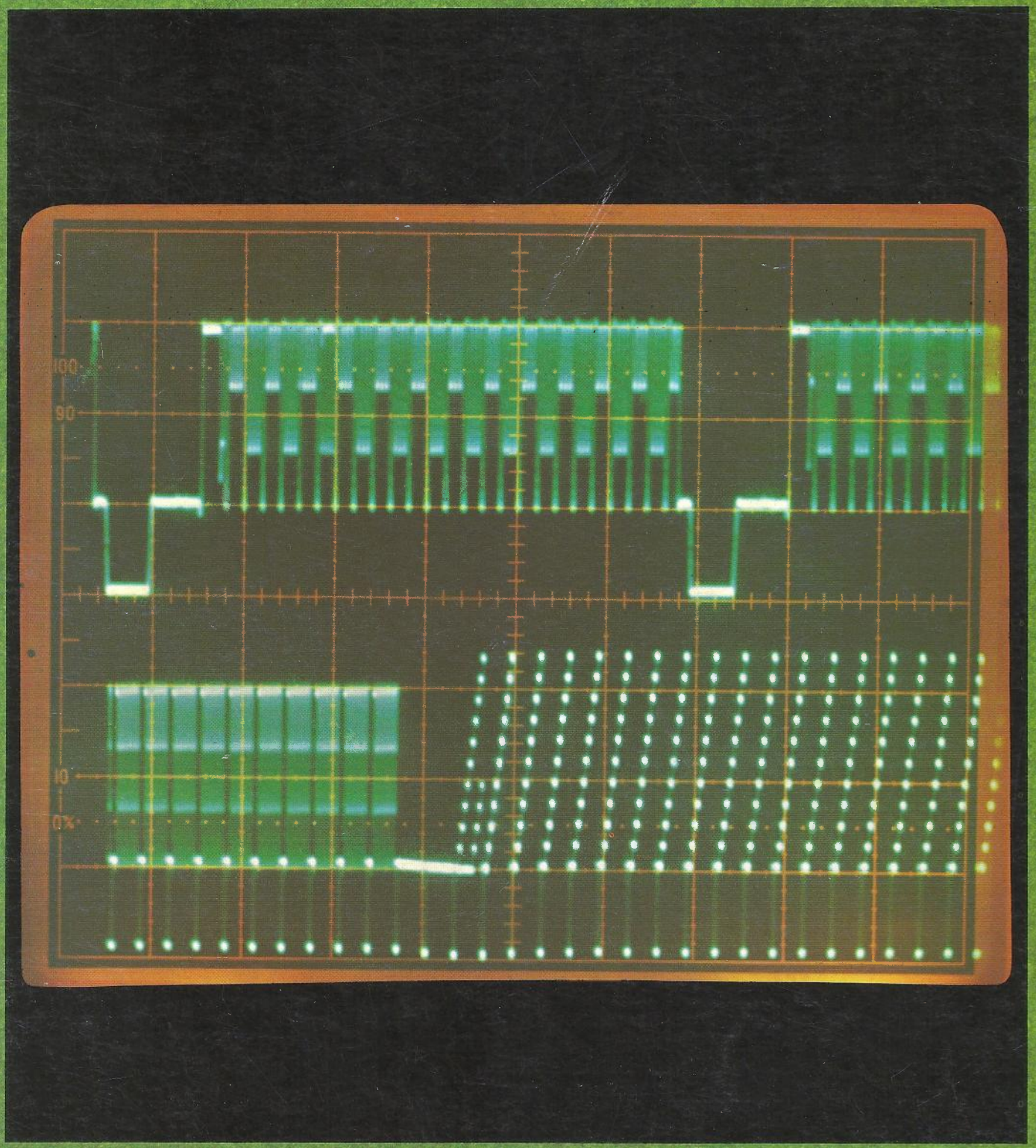
Mr Drummond

review of activities



AUSTRALIAN POST OFFICE RESEARCH LABORATORIES 1974-1975

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

This edition of the "Review of Activities of the Australian Post Office Research Laboratories" has some historical significance, in that it is the last of these annual reviews which will bear that title.

As many readers of the review are aware, the Australian Government has instituted major statutory and organisational changes by which the Australian Post Office will cease to exist as a Department of State on 1st July, 1975. It will be replaced by two new Commissions, the Australian Telecommunications Commission and the Australian Postal Commission, which will have the respective responsibilities, as statutory authorities, for the planning, provision and operation of Australia's telecommunications and postal services. For many years since Federation, both services have been the responsibility of the Australian Post Office, except for international telecommunications services which have more recently been the responsibility of the Overseas Telecommunications Commission.

These changes are being made to provide Australia with modern organisations equipped with the necessary authority, powers and skills to meet the challenges of providing Australia's needs for telecommunications and postal services into the twenty first century. The changes coincide with accelerating world-wide changes in telecommunications technology. The latter offer the prospect of a diversification of customer services and radically new designs of network systems. The possible adoption of digital techniques for switching and transmission could lead to fundamental structural changes in the networks.

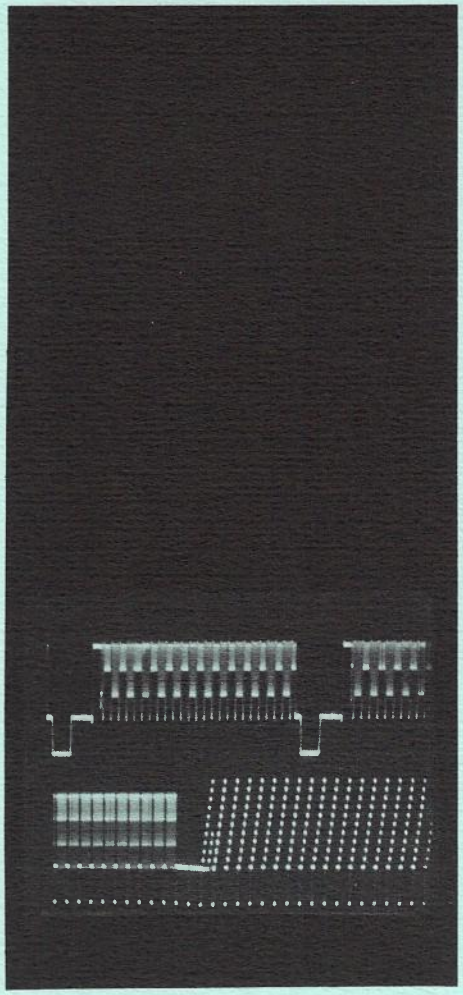
High capacity media under development, such as optical fibres and trunk waveguides, enhance the prospect of an integrated services network providing a diversity of audio, video, data and record information services to both business and domestic users.

For more than 50 years, the technical investigations of the Research Laboratories have provided a valuable contribution to the planning of the Australian telecommunications network and to the solution of its pressing technical problems. This Review demonstrates that the present work of the Laboratories is laying a foundation which will assist in the increasingly complex task of planning customer services and network systems, and which will have an important bearing on the maintenance of the technical viability of the future operations of the Australian Telecommunications Commission.

It gives me pleasure to recommend this Review for your interest.

E Lane

DIRECTOR-GENERAL
AUSTRALIAN POST OFFICE



DIGITAL CODING AND MULTIPLEXING TECHNIQUES ARE USED IN A PROTOTYPE SOUND-IN-VISION TRANSMISSION SYSTEM DEVELOPED FOR THE A.P.O. TV-CONFERENCE FACILITY AND DESCRIBED IN THIS REVIEW. THE WAVEFORMS IN THE COVER PHOTOGRAPH SHOW THE DIGITALLY CODED STEREO SOUND SIGNALS INSERTED IN THE VERTICAL BLANKING INTERVAL OF A TV TEST SIGNAL.

contents

THE ROLE OF THE RESEARCH LABORATORIES

In 1901, the Australian Post Office was established as a Federal Department of State with the responsibilities of providing both the nation's postal and internal telecommunications services. Since then, it has sought to fulfil these responsibilities economically, on a scale appropriate to the needs of Australian society and with a degree of sophistication matching demands and resources. In meeting these responsibilities, it has been conscious of the advantages offered by the timely adoption of new and improved apparatus and systems that result from advances in science and technology.

The tasks of planning, developing and operating the postal and telecommunications networks rely heavily on the correct choice of technology to ensure economies, efficiency and continuing technical flexibility for future network development. Over the years, the accelerating rate of technological change, particularly in the telecommunications field, has demanded emphasis on the efficient management of technology in the activities of all engineering sections of the A.P.O. It has long been recognised in the Post Office that the conduct of relevant research and development is an essential ingredient in the effective management of technology.

The focal point of A.P.O. research and development effort is found in the Research Laboratories. The Laboratories were established in 1923 to study "the latest discoveries, inventions and developments in electrical communications" and to advise "the Chief Engineer of those which are promising and likely to benefit the Department's telephone and telegraph services". The Laboratories are now a Sub-Division in the Central Administration and they are organisationally linked with the Planning and Programming Sub-Division and the National Telecommunication Plan Branch. Through the conduct of relevant R & D projects, the Laboratories seek to develop expertise in advanced scientific and technological fields which will assist the formulation and implementation of A.P.O. policies for the introduction of new or improved equipment, systems or services. The Laboratories also assist the Engineering Branches of the Central and State Administrations in the solution of technical problems that arise in the design, manufacture, installation, operation and maintenance of plant items in service in the networks.

To meet their responsibilities, the Laboratories must maintain a high level of expertise in telecommunications and associated engineering disciplines, 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.

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 Australia will originate overseas. Nevertheless, long experience has shown that without advanced knowledge available within the A.P.O., there is a danger that technical judgements and decisions made by the A.P.O. will be influenced by suggestions and pressures from outsiders whose interests differ from the long term interests of Australian telecommunications. The Post Office has therefore sought, through its own R & D efforts, as well as in other ways, to enable itself to judge the way in which a new development can be incorporated into the network and to assess the special requirements and adaptations necessary to make it effective.

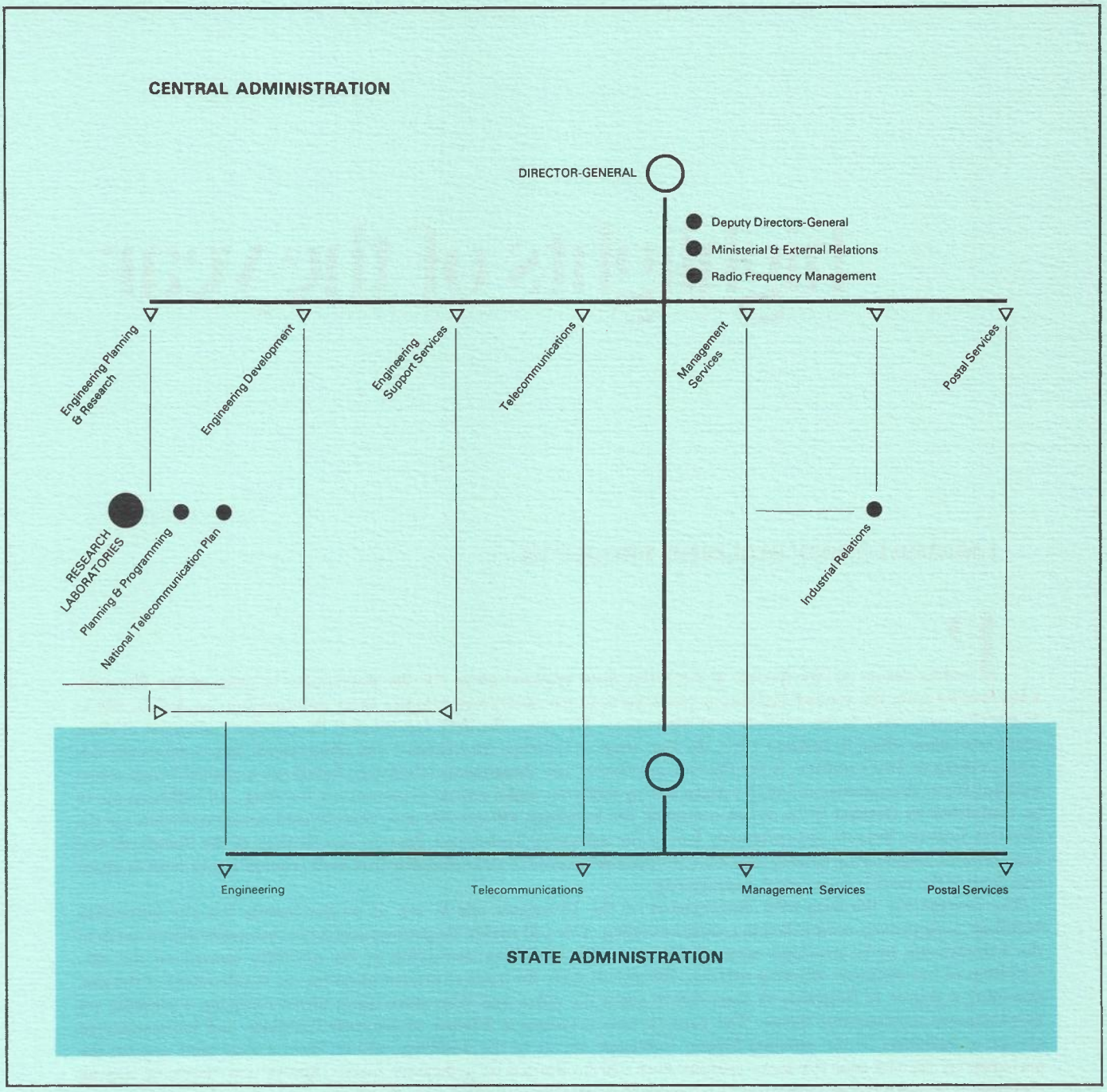
To provide the knowledge and expertise necessary to enable these judgements to be made with confidence, it is necessary to have first hand knowledge of the technology concerned, and the best way to achieve this is through the conduct of advanced development in the relevant field. Many advanced development projects in the Laboratories are undertaken with the understanding that they will 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 or in 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 playing a research and development role, the Laboratories house staff with specialist knowledge and facilities in a number of disciplines, including the physical sciences, and they also conduct investigations into 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 Development units 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 centres of higher learning 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 other organisations to undertake appropriate research tasks.

RELATIONSHIP OF THE RESEARCH LABORATORIES TO THE A.P.O. ORGANISATION AT 31ST MAY, 1975.



The role of the Research Laboratories remains basically the same as it was when they were first established. In essence, their basic function is to develop knowledge and skills in the advancing areas of telecommunications science and technology to assist the Department to decide when and to what extent new technology should be introduced into the operational networks.

Coinciding with the end of the year under review, the Post Office will cease to exist as a Department of State. New Government legislation, arising from the recent Australian Post Office Commission of Inquiry, will result in the establishment of two new Statutory Authorities, the Australian Telecommunications Commission and the Australian Postal Commission, on 1st July, 1975. These Commissions will be formed out of the Australian Post Office. The new organisations will continue to pursue the research and development objectives of the old ones, and the A.P.O. Research Laboratories will transfer with only minor changes to the central administration of the new Australian Telecommunications Commission and continue to perform the same basic role that they have performed in the Post Office for more than 50 years.

In the selection of activities reported in the following pages, this edition of the Review of Activities of the A.P.O. Research Laboratories illustrates the ways in which the Laboratories have sought to fulfil their role during 1974-75.

highlights of the year

LABORATORIES' BUILDING PROJECTS

Previous issues of the Review of Activities have outlined plans for the progressive transfer of the Research Laboratories from the central Melbourne city area to a new laboratory complex to be developed on an A.P.O. site at North Clayton, about 16 km south east of Melbourne. This year, the first step towards the positive realisation of these plans was taken when, in January 1975, the first stage of building construction was commenced. The contract for this stage, valued at $7.13 million, is for the construction of two three-storey laboratory buildings, a special single storey building for environmental and high voltage testing facilities, and a central plant services building. All buildings are to be completed by October 1976. When occupied, the buildings will provide new consolidated accommodation for the Physical Sciences Branch, approximately half of the Advanced Techniques Branch, two Sections of the Standards and Laboratories Engineering Branch and the Laboratories' executive and administrative staff, amounting in total to about one-third of the total Laboratories' complement.

The concept for the long-term development of the 19-hectare site is one of predominantly low-rise laboratory buildings progressively established in a campus setting. This will enable the present and future accommodation needs of the Laboratories to be provided economically and with minimum disruption of the activities housed on the site. Buildings of two distinctly differing external dimensions form the basis of present plans for the development of the site, providing a degree of flexibility to meet future needs for office and laboratory space whilst retaining a pleasing yet homogeneous architectural theme. The concept also envisages a mixture of separate buildings and interconnected groups of buildings in the ultimate layout. Vehicular access to the buildings will be from a ring road around the perimeter of the site and the inner campus area will be limited to pedestrian traffic. Spaces and courts of varying dimensions between the buildings will be landscaped to provide a pleasant and stimulating working environment.

The initial laboratory buildings have been designed on modular principles. Modular structural dimensions and a range of standardised partitions and furnishings have been chosen to permit flexible re-arrangement of laboratory areas. Internal and external ducts for the reticulation of building and laboratory services have also been generously provided on a modular basis. It is considered that the adoption of these design principles has provided the desired degree of flexibility for easy and economical re-arrangement or alteration of building layouts and services, should future activities require such changes.

Concurrently during the year, the first transfers of Laboratories' groups from the city to new leased accommodation at North Clayton took place. In December 1974, the Project Engineering Section occupied part of two new buildings erected by the lessor on a site about 1.5 km south of the A.P.O. site. The buildings are each of two storeys and were built by the lessor largely to A.P.O. specifications. They will serve as interim accommodation for about a third of the Laboratories' Sections until they can be accommodated in a later stage of development of the nearby A.P.O. site. The first building was completely occupied in February 1975 and the second in May 1975. The buildings have provided new and substantially improved accommodation for the Switching and Signalling Branch, three Sections of each of the Advanced Techniques and Transmission Systems Branches, and the Project Engineering Section of the Standards and Laboratories Engineering Branch.

When the first stage of development of the A.P.O. site is completed in late 1976, approximately two-thirds of the Research Laboratories will be re-established in more consolidated and improved accommodation at North Clayton. Present planning aims at completing the transfer of the Research Laboratories to the Clayton area by the end of 1979, when the Sections remaining in two of the original eight city buildings are scheduled to be moved into additional new buildings on the A.P.O. site. The preparation of briefing details for this second stage of development of the A.P.O. site has already commenced, as the first step in a programme for the preparation of the documents necessary for seeking tenders for the construction of the buildings. The programme is aimed at commencement of building construction early in 1977.

DEVELOPMENT CONTRACT FOR ECHO CANCELLER

In recent years, the Research Laboratories have been involved in research into the problem of echo control on voice telephone circuits, especially on circuits which are routed via satellite. It is recognised that the relatively long transmission delay occurring in satellite circuits, compared with terrestrial circuits, degrades the performance of the voice switching devices which form the basis of conventional echo suppressors. In parallel with other overseas establishments, the Research Laboratories have been investigating the technique of echo cancellation to overcome this problem. The technique is based on generating an equal and opposite cancelling echo and involves no voice switching.

Frequency offsets can occur in some unsynchronised carrier systems which terminate satellite circuits and these offsets cause special problems in echo cancellation. They result in a significant time-variance in the echo path characteristics which must be tracked by the control circuit of the echo canceller. Most overseas developments in the echo canceller field initially ignored these problems. However, the condition was observed and identified in early field trials conducted by the A.P.O. Research Laboratories, and development work in the Laboratories was directed towards an echo canceller capable of overcoming the effects of frequency offsets. Laboratories' engineers discovered a novel control technique which enabled the echo canceller to cope with practical frequency offset conditions. The technique was subsequently patented and a prototype echo canceller was developed which verified the validity of the technique experimentally.

The INTELSAT organisation, as a major international agency providing satellite communications facilities, is vitally concerned with echo control and has let several contracts for the development of experimental echo cancellers in recent years. During 1974, INTELSAT issued world-wide invitations for tender proposals for the development of an echo canceller that would handle the additional problems of time-variant echo paths, and the A.P.O. submitted a proposal based on the echo canceller invented and developed in the Laboratories. Subsequently, COMSAT, as managers for INTELSAT, invited the A.P.O. to enter into negotiations for a development contract based on the A.P.O. offer. Negotiations conducted in Washington in January 1975 resulted in the A.P.O. entering into a contract to conduct studies to identify circuits exhibiting time-variant echo path characteristics, to supply an echo canceller which can cope with these effects and to report a study of alternative techniques for echo control to INTELSAT for evaluation.

The work required under this contract is now being pursued by the Laboratories.

SATELLITE COMMUNICATIONS FOR AUSTRALIA — A 1974 Symposium

A three-day symposium entitled "Satellite Communications for Australia" was held at Melbourne University in May 1974. It was sponsored by the Radio Research Board and organised by the A.P.O. Research Laboratories. The Board aims at encouraging research work by Universities, Colleges of Advanced Education and Institutes of Technology in Telecommunications and Radio Science.

The theme of the symposium was chosen because the A.P.O. is currently investigating the role of satellite communication systems in the national telecommunications network, and a number of areas of potential research are seen.

Approximately 200 people from academic institutions, industry and Government agencies attended. Thirty papers were presented, covering satellite systems, techniques, components and related studies.

The symposium opened with papers on the applications of communication satellites to Australia. These papers proposed that a satellite system could not only complement existing broadband trunk relay facilities but could be developed to provide a whole range of new facilities such as automatic telephone and TV services to outback areas, even to individual homesteads, and more extensive educational radio and TV services. Other papers described the uses of satellites in civil aviation, for military communications, and the OSCAR series of amateur radio experimental satellites.

A number of papers, given mostly by industry representatives, demonstrated current and future trends in spacecraft and earth-station terminals. The rate of progress in satellite communication technology was dramatically illustrated by comparing the capability of the "Early Bird" satellite launched in 1965 with the Intelsat IV design now operational. Further developments were outlined which suggested that the early 1980s may see satellites each capable of relaying about 100,000 telephone channels. It was envisaged that more effective use of transmitter power will allow a considerable reduction in earth-station antenna sizes.

Other papers, mostly from University and Institute research workers, described investigations into antennas, satellite tracking, experimental earth stations, signal modulation and the effects of the ionosphere and atmosphere on radio signals.

From the papers presented, it was apparent that satellites could serve Australia in many ways and provide services not available by any other means. The symposium concluded that existing technology could meet many of Australia's requirements but in some applications such as remote area communications, there is scope for worthwhile research and development.

FIRST RADIO RESEARCH BOARD FELLOW JOINS THE LABORATORIES

In 1974, Dr. J. A. Bennett was appointed the first Radio Research Board Fellow. During his Fellowship, Dr. Bennett will study the attenuation of radio signals in tropical rain storms. He is undertaking this work in the A.P.O. Research Laboratories since the project is of particular interest to the Department in connection with its evaluations of the possible application of satellite communication systems in the national telecommunications network.

In announcing the award, the then Chairman of the Radio Research Board, Mr. L. M. Harris, O.B.E., stated that the object of the Board was to foster research in radio science and telecommunications in universities and other tertiary educational establishments and to encourage the transfer of knowledge and expertise from academic research institutions to authorities with radio and telecommunications responsibilities and to industry. Grants totalling $135,000 were made to assist 55 research projects in 1974-75, using funds provided by the Commonwealth Scientific and Industrial Research Organisation, the Australian Post Office, the Overseas Telecommunications Commission and Australian Broadcasting Control Board.

The fellowship awarded to Dr. Bennett is for a period of two years and is the first of such awards which will be made annually and which are tenable in appropriate academic, industrial or government research organisations.

Dr. Bennett was born in Adelaide, South Australia in 1942. He obtained the degrees of B.E.E.(Hons) and B.Sc.(Hons) in 1964 and 1965 respectively at the University of Melbourne. Subsequently, his Ph.D. degree was conferred in 1971 at the same University, following the completion of his thesis — "The Application of Variational Techniques to Radio Propagation in the Ionosphere". This research was carried out in the School of Physics at the R.A.A.F. Academy where he also spent one year as a temporary lecturer.

After completing his doctorate, Dr. Bennett continued research on the use of ray techniques in the study of wave propagation, first spending two years as a post-doctoral fellow at the University of Alberta, Canada. As an Alexander von Humboldt Fellow, he spent one year at the University of Dusseldorf, Germany, and four months at the University of Cambridge, England.

Dr. Bennett commenced his studies with the A.P.O. on 16th December, 1974, following the completion of his Alexander von Humboldt Fellowship.

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 normal method of publishing the detailed results of a research project is through a Research Laboratories Report, prepared when an investigation has reached a conclusion or a conclusive stage. It is the vehicle by which the results of the work are conveyed to the A.P.O. "client", other interested sections of the Department and in many cases, to other telecommunications agencies and industry as well as to other research bodies, both local and overseas.

In addition, the staff of the Laboratories often contribute to Australian and overseas technical journals and present papers to learned societies. An indication of the scope of this activity can be gained from the lists given in the last section of this Review of Activities.

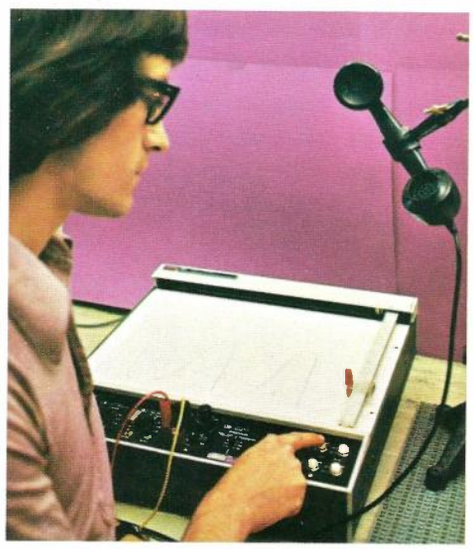
TELEPHONE INSTRUMENTS AND STANDARDS

Although the data communications business of the A.P.O. is expanding rapidly, the provision of telephone services will remain a predominant sector of A.P.O. telecommunications activity for many years to come. At present, there are 5 million telephone instruments in service and the total asset value of subscribers instruments represents about 8.5% of the total telecommunications assets of the A.P.O. Accordingly, it is necessary for the A.P.O. to invest a significant proportion of its research expenditure to ensure the effective use of its telephone assets, as well as to investigate new forms of service likely to be in future demand.

Although the A.P.O. uses telephone subscribers' apparatus that is virtually identical with that used in most other countries of the world, most of it is manufactured in Australia, and the A.P.O. Research Laboratories have an unusually large commitment in relation to instrumentation and standards needed for telephone production. Consequently, the A.P.O. maintains one of the largest and most active telephone transmission standards laboratories in the southern hemisphere.

Since the telephone standards activities require expertise in fundamental acoustic measurement, the Research Laboratories are occasionally called upon to provide primary acoustic calibration services and acoustic noise studies for outside industry, in addition to the work of this nature performed for the A.P.O. Similarly, years of specialization in the study of electro-acoustic transducers have resulted in the Research Laboratories performing a continuing role in the evaluation of the new telephone microphones and receivers which have subsequently been introduced into standard items of A.P.O. plant. A current study is directed at improving the reliability and long term performance of the carbon microphone through the use of pre-aged carbon.

A significant proportion of the Research Laboratories effort must, of course, be devoted to the study of new services such as the TV telephone and other modern adjuncts to acoustic telephony, and this proportion is expected to increase in the future as the rate of change of A.P.O. business rises to reflect the ever-increasing pace of technological change and more diverse community demands.



A CARBON MICROPHONE IS TESTED FOR D.C. CURRENT STABILITY

The Use of Pre-Aged Carbon in Telephone Microphones for Local Battery Service

The speaking resistance of carbon microphones increases with age through the combined effects of electrical and mechanical abrasion and exposure to atmospheric gases. Central battery telephones used in the automatic network operate under virtually constant current conditions, and the increased resistance of the microphone results in a greater d.c. voltage to be modulated and the deterioration in performance is to some extent compensated. A reasonably long life with fairly uniform efficiency is usual in central battery conditions.

In local battery telephones, of which there are about 160,000 still in service in Australia, approximately constant voltage conditions apply and the microphone current is determined almost entirely by its resistance. As a result, local battery telephones lose efficiency rapidly. A loss of 4 dB in the first two years is typical, increasing to 7 dB in five years.

Recent manufacturing improvements have resulted in the production of pre-aged carbon from which it is possible to make a microphone whose resistance remains constant for a much longer time. Previous studies showed that such microphones are of slightly lower sensitivity than that required to meet the A.P.O. requirements for telephone microphones.

Experimental work is being undertaken to investigate the claim that although such microphones may be of slightly lower efficiency initially, their efficiency after two years might well be higher than that obtained with present microphones after the same period. By optimising the electrode spacing and volume of granules and by selection of a suitable grade of carbon, it has already been possible to produce usable microphones under experimental production conditions. As a check on batch variation, two separate samples manufactured nine months apart were obtained and good agreement was found between them. The local battery efficiency of these microphones is about 1.5 dB lower than the initial efficiency of current microphones in use in A.P.O. telephones.

The possibility of improved long term performance could also enable planning standards for local battery telephone services to be upgraded since these currently take into account the degradation of performance due to ageing of present microphones.

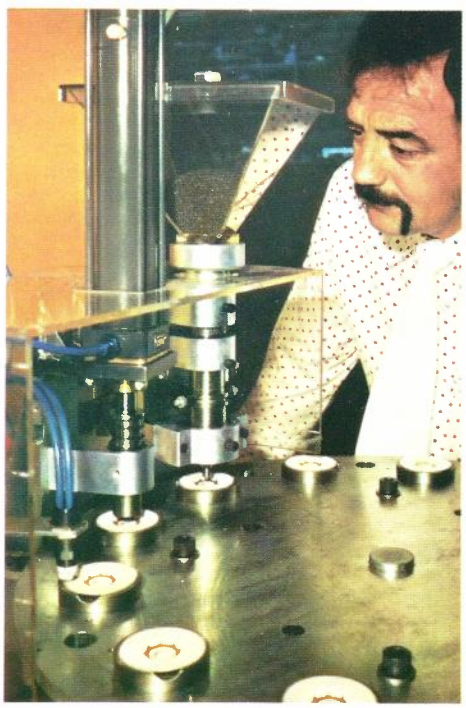
Other studies have shown that with extra dry cells and other appropriate measures, the transmitting performance of the A.P.O. 400-type local battery telephone, equipped with a microphone using normal or pre-aged carbon, can be raised to a level where it is acceptable as an interim long line telephone. Local battery telephones normally utilise two dry cells. However if more cells are used, a considerable improvement in sending performance occurs. On the other hand, laboratory experiments have shown that

THE MOULDED SPHERICAL TELEPHONE BOOTH TESTED IN THE LABORATORIES

increasing the number of cells can result in d.c. current instability. Within a few minutes of applying voltage, the microphone current can increase by a factor of six. Five to ten minutes later, it falls rapidly to a lower than normal value. After several more minutes, the current increases and the whole cycle is repeated again and again. Considerable heat dissipation in the microphone occurs and it is probable that its ageing is greatly accelerated.

Laboratory experiments have shown that the cycling only occurs if the microphone is not vibrated sufficiently by speech or by handling of the handset. Because such inactive periods exist, some measure to prevent or reduce the cycling is highly desirable. Work to date suggests that whilst a current regulator can be used, it is sufficient to use a resistor of appropriate value in series with additional dry cells in the d.c. circuit of the microphone.

Although it is planned to eventually replace all local battery telephone services in Australia with automatic central battery services, it is anticipated that about 80,000 will still be operating in 1980 and a significant number for a decade beyond that date. Consequently, the development effort directed at improving the quality of such telephones and reducing maintenance costs is considered worthwhile. The performance of the microphones which have been developed in these experiments will continue to be monitored and it is hoped that the work will result in a more satisfactory microphone for use in local battery telephones.



TELEPHONE MICROPHONES BEING LOADED WITH CARBON GRANULES IN PRODUCTION

Acoustics of Telephone Booths

A telephone booth should enable a telephone user to make his call in an adequate acoustic environment. It must provide isolation for the user from outside sounds such as traffic noise (environmental sound insulation) and privacy to reduce the probability of his conversation being overheard by passers-by or people using adjacent booths.

In some situations, a conventional style of booth is regarded as incompatible with the decor of the surroundings. Examples of such situations are in shopping complexes and airport terminals. There is therefore a continuing demand from architects and the like for a modern and more aesthetically pleasing style of telephone booth which, unlike outdoor booths, need not provide shelter for the user. As can be expected, a number of ad hoc designs have been installed, usually without much prior expert attention being given to the acoustic function of the booth. The results have often been fashionable but barely functional.

Following a recent request to determine the acoustic performance of a particular type of booth, the Research Laboratories extended their investigations and made some measurements of the acoustic performance of several types of telephone booth. These measurements showed that the acoustic performance of all of the booths tested was poor. Conventional outdoor booths gave environmental sound insulation figures of about 10 or 11 dB. The "modern" types of booth gave figures of between 2 and 6 dB. The 6 dB figure was obtained with a booth of spherical shape and moulded in an acrylic material, but only when the booth was installed carefully and used properly. Even so, this type of booth acted as a Helmholtz resonator and thus actually increased the sound level at lower frequencies. One such booth was found to increase environmental sound levels by up to 14 dB at frequencies around 70 Hz when a person was using the booth.

Speech privacy between pairs of booths was also measured and found to be satisfactory for most types if they were sensibly installed. Figures of about 30 dB were common but a low figure of 20 dB was found where two acrylic dome telephone booths were installed in a small reverberant lobby with their entrances facing a common point.

The experience gained in these investigations will enable the Post Office to offer improved technical advice on the acoustic design of modern non-standard telephone booths.

Training Device for Deaf Children

Due to their handicap, deaf children often do not become familiar with telephones. The Research Laboratories have sought solutions to the problems deaf people face, and following the development of a hearing-aid telephone, it was decided to develop a simple training device to assist deaf children to gain confidence in using telephones.

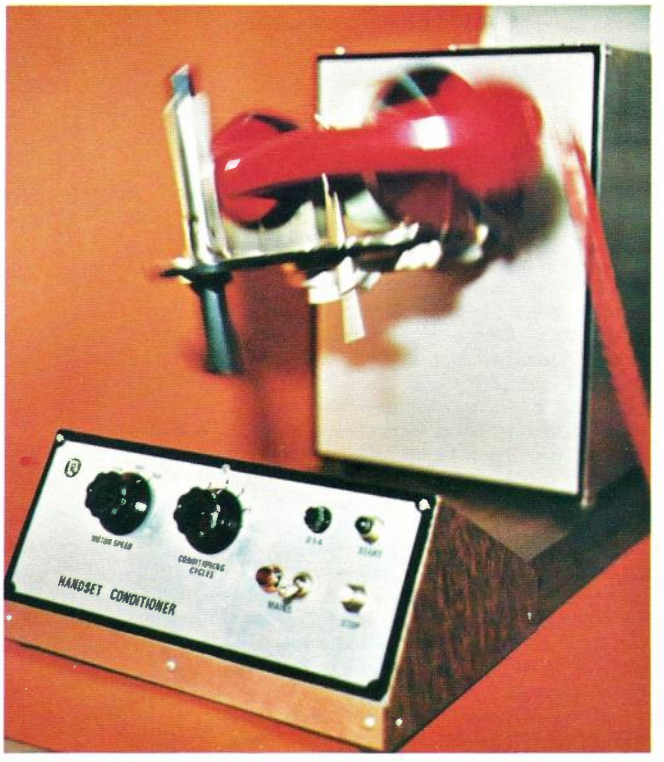
The telephones used in the training device are of the hearing aid type, which incorporate a "receive" volume control. As many hearing aids employ a magnetic pick up coil, the telephones are also equipped with hearing-aid

couplers. Associated with each telephone is a gliding-tone caller which may be used as the calling device instead of the internal bell. A gliding tone caller, as its name suggests, produces a tone which glides up and down in frequency. In contrast to the conventional bell, most of its sound energy output occurs below 1 kHz. Consequently, this is a more reliable calling signal for people with "high-tone deafness" since they often have difficulty hearing the normal bell. The remaining part of the system is a mains powered box containing a feed current supply, an artificial cable, an interrupted ring current generator and a control circuit.

The operation of the training device is extremely simple. If either handset is lifted, the calling device of the other telephone is sounded. Lifting the other handset stops the calling device, and conversation can then be conducted via the telephones. If either handset is replaced, calling will not be initiated. By replacing both handsets, the device is restored to its initial condition.

Development and design of the device was conducted in the Research Laboratories, and small-scale production was undertaken by the Queensland Postal Workshops. Samples of these units will be demonstrated to interested parties by the telecommunications sales staff in the State Administrations and the market potential will then be assessed.

PRACTICE WITH THE TELEPHONE TRAINING AID BUILDS CONFIDENCE IN DEAF CHILDREN



MECHANICAL HANDSET CONDITIONER FACILITATES TELEPHONE TRANSMISSION PERFORMANCE MEASUREMENTS

Instrumental Measurement of the Loudness Rating of Telephones

The standard method of rating the transmission performance of telephone circuits is by means of a loudness comparison against a reference circuit, using real talkers and listeners. However, such a procedure is laborious, time consuming and not very repeatable, and so instrumental versions have been devised. One electro-acoustic measuring system for this purpose, which is commercially available, includes an artificial mouth, an artificial ear, a test signal comprising a swept sine wave with a sweep period of about one second and a loudness power law weighting circuit with an analogue indicating meter. A facility is also provided to permit manual rotation of the handset to standardise the condition of the carbon granules of the microphone prior to measurement. The standard apparatus has several operational difficulties which have been largely overcome by the addition of two units designed in the A.P.O. Research Laboratories.

The first unit is a carbon microphone conditioner which obviates the need for the careful smooth manual rotation of the handset which would otherwise be necessary, and which is tedious and therefore a source of frustration to the operator. The conditioner mechanically holds and rotates the handset back and forth through 180°, with the axis of rotation, the speed of rotation, the number of rotations and the final stopping angle all capable of adjustment if required. The driving motor of the unit is coupled to the conditioner by a belt drive to reduce packing of the carbon granules due to vibration. The conditioner and drive motor both have low inertia to permit smooth and moderately rapid reversal and stopping. The conditioner may be remotely started, and a signal is available to indicate when the conditioning procedure has been completed.

The other unit is a varying power law integrating voltmeter with a digital display. This unit was developed to reduce operator fatigue, and therefore error, during measurements made with the analogue indicating meter originally supplied with the apparatus. The analogue indicating meter is damped to a compromise value to reduce pointer fluctuations during the period of the sweep, while also permitting the pointer to settle to its final deflection before the carbon granules in the microphone have become packed. This compromise damping still allows the needle to fluctuate significantly, and because of the packing phenomenon, the reading must be taken at a specific instant, such as during the fifth sweep. High concentration is therefore required, resulting in operator fatigue. The digital meter on the other hand integrates for an integral number of sweep periods and displays the value in a clear digital form. The loudness power function is also provided in the unit, where the following calculation is made:

$$\left\{\frac{1}{T}\int_{0}^{T}[e(t)]^{a}\,dt\right\}^{\frac{1}{a}}$$

In one mode of operation, the unit integrates during one sweep period while displaying the integrated value from the previous sweep. Since the readout is constantly being updated at the end of each sweep, continuous operation as required for interactive investigations is possible. In the other mode, the unit integrates for five complete sweeps and then displays this value indefinitely until another measurement is initiated. The second mode is more suited to routine measurements, and the displayed value is available in binary coded decimal format for automatic recording by paper tape punch, digital printer and the like.

The addition of this extra apparatus to the standard measuring system has greatly increased the rate and accuracy of measurements and reduced operator fatigue. It has also made possible the recording and analysis of data.

DIGITAL SWITCHING STUDIES

■

The demands made of switching equipment in telecommunications networks have increased rapidly in recent years, and this trend will continue as the number of customers wanting service increases, and the nature of the service requested grows in complexity. The largest telecommunications network at the present time is the telephone network, and electronic techniques combined with computer control are already being applied to telephone exchanges to increase their maximum size, their traffic carrying capacity and to provide the range of facilities seen to be necessary in the near future. Already, a need is forecast for a 100 000 line trunk exchange, whereas the current maximum size available is about 50 000 lines. In comparison to telephone services, data services are relatively few in number, and most use private line networks or telephone channels. However, data services are increasing at a much more rapid rate than telephone services, and the existing telex network and common user data network are only the forerunners of a range of data services and switched data networks that will be needed during the next 20 years.

System techniques and technology are becoming available to meet the challenge of these requirements. The Research Laboratories continually monitor world developments in these areas and undertake studies and experimental developments of advanced switching and signalling systems to ensure that the A.P.O. will be equipped to find solutions for the switching problems of tomorrow. Digital techniques offer the most attractive promise at the present time, and it is these that are under the most intensive study.

The range of studies undertaken includes the development of theoretical models, the testing and evaluation of new components, the devising of new techniques to apply technological developments efficiently and the design and construction of complete switching systems for evaluation in the laboratory and in the field. The effect of technological advances on the topology of telecommunications networks and estimates of relevant cost factors in those networks are also being studied.

To the present time, most of the work of the Research Laboratories has been directed towards telephony switching applications and the Laboratories have pioneered the application of computers to the control of switching equipment in Australia. They have also participated in an international field trial of an advanced common channel inter-exchange signalling system and are currently evaluating a fully electronic digital tandem telephone exchange in the Melbourne network. The emergence of data services as a high growth area is a relatively recent phenomenon, and plans are well advanced to study the potential problems of switching data at various speeds in a rapidly developing nework.

It is thought in some circles that subscribers will ultimately require a wide range of services provided by a single connecting link into a communications network, which must then handle telephony, data, facsimile, video services and perhaps services not yet conceived. The trend towards integrated services networks employing digital techniques for both switching and transmission is being studied as a component of very long range theoretical studies of the possible future shape of the communications networks.

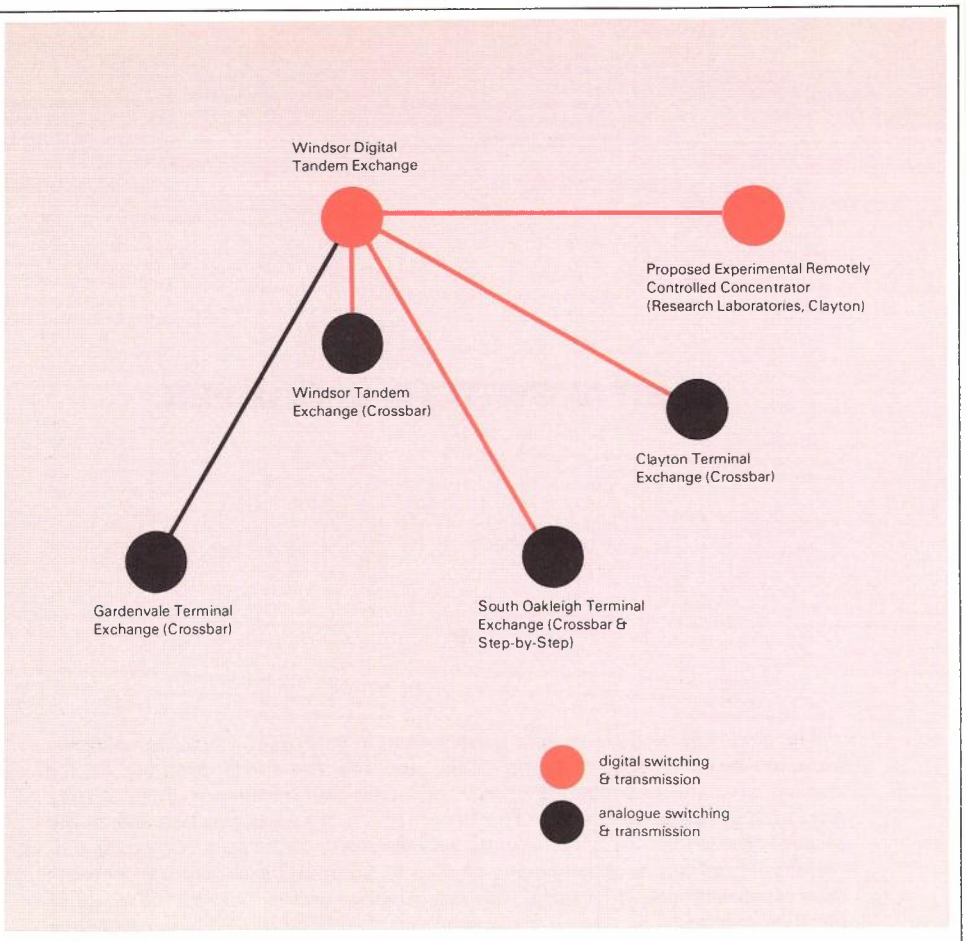
Telephone Switching Systems

The application of digital techniques to control telephone connections is currently being investigated in two phases. The first of these is already in field trial and consists of a digital tandem exchange which switches pulse code modulated (PCM) circuits connecting the tandem to crossbar and step-by-step terminal exchanges. The concept of integrating the switching and transmission techniques, using pulse code modulation, has been under study for some time as it offers economic and service advantages for the future. The trial exchange is located at Windsor, a suburb of Melbourne, and employs a high level of common control based on programs stored in a duplicated processor system. The exchange uses modern digital integrated circuit technology throughout. The digital tandem exchange was installed in August 1974 and placed in service after extensive system testing. It terminates approximately 100 junction circuits and is carrying a large number of calls reliably each day. The exchange performs all normal functions such as signal reception and analysis, inter-exchange signalling, path selection, call connection and monitoring. A large amount of statistical information related to the operation of the exchange is generated for analysis.

An extensive evaluation of the performance of the exchange is being carried out to determine how well it meets its design objectives, how readily it may be modified and extended, and its reliability. Results already indicate that the digital techniques employed offer a high level of service performance and reliability to the telephone switching network.

The second phase of the telephone switching studies involves the design and construction of a local telephone exchange designed for use in a digital network. Theoretical studies have indicated advantages to be gained from providing local exchange facilities using a central processor-controlled parent exchange which remotely controls a cluster of small terminal exchanges, or concentrators, situated in the surrounding district. The digital tandem exchange undergoing field trial at Windsor is also being modified to function as a parent exchange of the type described. This is being achieved by program modification to the central processor units, demonstrating the flexibility of stored program control. A remotely controlled unit, or concentrator, has been designed which has PCM circuits to the parent but which uses conventional electro-mechanical switches to perform the local switching function between the subscriber's line and the digital junctions to the parent. The remote control technique is the most important aspect of this development as electro-mechanical exchanges are well known. The concentrator will be connected to the parent exchange via two 30-channel PCM systems. These PCM systems will provide the junction circuits for telephone connections and two 65 kbit/s data

SWITCHING NETWORK ASSOCIATED WITH THE FIELD TRIAL OF THE DIGITAL TANDEM EXCHANGE AT WINDSOR ▶



DIAGRAMS HELP EXPLAIN THE SYSTEM DESIGN OF THE EXPERIMENTAL EXCHANGE TO VISITORS

links for the remote control facility. Each of these data links carries data from the concentrator to the parent on the state of subscribers lines and the various components of the concentrator, and in the reverse direction, the links carry commands from the parent to establish and clear telephone connections. The duplication of the links and of control circuitry in the concentrator is a reliability feature commensurate with the duplication of processors in the parent exchange.

A later development is planned to investigate a fully digital concentrator which will take the application of digital techniques closer to the subscriber. Ultimately, investigations will be extended to digital reticulation techniques which provide subscribers with a high capacity digital connection to the communications network and open the way for integration of a variety of subscriber services.

Data Switching Systems

The growth in data traffic throughout the world is vigorous. In Australia, the current annual growth rate is estimated at between 60 per cent and 90 per cent. Subscribers are demanding higher and higher transmission speeds and some 48 kbit/s services are already in operation. Major improvements are being plannned in the provision of data transmission channels and it is envisaged that by the mid-1980s, there will be a need for automatic switching of high speed data on a large scale.

The Research Laboratories have recently commenced a series of studies on the switching of data in a synchronous digital network. It is planned that later phases of the studies of system design concepts will involve experimental verification of theoretical conclusions in a laboratory trial of a model data network.

There are three basic modes of data switching:

- circuit switching, as in the Telex network,
- message switching, as in the TRESS and CUDN networks, and
- packet switching, which is the transmission of a message in a series of discrete packets.

The initial studies are investigating the problems associated with a synchronous circuit-switched data network to provide the A.P.O. with a technological base for its future decisions. The other forms of data switching may be studied at a later date.

It is planned that the studies will encompass:

- signalling requirements between customers and the network, and within the network, for setting up and supervising data connections. These studies will be directed at the definition of signalling systems and customer procedures.
- exchange configurations for a variety of exchange sizes.
- the technology to be used for the actual switching crosspoint.
- techniques for controlling exchanges and the network.

The digital exchanges used in the trial network will be operated by a small processor using stored program control. Both the hardware and software for the exchanges will use techniques similar to those developed for the digital tandem telephone exchange, and the experience already gained in the study of digital telephone switching systems will provide a valuable input to the data switching studies.

PROCESSORS BOTH CONTROL SWITCHING AND PROVIDE PERFORMANCE DATA AT THE EXPERIMENTAL EXCHANGE

Walsh Function Multiplexing

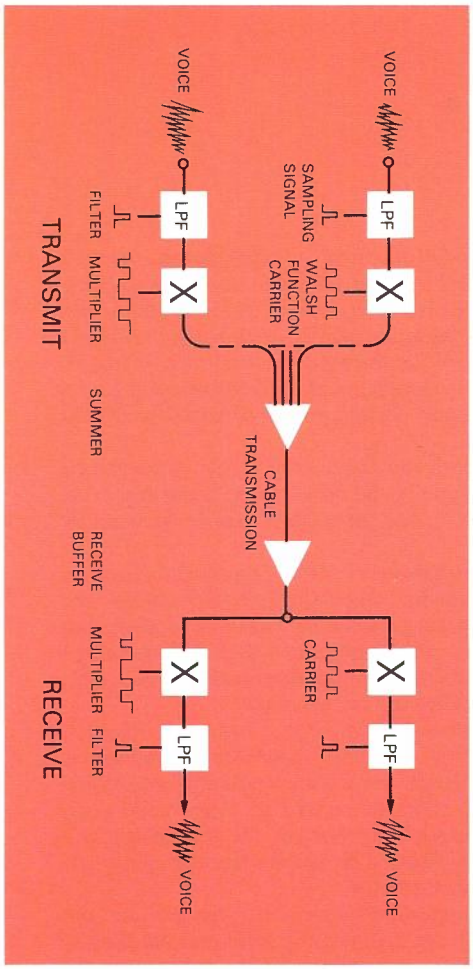
In an integrated digital telecommunications network, there is a need to encode voice information into a format suitable for multiplexing. Considerable work has been done to investigate the feasibility of various digital encoding methods at the subscriber's telephone. An important factor in the choice of signal format in the telephone network is the density of information traffic and its relationship to the equipment cost per subscriber. Multiplexing fo PCM signals, for example, becomes economically attractive at points in the network where the traffic density is high. However, on a cost-per-subscriber basis, the provision of individual coding equipment in each telephone is currently less attractive.

An alternative multiplexing system is under investigation which offers, in principle, cheap and simple coding and multiplexing equipment. The technique is quasi analogue-digital and is based upon a novel set of mathematical functions known as Walsh Functions. This set of functions is analogous in many ways to the set of trigonometric functions so well known in the communications world.

The waveforms of Walsh Functions are two-valued rectangular waves making them useful in both analogue and digital communications applications. Although Walsh Functions were evolved in the 1920s as an interesting set of orthogonal functions, their application to communications was not appreciated until the late 1960s. Since then, applications have been found in the fields of multiplex systems, pattern recognition, efficient point-to-point radio communication, TV bandwidth compression, high speed computer transform processing and radar.

When Walsh waveforms are modulated by a continuous voice signal in a fashion similar to amplitude modulation, various circuit and system simplifications arise. The technique is known as "sequency division multiplexing" in which modulation, filtering and single sideband operation are achieved with extremely simple circuits. Initial experimental evaluation of the technique led to the expectation that Walsh Function multiplexing may be useful as a preliminary multiplexing method for closed loops of twenty or so telephone subscribers. Further investigation has clarified some fundamental technology-based limitations of the technique. The most critical performance parameter for this technique is inter-channel crosstalk. Detailed experimental and computer simulation studies have indicated that desirable crosstalk levels can only be achieved by using some very expensive circuit components together with an unusually sophisticated circuit layout technique. This tends to eliminate the method in the per-subscriber modem application, despite the simplicity of the multiplexer principle. However, alternative techniques using Walsh Functions as binary multiplexing code-words are available for this application. These methods are also under investigation.

SEQUENCY DIVISION MULTIPLEX SYSTEM UTILISING WALSH FUNCTION CARRIERS



Digital Circuit Techniques

The rising interest in digital switching equipment has followed the introduction and development of low cost digital switching techniques and digital integrated circuits — components and techniques which, in many cases, were originally developed for military, space and computer industries. The further development of viable switching systems is dependent upon the correct use of the latest developments in technology. To this end, detailed studies are being conducted on the devices and techniques that may find application in digital switching systems, and covering topics such as:

Logic Family Comparisons
Interfacing
Line Driving and Receiving
Self Generated Noise
Mains-Borne Noise
Semiconductor Memory Techniques
Programmable Read-Only Memories
Programmable Logic Arrays
System Layout
Supply Decoupling Techniques.

Not long ago, the performance trade-offs between the available logic families were well-known and straight-forward. The decision whether to use emitter coupled logic (ECL) or one of the types of transistor-transistor logic (TTL) was almost made for the designer — he had only to look at a simple chart and determine what speeds were available, at what cost in power.

But over the past two or three years, the picture has become much more complicated. A dozen or so new logic families have now appeared, with overlapping specifications that make it far harder to decide which family now comes closest to satisfying a given set of requirements. The new logic families give the designer more freedom but also make him work harder. Not only do their specifications overlap, but many families are not interchangeable, so that it is difficult to mix, say, the micropower capability of complementary metal oxide semiconductor and the nanosecond capability of ECL on the same circuit board. Power-supply requirements vary, fan-outs are different, drive capabilities are never the same, and so on.

In large digital systems, problems can be encountered in attempting to make satisfactory interconnections between logic elements. The problems can arise on printed circuit boards with interconnections of a few centimetres in length, between chassis where distances of tens of centimetres may be involved, or between cabinets involving signal path lengths of metres or more.

When considering binary signals having low average pulse repetition rates, of the order of kilobits per second, the temptation can be strong for the designer to approach the equipment practice aspects of his design as if he were dealing with direct currents. However, if the integrity of pulses is to be maintained without "glitches" and ringing on the leading and trailing edges, the switching transition time of the gates employed is the critical factor — rather than the repetition rate of the system. Switching transition times of the order of 10 nanoseconds are typical of logic elements such as the industry standard 74 Series. Such switching times put the device in the VHF class and mean that signal paths of length greater than, say, 1 metre must be regarded as transmission lines. Line driving and receiving techniques for these conditions have been investigated, and as a result, recommendations have been made and adopted in the construction of the digital tandem exchange undergoing field trial. A large measure of the success of the trial exchange is due to the success of these high speed signal transfer techniques.

ANALOGUE TRANSMISSION STUDIES

Substantial effort is being expended in telecommunications research laboratories all over the world on digital transmission and switching systems, but recent economic studies in the A.P.O. have shown that telecommunications services will continue in the main to be substantially provided by analogue techniques for some time yet. The A.P.O. is therefore obliged to continue to devote a substantial part of its research, development and design effort to the adaptation and application of analogue techniques and systems to the Australian environment.

In every country, system disigners need data about the traffic to be carried and the important parameters of the signal to be transmitted, and a report on current work in studying signal levels in the Australian telephone network follows later in this Section.

In addition, Australia's long distances between centres of population and its thinly distributed rural community give rise to a number of special problems. The provision of services to the rural population provides an incentive to study and apply techniques for the voice frequency amplification of signals in long cables. The study of negative impedance boosting techniques described hereafter is an example of a research project stimulated by such an incentive.

With analogue transmission systems employing frequency division multiplexing continuing to predominate in the Australian transmission networks, the A.P.O. will continue to install transmission systems employing large quantities of filter circuits in a complex variety of types each year. Consequently, there is a research interest in techniques for the design and production of low cost and miniaturized filters. This is the object of one of the studies being pursued in the Research Laboratories.

The Laboratories also provide important specialist support to the Department's operations by developing and applying the skills and facilities of the "standards" groups centralised in the Laboratories. These encompass the Departmental reference standards of time interval, frequency and electrical quantity. From the Laboratories reference standards installation, signals of precise frequency are distributed for Departmental and other special purposes through the telecommunications network, and the development of techniques for the distribution of these signals without loss of frequency precision must therefore consider transmission systems. In turn, one of the projects being pursued in the Research Laboratories concerns the development of techniques to synchronise the carrier network based on the frequency standards installation in the Laboratories. Research is also being conducted into improved methods for the provision of the civil time services, which are also based on the above standards. These are important not only to the A.P.O. itself for its own operations but also for their value as a commercial enterprise which attracts more than 78 million telephone calls annually to the speaking clock services. An article in this section of the Review deals with a recent development in this field.

Signal Levels in the Telephone Network

The levels of signals at various points in the network are of importance to those who design, implement and engineer telephone equipment and ultimately to the far end listener. The work carried out in the Research Laboratories in this field has a twofold aim, first, to increase knowledge of the levels existing in the Australian network and secondly, to enable the A.P.O. to participate effectively in a worldwide investigation of speech levels co-ordinated by the C.C.I.T.T./C.C.I.R. Joint Study Group Special C. This programme has as its eventual aim the review of transmission system signal levels for international working.

As part of this participation, surveys of levels existing within several exchanges, both country and metropolitan, have been made and the results gained have formed the basis of a contribution to the C.C.I.T.T. study. Further surveys relating to levels within groups and supergroups of carrier systems have been carried out and the results reported upon in various publications. More recently, a survey of levels at the output of automatic voice recording machines was made by the Long Line Equipment Branch with the assistance of the Research Laboratories.

In order to check the accuracy of the measurement techniques of participants in the study, the C.C.I.T.T. recently co-ordinated a further series of tests in which the Laboratories participated. As a result of A.P.O. participation in this programme, it was found necessary to test certain assumptions inherent in the design of the original measurement system and to develop improved systems. This work has resulted in a further contribution to the C.C.I.T.T. regarding the minimum sampling rate usable in the measurements. The possibility of developing a real time sampling speech level meter not requiring post-measurement analysis to derive the actual speech parameters has also been demonstrated.

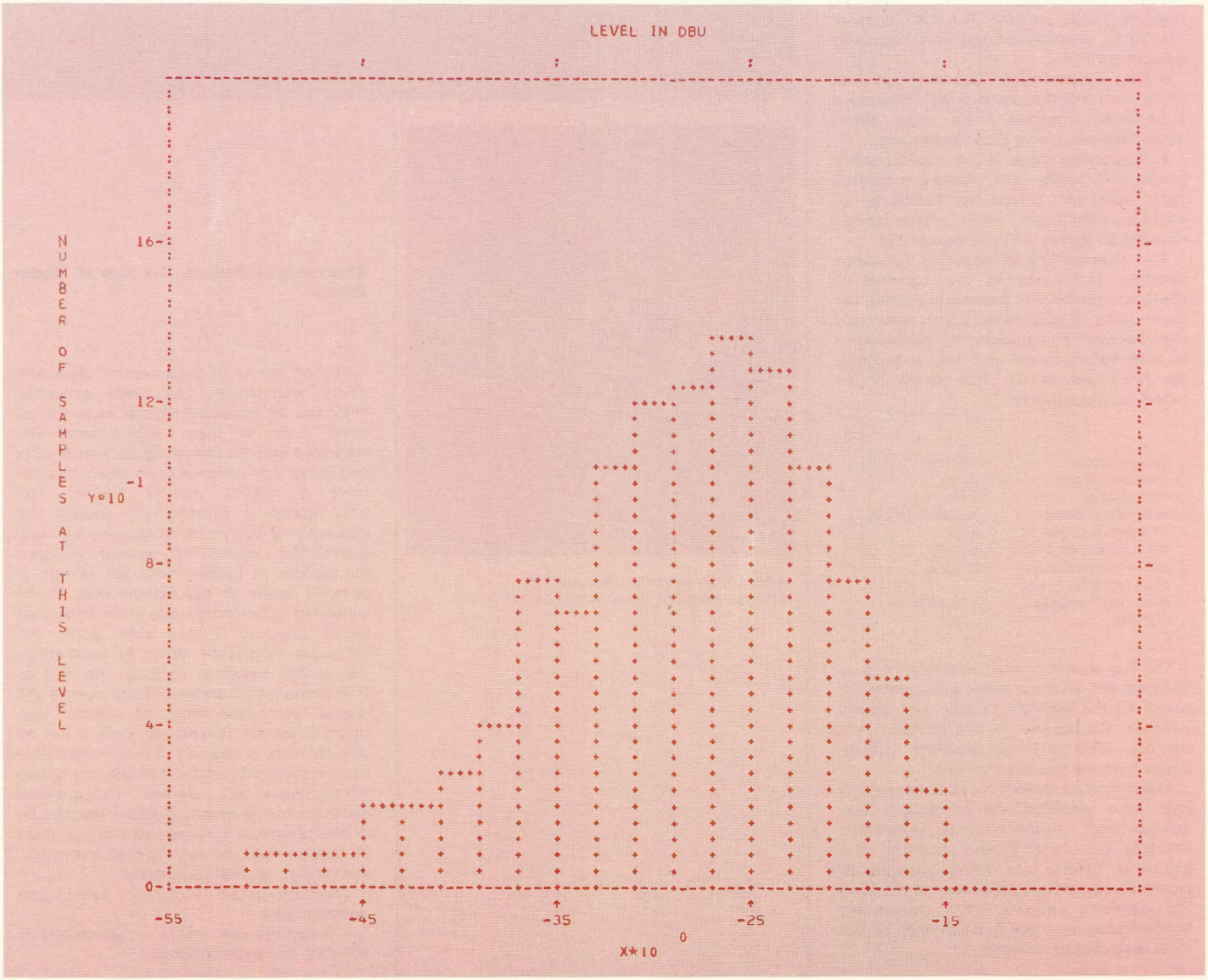
To assist the work, a recording logarithmic digital voltmeter was developed which samples the instantaneous level of the signal every 25 ms and quantises it into one of 20 contiguous ranges, each 2 dB wide. The coded and quantised value is then recorded on paper tape for later iterative processing to extract the necessary parameters. An ancillary control unit allows unattended data collection. Preparations have been made to use this instrument to carry out a further survey of speech levels in the A.P.O. trunk network and this survey is expected to yield more accurate results than earlier surveys which used lower sampling rates.

Of particular concern in these studies is the distribution of high level signals in carrier system supergroups, since high levels can cause serious degradation of all signals passing through a multichannel carrier system. For this aspect of the studies, an instrument was developed to measure the fine grain structure of the probability distribution

MINICOMPUTER ASSISTS DATA ACQUISITION AND ANALYSIS OF SPEECH LEVELS IN THE NETWORK

of high levels in supergroups. The instrument has proved adequate for the derivation of approximate statistics of the occurrence of high level signals. However, more accurate statistics require that the time and effort required to perform the necessary measurements be decreased significantly. Consequently, an improved instrument is being developed. This will sample at a much higher rate and provide finer resolution than the previous instrument. It will also produce data in a different format. It will enable levels to be measured in a sub-range of 10 dB with 1 dB resolution. The sub-range can be varied in 5 dB steps to cover a total range of 25 dB. It is intended that this instrument will be used in further surveys and analyses of the signal levels in the trunk network in the near future.

COMPUTER PLOT OF SIGNAL LEVEL DISTRIBUTION IN A TEST TELEPHONE CONVERSATION



Negative Impedance Boosted Lines

Negative impedance boosting is a technique for reducing loss in transmission lines. Practical cables exhibit loss primarily because of their distributed series resistance. If this could be eliminated, an ideal, lossless, distortion-free line would be obtained. The use of negative impedance boosting techniques allows this ideal to be approached by partially cancelling the line resistance. Negative impedance boosters (N.I.Bs.) are placed in series with the line at regular intervals, thereby approximating a distributed reduction in the line resistance. This leads to a marked drop in line loss, delay and impedance. At higher frequencies where the wavelength becomes comparable with the N.I.B. spacing, the line behaves like a low-pass filter. However, bandwidths of hundreds of kHz can be obtained by suitable design.

A computer aided study of structural sensitivity has predicted that negative impedance boosted lines would be no worse than loaded lines of comparable loss.

There are several areas in which the application of N.I.Bs show promise:

- Telephone lines. N.I.Bs could provide low-loss lines where this is specifically required, such as for P.A.B.X. outdoor extensions, junction circuits, and very long subscribers' lines.
- Data Transmission. The relatively low attenuation and flat group delay of negative impedance boosted lines make them particularly suitable for data transmission.
- Programme Lines. N.I.Bs. could provide programme quality over ordinary telephone cable pairs, and extend the bandwidth of existing programme lines where stereo multiplexed signals are to be transmitted.

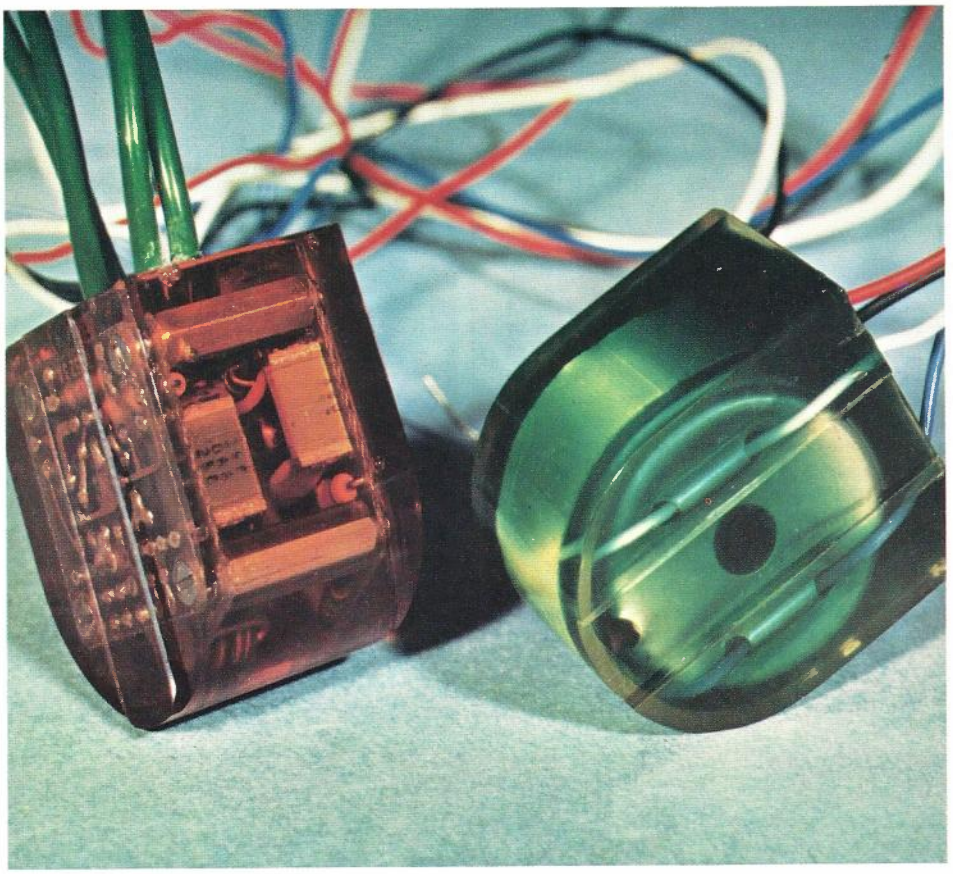
The investigations of negative impedance boosting techniques in the Laboratories comprised preliminary theoretical studies, the conclusions of which were largely confirmed experimentally by evaluating the performance of a laboratory model of a long subscribers line fitted with N.I.Bs. Brief details of the model are given below:

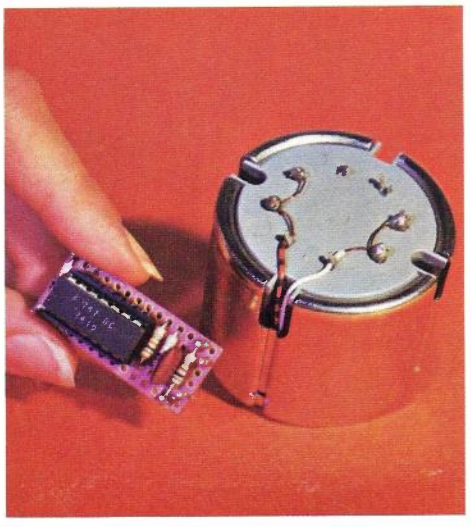
Cable simulated	: 0.90 mm
Simulated Length	: 80 km
N.I.B. spacing	: 8 km
Nominal impedance	: 200 ohms resistive
Attenuation (1kHz)	: 5 dB
Bandwidth (3dB down)	: 4.5 kHz
Group delay variation (0.3 to 4.5 kHz)	: 200 μsec
Propagation velocity (1.2 kHz)	: 1.2 x 10^8m/sec

The line was interfaced to a telephone at one end, and to an exchange at the other. All power for the telephone, N.I.Bs. and remote interface was supplied by the exchange, via the line. The exchange interface derived power from the exchange battery.

The laboratory investigations conducted to date have identified the advantages and disadvantages of the negative impedance boosting technique. Further practical and economic studies are being pursued to examine areas of likely application of N.I.Bs. in the telephone network. Initial studies are concentrating on lossy junction lines as the most likely area of application.

NEGATIVE IMPEDANCE BOOSTER (LEFT) AND LOADING COIL (RIGHT)





A SIMULATED INDUCTOR (LEFT) AND ITS FERRITE-CORED COIL COUNTERPART (RIGHT)

Microcircuits Reduce the Size of Audio Filters

The advent of microcircuit and thick film circuit technologies has made simulated inductors an attractive alternative to ferrite-cored coils in many applications. The simulated inductor can be significantly smaller and lighter than its ferrite counterpart, and can have a higher quality factor. The accompanying photograph shows the conventional 45 mm ferrite core inductor and a thick-film circuit which realised the same inductance. A further reduction in size is possible when all the components of the simulated inductor are made in the integrated circuit process. If this were done, the simulated inductance would fit comfortably into a T05 transistor package. As well as possessing the advantages of size, weight and quality factor, the simulated inductor also offers economic advantages, since it can be cheaply mass-produced in a widely adjustable form, requiring the addition of only one or two components to define inductances controllable over several orders of magnitude. In comparison, a conventional inductor must be custom made for each desired application and is only marginally adjustable.

The simulated inductor has some disadvantages:

- It requires bias power — approximately 100 mW for the circuit shown.

- It is limited to low frequency applications, typically below 1 MHz. Its best performance is obtained in the audio frequency range, where conventional inductors are usually bulky and tend to have low quality factors. At higher frequencies, conventional inductors become smaller whereas the size of the simulated inductor remains approximately constant.
- It has significantly higher electrical noise than the conventional counterpart and its harmonic and intermodulation distortion are critically dependent on the active components used in its manufacture.
- It usually has a very abrupt overload characteristic.

These disadvantages rule it out for use in some types of equipment, but in many applications, it is a viable alternative to the ferrite-cored inductor.

Foreseeable applications for simulated inductors are in the band-limiting filters of analogue-digital and digital-analogue converters, audio filters and equalizers, voice-band data equalizers and audio splitting filters.

Civil Time Distribution in Australia

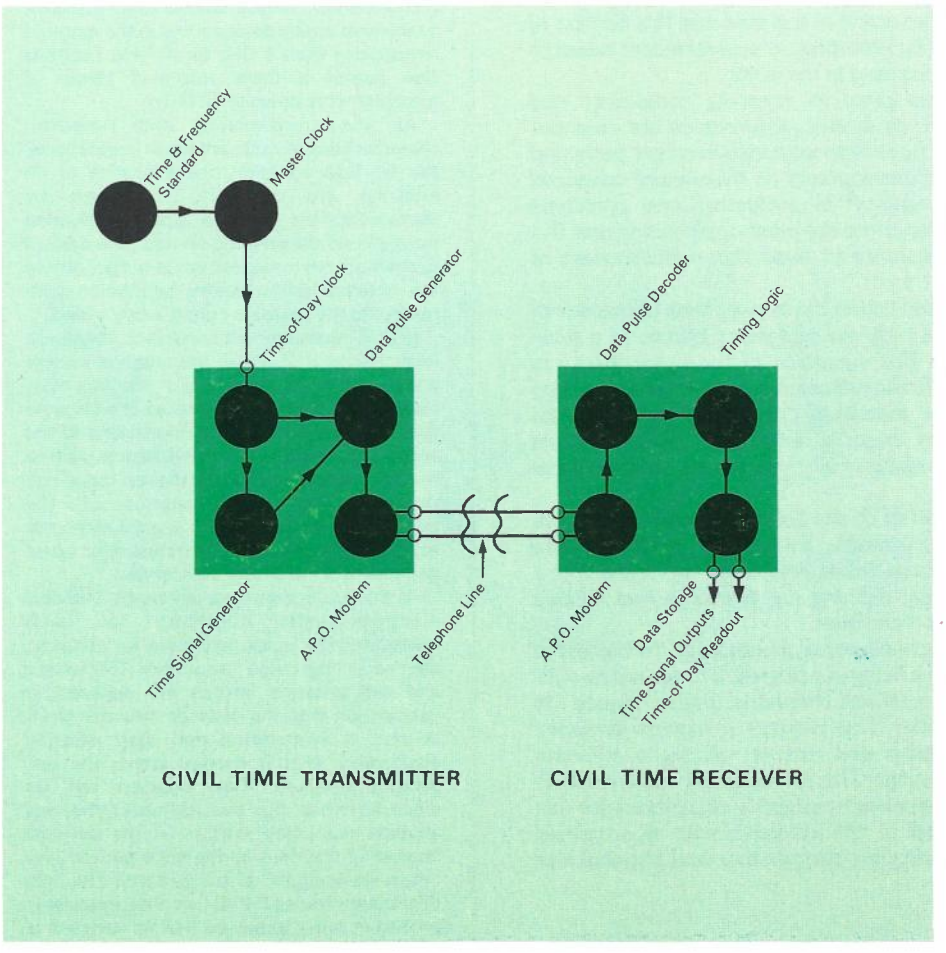
The time-of-day, or civil time, is an important quantity in daily life and in the proper functioning of the community. It must be available with adequate accuracy and reliability. The A.P.O. has for many years undertaken responsibility for keeping standard time and is the chief distributor of standard time signals in Australia. This activity is made possible by virtue of its time and frequency standard installation located in the Laboratories. The master clock in this installation, which controls time signal distribution, is calibrated continually against national and international standard time to ensure a high precision of time keeping. The main sources of precise civil time that are made available to the public are the speaking clock services and hourly time signals from radio stations. Time signals are also provided to special customers and authorities whose operations require reliable time, such as Railways Departments.

In anticipation of changing and growing requirements for time signal distribution, and to make time signals readily available at any point of the network, an experimental distribution system has been developed at the Research Laboratories and is at present being evaluated. The system provides a means of driving a digital clock readout via a signal received over a telephone line, with a precision and reliability unaffected by temporary power failure or signal interruption. This signal, generated by a civil time transmitter, contains coded information relating to the hours, minutes and seconds of time as well as various standard time signals. The civil time transmitter for such a new system would be located with the time and frequency standard installation at the Research Laboratories and would be driven from the master clock of this installation.

The experimental system allows a complete set of information to be sent during every second interval, plus a timing marker at the end of the second interval, which updates the readout with the next time. Because the complete time is available every second, the clock readout does not require initial setting or adjusting following a power or signal interruption.

The decoding to produce the time-of-day or other required forms of time signal is done by civil time receivers which would be connected to the distribution system via private lines. To obtain maximum precision of time readout, each receiver would be adjusted to compensate for the transmission delay from the transmitter over the trunk network to its location. Tests over a return path between Sydney and Melbourne showed an overall time accuracy at the receiver of better than 0.5 millisecond.

This newly developed civil time system would meet the growing need for time-of-day information to be available in a binary-coded-decimal data format suitable for loading into computer printers and other terminal printers. For Departmental use, the system would enable a time signal service to be provided in cities which at present do not have such a service. In addition, the system would enable generation of time signals to continue in capital cities where the speaking clocks which now provide this service must be replaced. The system also readily lends itself to the centralised placement of civil time transmitters, if this should be required.



SCHEMATIC DIAGRAM OF THE EXPERIMENTAL CIVIL TIME DISTRIBUTION SYSTEM

RADIO PROPAGATION PHENOMENA AND ANTENNA SYSTEMS

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In putting radio waves to work, the A.P.O. is involved both with broadcasting applications and with multichannel systems for bi-directional communications. The latter, integrated into the telephone network, supply many of its trunk channel-kilometres.

In any radio system, the transmitting and receiving antennas, in combination with the wave propagation volume in between, can be regarded as a four pole network. Propagation engineering requires definition of the performance of this network and thus involves the measurement of parameters defining antenna behaviour and also of parameters defining the often time-variant propagation processes. The Research Laboratories are active in this field and this Section of the Review illustrates the work in hand by reporting on several recent research projects and outlining some of the facilities used in the work.

As multichannel microwave systems grow in capacity, complexity and density, antennas with more stringently controlled performance are essential. The Laboratories' antenna test facilities have been upgraded in recent years and extended to facilitate research into, and development of, these more advanced antennas. These facilities are also employed in evaluating new prototype antennas being considered for use in Departmental plant applications and this work is of considerable interest and assistance to Australian manufacturers of such plant.

When studying propagation phenomena within the troposphere, conventional antenna-to-antenna measurements yield only the integrated effects of a time-variant mix of propagation processes. The dynamics of the component ray variations are not apparent as such. Radio-meteorological relationships may well be quite complex for each of the individual component rays, and the unravelling of such relationships can become extremely involved when considered only against the integrated results of single-frequency fixed-antenna measurements.

The propagation studies being conducted by the Laboratories seek to probe deeper into the internal structure of variable microwave fields, defining component rays spatially in terms of amplitude and angle of arrival by a holographic process, and also separately defining ray strengths and relative delays by swept-frequency measurement techniques.

In the mobile radio-telephone service, growth rates are amongst the highest in the network. For new mobile services now being considered, it is desired to offer fully bi-directional operation as in a conventional telephone, and to remove the "press-to-talk" switching hitherto essential. This requires a high-performance antenna diplexer, as the mobile transmitter and receiver, sharing a common antenna, must now operate simultaneously. The Laboratories have recently been engaged in studies of the performance and availability of diplexers for this application, and the work has resulted in the establishment of a refined technique which enabled a diplexer of adequate performance and physical size for mobile use to be designed.

Antenna Test Facilities

The Research Laboratories are conducting a number of investigations in the point-to-point radio, mobile radio and satellite communications fields. The elements of these projects which concern antenna design and development or the evaluation of antenna performance are performed by a small specialist group, and a comprehensive range of facilities and equipment has been established for this activity over recent years. An outdoor antenna test range permits all manner of measurements to be made on full-size working antennas, and an indoor test range established in an RF anechoic chamber copes with evaluations of the performance of small aperture radiating assemblies (feed units, etc.) and also scale models of working antennas.

Measurements are made to define the various antenna radiation characteristics, such as power gain, radiation efficiency and the spatial variation of the amplitude, phase and polarisation of the radiated wave, and also of the bore-sight alignment of the antenna. The facilities and equipment permit comprehensive measurements to be made for a variety of antennas operating in the range of frequencies from 1 GHz to 40 GHz. Facilities also permit a more restricted range of measurements down to 50 MHz.

As the transmitting and receiving characteristics of most antennas are identical, the far field radiation characteristics of an antenna are generally measured by illuminating the antenna under evaluation from a fixed transmitting source. The desired parameters are measured at the output port of the antenna as its spatial orientation with respect to the source is continuously varied.

In ideal measurement conditions, the phase relationships induced in the antenna system under test must appear as if the incoming electromagnetic wave originated at a distance very much larger than the dimensions of the antenna. In practice, restrictive factors such as the size and environment of the test range and the radiation characteristics of the transmitting source require special measures to be taken to simulate the actual operational conditions of the antenna under test.

At the outdoor antenna test range, the ideal electromagnetic condition for such measurements is approximated by adopting the "reflecting range" approach. The source and test antenna heights are adjusted in conjunction with the distance between them so that a symmetrical and slow tapering interference field is created across the test antenna aperture. This situation can be achieved when the dimensions of the test antenna are small relative to the periodic interval of the field interference pattern (the "mast wavelength" of the pattern). The field distribution across the test antenna aperture is probed in order to ensure that its variation is sufficiently small and to permit evaluation of the errors arising in subsequent measurements in that field due to its slight non-uniformity.

The distance between the transmitting and receiving antenna positions at the outdoor range is 500 metres. The receiving end is equipped with a heavy duty elevation-on-azimuth antenna positioner, mounted on a 15 metre tower. An additional stub-tower mounted on top of the antenna positioner enables antennas to be carried at up to 18.5 metres above ground and rotated azimuthally about their phase centres. The automatic positioner control, together with wide frequency range phase/amplitude receivers and tracking and recording instruments, are accommodated below the receiving tower.

The radio frequency source, power generator, various monitoring instruments and a height-adjustable mount for the source antenna are installed on a trailer and serve as a portable transmitter, adding to the versatility of the range.

The installation at the outdoor antenna test range has a capability of testing antennas up to 4.6 metres in aperture. The measuring and recording facilities have a dynamic range of more than 60 dB and the upper frequency limit for tests is 40 GHz at present. With the present installation, which was only recently established, tests and calibrations of standard antennas, prototype large aperture antennas and telecommunication plant antennas are greatly facilitated.

THE RECEIVING END AT THE OUTDOOR ANTENNA TEST RANGE
INSERT: ANTENNA UNDER TEST MOUNTED ON THE REMOTELY CONTROLLED ELEVATION-ON-AZIMUTH ANTENNA POSITIONER

A Technique for Analysing Ray Distributions in Microwave Propagation Fields.

When signals from a distant transmitter reach a radio receiver by several paths, their interference causes the transmission characteristic of the channel to deviate from the ideal. The maximum capacity of an optical tropospheric path is determined by the effects of such multipath propagation — observed as noise in FM/FDM systems or as error rates in digital systems. Another communications channel which is expected to experience severe multipath propagation effects is the mobile communications link between a moving vehicle and a stationary wideband transmitter in an urban environment.

A related effect, multipath scattering, may also be expected to arise to a greater or lesser degree in wideband reticulation systems using free space propagation in a suburban environment. The incidence of this type of propagation mechanism will tend to increase the number of errors occurring in high speed data transmission. For this reason, it is important that the incidence and severity of this mechanism be assessed, so that its effects can be considered in the planning of radio systems and, if necessary, corrective measures taken.

The Research Laboratories are undertaking an experimental programme to measure multipath propagation, initially for the line-of-sight microwave radio path. The experiment employs a large vertical array which is illuminated by a distant transmitter and a nearby reference transmitter, as used in holography. The purpose is to determine the amplitude and angle of arrival of each component ray.

The direct ray, the anomalous reflected or refracted rays and the reference ray form an interference pattern over the aperture. This complex field distribution is then coherently detected and recorded for subsequent computer analysis. First, the record is filtered to reduce noise. Then the desired solution, which is a sum of complex exponentials whose parameters define the component rays, is recognised as the solution to a differential equation. This equation is

CONFIGURATION FOR EXPERIMENTAL MEASUREMENT OF THE MULTIPATH PROPAGATION STRUCTURE USING HOLOGRAPHIC PRINCIPLES

successively integrated so that the solution is ultimately expressed as the sum of repeated integrals of itself with unknown coefficients. The measured data is then fitted to this equation by minimum mean square error approximation techniques. This enables the coefficients of the differential equation to be found. It is then possible to solve the corresponding algebraic equation whose roots are the required angles of arrival of the component rays.

Once these angles, which form the arguments of the exponential components, are found, the amplitudes can be determined by standard functional analysis techniques.

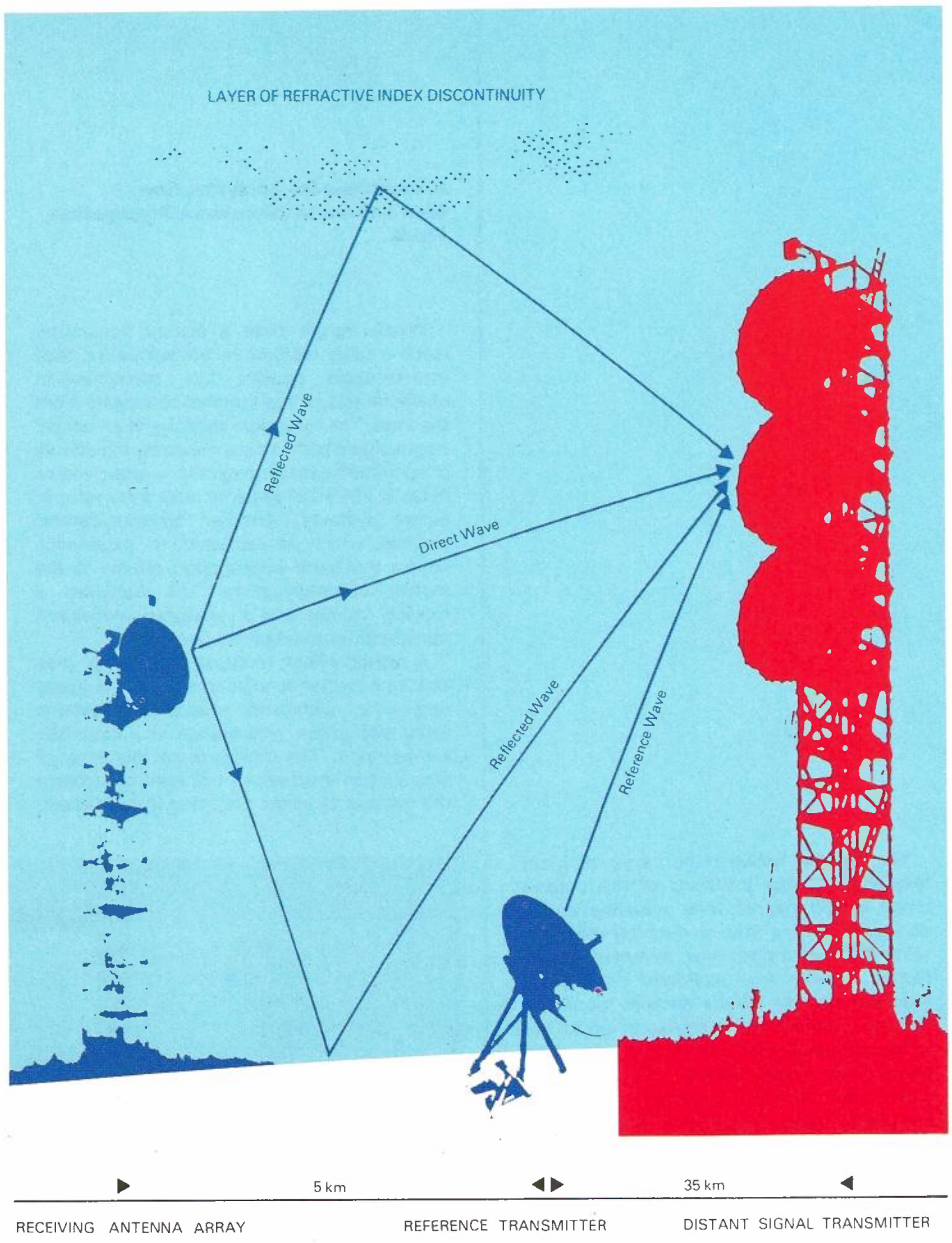
The method has been programmed and computer simulations have been run to test its resolution. Scaling the beamwidth of the aperture to unity, the program synthesised an interference pattern due to three components: the direct ray, a second component at a normalised angle of 0.16 and a third component at angle 1.3. The amplitudes were arbitrarily chosen as the three cube roots of one. If a simple Fourier analysis approach were used as an alternative to this technique, the third component would be just resolvable but the second would be obscured by the direct ray. This new technique provides a much greater resolution capability. The error in determining the amplitudes and delays of the components was evaluated against the width of the input filter as a fraction of the record length for a typical range of signal/noise ratios.

When convolving the record with the input filter characteristic, an amount of the record equal to the filter length must be discarded to avoid edge effects. As the filter width is increased, the amount of noise is reduced and the error consequently improves — until the record becomes significantly shortened, at which stage the error starts to increase again. Hence there is an optimum filter width for a corresponding minimum error.

Topics for further investigation include the determination of criteria for optimising the filter width for specific short-term noise waveforms. Studies of the dependence of the width of the error curve on the number of data samples are also planned, since preliminary work has indicated a strong relationship between these two factors.

Sites have been tentatively selected for an 11 GHz field experiment over the Kooweerup plain, some 60 km south east of Melbourne. Employing the same transmitter, swept-frequency measurements to determine the time delays of the component rays will be interleaved with the holographic observations. The holographic and swept-frequency data will be recorded on magnetic tape and the recorder will be operated under the control of a mini-processor to serve both experiments.

An identical mathematical technique will be employed to analyse the swept-frequency data. This technique can be extended to the case where only the amplitude of the input data is known. It is also an analytical technique which has application in other fields, including antenna design, nuclear instrumentation and astronomy.



Antenna Diplexers for Mobile Radio Telephone Systems

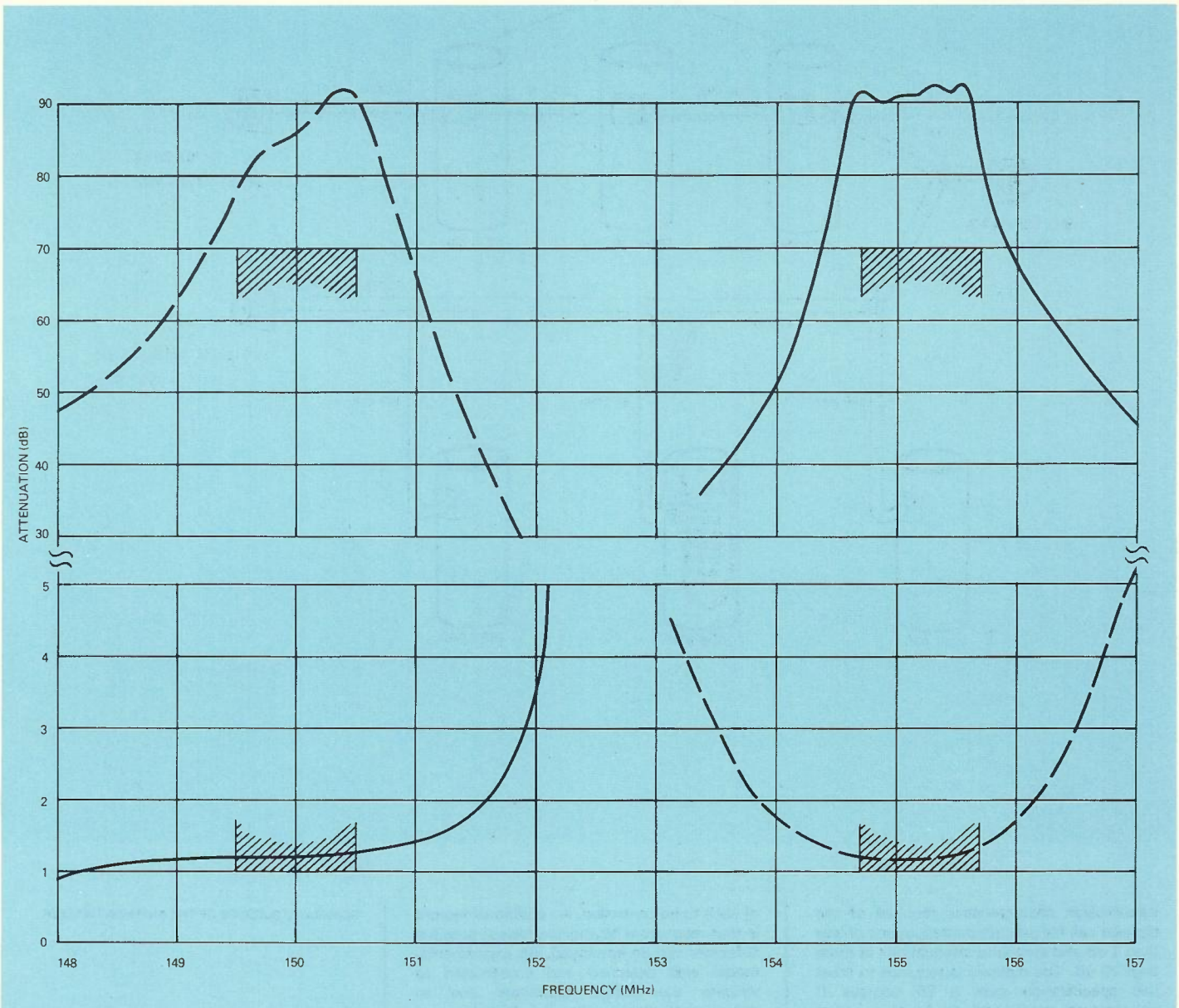
The A.P.O.is evaluating new systems for the provision of mobile VHF radio-telephone services in which the mobile unit has direct access into, and is directly accessible from, the fixed telephone network.

In the systems under consideration, the mobile unit must be capable of transmitting and receiving simultaneously on a single antenna, and a diplexer is therefore necessary to couple the transmitter and receiver to the common antenna, without allowing the transmitter power to enter the receiver. The technical performance specifications for the diplexers in this application are quite stringent and since commercially available diplexers were found to be unsuitable for the system under consideration, the Research Laboratories have been concerned with developing design techniques for the antenna diplexers required in these systems.

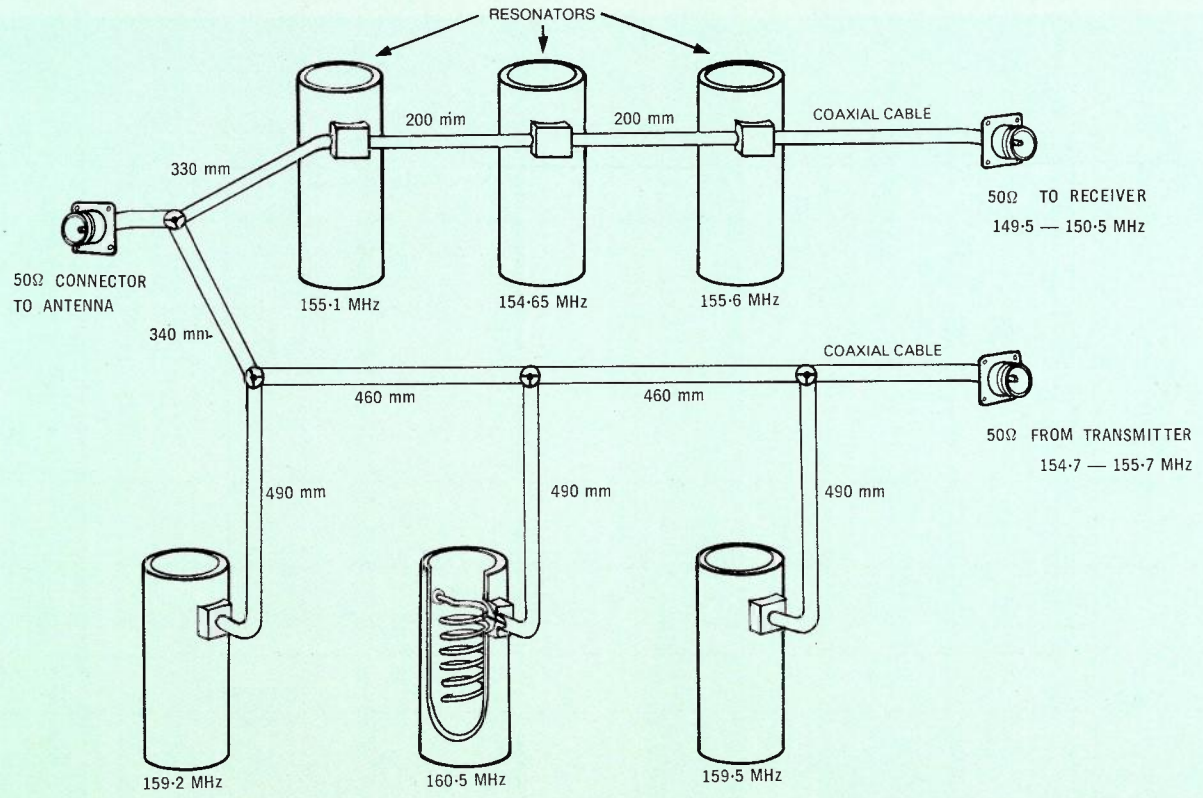
The 150 MHz band used for radio-telephone services has a high occupancy and the available frequency spectrum must be utilised as efficiently as possible. To achieve this, transmit and receive frequencies must be very close together and separations of 3 per cent, 6 per cent and 10 per cent are being considered. From he point of view of spectrum utilisation, the 3 per cent figure is the most desirable, but this places more critical demands on the diplexer.

In addition, to conserve spectrum in the system under consideration, an individual user of the mobile service is not allocated his own channel, with his own individual pair of frequencies for transmitting and receiving, but shares a group of channels with a larger group of users. Switching equipment automatically selects a vacant channel in the group to establish a call.This requirement places an additional load on the diplexer, since it must be capable of separating a group of transmit channels from the adjacent group of receive channels.

The transmit and receive channel groups each occupy a bandwidth of about 1 MHz and are separated by about 3.5 MHz. The



ATTENUATION CHARACTERISTICS OF THE EXPERIMENTAL DIPLEXER



SCHEMATIC DIAGRAM OF THE ANTENNA DIPLEXER

transmission characteristics required of the diplexer call for passband attenuations of less than 1 dB and stopband attenuations of more than 70 dB. The diplexer is required to meet this specification over a 55 degrees C temperature range and to have a power handling capacity of 50W in the transmit direction.

A study of commercially available diplexers using helical resonators showed that diplexers based on this design technique can provide pass and stop "notches" at about the required frequency separations, but that they lack the necessary bandwidth. Other studies showed that designs employing bandpass coupled-resonator filters were able to meet the passband bandwidth requirements, but that the physical size of such diplexers was too large for mounting in the space available in typical vehicles.

A refined design technique was therefore developed for the diplexers required in the multi-channel mobile radio-telephone system under consideration.The technique not only produces the required passband and stopband notches but also enables the width of each to be controlled. An additional feature is that resonators having the lowest possible Q-factors can be employed. An experimental model was designed and constructed to validate the design technique and to demonstrate that the physical dimensions of the diplexer are within practical limits.

The model was designed using quarter-wavelength helical lines which are open-circuited at one end and short-circuited at the other, so that each line behaves as a high quality resonant circuit. To form each branch of the diplexer, three of these resonators are coupled together by tapping close to their short-circuited ends with coaxial cable. The model had a receive band from 149.5 to 150.5 MHz and a transmit band from 154.7 to 155.7 MHz. The measured passband losses were below 1.3dB and unwanted band rejection was greater than 70 dB. The cylindrical resonators were 33 mm in diameter and 75 mm long in each branch of the diplexer, and the complete diplexer asembly of resonators and coaxial cables was satisfactorily accommodated in a box measuring 400 mm by 100 mm by 74 mm.

DIGITAL TRANSMISSION STUDIES

Many telecommunication administrations around the world are making use of digital transmission techniques. Indeed some, notably in the U.S.A., Canada, Japan and the U.K., already have a considerable number of digital transmission systems installed in their networks. Digital transmission techniques have some inherent technical advantages, particularly when associated with digital switching systems. However, the decision to introduce them is essentially an economic one. So far, in the Australian environment, the economics have been against the widespread use of digital systems, although in certain circumstances, the decision is a marginal one and the situation is being closely monitored.

In the medium term, it is likely that digital transmission systems will be introduced in Australia exploiting both cable and microwave radio bearers. In the longer term, there is a widespread view that, due to changing economic conditions and the increasing demand for more sophisticated facilities, particularly in non-telephony services, digital transmission techniques will become widespread in Australia. It is against this background that studies towards an assessment of these techniques in the Australian environment are being carried out in the Research Laboratories.

Primary level pulse code modulation (PCM) systems form the basic building blocks for digital transmission and have been the vehicles for its introduction in overseas areas, essentially to provide circuits between telphone exchanges in urban and near-urban areas. Two such competitive systems deriving respectively 24 and 30 telephone circuits have recently achieved international standardisation. Systems developed to each specification have been obtained and examined in the Laboratories in order to assess significant differences and to enable a choice to be made between them for local conditions. As might be expected from their international status, there appears to be little in technical performance terms to choose between them and the choice must be made in terms of their particular technical features and associated economic penalties, costs, likely markets and so on.

In addition to the general assessment of primary systems, an investigation has been made into the efficiency of PCM in the transmission of various non-telephony signals such as conventional data signals at various speeds, facsimile, multi-frequency coded exchange signalling and voice frequency telegraph. The results were encouraging, with most transmissions satisfactory, the limit being imposed by the linear distortion of the filters in the PCM systems connected in tandem rather than by quantization distortion. The linear distortion appears to be of the same order as that in FDM channel filters.

The use of time-division-multiplexing of digital data signals and the application of redundancy removal techniques to digitally encoded video signals can greatly improve the transmission efficiency of these signals. This requires the establishment of moderate to high capacity digital links and it is possible that special purpose digital links or networks might be established within the present analogue network specifically for such signals. For example, the digital links in a time-division-multiplexed network dedicated to data communication can be provided over the analogue network by extrapolating conventional data modem techniques.

Another possible special avenue for digital links within the existing analogue environment is in connection with the transmission of digitally encoded TV-Conference signals. The video encoding process is reported elsewhere in this Review. A high capacity data modem which derives a digital rate of about 17 Mbit/s within an analogue supermastergoup was described in the previous issue of this Review. Work is progressing satisfactorily with this modem development.

Some specific studies being pursued in the field of digital transmission are outlined in the next few pages.

PCM Tranmission

Part of the research currently being undertaken in the area of digital transmission is based on investigations associated with primary PCM transmission equipment. Although these studies are being carried out on commercial systems which operate with transmission rates of 1.5 — 2 Mbit/s, many of the problems experienced and much of the information gained is relevant to parallel studies on future high capacity (100 Mbit/s) digital transmission systems.

One aspect of the work has involved the development of specialised test equipment and test procedures to provide insight into the detailed operation of the line regenerators used with commercial primary PCM systems. Since the standard regenerators produced by some PCM equipment manufacturers are hermetically sealed with no provision for access to the associated circuitry, the test equipment design was based on the assumption that regenerators must be treated as a "black box", that is, test access is limited to the input and output terminals. This restriction led to the development of novel test approaches which ensure that the information required about the operation of the regenerator can still be obtained. In all cases, the test instrument which has resulted is convenient to operate and little or no additonal information would be gained from having access to the circuitry in the regenerator under test.

The individual regenerators which reconstruct the signal at intermediate points along the bearer must meet stringent operational requirements if a satisfactory overall system performance is to be achieved.

The signal impairments introduced with digital transmission are caused by the introduction of digital errors and the accumulation of timing jitter. Digital errors arise as a result of noise and interference in the cable sections between regenerators, and timing jitter arises primarily as a result of imperfections in the re-timing process performed during each regeneration operation.

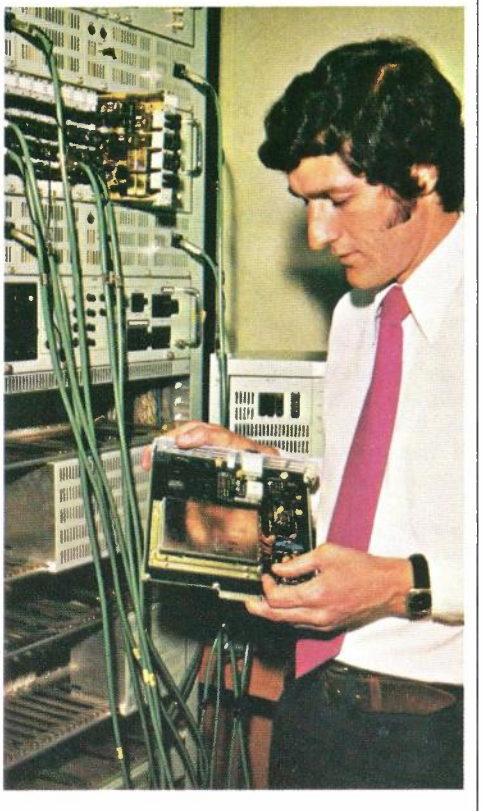
Due to the manner in which the re-timing deficiencies produce timing jitter, it is strongly correlated with the signal being regenerated. Since the same signal, neglecting digital errors, arrives in turn at each regenerator along a digital link, the jitter superimposed on the signal systematically accumulates as the signal propagates along the link. The overall effect of jitter depends on its magnitude and the sensitivity of the signal being transmitted to this form of interference. For example, digitally encoded voice signals are relatively insensitive to jitter and this form of impairment is generally not significant in conventional PCM systems. However, many encoded non-voice signals such as video are extremely sensitive to jitter, and stringent requirements must be met to achieve acceptable transmission standards. Consequently, the re-timing aspect of the operation of a regenerator is important in digital transmission. In a research environment, it is essential that means be available to identify and characterise the major causes of timing jitter in the conventional re-timing circuits used in primary PCM regenerators, so that steps can be taken to eliminate or minimize these sources of jitter in future regenerator designs for high capacity digital transmission systems.

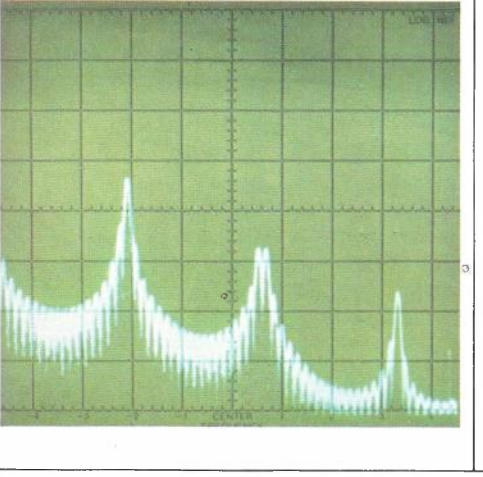
To facilitate timing jitter studies, a special test technique has been developed to allow the re-timing operation of an isolated regenerator to be assessed. This technique allows the major sources of timing jitter to be readily identified and the performance parameter associated with a particular regenerator design to be quantified. Further studies are being undertaken on the accumulation aspect of timing jitter.

The sensitivity of a regenerator to noise and interference depends on several factors, including the accuracy of the equalization applied to the distorted input signal and the position of the decision threshold level used to determine the presence of pulses in the equalized pulse train. The penalty of imperfect equalization is the introduction of inter-symbol interference which reduces the noise margin in the regenerator. In addition, since the relative height of the decision threshold level is adjusted automatically by a control signal which responds to the peak level of the equalised pulse train, inter-symbol interference, which affects the peak signal level, also affects the decision threshold level, causing a reduction in noise margin.When a regenerator has a reduced noise margin due to either imperfect equalization and/or incorrect adjustment of the decision threshold levels, it is more susceptible to noise and will generally cause a high error rate when installed in the field. To facilitate investigations associated with these aspects of the performance of a regenerator, a test technique has been developed which allows the decision threshold level of a regenerator to be measured directly. This technique also indirectly allows the amount of inter-symbol interference to be calculated.

The specialised test instruments developed for the above investigations are not only useful in a research environment but have application in field maintenance and service areas. Consequently, consideration is being given to the possible production of commercial versions by local manufacturers.

PCM EQUIPMENT UNDER EVALUATION IN THE LABORATORIES





SPECTRUM OF JITTER ENCOUNTERED IN PLESIOCHRONOUS MULTIPLEXING

Digital Multiplexing

Digital multiplexes are used in digital networks to combine a number of digital signals by time division multiplexing into one single bit stream and also to carry out the inverse process, to enable utilization of the capacity offered by digital links. Multiplexing techniques therefore form an important subject of A.P.O. research as part of the wider studies of digital transmission techniques and systems.

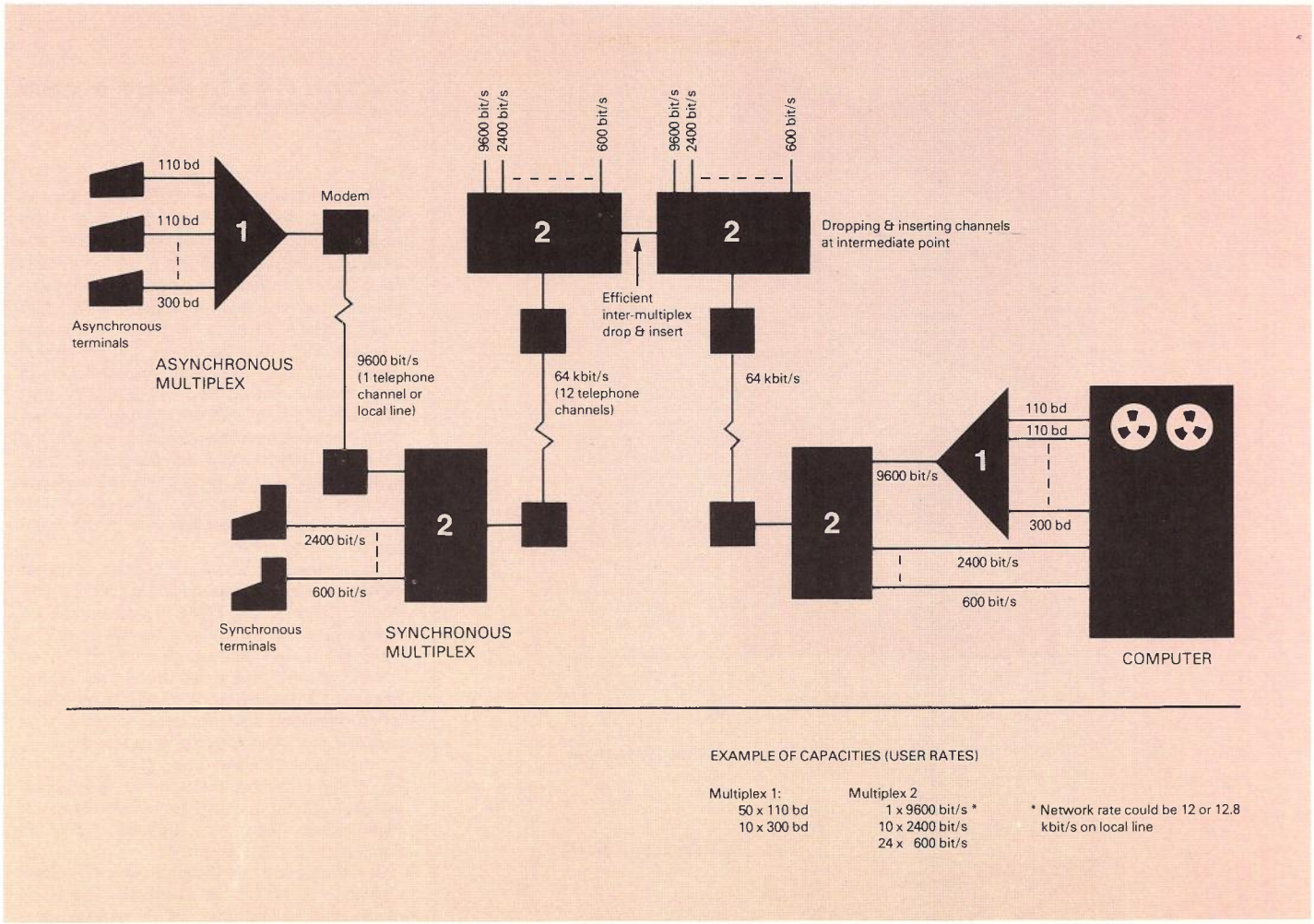
At a primary level, either 24 or 30 PCM speech channels are multiplexed giving bit rates of 1.544 Mbit/s and 2.084 Mbit/s respectively. The C.C.I.T.T. recommends that on a secondary level, four primary level PCM systems are multiplexed into a bit stream of either 6.312 Mbit/s or 8.448 Mbit/s. The secondary multiplex may be used directly as an input to a third or fourth order multiplex level. It could also be used to establish a transmission system for 96 speech channels at 6.312Mbit/s or 120 speech channels at 8.448 Mbit/s.

In the year under review, the development of a prototype 8.448 Mbit/s digital multiplex for four 2.048 Mbit/s digital inputs was completed. The developed multiplex does not require its inputs to be synchronised but simply requires that its input rates be within a certain tolerance range (plesiochronous multiplexing).Special processing in the multiplex ensures that no information gain or loss (slip) occurs due to the plesiochronous character of the inputs. The type of processing adopted for the prototype multiplex is positive-zero-negative (+/0/-) justification, which offers advantages over the more common positive justification method if the multiplex is to be used with synchronised inputs.

A novel method has been developed to reduce displacement of timing positions (jitter) caused by the plesiochronous multiplex process. The developed method is particularly effective for the low justification rates that occur with +/0/- justification. Multiplex jitter has been analysed, both experimentally and theoretically.

The techniques developed for the prototype multiplex are also applicable to other time division multiplexes such as for data networks, and will therefore benefit the studies of digital data networks reviewed hereafter.

DATA NETWORK — USER EXAMPLE



Digital Data Network Investigations

Data transmission facilities have hitherto been developed by using the network structure of the existing telephone network. However, the telephone network is optimized for speech communication and the characteristics of data communication differ quite substantially from those of speech. For example, although data signals can be readily transmitted on a telephone channel with the aid of modems, the available bandwidth of a telephone channel is normally far in excess of that required by data terminal equipment in service. As an illustration, using appropriate multiplexing techniques, up to approximately 80 terminals with a rate of 110 baud could be connected to a single telephone channel with a multiplex and a modem for 9600 bit/s.

Studies are being conducted into networks which are specially designed for data communication. The backbone of these networks must still be the telephone network, but the facilities offered will be better adapted to the special requirements of data communication.

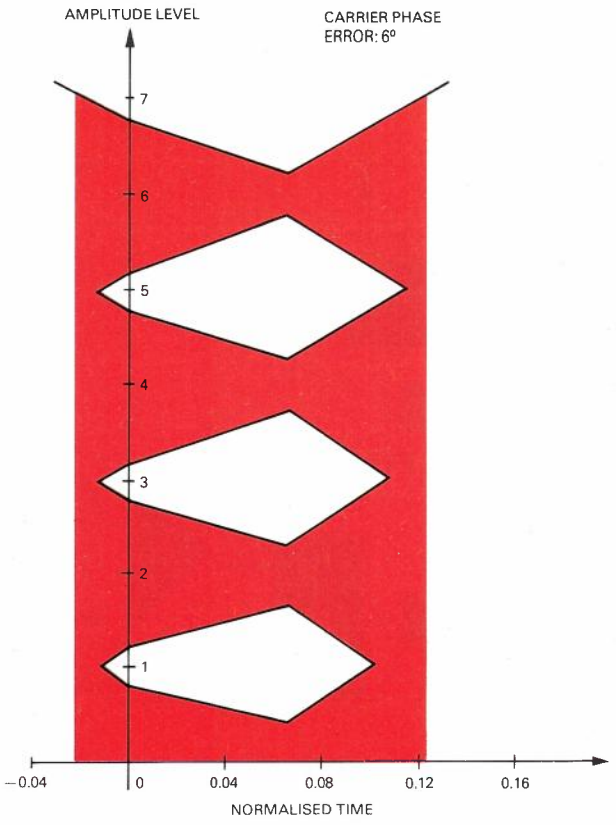
Current investigations are directed towards a leased line digital network with trunk links having capacities of about 64 kbit/s and utilizing the equivalent bandwidth of 12 telephone channels. Higher trunk link capacities of about 1.5-2 Mbit/s, utilizing the equivalent bandwidth of 120-180 telephone channels, are also envisaged. Digital multiplexes using time division multiplexing will subdivide the available trunk route capacity into suitable data terminal bit rates.

The overall aim is to greatly improve the utilization of available network capacity by applying digital multiplexing techniques and at the same time to provide a higher quality service. The trunk routes will have a standardized digital transmission rate and will normally be shared by a number of subscribers. Therefore, it should be economically feasible to improve the bit error rate performance of the transmission links by regeneration at suitable intermediate points. A further possibility is the improvement of maintenance facilities. Data communication equipment could be remotely tested from centralized points in the network to relieve the presently increasing maintenance burden. Network reliability may be improved by extensive monitoring facilities and by automatic stand-by switching.

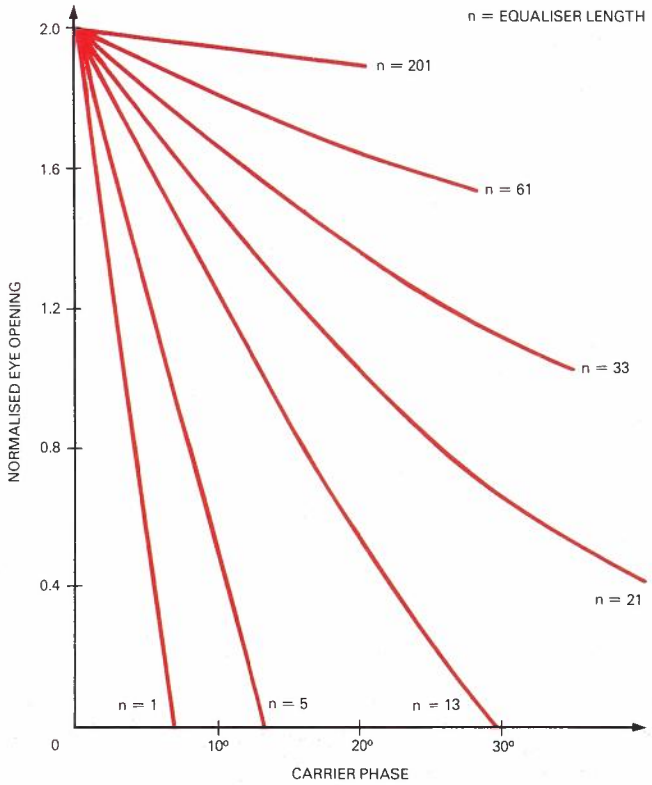
The network under study is a synchronous network. The essential timing signals of all multiplex centres in such a network are synchronised to a common source (master-slave network) or are mutually synchronised. In the initial stage, master-slave networks are being studied. In an evolving network, sufficient back-up facilities must be introduced in a master-slave network to offer a high degree of network reliability. An alternative approach, which will be studied at a later stage, is to introduce a mixture of master-slave and mutual synchronization.

In a synchronous network, data terminals which can operate in a synchronous mode, such as visual display units, will have their timing signals supplied by the network. The synchronization of data terminals allows very efficient multiplexing. An experimental 64 kbit/s synchronous multiplex has been designed and constructed in the Research Laboratories.

Asynchronous (anisochronous) terminals, such as teleprinters, can also be multiplexed efficiently in a synchronous network. Tests have been carried out in the Laboratories to evaluate the performance of multiplexes designed for asynchronous inputs.



7-LEVEL CLASS 4 PARTIAL RESPONSE EYE PATTERN



EFFECT OF EQUALIZER LENGTH ON A 15-LEVEL EYE PATTERN

The Study of the Eye Patterns of Partial Response Data Signals

The Laboratories are currently studying techniques for high speed digital data transmission over various channels in the analogue frequency division mutliplex (FDM) telephone network. In one development project, which is concerned with data transmission over a supermastergroup channel (900 voice channels), the line signal chosen entails multilevel single-sideband amplitude modulation (SSBAM) with response (Class 4) spectral shaping. The chief characteristic of a partial response signal is the deliberate introduction of controlled inter-symbol interference, giving an advantageous spectral shaping at the expense of an increased number of levels due to the inter-symbol interference.

At the receiver of such a system, a carrier signal must be generated for the synchronous demodulation of the SSBAM signal and then a timing signal to determine the sampling instants on the received data pulses. In an actual system, there will be errors in the phases of these two signals and it is important when designing such a system to know how sensitive the Class 4 partial response signal is to these errors. Furthermore, these errors can be partly removed by a linear transversal equalizer, and it is useful to know how much improvement can be obtained from an equalizer of a given length.

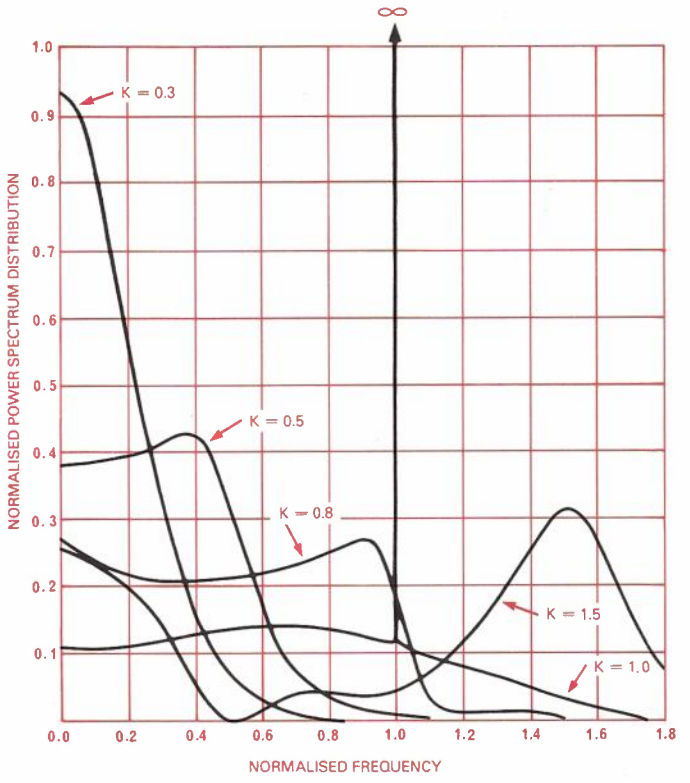
A theoretical investigation to obtain answers to the above questions has been made and a number of important and interesting results have been obtained. Some highlights of the results are outlined below.

A general expression for the eye pattern boundaries for any eye in a multilevel system has been derived as a function of the carrier and timing phase errors.

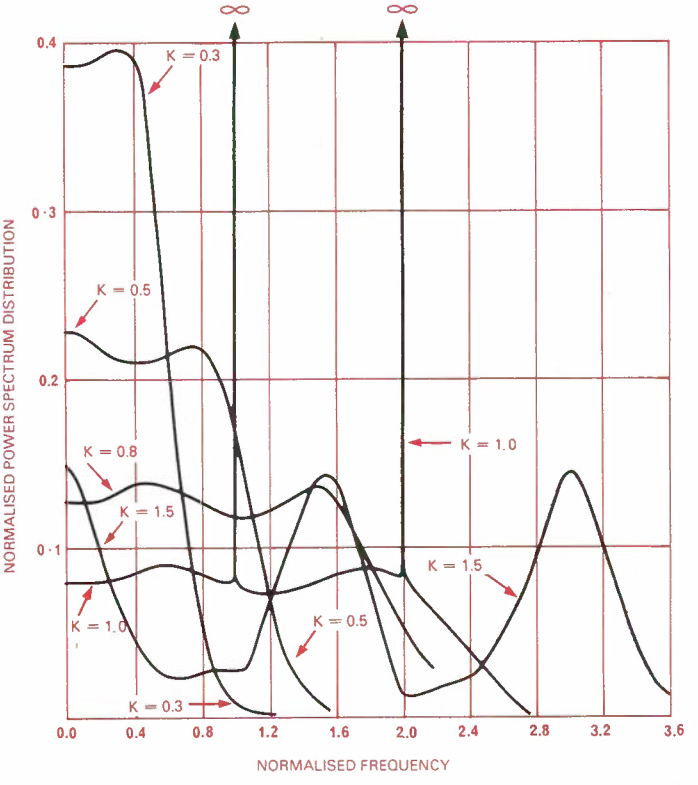
The eye pattern, which gives a measure of the peak distortion, is formed by superimposing segments formed from all possible sequences of the data pulses. The accompanying diagram shows the upper half of a 7-level eye pattern with a 6 degree carrier phase error. The results obtained indicate the stringent requirements on the phase of the carrier and timing signals. For example, a 15-level eye pattern has a horizontal opening equal to 5 per cent of the sampling period, and a carrier phase error of about 7 degrees will completely close the central eyes.

Expressions have been obtained for the minimum-mean-square-error transversal equalizer tap settings as a function of the signal-to-noise ratio, carrier and timing phase errors. Different length equalizers can improve the eye-opening of a multilevel signal distorted by carrier phase error, and an expression for the eye-opening at the optimum sampling time has also been derived as a function of the equalizer length.

The carrier and timing phase errors give rise to a pattern in the equalizer tap values which can be used to indicate how to reduce these phase errors. Similar results using the mean-square-error criterion have also been obtained.



POWER SPECTRA — 3-LEVEL MFSK



POWER SPECTRA — 5-LEVEL MFSK

K : FREQUENCY DEVIATION RATIO ($K = \frac{2fd}{fb}$)

fd : HALF OF THE FREQUENCY SEPARATION OF LEVELS

fb : DATA STREAM BIT RATE

fc : CENTRE FREQUENCY

f : FREQUENCY

β : NORMALISED FREQUENCY ($\beta = \frac{f - fc}{fb}$)

Spectral Studies of Digitally Modulated Radio Signals

In some overseas countries during the past decade, there has been a substantial increase in the use of digital techniques for the transmission of information over cable systems. A similar trend is apparent in microwave radio relay systems and the Laboratories are undertaking investigations into a number of theoretical aspects of relaying digital signals over radio systems. One current project is the examination of the power spectra displayed by such signals using the various types of modulation available.

A major problem arises when analogue FDM/FM signals occur in close proximity to digital signals in frequency and space on a radio system route. This is due to the wide frequency spread of the energy of the digital signal. To ensure satisfactory compatibility of the two types of signal, the constraints on the filtering of the digital channel must be fairly rigid, while not being severe enough to degrade the performance of the channel. It is important, both for the design of digital systems and for the use of digital channels on existing FM bearers, to be able to calculate the spectra of the appropriate digital signal.

To check the method of computation developed, preliminary studies included methods of modulation such as continuous phase multi-frequency shift keying (MFSK). In this mode, information is conveyed by the sequential transmission of pulses of constant amplitude and duration but at a number of different frequencies. Spectra have been computed for MFSK with a square modulating pulse for a large number of frequencies (levels) and a range of frequency deviations. Agreement was achieved with published curves for an even number of keyed levels. Some results for three and five levels, which have not been shown in other publications as far as it is known, are illustrated in the accompanying diagrams. As can be seen, high peaks can occur in the spectrum, which, when the frequency deviation equals one, become delta functions situated at the signalling frequencies. This is the type of occurrence which the systems designer needs to avoid, and it is only with the aid of such spectral calculations that he is able to determine the most suitable parameters for the sytem.

Investigations are continuing and present computer programs are being expanded to handle more modulation techniques and a variety of input signals and pulse shapes which may be produced by re-modulation filters in the transmission system.

OPTICAL FIBRE TRANSMISSION SYSTEMS

In 1971, the Division of Tribophysics of the Commonwealth Scientific and Industrial Research Organisation (C.S.I.R.O.) produced one of the first optical fibres having losses better than 20 dB/km. This was a multi-mode fibre having a liquid (tetrachloroethylene) core contained within a glass cladding. Since that time, the Research Laboratories have been investigating these liquid-cored fibres to build up an understanding of their transmission characteristics, with a view to developing systems suitable for communications purposes. In parallel with these investigations, research has been carried out into associated aspects of fibre systems, particularly the development of electro-luminescent sources compatible with multi-mode fibres both in geometry and bandwidth, and the system trade-offs between the many fibre and device parameters.

At this stage, the feasibility of transmitting broadband information in analogue or digital form over several kilometres of liquid-cored fibre, using light-emitting diodes as the optical source, has been adequately demonstrated. The potential applications of systems based on these principles are in a broadband local distribution network as required for advanced communications services to subscribers, or in the junction and trunk networks. Studies are now proceeding into the realisation of these possibilities.

Although liquid-cored fibres could, if necessary, be engineered into practical systems, it would obviously be preferable to use a solid-cored fibre to minimise the problems of terminating and jointing, and for improved reliability and stability. Until recently, losses in solid-cored fibres were still relatively high. However, during the past year there have been dramatic advances in glass technology, so that reported losses for silica based fibres are generally below 5 dB/km and at some wavelengths, can approach 1 dB/km. Coupled with these improvements is the recently demonstrated ability to manufacture fibres having a graded refractive index profile across the core by suitably doping silica with some other material, for example, germania.

Because graded-index fibres have much lower signal dispersion than stepped-index multi-mode fibres, it would appear that such fibres, particularly those produced from silica, offer great promise for long-distance, high capacity transmission systems. On the other hand, the transmission performance of stepped-index fibres is probably quite adequate for many applications, including broadband distribution networks. In order to arrive at a balance between fibre performance and system requirements, the Laboratories have commenced a programme of experimental and theoretical studies into both stepped and graded-index solid-cored fibres.

Other aspects of this programme include investigations into alternative sources and detectors, thin-film optical integrated circuits, fibre terminations and cabling techniques.

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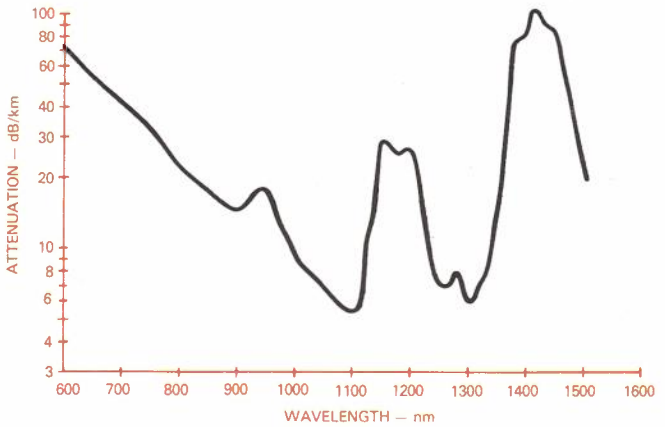
Fibre Transmission Characteristics

The important transmission characteristics of a fibre are the attentuation and the bandwidth or alternatively, the pulse dispersion. These transmission properties are a function of a number of parameters, including the materials used, refractive index differences between core and cladding, diameter and length of the fibre, material purity and manufacturing imperfections, as well as of excitation conditions.

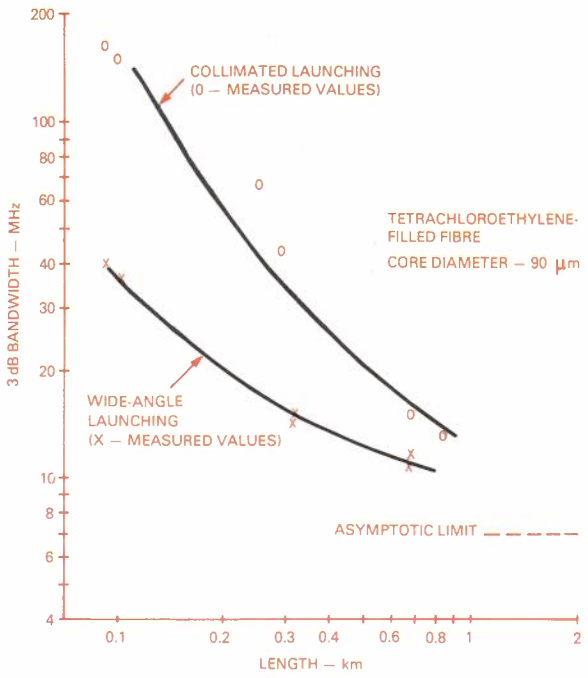
The two principal phenomena contributing towards loss in fibres are the inherent Rayleigh scattering due to the molecular structure of the core material and absorption losses due to the presence of impurities. A typical attentuation curve for a tetrachloroethylene-filled fibre is shown in the adjacent diagram. For wavelengths shorter than about 800 nm, the Rayleigh scattering losses dominate; while at longer wavelengths, the dominant losses are due to absorption.For example, the peaks at 950 nm and 1150 nm are due to the presence of water, while other peaks can be attributed specifically to the presence of other contaminants. Identification of contaminants has been achieved using infra-red spectroscopy, allowing considerable progress in purifying the core material by eliminating or reducing the contaminant materials.

The pulse dispersion in a multi-mode fibre such as a liquid-cored one can be determined by considering the path lengths of the rays that are able to propagate in the fibre. For a given length of fibre, the path length for a ray within the core is a function of the core diameter and the angle of launching into the fibre. The smaller this angle, the shorter the path length. Higher angle rays therefore take longer to traverse the fibre than do lower angle rays, and energy launched simultaneously into the fibre at different angles will be dispersed in time as a function of fibre length. This dispersion ultimately limits the information capacity of a multi-mode fibre. It follows that in an ideal loss-less fibre, collimated sources such as lasers which excite only low angle rays will lead to less dispersion for a given length of fibre than will non-coherent sources such as light-emitting diodes, whose outputs are highly divergent.

In non-ideal fibres, other factors operate to modify these effects. Firstly, if the cladding material is lossy, the higher angle rays which are reflected more often than the lower angle rays will suffer greater attenuation.Since the higher angle rays contribute to the tail of the



TRANSMISSION LOSS OF TETRACHLOROETHYLENE-FILLED FIBRE.



TYPICAL BANDWIDTH OF A LIQUID-CORED MULTI-MODE FIBRE.

dispersed pulse, it follows that increasing the cladding loss will reduce their influence and the overall pulse dispersion will be reduced. The second modifying influence in pulse dispersion is the presence of discontinuities or irregularities at the core-cladding interface or physical imperfections in the core. Rays of a given angle impinging on these tend to be scattered into rays at other angles, so that after some distance a distribution of rays exists. If the length of the fibre is sufficiently great, this distribution tends to an equilibrium condition independent of the launching conditions. These effects are illustrated in the accompanying illustration, where the bandwidth derived from pulse dispersion measurements is shown as a function of fibre length for a liquid-cored fibre.

Optical Device Development

Gallium arsenide electro-luminescent diodes are attractive sources for optical fibre communications because of their ease of injection modulation at bit rates up to 1 Gbit/s. Their narrow emission bands are near most fibre spectral attentuation minima and are in the region where fast sensitive silicon avalanche and PIN photo-diode detectors are available. While the diode in the injection laser form is the most promising in the long term for long distance high capacity digital communications, the incoherent light emitting diode form is attractive for short haul analogue systems.

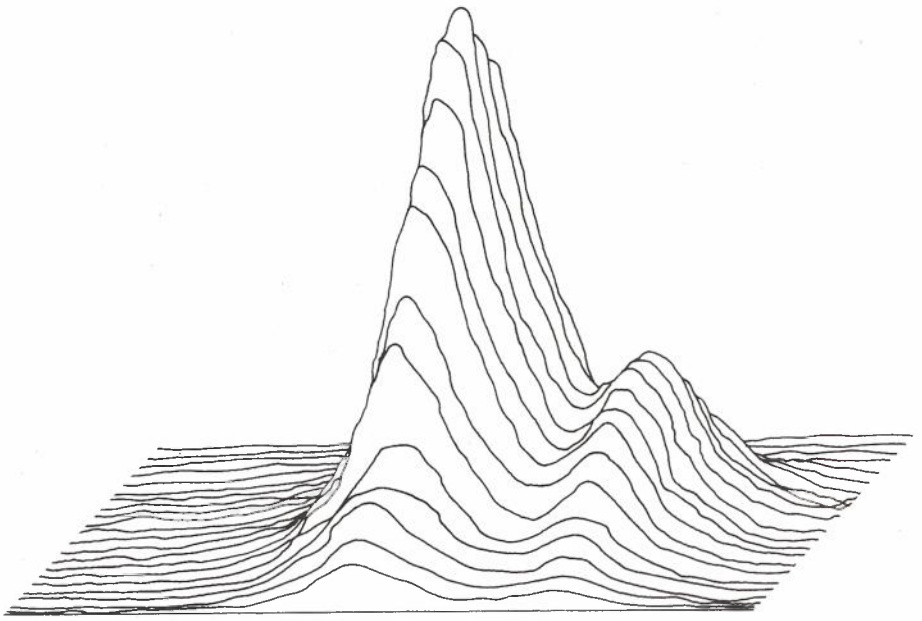
In that it is not a threshold device, the light emitting diode (LED) has the advantages that its reliability in terms of degradation characteristics and continuous operating lifetime is generally high. For this reason also, the LED is easily injection modulated in both analogue and digital modes, with the drive current being linear with optical power output. However, because the spectral and spatial radiation patterns of optical power from an LED are relatively broad, the radiance over the narrow line widths required for high capacity transmission is generally low.

High radiance Burrus type LED sources have been developed and fabricated in the Laboratories. In their design, the geometry and doping levels have been optimised to give increased power into the fibre. Recently, a number of improvements have been made in the diode fabrication and processing techniques used in the Laboratories. An RF sputter-etching facility has been built to enable the deposition of better silica diffusion control layers and injection confinement of isolation layers. These improvements, combined with improved etching and masking techniques, have led to better device yields and high power output in the devices produced within the Laboratories.

As optical sources, these diodes have been shown to give optical powers of 4 mW with spectral line widths of 45 nm centred on 890 nm. The response time and radiance are typically 2 ns and 45 watts/steradian/cm² respectively.

In order to use these diodes as signal sources in optical fibre systems studies, methods of optimally coupling the power from the diode to the fibre are being investigated. A number of diodes are also being prepared for operating life-time studies which are programmed for the near future.

RF PLASMA SPUTTERING FACILITIES FOR LED SOURCES.



THREE-DIMENSIONAL PLOT OF THE FAR FIELD RADIATION PATTERN OF A PULSED GaAs LASER

Modulation and Detection

The method of modulation to be used in an optical fibre communication system is highly dependent upon the optical source to be employed. Both the LED and the semiconductor injection laser can be modulated simply by varying the drive current. On the other hand, the neodymium doped yttrium-aluminium-garnet (Nd:YAG) laser must have an external modulator.

The gallium arsenide (GaAs) injection laser shows considerable promise as an optical source for long-distance high capacity fibre communication systems. Both analogue and digital modulation are possible, but digital modulation is very convenient for GaAs lasers. Switching the injection current from zero severely limits the modulation rate, since there is a delay of some nanoseconds in the building up of a population inversion necessary for lasing to commence. This limitation can be overcome by threshold biassing the laser and Gbit/s pulse rates can be obtained with suitable injection lasers.

An important characteristic of the GaAs injection laser is the occurrence of a resonance phenomenon that strongly affects its transient behaviour and has far-reaching implications with regard to modulation. This resonance effect is being investigated in the Laboratories. Because of the resonance phenomenon, the modulation efficiency of the injection laser exhibits a sharp peak at the resonant frequency. Thus, modulation with wideband signals generally must be restricted to frequencies below this resonant frequency to avoid signal distortion. However, it is possible under certain conditions to utilize the resonance phenomenon to generate self-induced pulsations, and oscillations at frequencies in excess of 1 GHz have been obtained in this way. Very short single optical pulses can also be produced with injection lasers and pulse widths at half-height of less than 200 picoseconds have been obtained. Far field radiation patterns of laser diodes emitting such pulses have been measured and these patterns show considerable variation of the pulse height with angle. The patterns provide information about the optical field generated by the diode undergoing the pulsing behaviour and they are also important from the viewpoint of coupling these fast optical pulses into optical fibres.

The Nd:YAG laser is another promising source for long-distance optical fibre communications. An external modulator is essential when a Nd:YAG laser is the source. Acousto-optic modulators are well-suited to operation at rates up to 100 Mbit/s, while for speeds around 1 Gbit/s, electro-optic modulators are attractive. Fabricating these acousto-optic and electro-optic modulators in thin film or "integrated-optic" form offers further benefits in terms of speed and efficiency. The use of optical modulators as fast switches and deflectors of optical beams greatly extends their range of applications.

The laser modulation technique known as mode-locking has received particular attention in the Laboratories. A mode-locking laser emits a continuous train of short optical pulses and thus is an ideal source for an optical PCM communications link. An intra-cavity acousto-optic modulator has been used to mode-lock a helium-neon laser radiating at the visible wavelength of 633 nm. The mode-locked laser pulse train has a repetition rate of 140 Mbit/s, each pulse having a peak power of 80 mW and a half-intensity width of 560 ps. Present efforts are directed towards the stable mode-locking of a Nd:YAG laser.

Optical fibre communications impose certain stringent requirements on photo-dectectors. These requirements include high sensitivity at the wavelengths of interest, low noise, sufficient information bandwidth, high reliability and lost cost. Moreover, the device must be compatible with the fibre in terms of size and coupling to the fibre. Semiconductor photodiodes best meet these requirements. Recent research has been aimed at enhancing the speed of response of silicon avalanche photodiodes by means of suitable circuit techniques. The speed of response has been improved to the stage where narrow optical pulses of 200 ps pulse width can be detected, at some sacrifice to the signal-to-noise ratio.

COMMERCIAL CTV MAIN ROUTE AMPLIFIER UNDERGOING SWEPT FREQUENCY RETURN LOSS MEASUREMENTS

ADVANCED COMMUNICATIONS SYSTEMS

The functioning of human society is becoming increasingly dependent on the availability of rapid communication facilities. The technology of transportation has already led to increased mobility of the individual by bringing continents into commuting distance. The technology of telecommunications is now expected to provide practically instant communication between any locations on the globe at any time. Future demands for advanced telecommunications facilities will have to go well beyond the conventional telephone and message services and will include high speed data, facsimile and visual communications services.

To study the development of such services, it is not enough to explore new technological avenues. Human and societal needs, the impact of new telecommunications technology on the individual and on business organisations, and social implications are of equal importance. Long term research programmes for such studies are in the process of evolution, but the most active investigations and practical developments are currently concerned with tele-conferencing. Historically, the only inter-personal telecommunications facility has been the telephone, by which a single person may interact with another. Increasingly, the complexity and pluralistic nature of modern society requires interaction between groups of people. Hitherto, the only way to achieve this mode of human communication has been to meet in face-to-face conference, often involving time-consuming travel and/or limited interaction due to the inconvenience of arranging such meetings between widely separated participants.

Recognising this gap several years ago, the A.P.O. pursued comprehensive in-house and public TV-Conference trials between Sydney and Melbourne. This resulted in the establishment of a commercial service between these cities early in 1975, after the response of participants in the trials had indicated that a genuine need for these services existed and that the technological realisation developed by the Laboratories provided a satisfactory medium for inter-group communication. The next step in a continuing development of this service is now aimed at a reduction of transmission cost and operational complexity.

Furthermore, the problem of secure visual communication will have to be solved to satisfy customers' needs for maximum privacy, and ancillary high speed data and document transmission facilities will have to be included in further developments of TV-Conference services. The need for multilocation tele-conference facilities, public and private, in other cities and within the same city, is already apparent and this will stimulate futher efforts to reduce transmission cost by digital coding and by developing more economical wideband transmission media, such as optical fibres, for local and trunk networks. As can be noted from the reports following in the next few pages, the Research Laboratories are pursuing projects in these subject areas.

Cable Television System Studies

As an alternative to broadcast television transmission, television signals may be transmitted over cable television (CTV) or community antenna television (CATV) systems direct to the subscriber's television set.

To date, CATV system installations in Australia are comparatively rare and are exclusively used to provide satisfactory TV reception in areas where propagation conditions cause intolerable deterioration of radiated TV signals. Privately operated "master antenna" TV systems such as those intalled in large residential buildings are more widespread.

CTV systems are, however, expected to lead in the future to the introduction of more advanced wideband subscriber reticulation networks. Of particular interest is the way in which advanced systems of this type might be integrated into the A.P.O. telecommunications network. As a stepping stone to these futuristic networks, the more advanced forms of CTV are being studied. Of special interest are those offering two-way transmission and/or capabilities for the transmission of various forms of recorded visual information and wideband data or which might be needed for the provision of facsimile, videophone, telemetering and automated educational services.

The Research Laboratories have studied various CTV concepts for several years and have gained a measure of expertise in CTV system design which will be of value should the A.P.O. become committed to the provision of such systems in Australia. A programme of CTV system evaluations is being carried out with the aim of gaining an understanding of the overall performance of CTV networks and their individual components. As a pre-requisite to this work, it has been necessary to embark on an in-depth study of advanced measurement techniques relevant to the study of individual components under a wide range of operating conditions. An outcome of this study will be the determination of laws governing the contribution of the performance of individual components to the overall system performance. This will be of use in the efficient design of any future CTV systems, particularly where systems having a large channel capacity are required.

The problems of multiple reflections in the final distribution and subscribers' lead-in cables are also being investigated. A computer program has been developed to calculate picture "smear" and other linear distortions which occur as a result of these reflections, and the results of these calculations are being checked against the performance of actual CTV lead-in configurations.

A Video Coder for TV-Conference Signals

The A.P.O. TV-Conference service permits convenient communication between groups of people in Melbourne and Sydney. This service was favourably received by internal Post Office and external commercial users during a prolonged trial period, and since the beginning of 1975, it has been available for regular commercial use.

However, the provision of the communication links over the distance of 900 kilometres between the two cities is a rather costly aspect of this service. Currently, one broadcast quality television channel and two broadcast quality sound channels are used in each direction. Additional channel requirements are foreseen for the transmission of high speed data, facsimile and other auxiliary information. Apart from the provision of the long distance channels, more complex setting-up and maintenance procedures are required for the TV-Conference links and terminal equipment than those for a uni-directional broadcast television relay. These procedures require the intervention of A.P.O. technical staff, both before and during the use of the TV-Conference service by private users.

In order to be able to assure users of the full confidentiality of their discussions, the A.P.O. must develop the system further to ensure that the transmitted signals are secure against involuntary or intentional monitoring by operational staff in the various centres along the transmission route. For this purpose, investigations aimed at the scrambling of television signals and coding of sound signals are being undertaken in the Research Laboratories.

In the longer term, digital coding and digital transmission are seen as promising solutions to most of these problems. Security is inherent in a composite digital stream which can convey all the types of information in time multiplexed form. The digital signals themselves are much more robust with respect to noise and interference, and are less critical with respect to system line-up procedures. In addition, it is possible to reduce channel capacity requirements by developing source coding and decoding techniques which incorporate means for the reduction of information redundancies.

Present experiments are directed at coding the video, audio and data channels into a single bit stream having a transmission rate of 17 Mbit/s. Using advanced channel encoding techniques, it is expected that such a bit stream may be transmitted over a conventional supermastergroup channel of an FDM system, this channel having a bandwidth of 3.6 MHz. Until such time as digital links are introduced into the A.P.O. transmission network, the transmission of such digital signals over analogue FDM channels is seen to offer significant advantages as regards costs and flexibility.

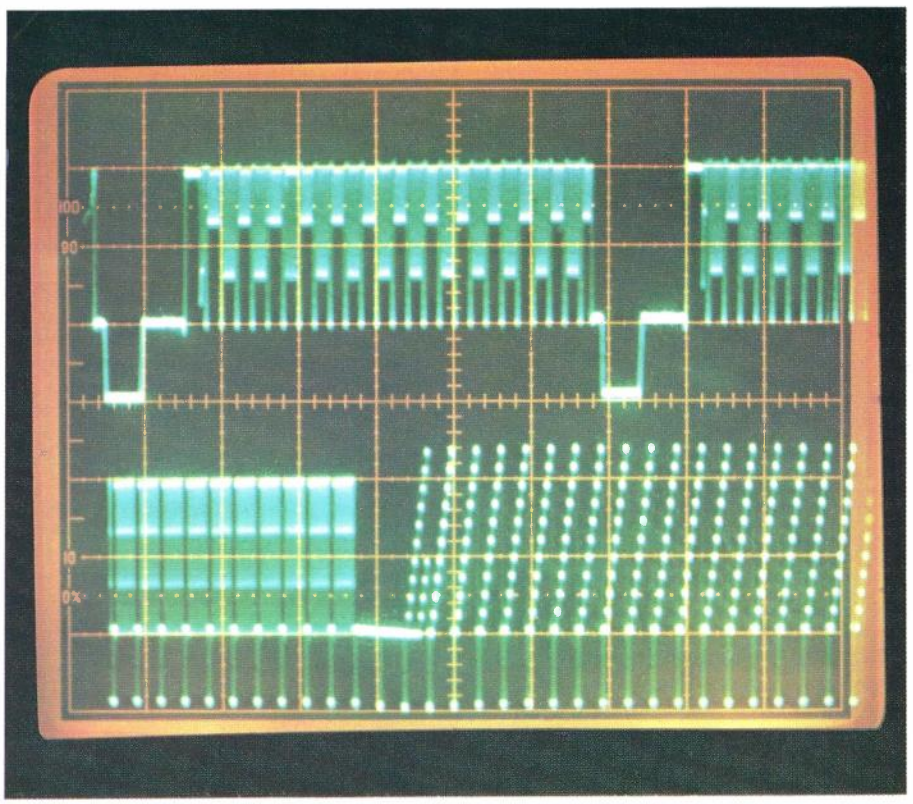
To encode all these signals into a 17 Mbit/s bit stream, approximately 16 Mbit/s have been assigned for the video signal, 0.3 Mbit/s for the two audio channels and 0.7 Mbit/s for slow scan graphics and facsimile type data channels. In order to encode a 5 MHz bandwidth video signal into a 16 Mbit/s digital signal and to maintain a picture quality equivalent to that of a 70 Mbit/s pulse code modulated signal, a redundancy reduction by a factor of approximately 4.5 is required. To this end, several approaches are being simultaneously exploited. First of all, a two to one dot interlaced sampling technique is used, in which every second dot or picture element is sampled as the picture is scanned horizontally and vertically. The sub-sampling pattern has been chosen to minimise its visibility in the decoded picture. At the receiver, the display is synthesized to full resolution by reconstructing the missing elements from the information contained in the neighbouring transmitted elements. Differential pulse code modulation is applied to the transmitted samples so that their amplitudes are quantized non-linearly in a manner which matches the characteristics of human visual reception. Using this coding technique, 4 to 5 bits per sample will be sufficient to obtain a subjective picture quality approximating that of the 8 bits per sample used to quantize signals in straight PCM.

Further reduction of channel capacity is obtained by coding the synchronising information associated with the video signal separately from the picture information. This is expected to yield a 20 per cent reduction of the bit rate.

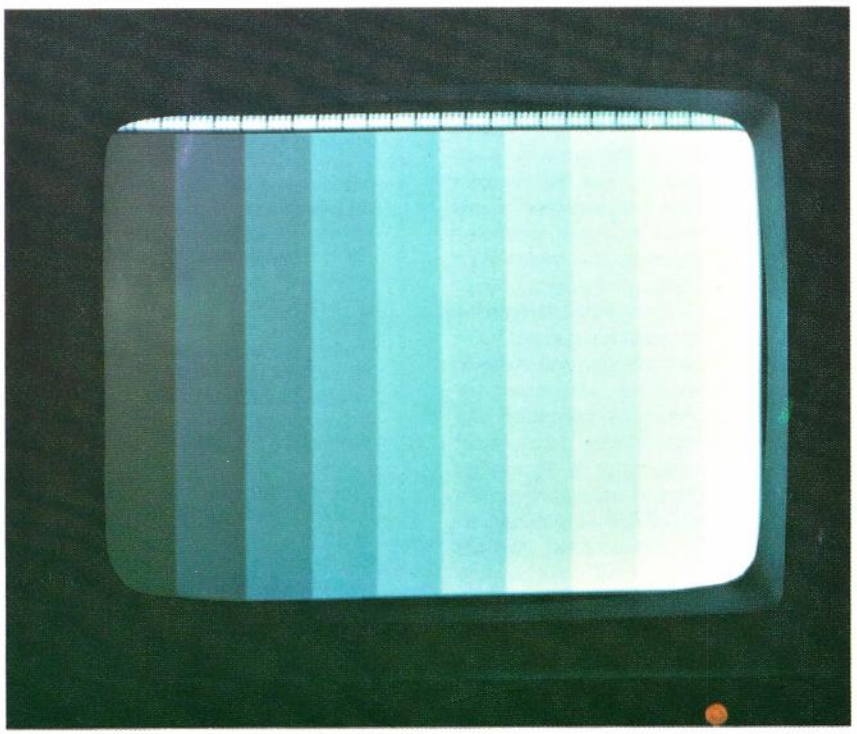
A prototype encoder and decoder for evaluating the obtainable subjective picture quality, as well as the technological factors of implementation of this system, are currently being assembled in the Laboratories. A limited series of laboratory and field trials is expected to be carried out in 1975/76.

Studies of Video Signal Scrambling Techniques

Users of the A.P.O. TV-Conference service may wish to discuss confidential matters over the conference link and it is therefore necessary to guarantee security of the links against surveillance, intentional or otherwise. Currently, the signal is visually monitored for picture quality at the TV switching centres which provide the route interconnections. The only security that can be offered under these circumstances is that of the Post and Telegraph Act, which prohibits A.P.O. staff from disseminating information gleaned in the course of duty. However, in some circumstances, this may not suffice and the only way to overcome this problem is to modify the TV signal before transmission so that it is no longer meaningful, but can still be reconstructed at the receiving end. The simplest way to achieve this is to invert the video signal on every second line, so that when viewed on a normal monitor, the blacks and whites average themselves out to a uniform gray all over the screen. A variation of this is to invert lines in a random-like order that is known to the receiver, thus making clandestine decoders difficult to construct. Work is being undertaken in the Research Laboratories to experimentally evaluate scrambling techniques and to develop a prototype system for use with the TV-Conference facility already developed. A prototype system based on alternate line inversion has been developed and has met some success in field trials. Further development of the scrambling system is being pursued to overcome the difficulties met in the field trial and to incorporate the better security features of random line inversion.



SOUND-IN-VISION SIGNAL WAVEFORMS
LOWER TRACE: AUDIO SIGNALS (LEFT) TIME MULTIPLEXED WITH VIDEO SIGNAL
UPPER TRACE: EXPANDED DIGITALLY-CODED AUDIO SIGNALS SLOTTED BETWEEN TWO VIDEO LINE PULSES



MONITOR DISPLAYS DIGITALLY-CODED AUDIO SIGNALS (TOP OF SCREEN) ADDED TO BLACK AND WHITE VIDEO TEST PATTERN

Sound-in-Vision Transmission

In conventional television distribution networks, at least one programme quality audio channel must be provided for each video channel. However, the cost of providing an audio channel is disproportionately high when the relative bandwidths of the audio and video signals are considered. In the A.P.O. TV-Conference facility, two audio channels are required, and it is important that these channels have similar gain and phase characteristics to preserve the stereo effect. In practice, it is not always possible to provide similar audio channels when TV relay links are time-shared among a number of users.

It is possible to transmit the sound signals as part of the associated video signal by time multiplexing, and several telecommunciations authorities are developing such systems. The "sound-in-vision" system developed by the Research Laboratories is unique in that it does not alter the standard TV synchronising pulse or the colour burst structure, and in that the composite signal is compatible with existing equipment in the television distribution network.

The system uses fifteen of the blank lines, which follow the vertical syncrhonising block in the television signal to carry the audio information. Two channels of digitally coded audio information are stored at the transmitter during one TV picture field, transmitted to the receiver during the following blanking interval, and reproduced by the receiver during the next picture field.

The two channels are of reasonable quality, having a signal to residual noise ratio of almost 50 dB and less than 0.5 per cent distortion at the present stage of development. They are also identical and invariant in their characteristics.

The system requires an elaborate decoder to monitor the audio information, thus contributing to the security fo the TV-Conference audio channels, as access to the decoders will be limited. A prototype system is at present being tested in the A.P.O. TV distribution network.

PHYSICAL SCIENCES ACTIVITIES

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The Research Laboratories conduct exploratory research in the fields of physics, chemistry and metallurgy in order to solve telecommunications engineering, postal and other Departmental problems. A great number of these scientific studies are directed towards the determination of the properties and behaviour of materials, components and other products under service conditions. In assessing these properties, and consequently in devising test or analytical methods and setting satisfactory performance parameters, the basic objectives are either to obtain assurance that the item being examined is suitable for introduction into the A.P.O. network or plant, or to elucidate the reasons for failure or degradation. In the latter instance in particular, an additional task may involve the finding of a suitable alternative, negotiation with a manufacturer for a change in production methods or materials, or consultation and advice to the operational Branch concerned on how to remedy a field problem.

In pursuing these functions, the Laboratories undertake investigations for all Branches of the A.P.O., dealing with both internal and external plant problems as well as postal matters. The items under examination range from the very large, for instance radio masts, to microscopic size devices. The conclusions reached in some cases influence very costly purchasing programmes where significant savings may be ahcieved if more reliable or less expensive alternatives are proved to be acceptable. In other instances, the material or device cost may not be high, but because of staff safety considerations or because early or unexpected failure may seriously affect a key service, a rigorous investigation followed by conclusions at a high confidence level is essential.

In the following articles, some of these activities are described in more detail. Some cases incorporate a conclusion, whereas in other cases, this is not yet possible as the studies are still continuing. Space has not permitted the description of other equally interesting projects currently under way. These include the study of methods to improve the corrosion resistance of aluminium cable conductors, the investigation of alternative potting and casting materials to replace the presently used epoxy compounds, a study of lightning surges to the cable car ropeway and towers at Mt. Bellenden Ker, Queensland, and the development of an improved technique utilising mixed thin layer chromatography for the analysis of organic and inorganic materials. During this year, Laboratories' metallurgists have been involved in assessing the state of communications equipment and metallic structures which had apparently survived the Darwin cyclone. Significant contributions have also been made to the activities of the Standards Association of Australia in such diverse fields as component reliability, flammability of materials, surface protective systems, testing of metal and plastics, and outdoor weathering methods.

Component Evaluation and Standardisation

Ideally, each new design or redesign of a component used in equipment installed in the A.P.O. telecommunications network should be thoroughly evaluated, first, to see if it performs its function correctly, and secondly, to determine if it will continue to do so throughout its service life. The Research Laboratories conduct such evaluations, particularly on those components which will be used in large numbers or in critical areas in the A.P.O. networks. The results of these evaluations enable standardised component specifications to be prepared for particular component applications, to ensure that the components used by the A.P.O. or in equipment purchased by the A.P.O. have adequate physical and performance qualities.

Some 4 million reed relays, for instance, are used in the stored program controlled 10C trunk exchange recently installed in Sydney, and other exchanges are planned which will use many more millions of this component. The Laboratories have a continuing programme of reed relay life and performance tests which are being conducted under conditions similar to those in the 10C exchange. Comparison of past and present results shows that the manufacturing process for the reeds is well controlled. Life predictions from the data are being used in formulating probable fault patterns and maintenance requirements for this type of exchange.

Current work in this area also includes a variety of novel components which are used in private automatic branch exchange (PABX) systems. The components investigated range from integrated circuit decoders and thick film interface units to key sender pads ("pushbutton dials") and miniature cross-point switches. Such tests frequently uncover items which would be unreliable in the Australian environment and feedback to the manufacturer enables corrective action to be taken before the equipment goes into service in the A.P.O. networks.

One of the more unusual items to be investigated recently was a miniature piezo-electric crystal driven tuning fork which will be used in a 1 kHz tone generator. It was found to have excellent frequency stability over a wide range of temperature and in accelerated ageing tests.

Other large usage components being evaluated include light emitting diodes, printed circuit boards, lightning arrestors, connectors, ceramic and electret microphones for telephone handsets, printed circuit board relays and miniature toggle switches.

In shorter-lived items such as dry cells, where there is also a very wide market, the testing program is aimed at selecting the most cost-effective product. In a current project, six sizes of any cell from each of 6 manufacturers are being evaluated in tests derived from Australian Standard C387. Some significant differences in quality have been detected and experience in the use of the tests has led to a recommendation for a possible revision of the Standard.

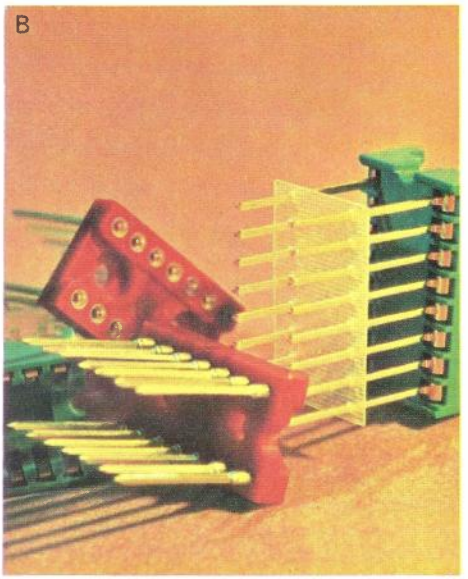
EXAMPLES OF COMPONENTS RECENTLY EVALUATED

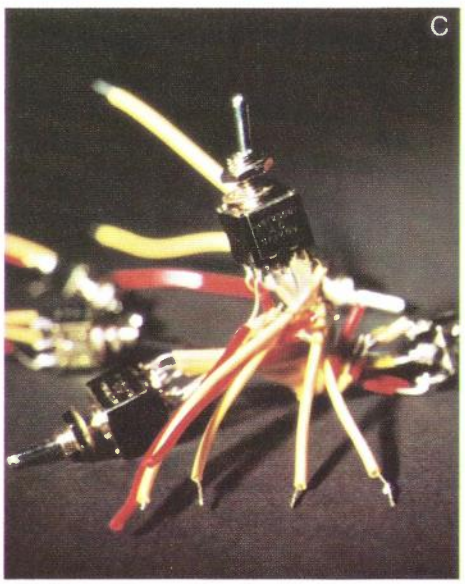
(a) MINIATURE PIEZO-ELECTRIC CRYSTAL DRIVEN TUNING FORK

(b) INTEGRATED CIRCUIT SOCKET FOR WIRE-WRAPPED INTERCONNECTION SYSTEMS

(c) MINIATURE TOGGLE SWITCHES

(d) DRY CELLS AND BATTERIES





Cable Developments

The A.P.O. first adopted plastic for external cable use in 1956 and its performance and ready acceptance as an insulant in distribution cable and as a sheathing material for both underground and aerial cables has been such that current annual purchases of polyethylene insulated and sheathed cable alone are approximately 860,000 pair-kilometres, costing about $14m and consuming around 5000 tonnes of polyethylene.

Changes in construction and materials are constantly being made as technological advances place an ever increasing demand on the quality of the cable. One new cabling concept which has been accepted by almost all telecommunications organisations in the world is that of fully-filled cables. In this system, the 55 per cent air-space within the currently used polyethylene insulated cable is filled with a semi-solid, hydrophobic material to prevent moisture entry into or movement along the cable. The replacement of air by a solid filler, however, increases the dielectric constant of the cable pairs and proportionally increases the capacitance of the cable. The latter may be restored virtually to that of an air-filled cable in many ways, and investigations are being pursued in various parts of the world to determine the optimum components and conditions. In the A.P.O., eight different polypropylene and eleven different filling compounds all based on a mixture of microcrystalline paraffin wax and mineral oil are under evaluation. The results of the survey will be compared against those obtained on commercial cables manufactured in the U.K. and Canada. The aim of the examination is to provide information for the determination of a specification covering material components and performance of a fully-filled cable, compatible with the existing A.P.O. cable network and unaffected by the large variation in climatic conditions possible throughout the Australian continent.

Also under investigation is the plastic insulation of tail cable. The latter is the short length of cable connected to equipment items such as loading coils and pillar terminal strips and which simplifies installation of these items in the field. The currently used tail cable is predominantly a lead sheathed, polyethylene jacketed cable with low density polyethylene insulation over copper wires. Connection to the equipment or existing cable is made by plumbing of the lead sleeve. The temperature immediately under the plumbed area of sheath can reach 220 degrees C and hence the low density polyethylene insulation, which melts around 110 degrees C, can soften and fuse together, creating a fault condition. As attempts to thermally insulate the wires with paper were unsuccessful, consideration was given to polymers with a higher melting point. Trials with polypropylene confirmed that this material degrades badly in the presence of the metallic salts used as colourants for the insulant. Polymers such as the thermoplastic polyesters or nylons, neither of which exhibit metallic degradation and which have much higher melting points than polypropylene, are now under consideration.

Faults occurring in buried plastic-jacketed, lead-sheathed cable in north east New South Wales have been traced to the presence of numerous microscopic holes in the jacket and sheath. Research has proved the holes to be caused by electric discharges and although similar imperfections have been reproduced in laboratory experiments, it has been found impossible to create holes of such small diameter. Trial quantities of replacement cable with a specially formulated semi-conductive jacket over a metallic sheath, to provide lower longitudinal resistance to lightning surges and mains power contacts, have been installed. These jackets are expected to withstand minor surges without puncture whilst still providing protection against corrosion and ingress of water. Such jackets are made from an ethyl acrylate/polyethylene copolymer loaded with approximately 40 per cent special furnace-type carbon black. For dissipation of any build-up of electrical activity in the vicinity of the cable, good electrical contact is imperative between jacket and sheath. In such a construction, this can best be achieved by the use of a semi-conductive, semi-solid inter-layer compound capable of filling all the irregularities betwen the two cable constituents. Such a compound with a conductivity similar to that of the cable jacket has been developed in the Research Laboratories and successfully used in the manufacture of cable.

Damage to buried telecommunication cable due to insects has occurred for the past 50 years but an increase in attack was noticeable with the introduction of polyethylene sheathed cable in 1956. Investigation over the years has led to the development of "insect resistant" cable which has a thin layer (0.38 mm) of nylon 11 or 12 over a normal thickness of polyethylene sheath. The combined properties of hardness, resiliency and surface finish has proved this type of construction almost immune from attack since its full scale use commenced six years ago. The small number of attacks that have been reported can in each case be attributed to a surface imperfection in the jacket, such as a score mark or crease, which has allowed the insects' mandibles to obtain a purchase on the otherwise smooth, glossy surface. Although nylons 11 and 12 have performed well in service, nylon is an expensive material and cable costs are increased by its use as a jacket. Investigations are therefore in progress to obtain a more versatile alternative to nylon which will not only resist insect attack but may even combine the role of sheath and jacket. Current investigations are concentrated on polymeric plasticised PVC, and if early indications are confirmed by termite resistance tests being conducted by the C.S.I.R.O. Division of Entomology as part of a joint research project, significant economies in both raw material and cable manufacturing costs could be achieved.

TESTS OF THE LONG-TERM STABILITY OF CONTACT RESISTANCE OF CABLE CONNECTORS INCLUDE THERMAL CYCLING IN AN ENVIRONMENTAL TEST CHAMBER

Cable Conductor Connectors

The conductors in about 60 per cent of new large-size cables in the A.P.O. network are jointed using crimping machines and pressed-metal connectors. Permanent, electrically stable, insulated, in-line connections are produced in paper and polythene insulated copper conductors at about twice the speed that twist joints can be made. Twist jointing involves cutting the conductors to length, stripping the insulant, twisting the conductors together and sleeving the completed joint. In connector jointing by machine, all of these operations are done in the one crimping operation. Even when the time taken to set up the machine and the extra cost of the connectors is taken into account, connector jointing is still the less expensive method. It also has other marginal advantages, such a the elimination of much of the effect of variations in jointer skill and the reduction in moisture absorption by the cable because it needs to be open for a shorter time during jointing.

At the present time, a number of different designs and sizes of connector are required to joint all the sizes of copper and some of the aluminium conductors used in A.P.O. cables. Manufacturers are endeavouring to improve their connector designs, to widen their application by developing new designs and to reduce their manufacturing costs. Designs offered to the Post Office and which show promise of improving the effectiveness of this cable jointing method are evaluated by the Laboratories before field trials are considered. Batches of simple joints are made, using the machine and method specified by the manufacturer, in a wide range of conductor sizes and insulants and generally in both copper and aluminium. The general quality of each batch of joints is assessed by monitoring contact resistance, insulation resistance, dielectric strength and mechanical strength. If these aspects are satisfactory, the joints are given accelerated life tests which have been designed to assess, in a few weeks, their performance in service over a period of up to 40 years.

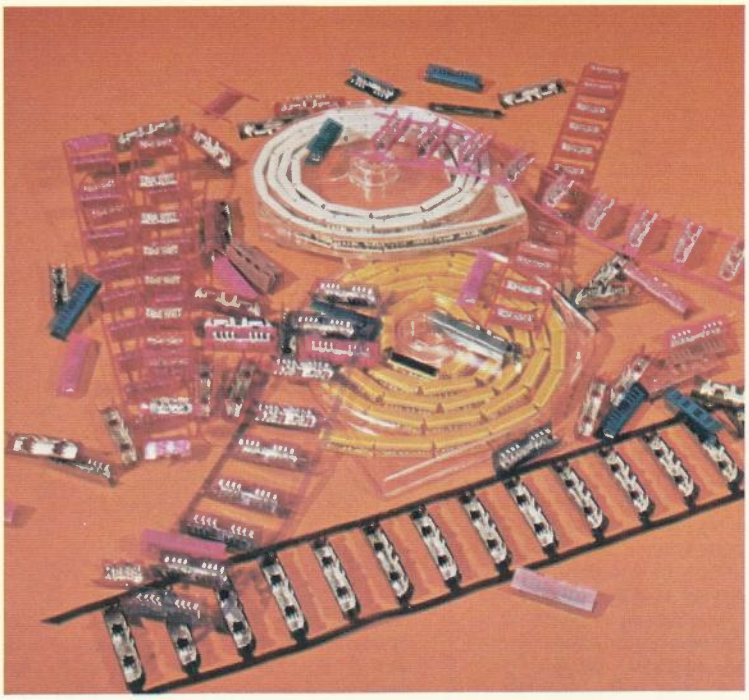
The long-term stability of the contact resistance of the joint depends on the connector maintaining the stresses which are put into it during the machine crimping operation. In the laboratory, this stability is assessed by making precise resistance measurements before and after subjecting the joints to:

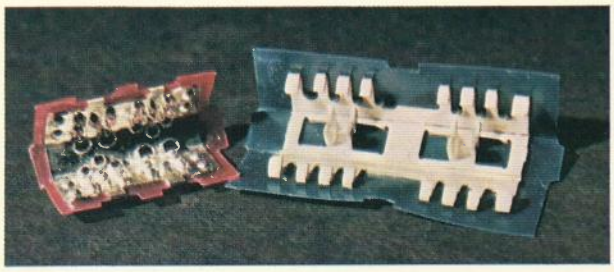
- thermal cycling between -35 degrees C and 65 degrees C which, by differential thermal expansion and working of the stressed portions of the connector, tends to reduce contact pressure and gas tightness at the contact areas, and
- thermal ageing at 100 degrees C which accelerates the natural, slow release of the remanent stress.

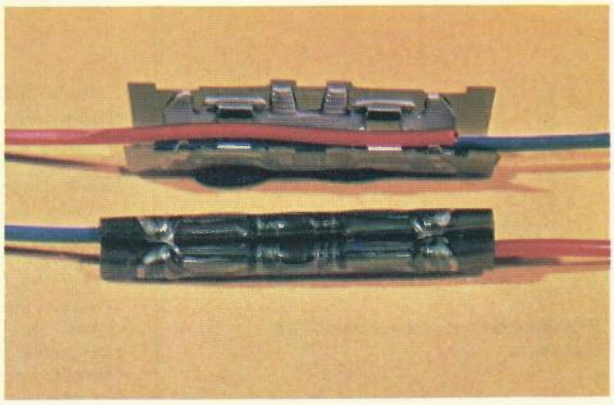
The test procedures are also being assessed and modified. Correlation experiments are being conducted in which resistance changes in joints, stored in an environment similar to that experienced by cable joints in service, are compared with resistance changes measured in similar joints undergoing thermal cycling. From such studies, it is hoped to establish the relevance and acceleration factors of these and other similar tests. Attempts are being made to further accelerate the tests by conducting them in oxygen-rich atmospheres and over wider temperature ranges.

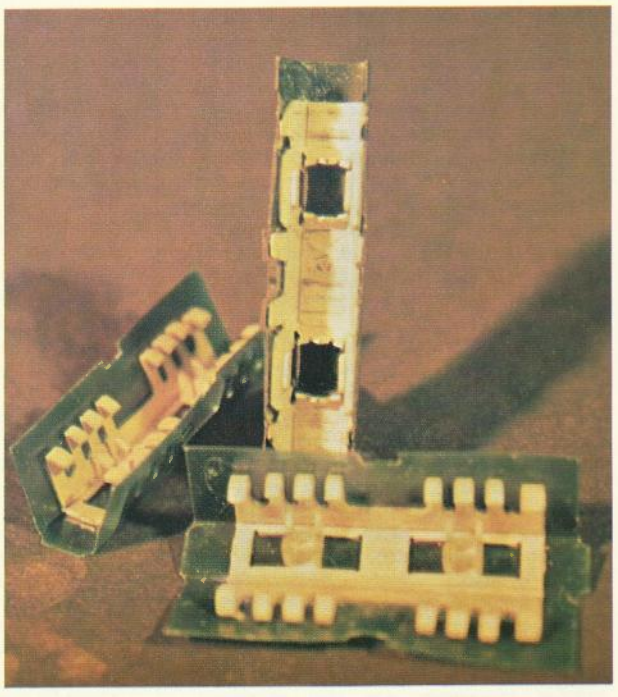
Connectors used to joint small size subscribers' distribution cables must have the additional feature of moisture tightness, because these joints are often exposed to conditions of high humidity and moisture condensation. The effectiveness of various designs of connector supplied for this application is being assessed by monitoring the insulation resistance of sample joints while they are immersed in salt water. No connector with a sufficiently high long-term moisture resistance has yet been found using this method.

PHOTOGRAPHS ILLUSTRATING THE VARIETY OF CABLE CONDUCTOR CONNECTORS UNDER EVALUATION









The Growth and Prevention of Zinc Whiskers

It has been established that zinc plating produces whisker growth. Several months after plating, hair like growths appear on the plated surface, sometimes growing to sufficient length (5mm) to bridge across adjacent electrical circuits and cause permanent shorts. The impact of this problem has increased with the current trend to miniaturised electrical equipment. Growth appears to occur in a random manner and relays stored under identical conditions may or may not produce whisker growth. Evidence suggests that growth is initiated during the electroplating process.

Because of the extensive use of zinc plating as a surface treatment in telecommunications equipment, the Laboratories undertook a study to determine the plating variables which influence whisker growth. The effect of addition agents, current density and plating time were studied using a Hull cell. These studies indicated that brightener concentration can affect whisker growth considerably, apparently independently of current density.

A plating tank was constructed to allow more accurate control of the plating conditions during the investigations. In this tank, the plating solution was aerated and cathode movement was also employed. Whisker growth was most prolific with current densities up to 300 A/m² and plating thickness under 15 μm. Samples plated with 50 per cent excessive brightener have not had sufficient growth time for any conclusive results to be obtained to date.

Lead-Acid Batteries

Rechargeable lead-acid batteries are used extensively in the power systems of telecommunications plant. In a number of situations, the continuity of provision of essential services relies on no-break power supplies to safeguard against mains power failures, and these no-break systems demand reliability in the performance of batteries to initiate the connection of a second power source to the equipment load and to maintain power to the equipment during the changeover interval. In other situations, float-charged lead-acid batteries provide low impedance d.c. sources with short-term reserve capacity in the case of mains power failure. In other instances, rechargeable batteries are used in a cycling mode of charging-discharging in conjunction with wind and/or diesel engine powered generators to power telecommunications equipment in remote locations where no mains power supply is available.

There is therefore good reason for the A.P.O. to be concerned about the reliability and performance of lead-acid batteries and the Research Laboratories are collaborating with the Buildings Branch in performance and reliability studies of lead-acid batteries of various capacities. These studies are directed at improved specifications for batteries purchased by the A.P.O. for use in network systems.

Batteries are used in three categories of operation:

- on float charge, as in telephone exchanges,
- in cycling operation, as at automatic stations,
- in intermittent circumstances, such as for engine starting, power for cable jointers tip welding equipment, etc.

The three types of operation require different battery characteristics and an extensive programme of life tests is being pursued in the Laboratories to establish criteria for battery performance for the various types of operation. The studies also seek to establish whether a stationary battery made for float charging operation is suitable for use in cycling operation.

A number of lead-acid batteries from different manufacturers and ranging in capacity from 25 Ampere-hours to 2000 Ampere-hours have been subjected to a life testing duty cycle. The test cycle was designed to assess battery performance under well defined testing conditions. Electronic equipment has been developed to perform the necessary switching and a teletype interface is used to automatically print out cell potential, positive and negative plate potentials, and the corresponding charging and discharging currents of the batteries under test at appropriate intervals. For the lower capacity 6 and 12 volt batteries, current is controlled electronically. For the larger capacity batteries, current is controlled manually.

To date, the tests suggest that the stationary batteries tested are satisfactory for float charging operation, although tests to assess capacity changes with time are still continuing. However, the batteries tested have not displayed reliable peformance in cycling operation. Faults such as treeing, open circuits, and positive as well as negative plate disintegration have occurred. Potentials during charge and capacities on discharge have been quite unpredictable after a number of charge-discharge cycles, and results so far indicate that the distribution of the number of cycles before battery performance deteriorated was quite random. However, a general pattern has emerged, which suggests that batteries not subjected to the full 3-hour and 10-hour discharge rates maintain their performance for many more cycles than those subjected to these rates.

It is planned to continue the programme of tests and to study the characteristics of traction batteries and to test and compare their performance on cycling duty with that of stationary batteries.

the laboratories & its staff

ORGANISATION

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 of the Australian Post Office.
The Laboratories are comprised of 24 Sections which are grouped into five Branches. The Sections comprise professional, technical grade and other staff, with each Section possessing expertise in particular areas of the engineering and scientific fields.

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The names given below are those of the actual occupants of the positions (appointed or acting) at 30th April, 1975.

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

■

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R.W. Kett, Fell.Dip.Comm.Eng., A.M.I.R.E.E.
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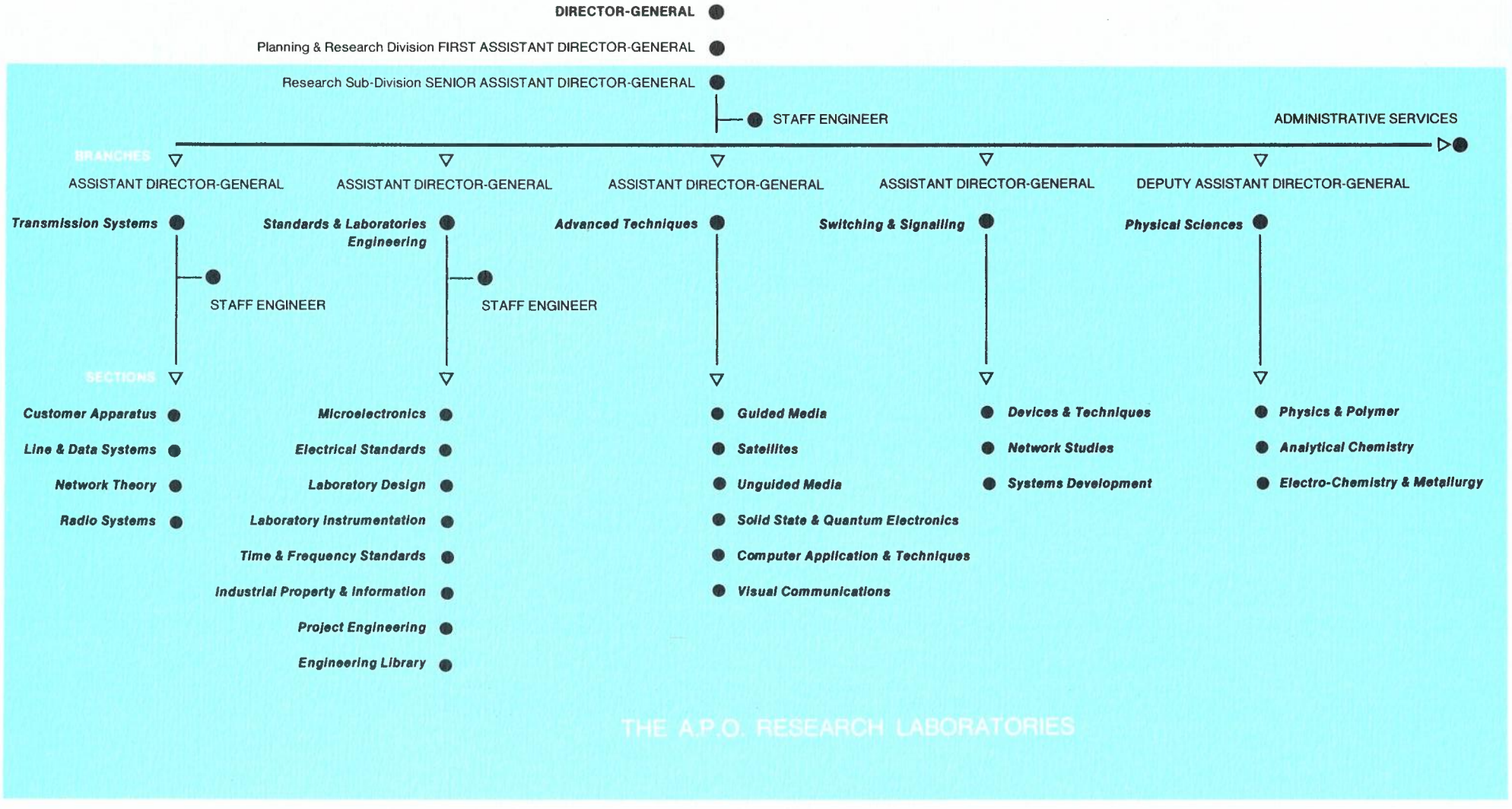
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R. Ayre, B.E.(Elec.)(Hons.), B.Sc.(Hons.), M.Eng.Sc.
J.K. Craick, B.E.(Elec.)(Hons.), B.Sc.
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D.Q. Phiet, B.E.(Elec.)(Hons.), Ph.D.
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N. Wolstencroft

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PRINCIPAL PHYSICIST: D. McKelvie, B.Sc.(Hons.)
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Ms. S.J. Charles, Assoc.Dip.App.Phys., B.App.Sc.
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CHEMISTS:
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F.M. Petchell, Dip.App.Chem.
R.J. Western, Dip.App.Chem.
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R.R. Pierson, M.A.I.S.T.

Electro-Chemistry and Metallurgy Section

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K. Keir, Fell.Dip.Met.Eng.
J.R. Lowing, Dip.Sec.Met.
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M. Jorgensen
B. Listopad
J.W. Smith

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EXECUTIVE ASSISTANT: A.B. Conroy
OFFICE MANAGER: T.H. Brown
EQUIPMENT OFFICER: M.R. Shanahan
BRANCH ADMINISTRATIVE OFFICERS:
C.J. Chippindall
M. Chirgwin
Ms. D. Forster
E. Scates
J. Sergeant

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

Budrikis, Z.L. & Caro, N.W.	"A Demonstration of Adaptive Source Encoding", Australian Telecomm. Research, Vol. 8, No. 2, 1974.
Cahill, L.W.	"Approximate Formulae for Microstrip Transmission Lines", Proc. I.R.E.E., Vol. 35 No. 10, October 1974.
Colvin, J.P.	"Coupling (Launching) Efficiency for a Light-Emitting Diode, Optical Fibre Termination", Opto-Electronics, Vol. 6, September 1974.
Davies, W.S.	"Dispersion in Large Ideal Optical Fibres", Australian Telecomm. Research, Vol. 8, No. 1, 1974.
Davies, W.S. & Kidd, G.P.	"Bandwidth Results for Liquid - Cored Optical Fibres", Electronics Letters, Vol. 10, No. 19, September, 1974.
Davies, W.S.	"Significance of Leaky Rays in Liquid-Filled Optical Fibres", Electronics Letters, Vol. 10, No. 21, October, 1974.
Denger, L.A.	"Coupled Wave Equations with 3 or More Elements", Journal of Applied Physics, Vol. 45, No. 8, August, 1974.
Duc, N.Q.	"Majority-Logic Decoding of Product Codes", Australian Telecom. Research, Vol. 8, No.1, 1974.
Gerrand, P.H.	"Call-State Transition Diagrams", Australian Telecomm. Research, Vol. 8, No. 1, 1974.
Gibbs, A.J. & Quan, A.	"Control Algorithms for Automatic Systems", Australian Telecomm. Research, Vol. 8, No. 1, 1974.
Gibbs, A.J.	"Minimum Mean-Square-Error Approximation Using Transversal Type Filters", I.E.E.E. Trans. on Circuits and Systems, May 1974.
Gibbs, A.J.	"Time-Varying Complete Step-Up n-Ports", I.E.E.E. Trans. on Circuits and Systems, January 1975.
Gray, R.L.	"Asymmetric Bandpass Filter and Aerial Diplexer Design", Australian Telecomm. Research, Vol. 8, No. 2, 1974.
Horton, R.	"Equivalent Representation of an Abrupt Impedance Step in Microstrip Line", I.E.E.E. Trans. on Microwave Theory and Techniques, August 1974.
Loftus, J.E.	"An MFC Display Instrument", Telecomm. Journal of Australia, Vol. 24, No. 2, June 1974.
Miles, D.T.	"Anti-oxidant Analysis Incorporating a Unique Separation Procedure", The Analyst, Vol. 99 No. 1184, November 1974.
Morgan, R.J. & Holmes, W.H.	"Reliability Analysis of Regular Distributed Chain Structures", I.E.E.E. Trans. on Reliability, April 1974.
Morgan, R.J.	"A Reliability Consideration for a Distributed Chain Structure with Unreliable Nodes", Electronics Letters, Vol. 10, No. 7, April 1974.
Petchell, F.M.	"Solvents and Safety", Telecomm. Journal of Australia, Vol. 24, No. 2, June 1974.
Semple, G.J.	"A Method for Assessing the Retiming Performance of PCM Regenerators," Australian Telecomm. Research, Vol. 8, No. 2, 1974.
Smith, B.M.	"Some Results for the Eyepatterns of Class-4 Partial Response Data Signals," I.E.E.E. Trans. on Communications, May 1974.
Steel, J.	"A New Method of Generating Minimal Polynomials", Australian Telecomm. Research, Vol. 8, No. 1, 1974.
Steel, J. & Smith, B.M.	"The Effects of Equalization, Timing and Carrier Phase on the Eyepatterns of Class-4 Partial Response Data Systems", I.E.E.E. Trans. on Communications, February, 1975.
Wise, J.	"An Optical Fibre Data Link for Processor-Peripheral Communication," Australian Telecomm. Research, Vol. 8, No. 2 1974

LECTURES AND TALKS

Balderston, J.M.	"Remote Area Services — System and Earth Terminal Characteristics", R.R.B. Symposium on Satellite Communication for Australia, Melbourne, May 1974.
Brett, P.R.	"The Management of Research and Development", Residential School on Financial Management, Swinburne College of Technology, February 1974, and Monash University School of Administration, June 1974.
Brett, P.R.	"Metrication of Posts and Telecommunications" — North American - Australian Metric Conference, Melbourne, April 1975.
Brett, P.R.	"What Does Industry Expect of Universities and Colleges of Advanced Education" — Conference of Tertiary Research and Development/Industrial Liaison Organisations — Melbourne, May 1975.
M. Cassidy	"Engineers and the Law — the Expert Witness", I.E. Aust., Canberra Division, April 1975.
Craig, E.R. & Perkins, B.	"The Australian National Satellite System", R.R.B. Symposium on Satellite Communication for Australia, Melbourne, May 1974.
Dossing, S.	"Overview of Cable Television", P.O.A. Engineers Group, Melbourne, March 1975.
Flatau, G.	"The Telecommunication Scientist", Department of Applied Physics, University of New South Wales, August 1974.
Flatau, G.	"Reliability or Failure", South Australian P.M.G. Engineers Group, Adelaide, November 1974.
Flavin, R.K.	"Geostationary Satellite Earth Station", R.R.B. Symposium on Satellite Communication for Australia, Melbourne, May 1974.
Gale, N.J.	"Introduction to Electronic Exchanges and Integrated Switching and Transmission", Lectures to Practising Engineers in a series on "Engineering Considerations in the Australian Telecommunications Network", Footscray Institute of Technology, May 1974 and February 1975.
Howard, S.E.	"Rain Attentuation Investigations at 11 and 14 GHz in Tropical Australia," R.R.B. Symposium on Satellite Communication for Australia, Melbourne, May 1974.
Jenkins, G.K.	"Application of an Identification System in a Postal/Telecommunication Environment", 6th Australia Computer Conference, Sydney, May 1974.
Kidd, G.P.	"Mathematics of Reliability", Continuing Education Series on Reliability in Electronic Systems, Royal Melbourne Institute of Technology, July 1974
Kidd, G.P.	"Liquid-Filled Optical Fibres for Communication Systems", I.E. Aust., Annual Conference, Hobart, February 1975.
Mazaferri, F.D.	"General Switching Theory", Royal Melbourne Institute of Technology, June 1974.
Mazaferri, F.D.	"Electronic Exchanges", Royal Melbourne Institute of Technology, August 1974.
Rosman G.	"Optical Fibre Transmission — Some Theory and Experiments", I.R.E.E. Groups, Hobart and Launceston, October 1974.
Sastradipradja, S. & Smith, D.	"Antennas for Earth Stations", R.R.B. Symposium on Satellite Communication for Australia, Melbourne, May 1974.
Semple, G.J.	"Digital Transmission Techniques", Extension Course in Communication Theory for Practising Engineers, South Australian Institute of Technology, February 1974.
Smith, B.M.	"Data Transmission" Extension Course in Communication Theory, South Australian Institute of Technology, March 1974.
Smith, B.M.	"Current Techniques and Trends in Data Transmission", and "Current Research and Development Work on High Speed Digital Transmission Over Supermastergroup Channels", University of W.A., July 1974.
Smith B.M.	"Digital Data Transmission Techniques", Continuing Education Course for Practising Engineers, Royal Melbourne Institute of Technology, September 1974 and October 1974.
Stevens, A.J.	"A Programmed Instrumentation Measuring System", I.E. Aust. Conference on Computers in Engineering, Sydney, May 1974.
Symons, F.J.	"Principles of Time Division Digital Switching", School of Electrical Engineering, University of Sydney, October 1974.
Wise, J.B.	"A Short Range Optical Fibre Data Link," I.R.E.E. Group, Adelaide, June 1974.
Wragge, H.S.	"Integrated Switching and Transmission — The Communication Network of the Future", I.E. Aust., Electrical and Communications Engineering Branch, Victorian Division, June 1974.

RESEARCH LABORATORIES REPORTS

Report No.	Author	Title
6344	E. Rumpelt	Computer-Aided Filter Synthesis from the Chain Matrix.
6591	N.J. Sadler	Professional Grade Aluminium Electrolytic Capacitors — A Summary of Results.
Addendum 4		
6662	N.W. McLeod	C.C.I.T.T. Signalling System No. 6 Field Trial — Digital Addressing and Control of Switching.
6663	G.J. Champion	Software for the C.C.I.T.T. System No. 6 Exchange.
Issue 2	R.H. Haylock	
6742	P.J.Tyers	Relay Signalling System for Subscribers Rural
Issue 2		Radio.
6773	I.L. Jenkins	Determination of Transmitter Power for Radio Paging Service.
6788	G.G. Mitchell	Increasing the Shielding Effect of Galvanized Iron Pipe.
6800	J. Wise	A General Purpose Processor Simulator.
6824	H.J. Ruddell	Semi-Conductive Compound for Cables.
6827	H.J. Ruddell	Modified Forumlation for A.P.O. Epoxy Resin Unit Pack.
6828	W.S. Davies	Estimate of Peak Electric Field Intensities on the Transmission Lines at Radio Australia — Darwin.
6835	L. Davidovits	A Battery Charger Controller.
6838	W.J. Lavery	Coding of Conference TV Signals for Digital Transmission Over Super Master Group Channels.
6840	C. Barling	An Investigation of Equipment Maintenance.
6842	R.J. Western	Lightweight Concrete Polystyrene Bead Aggregate.
6843	G. Flatau	Report on Overseas Visit — 8th June to 7th July 1973.
6845	G.G. Mitchell	Coating of Telephone Printed Circuit Cards.
6848	G.W.G. Goode	Machine-Made Connector Joints for Large Sized Cable.
6850	G.P.Kidd	Report on Overseas Visit September-October 1973 — Optical and Millimetre - Wave Guided Transmission Media.
6855	A.Y.C. Quan	An Experimental Baseband 150 Mbit/s Digital Link over Standard Coaxial Cable.
6866	R.K. Flavin	Earth Stations for Satellite Communications.
6867	J.M.Balderston	An Historical Survey of Communications Satellite Systems.
6869	J.L. Kelly	Some High Frequency Tests on an S.T.C. Miniature Crosspoint Switch.
6871	D.J. Adams	Repair of Gas Leaks in Epoxy Resin Cable Terminal Units.
6873	G. Willis	A DUT 1 Code Generator DCG-1.
6874	J.V. Murphy	Distortion Due to Multipath Transmission in an F.M. Broadcasting System.
6879	B.M. Smith	Report on Overseas Visit, January-February 1974.
6883	E. Gray	Evaluation of an A.P.O. Electronic Erlang-hour Meter.
6893	R. Horton W.J. Williamson	Measurement of the Geometry of Hollow Glass Fibres.
6901	J.M.Balderston	Operating Frequencies for Communication Satellites.
6902	L. Cahill	Report on Overseas Visit January-February 1974 — Integrated Optics.
6906	A.J. Gibbs	Analogue and Digital Time-Invariant Step-Up n-Ports.
6907	A.J. Gibbs	Colour TV Transmission Over Single Quad Cable — Transmission Limits Imposed by Crosstalk.
6912	L.F. Lind	Improved Test Fixture for Microwave Transistors.
6913	L.F. Lind	Sensitivity Analysis of Interstage Matching Networks.

In addition 17 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. These include:

NATIONAL PROFESSIONAL BODIES

VICTORIAN EDUCATION DEPARTMENT	
Higher Technician (Applied Science) Certificate Course Development Committee	G. Flatau
VICTORIA INSTITUTE OF COLLEGES	
Committee on College Staffs	P.R. Brett
MELBOURNE UNIVERSITY	
Faculty of Engineering	P.R. Brett
MONASH UNIVERSITY	
Faculty of Engineering	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.H. Murfett
Master of Engineering Ad Hoc Advisory Committee	L. H. Murfett
CAULFIELD INSTITUTE OF TECHNOLOGY	
Course Advisory Committee	H.S. Wragge
ROYAL MELBOURNE INSTITUTE OF TECHNOLOGY	
Capital Funds Committee	M. Cassidy
Course Advisory Committees	M. Cassidy
	R.D. Slade

NATIONAL PROFESSIONAL BODIES

COUNCIL FOR AN AUSTRALIAN ACADEMY OF TECHNOLOGICAL SCIENCES	P.R. Brett
Executive Committee	A.J. Seyler
	P.R. Brett
AUSTRALIAN NATIONAL COMMITTEE FOR RADIO SCIENCE	P.R. Brett
RADIO RESEARCH BOARD	P.R. Brett
TRANSPORT AND COMMUNICATIONS ADVISORY COMMITTEE OF METRIC CONVERSION BOARD	P.R. Brett
AUSTRALIAN INSTITUTE OF SCIENCE TECHNOLOGY	
Victorian Branch Council	F.C. Baker
AUSTRALIAN ADVISORY COUNCIL ON BIBLIOGRAPHY SERVICES	
Federal Committee	Ms. M. Cuzens
Victorian Regional Committee	Ms. M. Cuzens
Working Party on Systems and Communications	M. Cassidy
THE INSTITUTE OF RADIO AND ELECTRONICS ENGINEERS, AUSTRALIA	
Board of the College of Electrical Engineers	M. Cassidy
	H.S. Wragge
Electrical and Communications Engineering Branch Committee	M. Cassidy
	H.S. Wragge

TELECOMMUNICATION SOCIETY OF AUSTRALIA	
Council of Control	H.S. Wragge
Board of Editors: "Australian Telecommunication Research"	H.S. Wragge
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	A.J. Gibbs
	G. F. Jenkinson
	A.H. O'Rourke
	I.P. Macfarlane
	A.R. Gilchrist
Board of Editors: "Telecommunication Journal of Aust."	D.A. Gray
STANDARDS ASSOCIATION OF AUSTRALIA (S.A.A.)	
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Executive Committee	P.R. Brett
Telecommunications and Electronics Standards Board and Executive Committee	P.R. Brett
	E.F. Sandbach
Australian Electrotechnical Committee	P.R. Brett
	E.F. Sandbach
Acoustic Standards Board	D.A. Gray
Plastics Industry Standards Board	R.D. Slade
TECHNICAL COMMITTEES	
Acoustic Standards	
• Instrumentation and Techniques for Measurement of Sound	E.J. Koop
Chemical Industry Standards	
• Adhesives	F.C. Baker
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
Plastics Industry Standards	
• Phenolic Laminated Sheeting	G. Flatau
• Methods of Testing Plastics	G. Flatau
• Outdoor Weathering of Plastics	G.W. Goode
• Polytetrafluoroethylene	B. Chisholm
• Flammability of Plastics	H.J. Ruddell
Safety Standards	
• Industrial Safety Gloves	F.C. Baker
Telecommunications and Electronics Industry Standards	
• 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
NATIONAL ASSOCIATION OF TESTING AUTHORITIES (N.A.T.A.)	
Electrical Registration Advisory Committee	J.M. Warner
Assessor for Environmental Testing	G. Flatau
Assessor of Laboratories Engaged in Testing Plastics	B.A. Chisholm
Assessor for Aerial Equipment and Measurements	O.F. Lobert

INTERNATIONAL BODIES

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 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 International Standards Organisation (I.S.O.)
- 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 patent portfolios to cover worthwhile inventions by its staff. Many of these inventions are made by the staff of the Laboratories, who also contribute largely to the assessment of novelty and likely usefulness of new ideas which may lead to patentiability.
The list below summarises patents granted to the A.P.O. or patent applications lodged by the A.P.O. in the past two years.

Subject	Inventor(s)	Countries
Polarization Diversity in Domestic Radio Receivers	D. Rodoni T. Van Bemmel (non A.P.O.)	Australia Philippines India Japan United Kingdom
Broadband VHF Antennas	R.P. Tolmie	Australia
Cable Pair Identifier	G. Devey	Australia New Zealand United Kingdom
Smoke Detector (Nephelometer)	C.S.I.R.O. A.P.O.	Australia Switzerland Japan U.S.A. United Kingdom
Detection of Digitally-Encoded Frequency Signals	A. Proudfoot	Australia U.S.A. Belgium Federal Republic of Germany Netherlands France Switzerland Sweden United Kingdom U.S.S.R. Canada Japan
Methods of Bonding	H.J. Ruddell R.J. Western	Australia
A Table-Top Switchboard	M. Murnane B. T. Burland	Australia
Justification Jitter Smoothing	J. Bylstra	Australia
Improved Integrating Current Meter	J.R. McIntyre	Australia
Projector Switching Unit	J. Straford J. McLaren	Australia

VISITORS TO THE LABORATORIES

The work of the Laboratories often calls for close liaison with various Australian universities and other tertiary colleges 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.
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.

OVERSEAS VISITS BY LABORATORIES STAFF

It is an important responsibility of any viable organisation to keep abreast with developments and changes in particular fields of interest. To this end, the Laboratories arrange a programme of overseas visits each year during which members of staff interchange experience, technical knowledge, opinions and ideas. The visits are normally to other administrations, universities and industry, as well as to international forums and conferences of world telecommunications bodies and related organisations.
The following staff members have travelled overseas during the past year:

F.C. Baker
E.R. Craig
N. Demytko
G. Flatau
E.J. Koop
L.K. Mackechnie
H.J. Ruddell
E. Sandbach
V.K. Sargeant
S. Sastradipradja
H.S. Tjio
J.M.Warner
H.S. Wragge

ASSISTANCE WITH STUDIES

The Laboratories have a policy of encouraging staff to further their educational qualifications and technical expertise by study in fields relevant to the work of the Laboratories. Professional staff are selected to pursue postgraduate courses, often leading to higher degrees, at universities and colleges of advanced education, or to broaden their expertise 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. 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 postgraduate studies or to seek wider professional experience during the past year:

Brunelli, A., Royal Melbourne Institute of Technology
Kirton, P.A., Monash University
Newton, A.R., University of Melbourne
Young, I., University of Melbourne

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 and other centres of higher learning. Current contracts administered by the Laboratories involve research on the topics below:

- Transmission Equalisers for TV-Telephones
- Strategies for TV Signal Coding
- Mathematical Optimisation Techniques
- Very High Speed Pseudo-Random Noise Generation and Detection
- Solid State Technology for Microwave and Millimetre Wave Sources
- Solid State Technology for Microstrip Circuits
- Transmission Characteristics of Trunk Waveguide Systems
- Multi-mode Liquid-filled Optical Fibres
- Active Devices for Integrated Optics
- Electrical Discharges and Plumes on High Power HF Antennas
- Interdependence of the Physical and Chemical Properties of Plastics with Insect Resistance.

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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