AUSTRALIAN POST OFFICE RESEARCH LABORATORIES

OCCASION OF GOLDEN JUBILEE
1923-1973

REVIEW OF ACTIVITIES

AUSTRALIAN POST OFFICE RESEARCH LABORATORIES 59 LITTLE COLLINS STREET MELBOURNE 3000 AUSTRALIA

Foreword

The publication of this special edition of the Review of Activities of the Australian Post Office Research Laboratories marks the fiftieth year of their existence as a separate organisational unit in the Headquarters Administration of the Post Office.

On the occasion of this Golden Jubilee, it is appropriate to concentrate a little more attention than usual to recalling the past projects and achievements of the Laboratories, and a substantial part of this review is devoted to this purpose.

In looking back, we should not overlook our present concerns. The sections of this publication reviewing selected current activities of the Laboratories illustrate the awareness in the Post Office of our reliance for future viability on the timely adaptation to technological changes which are taking place in telecommunications.

I would like to congratulate the Laboratories staff, past and present, in this their Golden Jubilee Year, and I commend this Review of Activities to readers who have an interest in the Australian Post Office Research Laboratories.

E Lane

(E. F. LANE)
Director-General
Australian Post Office

Contents

The Role of the Research Laboratories

The Australian Post Office is charged with the responsibility of providing the nation's internal telecommunications and must do this economically, on a scale appropriate to the demand, and with a degree of sophistication that matches the needs of modern society. The discharge of this responsibility requires the timely adoption of new and improved apparatus and systems that result from advances in the science and technology of telecommunications.

It is the task of the Research Laboratories to maintain a position at the forefront of the relevant science and technology in order that they may participate expertly in the formulation and implementation of Post Office policies for the introduction of new or improved equipment, systems and services. In addition, the Laboratories are called on to assist in the solution of the technical problems that arise in the design, manufacture, installation, maintenance and operation of Post Office plant.

The execution of these responsibilities means that the Laboratories must maintain a high level of expertise in all forms of telecommunications and in the related disciplines of physics, chemistry and metallurgy. This is done through the conduct of research and advanced development on topics that are relevant to operations in Australia, having regard to work that is known to be in hand elsewhere in Australia and overseas.

A proportion of this work is aimed at problems that are of vital concern to the Australian Post Office and which appear to be receiving inadequate attention in other research and development organisations. In these cases, the work is carried through to the stage where the results are available for adoption — be it as a proven item of new equipment or as a proven solution to some installation or operational problem.

It is recognised that telecommunications research and development engages the attention of very large organisations in overseas countries and it is inevitable that many of the improvements proposed for adoption in the Australian Post Office will originate overseas. Nevertheless, long experience has shown that without advanced knowledge available within the Post Office, there is a danger that our technical judgements and decisions will be influenced by suggestions and pressures from outsiders whose interests differ from the long term interests of the Post Office. The Post Office must be in a position to judge for itself the way in which a new development can be incorporated into the network and be able to assess the special requirements and adaptations necessary to make it effective.

To provide the knowledge and expertise necessary to enable these judgements to be made with confidence, it is necessary to have first hand knowledge of the technology concerned, and the best way to achieve this is through the conduct of advanced development in the field concerned. Some of the advanced development projects in the Laboratories are undertaken with the understanding that they may not be carried to the production stage and that the principal benefit will be knowledge which will find application in the specification of new requirements and the assessment of offers from manufacturers.

At the same time, the Laboratories do not underrate the ability of their own staff to produce successful innovations, and each advanced development project is monitored carefully and, in appropriate cases, the development is carried through to production and field use.

In addition to its research and development role, its wide range of specialist knowledge and techniques in a number of disciplines, including the physical sciences, enable the Laboratories to conduct investigations into many of the difficult technical problems that arise in the operation of Post Office plant. Furthermore, the Laboratories are responsible for the electrical standards and the time and frequency standards used by the Post Office. In the latter case, they are an Agent of the National Standards Commission.

The Laboratories cannot, of course, operate in isolation, and extensive collaboration exists with the Planning and the Engineering Works activities of the Post Office in the selection of projects and in the application of specialist knowledge in those areas where the prime responsibility rests with other groups.

It is also recognised that a great deal of research talent exists in universities and in industry in Australia, and the Post Office would be foolish to ignore the contribution that these sectors can make to telecommunications knowledge. The Research Laboratories attempt to provide a focus for telecommunications research in Australia and to encourage universities and industry to undertake appropriate research tasks.

The preceding remarks have been concentrated on telecommunications and, in fact, a very large proportion of the resources of the Laboratories is applied in this field. Nevertheless, the Laboratories have an equivalent responsibility for the postal area and for many years a small proportion of resources has been applied to postal problems. With the increasing use of sophisticated automatic equipment for handling mail, an increasing research and development effort on postal problems can be expected.

Although modes of expression have altered and resources have multiplied, the role of the Research Laboratories remains basically the same as it was when they were established 50 years ago. In essence, the Laboratories are responsible for acquiring relevant new knowledge and new skills and applying them to the technical problems facing the Post Office. The pages that follow give some indication of the way in which the role has been fulfilled over the years and the way it is being fulfilled by the current programme.

The Research Laboratories - a Historical Review

It has been considered appropriate, in this edition of the A.P.O. Research Laboratories Review of Activities on the occasion of the Laboratories Golden Jubilee, to depart from the usual practice of giving the principal emphasis to a review of current activities and to devote some pages to a record of the history of the Laboratories. The following section of the review outlines the growth of the Laboratories since they were first established in 1923 and traces the development of the various present-day activities from their beginnings.

The original charter of the Laboratories emphasised the need to study "the latest discoveries, inventions and developments in electrical communications" and to advise on those "which are promising and likely to benefit the Department's telephone and telegraph services" and this charter remains equally relevant today. The passage of 50 years has seen rapid advances in the science of telecommunications and these are reflected in the growth of the Laboratories and their span of activities.

A history of the Laboratories is therefore a reflection of the technological development of the Australian network. The highlights recalled as Laboratories' achievements are not claimed to be exclusive contributions of Laboratories' staff, but serve merely to recall the forward role played by them, in association with other Departmental staff, in keeping the Australian network abreast of technological developments.

THE ORIGINAL CHARTER

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Although the Research Laboratories were established as a one-man section in 1923, the only extant "original charter" is comprised of the combined functional and duties statements reproduced below. These were approved on 23.4.1925, when the Section had grown to one of five staff.

RESEARCH SECTION — LIST OF STAFF AND FUNCTIONS

1. SUPERVISORY AND CO-ORDINATING FUNCTION —

Engineer:
Duties:

1.1 — Generally supervise and co-ordinate the activities of the Section as a whole.

1.2 — Co-operate with other Engineering Sections and Traffic Sections so that work undertaken by the Research Section is properly planned, and to see that the joint efforts are co-ordinated within the Department's aims and policy.

1.3 — To formulate standards of transmission designed for providing intercommunication throughout the telephone system of the Commonwealth.

1.4 — To deal personally with the more important problems of investigation undertaken by the Section.

1.5 — To keep in touch with the latest discoveries, inventions and developments in electrical communication, and to keep the Chief Electrical Engineer advised of the progress of those which are promising and likely to benefit the Department's telephone and telegraph services.

1.6 — To keep in touch with research organisations and institutions in other countries with a view to avoiding unnecessary duplication of work in the Department's Research Section.

1.7 — To furnish to the Chief Electrical Engineer annual estimates of instruments, material and plant involved in the anticipated activities of the Section.

1.8 — To authorise under a general delegation from the Chief Electrical Engineer the expenditure embraced in the approved annual estimates.

2. TRANSMISSION AND REPEATER INSTALLATION FUNCTION —

Engineer:
Duties:

2.1 — To make transmission measurements on main trunk lines for the purpose of assuring the maintenance of transmission standards.

2.2 — To perform the calculations and other detailed work necessary in considering new trunk line or trunk cable schemes that may be referred to the Section in connection with other transmission aspects.

2.3 — Keep in touch with actual jobs in the field involving the application of transmission standards so that any unforeseen difficulties may be quickly analysed.

2.4 — Determine location of repeating stations.

2.5 — Prepare design and layout of apparatus in repeating stations.

2.6 — Make measurements of the electrical characteristics of lines upon which are based the calculations for repeater balance networks.

2.7 — Keep in touch with Engineers in the various States who are carrying out the actual work of installing repeater plant.

3. INVESTIGATORY FUNCTION —

Engineer:
Duties:

3.1 — To take charge of the Laboratory.

3.2 — To supervise condition of instruments, check calibrations, maintain reference standards of telephone transmission equipment.

3.3 — Undertake investigations requiring Laboratory or experimental work.

3.4 — Prepare complete electrical data of telephone and telegraph apparatus so that other Engineering Sections may be able to put such apparatus to its most effective use.

3.5 — To work in co-operation with other Sections on investigations requiring experiments in the actual field of utilisation.

4. LABORATORY SUB-FUNCTION —

Mechanic:
Duties:

4.1 — To keep laboratory equipment in order.

4.2 — To wire up test and experimental circuits.

4.3 — To make experimental designs in cases where it would be uneconomical to have the work done in the Departmental Workshops.

4.4 — To assist the Engineer in charge of the Laboratory (3) in making tests and measurements.

5. COMPUTING AND RECORDING FUNCTION —

Clerk:
Duties:

5.1 — To perform general computing work such as that arising from the compilation of multi-item electrical measurement schedules and test sheets.

5.2 — To maintain the system of filing technical and experimental data.

5.3 — To keep records of laboratory plant.

5.4 — To keep note of the expenditure of the Section.

5.5 — To prepare reports under direction.

5.6 — To prepare requisitions for material.

THE PRESENT CHARTER

The present charter of the Laboratories, now a Headquarters Sub-Division comprising 4 Branches and 22 Sections, is illustrated in the statement of Objectives and Functions of the Sub-Division reproduced below:—

OBJECTIVE

The main objective of the Research Sub-Division is to maintain a position at the forefront of knowledge in communications science and technology, in order that it may provide expert participation in the formulation and implementation of policies for the introduction of advances in science and engineering of relevance to the Post Office. It also conducts specific development and design projects and scientific and engineering investigations into Post Office problems.

FUNCTIONS AND RESPONSIBILITIES

- Conduct basic and applied research in the natural sciences and engineering aimed at discovering new knowledge of telecommunications and postal services on topics relevant to operations in Australia, and having regard to research known to be in hand overseas or in Australia.
- Conduct investigations in areas of developing technology to provide expertise necessary to carry out the other functions of the Research Laboratories.
- Establish and maintain specialist resources necessary to ensure that investigations and developments are conducted at an appropriate level of scientific and technical competence and to provide and maintain as necessary standards of adequate accuracy for weights and measures.
- Encourage and support basic research on telecommunications and postal topics in universities and other centres of higher learning, and encourage and support post-graduate training of engineers, scientists and others in these fields.
- Encourage and develop liaison channels between the research establishments of the Department and other appropriate research establishments in Australia and overseas to ensure adequate co-ordination of policies and projects, and economy in the use of professional resources.

In collaboration with other Divisions and the Planning and Programming Sub-Division:—

- Formulate research and development programmes.
- Participate in the formulation and implementation of policies for the introduction of new advances in communications technology into Departmental operations.
- Conduct basic and applied research in the social sciences aimed at discovering new knowledge relevant to Post Office operations in Australia, and having regard to research known to be in hand overseas or in other Australian laboratories.
- Conduct specific investigations on aspects of systems or equipment performance and development.
- Define Departmental requirements for certain new types of equipment and systems and appraise newly developed equipment offered by manufacturers.
- Design and develop telecommunications and postal systems and equipment to meet Australian requirements, having regard to what is available from overseas and to the resources of local industry and of other Divisions of the Department.
- Encourage and, in appropriate cases, arrange research and development on telecommunications and postal topics by industry in Australia.
- Provide advice on trends in science and technology of relevance to the Post Office.

Heads of the Laboratories - Past & Present

Sidney Herbert Witt (1923 - 1945)

The selection of Mr. Witt as the founder of the Research Laboratories in 1923 was indeed fortunate. His technical perspicacity and foresight, his early acceptance as an expert in telecommunications in both Australia and overseas, and his long tenure of office as "Head" of the Laboratories combined to assist the development of the infant Laboratories to a mature and effective working unit in the Department. His vision of the Laboratories was that of a special group set aside to advise the Department on how best to make use of growing technology and this vision is still reflected in present-day statements of the functions of the Laboratories.

Mr. Witt joined the Department on 10th February, 1910, as a junior Instrument Fitter in the Electrical Engineer's Branch, Melbourne Office. He was then almost 18 years old. By 1917, he had advanced to Assistant Engineer, Class D, in Central Office, and had already demonstrated his ability in 1913 by suggesting an improvement to junction line circuits working between C.B. and magneto exchanges.

In 1921 and 1922, he undertook a study tour of America, England and Europe, investigating the latest overseas developments in telegraph, telephone and radio communication, and on his return, he played a leading role in the planning of the Australian trunk network. This led to his appointment as the founder of the Laboratories in 1923 and his subsequent appointment as Supervising Engineer, Research, in 1924.

For the first few years, Mr. Witt and his small team of four concentrated on the introduction of voice frequency repeaters and 3 channel carrier systems into the trunk network.

In 1927 Mr. Witt was seconded to play a leading role in the planning and establishment of the National Broadcasting Service. This work introduced the Laboratories to the radio broadcasting field as well as that of telephone transmission, and many of the present-day activities of the Laboratories can be traced back to these personal activities of Mr. Witt and his early team.

Throughout his career, Mr. Witt was active in the international telecommunications arena, becoming one of the first A.P.O. representatives to participate in the activities of the International Telecommunications Union (I.T.U.), and its associated consultative committees in the post-war years. Ultimately, this association led to Mr. Witt's retirement from active control of the Laboratories in June 1945, when he undertook a series of overseas assignments as Australian delegate to international meetings of the I.T.U. These were mainly concerned with formulating an international plan of radio frequency allocations for radio communications and they led, at the Plenipotentiary Conference of 1947, to the establishment of the International Frequency Registration Board (I.F.R.B.) as a body of the I.T.U. Mr. Witt was elected as one of the eleven original members of the Board on the nomination of the Australian Government and took up full-time duties in Geneva in January, 1948. He continued to serve on the Board until his retirement in 1957, and served as its Chairman in 1949.

The dynamic personality of Mr. Witt was not confined to Departmental activities. He was an energetic member of a number of professional associations, notably the Postal Electrical Society and the Institution of Engineers, Australia, and a founder member of the Melbourne Division of the Institute of Radio Engineers. Records show that he frequently held important office in all of the above associations and that he was a ready and lucid author of technical articles in their respective journals. He was also a member of the Institution of Electrical Engineers, London, and of the Institution of Post Office Electrical Engineers, London.

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Eric Percival Wright, B. Sc. (1945 - 1953)

Mr. Wright was the second staff member of the original Research Section, joining Mr. Witt on 11th of February, 1924, and it was appropriate that he succeeded Mr. Witt as acting Supervising Engineer, Research, upon Mr. Witts departure from active leadership of the Laboratories in 1945. Mr. Wright occupied the position until the appointment of Mr. N. J. McCay in 1953.

Mr. Wright was born in 1898 and joined the Department as a junior Mechanic-in-Training in February 1915. By 1918, he had been promoted to Engineer-in-Training, Class F, in the Electrical Engineers Branch, Melbourne Office. On his temporary transfer to the Research Section in 1924, he and Mr. Witt were "the Laboratories". His permanent transfer to the Laboratories as Engineer came in 1925, after the Research Section was formally established, comprising 3 engineers, 1 mechanic and 1 clerk/typist.

Mr. Wright spent his first years with the Research Section pioneering transmission measurement techniques, establishing transmission standards and assisting in the installation of some of the first voice frequency repeaters in the trunk network — including those on the Perth-Kalgoorlie and Melbourne-Sydney routes. In 1924, he obtained his Bachelor of Science degree from Melbourne University after satisfactory completion of part-time studies.

In July 1927, he was promoted to Divisional Engineer and soon after took charge of the Laboratories for about 3 years, while Mr. Witt was occupied with the special responsibility of planning the National Broadcasting System. During this period, the work on telephone transmission and instrumentation continued, and the Laboratories entered the field of high frequency radio transmission as an offshoot of the work on the National Broadcasting System.
By late 1937, Mr. Wright had been promoted to Assistant Supervising Engineer, assisting Mr. Witt as second-in-charge of the Research Section. In this period, Mr. Wright continued his original role as a transmission expert, laying the foundations of the present-day A.P.O. telephone and telephone transmission standards.
Following Mr. Witt's transfer to special duties in 1945 and his subsequent resignation from the Department in 1948, Mr. Wright acted in the capacity of Supervising Engineer, Research, until 1953, when he reverted to the position of Sectional Engineer, Line Communication, upon the appointment of Mr. N. J. McCay as Supervising Engineer. He later transferred to the position of Sectional Engineer, Radio, in the Laboratories, and maintained his position of second-in-command by regularly relieving the position of Supervising Engineer for short periods.
Although Mr. Wright was never formally appointed to the position of head of the Laboratories, he performed the task in an acting capacity for a long period, and this fact, together with his long association with the Laboratories as a hard-working founder-member of the Section from 1924 until his retirement in 1963, ensures his recognition as the second "Head of the Laboratories", and as one who played a major role in their establishment.

Norman James McCay, B. Sc. (1953 - 1960)

N. J. McCay was the third "Head of the Laboratories". He was promoted to the position of Supervising Engineer, Research, in 1953. Mr. McCay had had extensive experience, both in the Department and in the Army, in long line equipment aspects of telecommunications.
Born in 1896, Mr. McCay joined the Department in 1913 as a Clerk, in which capacity he served in a number of positions until the First World War. He then joined the Army and after a period of five year's war service during which he rose to commissioned rank, he returned to the Department as an Engineer-in-Training in the Electrical Engineer's Branch, Victorian Office. He subsequently successfuly qualified as Engineer, gaining the degree of Bachelor of Science from Melbourne University.
In the early 1920's, Mr. McCay was one of the first engineers to install Western Electric Type B 3-channel carrier telephone systems in Australia — between Sydney and Melbourne, and thus began his first associations with Mr. Witt, who was also involved in this work. Mr. McCay also participated about this time in the task of installing the co-axial trunk system between Brisbane and Southport, and in the extension of the 2-wire route to Tweed Heads by the installation of a carrier system.
In 1931, Mr. McCay transferred to the Transmission Section at Headquarters, and was subsequently promoted to Divisional Engineer in 1934, and to Assistant Supervising Engineer of the Section in 1938.
In 1942, he re-joined the armed forces as Lieutenant-Colonel in the Australian Corps of Signals. His responsibilities were those of "Civil Communications" which, inter alia, included liaison with the Postmaster-General's Department.
The Department's role at the time included the provision of fixed telecommunications services for the Armed Services in Australia. In this second period of war service, Mr. McCay was responsible for several major aerial and cable installations and microwave radio projects in Australia, New Guinea and other Pacific islands.
Returning to the Department in 1946, as Supervising Engineer of the new Transmission and Long Line Equipment Section, he played an important role in laying the foundations of the present Australian trunk carrier network.
A short period as Supervising Engineer, General Works, was followed by promotion to Supervising Engineer, Research, in 1953 — a position which he held until his retirement in 1960. During this period, Mr. McCay gave his attention to building up the status of the Laboratories and its staff. He represented the Department on a number of scientific and research bodies, and was, for a time, Chairman of the Research and Development Sub-Committee of the Inter-departmental Telecommunications Advisory Committee and a member of the Council of the Standards Association of Australia.

Leonard Michael Harris, O.B.E., B. Sc. (1960 - 1964)

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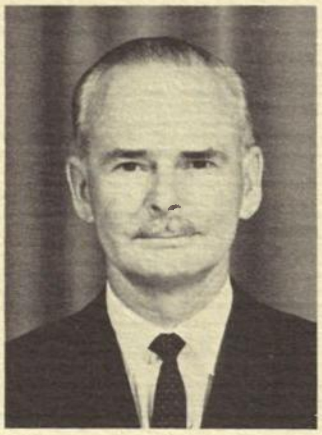
Mr. Len Harris became the fourth head of the Laboratories following the retirement of Mr. McCay in 1960. He was promoted to the position of Supervising Engineer, Research, from that of Supervising Engineer, Long Line Equipment, in the Engineering Works Division. He was, however, well acquainted with the Laboratories, having served for a period of 24 years as a member of their staff from 1930, when he first qualified as an engineer.
Mr. Harris joined the Department as a Cadet Engineer in 1926, just after his eighteenth birthday. He completed his training in 1930, gaining the degree of Bachelor of Science from Melbourne University, and was appointed as an engineer in the Laboratories.
Mr. Harris remained with the Laboratories until 1954, gaining promotion to Divisional Engineer in 1948 and acting as Sectional Engineer, Line Communication, from 1947 to 1954. During this period, his work lay in the fields of telephone transmission standards, transmission equipment and systems, and the design and evaluation of telephone apparatus and broadcasting studio equipment. His name is closely associated with the early establishment of the A.P.O. telephone and telephone transmission reference standards, with the National Broadcasting System, and with carrier system investigations.
In 1954, he was promoted to Sectional Engineer, Long Line Equipment, leaving the Laboratories for a period of 6 years before returning as Supervising Engineer. During this period he became Supervising Engineer, Long Line Equipment, and was heavily involved in the Sydney-Melbourne coaxial cable project — the first broadband system to be used in Australia to link capital cities.
He returned to the Research Laboratories as Supervising Engineer, Research, in 1960 and immediately became involved in a joint Post Office/Public Service Board committee review of the Scope, Functions and Organisation of the Research Laboratories. The report of the committee, known as the Harris-Brown-Dwyer Report, formed the basis for the reorganisation of the Research Laboratories as a Branch in 1963, and Mr. Harris was promoted Assistant Engineer-in-Chief in charge. This reorganisation gave the Research Laboratories enhanced status in the Department and the framework then laid down has been the basis of growth over the ensuing years.
In 1964, following a major reorganisation of Headquarters, Mr. Harris was promoted to First Assistant Director-General in charge of the new Planning and Research Division, with overall responsibility for the Planning and Research activities of the Post Office. This promotion ended his period of direct responsibility for the Research Laboratories, although, in his position as First Assistant Director-General, he continued to guide the growth and programme of the Laboratories and worked for closer liaison between the Laboratories' activities and the mainstream of the Department's engineering requirements.
Mr. Harris recognised the opportunity that the growing research schools in the Australian universities offered for stimulating research on projects of interest to the Department and he has actively fostered relationships between the Research Laboratories and the Universities. In recent years, he was Chairman of the Radio Research Board — a body that provides grants of over $100,000 per annum to support research projects in Australian universities. His interest in tertiary education was demonstrated by his membership of the Engineering Faculty of the University of



Melbourne until 1972.
Mr. Harris continued to occupy the position of First Assistant Director-General until his retirement in May, 1973, but for the last year or so, he was assigned to special duties associated with the telecommunications planning aspects of national defence.
During his career, Mr. Harris was active in the international relationships of the Department and participated in and led Australian delegates to I.T.U. and associated conferences and to other international organisations. Outside the Department, Mr. Harris showed an active interest in professional and scientific bodies such as the I.E. Aust., I.R.E. and ANZAAS. His services to Australian telecommunications were recognised in 1972 when he was awarded the rank of Officer of the Order of the British Empire.

Percy Rollo Brett, B. Sc. (1964 - present)

Mr. Rollo Brett succeeded Mr. Harris as head of the Laboratories in 1964. He was no stranger to the Laboratories, having been a member of the staff for the whole of his professional career.
He joined the Post Office as a Clerk in 1940 at the age of 16, and during the next 5 years, he spent varying periods in the Department, as a civilian in the Department of the Army, in the Armed Services and at Melbourne University, where he graduated Bachelor of Science in 1944 after majoring in Physics and Radio Physics. After graduation, he joined the Laboratories as a Physicist, Grade 1, where he became part of the team of physical scientists being built up under D. O'Donnell.
Over the next few years, this team grew to include Chemists, Physicists and Metallurgists.
In the early 1950's, Mr. Brett was active in Professional Officers Association affairs, preparing and presenting cases to Central Classification Committees of the Public Service Board which resulted in substantial organisational and classification improvements for the Physical Sciences Sub-Section, as it became known. Mr. Brett's main technical contributions were in the field of materials and components and their environmental behaviour, and he was involved in establishing the understanding and standards required for the adoption of modern polymer materials in Departmental equipment.
He was promoted to Senior Physicist in 1952 and to Sectional Engineer, Physical Sciences, in 1958, following the retirement of Mr. O'Donnell.

Following the reorganisation of the Laboratories in 1963, he was promoted to the position of Assistant Director-General, Apparatus and Services, and in 1964, to the position of Senior Assistant Director-General, Research.
During his period in charge of the Laboratories, he has concentrated attention on the management of the research programme to obtain the maximum relevance of the programme to the immediate and the long term needs of the Department, and on developing and maintaining an awareness elsewhere in the Department of the necessity for long term research and development, and of the value of the large resource of advanced knowledge and skill that is available in the Research Laboratories. In order to expand the extent of advanced knowledge of telecommunications in Australia, he has continued to foster relationships with Universities, and, at the present time, there is post graduate work of direct interest to the Department being undertaken in almost every Australian University.
Mr. Brett has also pursued the problem of the poor accommodation and facilities available in the present laboratory buildings and his actions have reached the stage where plans to consolidate the Research Laboratories at a single location in specially-designed laboratory buildings are nearing completion. It is hoped that the occupation of the first of these buildings will commence in 1975.
Mr Brett's earlier career involved him closely with the relevant activities of the Standards Association of Australia and currently, he is a member of the S.A.A. Council and Chairman of the Telecommunications and Electronics Industry Standards Committee. In recent years, he has become involved in tertiary education and is a member of the Faculty of Engineering at Melbourne University and of the Academic Policy and the College Staffs Committees of the Victoria Institute of Colleges. He is a graduate of the Australian Administrative Staff College, 1963; a Fellow of the Institution of Radio and Electronics Engineers; and a member of the Radio Research Board and of the Australian National Committee for Radio Science.

An Outline History of the Research Laboratories

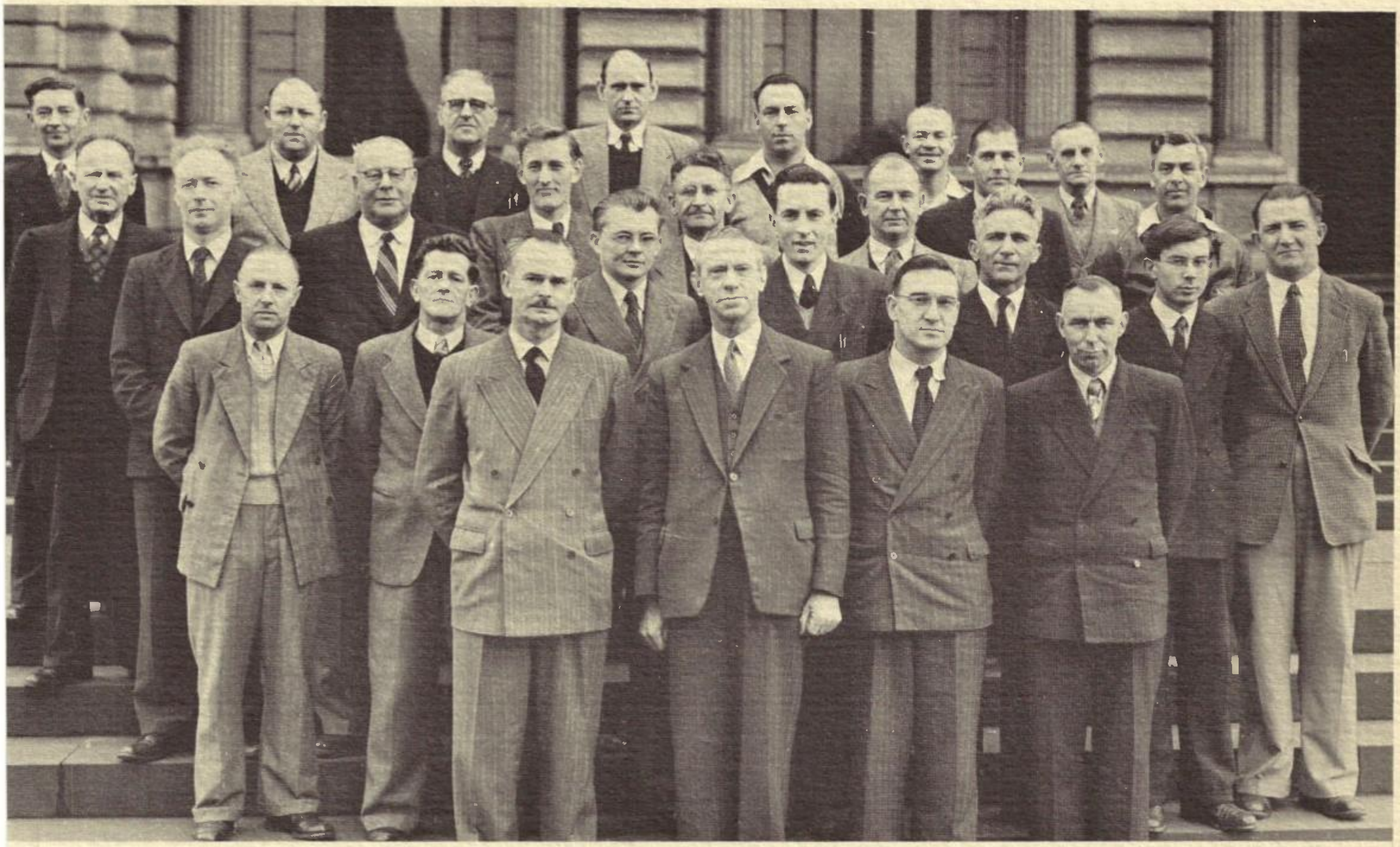
The Research Laboratories owe their origin as a special unit of the A.P.O. to the need, after World War 1, for the Department to introduce new technology into the telephone and telegraph networks to maintain their technical and economic viability. This called for specialists who would carry out investigations into the technical aspects of new systems and give timely advice to the Department on their potential application in its operations.

World War 1 had advanced Lee De Forest's vacuum tube triode from a laboratory device to a commercially available component. Its potential application as an amplifying device in the telecommunications field was recognised quickly and this was to lead to the development of telecommunications into a highly complex science rather than an empirical art.

Prior to 1920, Post Office telecommunications activities centred upon the provision of telegraph and telephone services in capital and provincial cities, with an infant trunk network of aerial lines linking them rather tenuously. The overseas use of vacuum tube voice frequency repeaters had demonstrated their potential in long-distance trunk routes. The A.P.O., realising this, introduced the first 2-wire V.F. repeaters into the Sydney-Melbourne route on an experimental basis in 1922, after the then Chief Engineer, accompanied by Mr. Witt, had visited the U.S.A., England and Europe to assess their use.

This activity led R. N. Partington, then acting Chief Engineer, to agree, on the nineteenth of March, 1923, to a proposal for the establishment of a Research Section to provide specialist technical advice on the introduction of these new devices into the Australian network. The Section was established about June, 1923, and Sidney H. Witt, Engineer, went to work as a one-man Research Section — with little equipment and about 300 square feet of space in the then Headquarters building in Treasury Place, Melbourne.

The Section increased to two engineers on the eleventh of February, 1924, when E. P. Wright was transferred from the Victorian Administration to assist Mr. Witt. During 1925, the embryo Laboratories moved into a larger area of 1,600 square feet in Melbourne House, 360 Post Office Place, Melbourne.



STAFF INVOLVED IN THE BASS STRAIT SUBMARINE CABLE EXTENSION PROJECT — 1954.

REAR: H. COOPER, W. FITZPATRICK, J. CARKEEK, W. YELVERTON, B. BLADIER, J. SMITH, N. HAMMOND.
SECOND ROW: W. HAYES, J. LYNCH, A. MEAGHER, D. TONKIN, R. BURING, J. FITHIE, J. LAUGHLIN, J. WALSH
THIRD ROW: A. ADAMSON, G. MITCHELL, E. RUMPELT, M. FARMER, J. ANSELINE, R. KETT, J. GROVES.
FRONT ROW: L. M. HARRIS, E. P. WRIGHT, D. A. GRAY, A. LATIMER.

By 1925, the Section had been formally established with Mr. Witt as the Supervising Engineer, assisted by E. P. Wright and A. A. Lorimer, Engineers, G. G. Robb, Mechanic, and Miss F. Terrell, Typist/Clerk. The infant Laboratories were charged with the task of establishing Departmental expertise in the field of telephone and telegraph transmission by studying "the latest discoveries, inventions and developments in electrical communications" and advising the Chief Engineer of "those which are promising and likely to benefit the Department's telephone and telegraph services". This early purpose of the Laboratories still applies today.

The early years were spent mainly in the conduct of transmission measurements, the determination of transmission standards and the study of evolving transmission theory and practice as required by the application of V.F. repeaters and early carrier systems in the trunk network. The year 1925 saw Mr. Witt installing the first 3-channel carrier system in Australia on the Sydney-Melbourne route, Mr. Wright installing V.F. repeaters and later the first single channel carrier system in Western Australia, and Messrs. Lorimer and Mair developing transmission test equipment, practices and transmission standards. The study of problems and advances in telegraph and telephone transmission continued to occupy the growing Laboratories as time and technology led from V.F. repeaters to single and three-channel carrier systems in the 1920's and early 1930's and to twelve-channel systems in the late 1930's.

This work required the development of technical specialities in telephone performance standards, telephone transmission measurements and standards, transmission systems evaluation, and in the study and characterisation of transmission media. The growth of these specialities has continued and a significant number of present-day activities, as reflected in a current organisation chart or work programme of the Laboratories, can be traced back to these modest beginnings.

From 1925 onwards, the Laboratories' staff became involved in the transmission of radio broadcast programmes over the trunk network, engineering in 1925 the first simultaneous interstate broadcast in Australia. This broadcast was a promotion of a Commonwealth Conversion Loan by the Secretary to the Treasurer, J. R. Collins, via a network hook-up of six stations — 2FC, 2BL, 3LO, 3AR, 4QG, and 5CL. They went on to arrange the nation-wide broadcast of the opening of Federal Parliament in Canberra in 1927 by means of a similar transmission network for the radio broadcast stations of the day.

Between 1925 and 1927, the Laboratories had equipped themselves to conduct radio frequency field strength measurements and were carrying out these measurements on the medium frequency broadcast transmitters. At this time, decisions were made to extend and upgrade the National Broadcasting stations to provide a reliable service to 90% of the population, and in 1927, Mr. Witt and several other Laboratories' staff were seconded to plan the present National Broadcasting System. Following the planning phase, which lasted several years, the Laboratories were closely involved with the implementation of the plan, going on to design broadcast transmitting equipment and antenna systems and evaluate studio equipment and the like during the years prior to World War II.

This involvement with the technical side of radio broadcasting has since ceased, but it is of note in that it led from medium to high frequency broadcasting, the Laboratories setting up the first Australian HF transmitter on an experimental basis at Lyndhurst, Victoria, in 1928 and later developing it until it provided a regular service. This early involvement with radio built up the expertise in transmitter design, antenna design, radio field strength measurements and propagation theory which was turned to V.H.F. radio telephony applications and investigations in the late 1930's. In 1938, when the submarine cable link to Tasmania was under repair, the staff of the Laboratories were instrumental in establishing the first A.P.O. radio telephone system from Mount Tanybryn in Victoria to Stanley in Tasmania, a distance of 168 miles across Bass Strait.

By 1932, the staff had increased to 35 and they had outgrown the 5,000 square feet they then occupied in Melbourne House. The value of test equipment had risen from $6,000 in 1925 to $32,000. In this year, they moved into a larger area of 24,000 square feet at 59 Little Collins Street, Melbourne. This building was originally purchased as the future home of the City East Exchange and, by coincidence, it was directly opposite the building at 60 Little Collins Street which had housed the Office of the Superintendent of the first Australian telephone exchange. This manual exchange was established in 1880 under the private ownership of W. H. Masters and J. T. Draper, and was located on the site of the Old Stock Exchange building at 367 Collins Street, Melbourne. The Laboratories still occupy 59 Little Collins Street as their Head Office today, although their activities have spilt over into a further six buildings at the eastern end of the city of Melbourne, and one at North Carlton. The present total building area occupied is about 140,000 square feet, and the replacement value of test equipment is now in excess of $6 million.

The war years saw the Laboratories assisting in the development of radar systems and engaged in other work for the armed services. Following the war, the radio frequency activities of the Laboratories were turning more towards radio telephone systems. However, for a period after the war and as a preliminary to the introduction of TV broadcasting into Australia, the Laboratories were engaged on TV propagation studies, as well as on a series of studies to determine the optimum parameters for a working television broadcast service. This latter work has now changed emphasis and is directed at studies of the coding of television signals for optimum bandwidth utilisation, with particular attention being given to broadband digital systems of the future.

The extension of the radio telephony work at V.H.F. and U.H.F. has naturally involved the Laboratories in the investigation of satellite systems, and staff of the Laboratories have participated in the A.P.O. studies on the use of satellites for telecommunications purposes since 1960. The post war years have also seen an expansion of the Laboratories' interest in broadband systems and guided transmission media — as might be expected with the addition to the older telephony and telegraphy services provided by the Department of the newer video and high-speed data services. The expertise developed in the Laboratories in the late 1940's in the microwave systems and media fields has extended through the coaxial cable phase of the 1950's, and is now engaged in investigations of the potential of optical devices and optical fibre media.

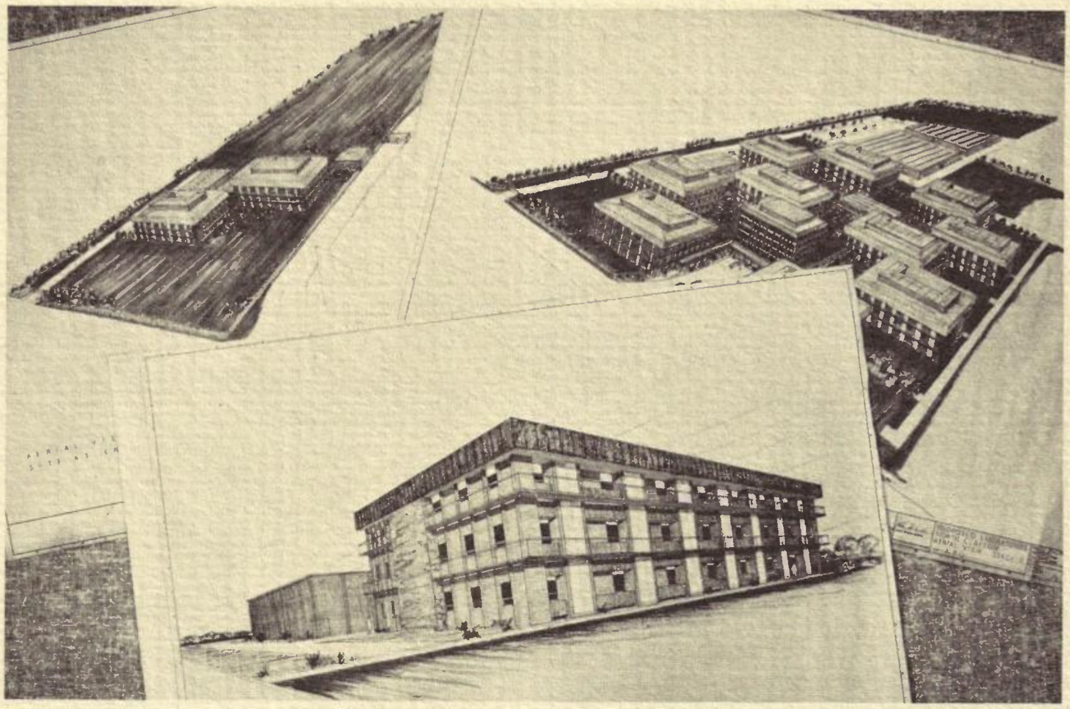
The invention of the transistor by Shockley, Bardeen and Brattain in 1948 was followed soon after by increasing use of these and later generation semiconductor devices in the realisation of experimental systems in the Laboratories. This is particulary evident in the growth of expertise and activity in the Laboratories in the investigation and development of digital electronic switching and transmission techniques and systems. In particular, this advance was responsible for the Laboratories becoming heavily committed in the technology of future generation all-electronic exchange systems.

Over the years, the Laboratories have also come to house Departmental specialist groups. One such is the physical sciences group, which, from a modest beginning under D. O'Donnell in 1931, has grown to comprise physicists, chemists and metallurgists capable of conducting a wide variety of material investigations and evaluations and equipped with advanced analytical and environmental test facilities. This group played an important role in the years during and following the war, when it provided specialist advice and investigational facilities to assist with the many problems being encountered by the infant telecommunications equipment and cable manufacturing industries. Other such groups include those whose task it is to maintain, develop and apply the Departmental reference standards of time interval and frequency, and of electrical calibration, with the precision required of national verification bodies.

The Laboratories have kept pace with the expanding frequency spectrum, technological developments and the increases in A.P.O. services. They now employ a total of 533 staff, comprising 122 professional engineers, 28 professional scientists and 5 librarians, together with 170 supporting technical staff in both the scientific and engineering disciplines and 26 tradesmen. Computer programmers number about 25, the administrative staff totals 41, and

◀ PRESENT HEAD OFFICE OF THE LABORATORIES AT 59 LITTLE COLLINS STREET, MELBOURNE.

ARCHITECTS' SKETCHES OF PROPOSED NEW LABORATORIES' BUILDING AT CLAYTON.



the Engineering Library, which renders its services to all engineering groups in Headquarters and the States, has a total complement of 31 librarians, library officers and clerical staff. Trainee technical and trade staff number about 70 and are engaged in a variety of courses.

The Laboratories have outgrown the present accommodation and plans are well advanced to re-establish them in a number of stages, commencing in 1975, in new, specially-designed laboratory buildings to be built on an A.P.O. site in Blackburn Road, Clayton — adjacent to Monash University.

One measure of the effectiveness of a Laboratory is the eagerness of its staff to communicate the results of their work, both in Departmental publications and in journals of learned societies. In the fifty years of their existence, the Laboratories have published about 7,000 Research Laboratories' Reports. These form the official record of the work of the Laboratories. The number of contributions to journals, both national and international, also runs into many hundreds. This is evidenced, in particular, by the continuing role Laboratories' officers have played in the Telecommunication Society of Australia, and by their frequent contributions to its publications, The Telecommunication Journal of Australia and Australian Telecommunication Research (A.T.R.). Laboratories' staff have been prominent editors and contributors to the Journal since it was first produced in 1935, and the society's more recent publication, A.T.R., was in fact started following initiatives taken by the Laboratories.

This outline of the history of the Laboratories cannot do justice in a few pages to fifty years of activity. Hence the pages which follow recall in a little more detail the history of specific pursuits engaged in over the years. The occasion of the Golden Jubilee of the Laboratories is considered one which justifies more extensive reflection on our past, thus enabling us to step into the future with renewed vigour and enthusiasm.

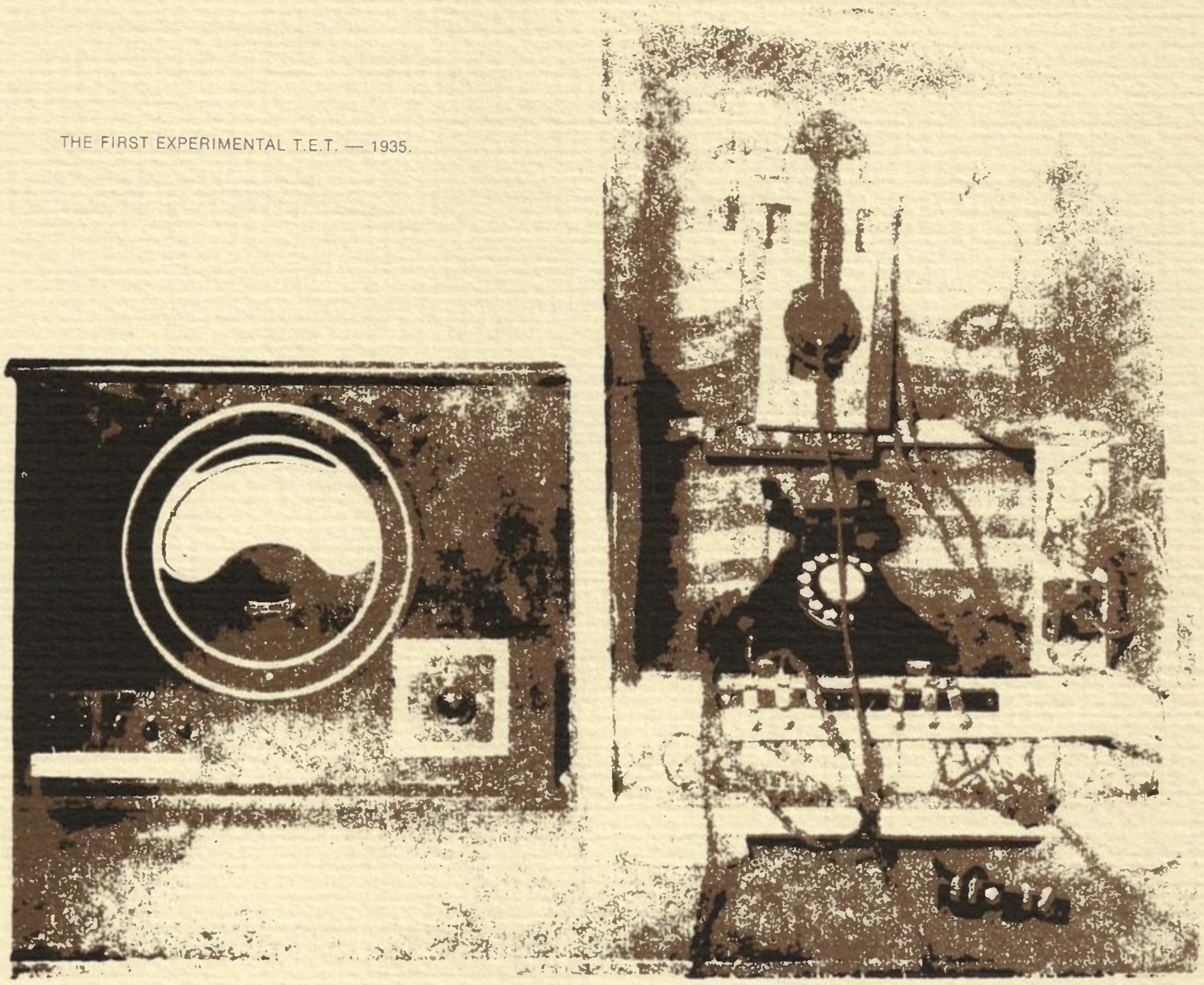
Telephone Transmission & Switching Activities

SENDING END COMPARISON USING A.P.O. N.O.S.F.E.R.

THE DEVELOPMENT OF THE A.P.O. TELEPHONE AND TRANSMISSION STANDARDS

A telephone network requires a transmission planning standard to guarantee satisfactory communication between any two subscribers and telephone acceptance testing standards to ensure that the equipment purchased is capable of giving the planned performance. The determination of these standards has been a continuing function of the Laboratories since their inception.
The first A.P.O. national planning standard was set up in 1923 and followed typical British practice. It was defined in terms of a candlestick telephone type 38 CBT, with a solid-back transmitter and a Bell receiver, connected by a 300 ohm non-reactive line to a 22 volt Hayes feeding bridge and thence through 24 miles of standard cable to a similar local end. This circuit represented the limiting condition for any call within the network. This work was further consolidated in 1927 through the efforts of S. H. Witt and E. P. Wright and published in Research Laboratories Report No. 18.
At this time, the only way in which the performance of telephones could be measured was by a time-consuming speech or "voice-ear" comparison with sealed samples of similar telephones. Large organisations such as the British Post Office (B.P.O.) and the American Telephone and Telegraph Corporation (A.T.&T.) maintained hierarchies of such standard telephones, rating them by voice-ear comparison with each other. These subjective and rather empirical methods were due to the difficulty of measuring speech voltages in those days and the complex nature of the parameters to be measured.
To control the quality of telephones purchased for the A.P.O. network, seven sets of standardised components were obtained from the B.P.O. in 1925 to set up the A.P.O. standard, it being envisaged that voice-ear testing would have to be used in each state. Voice-ear methods were too slow for production testing, and so the Research Laboratories began to develop a Telephone Efficiency Tester (T.E.T.). This was largely the work of G. N. Smith. In 1935, an experimental version was sent to Sydney to test deliveries of the new anti-sidestone handset telephone type 162. A new transmisssion standard had been issued embodying the new telephone and replacing the old standard cable junction by a 600 ohm attenuator. It was known as the Standard Grade of Local Line Transmission and this circuit was embodied in the T.E.T. The T.E.T. was actually a transfer instrument, deriving its standardisation from a daily "line-up" with working standard handsets, calibrated by voice-ear volume balances against Reference Standard Handsets obtained from the

THE FIRST EXPERIMENTAL T.E.T. — 1935.



B.P.O. Each of the State Workshops and Inspection Laboratories were progressively equipped with the T.E.T. R1A from 1939 under the direction of P. J. Killey.
In the early 1940's, a new "equalised" receiver type 2P with greatly improved frequency response was introduced and appropriate new Reference Standards were obtained from the B.P.O. The use of the receiver in the 300 series telphones improved its intelligibility and allowed it to be used on longer lines.
During the late 1940's, a voice-ear technique known as Immediate Appreciation, a type of sentence articulation test, was introduced by J. C. Wilson and D. A. Gray and used to set up the present transmission standard. This standard comprised the 300 series telephone, a realistic local line, a 50v Stone feeding bridge and a 600 ohm junction. It also introduced a new concept of 60 phons of ambient room noise at each end of the overall system.
In 1957, another improved receiver design, the rocking armature type 4T, appeared. This receiver had somewhat better frequency response than the type 2P and much greater sensitivity, enabling the 400 series telephone in which it was used to be installed on longer lines than could the 300 series.
The original Laboratories-designed R1 T.E.T.'s remained in service from 1939 until 1962, when a new version, type R3, was introduced concurrently with the Australian 801 telephone. This T.E.T. was also designed and developed in the Laboratories by R. W. Kett.
During the war years, contact with B.P.O. standards was lost and it was subsequently found that the A.P.O. standards had drifted. This served to highlight the hazards of depending on an overseas authority.
In 1959, the B.P.O. issued transmitter and receiver specifications in physically-realisable terms for the first time. It was decided therefore that these should be used to standardise the R3 T.E.T. and the A.P.O. became independent of B.P.O. calibrations.
In 1966, the Laboratories, under E. J. Koop, had developed and completed the installation of the A.P.O. primary reference standard, similar to the international N.O.S.F.E.R. standard held at Geneva, enabling us to make our own determinations of Reference Equivalents. The N.O.S.F.E.R. speaking position is now considered unrealistic, and a modified method to obtain "Effective Reference Equivalents" for A.P.O. planning purposes is a current subject of investigation in the Laboratories.

NOTABLE ACHIEVEMENTS IN MULTICHANNEL SYSTEMS

The first staff members of the A.P.O. Research Laboratories busied themselves with the immediate problem of the time — the application of the thermionic valve to the provision of equipment to cope with circuit growth in a trunk line system which was rapidly growing. Today, on intercapital routes, it doubles its size every four years.

Soon after the establishment of the Laboratories, S. H. Witt was a member of the team which installed the first multichannel carrier system on the Sydney-Melbourne route. Known as the B type carrier telephone system, it was a 3-circuit system using single sideband amplitude modulated channels with transmitted carrier. Transmitting channel carriers in a multichannel system involves a waste of power-handling capacity in repeating amplifiers and this system was superseded a few years later by the type C system which transmitted suppressed carrier channels and used common amplifiers at repeater stations for all three channels. (H. S. Black's invention of negative feedback, which made possible highly linear wideband amplifiers and transformed the economics of broadband systems, was patented in 1927.)

The next decade saw the development of the Department's network of multichannel telegraph systems. This started in 1928 with the establishment of a type B carrier telegraph system which provided 10 duplex circuits in the frequency band 3.3 to 10 kHz, and was soon followed by voice frequency carrier telegraph systems which could be superimposed on one circuit of a carrier telephone system. The Laboratories' expertise in carrier telegraph system grew during the thirties and was used to good effect during World War II with the development of the type R (4-channel) telegraph system which operated in the band 3.0 to 5.2 kHz. The first of such systems was brought into service on the Alice Springs to Darwin open wire route at the time of the first enemy air raid on Darwin in February 1942. Shortly afterwards, the A.P.O. commenced construction of 9-channel voice frequency carrier telegraph systems. These were used extensively all over Australia to provide circuits for the fighting services. Filters for these systems were designed and constructed in the Laboratories under the leadership of E. H. Palfreyman.

The year 1935 saw the installation of a co-axial submarine cable between Victoria and Tasmania. The Department was represented on the installation team by a Laboratories' engineer, G. N. Smith, later to become Director, Posts & Telegraphs, Victoria. A notable world first was achieved with the laying of the cable from Apollo Bay, Victoria, to Perkins Bay, Tasmania, via King Island. It was then the longest submarine cable in the world. Initially, the cable operated on a bandwidth to 40 kHz. In 1954, this was increased to 108 kHz to extend its capacity to 15 channels. This was achieved by the installation of a special 9-channel carrier system which was designed and constructed in the Laboratories under the direction of L. M. Harris, who later became Head of the Laboratories.

In 1948, W. Shockley, J. Bardeen and W. H. Brattain of the Bell Laboratories announced the invention of the transistor. This produced an immediate reaction in the A.P.O. Laboratories and resulted in the first technical paper on the subject being presented by D. A. Gray to the Postal Electrical Society of Victoria in 1949.

Promising applications of the transistor were foreseen and after junction transistors became available commercially, development work on transmission applications commenced in 1954 under J. C. Wilson. Field trials of plant equipment prototypes started soon after. This experience with transistor circuits provided the A.P.O. with the expertise it needed in the evaluation of the first commercial transistorized carrier systems (for rural circuits) which were introduced in 1958. Laboratories' designs were used

A.P.O. STAFF RESPONSIBLE FOR THE INSTALLATION OF THE FIRST 3 CHANNEL CARRIER SYSTEM ON THE SYDNEY-MELBOURNE ROUTE — 1925.
STANDING: H. S. ROBERTSON, H. A. BROWN, N. J. McCAY, F. R. BRADLEY, R. SCOTT, R. J. BUSSELL.
SEATED: E. S. HOWSON, R. N. PARTINGTON, S. H. WITT, J. H. DURRANT.

for a single channel carrier system installed between Normanton and Burketown in 1959 and for pole-mounted repeaters for the first 12-circuit open wire carrier systems (for rural circuits) which were Darwin in 1961.
During the late 1950's and early 1960's, the properties of the transistor were leading to renewed interest in logic circuits and pulse coded transmission systems generally. After early work by H. S. Wragge and F. W. Arter on delta coding, the Laboratories made intensive studies of the Australian application of pulse code modulated (P.C.M.) systems during the early 1960's. Field trials of commercial P.C.M. systems commenced in 1967.
In recent years, the transmission systems effort in frequency division multiplex systems has been largely transferred to time division systems such as that used for P.C.M. However in 1968/69, the Laboratories re-designed and supervised the construction of a 24-channel 2 kHz spaced frequency division multiplex system (the "Channel Doubling" system) for use in North-Western Australia. In addition, the novel "carrier burst" method of measuring high frequency characteristics of cable was developed.

A LABORATORIES' HISTORY OF SWITCHING AND SIGNALLING

There was little real activity in matters concerned with the broad aspects of switching and signalling until the mid-1950's, when H. S. Wragge joined the Research Laboratories. At that stage, the transistor had just become commercially viable and its potential was being explored in numerous small investigations.

In 1960, a resonant transfer switch which provided a low loss bi-directional electronically-switched connection was developed out of one of these investigations. It had potential for use as the basis of a time division multiplexed telephone exchange, and a fully solid state model exchange was developed in 1961 by H. S. Wragge, F. W. Wion, F. W. Arter, and R. Smith.

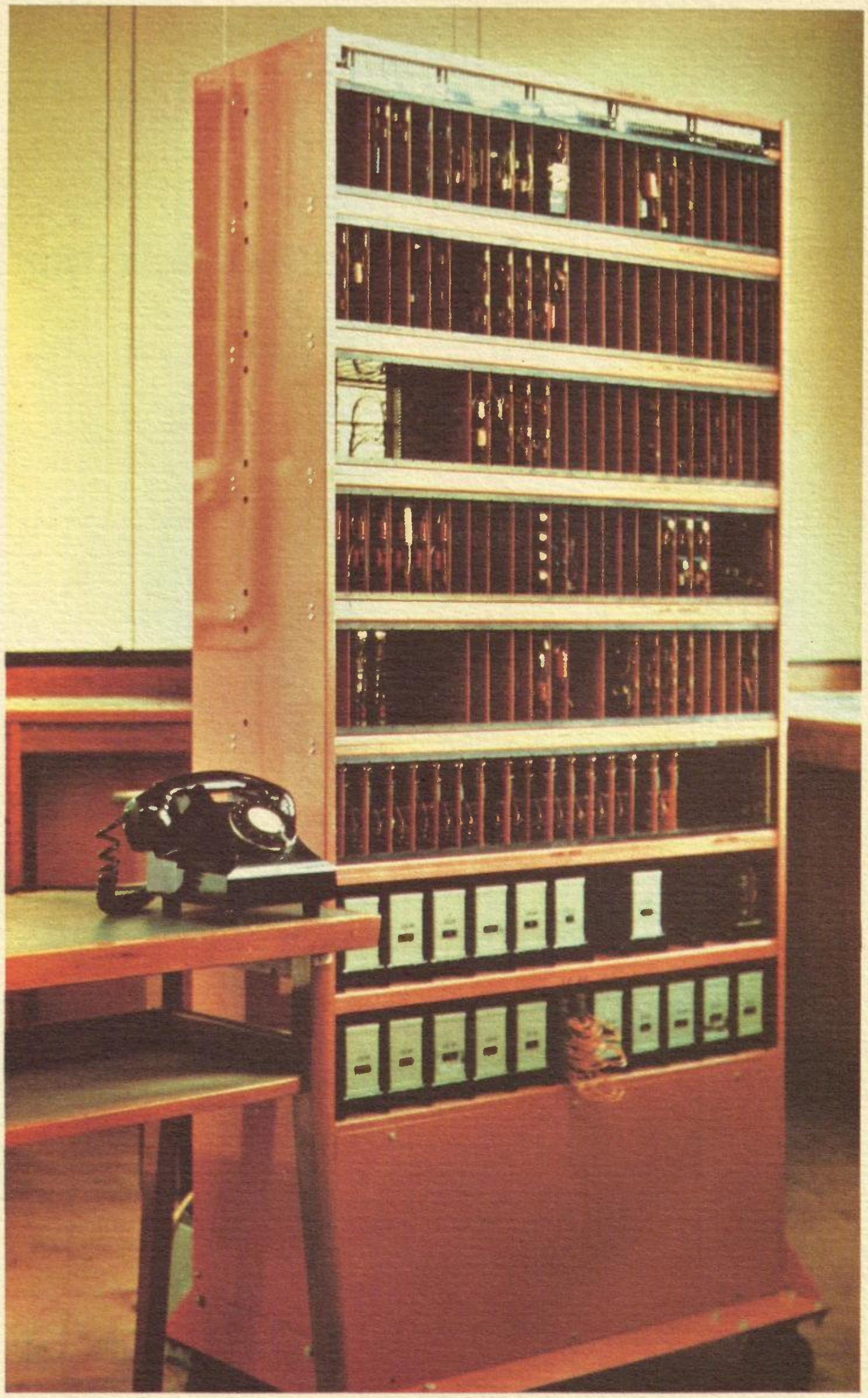
This model exchange had 20 lines and utilised a modified telephone in which an acoustic caller was used in place of the telephone bell. The exchange was placed into service within the Switching Group and interconnected with the Melbourne telephone network, thus providing a centrex type PABX function. The model exchange was used for a number of investigations and system studies during the next few years. The resonant transfer technique was also actively studied by a number of groups engaged in the development of electronic switching equipment overseas, but was eventually discarded because it limited the maximum size of telephone exchanges to about 10,000 lines, besides adding a small loss of about 2 to 3 dB per switched connection.

The next major involvement of the Switching Group was the consideration of a proposal that an experimental network of electronic exchanges should be established at Lowood in Queensland in the mid-1960's. However, this proposal was subsequently dropped, and the Switching Group became involved with the considerations which ultimately led to the purchase of 10C type equipment for use in trunk exchanges.

LABORATORIES' EXPERIMENTAL 20-LINE ELECTRONIC EXCHANGE (S.C.A.T.S.) — 1961.

In the mid-1960's, the current Integrated Switching and Transmission (I.S.T.) project was formulated and development work was commenced. The project is described more fully under Current Activities.

In 1967, a Laboratories engineer, G. L. Crew, attended a C.C.I.T.T. "group of seven" meeting in Geneva. This was a meeting of seven international signalling experts who were charged with the preparation of the specification of C.C.I.T.T. Signalling System No. 6. This work continued until 1972, when the specification was accepted at the C.C.I.T.T. Plenary meeting. An international field trial co-ordinated by the C.C.I.T.T. was conducted during the 1968 to 1972 period, and the Research Laboratories participated in both theoretical studies and assessments and in practical testing of the specification by means of a special trial exchange. The exchange was specifically developed to utilise the new C.C.I.T.T. Signalling System No. 6 and was used in tests which formed part of the international field trial, as well as in tests of the new signalling system for handling national trunk calls. This exchange earned the two distinctions of being the first to utilise processor control in the switching



of telephony in Australia and of handling the most live traffic calls of any of the special exchanges taking part in the international field trial.

In the early 1970's, the Switching and Signalling Branch also became actively engaged in the development of special purpose solid state devices for switching applications. Work on devices by I. P. Macfarlane, A. Domjan and N. McLeod provided initial support for the Department of Supply in their successful attempts to have local industry set up diffusion facilities for the production of integrated circuits.

The Expanding Frequency Spectrum

MEASURING RADIO FIELD STRENGTHS AT
3LO TRANSMITTING STATION, BRAYBROOK, VICTORIA — 1923. ▶

THE ROLE OF THE LABORATORIES IN THE RADIO FREQUENCY DOMAIN

From their early years, the Laboratories have grown with the exploitation of the radio frequency spectrum. The initial involvements were in the field of radio broadcasting. Following a transition period in the World War II era when attention was turned to the development of wartime applications of the newly-realised radar principles, the emphasis in the Laboratories turned more to work associated with the introduction of radio telephone systems into the trunk network. The common thread binding these activities over the years has been the work on propagation path evaluation and research into propagation phenomena.

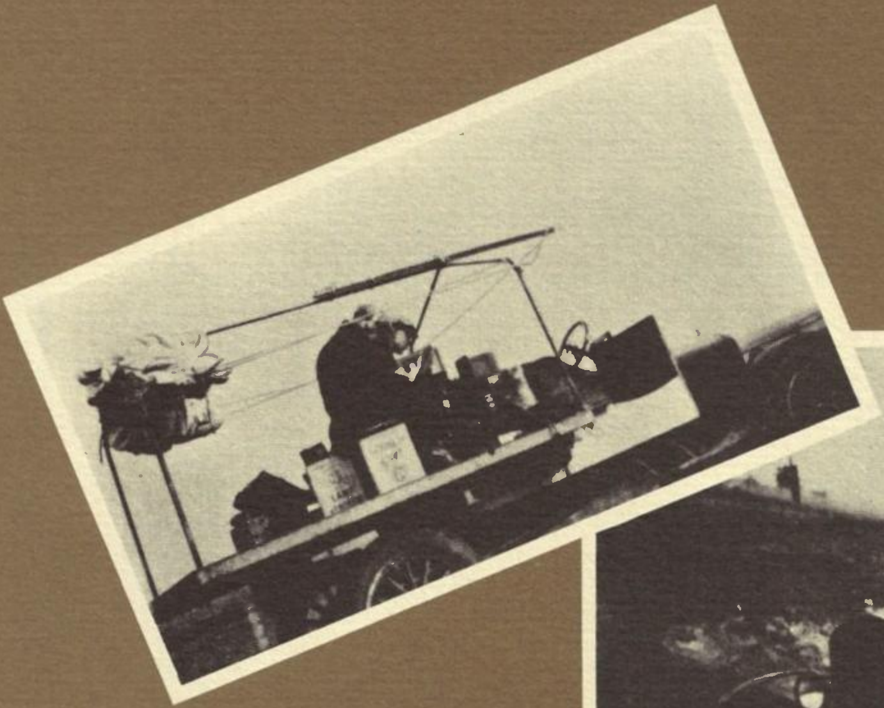
Radio broadcasting in Australia started officially on the 23rd of November, 1923, when 2SB, later 2BL, commenced transmission in Sydney. Stations 2FC and 3AR followed shortly after. Thus, the Laboratories and radio broadcasting in Australia were infants together.

Possible broadcasting systems were the subject of much discussion in the early 1920's, with Amalgamated Wireless (Australia) Ltd. the main private contributor. In 1923, a conference of those interested in broadcasting had determined that the Australian broadcasting system should be based on the "sealed set" and that each station would be maintained by its listeners' licence fees. This sealed receiver scheme was abandoned after 12 months trial, when the licensed listeners numbered 1400 and only one more station, 6WF, had been established.

In July 1924, new broadcasting regulations established A-class stations maintained by licence revenue and B-class stations supported by advertising revenue, with operation confined to the band between 150 and 1200 kHz. The benefits of using the "long wave" end of the band were under debate then and for some time later. The early rate of Australian broadcasting progress is evident from the fact that by 1925, there were 8 A-class and 6 B-class stations with 64,000 listeners.

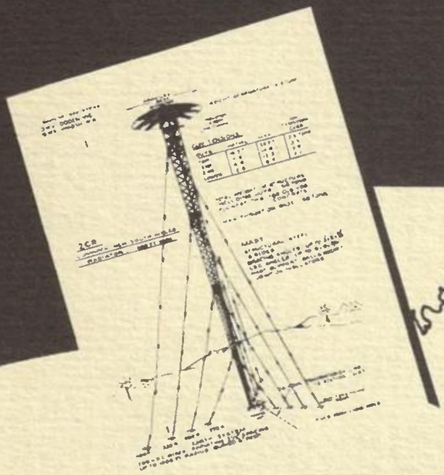
At this time, the Laboratories were guiding the development of the long-distance trunk network, and the potential use of the telephone network to provide programme links between broadcasting stations was speedily recognised. As early as 1925, Laboratories' staff were involved in the transmission of radio programmes over the trunk network, achieving an Australian first by engineering the first simultaneous broadcast from 6 stations of a War Loan Conversion Appeal by the Secretary to the Treasurer, J. R. Collins, who spoke from the Melbourne Trunk Exchange on 20th August. On 9th May 1927, a more ambitious hook-up was achieved by Laboratories' staff to enable the Opening of Parliament House, Canberra, by the then Duke of York, to be broadcast to the nation.

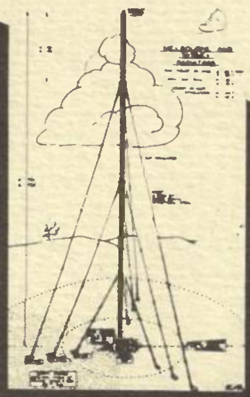
By 1926, radio frequency investigations had been



started in the Laboratories, with R. B. Mair, later the first Director of Technical Services, Australian Broadcasting Control Board, examining broadcast interference from country exchange equipment.
Weaknesses of the second broadcasting scheme were also becoming evident, in that service to less populous areas was being neglected by the commercial broadcast operators, who were confining their interest mainly to the capital cities. These and other considerations led to the 1927 Royal Commission on Wireless. Among its many recommendations, it urged that further research be conducted to assess the relative merits of high power stations and relay stations as soon as possible. At the time, radio research was being conducted by A.W.A., and the A.P.O. Research Laboratories, and under the auspices of the Radio Research Board of the Council for Scientific and Industrial Research.
Mutual co-operation and interworking of the broadcasting stations did not follow as the Commission had hoped, and in July 1928 the Government stepped in to announce its plan to establish a partly national scheme by acquiring the A-class stations, leaving only the B-class stations to commercial operators.
The Post Office was made responsible for the technical operation of the A-class stations and S. H. Witt of the Laboratories was seconded to head a team to plan this new network, the National Broadcasting System, with the object of giving reliable service to 90% of the population. In the initial stages of the task, the team was also given construction responsibilities. Programme provision was entrusted to the Australian Broadcasting Company, specially formed for the task. When their contract expired on 30th June, 1932, their role was taken over by the Australian Broadcasting Commission.
Up till this time, the Laboratories had both investigated, planned and installed all new systems in the telephone trunk network. With the increased workload, a Transmission Section was formed in September 1928 to handle the installation and maintenance of new

THE PLANNING & IMPLEMENTATION OF THE NATIONAL BROADCAST SYSTEM (N.B.S.) ENGAGED THE ATTENTION OF LABORATORIES STAFF BETWEEN 1928 AND 1938.





equipment. This new section was the forebear of the present Long Line Equipment and Radio Branches of the Engineering Works Division. The Research Section was still responsible for the supervision of initial installations of new equipment types and their research studies extended to the propagation of radio waves.

In planning the N.B.S., the Laboratories first made propagation studies over the continent, considering factors such as atmospheric noise levels, soil conductivity and ionospheric conditions. Since overseas countries were at the same stage of development of their systems and because of the unique Australian population spread, little help was forthcoming from overseas, and one of the first actions of the Laboratories was the establishment of field measuring equipment which was used to optimise the system layout as it was devised. After consideration of both the "long wave" band (150-300 kHz) and the "medium wave" band

(550-1500kHz), the latter was selected for the N.B.S. Early data on soil conductivity was obtained by ground-wave attenuation measurements, first conducted by A. J. McKenzie as early as 1927, and by D. McDonald, later to become a member of the Australian Broadcasting Control Board, about 1936. Measurements extended from Perth to Cairns. Transmitters were designed and specified for supply by tender. Studio design and evaluations of studio equipment were also undertaken, and L. M. Harris did much of this work in the early 1930's.

Recognising that M. F. service to remote areas was not feasible, the Laboratories established an experimental short wave (9.5 MHz) station at Lyndhurst, Victoria, in 1928. It went into regular service in 1934, and the Laboratories were responsible for upgrading the equipment and service in 1938.

During the 1930's, much work was directed at reducing noise and distortion in studio equipment and in programme channels, and at programme switching systems. Aerials for the N.B.S. transmitters also received particular attention and A. J. McKenzie developed top-loaded vertical radiators with improved anti-fading properties. Four of these aerials were later installed, the first at Grafton, and with heights ranging from 400 to 730 feet, they were then the tallest engineering structures in Australia. Laboratories' studies extended beyond their electrical aspects into both structural and foundation problems.

Early in 1941, the Australian government agreed to establish a high power short wave transmitting station in Australia to broadcast to the nearby Pacific Islands and to South-East Asia.

Again, S. H. Witt was asked to plan the station — now known as Radio Australia. Radio propagation factors, security from attack, and other factors such as the availability of power and water led to the choice of the Shepparton site. Laboratories and Workshops staff combined to design and set up the station, and by May 1944, it was operating with a 50 kW RCA transmitter. Leading roles were played by A. Kline and R. B. Mair. Shortly after, the transmitted power was increased by the installation of two main transmitters of 100-140 kW by S.T.C. and A.W.A. as a joint venture. The transmitters operated over the frequency range 6-22 MHz and the 19 antenna arrays were remotely switched. The high powers involved required the solution in Australia of problems for which there were no known solutions.

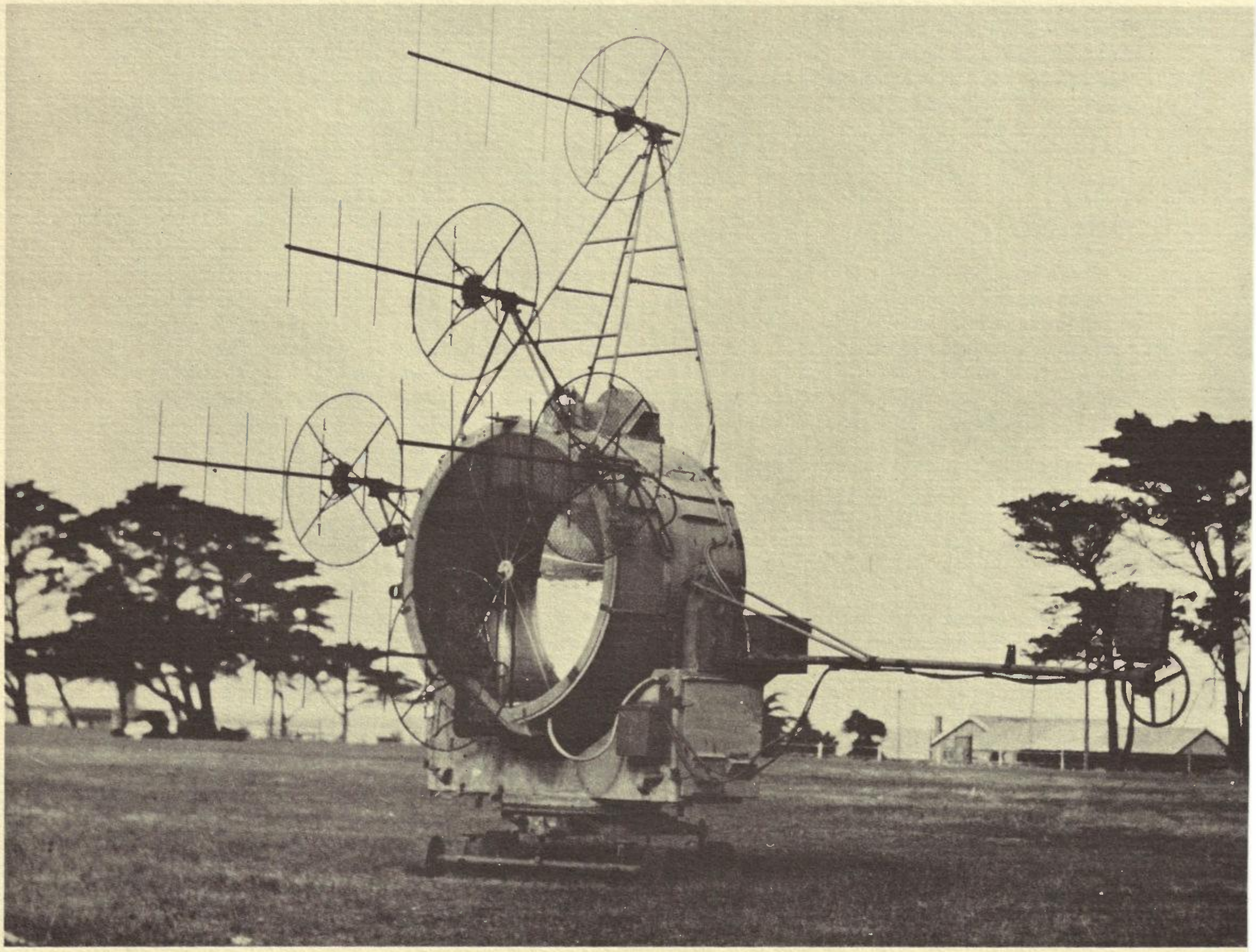
With the outbreak of World War II, a significant section of the Laboratories turned to investigations and developments of radar and radio communications systems for the armed services. Radar systems for gunnery and searchlight control, and airborne and naval identification "friend or foe" radar units were subjects for a number of investigations; some of the units were designed and developed for Australian manufacture. Messrs J. D. Campbell, E. J. Stewart, T. H. Skelton, M. R. Stradwick, J. Fisher, R. Pitkethly and others were involved in this work. Radio transmitters and receivers for air, ground and armoured tank service were evaluated. A special radio receiving station for overseas transmissions was designed and installed at Werribee, Victoria, for the joint use of the R.A.A.F., D.C.A. and the A.P.O. With 31 aerials, this station used remote-controlled aerial switching and aerial amplifiers, which were then significant advances on current practice. Radio and transmission line systems were developed for 7 other R.A.A.F. stations and L. M. Harris and the late R. Buring were particularly concerned in this work. VHF radio direction-finding equipment was also designed and installed for the R.A.A.F.

In 1937, just prior to the war, the first work in the radio telephone field had commenced, with 40 MHz propagation measurements between Tanybryn on the mainland and Stanley in Tasmania being undertaken by A. J. McKenzie and D. McDonald. These demonstrated the feasibility of a multichannel radio link which was realised several years later as a 12 channel A.M. system. Several VHF single channel 40 MHz systems were installed to link Tasmania and Flinders Island in 1942, and the Melbourne broadcast studios with their transmitters in 1945.

In the years following the war, considerable interest was focussed on pulse modulated UHF systems. Between 1944 and 1946, a 3-channel 2 GHz microwave system was developed by J. Campbell, J. McLeod and F. Orr using klystrons and components from the radar field. It was used for experiments between the Laboratories and their field site at Mont Park, and this work lent valuable experience to the specification of the 23-channel pulse modulated systems later supplied by S.T.C. and installed in Victoria, New South Wales and Queensland. About 1946, the Laboratories also joined in an Army trial to establish an experimental link between Melbourne and Sydney using a pulse modulated microwave system (the No. 10 Set) following propagation tests with this equipment over Port Phillip Bay.

From 1946, Messrs. Moriarty and Hyamson concentrated on radio propagation studies, and other investigations concerning VHF 160 MHz mobile services were made by N. Feltscheer. Much work was done to evaluate paths to improve the link between the mainland and Tasmania. This led to the rejection of King Island as a repeater site and to the choice of the present Wilsons Promontory-Flinders Island-Tasmania route, which was equipped using an

RADAR CONTROL SYSTEM FOR DIRECTING SEARCHLIGHTS — DEVELOPED DURING WORLD WAR II.



80-80/160 MHz Marconi System in 1954. This work involved the design and construction of new aerials and the development of two 160 MHz power amplifiers by the Laboratories.

Propagation studies next centred about 3 and 9 GHz and in 1949, they found application in testing five paths for the Sydney-Goulburn system.

The possibility of a Sydney-Melbourne microwave relay system was under close investigation in 1950, and J. Reen, K. Hamilton and K. Faragher undertook path evaluation studies for the Albury-Wagga and Euroa-Dookie sections of the route, where propagation problems were anticipated.

The work of the Laboratories in its radio path evaluation role has continued to the present day and has not only consisted of measurement activity in the field, but much of the test equipment has been designed and constructed in the Laboratories since it has not been available commercially. To list all path evaluation projects in the space available is impossible, but some other examples of this activity at a variety of frequencies include field strength surveys at 160 MHz to predict Melbourne TV coverage by the Mt. Dandenong transmitters in the mid-1950's; aerial height-gain measurements at 4 GHz for the Sydney-Wollongong-Goulburn route; ionospheric scatter studies at 42 MHz between Hobart and Sydney in co-operation with C.S.I.R.O. in 1959; trans-horizon tropo-scatter studies at 810 MHz between Melbourne and Launceston in the early 1960's, and tests at 450 MHz for the Tasmania-King Island route in the mid-1960's. Between 1966 and 1970, much path evaluation effort was contributed to the planning of the East-West microwave relay route, and more recently of the Townsville-Mt. Isa-Darwin route and the Carnarvon-Port Hedland route, Western Australia.

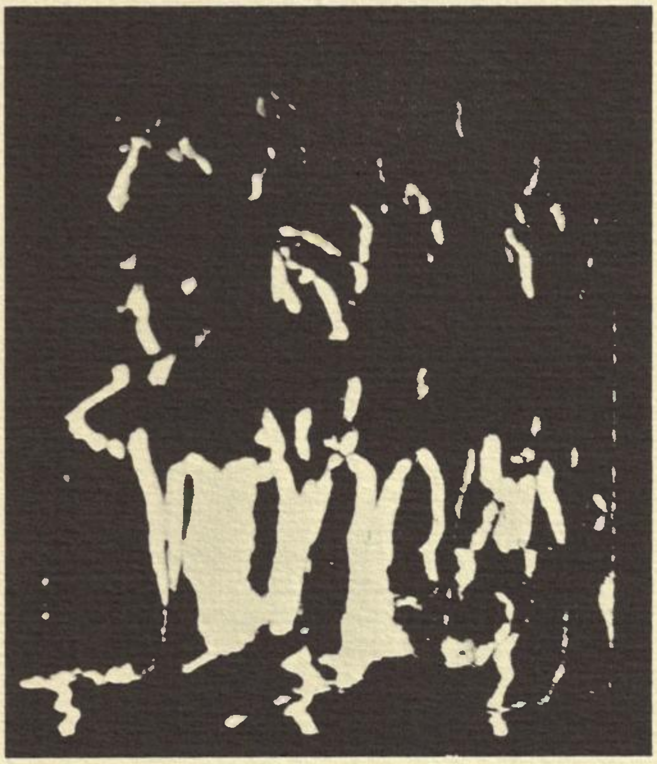
The year 1969 saw further work at 2 and 4 GHz across Bass Strait and this work is still a current project in the task of extending the existing links to Tasmania.

In the radio-meteorological investigations on the Nullabor and Townsville-Mt. Isa routes, a most fruitful liaison was established with the Meteorological Bureau, whose scientists co-operated in the meteorological component of these studies. This co-operation continues in rain attenuation studies currently being conducted in Queensland. These investigations use the sun as a signal source, and the solar radiometer and much of the automatic tracking antenna gear and data-logging equipment for these tests has been designed and constructed in the Research Laboratories. These tests have particular importance in the present A.P.O. studies in preparation for an Australian national satellite system.

An earlier and interesting propagation study occurred in 1969 when the Laboratories joined with the Department of Supply in tests of HF, VHF and microwave frequency transmissions through a deliberately lit "bushfire" at Rockhampton. These tests arose out of complaints by firefighters that, during a serious bushfire near Geelong in the previous summer, the loss of radio communications had contributed to the loss of several lives. However, the tests showed only that some sub-refractive bending of rays might occur in a very intense fire and that this was unlikely to be a serious problem in practical situations.

Work on radio systems has been overshadowed somewhat by the work of developing propogation measuring equipment. However, over several years from 1953, the Laboratories designed and constructed a 900 MHz 120-channel radio system which was installed for a time between Korrumburra and Mt. Oberon. This was done to allow the Marconi system across Bass Strait to take extra channels whilst the submarine cable link was being repaired after a serious failure. In more recent years, the systems aspect has received greater attention, and several single channel systems have been and are being developed for evaluation in special purpose applications in the outback, particularly by O. Lobert, R. Smith and A. M. Fowler. One such system is a delta-modulated 900 MHz system and another an experimental 160 MHz F.M. system, which was evaluated in a field trial installation at Winchelsea, Victoria. Current work involves aspects of the potential use of satellite systems for outback services and of mobile radio services.

TV - TRANSMISSION — BANDWIDTH COMPRESSION



After some early exploratory work in the late 1930's, the Research Laboratories from 1947 onwards became intensively engaged in the examination and development of Australian television service and systems standards, and in 1948 recommended a 625 line systems standard, which was similar to the C.C.I.R. TV-standard later adopted for the introduction of TV in Australia in 1956.

Government policy on television led to a reduction of effort in 1949 and work in the Laboratories was concentrated on high-speed waveform and time-domain network investigations which provided the engineering expertise and knowledge-base for the Department when television services were established in 1956. At the same time, it became obvious that television relaying would eventually become an important part of the A.P.O.'s telecommunication operations. Thus, most of the Laboratories' effort in the television field was concentrated on the unique problems that would arise from the long distances such relay links would have to span in Australia.

Investigations of waveform techniques and instrumentation for transmission performance specification, testing and equalisation, provided the Department with the knowledge and equipment which in concepts and hardware were at least equal to, if not in advance of, overseas developments. Typical of these achievements was the "pulse and bar" waveform test concept which was contained in the "Video Transmission Test Set" developed by A. J. Seyler and J. Potter in the early 1950's. Later, the first all solid state operational pulse and bar waveform test signal generator was developed by the Laboratories and manufactured by Australian industry for installation and use in the A.P.O.'s network, and was also exported in the mid-1960's.

Simultaneously, the problem of long distance TV-relaying motivated early fundamental research on the problem of reducing the bandwidth of television signals. This was initially inspired by the concepts of Shannon's Information Theory (1948) and followed the ensuing developments of statistical signal coding and processing concepts. Although early work on applying these concepts to television signals caused great optimism, it soon became apparent that the highly time variant small sample statistics of the television signal, the need for maintaining the real time information flow between source and receiver, and the associated interacting phenomena of human

PICTURE TUBE DISPLAYS OF TV FRAME DIFFERENCE SIGNALS — 1963
ABOVE: HEADS & SHOULDERS OF TWO MEN.
OPPOSITE: HORSES & RIDERS.

visual perception made the direct application of theoretical concepts less effective than predicted. Basic research work in the Laboratories by A. J. Seyler and Z. L. Budrikis was then directed towards the time variant nature of the information flow of television signals and the related visual perception phenomena. This led to the development of the concept of "adaptive parameter coding", with experimental work concentrating on spatial detail perception and presentation in moving images, and on the statistics of television frame differences.
The publications of the results of this work in the late 1950's and early 1960's, established the Laboratories as one of the major contributors to research in the field of television signal coding, together with Bell Telephone Laboratories, Massachusetts Institute of Technology and Imperial College.
It is only in most recent times that a number of these basic research results are being practically applied and their validity experimentally confirmed, both here, by J. O. Limb, J. Hullett, W. Lavery and J. Craick, and overseas, since only now has the electronic technology become available for economic practical realisation. Moreover, the development of operational systems for the reduction of the channel capacity required in TV-signal transmission has gained renewed impetus from the use of television communication techniques for person-to-person (Videophone, TV-Conference), educational and other visual information transmission applications.

THIRTEEN YEARS OF SATELLITE SYSTEMS RESEARCH

The first two-way voice conversation by satellite used the passive ECHO 1 balloon in August 1960. This achievement fired the imagination of communicators throughout the world because it showed that space techniques could be developed to give high quality telecommunication services spanning thousands of miles. Australia, being a large country and separated from other land masses by major oceans, was especially interested in what satellites could offer to assist the build-up of the internal and external communications network. Thus, when news of the successful ECHO experiment arrived, the Research Laboratories started a study to survey the possibilities opened up by satellite methods. The results of this first study were published in an Information Bulletin and in an article in the Telecommunication Journal of Australia in 1961.

Passive satellites, which merely reflect the signal from the transmitting station towards the receiving station, have some serious limitations. All modern communcation satellite systems therefore use active satellites which amplify the signal before re-transmitting it to the receiving station on earth. The forerunner of active satellites for commercial communications was TELSTAR 1 which in July 1962, allowed for the first time the exchange of standard television signals over inter-continental distances virtually instantaneously.

There were three earth stations co-operating in the TELSTAR experiments — Andover in USA, Goonhilly in England and Pluemeur-Bodou in France. The Goonhilly station was designed and built as a British Post Office project but the A.P.O. Research Laboratories were given an opportunity to contribute. E. R. Craig was loaned to the project and was responsible for the transmitter installation, thereby participating in the historic first exchange of television and telephony signals between the U.K. and the U.S.A. via TELSTAR 1.

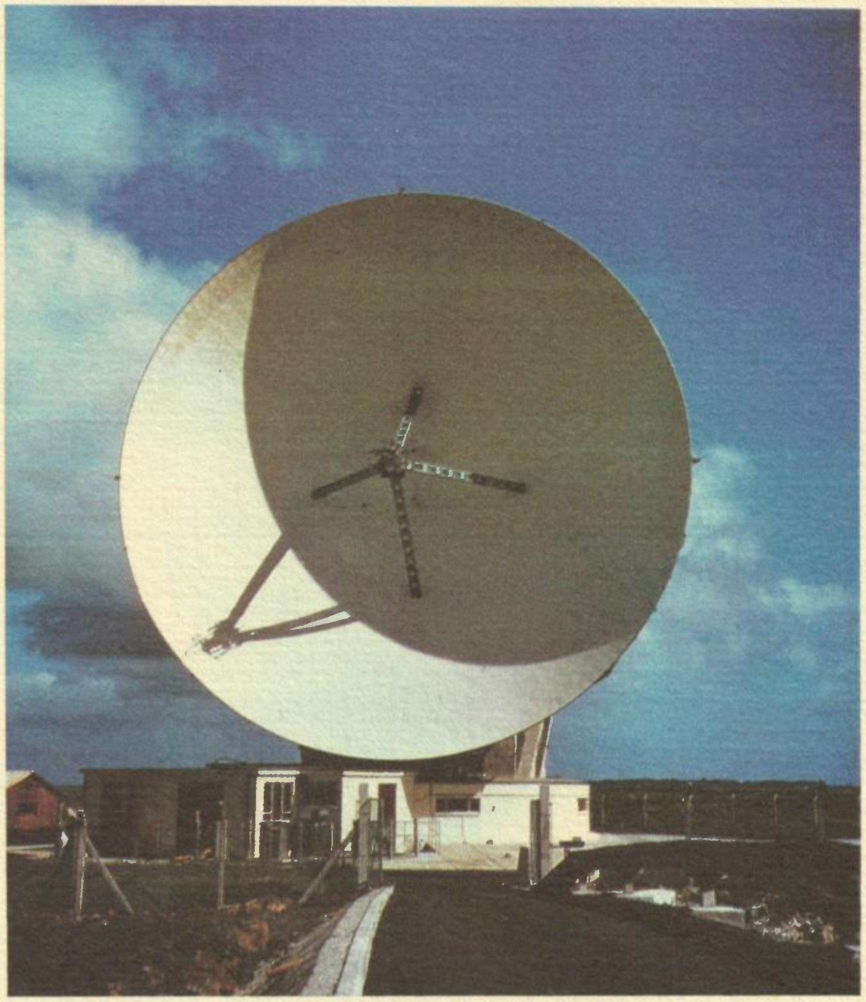
Laboratory engineers also participated in later international projects, notably the Applications Technology Satellite (ATS) project of the U.S. National Aeronautics and Space Administration. One of the ATS earth stations was located near Toowoomba, Queensland, and two of the systems engineers there, B. Perkins and P. Kelleher, were Research Laboratories' staff members. Mr. Perkins was later assigned to NASA's Goddard Space Flight Centre, where he was responsible for investigatory work on ATS and meterological satellites.

One of the problems in Australia is to provide communications to remote areas, and satellite techniques seemed to offer a possible solution. However, since no investigation of this possible application was known to be going on overseas, the Research Laboratories made a systems study and carried out a programme of experiments using the ATS 1 satellite in 1969 and 1970. This project showed that the system concepts evolved in the study were technically feasible and with further developments, might be incorporated in a national satellite system.

Because satellite systems have to share frequency bands with other services and could cause interference to other services in many countries, their introduction and implementation have been the subject of much detailed international co-operation in forums such as the International Telecommunication Union and Intelsat. Research Laboratories' officers have played a prominent part in this work, starting in 1962. One staff member, E. Sandbach, was Chairman of the Technical Committee of the World Administrative Radio Conference for Space Telecommunication in 1971.

E. R. Craig is the present Vice-Chairman of C.C.I.R. Study Group 4, which is concerned with questions relating to fixed services using satellites.

At present, the Satellite Section in the Laboratories is engaged in a joint study with the Satellite Group in the Planning and Programming Sub-Division in preparation for an Australian national satellite system. The indications are that it would be advantageous to implement a satellite system within the present decade. One Research Laboratory project in this context is the investigation of rain attenuation and this project is covered in the latter part of this Review.



GOONHILLY No. 1 ANTENNA AS USED IN TELSTAR & RELAY EXPERIMENTS — 1962/63.

NASA TRANSPORTABLE STATION AT COOBY CREEK FOR ATS PROJECT.
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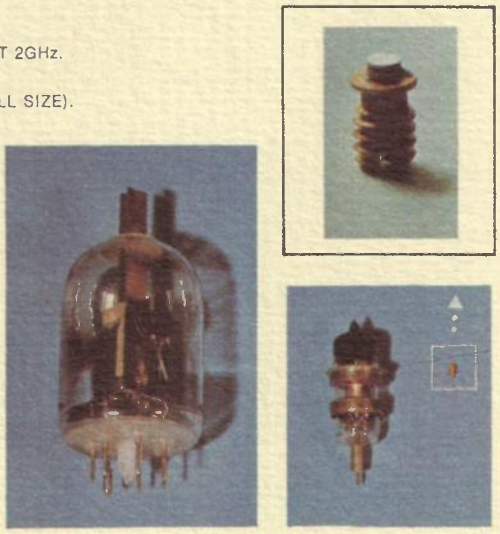
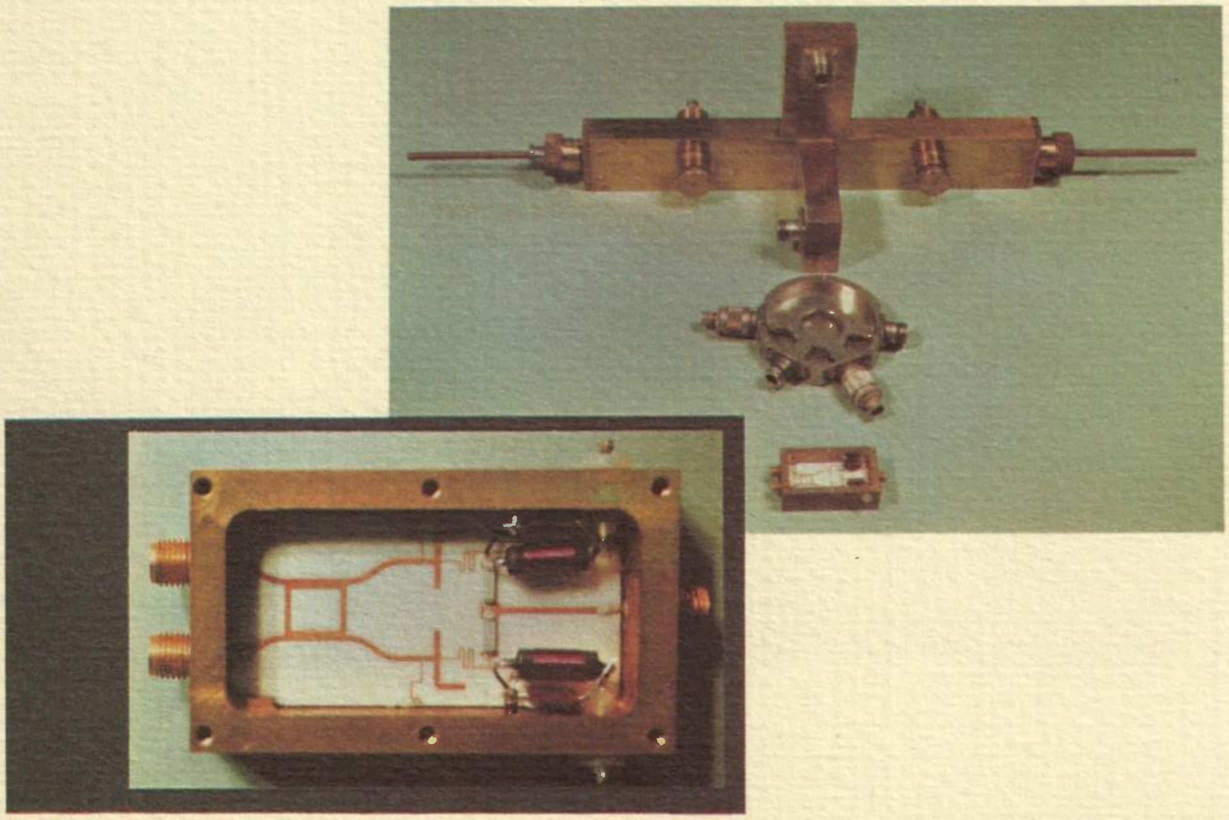
The Evolution of Devices & Techniques

DEVELOPMENTS IN MICROWAVE SOURCES AT 2GHz.
LEFT: AN EARLY KLYSTRON.
CENTRE: A TRIODE:
RIGHT & INSET: GUNN DIODE (INSET 2 x FULL SIZE).

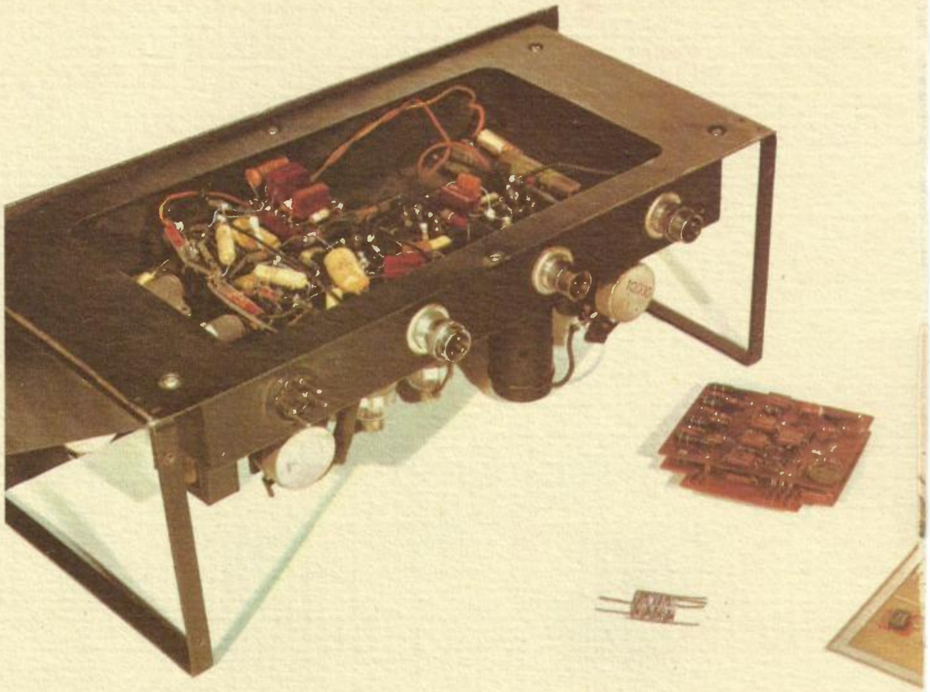


SUCCESSIVE VERSIONS OF MICROWAVE MIXERS.
TOP: WAVEGUIDE MIXER.
CENTRE: SLABLINE MIXER.
BOTTOM & INSET: MICRO-STRIPLINE MIXER (INSET — FULL SIZE).



DEVELOPMENTS IN MICROWAVE DEVICES AND TECHNIQUES

The need for multichannel microwave trunk routes in Australia in the late 1940's stimulated interest in microwave devices and techniques, and specialised A.P.O. research work in this area commenced in 1948 when the late Dr. W. H. Otto joined the Laboratories staff. The main activities in those days were concerned with the provision of specialised test equipment for measurements of microwave propagation phenomena, and this has continued as a major interest to this time. The first equipment operated at frequencies around 2 GHz. Vacuum tube triodes and klystrons were used for microwave power sources. In contrast, current work by W. Williamson and N. Teede is aimed at frequencies around 35 GHz using all solid state devices such as impatt diodes for transmitter power. Until recent years, microwave engineers were often referred to as "plumbers" as they used large sections of rectangular brass waveguide for their circuits. Machine shop practices, often of considerable precision, were used to manufacture waveguide components, which still relied on tuning screws and sliding short circuits to be adjusted to achieve design specifications. During the 1960's, stripline and later microstrip were introduced into microwave techniques in the Research Laboratories. To some extent, these circuit techniques were introduced to make optimum use of the potential of new and highly successful solid state devices that became readily available during those years. They also had intrinsic advantages such as small size, reduced fabrication costs, and increased reliability. However, in contrast to waveguide components, stripline and microstrip components cannot be adjusted readily after manufacture, and precise design techniques are needed for their successful realisation. Unfortunately, the electromagnetic field problems for these circuits in general cannot be solved analytically, and numerical techniques have to be applied to the problems to get design formulae sufficiently accurate for practical use. Investigations of the properties of discontinuity such as impedance steps in microstrip are still in progress in the Research Laboratories. A precision photolithographic and plating facility has been developed to provide circuits for experimental checks on the calculations. This precision microstrip facility is used also to produce microwave integrated circuits to satisfy operational equipment requirements.



ADVANCES IN CIRCUIT WIRING TECHNIQUES

Prior to 1950, the conventional method of constructing electronic circuitry involved attaching major components to a metal chassis and interconnecting them with wire by hand soldered jointing techniques. The method was laborious, costly and unreliable, and the product generally cumbersome. The development of printed circuit techniques in the 1950's reduced many of these problems, and the subsequent proliferation of semiconductors and the general trend to miniaturisation have resulted in printed circuits being used to realise most circuits today.

The Laboratories became interested in the use of printed circuit techniques in the mid-1950's, when the early work to establish a Laboratory facility to produce prototype quantities of printed wiring boards was undertaken by A. Baddeley and R. Potter. Early work used silk screening techniques to reproduce the conductor patterns on the copper clad laminate sheet and chemical etching of the copper was achieved with equipment which had to be developed in-house. Techniques were also developed to mask the conductor pattern on the copper surface using photographic techniques, whereby a photo-sensitive etch resistant layer was applied to the copper and the conductor pattern reproduced by a contact printing process.

Coupled with this early work to develop processes for the in-house production of printed wiring boards were investigations of methods of mounting components, dip-soldered connections and a variety of printed circuit board connectors. As a necessary adjunct, methods of preparing the appropriate artwork were being formalised, and by the mid-1960's, the regular use of single and double-sided printed circuits in experimental laboratory hardware realisations was becoming commonplace, and the early production equipment had been upgraded to cope with demand.

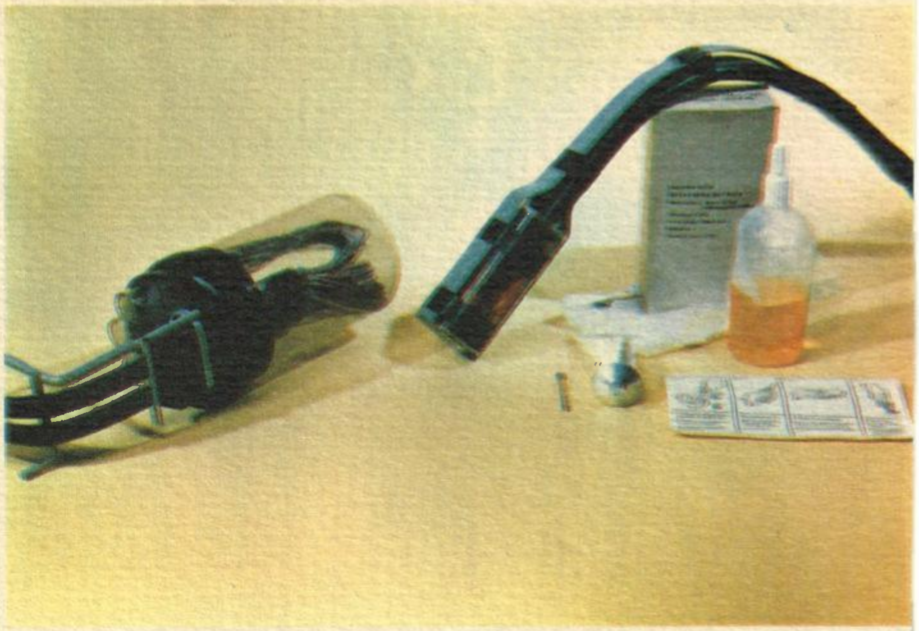
DEVELOPMENTS IN CIRCUIT WIRING TECHNIQUES.
LEFT: AN EARLY WIRED CHASSIS.
REAR CENTRE: A PRINTED CIRCUIT OF THE 1960'S.
RIGHT: A PRINTED CIRCUIT OF THE 1970'S.
FRONT CENTRE: AN EXPERIMENTAL THICK FILM CIRCUIT.

With the establishment of the early facility, work continued in the late 1960's to improve the quality control of the boards by refining the photo-chemical processes and striving for greater accuracy in the artwork. This had become necessary with the desire to adapt the techniques to produce microwave striplines and multilayer printed wiring boards. The former offer significant savings in costs of realisation of circuitry at microwave frequencies and the latter offer higher component packaging densities and higher frequency operation, particularly in digital circuitry using high speed semiconductor integrated circuits. Multilayer board production also called for the extension of the facility to include electroless plating and electro-plating processes. Initial development was undertaken by H. S. Tjio, P. Battlay and J. Der about 1968.

The purchase of a copying camera in 1967 facilitated the production of routine artwork, but it soon became obvious that more accurate facilities were required to meet the needs for stripline and the required artwork for thin film circuit research by the Solid State and Quantum Electronics Section. This resulted in the purchase of a high-precision copying camera and a co-ordinatograph drafting machine in 1971.

Presently, the techniques for producing multilayer boards are undergoing refinement with a view to setting up a small scale in-house production facility, and attention has now been turned to the development of processes for the production of thick film hybrid circuits on ceramic substrates as the next phase in the advance of technology in this area. These techniques call for the deposition of conductors and passive components on the substrate, layer by layer, by a series of silk screening and controlled firing processes, until ultimately, only the active semiconductor devices are attached by micro-bonding techniques. It is expected that the increased demands for packaging density, miniaturisation and reliability will see this, or the allied thin film hybrid circuit, as the next generation methods of realising electronic circuitry. It can be anticipated that before very long, many circuits will be realised by mounting thick or thin film hybrid circuits on multilayer printed wiring boards.

One outcome of the work by the Laboratories in printed circuitry has been the encouragement of local industry to enter the field. Another has been the ability of the Laboratories to be well placed to advise Departmental Workshops on the establishment of similar facilities to meet their range of larger scale activities.



EPOXY RESIN FIELD PACK WITH RE-OPENABLE JOINT (LEFT) & FULLY ENCAPSULATED JOINT (CENTRE).

THE GROWING APPLICATION OF PLASTICS IN THE A.P.O.

The successful commercial development, production and application of a class of synthetic polymers — commonly known as "plastics" — has left an imprint on the field of telecommunications in recent years. A detailed outline of their impact on A.P.O. operations would be voluminous. However, it is fitting to recall some landmarks and look at some current developments in this field, since the scientific staff of the Laboratories have played a leading role in evaluating these materials as they were developed and in investigating their applications.

Fifty years ago, the only plastic materials available were shellac, gutta-percha, ebonite and celluloid, and materials such as natural rubber, glass, ceramics, wax, paper and wood were used as insulating and dielectric materials. Late, phenol formaldehyde or phenolic resins (Bakelite) became available and use of these early plastics in the A.P.O. was confined mainly to internal plant.

The 1930's saw the initial development of synthetic rubbers such as "Neoprene", and thermoplastics such as polystyrene, polyvinylchloride (PVC), polythene and polymethylmethacrylate (acrylic or "Perspex"). During World War II, synthetic rubbers and plastics were substituted for the traditional materials such as natural rubber, which were in short supply.

In Australia there was little technical expertise available to judge the merits of these "substitute" materials and the physical sciences activities of the Laboratories under D. O'Donnell were built up to handle this work. It soon became apparent that some of the "substitute" materials had properties that were superior to the original materials and that their use offered the possibility of reducing the incidence of the widespread insulation troubles that occurred in the enamel and textile insulated wiring used in telephone instruments, exchange equipment and cabling, and in pillars and outdoor wire.

Specifications were developed in the Laboratories by P. R. Brett and from the early 1950's, PVC insulation was adopted for outside distribution wire, for switchboard cables, jumper wires and for hookup wires. Nowadays, newer synthetics such as cross-linked polythene are being considered as substitutes for PVC, because, although economical and flexible, PVC has been found to release hydrogen chloride gas when it burns, which could cause serious damage to equipment.

In the external plant area, rigid PVC has taken over from earthenware and asbestos cement for cable conduits since 1964, and today, about 8000 tonnes of PVC are used annually to provide one third of all A.P.O. cable conduits.

Following Laboratory evaluations demonstrating the excellent physical, chemical and electrical properties of polythene, the A.P.O. commenced using polythene insulated subscribers distribution cable in 1956. For economic and technical reasons, however, paper insulation and lead sheathing were retained for cables of more than 100 pairs. From 1956, the water vapour penetration problems associated with the larger diameter paper-insulated cables were investigated, and this work contributed to the development of the moisture barriered sheathed cable introduced into A.P.O. plant in 1967. Moisture penetration was prevented by the addition of aluminium foil laminated to the inside surface of the sheath.

The introduction of polythene sheathed cables markedly increased the incidence of insect damage throughout Australia. This problem had been under study in the Laboratories since 1951, and early investigatons led by G. Flatau had proved that the incorporation of insecticides in the plastic did not provide a solution to these problems. During the 1960's however, Laboratories' staff, in conjunction with C.S.I.R.O., developed insect-resistant cables with their polythene sheaths protected by a thin jacket of nylon.

One of the major problems facing the introduction of polythene sheathed cables in the late 1950's was the lack of a suitable jointing technique. A variety of tapes, mastics and mechanical closures were investigated in the Laboratories and in field trials, with little success until 1962, when the single ended, fully encapsulated epoxy resin joint was developed in the Laboratories by H. J. Ruddell in co-operation with State Lines staff and introduced into the field. It was used mainly on small size cables until 1969, when it was supplemented by an openable joint using an epoxy resin moisture seal and a PVC mould. For larger cables, jointing techniques were developed which consisted of lead moulds anchored to the cable with epoxy resin. At present, the suitability of thermo-shrinkable sleeving made from irradiated polythene is being evaluated as a replacement jointing material.

Epoxy resins first interested the Laboratories in 1955, and techniques have since been developed to use them in the sealing of terminal boxes, cable pressure dams, terminal pillar units, non-skid surface coatings for manhole covers, cable pulling eyes and cable joints.

Since 1931, phenolic resins had been used to make telephone cases and handsets. If other than black colours were required, melamines were used but colour matching was difficult. In 1963, production of the cheaper, lightweight 800 series "Colorfone" was made possible by the adoption of ABS, a terpolymer of acrylonitrile-butadiene-styrene and a tough, impact-resistant thermoplastic. Research Laboratory evalutions led to the selection of this material in preference to another highly recommended thermoplastic in use in some European countries and subsequent experience has proved the decision to be correct. Plastics and synthetic rubbers continue to find incerasing use in telephone design, and recent work has included the evaluation of the new and predominantly plastic DMS dial. Other current work involves laboratory evaluation of 19 different plastics which might be superior to ABS.

Plastics have also made an impact in components as insulation or dielectric materials and the evaluation of these has been a continuing concern of the Laboratories. The use of plastics to encapsulate or package components has also been the subject of a number of studies since the development of materials such as epoxies, silicones, polyurethanes and polyesters.

The light weight and serviceability of fabrics woven from synthetic fibres has resulted in their use in the postal field, where cotton has been replaced by polythene, polypropylene, nylon and polyvinylidene chloride in mail bags and polyester in uniforms. The use of PVC seals in place of lead seals for mail bags is presently under study. Private letter box doors, originally of brass and later of diecast aluminium, have been moulded from glass-fibre filled nylon since 1971 and are proving serviceable alternatives. The introduction of new materials has not been without its problems, such as those due to the migration of silver from silver plated contacts across and through poor quality phenolic insulants. These were the subject of detailed investigations in the 1930's and again in the early 1950's.

The A.P.O. has thus utilised the properties of specific plastics to achieve both technological improvement and substantial economic savings. The expertise of the Laboratories in the science of polymers has contributed significantly to these advances through participation with industry in the development of new materials and components, and through devising applications to meet the special needs of the Post Office. This has often required the design of novel test methods to simulate various environments, so that the life expectancies of plastics chosen for use in A.P.O. plant could be assessed. Plastics have now spread throughout the network and are found in many plant applications and there is no doubt that the variety and usage of these materials will continue to increase in the future.

FOUR GENERATIONS OF TELEPHONES.
TYPES 162, 300, 400 (REAR) ARE PHENOLIC,
800 SERIES COLORFONES (FRONT) ARE A.B.S.

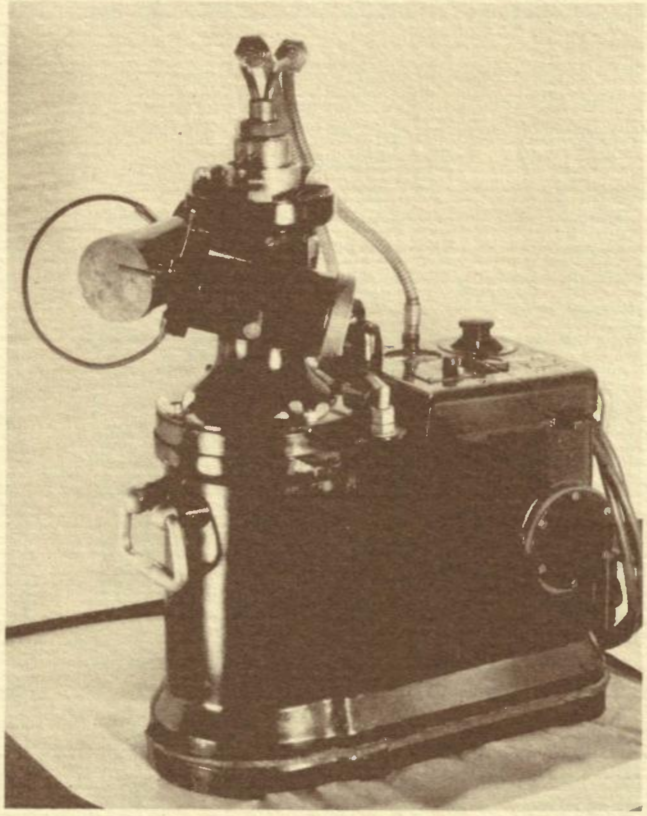
Scientific Measurements & Standards

THE CHEMISTRY LABORATORY CIRCA 1948.

SCIENTIFIC EVALUATION OF MATERIALS, COMPONENTS AND EQUIPMENT

Within the Research Laboratories is a group of scientists consisting of physicists, chemists and metallurgists who are the A.P.O.'s experts in the evaluation and use of materials of any sort in the wide field of telecommunications. Their duties cover the entire area of the Physical Sciences, requiring them to use the most modern techniques and equipment. Examples of their present activities range from atomic absorption spectrophotometry, lightning simulation studies using a 1.4 million volt impulse generator, optical and electron microscopy, tensile, compression and impact testing, and component failure and reliability studies often involving the controlled simulation of environment.

The present-day scientific activities had a very modest beginning. About 1930, Dennis O'Donnell was both



THE SIEMENS & HALSKE X-RAY DIFFRACTION UNIT OF 1938 WAS ONE OF THE FIRST IN AUSTRALIA.

the Departmental physicist and chemist, after joining the Laboratories and working initially in the radio field for several years. Mr. O'Donnell produced the first "physicial sciences" Research Laboratories Report in May 1931. The report detailed an investigation into the corrosion of lead-sheathed underground telephone cable, and most of his work during the 1930's was concentrated on corrosion and cable protection investigations and on evaluations of the physical and chemical properties of materials. In 1937, he was joined by S. Chivers, who boosted the chemistry expertise of the infant group. During the 1930's, these two staff members set up the physical and chemical laboratories which became the foundation of the present-day physical sciences activity. Later, in 1944, P. R. Brett joined the group as a Physicist. Metallurgical expertise was added in 1947, with the recruitment of R. D. Slade. It is of interest to observe that in December, 1938, the Laboratories became the proud owner of one of the first, if not the first, X-ray diffraction units to be bought into Australia — at a cost of £302/12/1. It was a small compact Siemens and Halske unit of 30, 37 and 45 kV accelerating voltage and capable of taking Debye-Scherrer powder and Laue back reflection X-ray photographs. This unit was used extensively in the identification and analysis of materials and corrosion products, and proved so valuable that it was decided to build another unit, and this was designed and built in the Research Laboratories. The new unit with 2 X-ray tubes (one with a copper target, the other chromium) was commissioned in 1947 and was subsequently to be given much work by P. R. Brett in investigations concerning properties and uses of materials.

During the war years, the physical sciences group were primarily concerned with the evaluation of materials and materials substitutes, as was required in providing telecommunications facilities for the armed services. Testing of materials under simulated environments was also a big part of the work of the group, and this was given an impetus by the wartime need for the Australian telecommunication components industry to become more independent.

The immediate post-war years proved to be some of very rapid growth in the physical sciences activities of the Laboratories. This was brought about by the continued policy of encouraging production of telecommunication equipment in Australia with as high a content as possible of Australian materials. The Post Office Research Laboratories' staff expertise and facilities were accordingly made available to assist manufacturers to produce communication equipment of the quality required for satisfactory performance.

During this period, the Laboratories purchased the most modern scientific test equipment available to meet the rapidly expanding requirements. As with X-ray diffraction, the Laboratories were among the first in Australia to use many of these new techniques. Where no existing technique was available for the particular requirement, new methods or processes were devised by the Laboratories' staff.

Currently, the Laboratories are equipped to carry out almost any investigation in the Physical Sciences area covering the broad disciplines of general chemistry, electro-chemistry, physics, metallurgy and polymer chemistry. Subjects such as infra-red and atomic absorption spectrophotometry, gas chromatography, X-ray fluorescence analysis, environmental reliability, life testing and metallurgical investigations are but a few general fields of activity.

THE A.P.O. REFERENCE STANDARDS OF TIME INTERVAL AND FREQUENCY

The first frequency measurements in the Laboratories were made by using known inductance and capacity, but the A.P.O. required a primary standard for its engineering activities and for administration of the Wireless Telegraphy Act. Early in 1928, a 1000 Hz valve-maintained tuning fork was ordered from H. W. Sullivan, England, and was set up in 1930 at 360 Post Office Place, Melbourne, by D. O'Donnell. The frequency accuracy was a few parts in 10^6. Immediate use of the new standard was made to set broadcasting stations throughout Australia on frequency and to implement 10 kHz channel separation. In 1934, A. Cannon arranged a frequency comparison experiment with the British Post Office using simultaneous measurements of a transmission from GBR, Rugby. Agreement bewteen the standards was 1 part in 10^6.

In 1936, the Laboratories obtained Sullivan's improved fork standard type R12A, with an accuracy of a few parts in 10^7. The new standard was transmitted permanently on a line to the Frequency Measuring Centre at Mont Park to provide a reference for the Radio Inspectors. It was also distributed to city exchanges and became known as "fork tone" for many years. Calibration was made against the standard frequency transmission of WWV, operated by the United States National Bureau of Standards. A system of time signal comparison against WWV was then developed by Mr. Cannon to improve the calibration accuracy which had been limited by Doppler shift. Local time signals were produced by driving a synchronous clock from the fork. This fork clock was the first time standard operated by the Department. The Melbourne Observatory now joined in the comparison system, sending its signals by telephone line from the Domain, and thus the link between the A.P.O. time standard and the Observatory commenced.

The quartz crystal had by now surpassed the fork as a reliable and accurate frequency controlling element, and in 1939, two pin-mounted 100 kHz Z-cut ring quartz crystals designed by Dr. Essen were ordered from the National Physical Laboratory (N.P.L.), England. They were tested at the Laboratories late in 1942. Their accuracy capability was a few parts in 10^9. Mr. Cannon and his assistants designed a complete frequency and time standard installation, and measuring and distribution system, based on these crystals. This installation was housed in 59 Little Collins Street, and the present standards are in the same location today. The standard frequencies became available for distribution to Commonwealth Departments and scientific and commercial bodies. Since 1964, radio dissemination of standard time and frequency has also been made from the A.P.O. station VNG, Lyndhurst.

In 1943, the Melbourne Observatory began closing down to move to Mount Stromlo, Canberra, where the Commonwealth Observatory had been formed. The liaison commenced at Melbourne continues with the Mount Stromlo Observatory and until 1945, the two A.P.O. standard quartz clocks were used as primary standards of time by both Observatories. Indeed, from 1930, the A.P.O. frequency standard was known as the Commonwealth Primary Standard of Frequency. The National Standards Laboratory was formed in 1938 but did not establish a frequency standard until ten years later. By arrangement between the N.S.L. and A.P.O., our standard was used as the Commonwealth Standard until 1948. The historic liaison between N.S.L., Mount Stromlo and the Research Laboratories has continued to the present and daily comparisons are made between the standards at the three laboratories.

In June 1945, the Melbourne Observatory closed down its activities, including its Time Department which had provided the Victorian Time Signal Service. The A.P.O. had agreed to accept responsbility for this service and a smooth transition of the function was arranged without loss of time or signals. The time distribution equipment from the Observatory was now installed at the Laboratories and the service operated from the Laboratories until the Melbourne A.P.O. Speaking Clock was installed in 1955. Ancillary equipment driven from it then provided the service, which became the responsibility of the Victorian Administration. However, control of accuracy and general oversight were still exercised by the Laboratories.

From 1955, precise telephone time-of-day was made available from Sydney and Melbourne, and larger rural centres, from Speaking Clocks designed by the British Post Office. These were installed and put into service with the help of F. A. Milne, a B.P.O. engineer who had taken a leading part in their design. These installations were controlled directly from the A.P.O. frequency and time standard, and even now, continue to provide the most accurate telephone time service in the world. They also provide time signals for a variety of local uses, such as the hourly time signals broadcast on radio stations.

The up-grading of the A.P.O. frequency standard continued with the installation in 1954 of three Essen silk-suspended ring crystals using Meacham Bridge oscillators. These standards eventually reached ageing rates of only a few parts in 10^{11} per day, and still operate as references in the Universities of North Queensland, Adealaide and Monash.

In 1960, Speaking Clocks manufactured by Siemens were installed at Brisbane, Adelaide and Perth. These, too, were corrected from the A.P.O. standard. However, they were of a much more economical design, and were not capable of the accuracy obtained from the B.P.O. clocks. Since its initial installation, the performance of the Adelaide Speaking Clock Service has been considerably upgraded by the addition of special equipment. The Brisbane clock has since been re-located in Hobart, and Brisbane now takes its time from Sydney.

In 1958, following negotiations initiated in the U.K. by J. Ward, E. Sandbach obtained an Ammonia Maser Oscillator from the Signals Research and Development Establishment, England (S.R.D.E.). This used a quantum transition and gave a significant advance in frequency stability. Better standards require better calibration, and, in the same year, equipment was developed to enable comparison of our standard to a part in 10^9 in 24 hours with the standard frequency transmission from GBR, Rugby, on 16 kHz. GBR was established in 1957 against the newly-developed Essen atomic caesium beam reference at N.P.L., which was accurate to a part in 10^{10}.

Advancing technology had now created the need for better agreement between world time keepers. Up to this time relative displacements of the order of one-twentieth of a second had existed. In 1960, the International Time Bureau (B.I.H.), Paris, called for laboratories with the ability to maintain time synchronisation to 1 millisecond to adopt a new time scale, later called "Universal Co-ordinated Time", or U.T.C. The quality of the A.P.O. standard and our background in time-keeping allowed us to be included in this group.

In 1964, the need for a broadcast time signal service which would be continuously available throughout Australia became apparent. The Weapons Research Establishment requested time signal coverage for its rocket range, and mapping and exploration activities in various areas, often remote, required accurate and dependable time signals. The Research Laboratories were requested to set up, in co-operation with Central Office Radio Section and the Victorian Administration, a time signal service as a matter of urgency. In a few weeks an interim time signal service with call-sign VNG was broadcasting from the Inland Radio Station at Lyndhurst, Victoria, on three frequencies in the H.F. band.

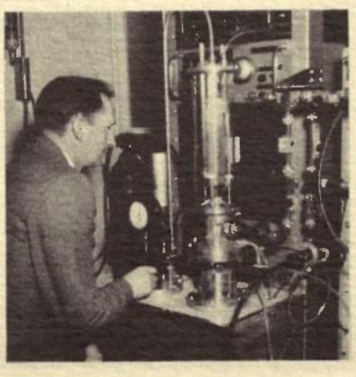
In December, 1969, the equipment developed at the Laboratories for the final form of the VNG service was installed at Lyndhurst. VNG conforms with C.C.I.R. recommendations for such services, which require that carrier frequencies be accurate to 1×10^{-10} and time signals to 100 microseconds. The accuracy is continuously controlled via landline from the A.P.O. time and frequency standard.

The development of atomic oscillators was also proceeding. In 1967, our standard became a Rubidium Gas Cell (drift rate 3×10^{-13} per day) and in 1968, a Caesium Beam (absolute accuracy 5×10^{-12}; drift rate extremely small).

Because of the constancy of atomic processes, the time-keeping potential of laboratory clocks far exceeds that of astronomical clocks and in 1967, the second was defined in terms of a transition of the caesium atom.

The A.P.O. standard is now kept within a handful of microseconds of U.T.C. as per the B.I.H. and its frequency is measured to parts in 10^{13}. An important means of calibration is by portable atomic clock from the United States Naval Observatory. The C.S.I.R.O., in their capacity as an Organisation appointed by the National Standards Commission, has authorised the A.P.O. frequency and time standard as a Working Standard of Time Interval and Frequency for the Commonwealth under the Weights and Measures (National Standards) Act 1960-1966.

WORKING STANDARD CLOCKS OF THE VICTORIAN TIME SIGNAL SERVICE — 1945.
LEFT TO RIGHT: MEAN TIME CLOCK, AUXILIARY GATING CLOCK, AND SIGNALLING CLOCK.



THE AMMONIA MASER TRANSFER STANDARD.

80 YEARS OF STANDARD 1 OHM RESISTORS.

TEST EQUIPMENT CALIBRATION IN AN EXPANDING TECHNOLOGY

From the very beginnings of the Laboratories, one of the duties of the early trio of engineers was "to supervise condition of instruments, check calibrations, maintain reference standards of telephone transmission equipment". These early duties were primarily carried out by A. A. Lorimer. Mr. Lorimer had joined the infant Laboratories in March, 1925, and he later saw this activity grow to almost its present size before his retirement 40 years later.

In a description of the activities of the Laboratories in the 1938 era, S. H. Witt wrote — "The greater part of the measuring equipment of the Laboratories is connected to appropriate systems of calibration to laboratory standards or sub-standards and calibration records are maintained for all important units". This demonstrates the early awareness of the need for precise calibration of Departmental test equipment. In more recent times, this has led to the Laboratories becoming the ultimate centre of calibration verification for all Departmental test equipment as well as for its own in-house test equipment, through its new formalised links with the States Calibration Centres.

From the early years, the standards on which this calibration was based were those of the classical electrical standards laboratory. In 1927, the Laboratories purchased reference standard cells and resistors, which were certified by the National Physics Laboratory in England, and this tradition was continued with replacements until 1940. Thereafter, the calibrations of reference standards were performed by the Australian National Standards Laboratory, which had been established in Sydney in 1937. In 1928, the Laboratories purchased a potentiometer which was in use for the following 22 years, and which, together with the original standard cells and resistors, is still kept as a museum item.

The calibration records of what was known for many years as the Instrument Section date from 1926. It is possible to correlate the general calibrations performed there with the development of projects within the Laboratories and to some extent with the wider activities of the Department. In the early days, there was considerable demand for the calibration of thermocouple instruments due to the developments in carrier systems, which were of vital concern to the Laboratories in those times. By the 1940's, this demand had practically ceased. It was replaced by the calibration of vacuum tube voltmeters, which, by 1960, were being checked up to 1000 MHz. The first reference to thermionic voltmeter appears in 1928, when a Moullin voltmeter was checked at 1000 Hz.

PRESENT DAY MICROWAVE POWER METER CALIBRATION.

During the 60's, the V.H.F. radio era passed so far as the Laboratories were concerned, and the microwave region became of interest.

In the present decade, users of cable are interested in the frequency region that was formerly classed as "radio frequency", and a renewed interest is developing in impedance and power level measurements from the old carrier frequencies up to about 200 MHz. In the microwave measurement field, power is the paramount measurement parameter rather than voltage, which was of importance at lower frequencies. Today the Research Laboratories are the leading centre in the country for the measurement of microwave power.

Because of the collection of both precision measuring equipment and specialised knowledge in the Laboratories, they have from the beginning provided a precision measurement service to other sections of the Department, and also to organisations outside the service with which the Department has a common interest. Calibrations have been performed for Australian manufacturers who are suppliers to the Department, and for many other Commonwealth Departments.

In 1960, the Laboratories joined the National Association of Testing Authorities, an Australian body whose function is the provision of calibrations having traceability of accuracy to the Australian National Standards of measurement. The Laboratories are registered for a range of specific tests in the electrical field, the limits and accuracy of which are continually updated.

A Selective Review of Current Activities

In accord with their functions, the Laboratories are engaged in a large number of investigatory and developmental projects and specialty activities in the engineering and scientific fields. This work has application in both the telecommunications and postal networks, and comprises a wide variety of specific topics pertinent to the present technical standards and future technical advance of these networks.

It is not possible to report, even briefly, on all the Laboratories' projects and activities in this review. As a consequence, the activities reviewed in the following pages have been selected to give an overall picture of the type and breadth of work undertaken, and of the degree to which the Laboratories are keeping abreast of world developments in communications science. A more comprehensive list of current projects is issued in a "Quarterly Progress Report" and this is available to selected bodies with special and more specific interest in the work of the Laboratories.

The Laboratories activities are not pursued in isolation. The ultimate value of the work depends heavily on continued liaison with other sections of the Department, and on interaction with industry and those conducting pertinent research in universities and similar learned institutions. These resultant formal and informal interactions are of considered importance in leading to the mutual benefits of a Laboratories with their feet on the ground, responsive to the Department's requirements, and a clientele aware of the talents and expertise available to them from within the Laboratories.

Switching Studies

INTEGRATED SWITCHING AND TRANSMISSION (I.S.T.)

The Switching and Signalling Branch is developing an experimental digital telephone exchange which will be installed shortly at the Windsor telephone exchange.

This exchange will have a number of novel features:—

- it will switch speech signals which are encoded in PCM and will operate in a time division multiplex mode, thus considerably increasing the utilisation of the switching equipment,
- it will utilise solid state techniques throughout,
- it will utilise processor control.

This exchange will enable PCM circuits to be directly interconnected without the need for decoding and subsequent recoding at intermediate switching points, and should lead to both transmission improvement and a reduction in network costs. A concentrator is also being developed which will enable subscribers to be connected to a network of PCM links and digital exchanges.

This project is drawing heavily on many other projects under study in the Switching and Signalling Branch and also serves to lend a background of realism against which these studies can be conducted.

STORED PROGRAM CONTROL (SPC)

The use of common channel signalling techniques enables processor control to be separated from switching to a much greater extent than is possible with conventional switching equipment. This enables some functions to be centralised more than is usual at present. Studies are in progress to determine the relative advantages and optimum disposition of control. Programming techniques for use in the development of processor programmes are also being actively studied for a digital network.

Several complete software systems have already been developed for the special purpose exchanges being used for the C.C.I.T.T. Signalling System No. 6 trials and the I.S.T. project. These include all of the necessary support software, including man-machine communications, simulation testing, etc. The extent of the current software systems is approximately one and a half million bits.

SIGNALLING TERMINALS IN C.C.I.T.T.
SIGNALLING SYSTEM No. 6 TRIAL EXCHANGE.

SWITCHING EQUIPMENT IN C.C.I.T.T.
SIGNALLING SYSTEM No. 6 TRIAL EXCHANGE.

SIGNALLING STUDIES

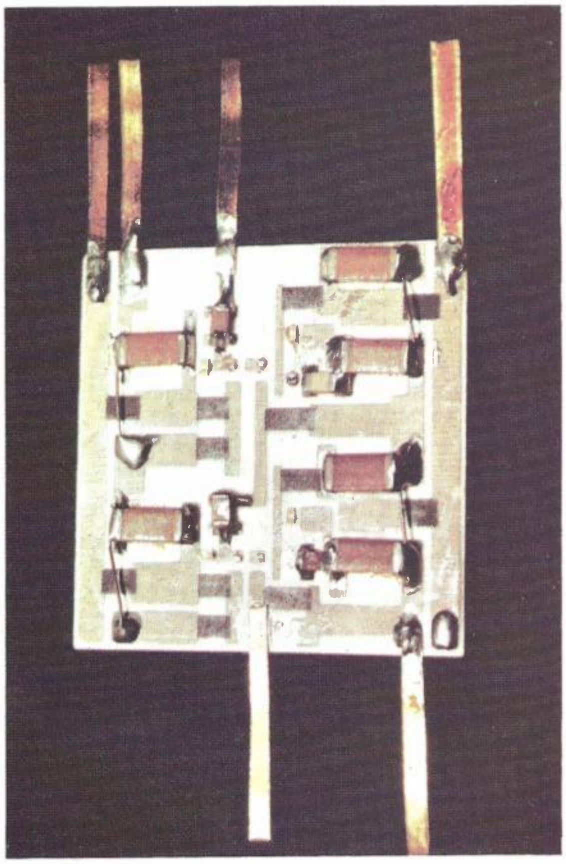
Common channel signalling using data transmission techniques over a single signalling channel, rather than the more conventional method of signalling over individual circuits, enables higher signallng speeds to be realised and is well suited to the use of processor control. This technique is used in the C.C.I.T.T. Signalling System No. 6 and is now being studied for use in an I.S.T. network.
A special signalling system known as T5 has been developed for use over PCM circuits. This will be used to interconnect the model I.S.T. network with the existing electro-mechanical network. The T5 system, which utilises two signalling channels in each direction per speech circuit, enables the cost of signalling equipment to be significantly reduced.

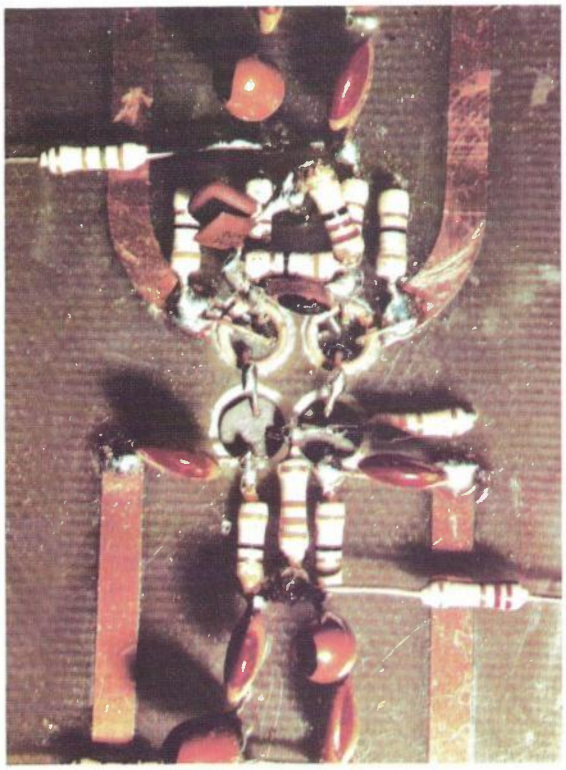
DEVICES AND TECHNIQUES

The Devices and Techniques Section is engaged in the study, assessment and development of special purpose devices for use in electronic switching applications. Several special purpose devices have been designed for use in the No. 6 and I.S.T. model exchanges using monolithic bipolar techniques, some of which are the subject of patent applications.
Other topics under investgation include computer aided design, and distribution problems in large digital systems using high speed logic, with particular emphasis on noise, interference and timing.

Digital Transmission Studies

THICK FILM HYBRID CIRCUIT REALISATION
OF THE SECTION OF ACTIVE CABLE EQUALISER.





HIGH CAPACITY DIGITAL COMMUNICATIONS VIA COAXIAL CABLE

Following on the studies of digital PCM transmission on voice frequency junction type cable pairs, a feasibility study has been carried out on the digital capacity of standard 2.6/95 mm coaxial cables. Clearly, there will be an advantage from the plant compatibility point of view if digital coaxial systems were to operate with the same repeater/regenerator spacing as for the presently installed 12 MHz and planned 60 MHz analogue systems. Hence the studies concentrated on the capacity assuming 4.5 km and 1.5 km regenerator spacing, and concluded that 0.25 Gbit/s and 1.5 Gbit/s were feasible targets for a design study.

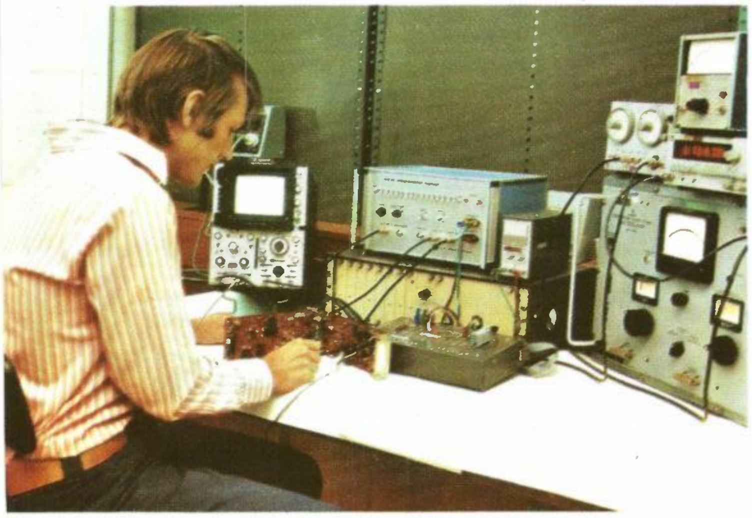
The capacity advantage vis-a-vis analogue systems with the same repeater spacing is greatest at the higher bit-rate, the capacity being approximately doubled for telephony signals. However, the advantage is most spectacular for non-voice signals such as data, with a gain of about 12 times, and for video signals such as television and video-phone which show a gain of between about 2.5 and 12 depending upon the efficiency of the signal source coding.

A long-term design study has commenced which is aimed at the development of equipment operating at about 1.5 Gbit/s using the 1.5 km span within ten years. Initial work is concentrated on achieving 150 Mbit/s over the 4.5 km span with a subsequent extension to 250 Mbit/s. Thick film hybrid technology with emitter coupled logic (ECL) is being used because of the high symbol rate requirements.

SECTION OF ACTIVE CABLE EQUALISER —
PRINTED CIRCUIT PROTOTYPE.

REGENERATION OF TIMING INFORMATION IN DIGITAL SYSTEMS

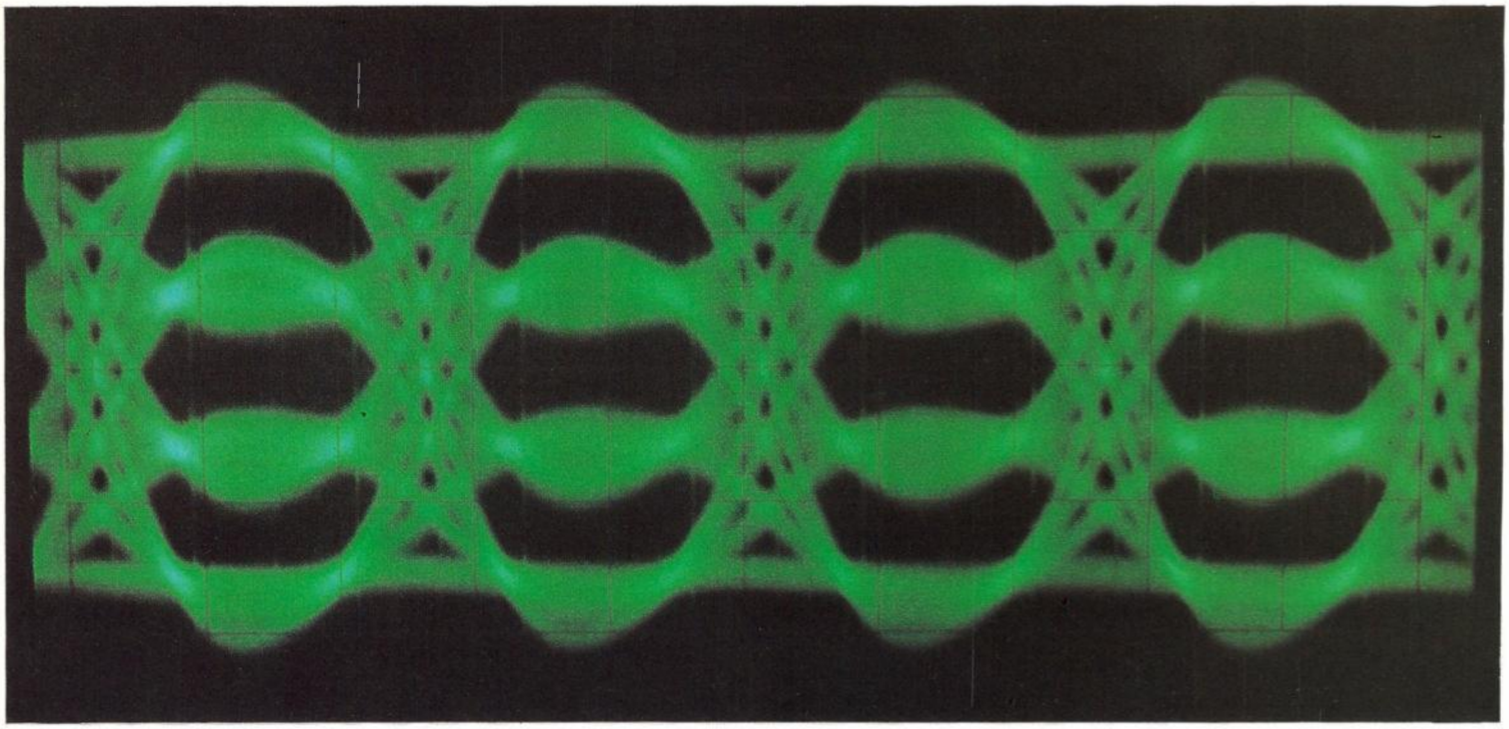
In digital transmission line systems, regenerators are used to re-time and re-shape the transmitted signal at regular intervals along the communication link. The operation of these regenerators centres on the extraction of timing information from the transmitted pulse-stream. This timing information is acquired with the aid of a clock extraction filter and is used to sample the received pulse train at the positions where the pulse peaks are expected to occur. It is also used to maintain the correct pulse width and the correct separation between the re-shaped pulses transmitted by the regenerator.
Due predominantly to practical deficiencies in the operation of the clock extraction filter however, the extracted timing signal contains jitter which causes the phase of the regenerated pulses to fluctuate around their ideal positions. This type of signal impairment — known as timing jitter — can accumulate along a chain of regenerators and thereby seriously degrade the operation of a digital transmission system, unless special jitter reduction techniques are employed. Consequently, timing jitter is a significant factor which plays an important part in determining the overall design and cost of a digital transmission system, and is one of the aspects of the regeneration of timing information being studied in the Laboratroies, as part of more general studies of digital transmission systems.



TESTING THE TIMING OPERATION OF DIGITAL REGENERATORS.

DIGITAL MULTIPLEXERS

Synchronous sub-multiplexing techniques are being investigated for data transmission applicatons.
Although a single PCM time-slot transmits 64,000 bits of information each second, a speech channel derived from it can only transmit data at 4,800 bits per second. The system could handle digital data much more efficiently if the data were synchronous with, and fed directly into, the digital stream. If part of the available capacity is used for control, 48,000 bits of data per second may be conveniently transmitted from either a single source or a number of low speed sources multiplexed together. The current research programme aims to identify the problems of using a PCM time-slot to transmit multiplexed data streams using synchronous sub-multiplexing techniques.
Concurrently, asynchronous mutliplexing techniques are also being examined.
In a digital transmission network, it is often advantageous to combine several low capacity systems by time division mutliplex to form a single high capacity system. To do this in an error-free mode requires that each tributary to the multiplexer must have an information rate which is synchronous at all times with the multiplexer clock and with other tributaries. Often, this is not so, particularly where the incoming sources are derived from autonomous clocks. In such cases, it is necessary to equalise or "justify" the rates of the incoming tributaries by special processing. In the Laboratories, a novel system of "positive-zero-negative justification" has been developed which has particular adavantages over more conventional justification techniques developed overseas.



EYE PATTERN INDICATES PERFORMANCE OF 4-LEVEL DIGITAL F.M. MODEM.

DIGITAL RADIO SYSTEM TECHNIQUES

In analogue radio systems, the instantaneous signal vector is at all times directly proportional — in amplitude, phase or frequency — to the instantaneous amplitude of the base-band modulating signal. This is a one-to-one relationship and the modulator has to achieve this in a linear manner over the entire amplitude range of the baseband signal.

In digital radio systems, the instantaneous RF signal vector can assume only pre-determined discrete values of amplitude, phase or frequency under the control of the modulating signal. The resulting RF signal is quantized and its spectrum has, in general, widely dispersed spectral components. However, by suitable selection of design parameters, a compact spectrum is readily achieved.

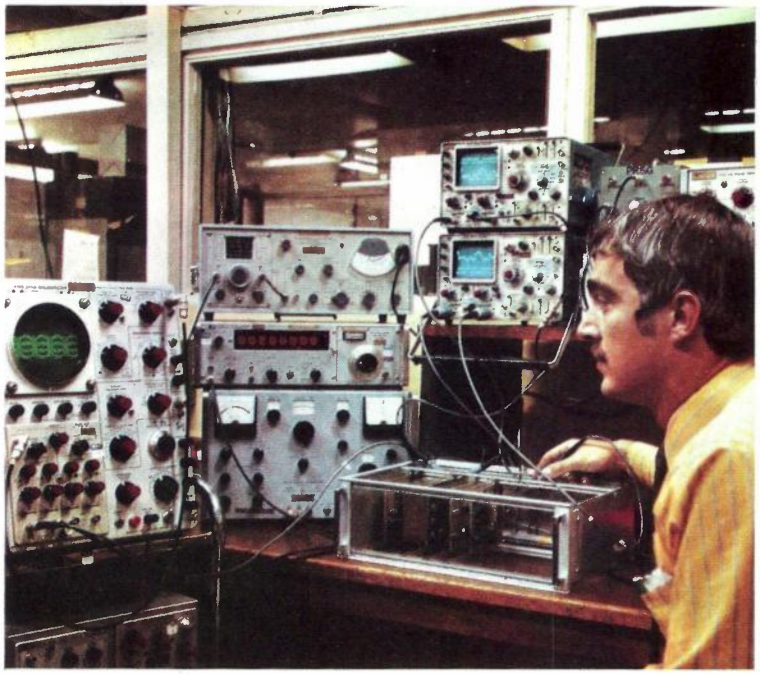
An analogue radio system can transmit both analogue and digital baseband signals, whereas a digital radio system can only transmit digital baseband.

The outstanding advantage of digital radio is regeneration, which results in non-cumulative noise and distortion, greater immunity to interference and temperature variations, and a clear superiority for transmission of digital data. Conversely, the main disadvantages are quantization noise and larger bandwidth requirements in practical systems for analogue signals such as voice signals.

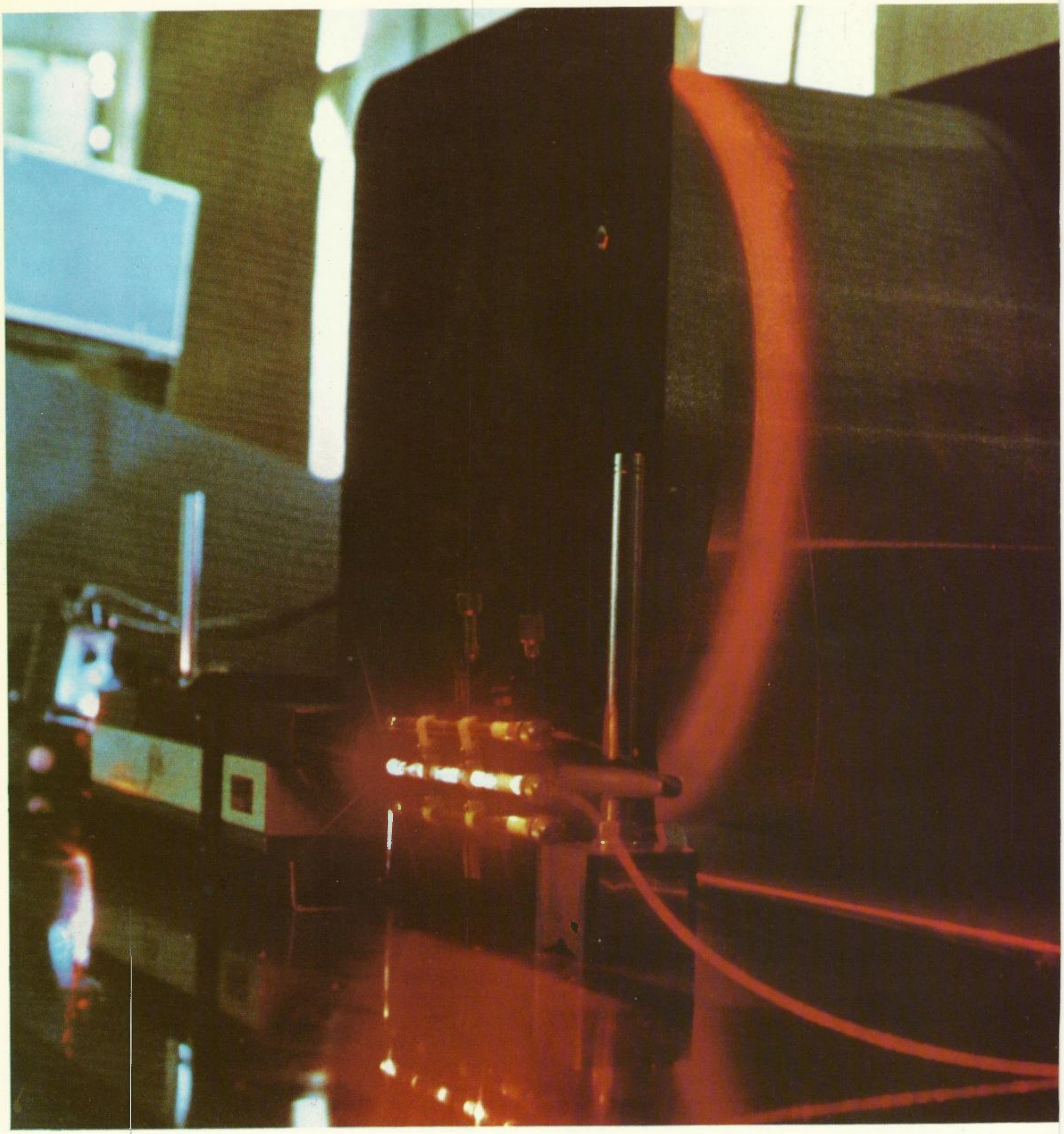
The advantages permit, in particular, tandem connection of repeaters almost without limit, dual-polarized co-channel operation, setting up of close-meshed radio networks, greater azimuthal concentration of radio paths at metropolitan terminal stations, and manifold increases of transmission capacity for video signals with simple processes of redundancy reduction. Quantization noise, although a disadvantage, can be designed to be within permissible limits. Bandwidth requirements of PCM are greater by a factor of 2 to 6 compared with analogue FDM/FM. With multi-level coding, significant bandwidth reduction appears possible at the expense of error rates or higher required transmitter power.

For obvious economic reasons, it would be desirable to install new digital systems along the same route as analogue radio systems. Because of possible interference from digital systems, such a hybrid application has to be carefully investigated and a compatibility study for the Australian network has commenced. The investigation also seeks to study the cost effectiveness of digital techniques on local and trunk routes, and whether digital radio is best used at frequencies above 10 GHz. At these frequencies, there is less crowding of systems, the larger bandwidth requirements of digital radio can be more easily accommodated, and the greater immunity of digital techniques to disturbances, combined with regeneration at each receiver, can better overcome the propagation hazards of rain, fog and other similar weather effects.

The reduction of bandwidth in hybrid applications is being investigated in the Laboratories at the present time. "Partial response coding" is being studied as a method which may be applied to avoid some of the problems, particularly in channel characteristics, which arise in bandwidth reduction using multi-level coding. Theoretical and experimental studies are also being made of four-level digital FM modulation.



MEASURING PERFORMANCE OF A 4-LEVEL DIGITAL F.M. MODEM.



UNCOATED OPTICAL FIBRE AXIALLY ILLUMINATED BY HELIUM-NEON LASER.

High Capacity Transmission Media

OPTICAL FIBRE RESEARCH

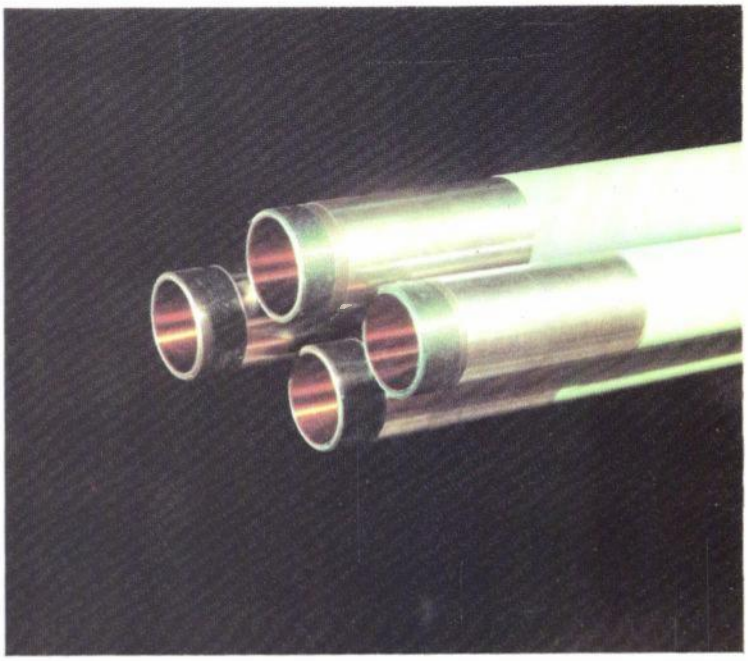
An optical fibre consists of a central "core" and a surrounding "cladding" of lower refractive index. Light is guided along the fibre by total internal reflection at the core-cladding boundary, with the degree of attenuation of the light being determined principally by the purity of the materials and the precision of manufacture of the fibre.

As reported in last year's Review, the Tribophysics Division of C.S.I.R.O. has developed a novel optical fibre which has a low-loss liquid core instead of the more usual glass core. The difficulties associated with obtaining sufficiently pure glasses have therefore been avoided.

The attenuations of a number of these fibres filled with different liquids, and in lengths up to 1 km or more, have been measured in the Laboratories. Best loss figures so far achieved have been lower than 10 dB/km over portions of the near-infra-red spectrum. Current research is aimed at determining the transmission capacity of the fibres; and other aspects of optical fibre systems such as coating, launching, and terminal devices are also being studied in the Laboratories.

The first applications for optical fibres will probably be for the transmission of broadband analogue signals (for example, a number of TV channels) over relatively short distances. However, in the long term, it may also prove advantageous to use optical fibres in the trunk network. Each fibre is capable of transmitting several thousand speech channels, so that a great many of these small fibres could be bundled together to give a "cable" having limitless capacity. Present indications are that repeater spacings could be of the order of 5 km, and by using digital techniques, the overall length of the system could be unlimited.

CIRCULAR WAVEGUIDES.



CIRCULAR WAVEGUIDES

Circular waveguides having a diameter of about 50 mm and operating in the millimetre-wave band above 30 GHz can have a very low transmission loss over a large bandwidth, thereby allowing high-capacity systems with large repeater spacings. To minimise signal distortion, special waveguide inner wall structures are needed, the most usual being helically-wound insulated wire encased in a lossy dielectric, or a thin dielectric material coated onto the inner surface of the waveguide. The losses and useable bandwidth of such waveguides are strongly dependent on the precision of manufacture and of laying.

The Laboratories have recently acquired lengths of circular waveguide which will be used to check theoretical predictions of transmission performance against that actually measured. Later, the theory will be extended so that the mechanical tolerances of a waveguide having particular transmission characteristics can be predicted, with the aim of ultimately producing an economic waveguide for the Australian trunk network.

Radio Propagation Phenomena

SOLAR RADIOMETER — INNISFAIL, QUEENSLAND.

MICROWAVE SOLAR RADIOMETER EXPERIMENTS

At the World Administrative Radio Conference for Space Telecommunications held in 1971, substantial additional frequency bands were allocated for use by space services. Nearly all of the new bands lie above 10 GHz and it may be desirable to make use of these in Australia to minimise mutual interference between satellite systems and terrestrial microwave radio relay systems.

One problem at frequencies above 10 GHz is that the radio signal is attenuated by rain — the higher the frequency and the heavier the rainfall, the worse the effect becomes. Knowledge about the allowance to be made in system design to cater for this effect in tropical areas subject to monsoonal-type rainfall is lacking. Consequently, the Research Laboratories are currently carrying out a project to gain an understanding of the phenomenon and ascertain the engineering allowances appropriate to Australian conditions.

The measuring method being used to provide the basic data depends on the fact that the sun radiates a considerable amount of energy in the frequency bands of interest which, for this project, are in the range 10.95 to 14.5 GHz. This "signal" from the sun is affected by rain in the same way as would a signal from a satellite transmitter, and the effect can be recorded by suitable receiving installation. The installaton required is commonly called a "solar radiometer".

The equipment used to make the primary measurements consists of a solar radiometer tuned to 11 GHz and a network of rain gauges. This radiometer was designed and built in the Laboratories and is equipped with a parabolic antenna of 1.22 m diameter. During daylight hours, the antenna is automatically directed first towards the sun and then towards the adjacent sky in a cycle which takes 10 minutes. Thus,

PAGING RECEIVER UNDER TEST IN CALIBRATOR.

regular sampling of sun and sky temperatures is done and from these samples the attenuation characteristics can be computed. The corresponding rainfall characteristics are to be derived from tipping-bucket rain gauges which register once for each point (about 0.25 mm) of rain collected. The installation is now operating near Innisfail in Queensland where rainfall averages 150 inches (3800 mm) per year.

This investigation programme is required to give a proper theoretical base from which system engineers can decide the best frequency bands to use for the Australian national satellite system. This decision is of fundamental importance because it affects where the satellite earth terminals can be located and what technology is appropriate to meet Australian requirements.

A VHF FIELD STRENGTH CALIBRATOR FOR MEASURING RECEIVER SENSITIVITY

In the business or professional sphere, continuous urgent telephone contact is often essential. To this end, the Australian Post Office plans to introduce a radio paging service in the near future. A pocket-sized automatic radio receiver will indicate by a suitable tone that the wearer is urgently required. This service is intended to operate over a wide area, initially over the whole metropolitan zone and adjoining near-country areas, and ultimately around the whole of the eastern states' coastal fringe.

Such a service can be introduced only by close co-operation between industry and the A.P.O., since a number of technical problems need to be overcome to ensure successful operation. One such problem is related to the fact that the miniature receiver contains a small integral antenna which is a limiting factor in the ability of the receiver to pick up weak signals at the fringe of the service area.

The Research Laboratories have developed a means to determine the limiting sensitivity of production radio paging receivers with integral aerials under laboratory conditions. This work has resulted in the design and development of a VHF field strength calibrator, which consists of a strip transmission line (380 mm wide x 250 mm high) into which the paging receiver (120 x 60 x 25 mm) is inserted for measurements. The standard field conditions are set by suitably driving the transmission line with a signal generator. To ensure that the design field strength is actually established, a special miniature (60 mm diameter) shielded loop antenna was also developed for initial calibration and subsequent monitoring of the field. This prototype calibrator is now being successfully employed in sensitivity measurements of receivers from different manufacturers to ensure that they meet the highest standards set down by the A.P.O. for this service.

LIKELY CAUSES OF R.F. CORONA ON HIGH POWER H.F. ANTENNAE

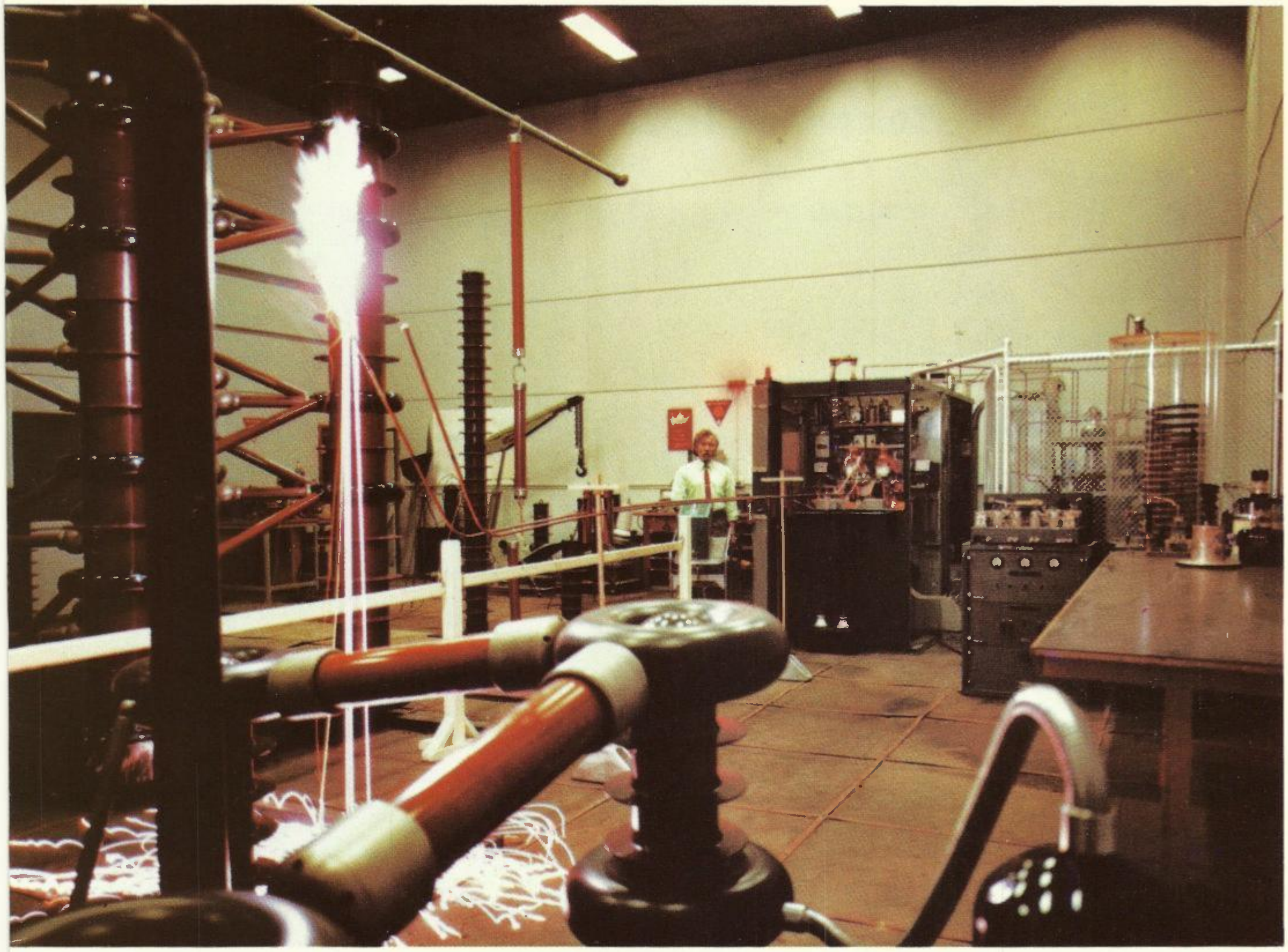
The extension of radio transmission to high power levels has aggravated the problems caused by electrical discharges from transmitting antennae by making discharges more probable and by raising the power dissipated by them. These discharges, which are also referred to as flares, plumes or corona discharges, can cause severe damage to the antennae. Although electrical discharges and the properties of gaseous electrical conductors have been investigated for nearly a century, mostly under d.c. and power frequency conditions, corona discharges are so complex that no analytical expression is yet available to generalise the conditions required for the initiation and maintenance of this type of discharge. Thus it has not been possible to predict the probability of electrical discharges from antennae which must operate over a wide range of field environments, nor to suggest universally applicable methods of preventing such discharges.

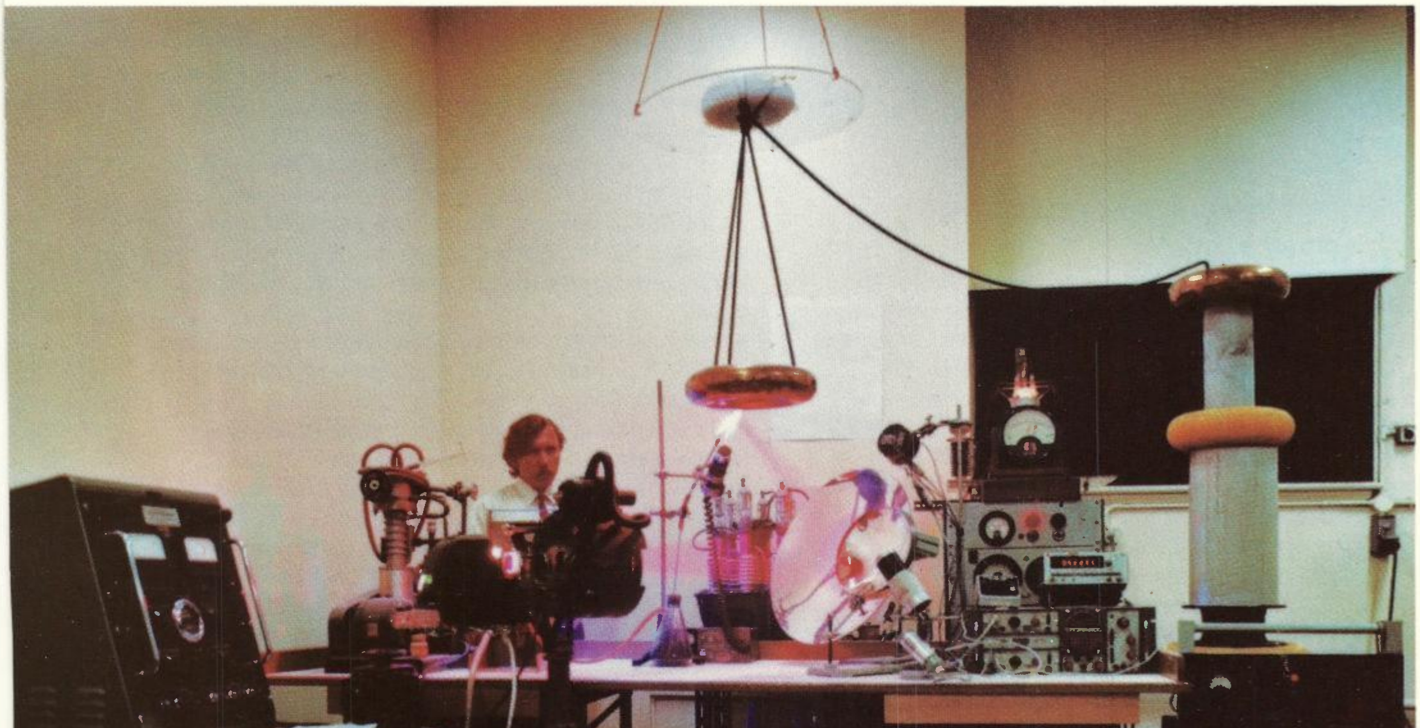
The A.P.O. has recently suffered corona discharges at one of its transmitter installations. These discharges look like long slender arcs with luminous cores between one and two metres in length, with one end terminating at a dipole and the other diffusing in air. As several kilowatts of power is dissipated in these discharges, they can damage the antennae by melting the discharging elements.

Although certain modifications to the original antennae and the provision of a corona detection system and a method of extinguishing the discharges have removed most of the hazards and interruptions previously created by these discharges, the discharges still occasionally occur. It has become evident that there is a need for a better understanding of the properties of such discharges, particularly the mechanism by which they are initiated and the conditions under which they develop and become self-sustained. Owing to the complexity of the processes involved and the need to purchase or design highly-specialised equipment, a full understanding of all or any of the relevant processes will require a lengthy investigation. However, the results of some preliminary laboratory studies are quite promising. Using a modified 10 kW transmitter as a high potential source, it has been established, so far only qualitatively, that certain environmental factors can cause a large reduction in the corona onset potential, so that at least a part of the initiating mechanism is now better understood.

R. F. CORONA DISCHARGE GENERATED IN THE LABORATORY.

INVESTIGATING EFFECTS OF INCANDESCENT PARTICLES ON CORONA ONSET POTENTIALS.





Telephone Transmission Studies

EVALUATING THE EFFECTS OF DROP WIRE ON LONG LINE TELEPHONE PERFORMANCE.

DEVELOPMENTS IN LONG LINE TELEPHONES

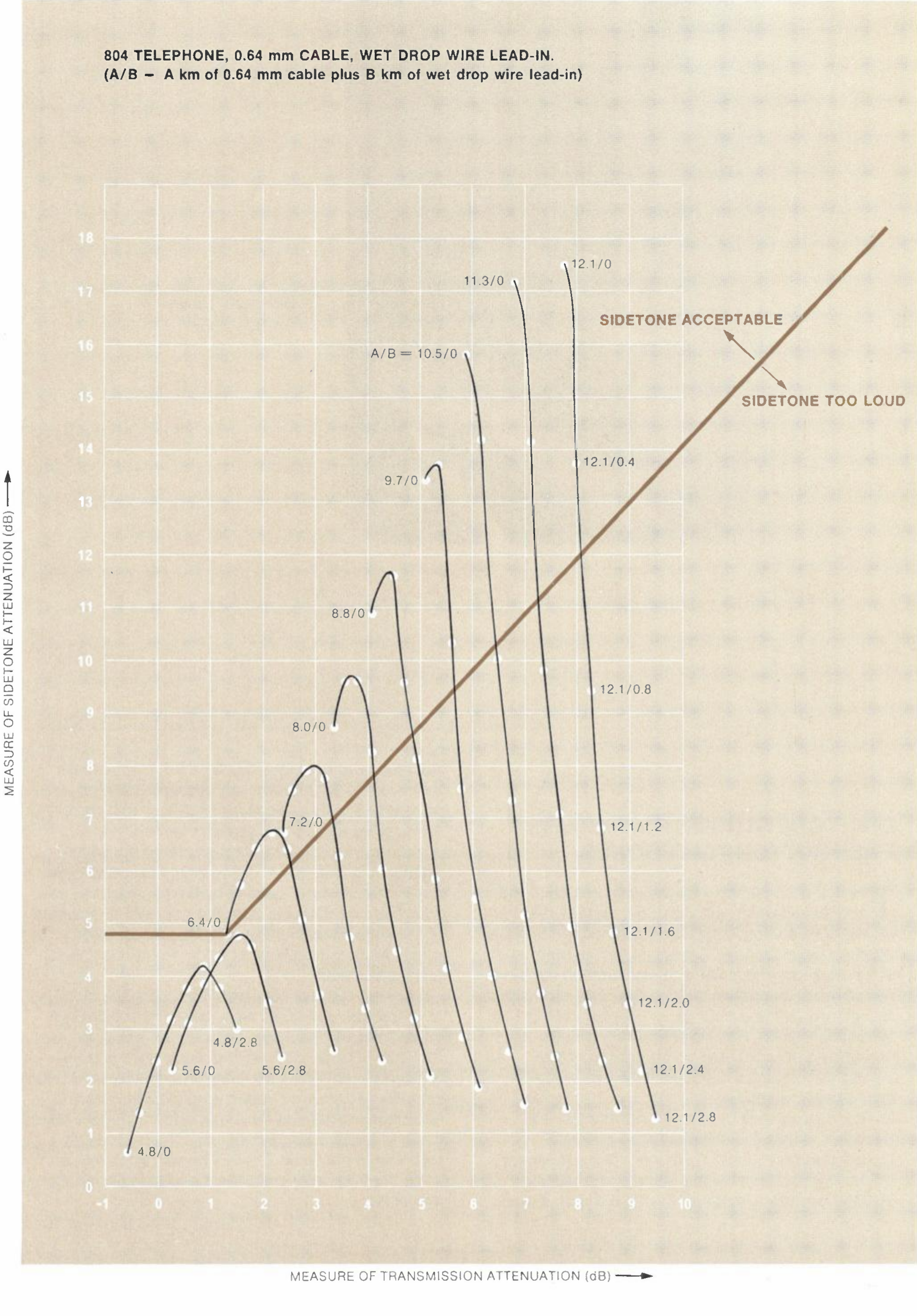
Previous Reviews have reported on the early stages of development of the type 804 long line telephone. Emphasis was given to the principles of operation and advantages of the telephone. Not discussed, however, was the problem of crosstalk between adjacent subscribers' lines which is made worse in the case of a long line telephone because of its increased sending and receiving sensitivities. This problem is most acute with a loud talker. By including a volume limiter circuit in the microphone amplifier to restrict the speech volume to line with a loud talker, and by restricting its application to new cables which have a 5 dB improvement in near-end crosstalk attenuation, the incidence of crosstalk with the type 804 telephone has been sufficiently minimised.

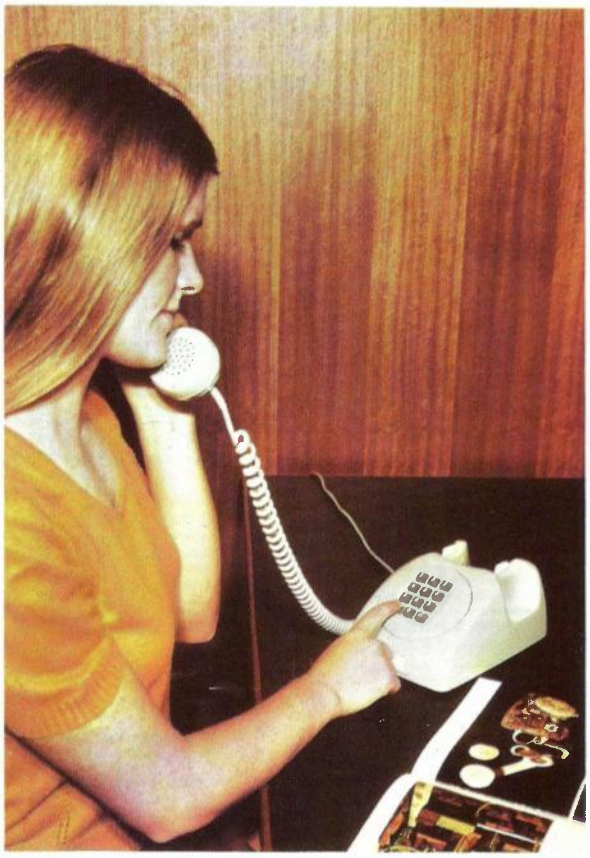
Any new telephone design must be extensively tested in the laboratory to ensure that its transmission performance is compatible with the requirements of the telephone network. A high sensitivity telephone such as the 804 requires particularly close attention, especially with regard to its sidetone performance. In particular, numerous measurements have been made on the 804 to optimise the balance network for use with each cable type and to determine the maximum length of drop wire lead-in which can be used with each.

A field trial of 100 long line telephones was concluded in 1972. It proved useful in locating minor deficiencies in the performance of the telephone. Subsequently, modifications were made to its volume limiter and lightning protection circuits, and the installation procedure was simplified by reducing the number of different balance networks and by placing tighter restrictions on cable practices. The optimum balance network to be used in each installation will now be selected to match the cable type and no test instrument will be necessary at installation.

Interim production standards have been set and an initial batch of 6000 long line telephones are on order and should be available for installation in the second half of 1973.

RULES FOR THE USE OF VARYING LENGTHS OF DROP WIRE LEAD-IN WITH THE TYPE 804 LONG LINE TELEPHONE WERE DETERMINED FROM A NUMBER OF FAMILIES OF CURVES SIMILAR TO THE ONE BELOW.





DIALLING IS QUICKER & EASIER WITH A PUSH BUTTON TELEPHONE.

DIAL TONE STUDIES FOR FUTURE PUSH BUTTON TELEPHONES

The A.P.O. is planning for the early introduction of telephones which will signal the exchange by means of voice frequency tones transmitted under the control of push buttons. Conventional dial tone, which is a pulsed low frequency tone, has a broad spectrum of frequency components which could prevent proper recognition, at the exchange, of the push button telephone signals. It is therefore necessary to introduce a new dial tone which does not have significant frequency components within any of the tone signalling bands.

For the convenience of international visitors, it is desirable to adopt a common internationally-standardised dial tone. It is unlikely that agreement will be reached upon such a standard for at least another four years, so as an interim solution, it was decided to select a new dial tone from those tones which are in widespread use overseas. Several factors had to be considered in making this choice.

It was preferable for the selected tone to have a similarity in sound to existing dial tone, but not be readily confused with other audible tones already in use in the network. The tone had to be adaptable to machine recognition and should generate a minimum of spurious components within the tone receiver bands when the dial tone is fed to a non-linear local telephone circuit.

As a result of these considerations, samples of possible new dial tones were prepared comprising either a single frequency, a mixture of two, or a modulated group of three frequencies in the range 350 to 440 Hz. Following further consideration of these samples and an examination of the relative costs of implementing them, a recommendation has now been made to adopt a single frequency of 425 Hz as the new interim dial tone. This will be subject to review when the international standard dial tone becomes available.

ADJUSTING LIP RING TO LOCATE SPEAKING POSITION.

THE TELEPHONE HANDSET SPEAKING POSITION

In a telephone conversation, subscribers are not subject to any rigid restraint on the position of their lips relative to the microphone. A close coupling to the handset is desirable in the interests of achieving maximum speaking and listening efficiencies, but in practice, each subscriber tends to adopt a compromise position of the handset which optimises personal comfort rather than transmission performance. When rating the sending performance of a telephone, it is both desirable and customary to fix the speaking position relative to the handset. Such a speaking position should be representative of the lip positions of telephone users.

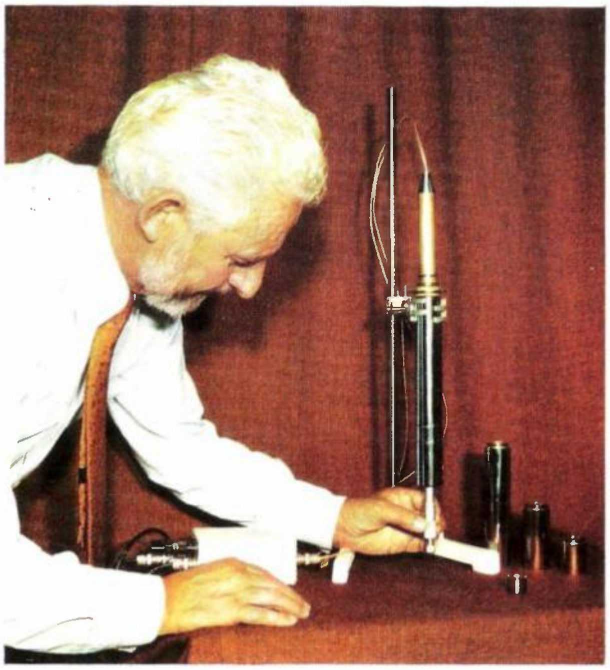
Although two speaking positions have been internationally standardised for telephone measurements, it has become apparent that for the six basic handset shapes in use in the Australian network, at least one of the standard positions is unrealistic. Tests were therefore carried out in the Research Laboratories to determine the speaking position behaviour of telephone users for these handsets. More than 70 subjects of various ages and professions, and representing both sexes, were involved in these tests which required each subject to converse with another over a simulated telephone connection using each of the test handsets in turn. The subject's speaking position for each of the handsets was observed by an operator, who progressively set an adjustable guard ring mounted on the test handset until the speaker's lips just brushed the guard ring while talking. The position of this guard ring was subsequently measured in terms of co-ordinates relative to the handset ear cap. To supplement the speaking position tests, head dimension measurements relating lip and ear positions were also carried out on all of the subjects.

The results of the tests showed that one of the standard lip positions (N.O.S.F.E.R.) was, as expected, quite unrepresentative of real speaking positions for all handsets, and that the second standard lip position (A.E.N.) was only realistic for the more conventional shapes of handset. As a result, it is proposed that for transmission rating purposes, a separate effective speaking position corresponding to the mean speaking position of telephone users be adopted for each handset.

Measurements

TWO MICROPHONES FOR RECIPROCITY CALIBRATION ▶
BEING INSERTED INTO THE 3cc COUPLER.
THE 18cc COUPLER IS AT FRONT LEFT.

MICROMETER ADJUSTMENT OF ACOUSTICAL SHUNT
FOR MEASURING MICROPHONE DIAPHRAGM COMPLIANCE.



RECIPROCITY CALIBRATIONS OF CAPACITOR MICROPHONES

Acoustical measurements and calibrations carried out in the Research Laboratories generally utilise standard capacitor microphones because of their stable sensitivities and their smooth and predictable frequency responses. In order to achieve a known accuracy, such measurements must be related to an established standard of sound pressure level.
For many day-to-day measurements, secondary standards, such as the pistonphone and sound level calibrators, which generate a nominal sound pressure level at a given frequency in a small chamber to which the measuring microphone can be coupled, are useful in checking microphone calibrations. However, the Laboratories' basic acoustic standard is a set of standard capacitor microphones, each with an absolute sensitivity calibration achieved by the reciprocity technique.
The reciprocity technique has, for the last decade, been the standard microphone calibration technique of major national standards laboratories throughout the world, and in recent years, the International Electrotechnical Commission (I.E.C.) has attempted to standardise the method to ensure a high degree of consistency in the calibration of capacitor microphones. The Standards Association of Australia is currently preparing an Australian Standard on this technique. Because the A.P.O. Research Laboratories is the only Australian organisation with experience in the technique, it prepared the basic draft of this Standard for study by the appropriate S.A.A. Technical Committee.
The reciprocity method provides for the absolute calibration of microphones which are reversible — that is, those which can be used either as a generator of sound or as a microphone. When two reversible microphones are acoustically coupled, the product of their sensitivities as microphones can be obtained from the ratio of the input and output voltages and the

acoustic coupling impedance. Although the microphones can be coupled in free space, such as in an anechoic room, it is usual to couple through a small chamber of from 3 to 20 cc in volume. If three microphones are available and used in turn in pairs, it is readily possible to calculate separately the absolute sensitivity of each microphone.

With moderate care, calibrations with an absolute error of the order of 0.4 dB at a frequency in the region of 1 kHz can readily be obtained, but errors of less than 0.1 dB over the frequency range of at least 100 Hz to 5 kHz are desirable objectives for an acoustic standard. Such accuracies are only obtainable with a considerable refinement of the basic technique, involving sophisticated instrumentation and virtually state-of-the-art limits in mechanical and electrical construction and measurement techniques.

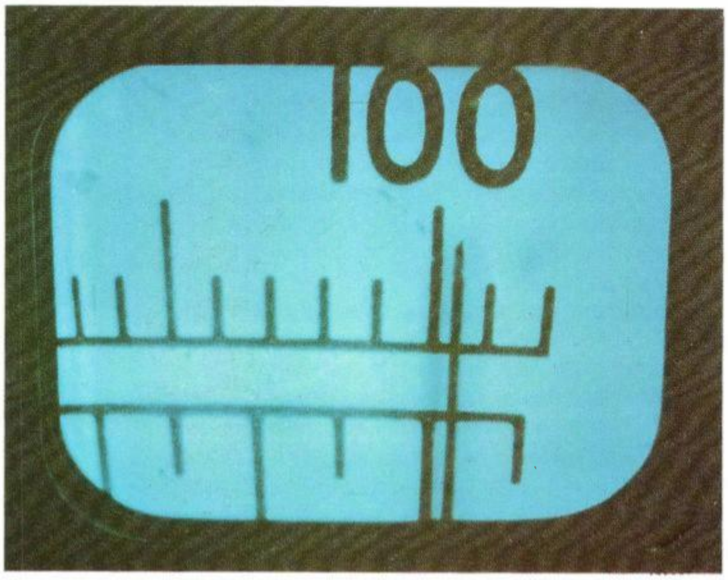
Considerable progress has been made in the Laboratories towards achieving this accuracy. The mechanical construction of the coupling chambers has been improved; corrections for capillary vents ascertained; a technique for the measurement of the acoustic compliance of the microphone diaphragms (which effectively increases the volume of the 3 cc coupling chamber by about 10%) has been developed; and thermal gradients between the two coupled microphones are being minimised by the use of a special solid state microphone pre-amplifier.

AUTOMATED CALIBRATION CHECKS ON LABORATORY TEST EQUIPMENT

The Research Laboratories use a large number of multimeters and electronic voltmeters whose calibration accuracy must be checked on a regular basis. To reduce the "out-of-service" time for instruments and the period of re-calibration, the calibration equipment and procedures have been automated. Increased accuracy of measurement due to reduction in operator error has also resulted.
To reduce fatigue in reading and setting the meter under test, a closed circuit T.V. system is employed which produces a parallax-free image of part of the meter scale on a 14 unit monitor screen, with a magnification of about 20 times. The meter is placed on a rotatable platform below the vertically mounted camera so that the entire scale can be viewed by one simple monitor.
This viewing system has been used both with the present commercial calibrator and an earlier laboratory-built system using a digital voltmeter, a tape reader and an electric typewriter. In the latter, a perforated tape was read into the system giving a series of typed instructions for the operator to follow and a typed list of calibrations from the DVM standard, leaving the operator to calculate the errors. The system operated satisfactorily and, although tedious to operate, it was faster than the previous traditional method employing two operators.
The success of the laboratory-built system led to the purchase of a commercially available system from Electro Scientific Industries. This system contains a programmed calibration source controlled by a punched card — one for each type of instrument. The associated electric typewriter prints out calibration errors expressed as a percentage of the full scale value, together with meter range and scale values. The operator is instructed by illuminated panel displays as well as by typed instructions.
The calibration of the testing system itself has to be checked periodically against its own specifications. This can be a time-consuming job for meter calibrators like the Weston-Rotek 166, Fluke 760 and E.S.I. Model 70. By using automatic techniques developed from the earlier laboratory-built calibration system, a new and faster system in this respect has been built using a 5-digit digital multimeter, an instrumentation coupler and a programmable desk calculator. With a given programme, commands are passed through the interface to the calibrator, the digital multimeter measures the output of the calibrator, and the calculator compares the value with the specification, calculates and prints out the error and then steps the calibrator to the next value.
At present, the closed circuit T.V. viewer and the E.S.I. system are used as a quick and accurate means of calibrating multimeters, with a manually operated calibrator (Weston-Rotek Model 166) used for non-standard and special instruments. The calculator based, laboratory-built system is used for checking these two calibrators and is also employed on other repetitive measuring tasks.

AUTOMATED CALIBRATION REDUCES OPERATOR FATIGUE.

TV TECHNIQUES MAGNIFY METER SCALE.



EVALUATION OF EXCHANGE BATTERY LIFETIMES

Lead acid batteries are used very extensively by the A.P.O. to ensure an uninterrupted power supply to the network. Some automatic stations obtain their entire power needs from batteries. Consequently, these batteries are used on "cycling operation". In exchanges, the batteries are usually used in float operation and are exposed to occasional cycling only. Batteries are also required as "stand by" power sources for such things as diesel starting. The wide variation in the type of usage demands a reliable battery which is capable of giving good performance under all service conditions.

An extensive test programme is under way to ensure that the right type of battery can be selected for any particular duty cycle. Another aim of this test programme is to determine the controlling parameters and their influence on the expected life of the battery. The investigation is divided into two main sections — prototype testing and cycling testing.

The protype testing is defined by an A.P.O. specification. It covers the determination of positive and negative plate potential characteristics under various charge and discharge conditions, the recoverable capacity under different load conditions, and the float current values at selected potentials. The battery components are tested for their chemical impurities and the quality of the electrolyte is also determined.

During the cycling test, the batteries are exposed to a simulated but reasonably severe field condition. The performance of these batteries is assessed by the change in capacity versus the number of cycles to which they are exposed. The potential changes during cycling for both charging and discharging conditions are also assessed and evaluated. When the performance of a battery falls outside the specification, the components of the battery and the electrolyte are analysed.

Besides the testing carried out on batteries, investigations are also being made to improve test methods and to design new ones, so that the ever-increasing demand on secondary power sources can be met with a minimum amount of uncertainty as regards their quality.

EARTH ROD AFTER REMOVAL FROM GROUND.

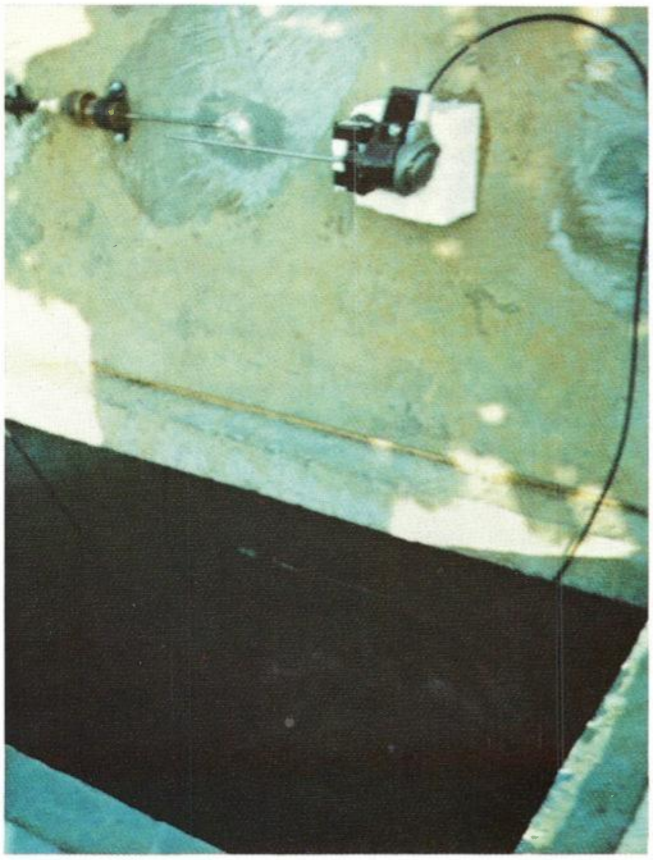
MEASUREMENTS OF EARTH ROD RESISTANCE

Electrical equipment is earthed to minimize interference and to protect personnel from injury caused by high voltages due to accidental contact of equipment with power sources or lightning discharges. The ideal earth-rod material should provide a low resistance to earth, be corrosion resistant and should not accelerate corrosion in any materials which may be connected to it through the earth system.

Copper-clad steel rods, joined and progressively driven into the ground, were used for many years to provide a satisfactory earthing system. In most soils, copper earth-rods show only slight corrosion so that the replacement cost is low. Unfortunately, copper promotes galvanic corrosion of all common construction metals.

Stainless steel was suggested as an alternative to copper when coupled to lead. A test programme was organized in co-operation with the Victorian Cable Protection Division to test various earth-rod materials to determine their corrosion characteristics and also the possible galvanic corrosion problems encountered when coupled to lead. The five types of earth rod tested were copper-clad steel, galvanised steel, aluminium clad steel, stainless steel and a nickel-iron alloy. The potential changes and galvanic currents produced between the lead and earth-rod couples are measured and the corrosion determined by removing a set of rods and attached lead sheets at regular intervals.

Due to increased use of plastic and plastic jacketed cables, the selection of the right type of earth-rod materials is even more critical. The investigation should provide information as to the most suitable earth-rod material for a particular earthing application.



INSULATED MANHOLE NORTH OF PERTH, W.A., DURING INSTALLATION OF TEMPERATURE SENSORS.

BELOW: TEMPERATURE SENSORS MOUNTED ON UNDERSIDE OF UNINSULATED STEEL MANHOLE LID.

TEMPERATURE CONDITIONS IN COAXIAL CABLE REPEATER MANHOLES

To achieve proper transmission performance of certain coaxial cable sytems, the instantaneous temperature difference between each repeater and its associated cable must not vary by more than 1.6°C. In the hot arrid regions of Australia, the temperature of buried cable varies quite slowly, lagging behind average seasonal temperatures. However, unless special precautions are taken, a repeater situated in a manhole tends to follow actual air temperatures.

To investigate means of maintaining the repeaters at a more stable temperature, 2 manholes were constructed near Upper Swan, W.A., and repeater housings were installed with electric heaters to simulate working repeaters, together with temperature sensing and recording equipment. In each manhole, one repeater housing was installed in the normal position about 900 mm above the floor and another on the floor of the hole. One steel manhole lid was insulated with a 75 mm layer of polystyrene foam on the underside of the lid and roof.

For 3 years, recordings were made of the temperature of the repeaters, the buried cables 5 m from the manholes, and at significant points such as on and just under the steel manhole lid.

It was shown that not even the floor-mounted housing in the insulated manhole met the temperature variation requirement, although the insulation and the floor mounting each had some effect. White paint on the exposed surface of the manhole and thicker insulation were recommended. A new manhole design is now being examined at Maidstone, Victoria, using gas burners to simulate the high temperature environment.

Materials & Practices

PVC SEALS AS REPLACEMENTS FOR LEAD SEALS FOR MAIL BAG CLOSURES

Lead seals have been used for many years to secure the ties on mail bags. In 1969, this usage required approximately 100 tonnes of lead at a cost in excess of $44,000. As early as 1947, it was known that certain types of plastic seals, requiring heated presses, were in use overseas. This type of press is not only heavier and more difficult to operate than the simple hand lead-press used in the A.P.O., but the cost of fitting heating elements to the existing 10,000 lead presses would have been prohibitive. Hence no further action was taken at that time.

In the late 1960's, it became known that the Postal authorities of the German Democratic Republic were using plastic seals closed with non-heated presses. An examination of the seals and the method of sealing led to the production in Australia of a lightly plasticised, heat stabilised, filled PVC seal that could be deformed readily in the cold, without any apparent surface cracking or crazing. By following the design of the German seal (which had two circular holes, a little larger than the string diameter, through the body of the seal to about the centre where they merged into a single, oblong cross-section hole which ran through the remainder of the body) their technique of clamping onto a knot tied in the string could also be followed. Tests showed that the force required to pull the string out of the seal was higher than that required to break the viscose rayon string itself. The only additional requirement for the string was that its diameter be small enough, when knotted, for the knot to be pulled into the body of the seal.

On the basis of a limited investigation, it was shown that a cold-pressed plastic seal could be produced with adequate strength and good legibility of the identification markings. Because of the difference in specific gravity between PVC and lead (1.4 versus 11.3), the use of PVC would result in a substantial reduction of the mass of material required annually. The 100 tonnes of lead reportedly needed at present every year could be replaced by approximately 12½ tonnes of PVC at an estimated cost of $10,000 — an annual saving of over $30,000.

PROMOTING AWARENESS OF TOXIC AND DANGEROUS CHEMICALS AND SUBSTANCES IN THE A.P.O.

An unfortunate episode of "Yusho", a mass poisoning, which occurred during 1968 in Western Japan and affected more than 1000 people, was caused by ingestion of rice oil contaminated with polychlorinated biphenyl.

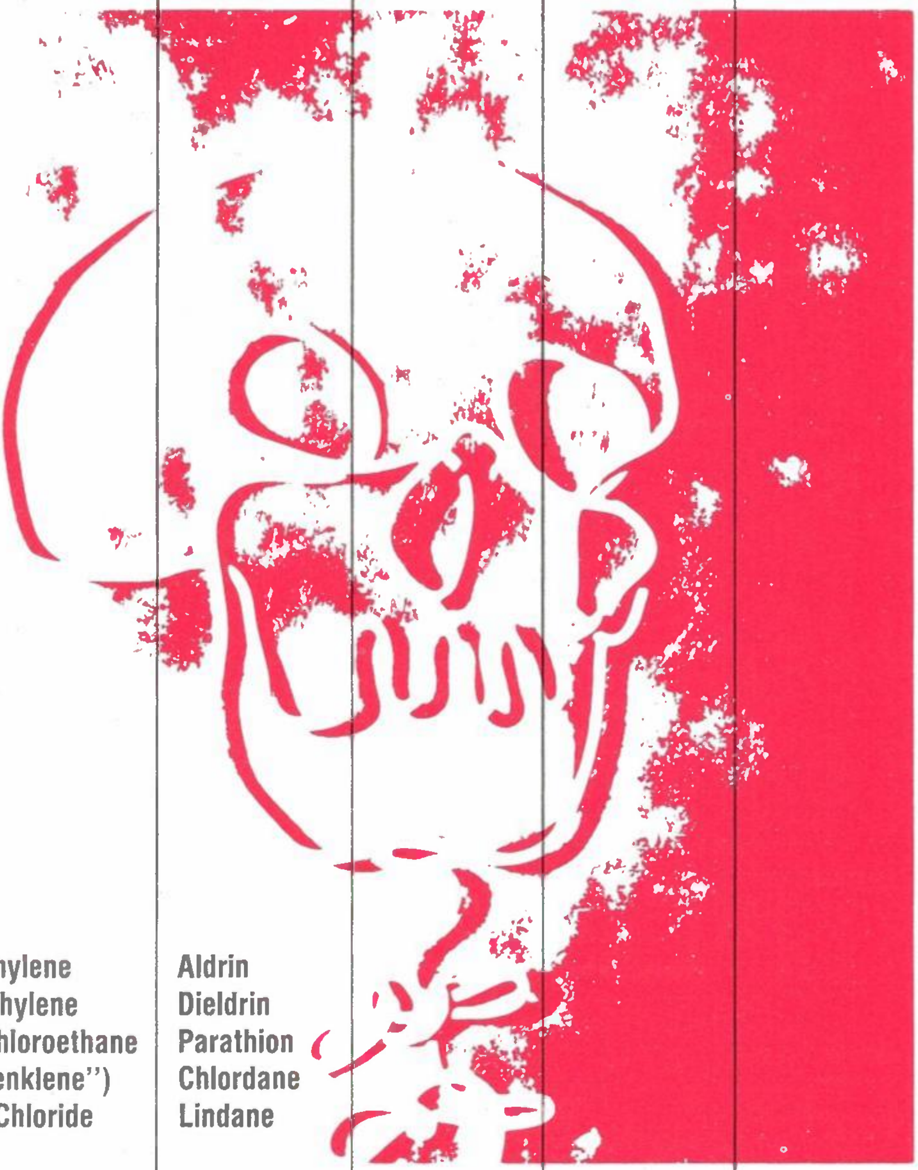
There is no doubt that indiscriminate and unintelligent use of a number of toxic compounds throughout the world has created many problems. The Research Laboratories of the A.P.O. are aware of this and have instigated a programme whereby personnel will become equipped to handle such compounds safely and give reliable and sound advice to others when needed.

A number of toxic compounds are handled each day by A.P.O. employees. Chlorinated hydrocarbons in contact cleaners and degreasing agents, polyurethanes in adhesives, benzene and toluene in general solvents, and chlorinated and phosphorus pesticides in insect repellants, weedicides and termite treatments are but a few examples.

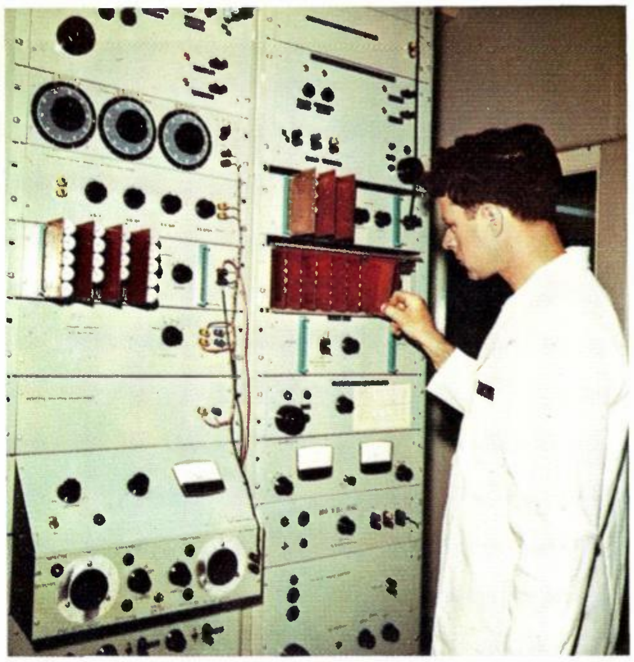
Current awareness within the A.P.O. has resulted in the preparation and subsequent issue of a report on the toxicity and properties of various solvents used by the Department. It has also led to discussions and written advice to officers engaged on work necessitating the use of toxic chemicals. Routine analyses are performed on proprietory formulations to detect the presence of hazardous and toxic components. Sampling tests of working atmospheres are also carried out for the detection of undesirable toxic gases, such as carbon monoxide, sulphur dioxide and phosgene. In addition to this, as a safety precaution, telephone linesmen are issued with gas detector kits when working in underground tunnels. The dangers present in workshop areas have also been highlighted, since the heat generated in welding operations can cause degreasing solvents to break down into phosgene, a highly toxic vapour with a maximum permitted concentration of 0.1 parts per million.

The staff of the Laboratories have been active in promoting awareness of toxic materials amongst A.P.O. staff by their role in establishing a recognised system of supervision of these materials and their uses. By this means, A.P.O. staff may be confident that any materials allowed to be used are safe and that there is satisfactory supervision of the manner in which these materials are being used.

Dangerous Chemicals



SOLVENTS		INSECTICIDES	POLYURETHANES	MERCURY	EPOXY CURING AGENTS
Carbon Tetrachloride **Benzene**	**Freon T.F.** **Freon 11** **Freon 12** **Trichloroethylene** **Perchloroethylene** **1, 1, 1 Trichloroethane ("Genklene")** **Methylene Chloride**	**Aldrin** **Dieldrin** **Parathion** **Chlordane** **Lindane**			
Highly toxic, chronic and acute poisons — whether absorbed by ingestion, inhalation or through the skin.	Low to moderate toxicity, but highly toxic and irritating gases may be formed when vapours come into contact with flames or hot metal surfaces.	Readily absorbed through the skin. Highly toxic, acute and chronic poisons — whether absorbed by ingestion, inhalation or through the skin.	When they contain free iso-cyanates, can have severe irritating effects on the mucous membranes, causing asthmatic and bronchial disorders.	Because of its volatility, it is readily absorbed by inhalation. It is highly toxic.	Can be extremely irritating to the skin and cause dermatitis.



EQUIPMENT USED TO ASSESS RELIABILITY OF ELECTROLYTIC CAPACITORS.

ASSESSMENT OF AEROSOL SPRAY LUBRICANTS

The ready availability of solvents and lubricants in spray containers has led to them being used or considered for use in many areas of the Department. The products fall into two main classes: solvent cleaning and lubricant-dewatering type sprays. The aerosol products are being evaluated for their performance in light of manufacturers' claims, their effect on telecommunication equipment and materials, such as metals and plastics, their flammability and the result of spray falling on active electrical contacts. In addition, the materials are being analysed for the presence of any components which may be harmful to the operators.

Most solvent cleaning aerosols contain either freon TF or 111 Trichloroethane as the solvent, with freon 12 or a mixture of freons 11 and 12 for pressurization. Freon TF has low toxicity and is quite volatile. It has no adverse effect on any of the metal or plastic surfaces evaluated. 111 Trichloroethane is a more effective solvent than freon TF, and although it has a slightly higher toxicity level, it is still considered to be a reasonably safe material to handle. It is, however, slightly less volatile, lowers surface resistivity until evaporated, and shows slight solvent action on some plastics — this being most noticeable on ABS plastics where it dulls the surface finish and softens the surface after prolonged contact.

The lubricant sprays are designed to lubricate electrical contacts, inhibit corrosion and, in some cases, to expel moisture. They generally consist of an oil, grease or dry lubricant, a solvent, a dewatering agent and a pressurizing gas. Several of the lubricant sprays contain petroleum derivatives as solvents, and these are generally flammable and cause heavy pitting and carbon deposits on low voltage arcing contacts. Most, but not all, sprays inhibit or prevent the corrosion of metals. They have no harmful chemical effect on metals, although several caused stress cracking, softening or marring of the surface of some plastics (particularly ABS). The aerosols which affected plastics contained a chlorinated hydrocarbon solvent, often 111 Trichloroethane. This effect on plastics is more serious with these sprays because the oil in the mixture delays the evaporation of the solvent.

THE RELIABILITY OF ALUMINIUM FOIL ELECTROLYTIC CAPACITORS

An extensive investigation into the properties of modern professional grade aluminium electrolytic capacitors has been carried out in the Physics and Polymer Section of the Research Laboratories. Tantalum electrolytic capacitors are often used in applications where high capacitance with leakage current and dissipation factor values less than those available from "entertainment" grade electrolytic capacitors are required. However, as tantalum capacitors tend to be expensive, an investigation of the suitability of cheaper alternatives was undertaken. Various tests were undertaken to determine capacitance stability, leakage current and dissipation factor, and the samples were finally dissected and visually examined. Most of the capacitors showed good shelf life stability, although some faults were found when they were subjected to environmental testing. In the higher grade aluminium electrolytic capacitors, failure at the applied working voltage was rare provided that the voltage was less than the knee in the leakage current characteristic curve. Most of those undergoing the charge-discharge test maintained a stable value of capacitance and none suffered self-healing breakdown. In a steady state damp heat test, some increase in leakage current was apparent but there was little effect on dissipation factor or capacitance stability. However, in a climatic cycling environment, leakage current increased and the dissipation factor was affected. The capacitors subjected to the vibration test either passed with negligible alteration to the parameters, or they failed catastrophically due to the detachment of the connections to the anode/or cathode foils.

In summary, some brands of modern professional grade aluminium electrolytic capacitors were shown to maintain high capacitance stability and low losses when subjected to severe environmental and accelerated life testing. An extension of their range of uses in telecommunications equipment has been recommended.

A.P.O. Reference Standards

DISTRIBUTION OF PRECISE FREQUENCY OVER THE CARRIER NETWORK USING 2-TONE DIFFERENCE TECHNIQUES

Modern telecommunications systems require highly stable and accurate frequencies for correct operation. For example, 2700 channel carrier systems, where line frequencies extend to approximately 12.3 MHz, require modulating and demodulatng signals whose frequencies are within approximately one part in 10^7 of each other. For a 60 MHz system, this requirement becomes approximately 2 parts in 10^8. The oscillators which supply these signals are located at each end of the carrier system (for example, in two capital cities) and therefore require special techniques to check their accuracy. In addition, the A.P.O. has the responsibility under the Wireless Telegraphy Act to measure the frequencies of all radio transmissions in the Commonwealth to ensure that they meet specified accuracies. Both these requirements are serviced by a standard frequency distribution network which preserves the accuracy of a standard frequency when transmitted over carrier systems by using a Laboratories' developed technique.

The technique used is to generate two tones, 1700 Hz and 2700 Hz, whose frequency difference is precisely 1 kHz. At the receiving end of the carrier system, these tones will both be in error by an amount equal to the asynchronism of the carrier system but their frequency difference will still be 1 kHz. The two-tone signal, which is generated by equipment associated with the A.P.O.'s atomic frequency standard (caesium beam), is transmitted over the broadband carrier network, and is demodulated at the trunk terminals in the capital cities and in some regional centres to provide a standard 1 kHz reference frequency.

The Frequency Measuring Centres operated by the Department's Radio Regulatory and Licensing Section are equipped with master oscillators whose outputs are continuously phase compared against the two-tone-derived 1 kHz. Installation of comparison systems at the Perth and Townsville Frequency Measuring Centres was undertaken during 1972/73, bringing the number of centres equipped with this apparatus to seven. The technique used for comparison allows a frequency difference of 2 parts in 10^{10} to be measured in one day.

Where faster measurements of moderate accuracy are required, as for example when adjusting carrier oscillators at the far end of broadband carrier systems, a different device is used, the circuitry of which has been designed to reject any short-term noise or jitter which would otherwise prevent quick measurement. This device, which is readily portable, demodulates the two-tone signal and passes the resultant 1 kHz tone through a band-pass filter of 1 Hz bandwidth at the 3 dB points. The short-term stability imparted by this filter allows this device to make frequency measurements of one part in 10^7 in 10 seconds or, under conditions of relatively stable temperature, an accuracy of one part in 10^8 in 100 seconds. Field trials of this device have been in progress during 1972/73 with favourable results.

A third phase of this work, which has been pursued during 1972/73, is the development of phase controlled quartz crystal oscillators whose long-term stability is governed by the standard frequency of the two-tone system, but whose short-term stability is determined by the excellent short-term stability of the quartz crystal itself. One type of phase controlling device, which has reached the field testing stage, employs a sampling phase detector which produces a d.c. voltage suitable for phase controlling a varactor-tuned quartz crystal oscillator. Development work is in progress to produce a phase controlled oscillator with "memory", that is, a quartz crystal oscillator which will hold its accuracy during periods when the two-tone reference signal is absent. One such device holds the varactor control voltage at the value determined just prior to removal of the reference signal, so that the oscillator performs as a newly-synchronised quartz crystal oscillator during periods of two-tone absence. Another type provides compensation for oscillator ageing during periods of loss of reference signal, such compensation being a function of the oscillator's ageing performance during previous controlled periods.

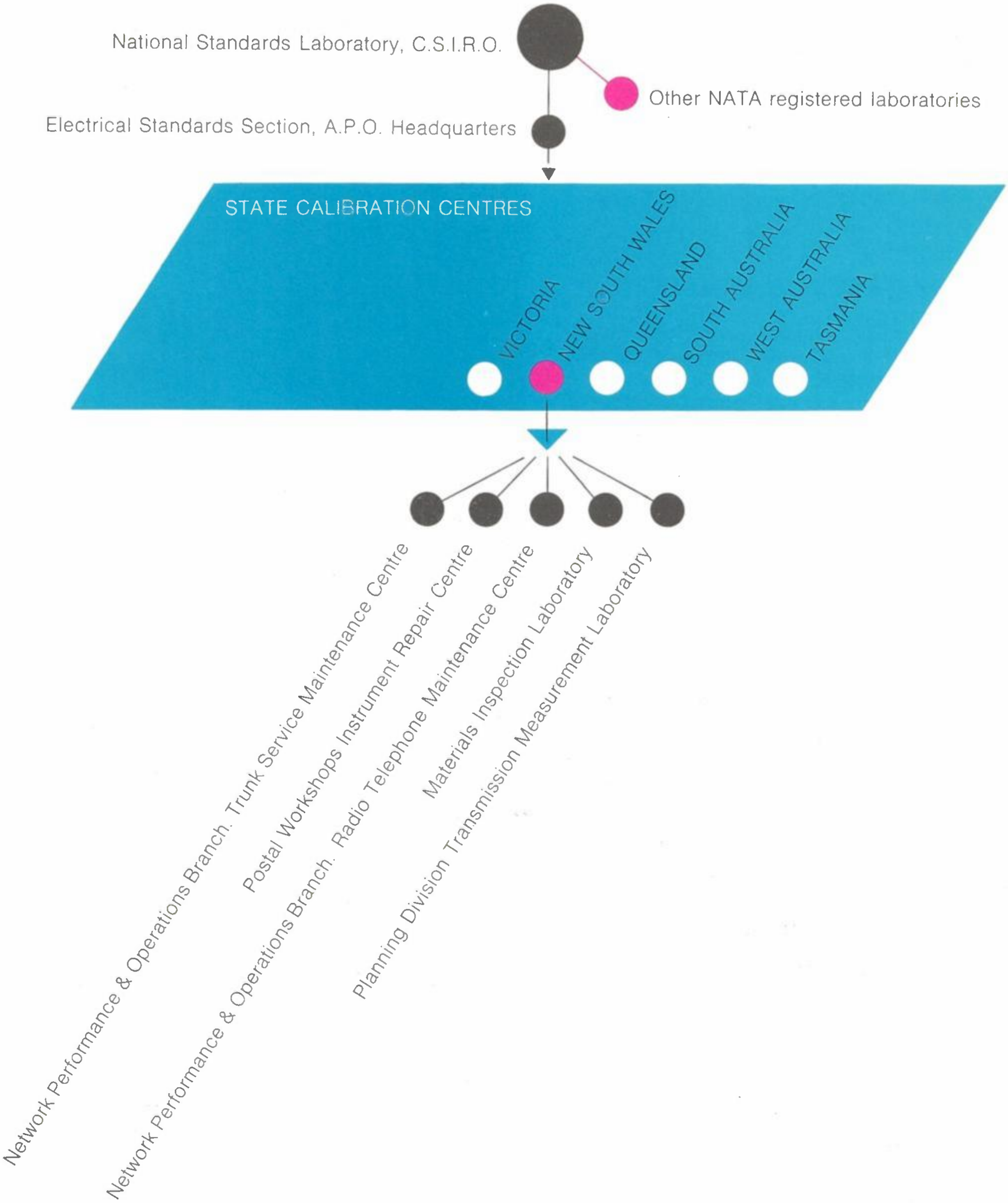
THE ROLE OF THE LABORATORIES IN THE STATE CALIBRATION SCHEME

Developments in communications technology are demanding increasingly higher accuracies of measurement in practically all areas of the Department. Projects such as subscriber trunk dialling and data transmission require very accurate measurement of such parameters as transmission levels, circuit loss and phase delay. Similarly, the acceptance testing of equipment for wideband bearer systems requires measurements of high accuracy to ensure compatability with other components of the network. Standardization of measuring equipment throughout the entire operating area of the Department is essential for these reasons.

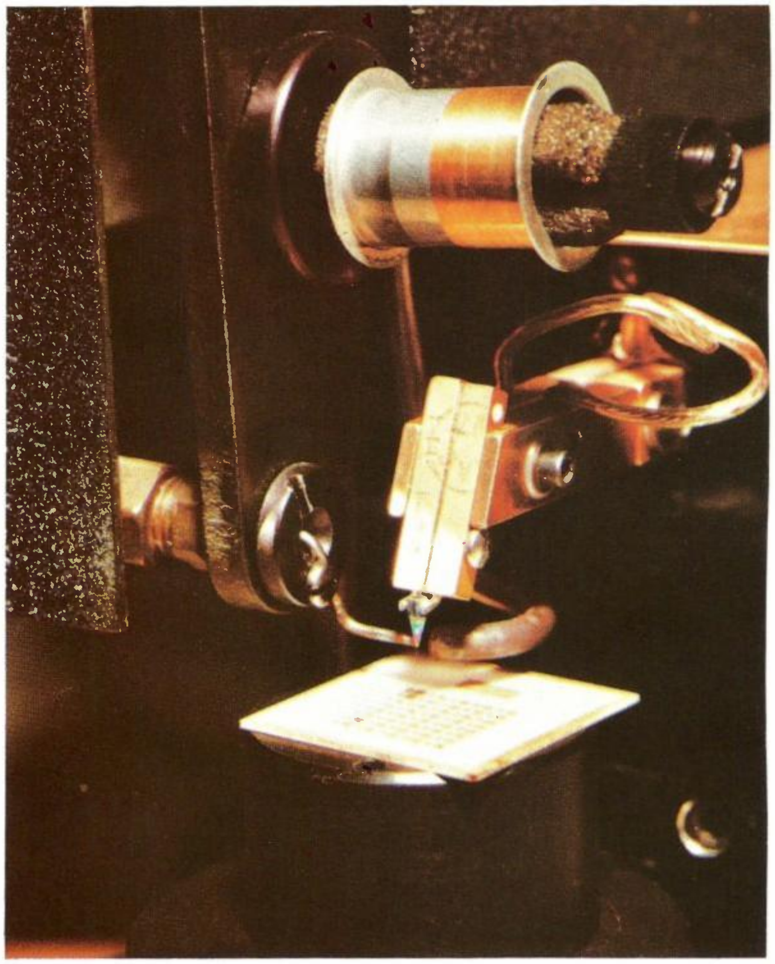
The State Calibration Scheme is a system whereby a routine calibration of traceable accuracy is provided for all Departmental electrical testing equipment in regular operational use, where errors could have a deleterious effect on the performance of operating plant, or result in the acceptance of defective equipment or material. It is not practical for all the measuring instruments of the same kind to be brought to the one place and calibrated against one reference standard. Standardization merely requires that they be calibrated "with reference to" a common standard. With contractors and suppliers, both local and overseas, it is essential that this common standard be a recognised one, and in fact, the Weights and Measures Act requires all measurements made in Australia to be made with reference to the relevant Australian Standard.

The technical oversight of calibration facilities spread throughout the Commonwealth is best maintained by a hierarchy of calibration laboratories with a structure like a family tree. The highest level within the Department is the Electrical Standards Section of the Research Laboratories, which has its reference standards calibrated by the National Standards Laboratory. This ensures demonstrable traceability of measurement to the Australian Standards as required by the Weights and Measures Act. The Electrical Standards Section calibrates test equipment and reference standards for five State Calibration Centres. These in turn calibrate instruments to be used as standards in about thirty Instrument Calibration Centres, which are to be situated either where the maintenance of test equipment is being carried out, or where equipment is used for critical testing. In this manner, measurement accuracy is disseminated to the working level in all parts of the Department.

Inherent in such a hierarchial structure of calibration laboratories is a loss of accuracy at each change of level. The extent of this loss varies with the electrical quantity being measured, but it can be in the range 3 to 10 times, resulting in a ratio in working accuracy between the highest and lowest laboratories in the 3 step hierarchy of between 27 and 1000 times. For this reason, the accuracy of the measurements made by the Electrical Standards Section has to be very high compared with that required at the operating level.


National Standards Laboratory, C.S.I.R.O.
Other NATA registered laboratories
Electrical Standards Section, A.P.O. Headquarters
STATE CALIBRATION CENTRES
VICTORIA
NEW SOUTH WALES
QUEENSLAND
SOUTH AUSTRALIA
WEST AUSTRALIA
TASMANIA
Network Performance & Operations Branch. Trunk Service Maintenance Centre
Postal Workshops Instrument Repair Centre
Network Performance & Operations Branch. Radio Telephone Maintenance Centre
Materials Inspection Laboratory
Planning Division Transmission Measurement Laboratory

Devices & Techniques



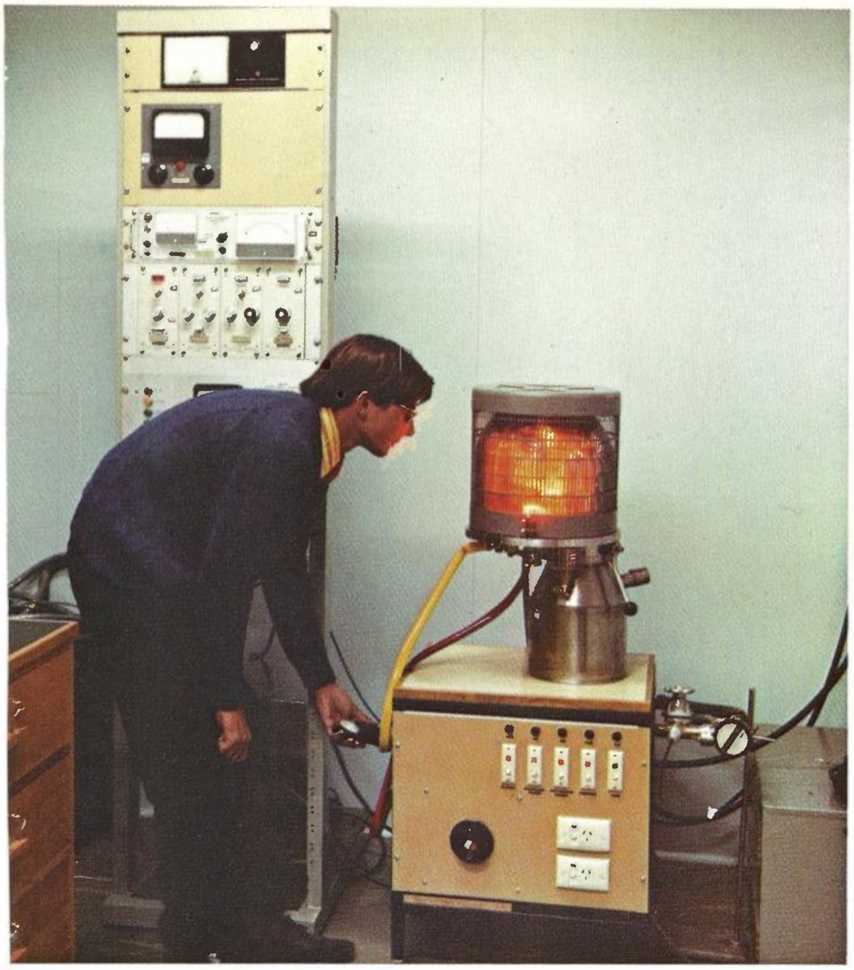
SOLID STATE DEVICE RESEARCH

The need for new devices to improve performance and lower costs has been a continuous motivation for semiconducting materials research, and only if materials and devices progress together will success be finally assured. There is a strong interaction — new materials technology leads to new devices, and new devices demand new technologies.

Until recently, advanced solid state device research in the Research Laboratories involved the use of commercially available bulk semiconductors. These were cut into wafers and lapped and polished to the desired thickness. Contact materials were evaporated onto the water surfaces and alloyed to form reliable contacts. Studies of travelling wave amplifiers and high-speed logic devices using the Gunn effect have been carried out using these techniques.

Unfortunately, the material that is available from commercial sources is often not satisfactory, and to overcome these problems, a programme to prepare epitaxial materials within the Laboratories has commenced. Because of its importance in a wide range of solid state devices, the material being studied is gallium arsenide. The preparation process being used can best be described as sliding boat liquid phase epitaxy. In this process liquid gallium, saturated with arsenic and including the appropriate dopant, is moved to a position on top of the seed crystal or substrate. A gallium arsenide layer grows onto the substrate when the oven temperature is lowered. The facility is initially being used to prepare diodes to be used as semiconducting lamps in optical fibre communcation systems. It will be used later to grow material for high frequency devices such as those using the Gunn effect.

The high frequency solid state devices now being developed are most satisfactorily used in hybrid microstrip circuits, rather than in the more conventional waveguide or coaxial circuits. Microstrip has advantages such as high reliability, small size and low cost. However, at the higher microwave and millimetric wave frequencies, little information on circuit performance is available, and the Research Laboratories are investigating these aspects of solid state device application. In order to evaluate microstrip performance at these frequencies, circuits have been prepared on thin aluminium oxide substrates so that effective dielectric constant and attenuation coefficients can be measured. The measuring equipment is all in waveguide componets, and transitions from waveguide to microstrip have been constructed. These involved four section ridged waveguide transformers. Satisfactory performance has been obtained with these transitions which have VSWR less than 1.8 from 26 to 36 GHz.



▲ EVAPORATING Au-Ge CONTACTS ONTO GALLIUM ARSENIDE.

◀ BONDING DEVICES INTO ALUMINA MICROSTRIP CIRCUITS.

CRYSTAL OSCILLATORS FOR HIGH FREQUENCY APPLICATIONS

The quartz crystal is still the only circuit element available which provides, with acceptable economy, the high frequency stability and selectivity required in many communication and instrumentation situations. Indeed, it is finding increasing application as technology advances and more stringent requirements are being imposed, particularly in the area of HF crystal devices. Even where the crystal has been surpassed as a frequency controlling element, such as in atomic oscillators, it still provides the interface between the atomic device and the load.

The HF quartz crystal oscillator of medium to high stability has now become an indispensable item of equipment in the field of electronics, both in the Research Laboratories and in the field, and it is not surprising that the Crystal Laboratory, a part of the Time and Frequency Standards Section, should be involved in the development of such oscillators.

Particular advantages over LF oscillators are the small size and robust nature of the crystal and the benefit of generating a high frequency as a starting point.

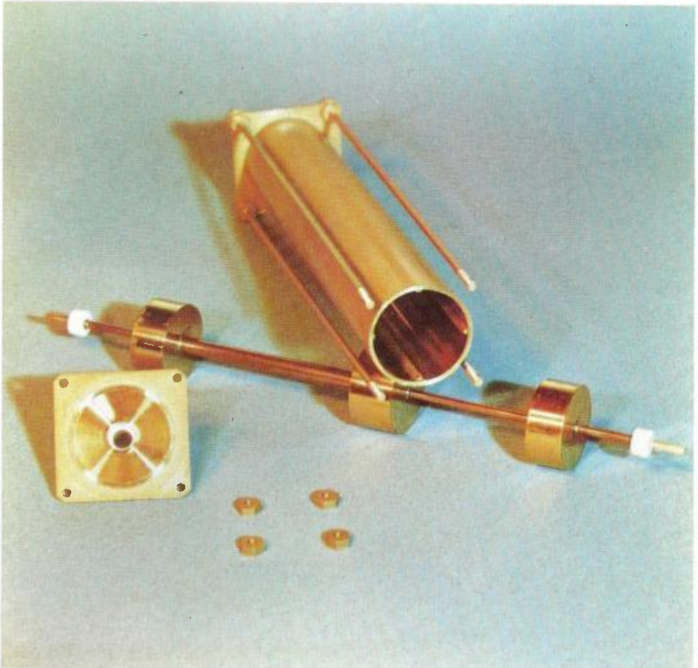
The main recent work of the Crystal Laboratory has been aimed at the production of specifications for a 5 MHz oscillator of standard frequency class and of moderate cost. A procedure has been formulated for processing a 5 MHz third overtone AT quartz crystal to give the required frequency stability and long-term ageing performance for standard frequency oscillator use. Resulting crystal units are comparable in performance with those produced overseas for frequency standards work. Ageing of parts in 10^{11} per day can be achieved. This work is unique in Australia and the expertise and the processes are made available to local industry. A complement of the project is the development of oscillator circuitry in which the crystal can function without degradation of its potential performance, and with a satisfactory degree of reliability. Several oscillators have been constructed meeting the specification and are being used as references on subsidiary standards.

A particular application of the oscillators concerns the Sydney and Melbourne Speaking Clocks, and a special version is under development to replace the existing 100 kHz reference oscillators which are approaching the end of their useful life. Similar oscillators, modified to allow external control, will be available for use as reference oscillators in the field. They will be locked to the two-tone frequency distribution systems and provide a "fly-wheel" to remove short-term noise and cover any periods of absence of the two-tone frequency standard. Thus the A.P.O. caesium standard will virtually become available at great distances per courtesy of the quartz oscillator.

A by-product of the above work is the development of a general purpose HF oscillator having precision in the region of 1 part in 10^8, with emphasis on low cost and robustness with reliability. Included in this range will be the temperature compensated oscillator, which uses a "cold" crystal and remains within about 1 part in 10^6 of the nominal value over a wide temperature range. One application of such oscillators is in SSB operation, particularly in the upper part of the HF band.

A further development being undertaken is the extension of processing methods for crystals through the HF band towards 50 MHz. One limiting problem in the manufacture of HF and VHF crystal units is the suppression of unwanted responses of the crystal. The detail of the formation of the metal electrode must be accurately determined to trap the energy of the oscillating quartz in the desired mode of resonance. If improvements can be effected in the energy trapping technique, then satisfactory performance at higher frequency becomes possible and some of the stability requirements which arise at these frequencies will be anticipated.

REFRACTOMETER DETERMINATION OF CRYSTAL PLANES.



DISSEMBLED COAXIAL FILTER.

A U.H.F. COAXIAL LOW PASS FILTER

In association with field measurements of tropospheric scatter propagation to commence this year, it was found necessary to develop a special low-pass filter to ensure that spurious signals arising in television and radio-telephone transmitters do not cause interference. This filter is to be inserted in the aerial feed of interfering sources. Hence, it must not significantly reduce the power fed to the aerial at the operating frequency of the transmitter (a 1% reduction is acceptable at frequencies below 500 MHz), and it must introduce a high power loss at the frequencies at which the tropospheric scatter measurements are to be conducted. The power in the frequency range 2.4 GHz to 2.6 GHz is to be reduced by a factor of at least 10^6. Such a filter has been realised in a coaxial configuration.

The filter consists of an outer conductive pipe, inside which is a cylindrical conductor with a stepped diameter. The approximate equivalent circuit of such a structure is a capacitor when the diameter of the inside conductor approaches the diameter of the pipe, and an inductor when the diameter of the inside conductor is small compared with that of the pipe. This concept is useful when relating the coaxial filter segments to the lumped components of the low-pass prototype. The low-pass prototype is used to obtain the initial estimate of the dimensions of the coaxial filter, the final dimensions being obtained by a process of optimization by repetitive analysis.

The design met all the specifications. The overall length of 230 mm is achieved using commercially available copper pipes and rods. It is expected that this filter will handle powers of up to 1 kW at frequencies below 500 MHz.

OPTICAL CHARACTER RECOGNITION STUDIES

There are many applications for a system which can automatically read machine-printed, typed or hand-printed alpha-numeric characters. One of the most important of these applications is in the field of mechanical mail handling. Already gaining wide acceptance in data processing environments are machines which can recognise a small set of characters printed or typed in a single font, or in some cases, in any one of several fonts. However, machines capable of true multi-font recognition, or of reliable hand-print recognition, such as are required in a postal environment, are still very much in a developmental stage.

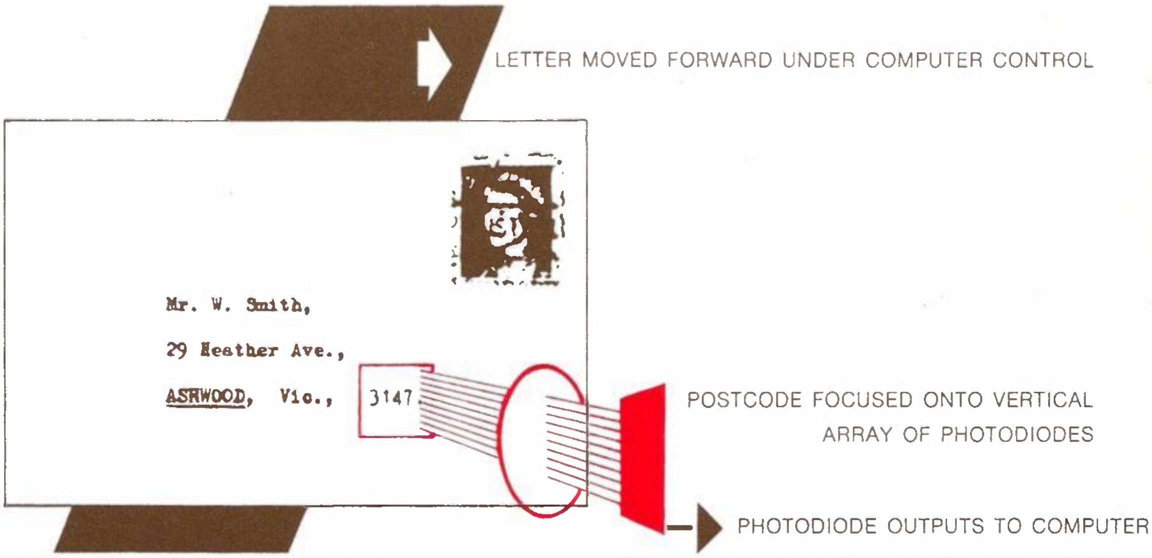
Within the Research Laboratories, a mini-computer is used to control a picture scanner, automatically adjusting the black-white threshold level according to the colours of the envelope and the writing/printing thereon. The digitised post-code images are then transferred, via paper tape or magnetic tape, to a large computer where various recognition strategies may be tested.

In present-day commercial machines, it is customary for scanning and recognition to be performed on the same piece of special purpose hardware, often with feedback between the two phases. However, new strategies are most easily developed and investigated using a general-purpose digital computer.

One strategy frequently employed involves the smoothing and/or thinning of line images, followed by a search and tabulation of such features as line ends, T-junctions, line crossings, etc. A logical classification is then made. For example, a numeric character which includes no junctions or crossings, and has only two line ends lying at the upper and lower extremities, is classified as a "one". Despite the apparently ad-hoc methods by which decision schemes are developed, strategies of this type have shown remarkably high accuracy when applied to the recognition of hand-printed numerals, character error rates in the vicinity of 1 per cent being commonly attained when a nominal set of constraints on hand-printing is applied.

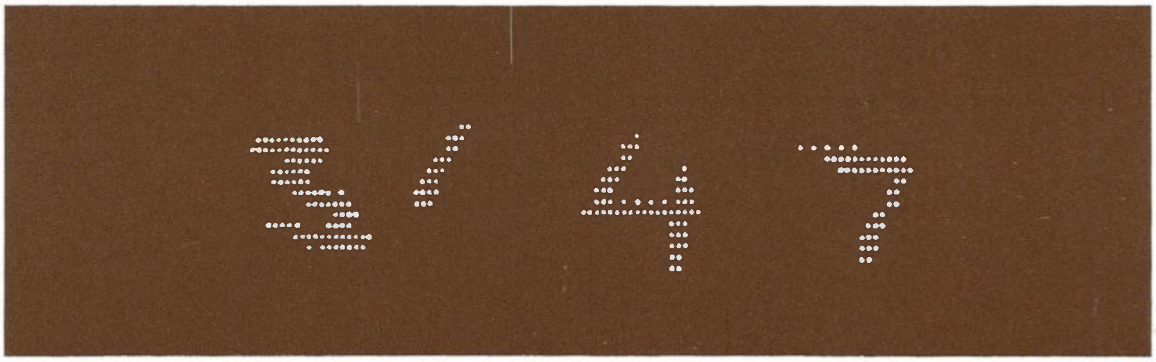
In another type of strategy, a set of pattern measurements, such as the normalised moments or the Walsh transform coefficients, is selected, usually so as to be independent of character size, position, and in some cases, skew. During a learning phase, these measurements are examined using thousands of "known" character samples, thereby enabling the placement of decision hyper-surfaces in multi-dimensional space. Subsequent categorisation of "unknown" characters is effected by use of these decision boundaries.

There is an important distinction between rejection of a character sample, and misclassification, particularly in a postal environment. Thus a letter containing a rejected character in the post-code would merely be diverted for manual sorting, whereas one with a mis-classified character would be despatched to the wrong destination. Strategies under investigation within the Research Laboratories are aimed at minimising the mis-classification rate — comparatively high reject rates being acceptable in the mail sorting application of the principles of optical character recognition.



1

SCANNER EXTRACTS DIGITISED IMAGE OF POSTCODE



2

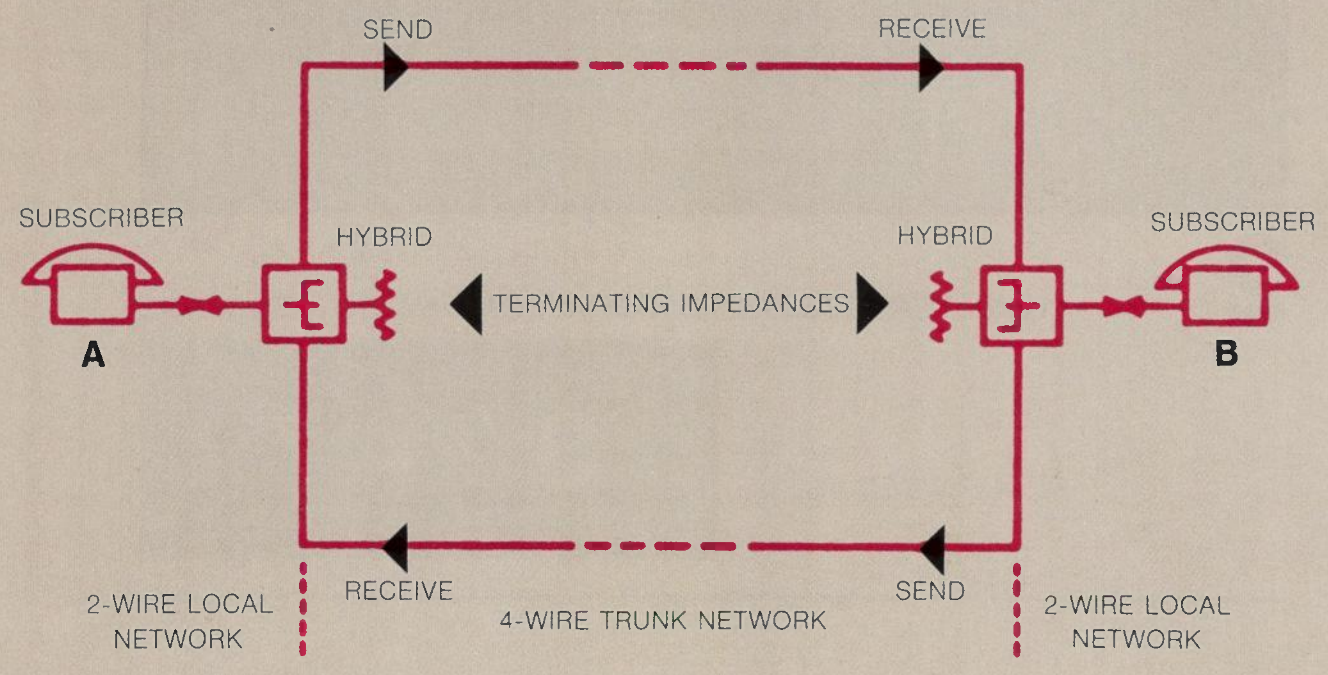
COMPUTER ATTEMPTS RECOGNITION OF DIGITISED IMAGE

RECOGNISED AS 3 ? 4 7

ECHO CANCELLATION IN LONG-DISTANCE VOICE COMMUNICATIONS

With the advent of communication satellites and the rapid growth of international telephone traffic, there is a renewed interest in the problem of echoes which occur in long-distance telephone calls. Echoes occur because it is not practically possible to have a perfect transition between the two-wire and four-wire sections of a long-distance telephone circuit. At each two-wire/four-wire junction, some of the speech in the receive path of the four-wire circuit inevitably finds its way, across the hybrid, into the corresponding send path and returns to the originating speaker's earpiece. Ideally, it should be channelled into the two-wire circuit and subsequently to the other party in the conversation. If the transmission time from originating speaker to distant hybrid and back (loop delay) is long, then the speaker perceives a distant echo. The annoyance effect of the echo increases with increasing loop delay, and with the long delays experienced on satellite circuits it is a serious impediment to the free flow of a conversation.
Echo suppressors are in widespread use to combat the echo problem. One suppressor is associated with each end of the long-distance circuit. The principle is to sense the presence or absence of speech in the receive and send paths of the four-wire circuit and use this information to switch attenuation into the send path, thus reducing the echo. However, with both

Simplified 2-wire/4-wire long-distance connection

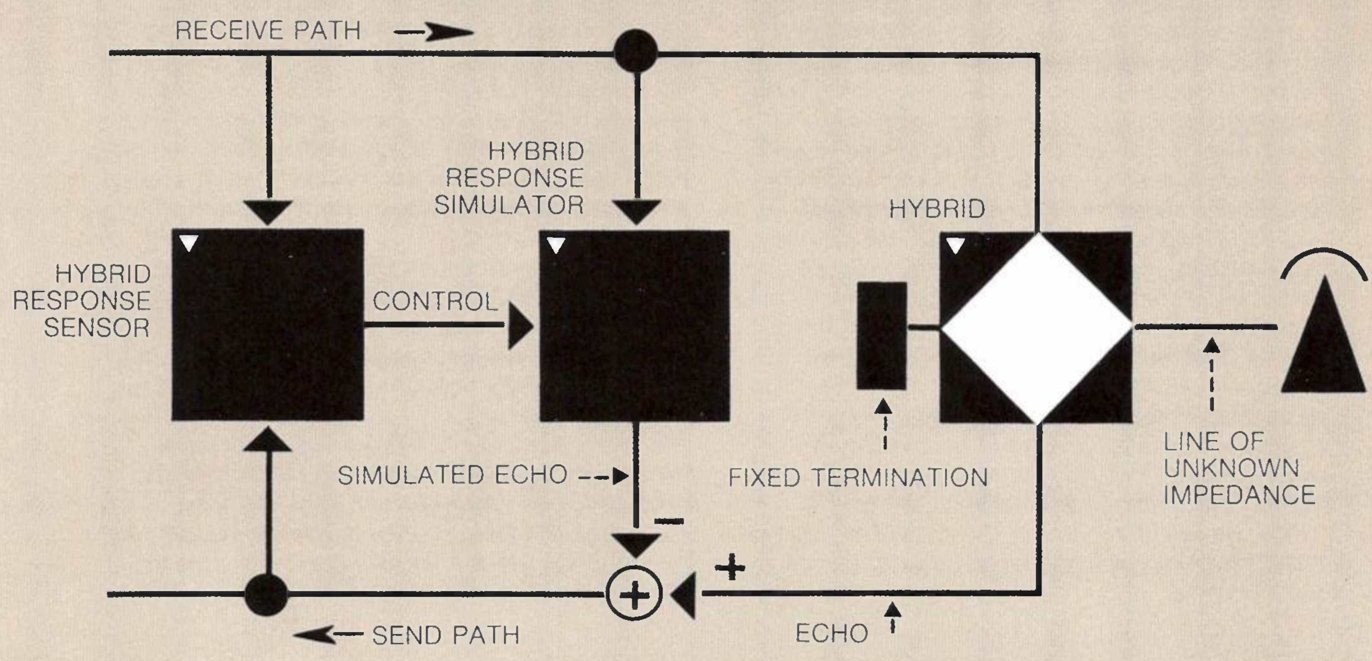


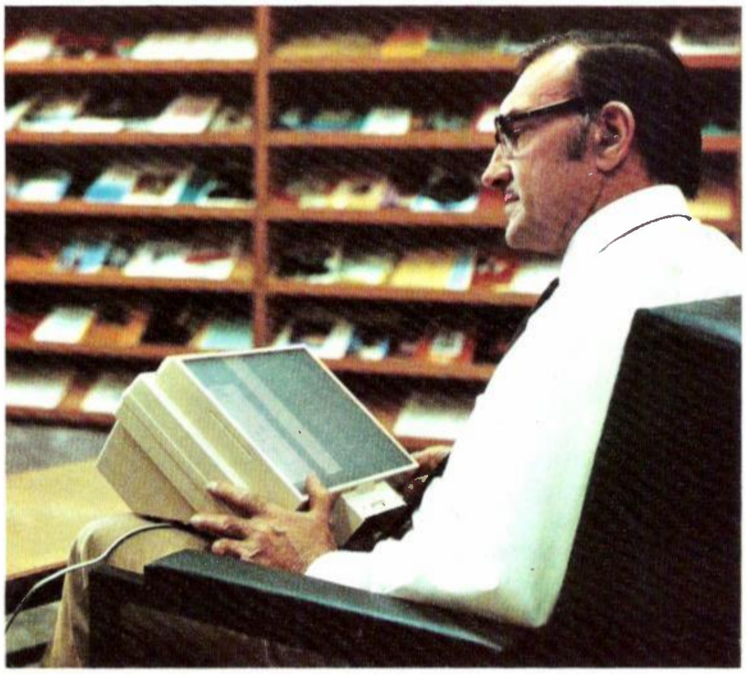
parties talking simultaneously, the two echo suppressors have the difficult task of differentiating between speech and echo, and as a result, syllables may be clipped from the speech by the switching operations and the quality of the conversation may be impaired.

The principle of echo cancellation avoids the switching problem of echo suppressors. Echo cancellers may be placed at the same locations as echo suppressors, with one canceller associated with each hybrid. A replica of each echo is generated from the incoming speech and it is added, with its polarity reversed, to the send path, thereby cancelling the echo. Any forward speech in the send path is not affected. It is necessary to first measure the trans-hybrid response and then use this to control a network which simulates the response.

Echo cancellation has received considerable attention throughout the world, although no cancellers are yet in general use. The simulator is almost always chosen to be a delay line. The main differences in approach have been in the control strategies. All of the control methods yet proposed by other investigators have resulted in echo cancellers which are slow to respond to changes in the echo path response. This is a problem when there is a frequency offset in any carrier system which might be in the echo path. Such an offset has the effect of producing a rapidly time-varying trans-hybrid response which the simulator control cannot follow. Recent work by the A.P.O. Research Laboratories has concentrated on a new control strategy having the potential to handle the offsets which do occur in practice. A trial model has been constructed which has verified this capability. Full speed operation requires faster electronic circuits than those used in the model. These circuits are available and further development will be dictated by economic factors.

Echo canceller & associated hybrid





PORTABLE MICROFICHE READER IN USE.

The Engineering Library

The library service of the Headquarters Engineering Divisions is located in and administered from the Laboratories. It is an information service designed to support the functions of the engineering, scientific and technical staff of the Department throughout Australia. The library service is guided by the advice of a Library Committee comprising senior officers from each Engineering Division in Headquarters.
The library traces its origins back to about 1925, when it was established by S. H. Witt as an essential repository of technical information to assist the work of the Laboratories. Originally, it was composed from the personal collections of books and technical journals of the Laboratories' staff, together with the official reports and technical notes documenting the work of the infant Laboratories. The library was managed with clerical assistance and material was classified by means of a modified Dewey system devised by Mr. Witt.
About 1928, Miss Belle Robertson joined the Laboratories as the first Librarian to be employed in the Department, and she took charge of the Engineering Library. One of her first tasks was to institute the use of the Universal Decimal Classification (U.D.C.) System to re-classify the growing amount of library material.

From these early beginnings, the Library has grown to comprise the main library located in the Research Laboratories, and five smaller branch libraries which serve Headquarters. There is also an Engineering Library in each State Administration.
One of the principal aims is to provide a current awareness service. This presently includes the selective dissemination of information (S.D.I.), and compilation of special subject information bulletins and regular lists of conferences, seminars and meetings relevant to the interests of the Department. The important services of literature searches, compilation of bibliographies, reference work and a translation service are in constant demand.
Studies are in progress to improve the library service and the main areas receiving attention are:—

(a) the application of computerised systems and other mechanical equipment to improve the efficiency of library house-keeping and information storage and retrieval techniques,
(b) review of and redeployment of staff and service points,
(c) collection and retrieval of technical publications in microform.

A computerized listing of periodical titles is recognized as an effective way of improving a library service as it mechanizes one of the time-consuming and laborious tasks of a library. Such a list has been designed, using C.D.C. System 2000, and the necessary information has been collated and the list will be produced in handbook form. It is in fact a "union" listing of the periodical holdings in all A.P.O. Engineering Libraries.
The computerized listing will be easily up-dated, and sub-lists for the retrieval of special information will be more readily available. The repetitive manual handling of the same basic information will be greatly reduced and library staff will be free to devote more effort to other services.
During 1972, a telephone answering device was installed on the loans/enquiry desk to provide an out of hours tele-reference service to library users. The device permits users to record requests for loans of publications and photocopying during overnight and weekend periods.
The recent purchase of two lightweight portable readers has permitted more use to be made of the publications on microfiche and strip film. The documents and the portable readers are available for loan to library users in the same way as are printed publications.

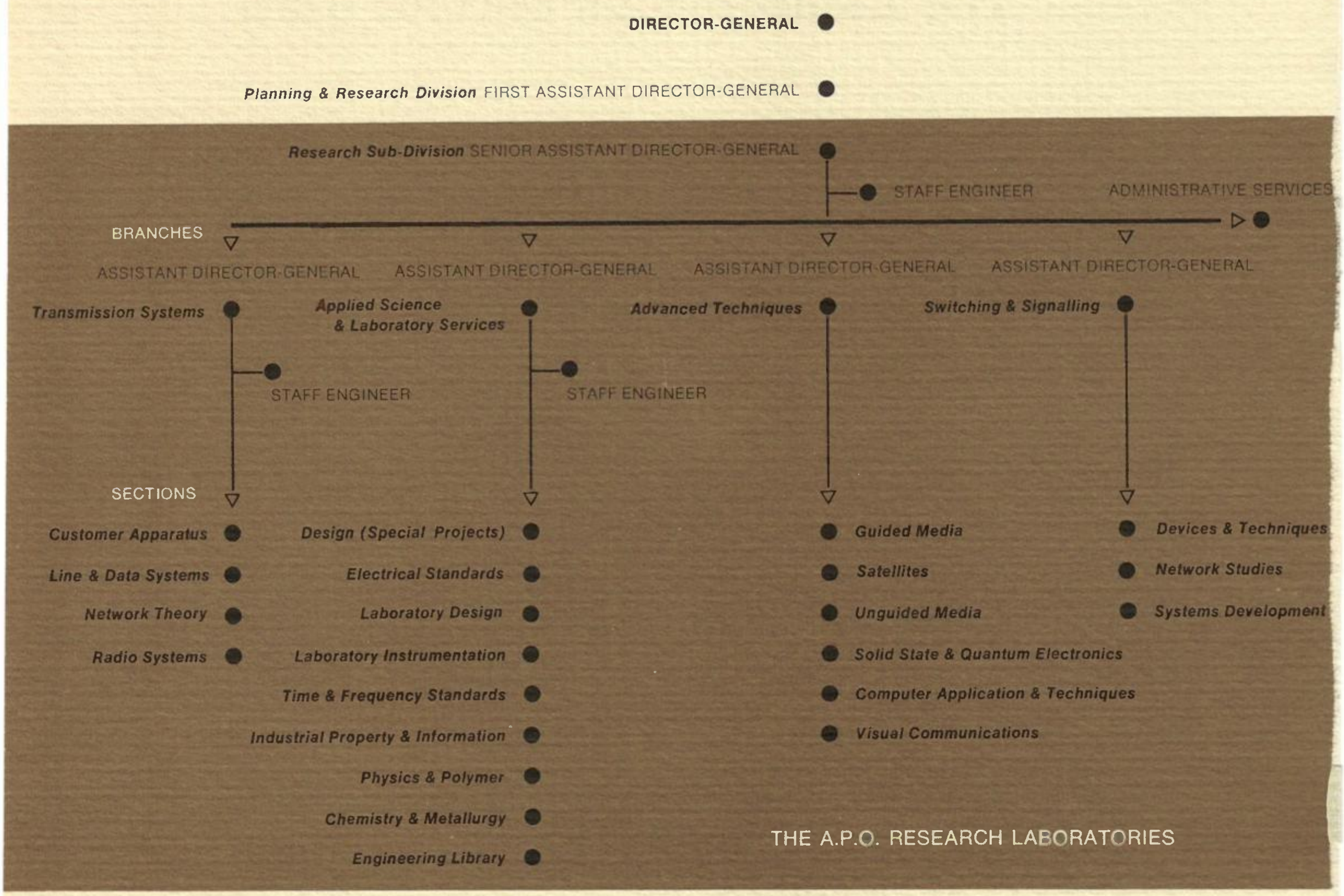
The Laboratories and its Staff

ORGANISATION

The Australian Post Office is a Department of the Commonwealth of Australia. Its chief executive is the Director-General, Posts and Telegraphs. With the assistance of five Headquarters Divisions, he controls and directs the operations of the Department through six individual State Administrations.

The Research Laboratories are a Sub-Division of the Planning and Research Division at Headquarters. The Senior Assistant Director-General, Research, heads the Laboratories organisation. He is responsible to the First Assistant Director-General, Planning and Research Division, who in turn is responsible to the Director-General.

The Laboratories are comprised of 22 Sections which are grouped into 4 Branches, and each Branch is under the direction of an Assistant Director-General. The Sections comprise professional, technical grade and other staff, with each Section possessing expertise in particular areas of the engineering and scientific fields.


DIRECTOR-GENERAL
Planning & Research Division FIRST ASSISTANT DIRECTOR-GENERAL
Research Sub-Division SENIOR ASSISTANT DIRECTOR-GENERAL
STAFF ENGINEER
ADMINISTRATIVE SERVICES
BRANCHES
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ASSISTANT DIRECTOR-GENERAL
ASSISTANT DIRECTOR-GENERAL
ASSISTANT DIRECTOR-GENERAL
Transmission Systems
Applied Science & Laboratory Services
Advanced Techniques
Switching & Signalling
STAFF ENGINEER
STAFF ENGINEER
SECTIONS
Customer Apparatus
Line & Data Systems
Network Theory
Radio Systems
Design (Special Projects)
Electrical Standards
Laboratory Design
Laboratory Instrumentation
Time & Frequency Standards
Industrial Property & Information
Physics & Polymer
Chemistry & Metallurgy
Engineering Library
Guided Media
Satellites
Unguided Media
Solid State & Quantum Electronics
Computer Application & Techniques
Visual Communications
Devices & Techniques
Network Studies
Systems Development
THE A.P.O. RESEARCH LABORATORIES

PROFESSIONAL AND SENIOR STAFF

The names given below are those of actual occupants of the positions (appointed or acting) as at 1st April, 1973.

Senior Assistant Director-General: P. R. Brett, B.Sc., F.I.R.E.E.

Staff Engineer: F. W. Arter, B.E.E., M.Eng.Sc.

TRANSMISSION SYSTEMS BRANCH

Assistant Director-General: D. A. Gray, B.E.E., Dip.Mech. and Elec.Eng., M.I.E.Aust., M.A.A.S.

Staff Engineer: M. Cassidy, B.Sc., M.E., D.P.A., F.I.E.Aust., M.I.E.E., A.A.I.P., A.Inst.P.

Customer Apparatus Section

SECTION HEAD: E. J. Koop, B.E.(Elec.), Fell.Dip.Elec.Eng., M.A.A.S.

PRINCIPAL ENGINEER

Kett, R. W., Dip.Comm.Eng., A.M.I.R.E.E.

SENIOR ENGINEERS

Casley, G. M., B.E.(Elec.), M.Eng.Sc., D.I.C., Ph.D., Grad.I.E.Aust., M.I.E.E.
Duke, P. F., B.Tech., Ass.Dip.Maths.
Metzenthen, W. E., Fell.Dip.Comm.Eng., M.E., M.I.R.E.E.

ENGINEERS

Blackwell, D. M., B.E.(Elec.).
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Kelso, D. R., B.E.(Elec.). M.Eng.Sc., Grad.I.E.Aust.
Wellby, P. J., B.E.(Hons.), B.Sc.

SENIOR TECHNICAL OFFICER

Wood, R. J.

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SECTION HEAD: R. Smith, B.E.(Hons), M.E., M.I.E.E., A.M.I.R.E.E.

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Gibbs, A. J., B.E.(Elec.), M.E., Ph.D., M.I.R.E.E.

SENIOR ENGINEERS

Bylstra, J. A., B.Sc., M.Sc., M.I.E.E.E.
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Duc, N. Q., B.E.(Hons), Ph.D., Grad.I.R.E.E., M.I.E.E.E.
Quan, A., B.E.(Hons), M.E., A.M.I.E.E.
Steele, J., B.E.(Elec.)
Tyers, P. J., B.E.(Hons)

SENIOR TECHNICAL OFFICER

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SECTION HEAD: I. McGregor, B.E.(Elec.), M.Eng.Sc., Ph.D.

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Snare, J. L., B.E.(Elec.)

SENIOR TECHNICAL OFFICER

Vigners, A.

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SECTION HEAD: O. F. Lobert, B.E.E., M.I.E.Aust., A.M.I.E.E.

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Lawson, I. C., B.E.E.
Sargeant, V. K., B.E.(Hons), M.Eng.Sc.

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Harris, R. W., B.Sc.(Hons), B.E.(Hons)
Hicks, P. R., B.E.(Elec.)
Martin, G. T., B.E.(Hons), M.E.

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Temby, F.
Thompson, D. J.

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Assistant Director-General: E. F. Sandbach, B.A., B.Sc.
Staff Engineer: L. H. Murfett, B.Sc.

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SECTION HEAD: H. J. Lewis.
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Sheridan, D. E., Dip.Elec.Eng., Dip.Mech.Eng.
Tjio, H. S., B.Mech.E., Ass.Dip.Electron.Eng.
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Battlay, P. I. J., B.Mech.E.
Brunelli, A., B.Eng.(Comm.), Fell.Dip.Electronics, Assoc.Dip.Electronics.
Day, R. J., Dip.Elec.Eng., Dip.Mech.Eng., Grad.I.E.Aust.
Kilby, R. L., Assoc.Dip.Elec.Eng., Grad.I.E.Aust.
Mangalore, C., B.E.(Mech.), Grad.I.E.Aust.
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Mackin, R. J.
Staley, W. W.
Westbrook, P. A.

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Erwin, J. B.

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SECTION HEAD: A. H. O'Rourke, Dip.Rad.Eng., Grad.I.E.Aust.

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SECTION HEAD: D. S. Geldard, M.I.E.E., M.I.E.Aust.
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Dalrymple, L. N., Assoc.Dip.Elec.Eng.

Laboratory Instrumentation Section
SECTION HEAD: A. M. Collins, B.Sc.
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Stevens, A. J., B.E.(Elec.), A.M.I.E.E.
ENGINEERS
Proudlock, R. E., B.E.(Elec.)
Wylie, F. R., B.E., M.I.E.E.E.
SENIOR TECHNICAL OFFICER
Jepson, R. R.

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Hamilton, A. N., B.E.(Hons)
Ratcliffe, B. R., Assoc.Dip.Comm.Eng.
Townsend, A. A. R., B.E.(Elec.)
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Thomas, V. E., A.M.I.R.E.E.
Yates, R.

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SECTION HEAD: G. Flatau, F.R.M.I.T.(App.Phys.)

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Dew, I. A., B.Sc., M.Sc., A.A.I.P.
Mitchell, G. G., B.Sc.(Hons), M.Sc.
Sadler, N. J., B.Sc., M.I.R.E.E., F.R.A.S.
Stevenson, I., B.App.Phys.
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Pether, R. H.
Bauer, A. R.

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Bondarenko, E. J., Dipp.App.Phys., F.R.A.S.
Charles, S. J. (Miss), Assoc.Dip.App.Phys.
Lloyd, I. J., B.Sc.(Hons), M.Sc., Ph.D.
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North, W.

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Chisholm, B A , Dip.App.Chem., Grad.R.A.C.I.
Western, R. J., Dip.App.Chem.
SENIOR TECHNICAL OFFICER
Elms, T.

Chemistry and Metallurgy Section
SECTION HEAD: R. D. Slade, Assoc.Dip.Met., M.I.M., M.A.E.S., M.A.I.M.F., M.N-D.T.A.Aust.

General Chemistry Division
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Miles, D. T., M.R.S.H., F.C.S., A.R.I.C.
Petchell, F. M., Dip.App.Chem.

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Slavik, Z., Dip.Eng., A.R.A.C.I.

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METALLURGISTS
Godfrey, J. R., Assoc.Dip.Met.
Keir, K. E., Fell.Dip.Met.Eng.
Keogh, T. J., Assoc.Dip.Sec.Met.
SENIOR TECHNICAL OFFICERS
May, R.
Smith, J.

Engineering Library
SECTION HEAD: Miss M. I. Cuzens, B.A., A.L.A.A., A.L.A.
LIBRARIANS
Heath, R. M. (Mrs), B.A., Dip.Lib.
Johnson, L. M. (Mrs), B.A., Dip.Lib.
Peters, S. M. (Mrs), B.A., B.Sc., Dip.Ed., A.L.A.A., A.R.M.I.T.
Rodd, H. V. (Miss), B.A., Dip.Lib., M.L.A.A.

ADVANCED TECHNIQUES BRANCH
Assistant Director-General: A. J. Seyler, Dip.Ing.(Hons), M.E.E., D.App.Sc., F.I.R.E.E.

Computer Application and Techniques
SECTION HEAD: L. K. Mackechnie, B.E.(Elec.), M.Eng.Sc., Ph.D.
ENGINEERS
Denger, L. A., E.N.S.E.M.N., M.I.E.E.E., M.Soc.Fr. de Phys., M.Soc.Fr. de Elec., Grad.I.E.Aust.
Jenkins, G. K., B.Sc., B.E.(Hons), M.E.
Jenkins, I., B.E.(Hons)

Guided Media Section
SECTION HEAD: G. P. Kidd, B.E.(Elec.), B.Sc.
SENIOR ENGINEER
Davies, W. S., B.E.(Elec.), M.Eng.Sc., Ph.D.
ENGINEERS
Colvin, J. P., B.E.(Elec.), Dip.Elec.Eng.
Duncan, A. M., B.Sc., B.E.(Elec.)
Morgan, R. J., B.Sc.(Eng.)

Satellites Section
SECTION HEAD: E. R. Craig, B.Sc.(Hons), M.I.E.E.
SENIOR ENGINEERS
Jenkinson, G. F., B.Sc., M.I.R.E.E.
Balderston, J. M., B.Sc.(E.E.), M.Sc.(E.E.), I.E.E.E., A.C.M.
ENGINEER
Flavin, R. K., B.Sc., M.Sc.

Solid State and Quantum Electronics Section
SECTION HEAD: W. J. Williamson, B.E.(Elec.)(Hons), Ph.D.
PRINCIPAL ENGINEER
Teede, N. F., B.E.(Hons), Dip.Mgt., Ph.D.
SENIOR ENGINEERS
Cahill, L. W., B.E.(Elec.), M.Eng.Sc., Ph.D., M.I.E.E.E.
Junghans, H., Dip.Ing.
ENGINEERS
Horton, R., B.Sc.(Hons), Ph.D., A.M.I.E.E., M.I.R.E.E.
Hubregsle, J., Fell.Dip.Comm.Eng.
Sabine, P. V., B.Sc., B.E.(Hons)
SENIOR TECHNICAL OFFICER
Wills, H., Assoc.Dip.Rad.Eng., A.M.I.R.E.E.

Unguided Media Section
SECTION HEAD: J. H. Reen, B.E.E., M.I.E.Aust.
PRINCIPAL ENGINEER
Murphy, J. V., B.E.(Elec.)(Hons), B.A.
SENIOR ENGINEERS
Harvey, R. A., B.Sc., Dip.Rad.Eng., A.M.I.R.E.E.
Sastradipradja, S., B.E.(Elec.)
ENGINEERS
Howard, S. E., B.E.(Elec.)
Ja, Y. H., B.E., Ph.D.
Lee, H. S., B.E.(Comm.), Grad.I.E.Aust.
Ridge, I. T., B.E.(Elec.), Grad.I.E.Aust.
SENIOR TECHNICAL OFFICERS
Barnard, S. A.
Fall, E.
Francis, R. J.
Lucas, J. E. W.

Visual Communications Section
SECTION HEAD: G. Rosman, B.E.E., M.Eng.
SENIOR ENGINEERS
Brueggemann, H., B.E.(Elec.)
Lavery, W. J., B.E.(Hons), M.Eng.Sc.
ENGINEERS
Ayre, R., B.E.(Elec.)(Hons), B.Sc.(Hons)
Craick, J. K., B.E.(Elec.)(Hons), B.Sc.
Demytko, N., B.E.(Elec.)(Hons), B.Sc.
SENIOR TECHNICAL OFFICER
Quirk, G. W.

SWITCHING AND SIGNALLING BRANCH

Assistant Director-General: H. S. Wragge, B.E.E.(Hons), M.Eng.Sc.(Hons), M.I.E.Aust., M.I.E.E.

Devices and Techniques Section

SECTION HEAD: I. P. Macfarlane, B.E.(Elec.), A.R.M.T.C.

SENIOR ENGINEER
- Wise, J. B., B.E.

ENGINEERS
- Black, D. L., B.E.(Hons)
- Jones, P. S., B.E.(Elec.), M.Eng.Sc.

PHYSICIST
- Keogh, D., M.Sc.

Network Studies Section

SECTION HEAD: F. J. W. Symons, B.E.(Hons), D.I.C., A.M.I.E.Aust.

SENIOR ENGINEERS
- Gerrand, P. H., B.E.(Hons), M.Eng.Sc., M.I.E.Aust., M.I.E.E.E.
- McLeod, N. W., B.Sc., M.I.E.Aust.
- Vizard, R. J., B.E.E., Dip.Elec.Eng.

ENGINEERS
- Even-Chaim, A., B.Sc., M.I.E.Israel
- Gale, N., B.E.

SENIOR TECHNICAL OFFICER
- Fegent, H. G.

Systems Development Section

SECTION HEAD: G. L. Crew, B.E., M.I.E.E.

PRINCIPAL ENGINEER
- Domjan, A., B.E.E., A.M.I.E.Aust.

SENIOR ENGINEERS
- Champion, G. J., B.E.
- Hunter, M. A., B.E.(Hons), A.M.I.E.E.
- King, D. J. E., B.E.(Hons), M.Eng.Sc., A.M.I.E.E., M.I.E.E.E.

ENGINEERS
- Baker, A. S., A.M.I.E.E.
- Chan, M. C., B.E.(Hons)
- Collins, J. L., B.E., Dip.Elec.Eng.
- Mazzaferri, F., B.E.(Hons)
- Tjia, S. M. (Miss), B.E.(Elec.)

SENIOR TECHNICAL OFFICERS
- Bowtell, P. J.
- Curley, K.
- Lambert, O.
- Long, T. R. A.
- McEvoy, W.
- Wolstencroft, N.

SENIOR CLERICAL STAFF

Adminstrative Officer: R. D. Coath
- Bohan, R. W.
- Chippindall, C.
- Chirgwin, M. A.
- Conroy, A. B.
- Evans, M. (Mrs)
- Forster, D. (Miss)
- Guilliard, K. H.
- McIntyre, P. R.
- Nolan, L. B.
- Scates, E. J.

PAPERS, LECTURES, TALKS AND REPORTS.

■ Research Laboratories Reports are the vehicle by which the results of research studies and investigations, development projects and other specialised tasks undertaken in the Laboratories are officially documented. The staff of the Laboratories also regularly contribute articles to Australian and overseas technical journals and present papers to learned societies.

PAPERS

Blair, R. H.	"Effect of Thermal Noise in an F.M. Microwave Bearer Carrying Digital Traffic", Aust. Tele. Res., November, 1972.
Bondarenko, E. J.	"Electrical Discharges from High Power Transmitter Antennae", Aust. Tele. Res., November, 1972.
Brueggemann, H. and Hullett, J. L.	"In Search of an Optimum C.C.T.V. Conference Configuration", Proc. I.R.E.E., December, 1972.
Cahill, L. W.	"Design Formulae for Parallel-Coupled Striplines", Proc. I.R.E.E. (A.E.C.), December, 1972.
Champion, G. J. and Haylock, R. H.	"National Field Trial of C.C.I.T.T. Signalling System No. 6 — Software", Telecomm. Journal of Aust., February, 1973.
Craig, E. R. and Jenkinson, G. F.	"The Study of Tropical Rain Attenuation at 11 GHz Using a Solar Radiometer", Aust. Tele. Res., May, 1973.
Demytko, N. and Mackechnie, L. K.	"A High Speed Digital Adaptive Echo Canceller", Aust. Tele. Res., May, 1973.
Dossing, S.	"Future Telephone Switching Systems", Telecomm. Journal of Aust., June, 1972.
Duke, P. F. and Koop, E. J.	"The Telephone Handset Speaking Position", Aust. Tele. Res., November, 1972.
Flavin, R. K., Howard, S. E., Kilby, R. L. and Sastradipradja, S.	"An 11 GHz Radiometer for Rain Attenuation Studies", Aust. Tele. Res., May, 1973.
Fowler, A. M.	"Specifying Electroplated Finishes for Radio Frequency Applications", Institution of Engineers, Aust., Elect. Eng. Trans., September, 1972.
Fowler, A. M.	"Electronic Reverberation", Electronics Aust., September, 1972.
Gray, D. A.	"Telephone Aids for the Hard-of-Hearing", Better Hearing, July, 1972.
Gibbs, A. J.	"Generalised Mean-Square-Error Minimisation with Application to Automatic and Adaptive Systems", Aust. Tele. Res., November, 1972.
Heath, R. M. Richards, D. J. and Rodd, H. V.	"Report on a Training Course for Clerical Assistants", Aust. Special Libraries News, September, 1972.
Hullett, J. L.	"The Choice of T.V. Phone Picture Standards — A Case of Compromise", Proc. I.R.E.E., June, 1972.

Hunter, M. A. and Vizard, R. J.	"Field Trial of C.C.I.T.T. Signalling System No. 6 — Interworking with Australian MFC System", Aust. Tele. Res., May, 1973.
Keogh, T. J.	"The Influence of Pickling on the Embrittlement of Mild Steel", Metals Australia, August, 1972.
Kidd, G. P., Esdaile, R. J. and Ogilvie, G. J.	"Transmission Loss of Tetrachloroethylene Filled Liquid Core Fibre Light Guide", Electronics Letters, Vol. 8, No. 22, November, 1972.
King, D. J. E.	"The Engineer-Programmer Relationship", Institution of Engineers, Aust., Chartered Engineer, December, 1972.
Lavery, W.	"Efficient Synchronisation for Digital T.V.-Phone Transmisssion". I.E.E.E. Trans. on Communic. Technology, December, 1972.
Proudfoot, A.	"A Simple Multi-Frequency Tone Detector", Electronics Letters, Vol. 8, No. 21, October, 1972.
Rosman, G.	"Variation of Pulse Delay with Launch Angle in a Liquid Filled Fibre", Electronics Letters, Vol. 8, No. 18, September, 1972.
Vizard, R. J. and McLeod, N. W.	"National Field Trial of C.C.I.T.T. Signalling System No. 6 — A Processor Controlled Exchange", Telecomm. Journal of Aust., February, 1973.
Warner, J. M.	"The Accuracy of Electrical Measurements made by Electronic Techniques", Telecomm. Journal of Aust., June, 1972.

LECTURES AND TALKS

Flatau, G.	"International Quality Assurance Schemes for Electrical Components", Stand. Assoc. of Aust. Conf., Sydney, September, 1972.
Flatau, G.	"Development of Nylon Jacketed Telephone Cable Resistant to Insect Attack", 21st Wire and Cable Symposium, U.S.A., December, 1972.
Keogh, T. J.	"Failures of Metals in Service — Case Histories", Aust. Institute of Metals, Melb., September, 1972.
King, D. J. E.	"The Engineer-Programmer Relationship", I.E.Aust. Electrical and Communications Engineering Branch, Melb., September, 1972.
Lavery. W. J.	"Controlled Redundancy Addition in Adaptive Variable Length Coding of T.V. Signals", Picture Coding Symposium, University of Southern California, January, 1973.
McGregor, I.	"Computer Aided Circuit Design", Bendigo Institute of Technology, July, 1972.
McGregor, I.	"Simple Filter Design", Wireless Institute of Australia, Bendigo, July, 1972.
McLeod, N. W.	"Digital Integrated Circuits for Technical Officers", I.R.E.E. Symposium, Monash University, August, 1972, and Royal Melb. Institute of Technology, November, 1972.
Sabine, P. V. H.	"Surface Acoustic Wave Scattering Phenomena", Seminar at University of Adelaide, September, 1972.
Seyler, A. J.	"Microwave Propagation Studies on the Nullarbor Plain in South and West Australia — A Case Study", Aust. Inst. Metals Seminar on Effective Research and Development, BHP/Research Labs., Warburton, August, 1972.
Seyler, A. J.	"Optical Fibre Research at A.P.O. Research Laboratories", Dept. of Electrical Engineering, University of Western Australia, September, 1972.
Seyler, A. J.	"Optical Communications — Techniques and Problems", I.E. Aust. Electrical and Communications Engineering Branch, Melb., May, 1973.
Warner, J. M.	"Accuracy of Electrical Measurements by Electronic Techniques", Elect. Eng. School, Melbourne University, July, 1972.
Williamson, W.	"Optical Communications", Qld. Div. of Telecomm. Society, July, 1972.

RESEARCH LABORATORIES' REPORTS

REPORT No.	AUTHOR	TITLE
6224 Add. 2	I. McGregor	Circuit Improvements to Variable Group Delay and Attenuation Equalizer for Voice/Data Circuits.
6487 Add. 1	I. Dew	Life Testing of B.T.M. H 40 Reed Inserts.
6492 Add. 1	N. J. Sadler	Assessment of Rifa Type RJK 379 and A.E.E. Type RJK 37913 CR Units.
6545 Add. 1	A. J. Stevens	Electrically Suppressed Zero Voltmeter (48-53 Volts) (Production Prototype).
6563 Add. 1	H. J. Ruddell	The Re-use of Sheathing Grade Polythene in A.P.O. Cables.
6570	N. Gale	Programmable Logic Tester.
6615 Iss. 2	A. Collins	Frequency Counter Type FCM 1.
6622	I. Dew	Evaluation of L. M. Ericsson Code Switch.
6630	L. Denger	Evaluation of the Magnetoresistance Effect at Microwave Frequencies.
6632	A. Proudlock	Single Frame Control Unit for Bolex Camera.
6637	A. J. Stevens	Erlangmeters: Past and Present.
6650	I. McGregor	Design of a Variable Active Attenuation Equalizer and the Associated Impedance Simulating Network for Unloaded Cables.
6652	R. J. Vizard	Report of Overseas Visit, October, 1971 — Field Trials of C.C.I.T.T. Sgnalling System No. 6.
6655	A. J. Stevens	Power Supply Transient Response Tester.
6659	L. Denger	The Calculation of the Resonance Frequency of a Cylindrical Cavity Frequency Meter at Micrometer Screw Settings Between the Set of Calibration Points.
6670	V. K. Sargeant	Variation of Balanced Pair Cable Parameters with Temperature.

6671	V. K. Sargeant and N. M. Deans	Variation of Cable Parameters with Temperature, 4 lb. P.I.U.T. and 2/40 P.E.I.Q.C.
6673	E. J. Bondarenko	Survey of Electric Shock Hazards with Special Reference to Rubber Safety Knee Boots.
6677	I. J. Lloyd	Electrical Tests of "Cerberus" Gas-filled Two-electrode Surge Arrestors, Types YS410 and UA410B.
6679	I. McGregor	V. H. F. Aerial Diplexer.
6681	T. J. Elms	Evaluation of "Ajicure" Curing Agent for Epoxy Resin.
6683	W. Lavery	A Programmer for Read Only Memories.
6685	G. Jacoby	Economic Design Optimization and Sensitivity Analysis of a Domestic Satellite Subscriber System.
6688	R. Wylie	Push Button Power Supply for Switchboard Lamp Photometer.
6690	G. Flatau	Report on Overseas Visit, August-October, 1971. — Study of the techniques and resources employed in evaluations and failure anaylsis of components, materials and assemblies. — Attendance at meeting of Technical Committee 56 of the International Electrotechnical Commission.
6691	K. Keir	Failure of Augat Plugs.
6692	A. J. Gibbs	Report on Overseas Visit, March, 1972. — C.C.I.T.T. S.G. XV and C.C.I.T.T./C.C.I.R. Joint SGC. — I.E.E.E. International Seminar on Integrated Systems.
6693	G. J. Semple	Report on Overseas Visit, November-December, 1972. — C.C.I.T.T. Special Study Group D. — P.C.M. Transmission.
6694	G. W. Goode	Temperature in Coaxial Cable Manholes between Perth and Bullsbrook, Western Australia.
6701	J. Bylstra	Investigation of Second Order 8.448 M bit/s Digital Multiplexers.
6702	A. J. Stevens	Serial to Parallel D/A Converter.
6705	A. Hamilton	Stability of the Gated Phase Locked Loop.
6706	H. Brueggemann	An Improved Linear Modulator.
6707	A. Quan	Generation of Fast Pseudo-Random Binary Sequences at High Bit Rates.
6712	M. Cuzens	Report of Overseas Visit, July-August, 1972. — Review of Recent Developments in Overseas Libraries.
6713	H. J. Ruddell	Development of a Suggested Design for Polythene Sheathed Closures on Large Size Cables.
6716	J. M. Balderston	Relative Costs of Single Versus Multiple Space Craft Launches.
6725	L. Denger	Investigation on the Calculation of the Electric Field inside a Waveguide Cavity in which there is a Thin Flat Metallic Sample.
6729	J. R. Lowing	Fatigue Tests on Bi-Metallic Aerial Line Wires.
6731	L. Denger	Coupled Microstrip Lines and Directional Couplers.
6732	P. J. Gwynn	Analysis of Manhole Water Samples from Plastic Conduit Routes.
6741	J. M. Balderston	System Parameters for a Remote Area Telephone and Television Service.
6747	A. Domjan	Report on Overseas Visit, July-August, 1972. — Application of Advanced Microelectronic Technology to Digital Telephone Switching Systems.
6748	G. J. Semple	P.I.Q.L. Cable Simulation.
6757	P. Duke	Report on Overseas Visit, September-October, 1972. — Assessment of Telephone Transmission Performance.

In addition 11 other reports were distributed on a limited or restricted basis.

STAFF AFFILIATIONS WITH EXTERNAL BODIES

Some of the staff of the Laboratories are active members of the governing bodies of educational establishments, learned societies, and professional bodies and institutions. Staff members also serve on a variety of national and international committees.

NATIONAL

TRANSPORT AND COMMUNICATIONS ADVISORY COMMITTEE OF METRIC CONVERSION BOARD	P. R. Brett
VICTORIAN EDUCATION DEPARTMENT	
Higher Technician (Applied Science) Certificate — Course Development Committee	G. Flatau
VICTORIA INSTITUTE OF COLLEGES	
Committee on College Staffs	P. R. Brett
Course Development Committee	A. J. Seyler
Equipment Review Committee	A. J. Seyler
Standing Committee on Academic Policy	P. R. Brett
MELBOURNE UNIVERSITY	
Faculty of Engineering	P. R. Brett
MONASH UNIVERSITY	
Engineering Faculty Board	A. J. Seyler
ADELAIDE UNIVERSITY	
Electrical Engineering Department — Hon. Consultant for Post Graduate Studies	A. J. Seyler
UNIVERSITY OF NEW SOUTH WALES	
Visiting Committee of School of Electrical Engineering	A. J. Seyler
FOOTSCRAY INSTITUTE OF TECHNOLOGY	
Course Advisory Committee	H. S. Wragge
SWINBURNE COLLEGE OF TECHNOLOGY	
Electrical Engineering Departmental Advisory Committee	L. Murfett
Master of Engineering Ad Hoc Advisory Committee	L. Murfett
CAULFIELD INSTITUTE OF TECHNOLOGY	
Course Advisory Committee	H. S. Wragge
ROYAL MELBOURNE INSTITUTE OF TECHNOLOGY	
Capital Funds Committee	M. Cassidy
STANDARDS ASSOCIATION OF AUSTRALIA (S.A.A.)	
Council	P. R. Brett
Telecommunications and Electronics Industry Standards Executive Committee:	P. R. Brett E. F. Sandbach
Acoustic Standards Committee	D. A. Gray

Technical Committees:	
• Instrumentation and Techniques for Measurement of Sound	E. J. Koop
Electrical Industry Standards	
• Winding Wires	G. Flatau
• Indicating and Recording Instruments	J. M. Warner
• Electrical Insulating Materials	G. Flatau
• Dry Cells and Batteries	G. Flatau
• Control of Undesirable Static Charges	G. W. Goode
Mechanical Engineering Industry Standards	
• Tensile Testing of Metals	K. G. Mottram
Miscellaneous	
• Pressure Sensitive Adhesive Tapes	G. Flatau
Metal Industry Standards	
• Zinc and Zinc Alloys	K. G. Mottram
• Coating of Threaded Components	R. D. Slade
• Galvanised Products	R. D. Slade
• Electroplated and Chemical Finishes on Metals	R. D. Slade
Plastic Industry Standards	E. F. Sandbach
• Phenolic Laminated Sheeting	G. Flatau
• Methods of Testing Plastics	G. Flatau
• Outdoor Weathering of Plastics	G. W. Goode
• Polytetrafluoroethylene	B. Chisholm
Telecommunications and Electronics Industry Standards	P. R. Brett E. F. Sandbach
• Capacitors	G. Flatau
• Resistors	D. McKelvie
• Printed Circuits	D. Sheridan
• Wires and Cables	G. Flatau
• Semi-Conductors	I. Macfarlane
• Environmental Testing	G. Flatau
• Reliability of Electronic Components and Equipment	G. Flatau
• Electro-Acoustics and Recording	E. J. Koop
THE INSTITUTION OF RADIO AND ELECTRONICS ENGINEERS	
Federal Council	A. J. Seyler
Victorian Division Committee	A. J. Seyler A. M. Fowler
THE INSTITUTION OF ENGINEERS, AUSTRALIA	
Research and Development Committee	P. R. Brett
Electrical and Communication Engineering Branch Committee, Victoria	M. Cassidy H. S. Wragge
Electrical and Electronics Board	H. S. Wragge M. Cassidy
AUSTRALIAN ADVISORY COUNCIL ON BIBLIOGRAPHY SERVICES (A.A.C.O.B.S.)	M. Cuzens
A.A.C.O.B.S. — Victorian Regional Committee	M. Cuzens
RADIO RESEARCH BOARD	P. R. Brett

INTERNATIONAL

The Laboratories participate in the activities of a number of international bodies and committees. These include:—

- the International Telephone and Telegraph Consultative Committee (C.C.I.T.T.)
- the International Radio Consultative Committee (C.C.I.R.)
- the World Administrative Radio Conference (W.A.R.C.)
- the Australian and New Zealand Association for the Advancement of Science (A.N.Z.A.A.S.)
- the Bureau International de l'Heure (B.I.H.)
- the International Electro-Technical Commission (I.E.C.)
- the Asia Electronics Union (A.E.U.)
- the International Federation of Documentation Committee for Asia and Oceania (F.I.D./C.A.O.)

PATENTS

It is A.P.O. policy to establish a patent portfolio to cover the inventions of its staff. Many of these inventions are made by staff of the Laboratories. They also contribute largely to the assessment of novelty and likely usefulness of new ideas which may lead to patentability.

A summary of current A.P.O. patents and patent applications is given below:—

SUBJECT	INVENTOR(S)	COUNTRIES
Joint Enclosure for Electric Cables	H. J. Ruddell J. D. Feehan (Research)	U.S.A.
Method and Apparatus for Testing Subscribers' Instruments in situ	J. F. M. Bryant R. W. Kett (Research)	Australia U.S.A.
Impulse Sender Mechanisms of Automatic Telephone Dials	R. J. W. Kennell (Assgd. 1968) (Non-A.P.O.)	Australia
Automatic Telephone Dials	R. J. W. Kennell (Assgd. 1968) (Non-A.P.O.)	Australia
Public Telephone Installation (Vandal Proof)	K. B. Smith A. A. Rendle (Subs. Equipt.)	Australia Britain Japan
Analogue Multiplier	H. Brueggemann (Research)	Australia Britain Germany Japan U.S.A.
Vibrating Cable Plough	E. W. Corless (Mech. & Elec. Serv.)	Australia Britain South Africa

SUBJECT	INVENTOR(S)	COUNTRIES
Tip Welding Means	E. Bondarenko (Research)	Australia Britain U.S.A.
Semiconductor Light Detector	N. F. Teede (Research)	Australia Britain Germany Japan
Apparatus for Routing Discrete Telecoms. Signals (I.S.T. Junctor)	A. Domjan (Research)	Australia Belgium Sweden Holland France Britain Germany Japan
Self Adaptive Filter and Control Circuit (Echo Canceller)	L. K. Mackechnie (Research)	Australia Germany Britain Japan Holland Italy France Sweden U.S.A.
Apparatus for Monitoring a Communication System and Detector (PETRA)	J. A. Lewis (Research)	Australia Britain Sweden
Control of Operation of a System (Faulty Circuit Isolator)	N. McLeod (Research)	Australia Britain U.S.A. France Germany Japan
Monostable and Bistable Devices (Edge Triggered Pulse Generator)	I. Macfarlane (Research)	Australia
Suppressed Zero Voltmeter	A. Stevens (Research)	Australia
Broadband VHF Antennas	R. P. Tolmie (Q'ld)	Australia
Polarisation Diversity in Domestic Radio Receivers	D. Rodoni (Radio) T. van Bemmel (Non-A.P.O.)	Australia
Cable Pair Identifier	G. Devey (Victoria)	Australia
Detection of Digitally Encoded Multi-Frequency Signals	A. Proudfoot (Research)	Australia
Methods of Bonding Thermoplastic Material to Substrate	H. Ruddell R. Western	Australia

OVERSEAS VISITS BY LABORATORIES STAFF

Staff of the Laboratories regularly travel overseas to participate as Departmental representatives in international forums and conferences of world telecommunications authorities. Illustrations of these involvements are given in the preceeding Section covering international staff affiliations.

Staff also visit overseas telecommunications authorities, research institutions and manufacturers in order to further their expertise through the interchange of technical knowledge, experiences, opinions and ideas.

During the past year, the staff listed below have travelled overseas:—

Brett, P. R.
Craig, E. R.
Domjan, A.
Duke, P. F.
Lavery, W. J.
Williamson, W.
Wragge, H. S.

VISITORS TO THE LABORATORIES

The work of the Laboratories often calls for close liaison with various Australian universities and with the research establishments of other Commonwealth departments, statutory authorities and private industry. Reciprocal visits are made by the staff of the Laboratories and of these other establishments for mutual participation in discussions, symposiums and lectures. In some instances, visitors with expertise in particular fields contribute more directly to the work of the Laboratories as consultants.

Laboratories' activities are also demonstrated to specialist and non-specialist groups from professional societies, other government departments, universities, and other centres of tertiary education. This is achieved through arranged inspection tours and exhibitions, and at longer intervals, by formal "Open Days", when the work of the Laboratories is exhibited to invited guests from many walks of life. The Golden Jubilee of the Laboratories is to be marked by a week of "Open Days" in August, 1973.

During the year, experts from overseas telecommunications authorities, universities, government departments and manufacturing companies have also visited the Laboratories. Other overseas visitors have participated in the work of the Laboratories for longer periods to further their training in telecommunications technology. Often, these visitors are Colombo Plan Fellows, whose visit to the Laboratories is a part of a more extensive period of training in the Department.

ASSISTANCE WITH STUDIES

It is Laboratories' policy to encourage staff to further their qualifications and expertise by study in fields relevant to the work of the Laboratories. Professional staff are selected to pursue post-graduate courses at universities leading to higher degrees or to broaden their post-graduate experience by working outside the Laboratories for short periods. Non-professional staff are also encouraged to seek higher technical or professional qualifications through part or full-time study at colleges of advanced education. Incentives are offered in the form of paid study leave and other concessions for part-time studies, or of extended leave without pay for full-time studies.

The following professional staff have been encouraged to engage in post-graduate studies or to seek wider professional experience during the past year:

WITHIN AUSTRALIA

Court, R. A. G.: Monash University, Vic.
Kuhn, D. H.: University of Melbourne, Vic.
Mattiske, D. D.: University of Melbourne, Vic.
Morgan, R. J.: University of N.S.W., N.S.W.
Newton, A. R., University of Melbourne, Vic.
Park, J. L.: Monash University, Vic.
Steel, J.: University of Melbourne, Vic.
Young, I.: University of Melbourne, Vic.

OVERSEAS

Mackechnie, L. K.: U.S.A.

SPONSORED EXTERNAL RESEARCH AND DEVELOPMENT

The Department is aware of the external telecommunications research and development capabilities which exist in universities and similar institutions, and also in local industry. Recognising the mutual benefits of co-operative effort, it actively supports pertinent projects in these organisations through formal contracts and agreements, and through its participation in the activities of bodies such as the Radio Research Board.

The Laboratories, in particular, support outside research and advanced development projects in specialised fields, particularly those conducted by universities. Current contracts administered by the Laboratories involve research on the topics below:

- PCM for Programme Transmission
- Transmission Equalisers for T.V.-Telephones
- Coding of T.V. Signals
- Phase Variation in HF Standard Frequency Transmissions
- Mathematical and Optimisation Techniques
- Very High Speed Pseudo-Random Noise Generation and Detection
- Solid State Technology for Microwave and Millimetre Wave Sources
- Liquid Filled Fibre Optics
- Electrical Discharges and Plumes on High Power HF Aerials.

In addition, the Laboratories participate in joint projects with other national and international bodies, and where appropriate, seek to co-ordinate their research programme with those of the participating bodies to achieve the most effective use of the resources available.

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