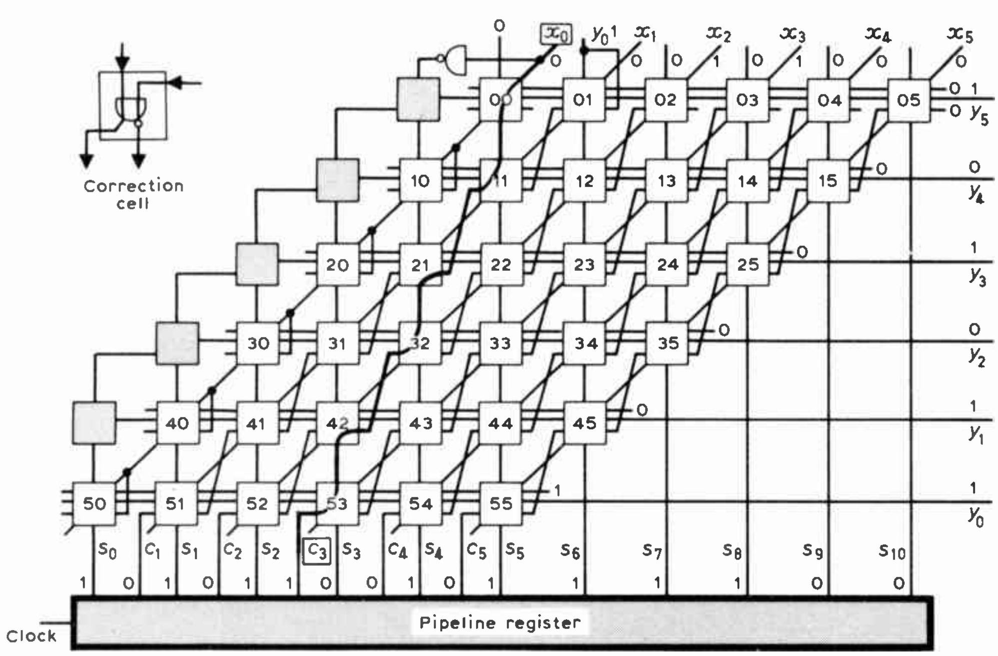
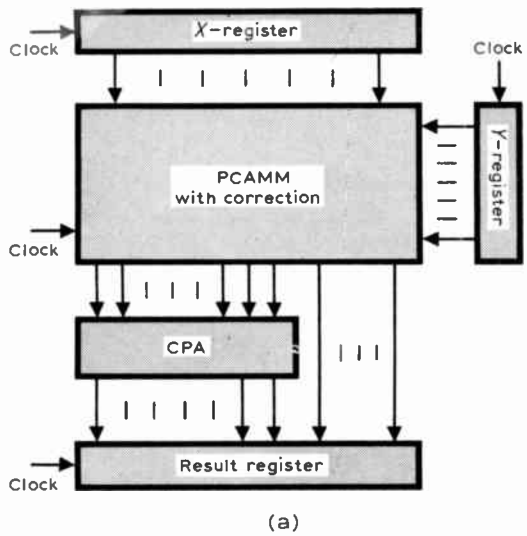


Fig. 3. Pipeline carry save array multiplier module (PCAMM) with correction cells (shaded).



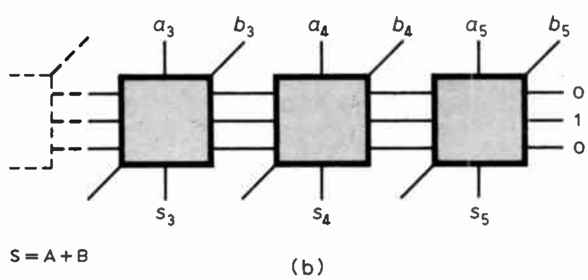


Fig. 4
(a) Two-level pipeline multiplier with one PCAMM and one CPA.
(b) Connection scheme of the CPA using the multiplier cell.

Fig. 2(a). The carry save multiplication time is given by:

$$T_{\mathrm{Mul}} = T_{\mathrm{BS}} + \frac{n}{2} \cdot T_{\mathrm{AC_{out}}} + \left(\frac{n}{2} - 1\right) \cdot T_{\mathrm{C_{in}S}} \quad \text{when } n \text{ is even}$$

$$= T_{\mathrm{BS}} + \frac{n-1}{2} \cdot T_{\mathrm{AC_{out}}} + \frac{n-1}{2} \cdot T_{\mathrm{C_{in}S}} \quad \text{when } n \text{ is odd} \tag{4}$$

The carry propagate adder time follows from (5):

$$T_{\mathrm{add}} = T_{\mathrm{BC_{out}}} + (n-2) . T_{\mathrm{C_{in}C_{out}}} + T_{\mathrm{C_{in}S}} \tag{5}$$

where

$T_{\mathrm{C_{in}C_{out}}}$, $T_{\mathrm{BC_{out}}}$, T_{BS}, $T_{\mathrm{AC_{out}}}$, $T_{\mathrm{C_{in}S}}$

are the cell propagation delay times (Fig. 2(a))
n = number of data bits

T_{reg}, the register delay time, increases the processing times T_{Mul} and T_{add}. The throughput rate is fixed by the slowest pipeline stage.

Compared with the arrays of Jayashri and Basu[11] there are three improvements:

(1) The quadratic array module can process upon Robertson's first algorithm as pointed out elsewhere.[10]
(2) If in pipeline mode, the array multiplication time does not depend on the number of data bits, because the carry save principle is used.
(3) Because of its quadratic form the modules can be connected to get multipliers for a variable number of data bits.

3 Realization

A 6-bit PCAMM was chosen ($n=6$) for realization. To increase the number of data bits to integer multiples k of n the number of pipeline stages, increases too. The throughput rate remains constant, while the multiplier delay time T_{MD} computes as follows:

cycle time (defined by the slowest pipeline stage) multiplied by the number of pipeline stages.

The PCAMMs and the CPAs are organized in k pipeline stages each. In Fig. 5 the pipeline structure of a 12-bit multiplier is shown consisting of four PCAMMs and two CAPs arranged in four pipeline stages.

PCAMM and CPA are realized in ECL-technology. Since the cells are not available in higher integrated

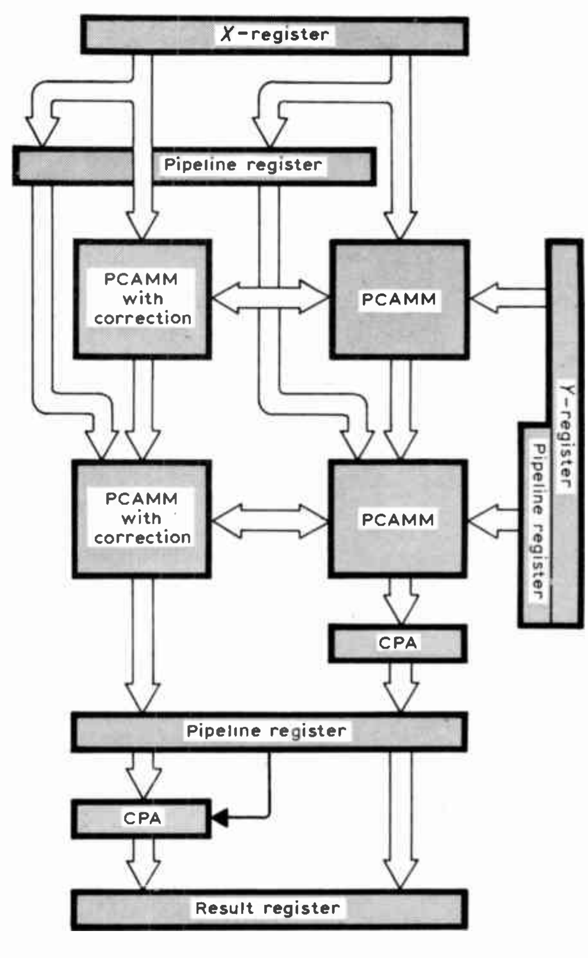


Fig. 5. Pipeline multiplier for 12-bit data using 6-bit PCAMMs and 6-bit CPAs.

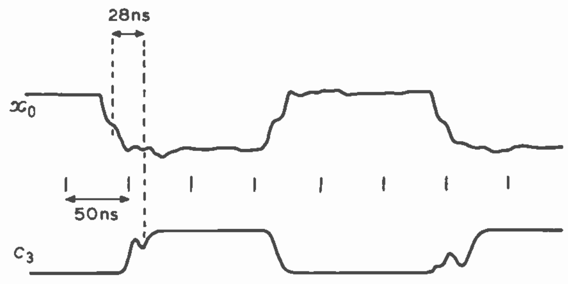


Fig. 6. Propagation delay time of the CAMM (input x_0 and output s_3 marked in Fig. 3).

circuits one had to use s.s.i. circuits. The cell which is the elementary circuit for the PCAMM as well as for the CPA was designed from the Motorola ECL series 10000. The circuit for one cell consists of two chips, MECL 10104 and MECL 10107 (Fig. 2(b)).

4 Test

The test procedure used takes advantage of the good testability of iterative structures. With aid of a 8080 microcomputer the modules are tested with a complete set of data. This test could be applied to higher integrated PCAMMs (e.g. one PCAMM in one chip) in order to detect bad cells and to cause a repair procedure when the chips are produced with redundancy.

5 Experimental Results

The worst case pattern (for the 6-bit module) has been studied by simulation of the CAMM (with a digital computer);[17] it is given by:

$$X = 0.01100$$

$$Y = 1.10101.$$

The measurements on a two-level multiplier were done with a sampling oscilloscope and a X–Y-recorder (Fig. 4). Figure 6 shows the critical signals x_0 and c_3 marked in Fig. 3. The multiplier's delay time T_{Mul} is 28 ns which gives a throughput rate of 35×10^6 multiplications per second. The delay time of the adder stage is less than 28 ns.

In practical applications propagation delay times on cables and capacitive loads reduce the maximal possible clock frequency of 35 MHz. In the signal processor mentioned,[2] the pipeline frequency is 20 MHz for 12-bit multipliers.

6 Conclusion

A fast iterative carry save multiplier has been proposed and a possible realization described. Taking advantage of the carry save principle and pipeline mode, the throughput rate is independent of the number of data bits. A two-level 6-bit multiplier has been realized which processes data in 2's complement form with a throughput rate of 35×10^6 multiplications per second.

7 Acknowledgment

The author wishes to thank Prof. Dr. G. Färber and Dr. R. Weiss for the many valuable and stimulating discussions and E. de Lorenzo for his aid during the realization phase.

8 References

1. Allen, J., 'Computer architecture for signal processing', *Proceedings IEEE*, **63**, No. 4, pp. 624–33, April 1975.
2. Demmelmeier, F., Kolmegies, B. and Weiss, R., 'A modular microprogrammable pipeline signal processor in ECL-technology', Third Symposium on Microarchitecture, Euromicro 1977, pp. 74–81.
3. Deverell, J., 'Pipeline iterative arithmetic arrays', *IEEE Trans. on Computers*, **C-24**, No. 3, pp. 317–22, March 1975.
4. Hallin, R. G. and Flynn, M. J., 'Pipelining of arithmetic functions', *IEEE Trans. on Computers*, **C-21**, No. 8, pp. 880–6, August 1972.
5. Pfeuffer, R., 'Entwurf und Realisierung eines schnellen, universellen arithmetischen Feldes in emittergekoppelter Logik (ECL)', Diplomarbeit, Technische Universität München, 1977.
6. Burton, D. P. and Noaks, D. R., 'High-speed iterative multiplier', *Electronics Letters*, **4**, No. 13, p. 262, June 1972.
7. Wallace, C. S., 'A suggestion for a fast multiplier', *IEEE Trans. on Electronic Computers*, **EC-13**, No. 2, pp. 14–17, February 1964.
8. Thold, E., 'Realisierung und Inbetriebnahme eines Rechenwerkes für einen ECL-Pipeline-Signalprozessor', Diplomarbeit, Technische Universität München, 1977.
9. Deverell, J., 'The design of cellular arrays for arithmetic', *The Radio and Electronic Engineer*, **44**, No. 1, pp. 21–26, January 1974.
10. Demmelmeier, F., 'Comment on cellular arrays for multiplication of signed binary numbers', *The Radio and Electronic Engineer*, **47**, No. 6, pp. 287–8, June 1977.
11. Jayashri, T. and Basu, D., 'Cellular arrays for multiplication of signed binary numbers', *The Radio and Electronic Engineer*, **44**, No. 1, pp. 18–20, January 1974.
12. Dean, K. J., 'Some applications of cellular logic arithmetic arrays', *The Radio and Electronic Engineer*, **39**, No. 4, pp. 225–7, April 1969.
13. White, G., 'Generalized cell for use in iterative and near-iterative arithmetic arrays', *Electronics Letters*, **6**, No. 9, pp. 270–1, April 1970.
14. Gex, A., 'Multiplier-divider cellular array', *Electronics Letters*, **7**, No. 15, pp. 442–4, June 1971.
15. Deegan, I., 'Concise cellular array for multiplication and division', *Electronics Letters*, **7**, No. 23, pp. 702–4, November 1971.
16. Chu, Y., 'Digital Computer Fundamentals', pp. 29–30 (McGraw-Hill, New York, 1962).
17. Mengele, S., 'Simulation iterativer arithmetischer Felder', Diplomarbeit, Technische Universität München, 1977.

Manuscript first received by the Institution on 12th October 1978 and in final form on 15th January 1979.
(Paper No. 1876/Comp 192)

212: 621.372.2: 621.396.44
ms: Telecommunication cables, coaxial, Propagation

Propagation characteristics of a loose braid coaxial cable in free space

A. S. de C. FERNANDES, B.Sc., Ph.D.*

SUMMARY

A loose braid coaxial cable is studied and two possible interpretations of the surface transfer impedance sign give two mathematical solutions of the characteristic equation; the two solutions correspond to two different modes, the coaxial and the 'Goubau' modes, which may propagate according to two different launching processes.
Solutions for the propagation constant, distribution of power between the inside and the outside of the coaxial structure, and outside radial decay are presented.

* *Centro de Electrodinâmica das Universidades de Lisboa, Instituto Superior Técnico, 1000 Lisbon, Portugal.*

The Radio and Electronic Engineer, Vol. 49, No. 5, pp. 255–260, May 1979

1 Introduction

Loose braid coaxial cables are often used as leaky cables in continuous access communication systems. In order to establish a basis for the more important case of a cable over a ground plane, a study which will be presented in a further paper, we will develop now an analysis of this coaxial structure in free space.

A cross-section is shown in Fig. 1; r_1 is the radius of the inner conductor, r_2 the radius of the outer conductor (loose braid), and in between there is a dielectric with permittivity ε_1 and permeability μ_0. No dielectric sleeve is considered as we do not think it would cause qualitative differences to the propagation conditions.

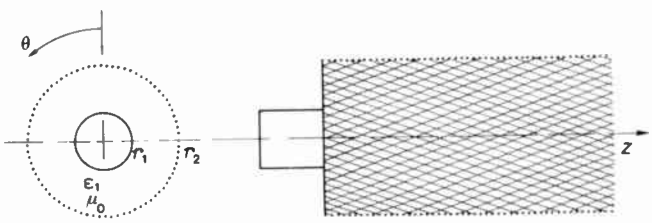


Fig. 1. Schematic diagram of a loose braid coaxial cable.

The fundamental difference between this cable and the normal braided type is the amount of coverage the braid provides. If it is a loose meshed braid the power is likely to leak through it and travel supported by currents flowing on the other side; thus, if the structure is fed in a coaxial manner we can expect a coaxial mode with a high percentage of the power travelling inside, but if it is launched as in the case of a single wire we should expect a solution corresponding to a Goubau mode, with the majority of the power travelling outside and with some leakage to the inner part of the coaxial structure.

Commercial cables of this type are readily available and have been tested in several environments;[1–7] BICC RPC 5097C and T3278, with braid coverage of respectively 67 and 63% are two examples.

2 Theory

An analysis will be made taking solutions of the wave equation, both in medium 1 ($r_1 < r < r_2$) and outside ($r > r_2$), and matching the surface impedances on both sides of the braid using the transfer impedance concept. The wave equation solutions will be such that the fields may vanish at infinity and the tangential component of the electric field will be zero at $r = r_1$. On the surfaces of the braid the series impedance will be used, defined as follows:

$$Z_{S-} = (E_z/H_\theta)_{r=r_2-} \quad \text{and} \quad Z_{S+} = (E_z/H_\theta)_{r=r_2+}$$

where E_z is the axial electric field and H_θ the azimuthal magnetic field. The definition implies a locally uniform field and so the non-uniform shield is here substituted by uniform or smoothed-version of the braid; thus the restriction of not working with too loosely meshed cable has been imposed.

0033–7722/79/050255+06 $1.50

The surface transfer impedance concept was initially developed by Ikrath[8] and Salt[9] and has lately been the object of further studies and measurements.[1,6,10,11,12,13]

Using Delogne's formulation,[11] also adopted by Wait,[14] the surface transfer impedance is defined as a series impedance on a surface but is now in relation to the discontinuity of the azimuthal magnetic field through the braid:

$$Z_{ST}=\left[\frac{E_z}{H_{\theta+}-H_{\theta-}}\right]_{r=r_2}$$

The use of this concept is intimately related to the following assumptions:

The braid is sufficiently thin such that E_z might be considered continuous across the grid.

The dimensions of a mesh are small compared with the wavelength, such that a quasi-static approximation is valid.

The fine structure of the field is neglected such that the only non-vanishing mean fields are H_θ, E_r and E_z.

Finally, we will use the dependence on the axial direction and the time as follows: $\exp(-j\beta z+j\omega t)$, β being the propagation constant and $\omega=2\pi f$ the angular frequency. The transverse wave numbers are defined as: $h_1{}^2=k_1{}^2-\beta^2$ (inside) and $h_0{}^2=\beta^2-k_0{}^2$ (outside) with $k_0=\omega\sqrt{(\varepsilon_0\mu_0)}$ and $k_1=k_0\sqrt{(\varepsilon_1/\varepsilon_0)}=k_0\sqrt{\varepsilon_r}$.

As an infinite conductivity for the conductors was assumed, no electromagnetic field is allowed for $r<r_1$. In the dielectric medium ($r_1<r<r_2$), the solution of the wave equation for the lowest TM mode with circular symmetry, can be used.

$$E_z=A[J_0(h_1r)+bY_0(h_1r)]\exp(-j\beta z)\exp(j\omega t) \quad (1)$$

$$E_r=jA\frac{\beta}{h_1}[J_1(h_1r)+bY_1(h_1r)]\exp(-j\beta z)\exp(j\omega t) \quad (2)$$

$$H_\theta=jA\frac{k_1{}^2}{\omega\mu_0h_1}[J_1(h_1r)+bY_1(h_1r)]\times$$

$$\times\exp(-j\beta z)\exp(j\omega t) \quad (3)$$

where $J_0(\ )$ and $J_1(\ )$ are the first-kind Bessel functions of order zero and one and $Y_0(\ )$ and $Y_1(\ )$ are the second-kind Bessel functions of order zero and one. A and b are constants yet to be determined.

Outside the braid ($r>r_2$) the fields must tend to zero as r increases to infinity and, as a slow wave solution is expected, the chosen form for the wave equation solution is:

$$E_z=A_0H_0{}^{(1)}(jh_0r)\exp(-j\beta z)\exp(j\omega t) \quad (4)$$

$$E_r=A_0\frac{\beta}{h_0}H_1{}^{(1)}(jh_0r)\exp(-j\beta z)\exp(j\omega t) \quad (5)$$

$$H_\theta=A_0\frac{k_0{}^2}{\omega\mu_0h_0}H_1{}^{(1)}(jh_0r)\exp(-j\beta z)\exp(j\omega t) \quad (6)$$

$H^{(1)}(\ )$ are Hankel functions of the first kind for orders zero and one and A_0 is a constant to be determined the normalization of the fields is done.

For the rest of the paper, $\exp(-j\beta z)\exp(j\omega t)$ will be omitted from the expression for the fields.

The first boundary condition that can be used is that at the surface of the inner conductor; this gives $E_{z_{r=r_1}}=0$

A second boundary condition will be taken at $r=r_2$. Across the braid E_z was assumed continuous and so A can be related to A_0 making

$$E_{z_{r=r_2^-}}=E_{z_{r=r_2^+}}.$$

The characteristic equation will be built from the surface transfer impedance definition:

$$Z_{ST}=\left[\frac{E_z}{H_{\theta+}-H_{\theta-}}\right]_{r=r_2}$$

Using another form we may write:

$$\frac{1}{Z_{ST}}=\frac{1}{Z_{S+}}-\frac{1}{Z_{S-}} \quad (7)$$

with

$$Z_{S+}=\left[\frac{E_z}{H_{\theta+}}\right]_{r=r_2+}=\frac{\omega\mu_0h_0}{k_0{}^2}\frac{H_0{}^{(1)}(jh_0r_2)}{H_1{}^{(1)}(jh_0r_2)}$$

$$Z_{S-}=\left[\frac{E_z}{H_{\theta-}}\right]_{r=r_2^-}=\frac{\omega\mu_0h_1}{k_1{}^2}\frac{J_0(h_1r_2)-\dfrac{J_0(h_1r_1)}{Y_0(h_1r_1)}Y_0(h_1r_2)}{J_1(h_1r_2)-\dfrac{J_0(h_1r_1)}{Y_0(h_1r_1)}Y_1(h_1r_2)}$$

as the series surface impedances on the two sides of the braid.

Using the approximations for small arguments, the characteristic equation (7) becomes, with $Z_{ST}=-j\omega L_{ST}$,

$$\frac{r_2}{\omega^2\varepsilon_0L_{ST}}-\frac{\varepsilon_r}{(k_0{}^2\varepsilon_r-\beta^2)\ln\dfrac{r_2}{r_1}}+$$

$$+\frac{1}{(k_0{}^2-\beta^2)\ln(0{\cdot}89h_0r_2)}=0 \quad (8)$$

L_{ST} being the surface transfer inductance. From this expression the value of the propagation constant (β) can be calculated.

The solution of this equation corresponds to the coaxial mode. For values of β/k_0 not too near unity we can drop the third term in relation to the other two. With this simplification the propagation constant can be determined by the simple expression

$$\beta=k_0\sqrt{\left[\varepsilon_r\left(1-\frac{L_{ST}}{r_2\mu_0\ln r_2/r_1}\right)\right]} \quad (9)$$

The Goubau mode corresponds to the solution of eqn. (8) but with $Z_{ST}=j\omega L_{ST}$

$$\frac{r^2}{\omega^2\varepsilon_0 L_{ST}}+\frac{\varepsilon_r}{(k_0{}^2\varepsilon_r-\beta^2)\ln\frac{r_2}{r_1}}-\frac{1}{(k_0{}^2-\beta^2)\ln(0{\cdot}89k_0r_2)}=0 \qquad (10)$$

As in this case β/k_0 will be close to unity, we can simplify eqn. (10) and arrive at a simple formula for the propagation constant of the Goubau mode:

$$\beta=k_0\sqrt{\left[1-\frac{L_{ST}}{L_{ST}\frac{\varepsilon_r}{\varepsilon_r-1}+r_2\mu_0\ln\frac{r_2}{r_1}}\times\frac{\ln r_2/r_1}{\ln(0{\cdot}54k_0r_2)}\right]} \qquad (11)$$

If in eqns. (10) to (11) we make $L_{ST}\to 0$, which means a coverage of the braid tending to 100%, the results will be, respectively

$\beta\to k_1$ for the coaxial mode

and

$\beta\to k_0$ for the Goubau mode.

3 Application of the Theory

3.1 Propagation Constant. Distribution of Power Between the Inside and Outside of the Coaxial Structure

For a comparison of the two different solutions of the characteristic equation, the parameters of the cable BICC RPC 5097 C will be used:

$$r_1=0{\cdot}00115\text{ m}$$
$$r_2=0{\cdot}005\text{ m}$$
$$\varepsilon_r=1{\cdot}3\text{ (semi-airspaced)}$$
$$L_{ST}=2\pi r_2 L_T=2\pi r_2\times 3{\cdot}79\text{ nH}.$$

The value of the transfer inductance (L_T) has been calculated and measured by Delogne *et al.*[11] For $f=100$ MHz and $Z_{ST}=-j\omega L_{ST}$, eqn. (8) gives the solution $\beta=2{\cdot}373$ rad/m which is a value clearly influenced mainly by the inside medium, which has $k_1=k_0\sqrt{\varepsilon_r}=2{\cdot}388$ rad/m. If the power that flows inside the coaxial structure is calculated we arrive at the figure 98·46%. Also if L_T decreases (increase of the braid coverage) the inside power tends to 100% and β tends to k_1. We will call this mode the coaxial mode and interpret it as a deviation from the normal coaxial mode, and so supported mainly by currents flowing on the inner conductor and inner part of the braid, but with some leakage to the outside.

If, on the other hand, we use the plus sign $Z_{ST}=+j\omega L_{ST}$ we arrive, for the propagation constant, at the value $\beta=2{\cdot}104$ rad/m, and for the power travelling inside, 14·24%; this mode propagates mainly outside, supported by currents flowing on the outer part of the braid, and with some leakage to the inside. It is also a slow wave with β slightly larger than k_0 (free space propagation constant, equal to 2·094 rad/m) and presents the characteristics of a Goubau mode as supported by an inductive surface impedance of the outer conductor.[15] In this case when L_{ST} decreases, P_i (%) decreases and β tends to k_0.

As the frequency increases, the inside power of the two modes decreases as the wave tends to travel in the medium with the smallest dielectric constant; in Table 1 are shown the data already mentioned together with the values for $f=300$ and $f=500$ MHz.

Table 1

Dependence on frequency of the inside power of the coaxial and the Goubau modes

Frequency	100 MHz	500 MHz
P_i % Coaxial mode	98·46	66·5
P_i % Goubau mode	14·24	0·68

As can be seen in both cases, as the frequency increases, the power tends more to travel outside and thus the coaxial mode also begins to resemble a Goubau mode.

Having derived these two theoretical solutions there follows a search for a corresponding physical significance. This is found in the launching method: the propagation of the coaxial mode (use of $Z_{ST}=-j\omega L_{ST}$) takes place when the cable is fed in a coaxial manner. The propagation constant of this mode has been verified experimentally with a 3% agreement.

For the second interpretation ($Z_{ST}=+j\omega L_{ST}$), the propagation of the Goubau mode is achieved by launching the wave on the outer as a single wire: at the feeding point the inner and outer are short-circuited and connected to the inner of the coaxial socket of the transmitter. Eaton and Kallaway[16] have measured the propagation constant when driving the cable as described and using a very similar cable; their result is $\beta/k_0=1$ while, in our example, we find $\beta/k_0=1{\cdot}005$.

It is normal practice to feed these cables in a coaxial manner and so we will proceed only with the study of the coaxial mode.

3.2 Density of Power Outside the Cable

To calculate the density of power at any point the field values must be related to an arbitrary level. The normalization will be done supposing that the power fed into the cable is 1 watt; since a lossless infinite cable has been considered, the 1 watt will spread out over the infinite area of a cross-sectional plane.

By relating it to 1 watt at the source and considering an antenna with 1 m² effective aperture, power density distribution will be quoted in dBW.

The fields are symmetric and at a point $r=r_0$ the density of power is $P=10\log_{10}(E_r{}^2/2Z)$ with $Z=E_r/H_\theta=Z_0\beta/k_0$. Figure 2 shows the decay of its value in a radial direction, for three values of L_{ST}. The rate of decay is

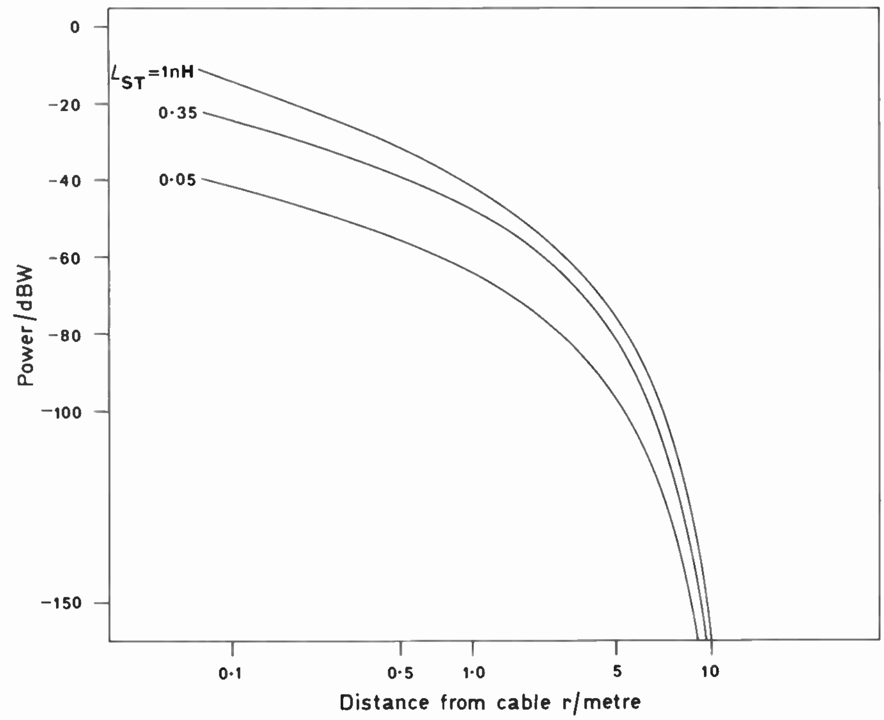


Fig. 2. Density of power outside the cable: influence of the surface transfer inductance.

$\frac{r_2}{r_1}=4{\cdot}38$; $\epsilon_r=1{\cdot}5$; $f=100$ MHz.

very large and is about the same for the three values of L_{ST}; it also shows that a higher value of the surface transfer inductance improves the coupling.

In Fig. 3 the influence of the frequency and inside dielectric permittivity can be seen. A lower frequency improves the coupling dramatically; the curve corresponding to 1 GHz presents a higher value close to the braid but a very high rate of decay, such that the wave travels very near the cable which implies less chances for the environment to affect the propagation conditions. A lower frequency, such as 1 MHz, allows a much larger coupling (up to several hundreds of metres) but, close to the cable, is about 10 dB weaker. A lower frequency can then be used when coupling to a large distance is necessary but it should not be forgotten that such a wave will be affected by any obstacle existing within a radius of 100 metres or so. A curve for $\varepsilon_r=2{\cdot}26$ is also shown for the case of 100 MHz; this has a better coupling near the cable but with a higher decay; such a cable will have a propagating wave travelling closer to the braid.

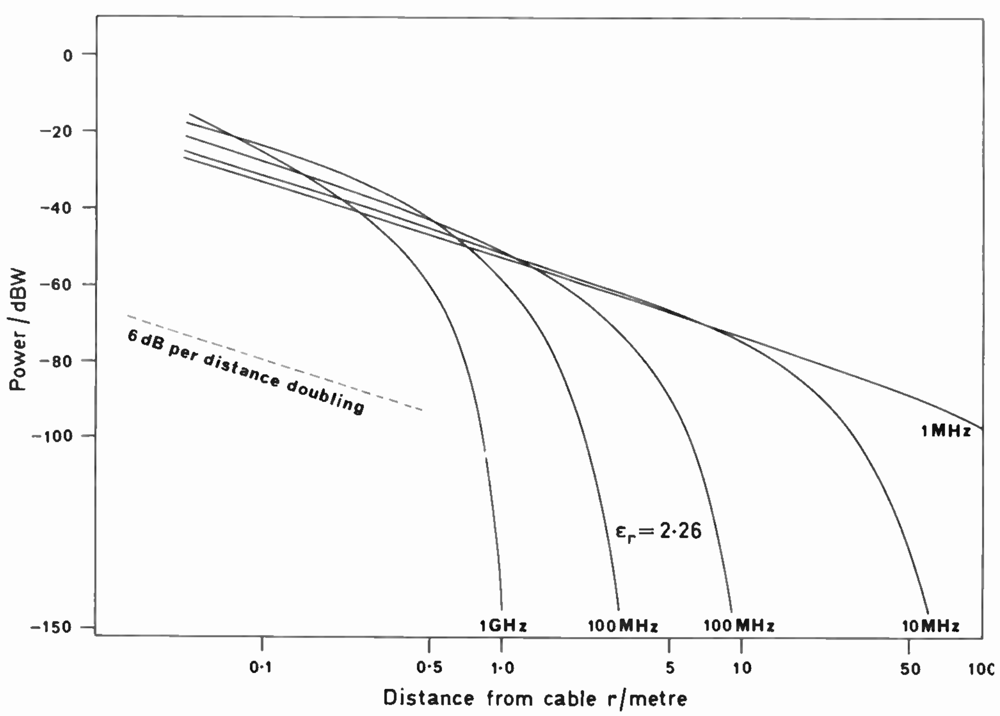


Fig. 3. Density of power outside the cable: dependence on frequency and inside dielectric.

$L_{ST}=0{\cdot}2325$ nH; $\frac{r_2}{r_1}=4{\cdot}38$; $\epsilon_r=1{\cdot}5$.

Practical measurements supporting the theoretical general trend that lower frequencies produce higher coupling can be found in Ref. 17; measurements with a leaky cable on ground showed, for instance, that the mean signal at 150 MHz was approximately 6 dB stronger than that at 500 MHz.

Higher coupling for lower frequencies was also measured by Cree and Giles[3] using braided cables, at 42, 86, 138 and 460 MHz. They measured higher coupling for a lower permittivity cable with similar construction, at 2 m and 10 m, and at the same height above the ground, which points at the same conclusion as the predictions of this theory.

4 Conclusions

In order to establish a theoretical background for the analysis of the propagation conditions of a braided cable over a ground plane, a study in a free space situation has been presented.

The possible interpretations of the surface transfer impedance sign gave two different mathematical solutions of the characteristic equation; the two solutions correspond to two different modes, called 'coaxial mode' and 'Goubau mode' which may propagate according to two different launching processes; only the coaxial mode was studied in detail as it corresponds to the classical way of feeding a 'leaky cable'—by a solid coaxial feeder.

The main conclusion is that the propagation mode, whose velocity of propagation is fairly independent of the frequency (eqn. (9)) is a surface wave ($\beta > k_0$), non-radiating with no cut-off and, as such, presenting an evanescent decay of the outside fields in the radial direction. This decay is very large for u.h.f. and v.h.f. but relatively small for lower frequencies (Fig. 3). The choice of frequency depends therefore, as far as the physical system is concerned, on the area where communication facilities are to be provided. A lower frequency implies more percentage of power travelling inside the coaxial structure which is advisable, as it would benefit the matching between the cable and a solid feeder. It also provides lower losses, however, it implies narrower bandwidths and lower gains for the same size emitting/receiving common antenna.

Concerning the braid characteristics, a high surface transfer inductance—little coverage—provides a higher coupling near the cable but it does not substantially extend the radial distance within which communication is possible (Fig. 3).

A higher value of the inside dielectric permittivity increases the power travelling outside and also the radial attenuation (the outer transverse wave number is higher); this means that the wave travels more concentratedly on the outer part of the braid. In practice this means that if a close link is to be assured, the cable should have a high permittivity dielectric, and vice versa (Fig. 4).

Finally, an increase of the ratio of radii implies slightly less power travelling outside and a slight increase on the radial attenuation. Therefore it seems that a 50 Ω cable is preferable to a 75 Ω one.

Good agreement with experimental values has been found concerning the propagation constant, characteristic impedance and the dependence of coupling with frequency.

The main limitations of this analysis are, from a practical point of view, the assumption of a free space situation and the absence of end effects.

As for the initial assumptions the limits of this theory can be applied and will be summarized here; these are basically the geometric characteristics of the mesh and the frequency; a thin braid with the mesh dimensions small compared with the wavelength is necessary; this can be translated to an upper limit for the frequency that would be around 5 to 10 GHz. Using the series impedance concept on the braid surfaces also implies a fairly uniform field which cannot be achieved with a loose mesh; from this it could be said that the mesh dimensions should be much smaller than the distance between conductors.

Finally, the use of the small arguments approximations for the Bessel functions, requires $(h_1 r_2)$ and $(h_0 r_2)$ much smaller than unity; in terms of frequency, and for cables of outer diameter of the order of 10^{-2} m, this means an upper limit of around 1 GHz.

5 Acknowledgments

The major part of this paper relates to work carried out at Standard Telecommunication Laboratories, Harlow and permission to publish is acknowledged with thanks. The author also wishes to thank Mr. Quintin Davis, from the University of Surrey, for his helpful discussions and advice.

The particular contributions of Mr. Rolf Johannessen, Mr. Peter Deane and Mr. John Greenwood, from S.T.L., are gratefully acknowledged.

Further investigation in these matters is being pursued at the Centro de Electrodinâmica das Universidades de Lisboa, Portugal, under the supervision of Prof. Manuel Abreu Faro.

6 References

1 Martin, D. J. R., 'Very-high-frequency radio communication in mines and tunnels', Ph.D. Thesis, University of Surrey, January 1973.

2 Martin, D. J. R., 'A general study of the leaky-feeder principle', *The Radio and Electronic Engineer*, **45**, No. 5, pp. 205–14, May 1975.

3 Cree, D. J. and Giles, L. J., 'Practical performance of radiating cables', *The Radio and Electronic Engineer*, **45**, No. 5, 215–23. May 1975.

4 Fontaine, J., *et al.*, 'Feasibility of two-way mobile radio communication in tunnels by means of a leaky braided coaxial cable', Symposium on Leaky Feeder Radio Communication Systems, University of Surrey, April 1974, pp. 38–48.

5 Fontaine, J., *et al.*, 'Improvements of two-way mobile radio communication in tunnels by means of a leaky braided coaxial cable', Symposium on Leaky Feeder Radio Communication Systems, University of Surrey, April 1974, pp. 25–37.

6 Slaughter, R. J., 'Field leakage and crosstalk with special reference to radiating cables with perforated tape screens', *The Radio and Electronic Engineer*, **45**, No. 5, pp. 248–52, May 1975.

7 Fernandes, A. S. C., Harms, P. O. and Johannessen, R., 'Some engineering considerations affecting the use of radiating cables in communications between vehicles and traffic control centres', Symposium on Leaky Feeder Radio Communication Systems, University of Surrey, April 1974, pp. 82–96.

8 Ikrath, K., 'Leakage of Electromagnetic Energy from Coaxial Cable Structures,' USA SRDL Technical Report, 1964, U.S. Army Research and Development Laboratory, 1958.

9 Salt, H., 'The surface transfer impedance of coaxial cables', IEEE Electromagnetic Compatibility Symposium Record, Seattle, Washington, July 1968, pp. 198–209.

10 Martin, D. J. R., 'Transferred surface currents in braided coaxial cables', *Electronics Letters*, **8**, No. 18, pp. 465–6, September 1972.

11 Delogne, P. P. and Safak, M., 'Electromagnetic theory of the leaky coaxial cable', *The Radio and Electronic Engineer*, **45**, No. 5, pp. 233–40, May 1975.

12 Fontaine, J., *et al.*, 'Feasibility of radiocommunication in mine galleries by means of a coaxial cable having a high coupling impedance', Through the Earth Electromagnetic Workshop, Colorado School of Mines, August 1973.

13 Fowler, E. P., 'Observations on the Use of $Z_T(C)$ for Comparing the Breakthrough Capacitance of Cable Braids', International Electrotechnical Commission, DOC SC 46A/WG1 (Fowler) 3.

14 Wait, J. R. and Hill, D. A., 'Propagation along a braided coaxial cable in a circular tunnel', *IEEE Trans. on Microwave Theory and Techniques*, **MTT-23**, No. 5, pp. 401–5, May 1975.

15 Goubau, G., 'Surface waves and their application to transmission lines', *J.Appl. Phys.*, **21**, No. 11, pp. 1119–28, November 1950.

16 Eaton, J. L. and Kallaway, M. J., 'The Radiation Characteristics of Leaky Coaxial Cables at VHF', BBC RD 1973/31, November 1973.

17 Johannessen, R. (Standard Telecommunication Laboratories). Private communication.

Manuscript first received by the Institution on 11th July 1978 and in final form on 12th February 1979.
(Paper No. 1880/Comm 182)

The Author

Antonio Simão de Carvalho Fernandes graduated in 1970 in electrical engineering at the Instituto Superior Técnico, Universidade Técnica de Lisboa. For the next seven years he held the appointment of Assistente (lecturer) in Propagation and Radiation of Electromagnetic Waves at the Instituto Superior Técnico, Lisbon, but from 1970 to 1973 was working in the Telecommunications Department of the Portuguese Navy. In 1973 he came to England to take up an appointment as a Research Engineer at Standard Telecommunication Laboratories, Harlow, Essex; his research work during this period on Leaky Feeder Transmission Theory gained him the Ph.D. degree from the University of Surrey. Dr Fernandes returned to Portugal in 1977 and is at present a Research Engineer at the Centro de Electrodinamica da Universidade Técnica de Lisboa. He is also Professor Auxiliar in Propagation and Radiation of Electromagnetic waves, Antennas, and Theory of Systems and Signals at the Instituto Superior Técnico, Lisbon, and in 1978 he lectured in Fundamentals of Telecommunications at the Academia Militar de Lisboa. Dr Fernandes has written several papers in the fields of leaky feeder propagation and antenna analysis.