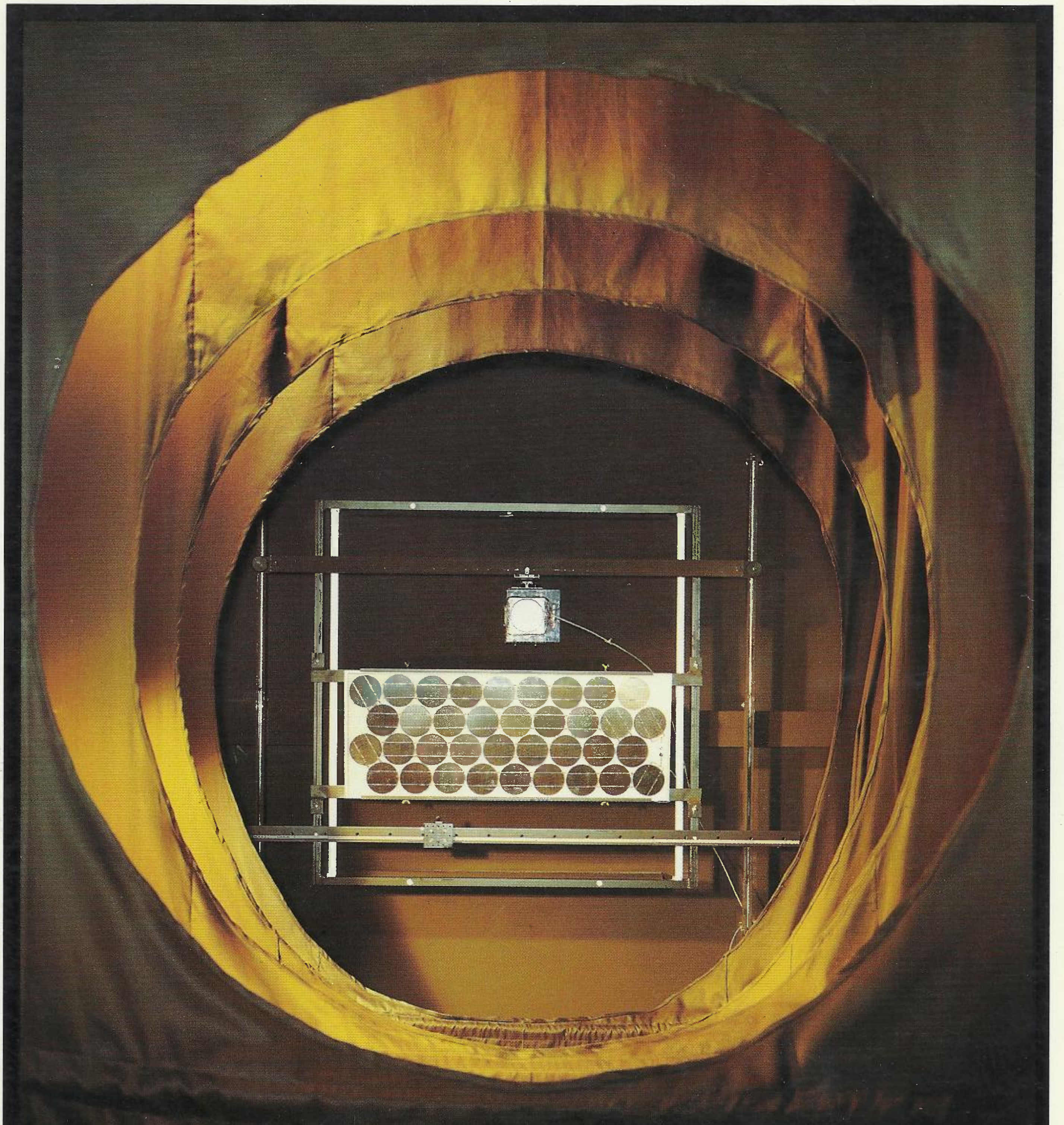
REVIEW OF ACTIVITIES
1982-83



Telecom Australia

REVIEW OF ACTIVITIES

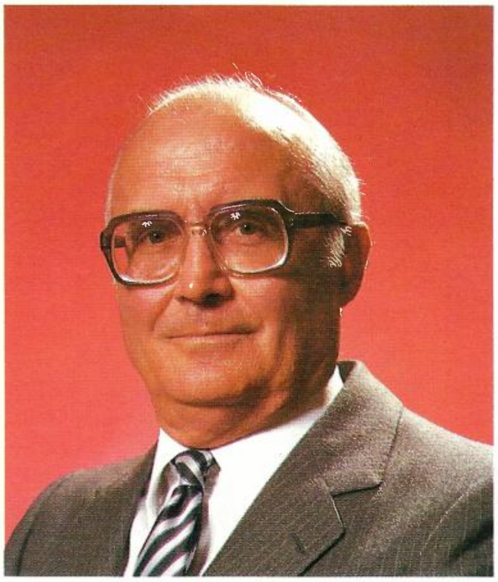
1982-83

Research Laboratories 770 Blackburn Road Clayton, Victoria 3168 Australia

Telecom Australia

ISSN 0314-1357

FOREWORD



Although Australia is a relatively small country with only about 2% of the world's telephones, Telecom Australia can claim with some pride that the telecommunications services which it provides to the people of Australia, and the national networks over which they are provided, are comparable with the best in the world. As in other developed countries, Telecom's services and networks owe this quality to the timely application of advances in telecommunications science and technology over the last five or six decades.

The ability to harness these advances depends on a telecommunication administration's capability to evaluate new against existing telecommunications techniques and technologies and to apply those most suited to network development in its particular national environment. Over the decades, national networks develop their own characteristics, but all national telecommunications administrations face a similar complex range of technological challenges.

For over fifty years, Australia's telecommunications administration has recognised that effective intra-mural R&D is an essential activity to develop and maintain its competence to harness new technology to Australia's advantage. This is doubly important in the Australian context since our geography and size isolates us somewhat from the world centres of telecommunications R&D.

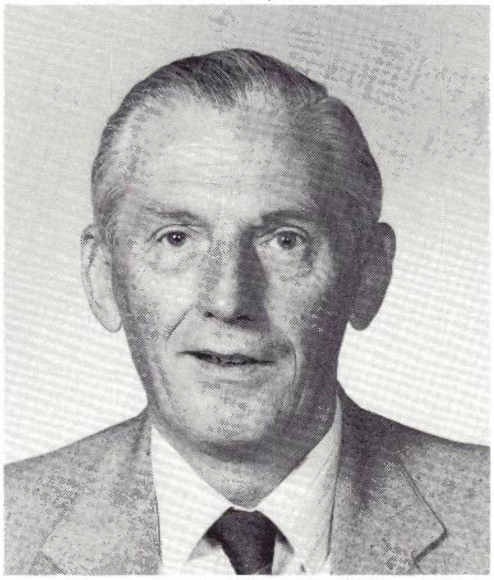
This Review of the Activities of Telecom Australia's Research Laboratories illustrates the breadth of the R&D activities which are being undertaken in the corporate and national interest, and on appropriate occasions, in the international interest of developing world telecommunications standards.

The selection of R&D activities outlined suggests that, in later decades, the 1980s will be recalled as the decade when Australian telecommunications services diversified and new networking concepts were introduced. It will also be seen as the decade in which digital signal handling and computer control techniques began to be applied to a significant extent in the Australian telecommunications network and in which the network began to undergo a fundamental change from an analogue network using electro-mechanical control technology. This change will be recalled as that which paved the way for dedicated services networks, through common technology and technical standards, to merge together in the evolution of an Integrated Services Digital Network.

I am pleased to introduce this Review as an illustration of the way in which Telecom Australia is facing up to the technical challenges of the 1980s.

R.G. MARTIN
CHIEF GENERAL MANAGER

OBITUARY



ERIC RAMSAY CRAIG

In January 1983, the staff of the Research Laboratories were saddened by the death of Mr. Eric Craig, following a short illness. Mr. Craig was Head of the Telecommunications Technology Branch.

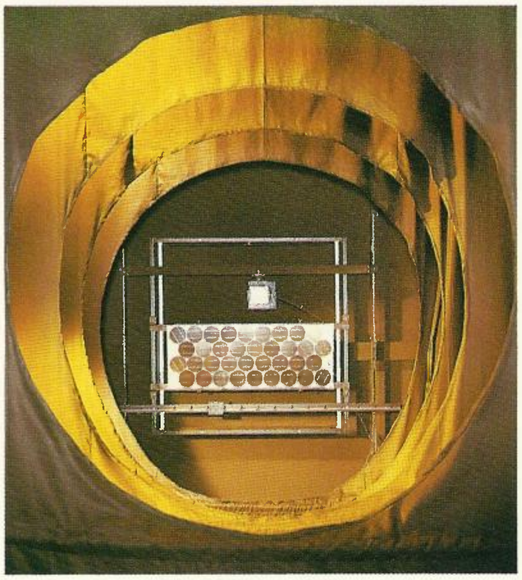
Eric Craig graduated from St. Andrew's University, Scotland, in 1945 with a BSc (Eng) honours degree in electrical engineering. He joined the Australian Post Office (APO) in 1949, and spent the first five years of his career working with the South Australian Administration on various radio projects such as the conversion of the Adelaide-Kangaroo Island system to multi-channel operation.

On being promoted to the Research Laboratories in 1955, Eric Craig continued his career in radio communications, with involvements in radio propagation measurements on systems employing tropospheric and ionospheric scatter techniques. It was at this time that he became aware of the potential of satellites in communications, and in 1960/61, he initiated and carried out a state-of-the-art review of this field.

From 1961 to 1964, Mr. Craig worked with the British Post Office on secondment from the APO. He was responsible for the technical direction and management of the Goonhilly satellite earth station, and during this period, he first became involved in the activities of the International Telecommunications Union (ITU) in the satellite field, which later became one of his major interests.

Eric's main ITU involvement was with the CCIR Study Group 4, which is concerned with the characteristics of fixed communications services using satellite systems. He travelled extensively overseas in the course of this work. Eric became Vice-Chairman of this Study Group in 1970 and, at his death, he was its Chairman. He was also the Chairman of the Australian National Study Group 4, which developed a national viewpoint on matters to be put before CCIR Study Group 4.

In his work in the Laboratories from 1964 until 1977, he was in charge of groups working on both transmission measurements and satellite communication studies. In 1977, he became Head of the Telecommunications Technology Branch of the Laboratories, a position which he held until his untimely death.



Cover Photograph

The cover photograph shows a solar cell panel module and associated test monitoring apparatus mounted inside the Laboratories' pulsed solar simulator facility. This recently-commissioned facility enables the electrical characteristics of solar cell modules to be evaluated in the laboratory under fully-controlled conditions of irradiance and temperature. This and other related test facilities are used in the Research Laboratories in studies of the performance and reliability of solar cell modules over a range of simulated and actual environmental conditions.

CONTENTS

THE ROLE OF THE RESEARCH LABORATORIES

Under its Charter established by the Telecommunications Act, Telecom has the national responsibility to provide, maintain and operate telecommunications services in Australia which best meet the social, industrial and commercial needs of the people of Australia, and to make its services available throughout the country so far as reasonably practicable. The Charter also requires that services are to be kept up to date and operated efficiently and economically, with charges as low as practicable.

In meeting this responsibility, Telecom is mindful of the economic and practical benefits to be gained by the adoption of new and improved techniques, equipment and systems that result from advances in telecommunications science and technology. The correct choice of technology and emphasis on the efficient management of this technology in planning, developing and operating the telecommunications network ensures economy, efficiency and continuing flexibility in the on-going task of developing the network which provides the services to the community.

The Research Department, known as the Telecom Australia Research Laboratories, is the focal point for much of Telecom's research and development effort. The Laboratories began in 1923 as a Section in the Headquarters Administration of the then Postmaster-General's Department, having been established to provide specialist technical advice to the Chief Engineer on "the latest discoveries, inventions and developments in electrical communications and their promising and likely benefits to the Department's telephone and telegraph services".

Today, the Laboratories are a Department in the Headquarters Administration of Telecom, and the Director, Research, is directly responsible to the Chief General Manager.

The Laboratories' work program is reviewed and determined annually through a corporate process which yields a rolling three-year Program of Research, Development and Innovation (RDI). The RDI process encompasses all technical activities performed within Telecom which, through the use of new or existing technology and techniques, will or could change the telecommunications services provided by Telecom to its customers, the technological nature or the technical performance standards of the systems used in the on-going development of the telecommunications network, or the operational efficiency by which Telecom provides services over the network.

About 90% of the Laboratories' work program comprises R&D projects and activities which are within the scope of the RDI program. As such, this work obtains corporate endorsement and is co-ordinated with the work of other Departments, primarily the Engineering and Commercial Services Departments at Headquarters. The remaining 10% of the Laboratories' work program comprises consultancy services in the specialised fields of precise technical and scientific measurement and analysis, technical information services and industrial property services. These latter functions are a natural extension of the primary investigatory functions of the Laboratories.

The Laboratories, by selecting relevant R&D projects, seek to ensure that Telecom has available the necessary advice in the relevant fields of advanced science and technology to assist in the formulation and implementation of policies and plans for new or improved services, systems, service standards and operational practices. Through the application of their special expertise and facilities, the Laboratories also provide assistance to other Departments in Headquarters and the State Administrations in the solution of technical problems that arise in the design, manufacture, installation, operation and maintenance of equipment in service in the telecommunications network.

To fulfil these responsibilities, the Laboratories try to maintain a high level of expertise in the telecommunications and associated engineering disciplines, and in the related disciplines of physics, chemistry and metallurgy. This is done by conducting research and advanced development work on topics that are relevant to the Australian network, having regard to the work known to be in progress elsewhere in Australian research laboratories and in similar institutions overseas.

Many of the innovations, ideas and improvements proposed for the Australian network originate overseas. However, it is necessary for Telecom to have advance knowledge of these developments so that they can be evaluated soundly on social, economic and technical grounds, before they are accepted or adapted and modified for incorporation into the Australian telecommunications network. To help make these decisions and judgements with confidence, it is necessary for Telecom to have, at first hand, sound and competent technical advice. This is best derived from its own R&D, conducted in relevant technological or scientific fields.

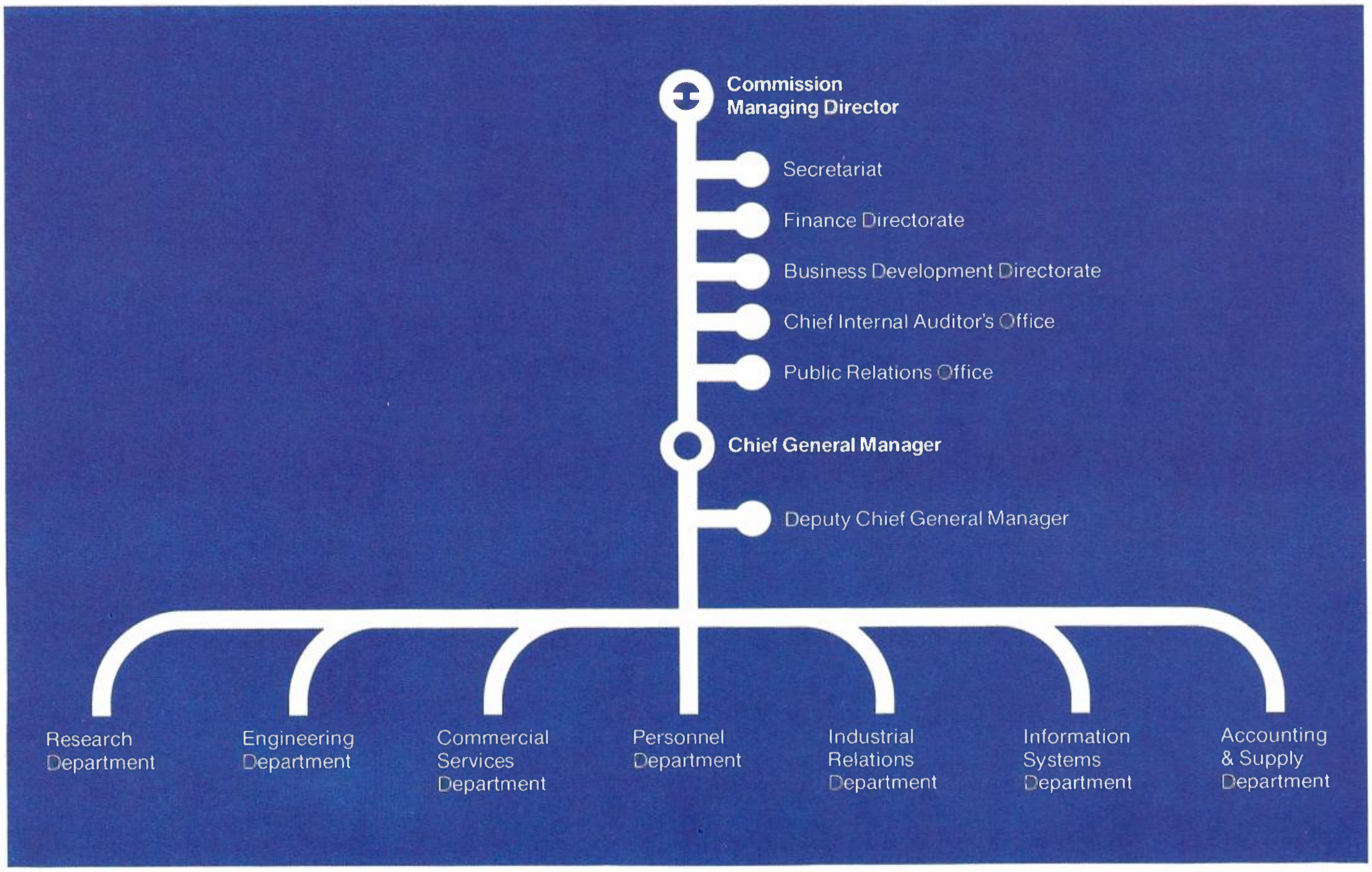
Most of the projects undertaken by the Laboratories, rather than being directed at product specifications, find their ultimate expression in the performance requirements incorporated in procurement specifications for the systems and equipment which are bought by Telecom from the international telecommunications industry. Other work is expressed in the assessment of materials, components and assembly practices used by suppliers in equipment tendered against Telecom procurement specifications. Occasionally, a project is carried to production when it is evident that the innovation, design and development work of the Laboratories will yield equipment directly suitable for field application.

Apart from carrying out a research and development role, the Laboratories have specialist staff with knowledge and facilities in a number of disciplines, including the applied sciences, who conduct investigations into difficult technical problems that arise in the operation of telecommunications plant. The Laboratories are also responsible for Telecom's scientific reference standards for the measurements of time interval, frequency and electrical quantities. In the former case, they are an agent of the National Standards Commission.

Telecom, through its Research Laboratories, recognises the great variety and depth of research talent which exists in centres of higher learning and in industry in Australia. The Laboratories encourage these other research organisations to undertake specific projects of interest to Telecom and act as a focus for this activity for Telecom.

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 Telecom to decide when, and to what extent, new technology is to be harnessed to provide new or improved customer services and systems. In the selection of activities reported in the following pages, this edition of the Review of Activities of the Research Laboratories illustrates the ways in which the Laboratories have sought to fulfil their role during 1982/83.

Organisational relationship of the Research Laboratories with other Headquarters units of Telecom Australia.



The Laboratories Consolidate at Clayton

The past year has been a historic one in terms of the location and accommodation of the Laboratories. The second stage of laboratory building development on the "Monash" site was substantially completed by the end of 1982. Its subsequent progressive occupation by the Voice Services, Business Communications, Reference Measurements, Instrumentation Engineering and Headquarters' Library Sections in the first half of 1983 has now consolidated all Research Laboratories activities on two sites in the Melbourne suburb of Clayton, some 18 kilometres from the city centre.

These events marked the end of a 60 year era, during which the Laboratories had grown to occupy eight dispersed buildings in the city, of which few provided satisfactory accommodation for R&D activities.

The Laboratories are now accommodated on two sites about one kilometre apart at Clayton. One site, known as the "Monash" site because it adjoins the eastern boundary of Monash University, is intended ultimately to become the permanent home of the Laboratories. The other site, known as the Winterton Road site, provides leased accommodation for about one third of the Laboratories' organisation, pending its ultimate relocation in buildings to be constructed in future stages of development of the Monash site.

The Monash site is extensive enough to provide for future growth of Laboratories' activities into the next century. It has an area of 19 hectares and it was purchased in two parcels in the early 1970s. The purchase followed comprehensive studies of several options for establishing the Laboratories in permanent and more suitable accommodation. Amongst other advantages, the site provided for the staged construction of economic and flexible low-rise laboratory buildings in a campus-style setting over several decades, allowing the cost of each stage to be kept in balance with capital funding constraints.

Site development is following a "master plan" developed during the early 1970s. It provides for the staged construction of high quality, specialised but flexible, low-rise laboratory buildings, grouped about environmentally pleasing, interlocking garden spaces and distributed parking areas within an inner campus, with vehicular traffic flows confined to perimeter roadways. Ultimately, the predominantly 3-storey laboratory buildings will focus on a centrally located group of slightly taller buildings which will house Laboratories' executive and administrative staff and common amenities such as library, theatrette, lecture rooms and staff cafeteria.

The first two stages in the development of the Monash site have been concentrated at its northern end, since the southern part of the site is leased until 1985 for use as a drive-in theatre. Capital funding considerations suggest that the next stage of development of the site will take place in the latter half of the 1980s, and this stage will extend into the southern part of the site.

The first stage buildings on the Monash site were completed and occupied by about 200 staff early in 1978. Prior to this, in 1974, a similar number of staff had occupied the leased laboratory premises at Winterton Road, Clayton. These moves left about 100 staff remaining in some of the old city buildings until they could be accommodated in the second stage of development of the Monash site.

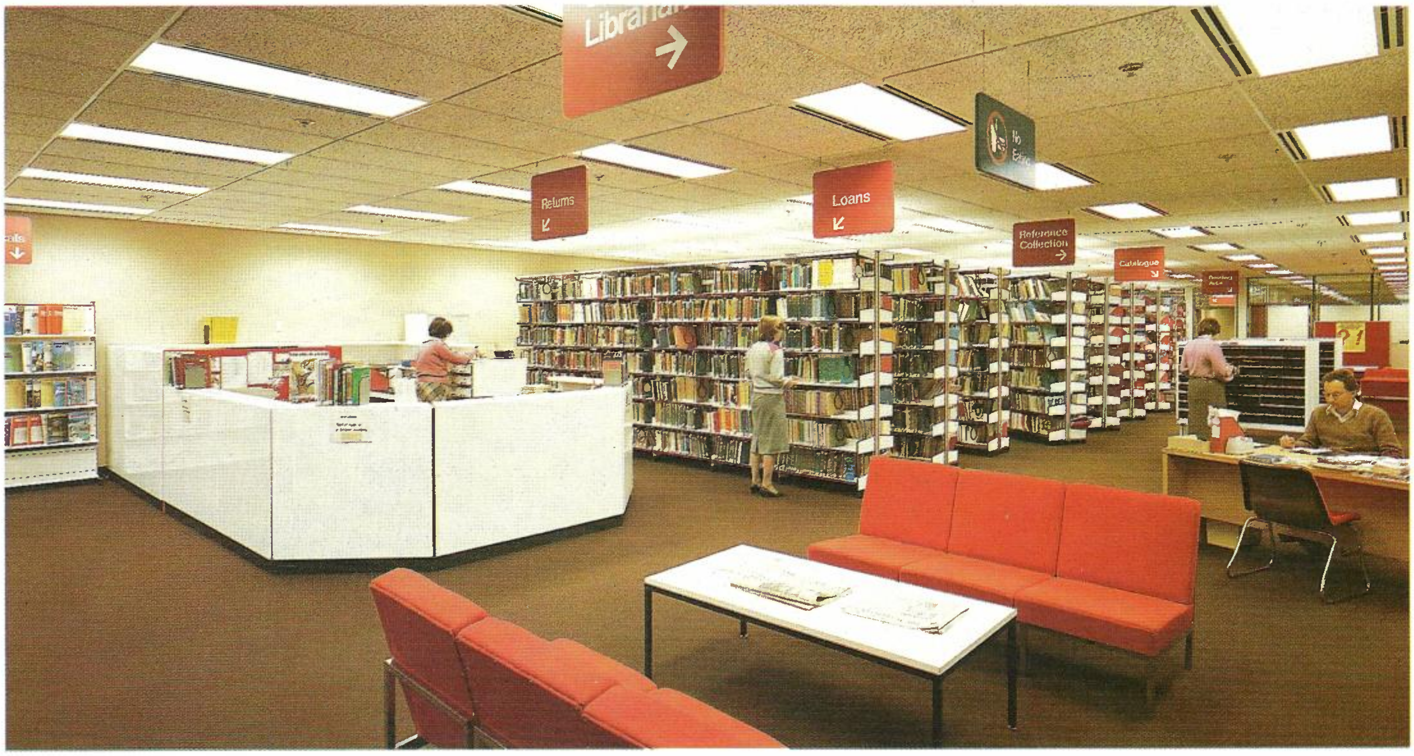
This latter stage was completed about December 1982 at a capital cost of approximately $11 million. Architectural briefing and construction specifications for the project were co-ordinated by the Headquarters Buildings Sub-Division. The work was undertaken by private building contractors, and the contracts were established and managed on behalf of Telecom Australia by the Department of Transport and Construction. Construction activity commenced in August 1979 and was substantially completed by December 1982.

The project involved the construction of, and establishment of building services and laboratory facilities in, two 3-storey laboratory buildings and a single storey storage building. The latter building is joined to one of the laboratory buildings by a single storey link, which houses special acoustic test facilities, comprising an anechoic chamber and a reverberant room. These facilities are used by the Voice Services Section in the performance of its functions related to telephone transmission standards.

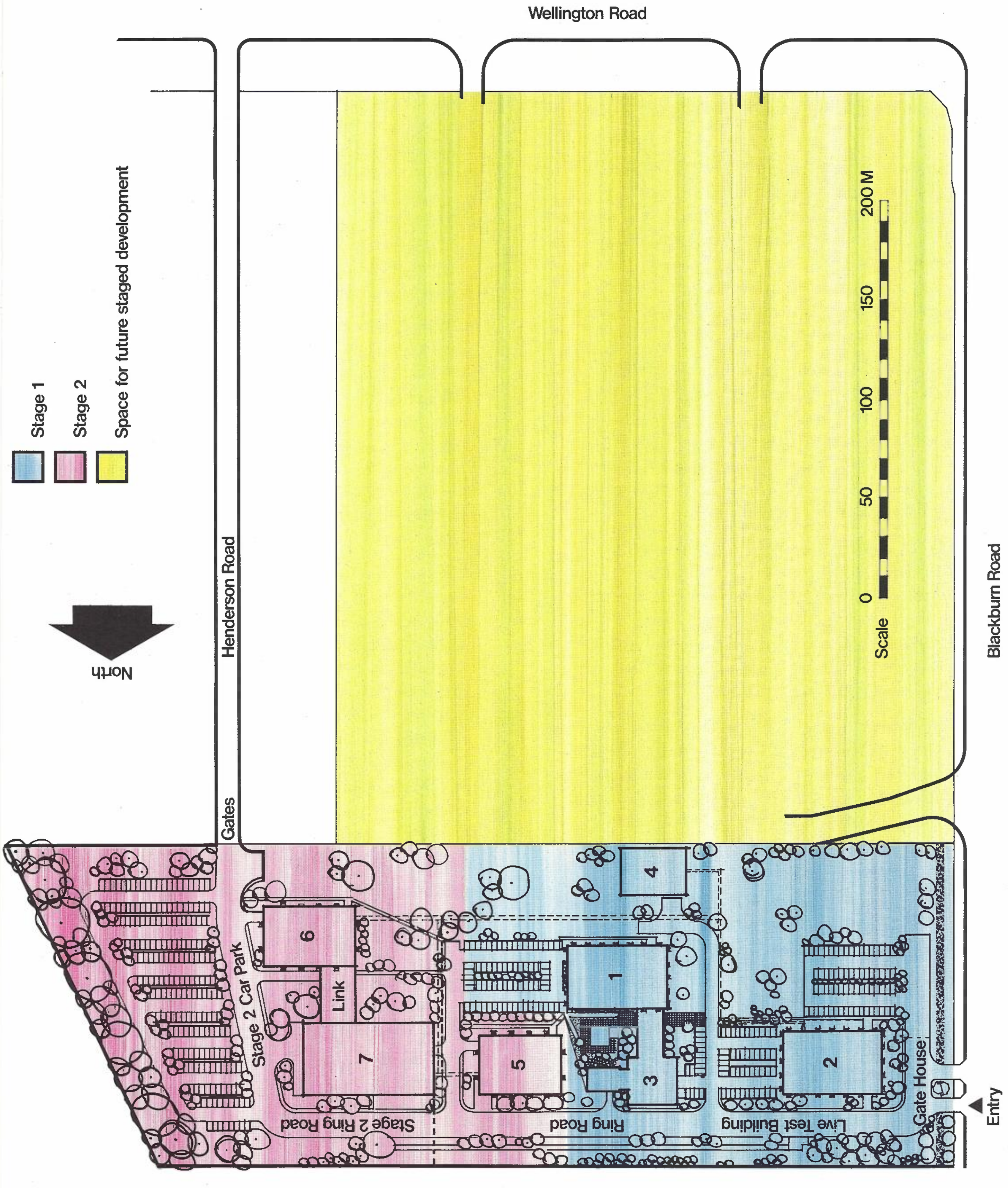
The external appearance, overall size, building services provisions and basic floor layout principles of the 3-storey laboratory buildings are similar to those of the previous stage. However, the structural design of the Stage 2 buildings is such that only the external walls and those of the central service core are load-bearing. This method of construction not only provided economic advantages, but it permitted large interior spaces, free of obstructions, to be utilised for facilities such as the library, cafeteria and theatrette. It also provides flexibility for future rearrangement of interior layouts using standard demountable partitions in a modular floor plan scheme determined predominantly, but with reasonable flexibility, by air-conditioning and fire sprinkler services.

The architect's brief for the new laboratory buildings posed a number of design challenges to provide a variety of special accommodation requirements of several laboratories' functional activities as well as those for more usual activities. One such specialised activity is that of the Reference Measurements Section, whose function is the development and application of Telecom Australia's reference standards for the precise measurement of electrical quantities, time interval and frequency. Another is that of the Voice Services Section, whose function is related to Telecom's reference standards of telephone

(i) Dining facilities in the staff cafeteria
(ii) Reading room of the Headquarters' Library



Schematic Monash site deveopment plan



transmission performance and to the subjective and objective rating of the performance of standardised telephone systems and connections. Specialised laboratories and internal facilities have been provided for these activities which variously meet unusually stringent specifications, alone or in combination, for isolation from structurally transmitted vibration, acoustic decoupling, radio frequency shielding, temperature and humidity control, environmental cleanliness and laminar air flow, and emergency power supplies.

Antenna platforms and towers are located on the rooftop of one of the buildings, with adjacent laboratory space, to provide facilities for the reception of VLF and UHF time signal transmissions and for experimental testing of advanced radio-communications systems. Other special facilities include those made for the secure and safe storage of hazardous or flammable materials.

One floor of the most centrally located building is dedicated to the Headquarters' Library, a theatrette and the staff cafeteria. The facilities and amenities so provided are substantial improvements on the past and create very pleasant environments for staff to seek technical information on one hand or sustenance and recreation on the other.

The single storey storage building houses the centralised goods reception centre for the Laboratories and secure longer-term storage areas for small components and materials, laboratory test equipment, archival library material, and laboratory furniture and fittings. It also accommodates workshops for maintenance staff.

The second stage development also encompassed the extension of internal roadways and walkways, the provision of several car parking facilities and garden landscaping. This work has substantially developed the whole northern end of the Monash site into a visually attractive as well as a functionally excellent working environment.

As funding permits, further staged developments of the Monash site will enable the activities presently housed in the leased premises at Winterton Road, Clayton, to be housed in more permanent accommodation. Presently, preliminary studies of the future long-term accommodation requirements of the Laboratories are being undertaken as a pre-requisite to the planning and specification of further developments on the Monash site.

Telecom Australia's PCM Repeater Specification Accepted by CCITT

A new technique developed by the Research Laboratories to characterise the crosstalk performance of digital line systems has achieved international recognition by being accepted by the International Telegraph and Telephone Consultative Committee (CCITT). The technique determines a specification called the Crosstalk-Noise Figure which quantifies the immunity of a particular digital line repeater to crosstalk interference. The specification, proposed by Telecom's Research Laboratories, was included in the modified CCITT Recommendations G.911, G.912 and G.921, which were prepared by Study Group XV and which relate to both North American and European Line Systems.

With digital line systems, repeaters are installed about every 2 km along the cable. Coupled crosstalk interference arises between co-located repeaters installed on different pairs in the same cable, and this limits the maximum number of systems which can be employed in a cable or the maximum distance between repeaters. The actual limits depend both on the crosstalk characteristics of the cable and on the sensitivity of the digital repeaters to this type of interference.

The Crosstalk-Noise Figure specifies a repeater's sensitivity to crosstalk. It can be readily measured for each repeater and can then be directly used by network designers to determine the maximum acceptable distance between repeaters for a given maximum number of systems on any proposed cable with established crosstalk characteristics. For a given digital line system error rate objective and a given number of required systems, repeaters with a better (i.e. lower) Crosstalk-Noise Figure performance can be more widely spaced along the cable and can therefore lead to reduced system costs.

Telecom has applied for patents for a system and method for measuring the Crosstalk-Noise Figure. The Research Laboratories have carried out studies and measurements to verify the practicality of the Crosstalk-Noise Figure concept. This work has been widely reported in technical publications and provided the basis of CCITT contributions by Telecom which led to the international acceptance of the Crosstalk-Noise Figure.

Prior to its acceptance by the CCITT, Bell Telephone Laboratories of the American Telegraph and Telephone organisation (AT&T) became interested in the Crosstalk-Noise Figure and commenced their own evaluation of its relative merits. During their investigations, they loaned several AT&T repeaters to the Telecom Research Laboratories as part of a joint program to assess the Crosstalk-Noise Figure measurement technique.

Australian industry has also been involved in this project and a prototype instrument for measuring Crosstalk-Noise Figure has been developed. This work was carried out under Telecom's industrial R&D contract program, which aims to foster the development of indigenous industrial expertise in telecommunications within Australia.

Crosstalk — Noise Figure test instrument

First National Workshop on Fault-tolerant Real-time Computing Systems

On 26 and 27 October 1982, the Research Laboratories hosted the first Australian National Workshop on Fault-tolerant Real-time Computing Systems.

The objectives of the Workshop were to bring together, in a representative Australian forum, academics with known expertise on fault-tolerant real-time computing systems and researchers, designers and operations personnel with experience of fault-tolerant telecommunications networks and switching systems. These objectives were achieved; the Workshop provided an excellent opportunity for the presentation and discussion of papers describing current work on this topic. It also enabled initial discussions to be held on the specific issues of terminology and performance objectives for fault-tolerant real-time telecommunications systems.

In order to promote group discussion of individual papers, attendance at the Workshop was restricted to 20 active participants and six observers. The participants were invited from Telecom Australia, the Overseas Telecommunications Commission (Australia), the Department of Defence, and four Australian Universities.

The Workshop included discussion of the following topics:

- Progress in the CCITT towards relevant terminology and performance objectives
- Progress in IFIP Working Group 10.4 (Reliable Computing and Fault Tolerance)
- Telecom Australia's operational experience with fault-tolerant switching systems
- How Telecom currently measures the reliability of its fault-tolerant systems and network
- Performance constraints for telecommunications networks
- The software reliability problem
- The Exchange Service Indicator concept
- Classification of fault-tolerant systems by processor architecture and software complexity
- Fault-tolerance of communicating sequential processors
- Modelling and performance analysis of fault-tolerant systems.

Follow-on activities from this Workshop will consist of the preparation of Australian contributions on performance objectives and relevant terminology for digital telecommunications switching systems to the CCITT Working Party XI/4, and also the preparation of Australian contributions to a proposed meeting of the IFIP Working Group 10.4 in Melbourne in February 1984.

Melbourne Meetings of Working Parties 2, 4, 5 and 6 of CCITT Study Group XI

In April 1983, Telecom Australia hosted meetings of Working Parties 2, 4, 5 and 6 of CCITT Study Group XI in Melbourne.

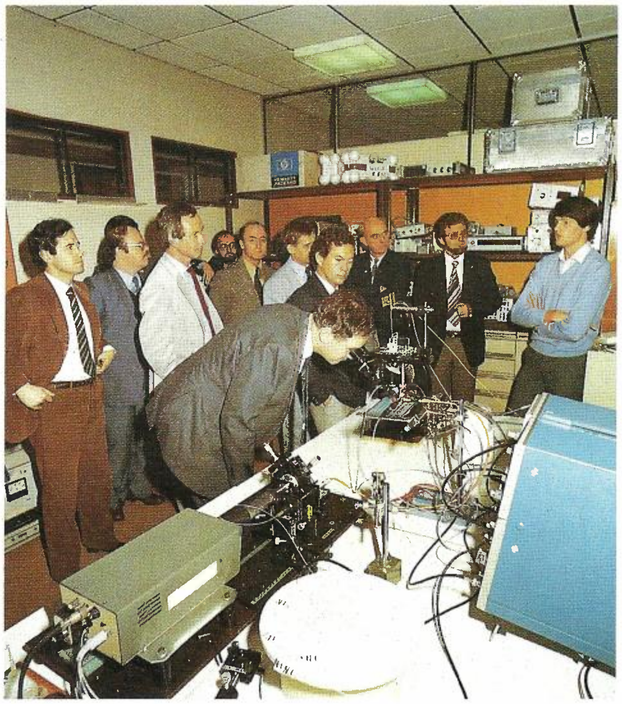
The CCITT Study Group XI is responsible for the development of recommendations for telephone switching and signalling systems and networks, with emphasis in the 1981-1984 study period on networks employing digital rather than analogue technology and on digital switching and signalling systems capable of supporting a range of customer services in addition to telephone services.

Working Party XI/2 is responsible for developing new standards for common channel signalling, using the CCITT No. 7 common channel signalling system.

Working Party XI/4 is responsible for developing specifications for digital transit and local telephone exchanges, capable of supporting integrated services as well as digital telephony.

Working Party XI/5 is concerned with making recommendations for national switching systems, with emphasis on the analogue network and the evolution from an analogue to a digital network.

Working Party XI/6 is concerned with developing standards for the signalling architecture for access from digital subscribers' equipment to public telecommunications networks.



Presentation on near-field measurement technique for single-mode fibre spot size to CCITT visitors

A total of 200 delegates from 20 countries attended the meetings in Melbourne, which were held over a period of three weeks from 11 April to 29 April, 1983.

Telecom's Research Laboratories were jointly responsible with the Engineering Department and the Secretariat at Headquarters for the organisation of the meetings. The Secretariat concentrated on administrative arrangements and the Research Laboratories and Engineering Department concentrated on technical matters. Mr. P.H. Gerrand (Research Laboratories) was the Chairman of the Organising Committee, and Mr. W.J. Hurren (Secretariat) and Mr. R. Darling (Engineering Department) were the Vice-Chairmen.

Mr. M. Betancourt, CCITT Counsellor, Mr. J. Ryan (Chairman, CCITT Study Group XI), Mr. P. Collet, Dr. S. Kano, Mr. P. Plehiers, Mr. R. Slabon and Mr. P. Sterndorff (Vice-Chairmen of CCITT Study Group XI) were amongst the international experts attending the meeting.

Following the CCITT meetings, a number of overseas delegates took the opportunity to visit Telecom's Research Laboratories for further discussion of projects of mutual interest.

Seminar on International Standards for Digital Telecommunications Networks

Following the Melbourne meetings of the CCITT Study Group XI Working Parties, Telecom Australia hosted a seminar on "International Standards for Digital Telecommunications Networks". The seminar was held at the Hotel Regent of Melbourne on 3-4 May 1983 and attracted an audience of over 400 people. The official opening was performed by the Chairman of the Australian Telecommunications Commission, Mr. R.W. Brack, AO.

The seminar was chaired by Dr. F.J.W. Symons of the Research Laboratories, who also chaired Telecom's organising committee. This committee comprised representatives of the Research Department, the Planning Division of the Engineering Department, and the International Branch at Headquarters.

Speakers at the seminar and their topics were:

- F.J.W. Symons (Telecom Australia): An Overview of Developments and Trends in the Key Features of Telecommunications Networks
- J. Ryan (AT&T, USA): The Setting of International Standards for Future Digital Telecommunications Networks
- S. Kano (NTTPC, Japan): Digital Access to Telecommunications Networks
- R.W. Slabon (Deutsche Bundespost, West Germany): Digital Switching in the Multiservice Digital Network
- P. Plehiers (RTT, Belgium): Common Channel Signalling in the Multiservice Digital Network
- D. Donohoe (AT&T, USA): Experience with Common Channel Signalling and Network Management in North America
- M. Romagnoli (SIP, Italy): Experience with and Plans for Common Channel Signalling in Europe
- R. Partridge (British Telecom): The UK Experience in Planning and Evolving towards a Multiservice Digital Network
- J. Craveur (CNET, France): Interfacing PABXs, Private Networks and Local Computer Networks to Future Digital Telecommunications Networks
- W. Dair (Telecom Australia): An Australian Perspective of Future Digital Networks
- P. Darling (Telecom Australia): Stepping Stones in the Evolution of an Australian Multiservice Digital Network.

Panel sessions were included among the individual presentations and allowed delegates to question the overseas and Australian experts.

The seminar enabled an Australian audience to hear, at first hand, expert descriptions and opinions of telecommunications developments which will increasingly impact on all areas of life in Australia.

The seminar was of direct relevance to users of telecommunications services and facilities and to suppliers and manufacturers of telecommunications equipment. Since the effectiveness of local computer systems and the electronic office depends strongly on the development of suitable telecommunications network standards, the seminar also provided an opportunity for discussions among experts from both the telecommunications and the computer sectors, enabling both sectors to plan future developments with greater confidence.

Melbourne Meeting of CCIR Interim Working Party 4/1

During the last week of May 1983, Telecom Australia hosted a meeting of Interim Working Party 4/1 (IWP 4/1) of the International Radio Consultative Committee (CCIR) in Melbourne. The Working Party which is part of CCIR Study Group 4 (covering the fixed-satellite service), is responsible for technical studies concerned with the efficient utilisation of the geostationary satellite orbit.

There is only one geostationary orbit – the orbit in which a satellite will appear to remain stationary over the earth. This orbit is a circular path which lies over the equator, 36 000 km above the earth. Practical constraints impose limits on the communications capacity of this orbit, but new developments progressively extend these limits. The geostationary orbit is often viewed as a limited natural resource although, unlike many other such resources, it can never be exhausted and it is only of value while it is being used!

Planning and regulation of the use of the geostationary orbit is one of the most contentious issues facing the International Telecommunication Union (ITU). The views of member countries of the ITU differ. Some wish to see this resource apportioned and allocated by a fixed plan as soon as possible; other countries wish positions to be assigned only as needs arise, so that some planning flexibility is retained to enable advantage to be derived from future technological developments which increase the overall communications capacity of the orbit.

These issues are being discussed in a series of CCIR meetings, culminating in a World Administrative Radio Conference (WARC), in two sessions scheduled for 1985 and 1988 respectively, which will seek to resolve the issue. Within this wider context, the function of IWP 4/1 is to develop a sound base of objective technical facts against which the regulatory options can be assessed.

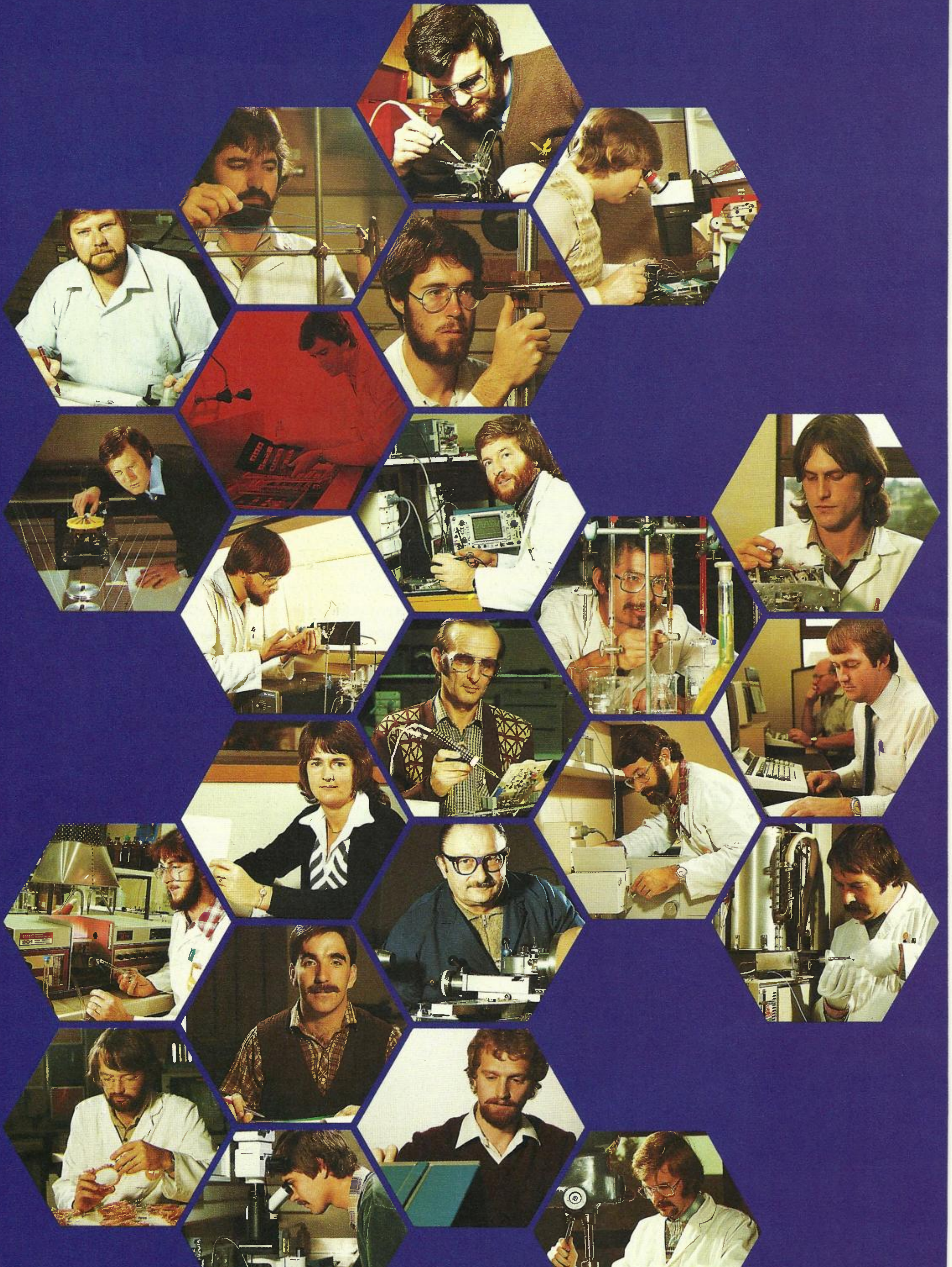
The topics under study by IWP 4/1 concern the design of satellite systems, particularly in relation to the management and control of interference levels between systems sharing the same frequency assignments. The interference effects being studied can occur both between different satellite systems and between satellite systems and terrestrial radio relay systems.

It is interesting to note that the only previous meeting of a CCIR body in Australia was also of IWP 4/1, in 1972. Other meetings of IWP 4/1, which was established in 1968, have been held in Ottawa, London, Washington, Munich, Tokyo, Paris and Geneva. The proposal for the 1983 Melbourne meeting arose from discussions between the CCIR and the late Mr. Eric Craig of the Research Laboratories. Mr. Craig was Chairman of Study Group 4.

The Melbourne meeting of IWP 4/1 was held at Telecom Australia's Headquarters. It was attended by 26 delegates representing 10 countries in Europe, North America, the Middle East and Asia.

During the week of the meeting, many papers outlining proposals for improving the use of the geostationary orbit were presented. The papers and subsequent discussion of the proposals have provided the basis for the drafting of a new technical report on the efficient utilisation of the geostationary orbit. This report will be brought to the attention of the CCIR Conference Consultative Group which meets in Geneva in July 1983, to plan for the CCIR Conference Preparatory Meeting (CPM) which is scheduled for July 1984. The report will form an input document to the CPM, which in turn has the responsibility of preparing technical guidelines related to the geostationary orbit for consideration by the World Administrative Radio Conference in 1985.

From the many comments received from delegates, the Melbourne meeting of IWP 4/1 provided a positive step forward in resolving some of the issues related to international use of the geostationary orbit.



In accord with their functions, the Laboratories are engaged in a large number of research investigations and developmental projects in the engineering and scientific fields. This work is chosen for its relevance to Telecom Australia's customer services and network systems, and it comprises a wide variety of specific topics pertinent to the present technical standards and future technical advance of these services and networks.

It is not possible to report, even briefly, on all Laboratories' projects in this Review. As a consequence, the activities outlined 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 telecommunications science and technology. A more comprehensive list of current projects is issued in the "Research Quarterly" and this is available to selected bodies with 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. The report is the vehicle by which the results of the work are conveyed to the "client" and other interested sections of Telecom Australia, and in many cases, to other telecommunications agencies, industry and research bodies, both local and overseas. Conclusions resulting from research studies are, on appropriate occasions, documented as contributions to the deliberations of national and international bodies concerned with technical standards relating to telecommunications.

The staff of the Laboratories also 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.

A Low Cost Audio Terminal for Multi-location Teleconferencing

There is increasing interest in a variety of teleconferencing services, both in Australia and overseas. Among the various possibilities, small-group multi-location audio-conferencing is one form of teleconferencing service for which there are existing and foreseeable applications, particularly in educational and business environments.

In essence, such a service requires simultaneous speech communication facilities to be established between small groups of people, where each group might be located anywhere within a private, national or international telecommunications network. If this basic speech facility can be enhanced by auxiliary media links to provide facilities for image, graphics and text communications or for remote device control, a new and versatile set of communications options becomes available to individuals and organisations.

Two basic types of equipment are required for a small-group multi-location conference to take place. Firstly, a means must be provided for establishing simultaneous communications between all locations involved. A device which allows such multi-point connection is generally known as a conference bridge. Secondly, special conference terminal equipment must be available at each location for use by the group of people at that location. Though a variety of bridges and conference terminals is currently available, further development is required in both areas if present and future needs for this form of conferencing are to be adequately serviced.

As part of its program of studies in teleconferencing, the Research Laboratories have developed laboratory prototypes of a low cost audio-conferencing terminal that is well suited to multi-location, small-group conferencing via the public telephone network. In a related project, work is also in hand on the development of an automatic conference bridge which allows individuals to set up their own multi-point connection without operator assistance or intervention. Though the bridge and the conferencing terminal are independent entities, each with an application in its own right, together they constitute a powerful solution to the technical and operational problems of providing a basic multi-location, small-group conferencing service.

The experimental terminal is intended to provide a vehicle for laboratory and field studies of teleconferencing and for demonstrating the possibilities of this type of service to Telecom management and potential users. The design objectives for the terminal were that it should be compatible with the existing telephone network, well suited to multi-location working, and usable in the wide range of acoustic environments likely to be encountered in meeting rooms, class rooms, offices, etc, where a small group of people might meet to participate in a teleconference.

The prototype terminal has been configured as a plinth-style telephone attachment. It requires no special installation procedures and can be used as a portable terminal if so required. Speech from the local group of participants in the conference is picked up by a central microphone which is column-mounted on the plinth. The local conferees hear the speech incoming from other conference locations through light-weight, cordless headphones.
The headphones are acoustically transparent to allow free communication between the local conferees.
An infra-red optical carrier is modulated by the incoming speech signals and the modulated signal is transmitted from the plinth to individual receivers worn by each of the local conferees, achieving cordless operation. As a bonus, this design approach enables each individual to adjust the volume or listening level to suit his own preference and hearing sensitivity.

With a system of this nature, acoustic feedback is effectively eliminated. Consequently, comfortable listening levels can be attained, a sensitive microphone may be used, and there is no need for voice switching or press-to-talk operational procedures.

The prototype terminal also has some simple, but important, auxiliary media capabilities. Signals from conventional audio equipment, microphones, tape decks, public address systems, etc can be transmitted and received through inputs and outputs provided at the rear of the terminal. A standard 12-key dialling pad is incorporated and dual-tone multi-frequency (DTMF) dialling tones can be transmitted while a conference is in progress. Such tones could be used as required to control devices in the network or at other conference locations. It is intended that subsequent prototypes will have a capability not only to send but also to detect and decode DTMF tones. Thus, during a conference session, ancillary equipment at one location (e.g. a slide projector, videotape player or computer system) could be controlled from any other location involved in the conference.

During 1982, six of the prototype audio-conferencing terminals and the experimental conference bridge were used in combination in a field study of teleconferencing in a rural district. The main emphasis in the study was on teleconferencing for educational purposes, but it also provided valuable information on the design and performance of the equipment. A number of design modifications were subsequently made in the light of this field experience and user comments. However, the study showed that, in general terms, both the concept and implementation of the terminal and the teleconferencing service were well regarded by the participants.

Several second generation prototypes of the terminal were used in a diffusion of innovation study described in this Review, while others have been made available to the Headquarters Commercial Services Department for assessment. Some units have been used by the NSW Administration in a pilot project for the training of business office staff by means of teleconferencing. Laboratories' staff have also used the terminals for a number of meetings and discussions. Some of these have been multi-location conferences, while others have used ordinary dial-up connections between two locations only. Local, interstate, and international discussions have all proved viable using the equipment.

In view of the equipment's potential and the interest it has aroused, the Laboratories are investigating means by which units could be further developed and manufactured by local industry.

The Diffusion of Innovation Study

A regular problem for telecommunications planners lies in forecasting the size of markets for new telecommunications services and the rate at which these markets will develop. The Laboratories are presently conducting a "Diffusion of Innovation" study in an attempt to shed new light, through the application of diffusion theory and social network analysis, on the processes through which one possible new telecommunications service, namely audio-conferencing, is adopted.

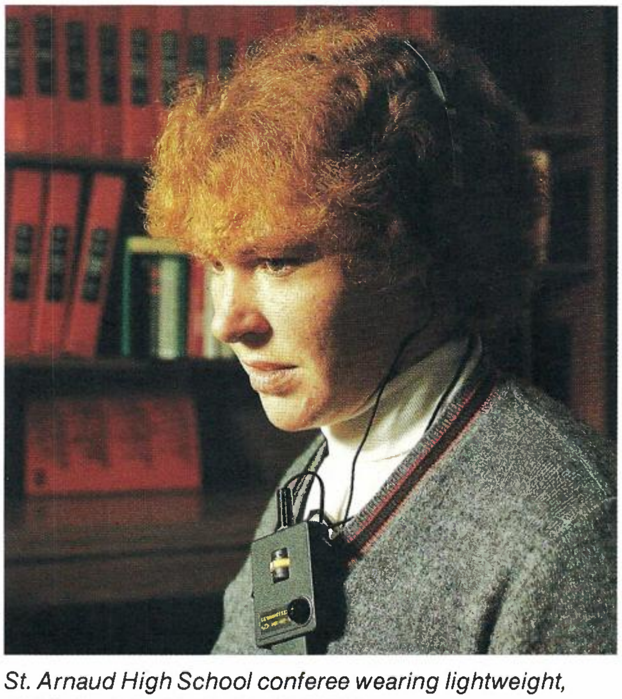
The study is taking place in a rural area of north central Victoria which includes the townships of Birchip, Boort, Charlton, Donald, Wedderburn, Wycheproof and St. Arnaud. This region had already been exposed to the concept of audio-teleconferencing as a result of a "distance education" project conducted jointly by the Research Laboratories and the Country Education Project during the second term of the 1982 school year.

Members of history class at Boort High School using the small-group teleconferencing terminal

In November 1982, equipment similar to that employed in the educational project was made available to the rural communities as a whole. Experimental small-group audio-teleconferencing terminals which were developed in the Laboratories were provided to schools and Shire Offices in each town, and, to permit group communication between people at up to ten locations (whether linked via the special terminals or via standard handset telephones), a commercial conference bridge was installed in the St. Arnaud telephone exchange.

The theoretical structure for the study was derived from diffusion theory, which maintains that inter-personal communication greatly influences people's decisions to adopt, or not to adopt, a new product or service. In order to trace inter-personal communication in the experimental region, a study population of 658 people was assembled by means of a modified "snowball" technique. Of these people, 534 were interviewed in person or by telephone before the study began. Each person was asked to nominate others in the district with whom they spoke at least once a month. This data was then analysed by means of a NETMAP program to produce graphical representations of the social networks within the district, and predictions were made about the direction and rate of diffusion of the innovation within them. Also included in the interview questions was a group of items of the kind commonly employed in conventional market surveys, in order to provide a benchmark against which the predictive power of the diffusion approach could subsequently be measured. To test the success of the network-based predictions, repeat interviews were conducted among the study population in March 1983 and again in June 1983, and this additional data will be analysed in conjunction with data obtained relating to the usage of the small group terminals and the conference bridge.

The Diffusion of Innovation study, while initiated by the Research Laboratories, has required the co-operation and interworking of many groups and individuals. The Workshops of Telecom Australia's Victorian Administration constructed the small-group teleconferencing terminals; staff of the Bendigo Telephone District are maintaining the equipment in the field; and the Commercial Services Department (Victorian Administration) is providing for liaison between the staff of the Laboratories and Telecom Australia's field staff in the study area. Touche Ross Service Pty. Ltd. conducted the telephone interviews, and Dr. J.J. Galloway, Senior Lecturer in charge of Communication Studies at Macquarie University, has acted as a consultant throughout the study to the group of Research Laboratories' psychologists and technical officers who form the nucleus of the project team.



St. Arnaud High School conferee wearing lightweight, cordless receiver and headphones

A Voice Store and Forward Service Simulation

Telephone traffic statistics indicate that a significant proportion of call attempts are unsuccessful due to the called subscriber being busy or not answering. One method of providing more efficient telephone communications in these circumstances is to promote the use of a voice store and forward (VSF) service, sometimes referred to as "voice mail". Such a centralised network service can record and store spoken messages and deliver them at some later user-specified or system-scheduled time. The VSF service will attempt to deliver messages until it is successful. Alternatively, a subscriber may dial the VSF service and retrieve any outstanding messages destined for him, in which case the VSF service functions as an intelligent answering machine.

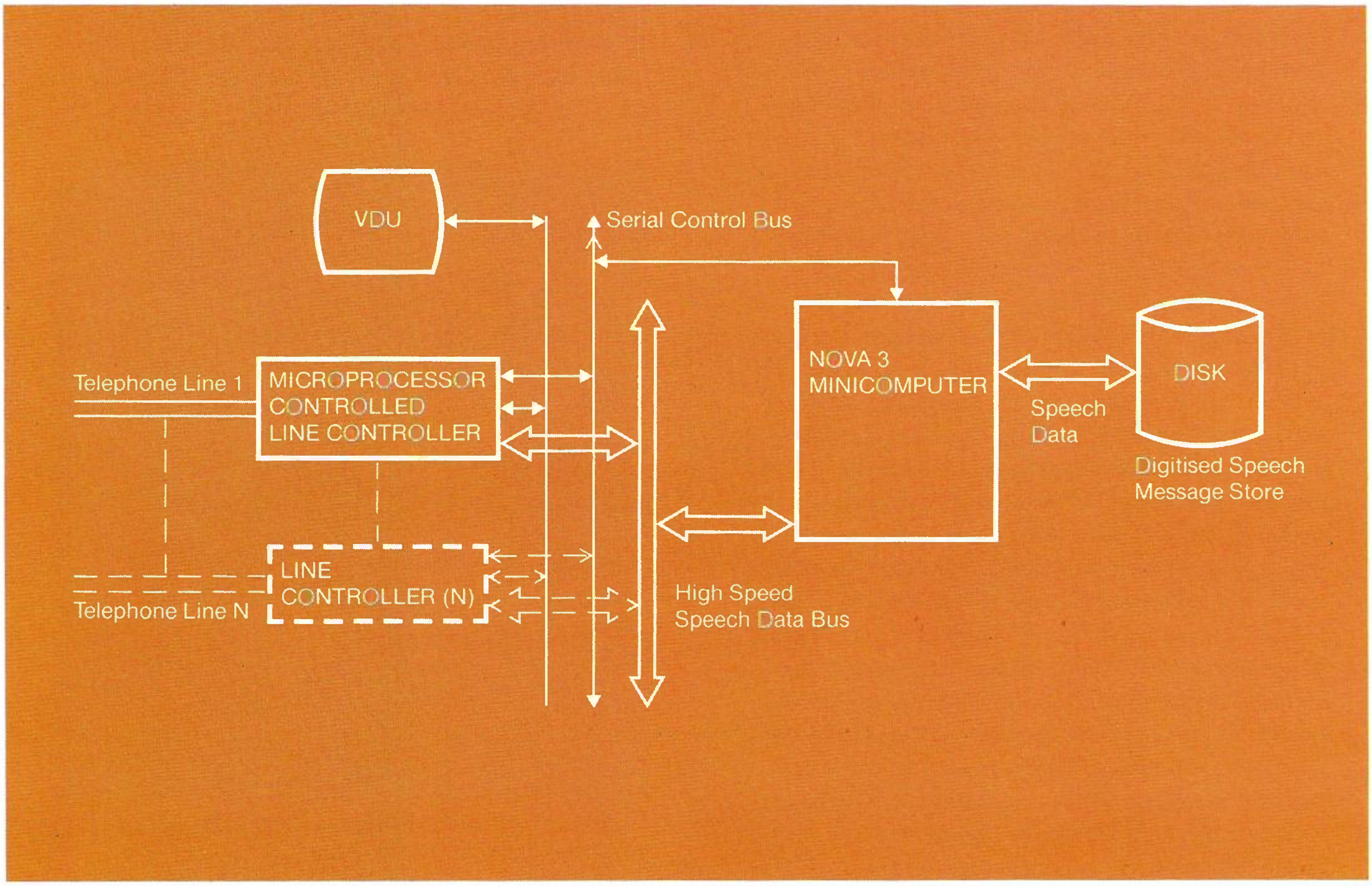
A small scale experimental VSF system has been designed and built by the Research Laboratories to investigate the design parameters and the user interface requirements of such a service.

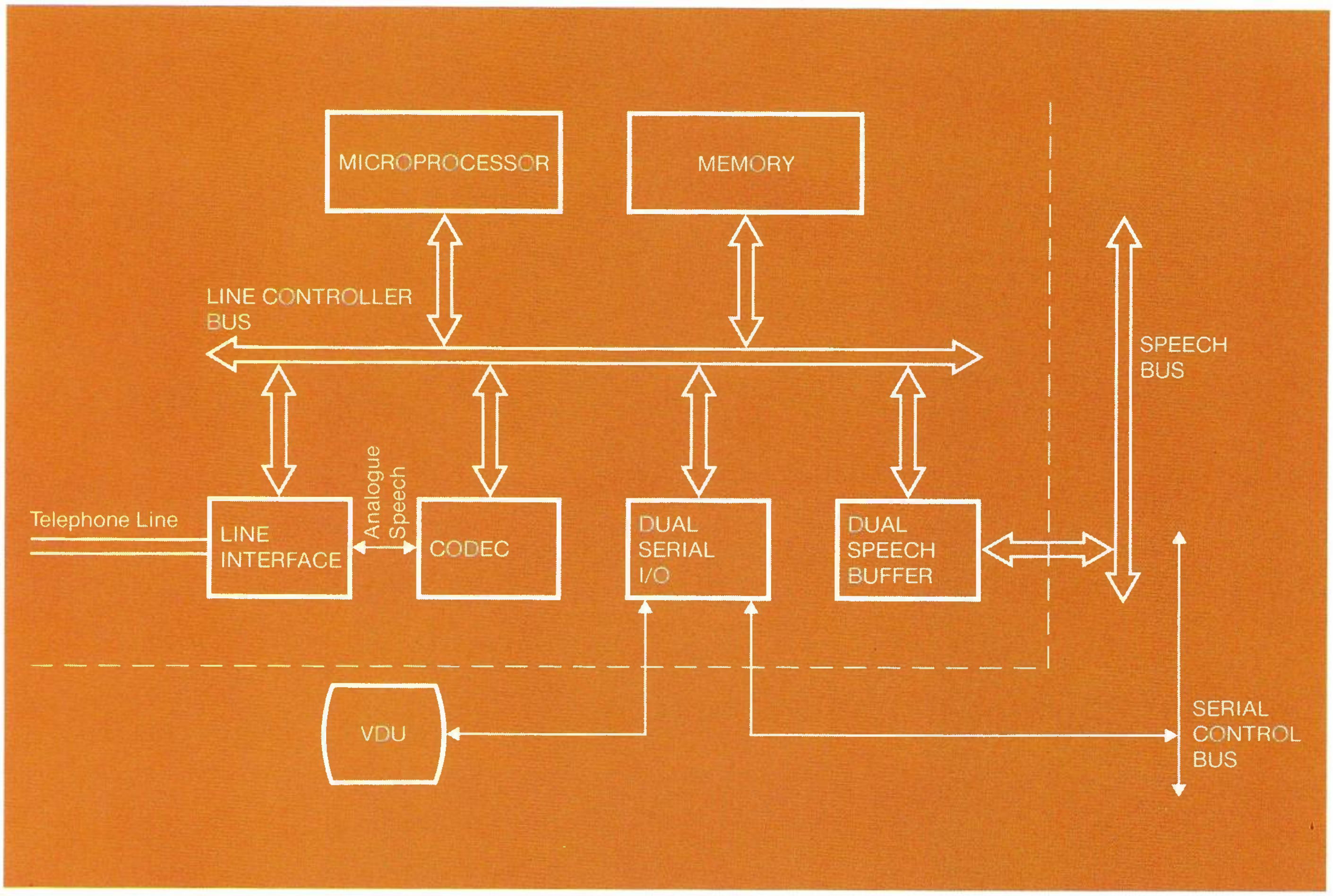
In the experimental system, the telephone user communicates with the VSF system via his line controller by means of dual-tone multi-frequency signals from a telephone keypad. The user, in turn, is prompted by spoken messages from the VSF system. A common NOVA 3 minicomputer stores and retrieves digitised speech data, schedules message deliveries, provides security checks, gathers statistical data and provides time keeping.

Under microprocessor control, the line interface of the line controller sets up speech and signalling paths to the user for both outgoing and incoming calls. Analogue speech is digitised by a codec for storage in the minicomputer or is retrieved and decoded for speech prompts and voice message delivery. A visual display unit provides a facility for communicating with either the NOVA 3 minicomputer or any line controller microprocessor for system monitoring and testing purposes.

As currently implemented, the experimental system requires that any user must enter his unique privacy code to gain access. The user may choose to input a message for subsequent delivery to another subscriber, retrieve any messages that have been left for him, or check the status of previously initiated messages. In using any of the available optional facilities of the system, the user is guided by voice prompt messages.

Schematic diagram of experimental voice store and forward system





Schematic diagram of line controller in the voice store and forward system

Tests on a Digital Speech Interpolation System

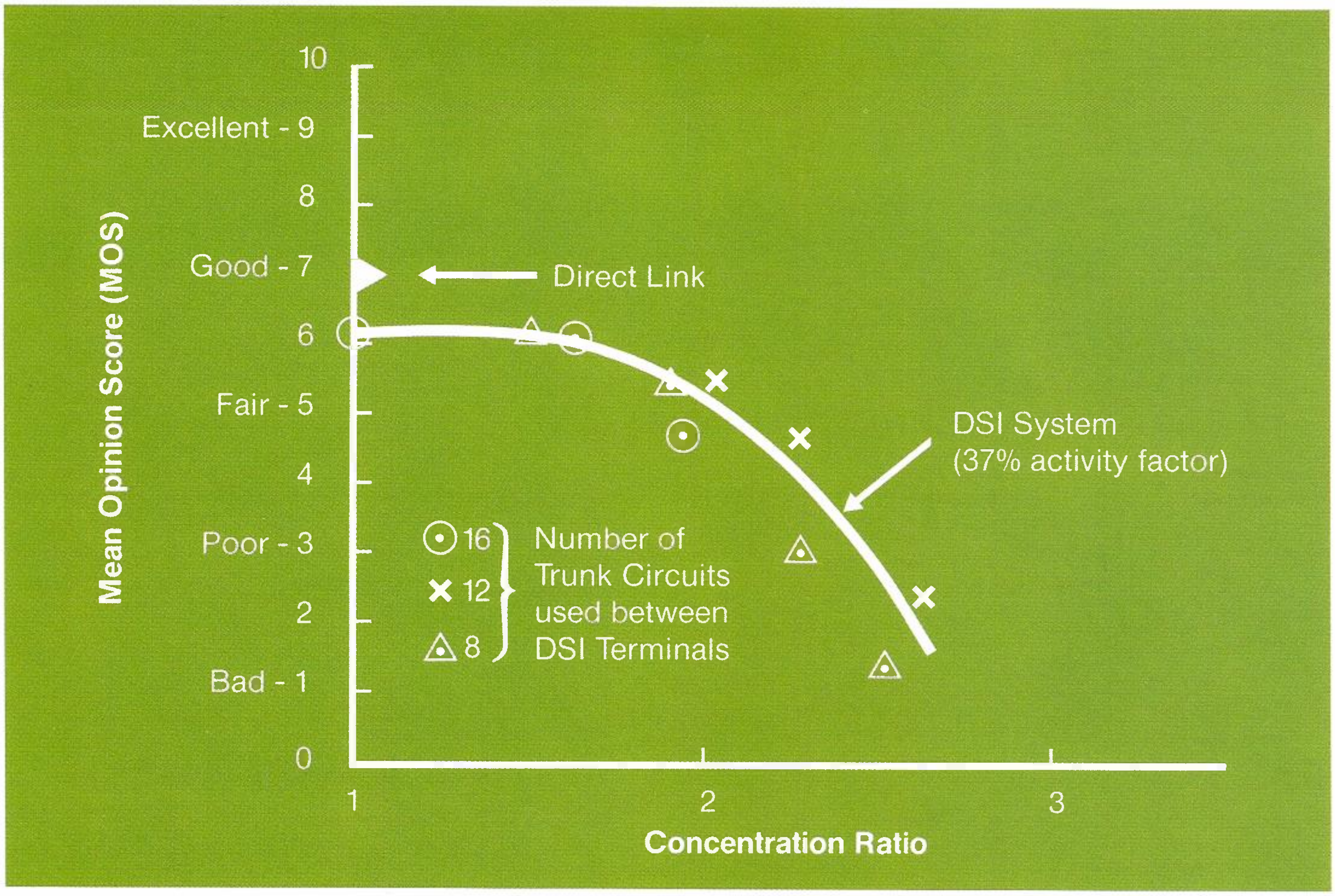
Time assignment speech interpolation (TASI) equipment which approximately doubles the capacity of trunk routes has been available for many decades. Such equipment exploits the fact that a channel is only needed during those periods when a user is actually speaking. In order to keep the probability of freeze-out (i.e. the non-availability of a channel at the instant it is required) to an acceptably low level, it has been necessary to restrict the use of such TASI equipment to large trunk groups where the statistics are more favourable.

More recently, digital versions known as digital speech interpolation (DSI) equipment have been developed which employ various forms of digital processing to improve performance, particularly for small trunk group sizes. Some of the techniques employed include:

- a fixed delay storage of speech for a few tens of milliseconds to allow the speech detector to "look ahead", to reduce clipping of initial sounds
- a variable delay storage of speech during periods of channel unavailability, to reduce clipping due to freeze-out
- the discarding of short segments of stored speech bursts, to allow the output speech to "catch up" after a significant storage delay
- the use of reduced bit-rate coding of speech (in fully digital systems only).

One version of a modern DSI system intended for small size trunk groups (31 derived circuits from 16 analogue circuits) has been evaluated in the Research Laboratories to investigate the effects of variable delay and shortening of speech bursts. Conversational tests were carried out on one circuit, while the remaining circuits were loaded with artificial speech (noise bursts with approximately the same on-off distribution as real speech, and an activity factor of about 37%). The quality for each condition was rated on an eleven point scale, and the mean opinion score (MOS) was plotted as a function of concentration ratio (effective circuit gain ratio) and compared with the rating for a similar direct link.

It was found that the quality falls significantly for concentration ratios greater than 2. Even for low concentration ratios, the quality is worse than the direct link, due mainly to noticeable switching of each speech burst. The propagation delay and burst shortening were also measured. For example, with 31 derived circuits fully loaded with traffic, carried on 12 trunk channels (giving a fairly high concentration ratio of 2.6), the median delay was increased from a few milliseconds to about 150 milliseconds and the median output burst length was shortened to 94% of its original length.



Perceived conversation quality with varying concentration ratios obtained with digital speech interpolation equipment

AUSTPAC Network Modelling

In 1982, the Laboratories were asked by the Headquarters Commercial Services Department to develop tools to assist the implementation of Telecom Australia's AUSTPAC Packet Switched Data Service. Computer programs were required to assist the design and dimensioning of the packet switched network to carry specified traffic loads.

The initial problem was to estimate the delays from one customer termination to another through the network for any specified offered load. The offered load was specified in terms of the number of customers at each exchange and their expected calling patterns, that is, the number and duration of calls, the number of packets per call and the amount of data per packet.

The problem was first tackled by developing a model of the network's performance and numerically solving for mean and variance of all unknown delays. Simulation studies are now planned to back up this analytical approach.

The processors and buffers within each exchange were modelled as a set of interconnected queues and servers, with individual packets following different paths depending on their destination and their function. The transmission paths of the network were also modelled as queues and servers, with additional fixed delays to account for propagation time. The model included the mean and variance of the arrival rate at each queue and the mean and variance of the service time of each server. Recently published theoretical work by P. Kuhn of Germany was adapted to the task of analysing the network of interconnected queues – iteratively solving for all unknown means and variances.

A set of computer programs was developed on Telecom's TACONET computer network and handed over to the Commercial Services Department for preliminary use in November 1982. The programs read data files, which are stored in human-readable format, and produce reports which give details of the mean and 95th percentile delays through the network. After initial experience with the operation of the system, the programs will be revised and a final version issued, together with complete user, system and technical documentation.

In the next phase of the work, dimensioning programs will be developed. The program inputs will be traffic demand and delay of links between every pair of exchanges. For the AUSTPAC project, it is planned to adapt methods which have been developed previously for optimising circuit switched networks subject to grade of service constraints.

Improved Formal Methods of Specifying X.25 Data Communications Protocols

A data communications protocol is a set of procedures which supports communication in a data network. Typically, protocols control calls, errors and the flow of information. It is important that they be precisely described and specified.

Traditionally, a natural language such as English has been used. However, since a precise, consistent and unambiguous natural language specification is a rarity, alternative ways of describing protocols have been widely explored.

One approach is that of the CCITT Specification and Description Language (SDL). In SDL, the operation of communicating abstract machines (or extended finite state machines) specifies protocols. The CCITT has provided a graphical, flow-chart-like syntax for describing the abstract machines of SDL, and it is now developing more precise semantics.

A complex data communications protocol to which the SDL technique has been applied in the Laboratories, and elsewhere, is the LAPB protocol of CCITT's X.25 Recommendation. In applying SDL to LAPB, there appeared to be unnecessary redundancy and complexity in the resultant specification, such that there was room for improving the specification by making it more concise, more elegant and simpler to understand.

The Laboratories have recently investigated methods of improving the conciseness and clarity of the specification. The changes made to improve the specification did not necessitate change to the underlying SDL model; only additions to the syntax of the language were required to make it more expressive. The syntactical addition which proved to be most effective was an element which allowed a hierarchy of machines to be described.

Each machine in SDL is known as a process, and the additional syntactic element which describes hierarchically related machines is called an "inner process" symbol. There is value in visualising the introduced idea as a hierarchy of co-operating processes since this clarifies the relationship between inner processes and the basic SDL. However, it is sometimes preferable to regard the hierarchy as a single process. From the perspective of a single process, a very flexible way is created for describing strings of SDL symbols that can replace the introduced inner process symbol. This has been achieved while retaining a finite-state machine orientation in the specifications.

The application of this technique and two other minor syntactical extensions reduced the X.25 LAPB description from 1630 SDL symbols to 558 symbols. This has allowed the protocol to be more clearly described and easily understood.

In X.25, the packet level protocol is an obvious candidate for further application of these ideas.

Data Network Interworking

The establishment of Telecom Australia's Packet Switched Data Service, AUSTPAC, has dramatically increased the opportunities for interworking between data networks. Hence, a variety of aspects related to the provision of connections between the packet switched network (PSN) and other public networks, such as the national telephone and telex networks and overseas packet switched networks, are currently under study within the Laboratories. The work in this area, and in the area of interworking with private packet switched networks and local area networks, is also providing a basis for Telecom Australia's contributions to CCITT international standardisation activities.

In many cases, no standard technique or protocol is yet available for interworking between networks. This is especially true for private networks, and until some more appropriate protocol becomes available, private networks must use CCITT Recommendation X.25 for interworking. This protocol was designed to permit communication between a data terminal and a public PSN. A private network using X.25 must emulate the actions of a single public network terminal, and it must utilise a gateway device between the two networks to implement the required protocols on each side and to perform the necessary data, format and address conversions.

With this arrangement, the full complement of X.25 services and facilities may not be available to terminals on the private network. Difficulties with addressing and with call progress signalling may require software modifications within the private network. For instance, in relation to the addressing aspect, a normal public network address will identify only the gateway to the private network. The address of a terminal within the private network must be carried in some other way, in such a fashion that the packet remains compatible with the version of X.25 supported by the public network.

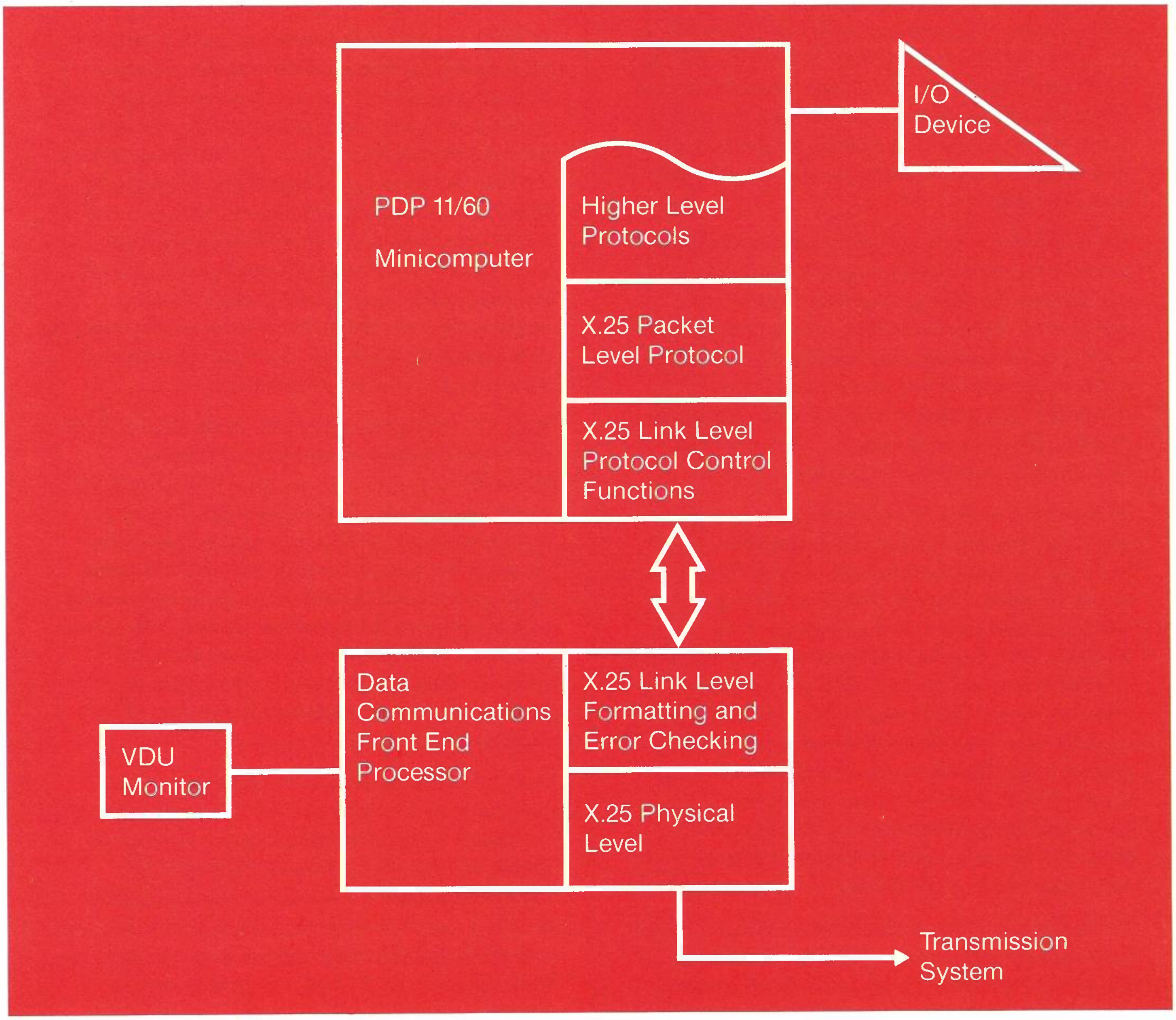
In recent years, the Research Laboratories have pursued studies which have enabled contributions to be made to international discussion on the topic of addressing and other aspects of interworking. Continued studies in this field are being pursued to provide a source of competent advice on data network interworking for internal application within Telecom Australia as the AUSTPAC service is developed further and as more private network operators with diverse requirements seek connections. The work will also provide further inputs to the CCITT, with the hope that this Australian participation will result in the early standardisation of a comprehensive and flexible method of interworking between private and public data networks, to the benefit of both the public network operator like Telecom Australia and also of the private network operator and the telecommunications manufacturing industry.

A Data Communications Front End Processor

The advent of packet switching networks allows user access to high performance data communications services offering a wide range of facilities. The protocols required to use such facilities are necessarily complex. Implementation of these protocols can make significant real-time processing demands on computer systems and consume a significant proportion of system resources, especially with interrupt handling.

There will be an increasing trend towards the realisation of such data communications functions in dedicated VLSI circuit devices as standards emerge and become accepted. This trend will result in the removal of many data communications processing overheads from computer systems. An interim arrangement could use a communications front end processor to perform some low level protocol

Schematic diagram of experimental X.25 packet switching terminal showing distribution of protocol functions



functions and use direct memory access (DMA) techniques for data transfer to and from a host computer.

To support studies of packet switching protocols and to provide a test bed for their experimental verification in a real-time environment, an experimental X.25 packet switching terminal has been implemented in the Laboratories. The terminal comprises a PDP 11/60 computer and a communications front end processor. The latter unit was built to enhance the performance of the experimental terminal and hence its potential as an experimental tool.

The front end processor utilises a 6809 microprocessor and a 6854 advanced data link controller in combination to perform the link level protocol data framing functions. Its purpose is to perform relatively simple, repetitive tasks that occur frequently. When a link level data unit (known as a frame) is required to be sent, an efficient DMA transfer passes the data content and relevant control information (typically about 1000 bits) to the front end processor. The processor then performs the functions of:

- calculation and appending of an error checking sequence to the message
- addition of frame delimiters to each end of the message and bit pattern manipulation, known as "bit-stuffing", to ensure that any data sequence can be sent by the user
- sending the frame to an appropriate serial transmission system.

The converse functions are performed when frames are received from a network or another terminal. The terminal is designed to support full duplex (simultaneous both-way) working. In order to perform these framing functions and support packet mode communications, the front end processor also performs the necessary physical level protocol functions.

To support experiments concerning the behaviour of the packet switching protocols in a real-time environment, the front end processor built in the Laboratories also collects a considerable amount of diagnostic and maintenance information. Some of this information, relating to the performance of the system, is displayed on a local visual display unit. Other information, relating to the protocol activity, is passed back to the host computer.

The composite packet mode terminal system is now being used to support studies related to protocol specification, testing, capacity and performance.

Interconnection of Private and Public Telecommunications Networks

De-regulation of the provision of telecommunications services in many parts of the world has given common interest and business groups the opportunity to design, construct and operate their own private telecommunications networks. These private networks may provide both telecommunications services as defined by the CCITT (such as teletex, videotex, etc) and non-CCITT-defined services (such as electronic file transfer, bank credit checking, etc) which are dedicated to the special needs of the common interest group.

It is anticipated that widespread use of private networks such as Local Area Networks (LANs) and integrated digital PABXs for automated office applications will become more prevalent in the business sector. Associated with these applications will be the need for these private networks to gain access to the public telecommunications networks. For this to be possible, it is necessary to define appropriate network interworking arrangements – commonly referred to as gateways.

The basic role of a gateway is to resolve the differences between two interconnected networks such that it permits communication between users on each of the different networks. This implies that an agreed set of functional interfaces and associated signalling procedures (or protocols) must be used at the gateway by the networks concerned.

The requirements for compatible interworking arrangements between interconnected networks will vary depending on the types and internal operation of the networks, especially their protocol architectures. However, no international standards currently exist to allow such compatible interworking. The Research Laboratories are therefore actively involved in studies of private-to-public network interconnection.

LANs constitute a class of networks which interconnect a variety of information processing systems by means of an efficient communication system. They differ considerably from the public network in several aspects, including network topology, transmission capacity and internal communication protocols. Standardisation of LAN protocols is under active study by several national and international organisations. Notable examples are the Institute of Electrical and Electronics Engineers (IEEE) 802 Local Network Standards Committee and the International Organisation for Standardisation (ISO), and to some extent, the CCITT.

The use of the ISO/CCITT Reference Model of Open Systems Interconnection (OSI) provides a common framework for the studies of aspects of LAN architectures by these organisations.

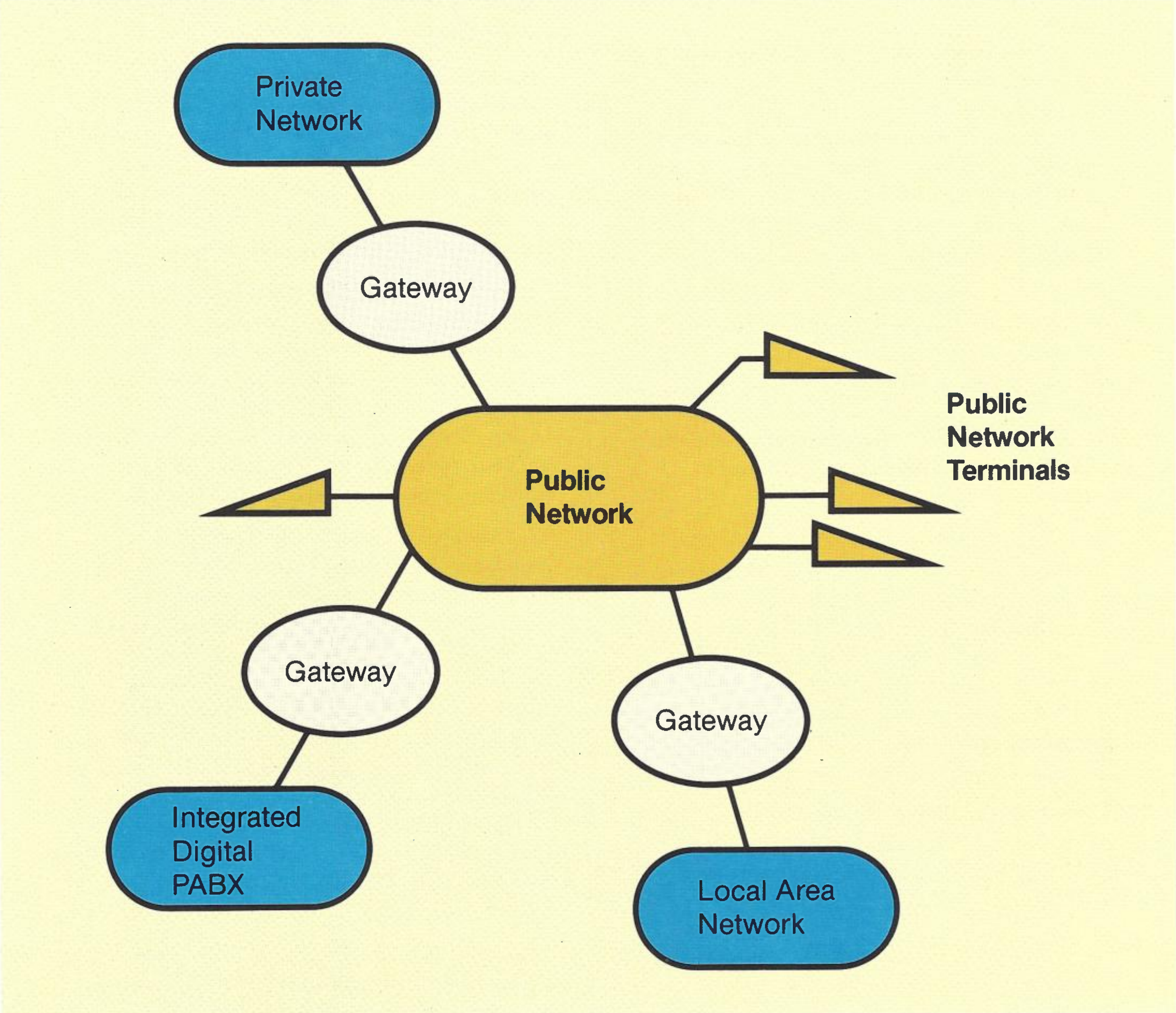
The Laboratories are following the same approach to study protocol architectures and interworking properties of LANs. Initially, the Laboratories' studies concentrated on LAN protocol architectures, since a sound understanding of these architectures is necessary before appropriate network interworking arrangements can be devised. The outcomes of these initial Laboratories' studies were summarised in a paper presented in August 1982 at the tenth Australian Computer Conference.

Studies of inter-networking issues are progressing. In view of the national importance of these issues and the relevant need for Headquarters groups to gain technical information, considerable effort has been expended on information dissemination through report publications and technical presentations.

The evolution of public networks towards an Integrated Services Digital Network (ISDN) environment will provide further impetus for LANs and digital PABXs (for both voice and data) to have access to the public networks. Moreover, opportunities will exist for interconnecting these networks to the ISDN using a set of universal customer-network access protocols. The work of the Laboratories in this field enabled a contribution to be made to the CCITT meeting held in Paris during November 1982, which was organised by Working Party XI/2 (Common Channel Signalling System No. 7) to discuss PABX-network access topics. The Laboratories' contribution suggested improvements to the existing draft for ISDN customer-network access protocols, which would allow existing protocols to be readily extended for PABX applications.

It is anticipated that further CCITT contributions will be made by Telecom Australia in this area in the future, as and when the studies being pursued in the Laboratories generate appropriate outputs.

Interconnection of private and public networks



ISDN Customer Access

Public telephone networks are generally becoming more digital in nature, with increasing use of 64 kbit/s Pulse Code Modulation (PCM) switching and transmission. This trend will produce, initially, a telephony-based Integrated Digital Network (IDN) and, later, a multi-service IDN in which customer-to-customer digital connectivity exists and through which a multiplicity of services (voice and non-voice) are accessible by the customer.

However, the IDN is increasingly being seen as a transitory step towards an Integrated Services Digital Network (ISDN) which, conceptually, may be regarded as a general-purpose network capable of supporting a range of different services (telephone, data, text, image, etc), using both circuit and packet switching techniques. The ISDN concept also provides a "unified approach" to the provision of these services and associated facilities, and it is therefore a concept being given increasing study in telecommunications research around the world, including Telecom Australia.

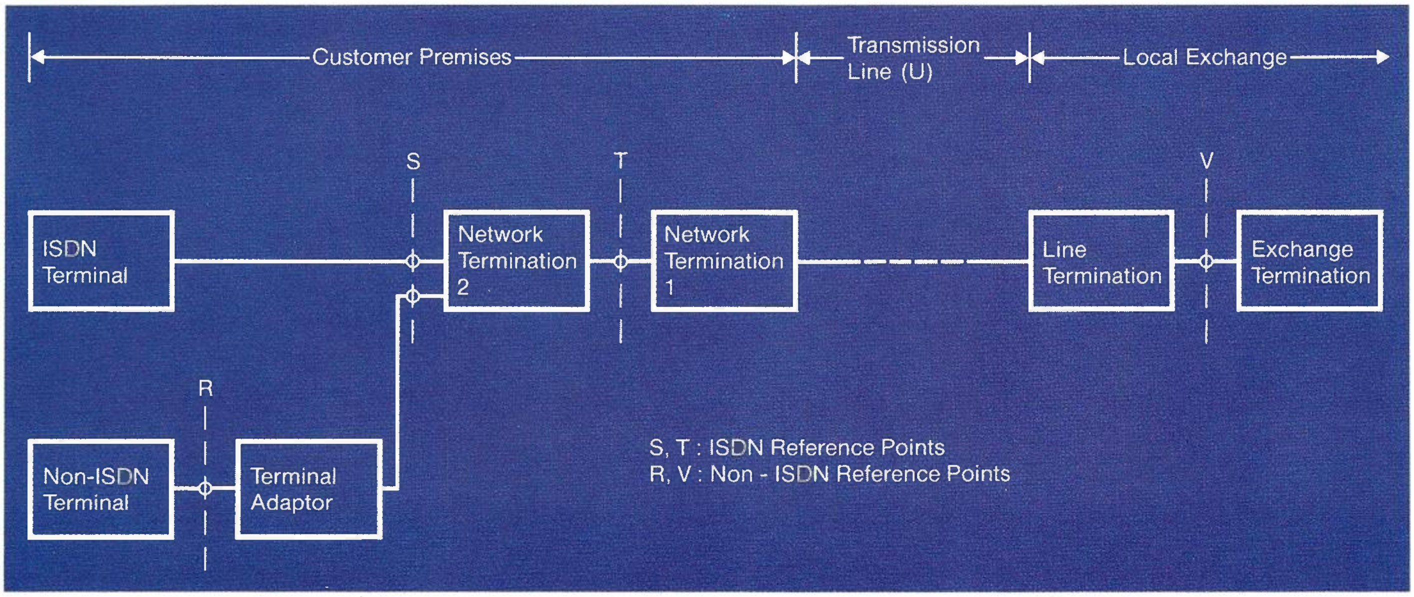
The main motivations for network development towards an ISDN environment are the economies and flexibilities which the integrated nature of the network would foster. These can be achieved, in a first step towards an ISDN, by integrating a wide range of different services (voice and non-voice) via a single customer-network access line. In turn, this requires universal customer access signalling arrangements, protocols and functional interfaces. From a customer's viewpoint, ISDN capability will be recognised by the service characteristics available through universal multi-service customer access interfaces. These interfaces are therefore of prime importance for ISDN development.

Customer access issues are under active study within the CCITT, with the objective of specifying an appropriate set of international standards for access interfaces and protocols. Several CCITT Study Groups are involved in these activities. They include Study Group XVIII (Digital Networks), which co-ordinates all ISDN discussions within the CCITT, Study Group XI (Telephone Switching and Signalling) and Study Group VII (Data Communication Networks). Achieving international standards quickly on ISDN customer access interfaces and protocols is important from all points of view – of customers, terminal manufacturers and network operators.

The Research Laboratories have been actively participating in the CCITT development of these ISDN access standards. Good progress has been achieved and a number of CCITT contributions have been submitted to relevant international meetings. These include the meeting of Working Party XI/6 on Digital Subscriber Line Signalling (Geneva, December 1982) and the CCITT Study Group VIII Meeting of Experts on ISDN matters (Kyoto, February 1983). The topics addressed in these contributions ranged from ISDN customer access protocol architecture to the classification of generic telecommunication services using Open Systems Interconnection (OSI) concepts.Further contributions by Telecom's Research Laboratories are being prepared following a special request by CCITT Working Party XI/6 for an assessment of the possible impact of an earlier proposal submitted by the Laboratories. Improvements to relevant CCITT recommendations are also being studied in the Laboratories and the interim results of these studies were the subject of a submission to the Study Group XI Working Party meetings hosted by Telecom Australia in Melbourne during April 1983.

To date, the Research Laboratories have developed a good understanding of the important technical issues associated to ISDN customer access as the basis for further work in this area in the future.

ISDN customer access reference configuration



This knowledge has been promulgated to the relevant Departments of Telecom Headquarters through discussion papers and technical presentations. This information transfer is considered to be a vital contribution toward the strategic formulation by Telecom Australia of a forward network development plan for Australia.

Specification of the Open Systems Interconnection Transport Service Definition

The marriage of communications and computers is rapidly leading towards the information age, when many new telecommunication services (e.g. teletex, viewdata, high speed facsimile and electronic mail) will become available to the community. In order to ensure the compatibility of terminal equipment designed by different manufacturers to support these services, there is considerable worldwide activity among network operators, including Telecom Australia, and the telecommunications industry to develop a set of standard procedures to allow compatible communication by computing equipment.

The common foundation of this activity is the ISO/CCITT Reference Model of Open Systems Interconnection (OSI), whose seven layers provide the architectural basis for the development of international standards. Each layer of the model provides a "service" to user processes residing in the layer above it.

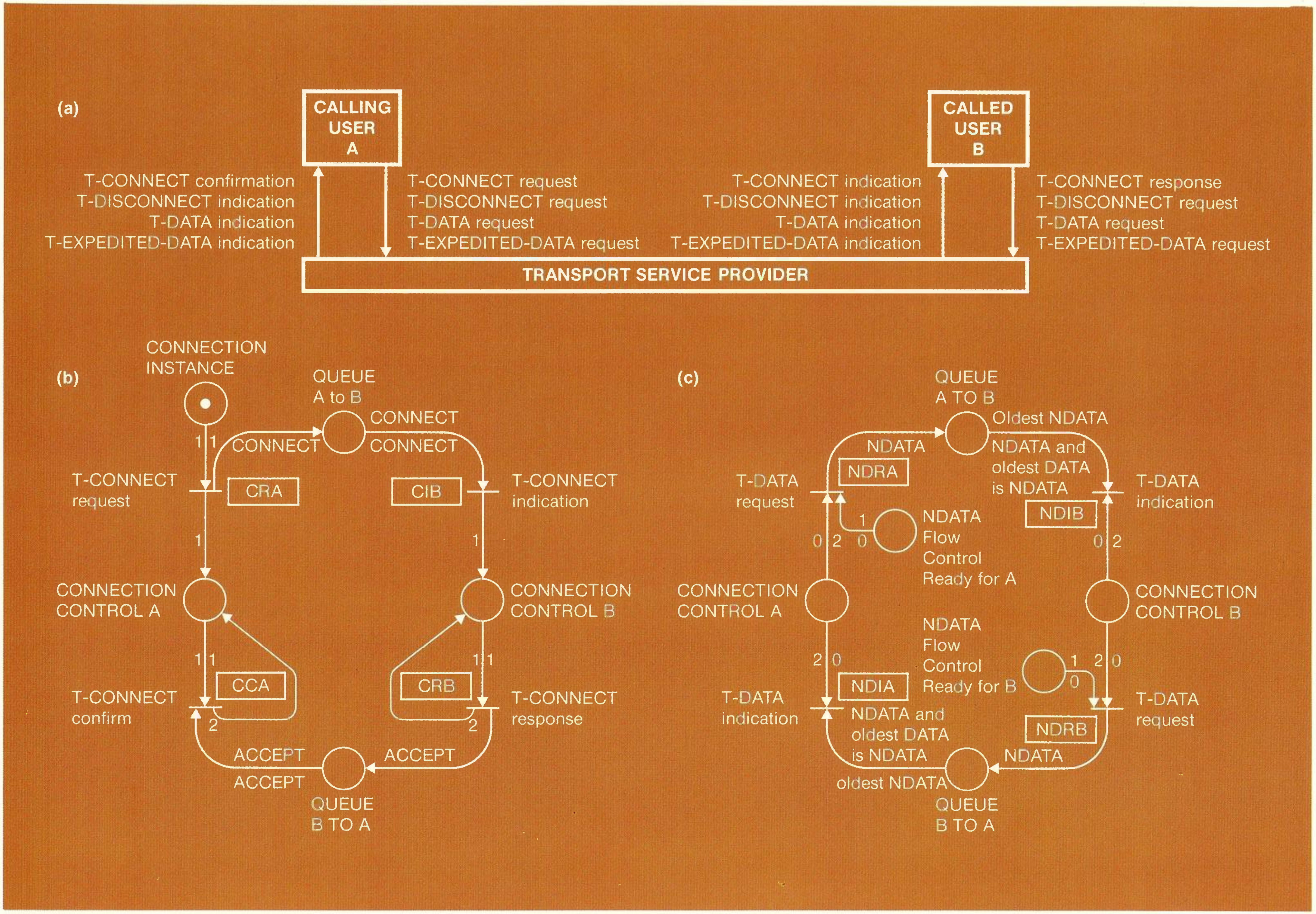
The Transport Service is provided in total by the first four layers of the Reference Model. This Service relieves application programs from the responsibility of ensuring the provision of a desired quality of service (throughput, delay, reliability, accuracy) for data transfer.

Both the ISO and CCITT will be producing standards defining the Transport Service within the next two years, and work is well advanced. The Research Laboratories and the CSIRO Division of Computing Research have been co-operatively contributing to the development of OSI standards, by correspondence through the Standards Association of Australia and by attendance, where possible, at relevant ISO and CCITT meetings.

The major contribution of the Research Laboratories to this work has concerned the formal specification of OSI services and protocols, in a manner which ensures an unambiguous description of the procedures. In particular, a Numerical Petri Net (NPN) specification of the Transport Service Definition has been developed which formally defines the mutual interaction between Transport Service Users communicating over a single Transport Connection. The NPN specification technique is presently being considered as a candidate formal description technique within the ISO and CCITT, and the work of the Laboratories has been well received by the group of international experts developing the Transport Service Definition.

The technique is now being applied within the Laboratories to define a common Network Service as part of the collaborative research programme with the CSIRO Division of Computing Research.

(a) Schematic representation of the interactions between Transport Service Users and Transport Service Providers
(b) NPN representation of Transport Connection Establishment Service
(c) NPN representation of normal Data Transport Service
(See diagrams opposite)


(a)
CALLING USER A
CALLED USER B
T-CONNECT confirmation
T-DISCONNECT indication
T-DATA indication
T-EXPEDITED-DATA indication
T-CONNECT request
T-DISCONNECT request
T-DATA request
T-EXPEDITED-DATA request
T-CONNECT indication
T-DISCONNECT indication
T-DATA indication
T-EXPEDITED-DATA indication
T-CONNECT response
T-DISCONNECT request
T-DATA request
T-EXPEDITED-DATA request
TRANSPORT SERVICE PROVIDER
(b)
CONNECTION INSTANCE
QUEUE A to B
CONNECT
CONNECT
CONNECT
T-CONNECT request
CRA
CIB
T-CONNECT indication
CONNECTION CONTROL A
CONNECTION CONTROL B
CCA
CRB
T-CONNECT confirm
T-CONNECT response
ACCEPT
ACCEPT
ACCEPT
QUEUE B TO A
(c)
QUEUE A TO B
Oldest NDATA
NDATA
NDRA
NDATA and oldest DATA is NDATA
T-DATA request
T-DATA indication
NDIB
NDATA Flow Control Ready for A
CONNECTION CONTROL A
CONNECTION CONTROL B
NDATA Flow Control Ready for B
NDIA
T-DATA indication
T-DATA request
NDATA and oldest DATA is NDATA
NDRB
NDATA
oldest NDATA
QUEUE B TO A

Digital Circuit Cross-connection Studies

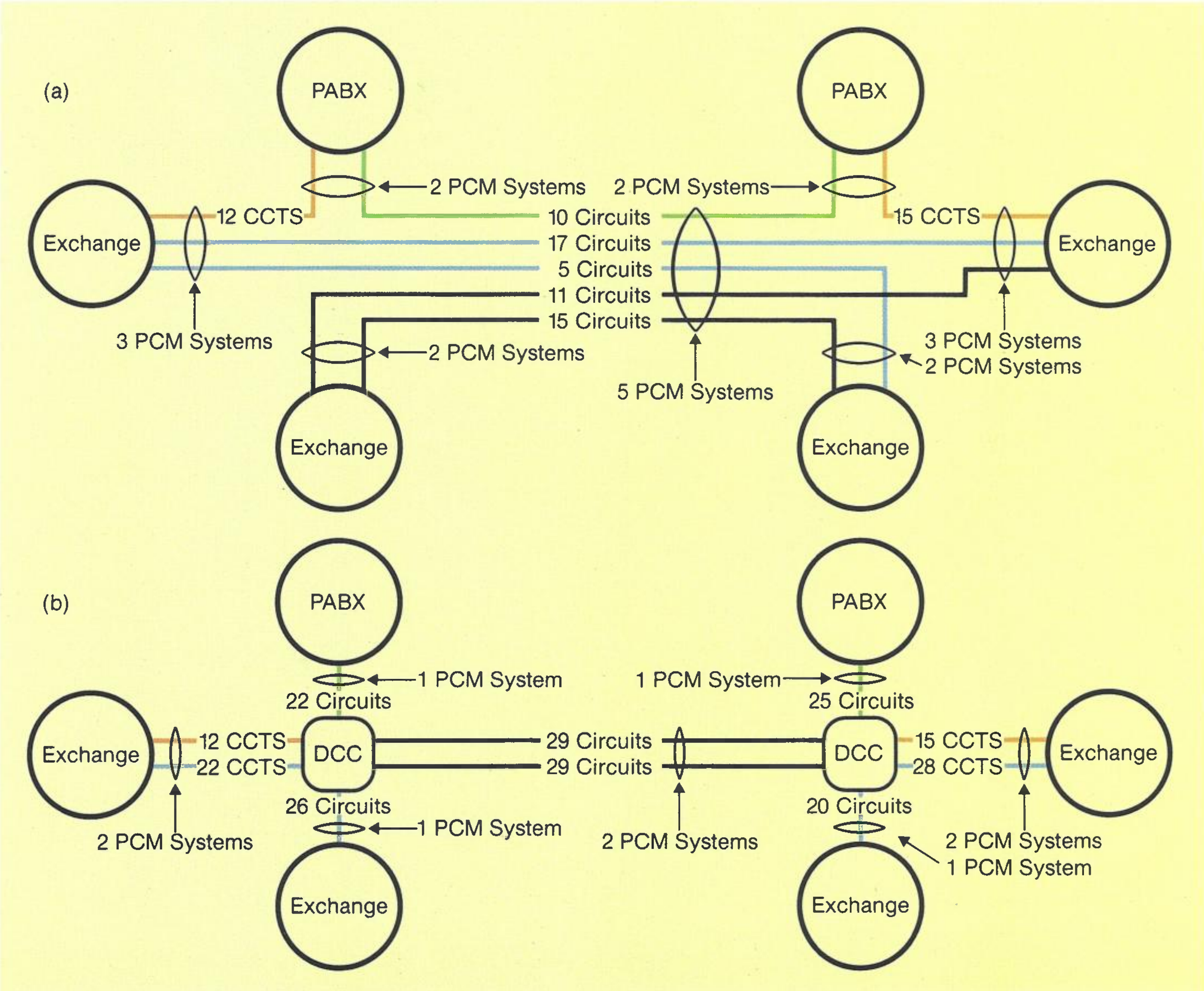
The traditional method of cross-connecting permanently required circuits at network exchanges has been by wired connections on distribution frames. However, the increasing use of digitally multiplexed circuits such as PCM inter-exchange junctions suggests that digital switching equipment could be applied with advantage to provide electrical, rather than physical, circuit cross-connections. This is not a new idea, but it has become much more attractive recently as digital switching hardware continues to decrease in cost. The Laboratories have therefore been studying techniques which might be employed in the design of digital cross-connects for use in the Australian telecommunications network.

Digital cross-connection at 64 kbit/s rates can be provided as an additional feature of digital exchanges in the telephone network. However, the cross-connection function itself does not need switching software to be provided, since a hardware switch transparent to circuits and signalling and a simple operator position satisfy the basic requirements. A variety of such equipment types is likely to evolve, satisfying requirements ranging in speed from lower data rates (X1 user rates), to 64 kbit/s rates for voice and special services, and up to wideband (2 Mbit/s upwards) transmission rates.

Generally, the use of cross-connection equipment provides an alternative to the use of multiplexing terminals, and where these would be expensive, cost savings can be expected. A general advantage of using digital cross-connection is that transmission systems such as primary PCM systems can be more efficiently used, since unused channels can be readily reduced by re-arrangement of working circuits at the cross-connection point. With careful design, a digital cross-connect may also offer substantial operational benefits.

In order to aid understanding of possible approaches to the design of digital cross-connects, the Laboratories let a study contract to Amalgamated Wireless (Australasia) Limited during 1982/83.

Illustration of the function of a 64 kbit/s digital cross-connect switch (DCC)
(a) Interconnection without a DCC
(b) Equivalent interconnection with a DCC



Following completion of this study contract, it is expected that more definite conclusions regarding the limits of application of such approaches will be possible.

Computer-aided Analysis of the T6 Line Signalling Specification

The T6 signalling scheme is Telecom Australia's standard line signalling scheme for use over PCM transmission systems between telephone exchanges. It is based on the CCITT R2D line signalling scheme and will be provided in AXE digital exchanges and in PCM-to-loop conversion equipment which provides a loop disconnect signalling interface (2 or 4-wire physical) to analogue exchanges.

The T6 scheme is specified using the CCITT Specification and Description Language (SDL), the first use by Telecom of SDL in a national signalling specification.

The initial SDL specifications of T6 for use in AXE digital exchanges and in loop conversion terminals were carefully designed to ensure correct operation. However, there remained a possibility that some combinations of call events could result in faulty operation, e.g. deadlocked states or deadlocked sets of states (livelocks). These possibilities and their rectification have been the subject of recent Laboratories' studies.

To investigate these possibilities, the T6 SDL diagrams were converted manually to Numerical Petri Nets (NPNs) and the various possible signalling link terminal combinations were analysed using an NPN analysis program developed in the Laboratories. This program, for given initial conditions, computes every possible combination of terminal states (called "markings") that a signalling link can enter. The program indicates whether any markings are deadlocked and will find any livelocks.

The Computational Flow Graph (CFG) produced by NPN analysis shows the possible state transitions that can occur in any particular marking and the new markings that result. By following the CFG through typical call sequences, correct operation of the signalling links can be checked.

The NPN analysis performed by the Laboratories revealed three deadlocked markings which followed rather unlikely sequences of events. However, if they occur, they put the link out of operation. They were removed by simple modifications to the SDL specifications. No livelocks were found.

A check of likely call sequences revealed a possibility for the link to become a "black hole" for calls. This followed a sequence which had not been anticipated in the original design. This fault was easily removed.

This NPN analysis of the T6 specification thus proved useful in finding specification errors. It has considerably increased Telecom's confidence that the T6 signalling scheme will work correctly in practice, if it is implemented as specified. Prototype loop conversion equipment has been tested and no protocol errors were found.

A major lesson learnt from this project was that, despite the relative simplicity of the T6 specification and careful design, deadlocked states and incorrect sequences were overlooked. More complicated protocols can be expected to contain more errors which NPN analysis can detect.

Enhancement of T6 Line Signalling to Provide Additional Network Functions

Telecom is planning the application of digital transmission systems for a number of uses in addition to the provision of inter-exchange junction circuits. These planned service applications require signals which are not provided by the T6 signalling scheme. Examples of these applications and their special requirements are:

- the digital Special Services Network (SSN) which is being established by Telecom to improve service to customers and which provides PABX tie lines and outdoor extensions. These require a number of line signals not provided by T6 line signalling.
- exchange lines to PABXs where digital transmission is used to improve service and enable the early introduction of 64 kbit/s digital transmission from customer to customer. These PABX exchange lines also require signals not currently available in the T6 scheme.
- the use of a Digital Cross-connect (DCC) function as a means of obtaining efficient usage of the blocks of 30 circuits provided by 2048 kbit/s digital transmission systems. This requires a channel-associated fault indication signal that is not provided by T6 signalling.

The Laboratories have been developing a proposal demonstrating that the T6 scheme can be enhanced to provide the signals required in the above applications by using all four signalling bits provided by PCM-30 transmission systems. At present, T6 uses only two signalling bits. The proposed signalling scheme can then be used for all services utilising digital transmission, reducing training and documentation costs and enabling the use of common equipment for the various services. The Laboratories' proposal concludes that common software could be used and common PCM-to-loop conversion equipment can be provided to interface to analogue services, substantially reducing network costs. The Laboratories' studies show that four signalling bits can provide the required signals, with capacity remaining for further enhancements, and that the existing T6 scheme can remain as a sub-set of the enhanced scheme, enabling interworking if necessary.

A Processor Complex for Switching and Signalling Research Projects

In order to carry out experiments in advanced switching and signalling concepts for both telephony and data, the Switching and Signalling Branch of the Laboratories has set up a complex of minicomputers with special connection facilities and peripheral equipment. The complex is based on the DEC PDP11 range of computers, with the standard Unibus allowing both switched interconnections and transfer of peripherals by plug and socket.

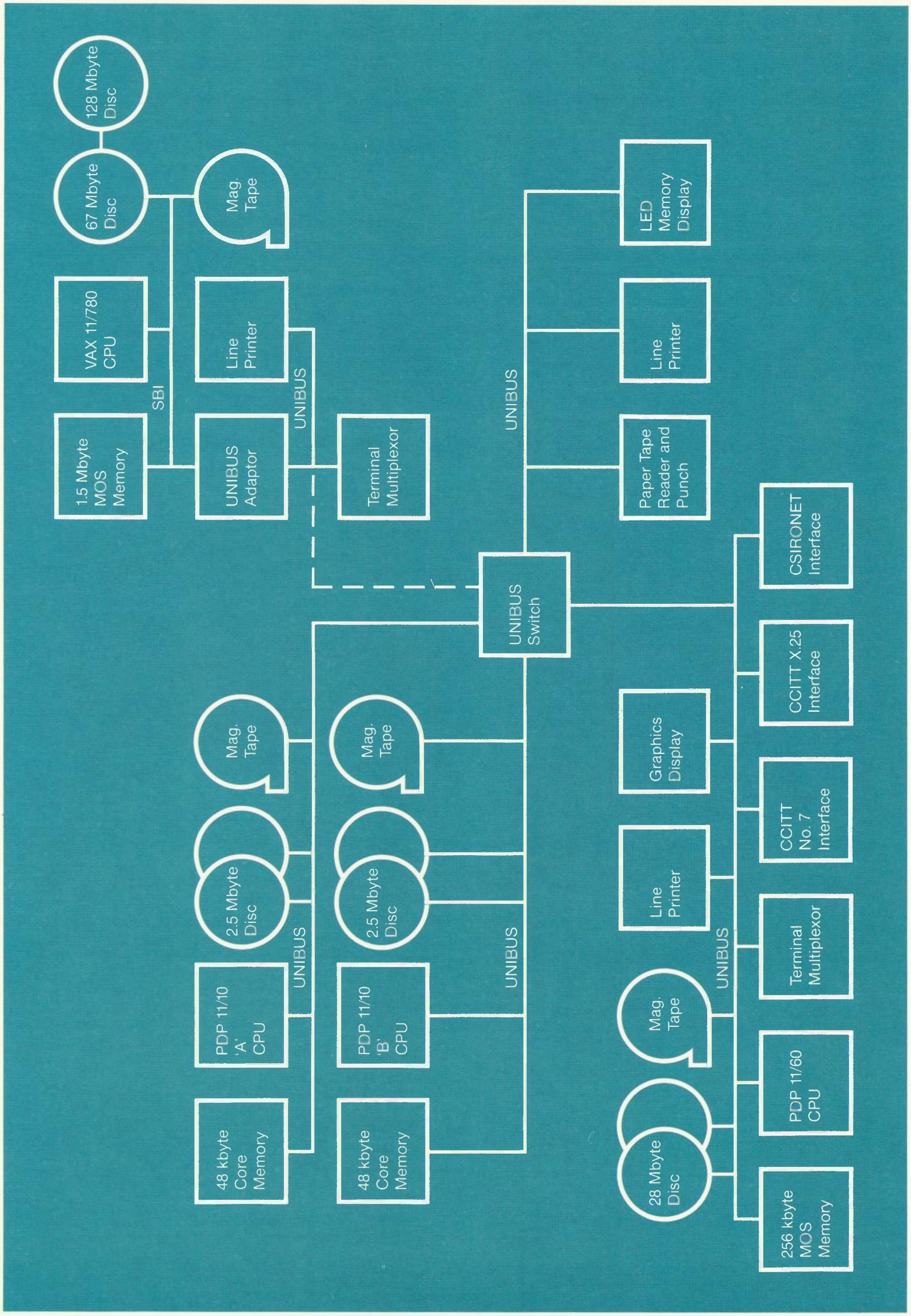
The basis of the complex are two PDP11/10 computers working at their maximum configuration with 48 kilobytes of magnetic core memory. These computers were purchased about ten years ago as program development machines for the Integrated Switching and Transmission Field Experiments, with the prospect of later use in data switching experiments. Three years ago, a PDP11/60 computer was added to provide the extended capability required for experiments with CCITT No. 7 Common Channel Signalling and X.25 data packet switching. As computer networking in telecommunications is a topic of research interest, the work program of the Switching and Signalling Branch includes this topic, and collaborative research on the topic has been organised with a number of bodies, including the CSIRO. To assist this work, the PDP11/60 is equipped to act as a node of CSIRO's computer network, CSIRONET, for interworking experiments.

Since the above three projects (CCITT No. 7, X.25 and CSIRONET) require most of the available time of the PDP11/60 and since future work plans indicate more computer-related projects, another processor was added to the complex during 1982/83. A VAX11/780 was selected because of its capacity, compatibility with existing equipment and proven performance. It is used for all software development. When the required software becomes available, it will take over the role of CSIRONET node, further unloading the PDP11/60 where operational time is at a premium.

The size of software systems is increasing because cheaper memory is becoming available and programmers no longer need to make space-time trade-offs. Because of this trend, it is intended to upgrade the two PDP11/10 computers shortly with new central processor units to obtain larger address space and thus more memory. One of these machines will be dedicated to running the Bell Laboratories Unix operating system for which a considerable amount of useful software is available and which provides facilities for computer-aided design of VLSI circuit devices.

Another modification currently being made to the complex is the addition of an electronic switch on the terminal side of the computers so that any computer can be accessed from any terminal without resort to a patch panel. This facility will provide much greater convenience in the application of the computer complex to a varying program of research investigations.

Processor complex for switching and signalling research projects
(See diagram opposite)



128 Mbyte Disc
67 Mbyte Disc
Mag. Tape
VAX 11/780 CPU
SBI
1.5 Mbyte MOS Memory
Line Printer
UNIBUS
UNIBUS Adaptor
Terminal Multiplexor
LED Memory Display
Line Printer
UNIBUS
Paper Tape Reader and Punch
UNIBUS Switch
CSIRONET Interface
CCITT X.25 Interface
CCITT No. 7 Interface
Terminal Multiplexor
PDP 11/60 CPU
256 kbyte MOS Memory
Graphics Display
Line Printer
UNIBUS
Mag. Tape
28 Mbyte Disc
Mag. Tape
2.5 Mbyte Disc
UNIBUS
PDP 11/10 'A' CPU
48 kbyte Core Memory
Mag. Tape
2.5 Mbyte Disc
UNIBUS
PDP 11/10 'B' CPU
48 kbyte Core Memory

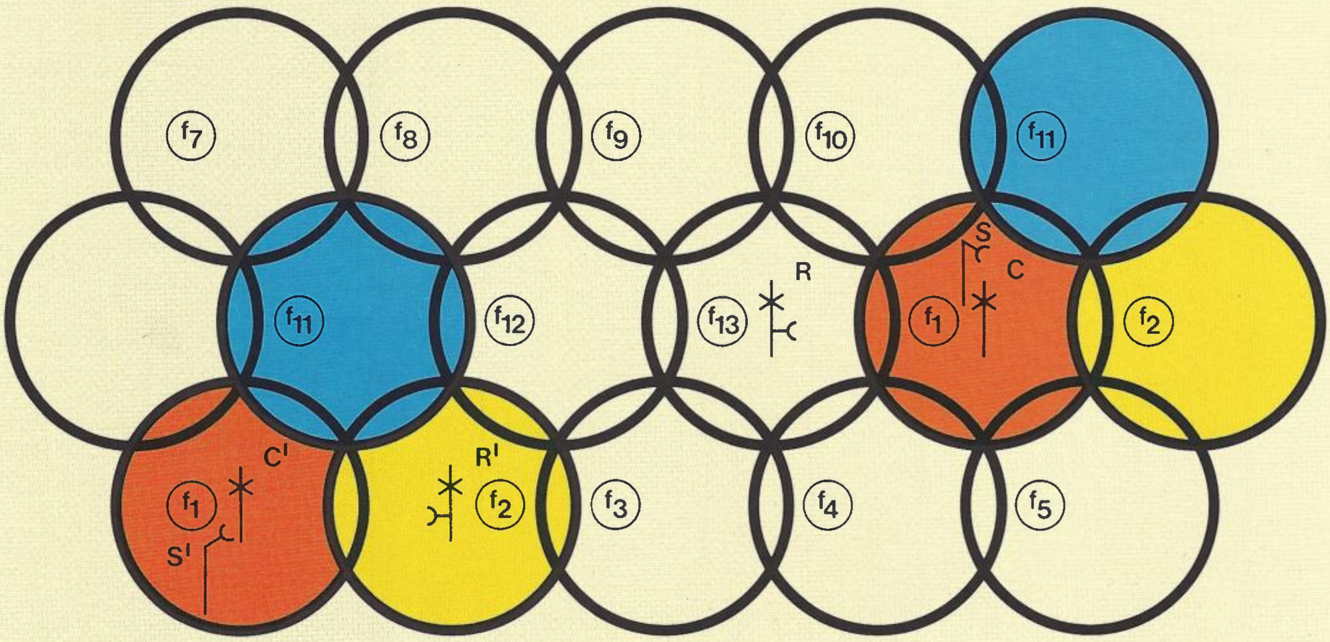
Frequency Re-use in the Digital Radio Concentrator System

The Digital Radio Concentrator System (DRCS) is a subscriber radio system intended to provide telecommunications services for customers living in more remote areas of Australia. In these areas, the population density is low, and the sparsely located customers can be separated from one another and from their local exchange by tens of kilometres. In these situations, the distances between exchange and customers are too large to permit the economic use of the more usual subscriber cable or open wire networks, but their geographic dispersion is not sparse enough to necessitate or justify the provision of telecommunications services by the use of satellite systems.

The DRCS project concept originated several years ago in the Laboratories as a means of providing improved telephone services to these areas of Australia, through the application of digital techniques and technology. The project has now been carried into its development phase by the Headquarters Engineering Department and systems are being developed by industry to Telecom's specification. The Research Laboratories are continuing to provide consultative assistance to the project, particularly in regard to frequency re-use.

The DRCS transceiver can cover a region, called a cell, of about 25 km to 40 km in radius. Within this cell, subscribers will transceive with the common, centrally located base station equipment. Each base station transmits on one frequency and receives on another, in this way achieving true two-way communication. A technique called Time Division Multiple Access (TDMA) is employed to allow up to 128 subscribers to share 15 time slots.

Part of 13-frequency DRCS cell plan illustrating possible interference between cells with frequency re-use



Interference Table

Wanted Path	Interference Path
S to C	R' to C S' to C
R to C	R' to C S' to C
C to S	C' to S
C to R	C' to R

Legend

Base Station

Repeater Station

Subscriber Station

(f) Cell Frequency Allocation

To cover a larger area, several cells are placed next to one another, each with base station equipment at its centre. The cells are arranged in a regular array called a cell plan. Each cell has a pair of frequencies assigned to it. Since the electromagnetic spectrum is a valuable national resource, only a restricted number of frequencies have been allocated to the DRCS service. In the 500 MHz and 1.5 GHz band, seven and thirteen pairs of frequencies, respectively, have been assigned. Thus, over a large area, there may be many cells using the same frequency at the same time. This frequency re-use could give rise to situations where cells interfere with one another.

To obtain adequate system performance, it is necessary to keep cells using the same frequency as far apart as possible. Since the number of frequencies is fixed, an optimum cell plan is determined, and the only way to increase signal separation between cells using the same frequency is to increase the cell radius. The problem for the system designer, therefore, is to determine a cell radius which is not too small (when interference would be too great) or too large (when subscribers at the maximum distance from the cell centre would experience a very weak signal). Thus, the designer must balance system performance degradation between poor signal strength and interference, by varying cell radius, antenna height and antenna gain.

In the Laboratories, computer modelling techniques have been developed to predict a system's performance from given system parameters and propagation data. In addition, a field experiment is being mounted by Telecom Headquarters in conjunction with the Queensland State Administration, to assess the modelling technique, the newly developed system equipment, and to provide local propagation data in the remote locations in which the DRCS will be eventually installed in service.

Remote Telecommunications Satellite Services

Telecom Australia has made a recent commitment to provide telecommunications services to remote areas of Australia using the planned Australian national satellite system. These services, generically known as the Remote Telecommunications Satellite Service (RTSS), will be markedly different from the international satellite service where three large and expensive high capacity earth stations handle all of Australia's international traffic routed via satellite. In contrast, Telecom's RTSS will have many small earth stations with low traffic capacity – in some cases, a single telephone channel only. The nature of the RTSS is such that attention must be given to the system design to ensure that the earth station cost component is a minimum.

The Research Laboratories have contributed to the planning of the RTSS by evaluating various technical aspects of the service and providing quantitative information to Telecom's system designers.

Telecom has selected a frequency modulated single-channel-per-carrier (FM-SCPC) system as that which best meets the objectives of the RTSS. In this system, the individual voice signal from each sending party frequency modulates a single carrier for transmission to the respective receiving party, so that two carriers are used for every conversation. Various voice processing techniques are also introduced to the simple FM-SCPC system so that circuit quality is perceived by the users to be better than it would otherwise be, thereby allowing smaller, less costly earth stations to be built for a given circuit quality objective.

One such technique which the Laboratories have closely studied is companding. This technique utilises a variable attenuator in the earth station receiver. The attenuation is varied as a non-linear function of the instantaneous received speech level, with higher attenuation added for the lower levels of speech where the background receiver noise would be more noticeable, and maximum attenuation when there is no speech. The application of this technique makes the background noise seem less noticeable but it expands the dynamic range of the received speech signal. This latter effect is compensated for by compressing the speech signal before it modulates the carrier at the transmitter. By closely matching the compressor and expander characteristics, the received speech is unaffected and the level of the receiver noise appears lower to the listener. The perceived improvement in circuit quality cannot be measured by a meter, and therefore subjective assessments must be made.

The Laboratories have conducted an extensive series of subjective measurements to determine the perceived improvement due to companding under a wide variety of circuit conditions. These results have been used by Telecom's system designers to specify the earth station performance and design requirements.

Another technique applied in the RTSS system which the Laboratories have recently investigated is the use of a voice operated carrier (VOX). Because two carriers are used for each conversation in an SCPC system, many carriers are simultaneously amplified by the satellite transponder during busy periods. The travelling wave tube amplifier in the transponder is non-linear and produces intermodulation noise which is a function of the number of carriers. To minimise this noise, the carriers are activated at the transmitter only when speech is present. At the receiver, a circuit detects the presence or absence of carrier and, by effectively switching the receiver off when the transmitted carrier is absent, prevents a sudden increase in noise to the receiving party. However, users become aware of this abrupt switching on and off of the receiver and find it disconcerting and disruptive to conversation.

The Laboratories therefore conducted a series of subjective measurements which quantified the perceived degradation of circuit quality when a VOX is added to an FM-SCPC system. It was found that, by deliberately adding low level continuous noise at the receiver, the intermittent noise due to switching on and off the receiver could be smothered and become less disconcerting to the user. A program of laboratory tests was used to determine the optimum amount of added noise. Consideration is now being given to the modification of the RTSS equipment which is being purchased by Telecom to incorporate this added noise feature.

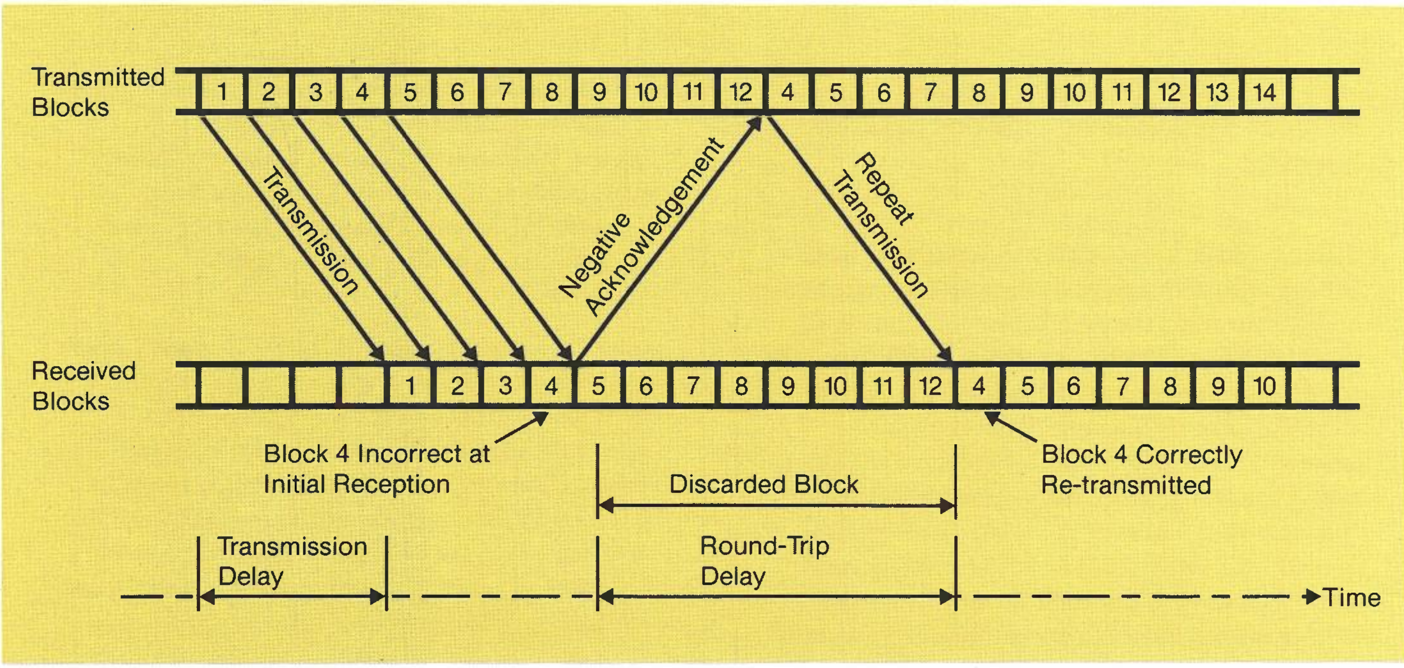
The Laboratories are continuing to conduct studies on the RTSS and other systems. In particular, a transponder simulator which was developed for earlier studies is being used to investigate the effects of intermodulation when other services are added to the Telecom transponder.

Investigation of Modified ARQ Protocols over Long Delay Circuits

The concept of block structured data transmission over terrestrial communication links is well-established. However in satellite communications, the protocol or agreement between operating entities is highly inefficient because of the large end-to-end delays encountered. Automatic Repeat Request (ARQ) protocols rely on acknowledgement of correct or incorrect reception by the receiver to determine re-transmission of incorrect blocks. Upon receipt of a negative acknowledgement, re-transmission of the incorrect block or blocks is initiated, with the receiver ignoring all blocks still in transit until the re-transmitted block is correctly received.
This protocol is based on the theory that infinite buffers at the receiver are otherwise required.
On terrestrial circuits, the protocol usually results in no more than one block being in transit prior to a re-transmit request. However, with the longer delays encountered on satellite circuits, there may be many blocks in transit which will be discarded, even if they are correct.

In the Laboratories, studies of this aspect of satellite communications are aimed at extending the theoretical basis initiated at several research institutions to find optimum block sizes and methods of modifying the proposed protocols to improve throughput efficiency. Current work has verified that the so called "Go-Back-N" protocols are highly inefficient in long delay circuits and that, for terrestrial transmission, the optimum block size and transmission rate are highly correlated. The more complex protocols used terrestrially are less sensitive to block size; but in a satellite circuit, they still suffer

Example of "Go-Back-N" protocol with block 4 error and 8-block round-trip delay



severe throughput degradation at high error rates.

Current work is being directed to the incorporation of forward error correction schemes and to the development of an enhanced hybrid scheme. The scheme will utilise the ready availability of microcomputer power which has only recently become cost-effective.

Microwave Technology Studies

Microwave radiocommunications systems provide a major proportion of Telecom Australia's extensive terrestrial trunk network. Within about three years, satellite communications systems will also be introduced into Telecom's network to provide telecommunications services to people and communities located in the remote outback regions of Australia as well as for the provision of some trunk circuits. Both terrestrial radio and satellite systems utilise microwave components and devices and it is therefore important for Telecom to maintain an in-house competence in state-of-the-art microwave technology, so that it can specify and evaluate new systems which might be utilised in the development of the network and apply them effectively.

To this end, the Research Laboratories are engaged in laboratory investigations of advances in this field of technology. The investigations involve:

- continuous monitoring of pertinent research conducted overseas
- development of appropriate research and measurement facilities in the Laboratories
- experimental investigations of microwave circuit designs which can impact on the implementation and performance of present and future telecommunications systems.

In the last year, this work has centred on the determination of the microwave characteristics of a copper-clad teflon/fibreglass substrate material. This material has great potential for the realisation of low-cost microstrip circuits for use at frequencies as high as 18 GHz. The dielectric material investigated is planar and 0.25 mm thick, and it has 0.02 mm copper plating on one side and 0.8 mm copper plate bonded onto its other side.

The characterisation of the substrate material was carried out using an automatic network analyser. This computer-controlled measurement system allowed the accurate determination of such

Computer-controlled microwave network analyser (The inset shows typical microstrip circuit elements investigated)

microwave parameters as effective dielectric constant, impedance, and losses or circuit quality Q factor. To complete the basic information needed to design general microwave circuits, various circuit elements such as transformers, stubs and hybrids were fabricated from the material and tested.

This work has developed the necessary knowledge required for the development and evaluation of low-cost microwave circuits such as low-noise amplifiers, mixers, power amplifiers and oscillators which are based on this material. The automated microwave network analysis system developed in the course of the investigation has also provided a valuable tool for future investigations in the field of microwave technology. It complements other Laboratories' instrumentation facilities for the accurate determination of circuit noise properties at microwave frequencies.

Parrot-Proof Windows for Antenna Feeds

The trunk network linking the capital and provincial cities of Australia spans long distances, often over sparsely populated country. A large proportion of this network is comprised of line-of-sight microwave radiocommunications systems. The repeater stations of these systems are about 40 to 50 km apart along these trunk routes and among these numerous stations across Australia, many are unmanned and located in remote places.

In some remote locations with large populations of parrots, system faults have regularly been traced to relatively minor physical damage caused by parrots to the antenna feeds of the microwave radio systems. Since the repair of these faults is expensive due to the remoteness of the repeater stations, the Research Laboratories and the Engineering Department have been engaged in a project aimed to limit the effects of any damage which parrots can cause.

The high antenna towers of these systems are attractive perches for parrots in the often flat terrain. The tower-mounted dish antennas employ a waveguide feed to carry signals to the microwave antenna element located at the focus of the dish. In normal practice, the waveguide feed is sealed at its outer end by a plastic window, and the waveguide is pressurised with dry air to ensure a stable electrical environment and to prevent corrosion and insect infestation problems. This sealing technique is used worldwide, and as supplied, the windows are made from 0.15 mm thick teflon plastic material. Unfortunately, parrots are able to damage these windows by persistent pecking and this leads to system performance impairment with loss of the feed air pressure, corrosion, etc. The frequency of parrot attacks and damage in some areas of Australia has significantly affected system reliability.

Laboratories' investigations into the properties of plastics has shown that there are six plastic compositions whose electrical and weather resistance properties might make them a suitable replacement for the teflon windows, when formed as 1.5 mm thick discs. A number of windows have been made from each of these six plastics and fitted to waveguide feeds so that their resistance to parrot attack can be assessed.

With the assistance of the management of the Sir Colin Mackenzie Fauna Park and of zoologists from Monash University, waveguide feeds incorporating the various alternative types of window have also been installed in an aviary containing several species of parrots, located in the Park. A single complete unit including the antenna reflector dish has been separately mounted to determine whether the acoustic noise reflection in this situation influences the general pattern of parrot behaviour.

Bird behaviour is being monitored by the zoologists and it is interesting to note that, to date, the teflon window has been the only type to have been damaged by the parrots.

In addition to the visual monitoring of parrot activity, each of 22 window specimens is being monitored for peck activity by means of a microphone mounted inside each waveguide feed. The time and duration of pecking for each feed is recorded and counted automatically. Testing does not require and does not include the use of microwave power.

While designed and set up as a long-term experiment to obtain general information on parrot behaviour as it may affect rural installations in general, and the feed tubes in particular, short term results have already confirmed the vulnerability of the present type of window and also suggest that it possesses a property which makes it attractive to the parrots. It is thought that the property which makes the window so vulnerable is the ease with which it can be destroyed by a parrot in relatively few seconds. Over such a short time span, there is little chance that some random occurrence will distract or otherwise destroy the concentration of the parrot pecking.

This study has already assisted field operations by yielding alternative types of window which resist parrot attacks better. It has also identified an unusual and interesting environmental problem which, at first sight, appears to be peculiar to outback Australia and which has called on multi-disciplinary skills to effect a solution.

Damaged antenna feed window undergoing inspection *(See photographs opposite)*

Deterioration of Polyethylene Spacers in Coaxial Cable

When Telecom Australia constructed its coaxial cable route between Sydney and Melbourne in 1962, cable from different manufacturers was used along three different sections of the route. Cable from an overseas source was used between Sydney and Canberra. Between Canberra and Wagga Wagga, a combination of imported and Australian-made cable was used. Between Wagga Wagga and Melbourne, only Australian-made cable was used. In all sections of the route, the structure of the cable comprised six coaxial tubes and 16 paper-insulated quads providing 32 interstitial cable pairs, surrounded by an armoured lead sheath.

To maintain the quality of transmission along the coaxial tubes on the Melbourne-Wagga Wagga section in recent times, it has been necessary to re-equalise the cable at decreasing time intervals. Since the need for frequent re-equalisation is costly both in terms of the manpower needed for the task and the loss of transmission capacity for prolonged periods of time, the Research Laboratories were asked to assist in the determination of the underlying reason for the unexpectedly frequent re-equalisation requirement and to recommend appropriate remedial action.

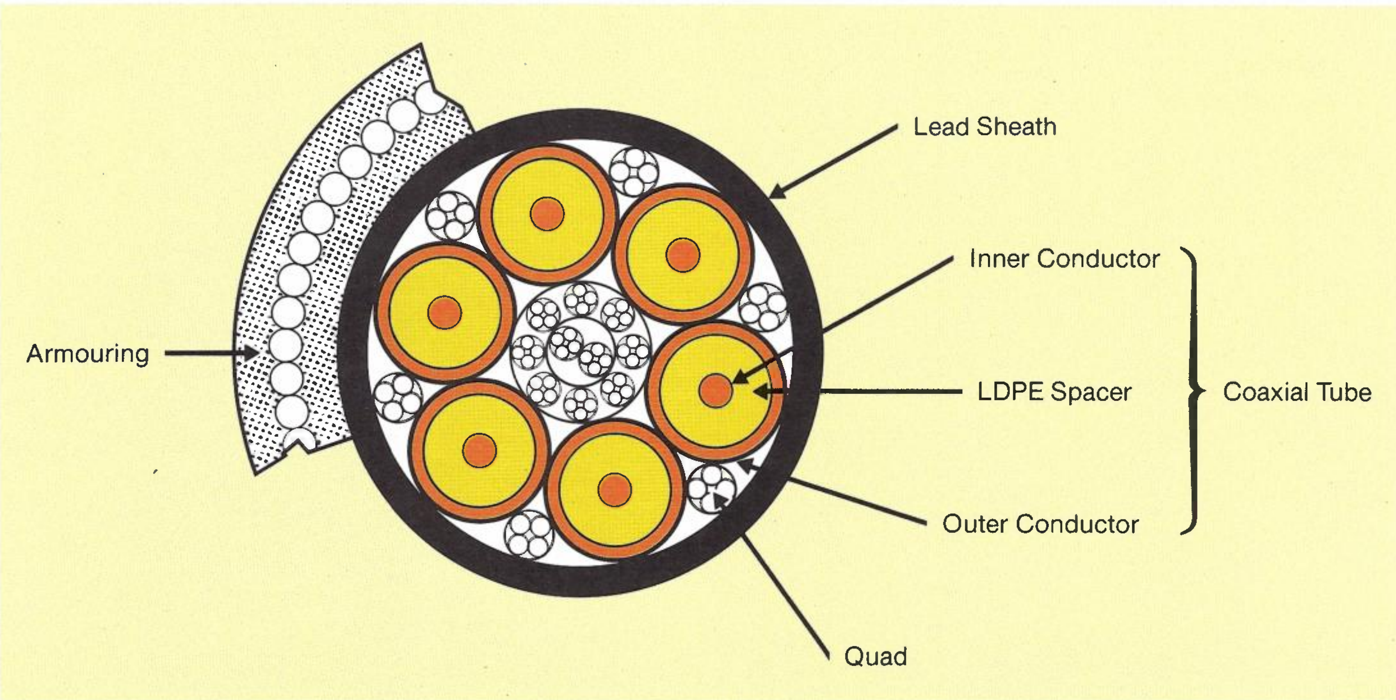
Initial investigations showed that the equalisation requirements were consistent with increased dielectric losses in the coaxial tubes. Hence, subsequent laboratory investigations focussed on the polyethylene spacers used to position the central conductor within the coaxial tubes.

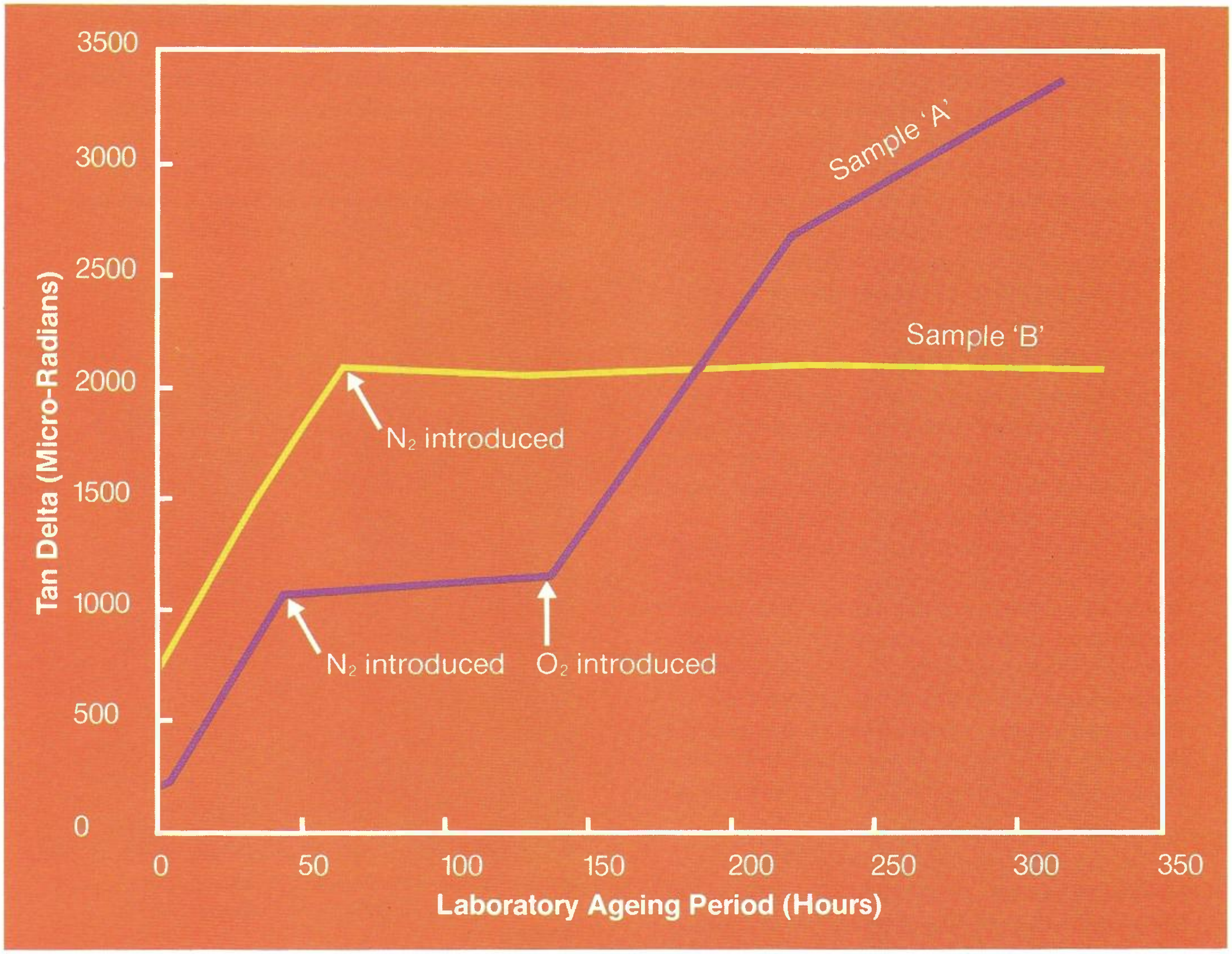
The spacers in the coaxial tubes were manufactured from low density polyethylene (LDPE) because of its low dielectric loss. However, in the presence of oxygen, LDPE will oxidise, a process that is catalysed by the presence of metal such as copper. The oxidation products are highly polar and ultimately lead to a rapid increase in dielectric loss. Oxidation may be inhibited by incorporating stabilisers into the LDPE during its manufacture, albeit with a slight, but tolerable, increase in dielectric loss.

For the Laboratories' tests, spacers were stripped from lengths of cable which had been held in storage as spare lengths and from other lengths which had been removed from service. All spacers tested were found to be unstabilised against oxidation. Dielectric loss measurements indicated that the spacers in certain tubes were at an advanced stage of oxidation in contrast to others and that it was necessary to gather more data in order to predict the remaining service life of the cable.

Spacer materials were therefore subjected to accelerated ageing in the laboratory and the changes in dielectric loss were monitored as a function of ageing time. The data obtained was compared with that obtained from similar experiments on a spare length of cable and the results were found to be in close agreement. By fitting the data to system transmission performance measurements, equalisation error accumulations of 10 dB/year were predicted beyond 1988. These predictions suggested that without remedial action, the transmission performance of the Melbourne-Wagga Wagga section of the route would have deteriorated severely by 1988. Further tests on spacers taken from cable used on the Sydney-Canberra section yielded similar predictions regarding deteriorating transmission performance, but delayed by three to five years.

Cross-section of Sydney-Melbourne coaxial cable





Graphs of dielectric loss for two coaxial cable samples verify retardation of oxidation of the spacers by purging cable with nitrogen

During further accelerated ageing studies on a spare cable length, it was shown that the increase in dielectric loss tangent could be arrested by the removal of atmospheric oxygen from the cable and its replacement with nitrogen gas. This was confirmed by laboratory tests on plaques pressed from spacers and polyethylene used in the production of the spacers. For oxidation to be inhibited, the ambient atmosphere must contain less than 0.3% oxygen. Industrial grade dry nitrogen has been shown to be satisfactory in this regard.

The results of the Laboratories' studies have been conveyed to the Headquarters Engineering Department, which is now investigating the engineering aspects of purging the cables with dry nitrogen gas. A continued consultative involvement of the Laboratories in this project is expected.

Temperatures in Cable Jointing Enclosures

Operations staff of Telecom Australia have noted premature embrittlement of the polyethylene insulation of cable conductors manufactured between 1965 and 1974 in above-ground joint enclosures as early as six years after installation. The polymer scientists of the Laboratories were subsequently asked to isolate the cause of such embrittlement with the objectives of estimating the likely extent of the operational problems it might cause and eliminating the problem in the future by any necessary amendment to Telecom's specifications for polyethylene insulants.

Insulation embrittlement occurs as a result of oxidation of the polyethylene which, as a consequence, loses its flexibility as it reacts with the oxygen in the air. When heavily oxidised, the polyethylene cracks and finally falls away from the copper conductors, leaving them bare. When this occurs, short-circuits can result, affecting telephone services.

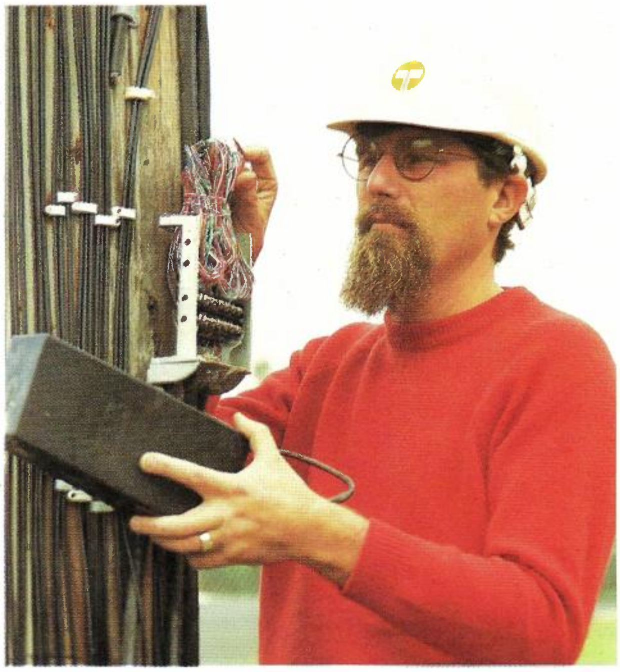
In the above-ground jointing enclosure environment, the cable insulation is shielded from direct solar radiation, but the exterior of the jointing enclosure is subject in daytime to intense direct radiation and constant diffuse radiation. This causes a substantial increase in the air temperature inside the enclosures and significant heating of the polyethylene insulation around the cable conductors terminated inside them. Chemical reaction, such as polyethylene oxidation, approximately double in rate with every 10° C increase in temperature. Measurement of the interior temperature of joint enclosures revealed it to be several degrees above the ambient air temperature, a significant factor in promoting the embrittlement of the polyethylene insulation.

When considering the effect of temperature on the rate of oxidation, the varying temperature over some fixed period of time may be replaced by an "equivalent temperature" of fixed magnitude which would cause the same total oxidation of the polyethylene. Calculation of "equivalent temperatures" is complex and requires a detailed knowledge of the oxidation mechanism and the activation energy. "Equivalent temperatures", calculated over a year, are higher in Australia than in most other countries. In other countries, such as the USA, the major part of the telecommunications network is located in areas which have relatively low winter temperatures. In Europe, the temperature is generally lower, even in summer.

In detailed Laboratories' investigations of the temperature environments experienced by cable insulants in above-ground joint enclosures, standard black enclosures and enclosures modified in various ways, such as by ventilation, colour changes to white, etc., were exposed at Clayton in Victoria and at Mount Isa in Queensland. The temperatures of the air space, on the surface of the conductor bundle and in the centre of the conductor bundle in each type of enclosure were measured hourly. The resultant data was transmitted via dial-up lines to a Laboratories' minicomputer and stored as computer records for future analysis. Early figures showed that, at the height of summer, the air in a pole-mounted black enclosure could reach 60° C.

The collected temperature data is being analysed by Siromath, a commercial consulting firm, to calculate a yearly "equivalent temperature" for various activation energy values, which can then be equated with the known degree of oxidation of the polyethylene. More importantly, the detailed mathematical analysis has been able to establish correlation between the measured temperatures and standard air (shade) temperatures recorded by the Australian Bureau of Meteorology.

The investigation has shown that an improvement in the reflectivity of enclosures will produce a significant decrease in conductor insulation temperatures and lead to a reduced yearly "equivalent temperature" and a corresponding decrease in the rate of insulation oxidation. Correlation of equivalent temperatures with recorded air temperatures allows estimates to be made of oxidation rates at sites other than Clayton and Mount Isa without the need for lengthy testing. It is thus now possible to calculate the probable extension in the life of the insulation due to more reflective enclosures substituted for the current black model, or due to changes in the insulant formulation which alters the activation energy values.



A Laboratories' scientist examines insulation on cable conductors terminated in an above-ground joining enclosure

The Calculation of Crosstalk Interference in a Digital Network using the Cyclo-stationary Characteristics of Digital Signals

Digital transmission in multipair cables is now well established within Telecom Australia's cable network. Digital line systems operating at 2.048 Mbit/s between exchanges are now widely used, whilst lower speed systems (e.g. 48, 72 and 144 kbit/s) are being introduced for the Digital Data Service or being studied for digital customer access to future networks such as the Integrated Services Digital Network (ISDN). A major limitation of this transmission is the coupled interference, commonly referred to as crosstalk, between the digital systems utilising different pairs in the same cable. This leads to a limitation in the number of digital systems operating over the same cable or in the transmission distance between regenerators of each digital system.

Most digital transmission systems make their decisions at the receiver by sampling the received stream of pulses at equispaced sampling times, where the sampling rate is equal to the pulse rate. With near-end crosstalk interference from another digital system using the same cable, crosstalk interference is relevant only at the sampling instants in determining whether a correct decision is made or not. Furthermore, because the inherent structure of the digital signal comprises a sequence of equally shaped and spaced pulses with random polarity or levels, this interference in general is a function of the relative clock phases of the disturbing and disturbed digital systems.

More precisely, the statistics of the interference vary cyclically, with a period equal to the pulse spacing. This particular form of non-stationary statistics is often referred to as cyclo-stationary.

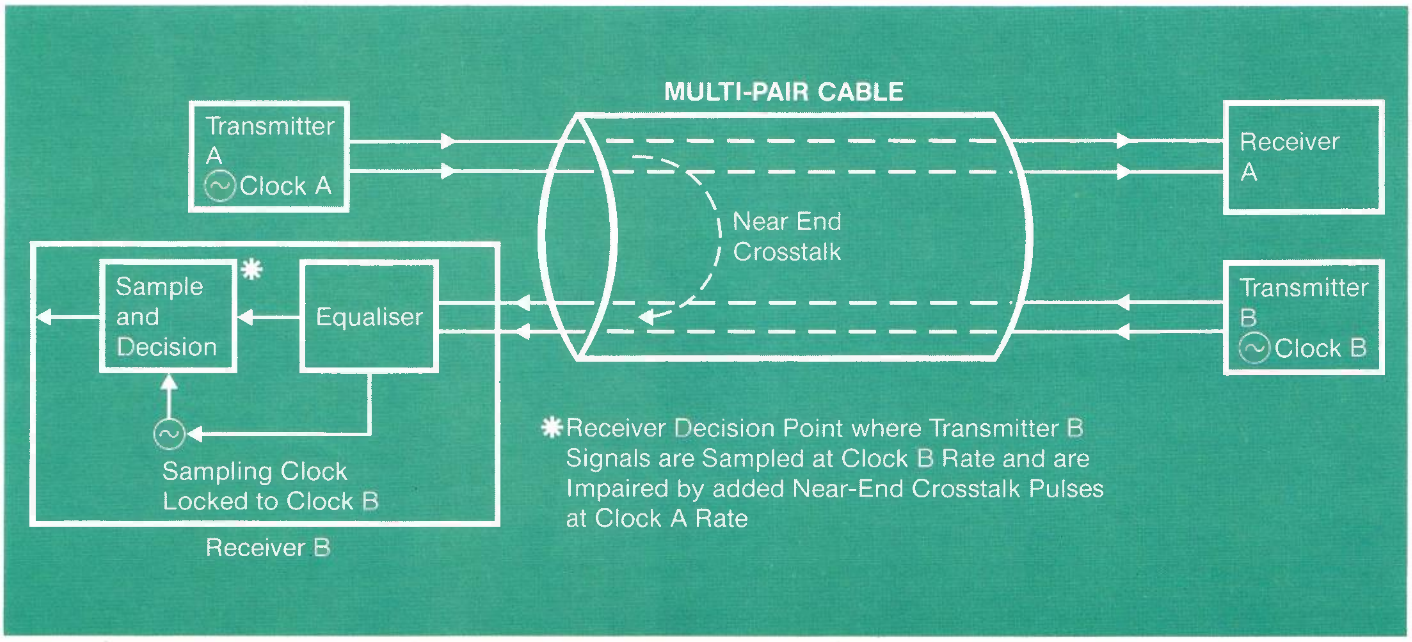
In Laboratories' studies of such interference, the cyclo-stationary statistics of the digital signal have been considered together with the commonly used statistical model of crosstalk in multipair cable. From these studies, fundamental results were derived from the near-end and far-end crosstalk interference in these digital systems. The results show that the periodic variation of the average near-end mean square interference is much less than that of the far-end interference.

These fundamental results have been applied to various network conditions. One such condition is that where a random phasing is encountered between the disturbing and disturbed systems, as for example, in current non-synchronised (plesiochronous) digital line systems. An alternative condition considered was that where fixed phasing occurs, such as is associated with the Integrated Digital Network, which is a synchronous network.

In particular, when applied to the engineering of primary-level 2.048 Mbit/s digital line systems in multipair cable, the Laboratories' studies have shown that the change from a non-synchronous to a synchronous network leads to a reduction in system margin of about 1.5 dB for near-end crosstalk and 2.5 dB for far-end crosstalk.

Previously published studies and engineering guidelines in this field have been based on the average statistics over one pulse period of the interference and hence cannot address the above problem of the differences in noise margin when going to a synchronous network.

Near-end crosstalk interference from transmitter A impairs digital signals arriving at receiver B



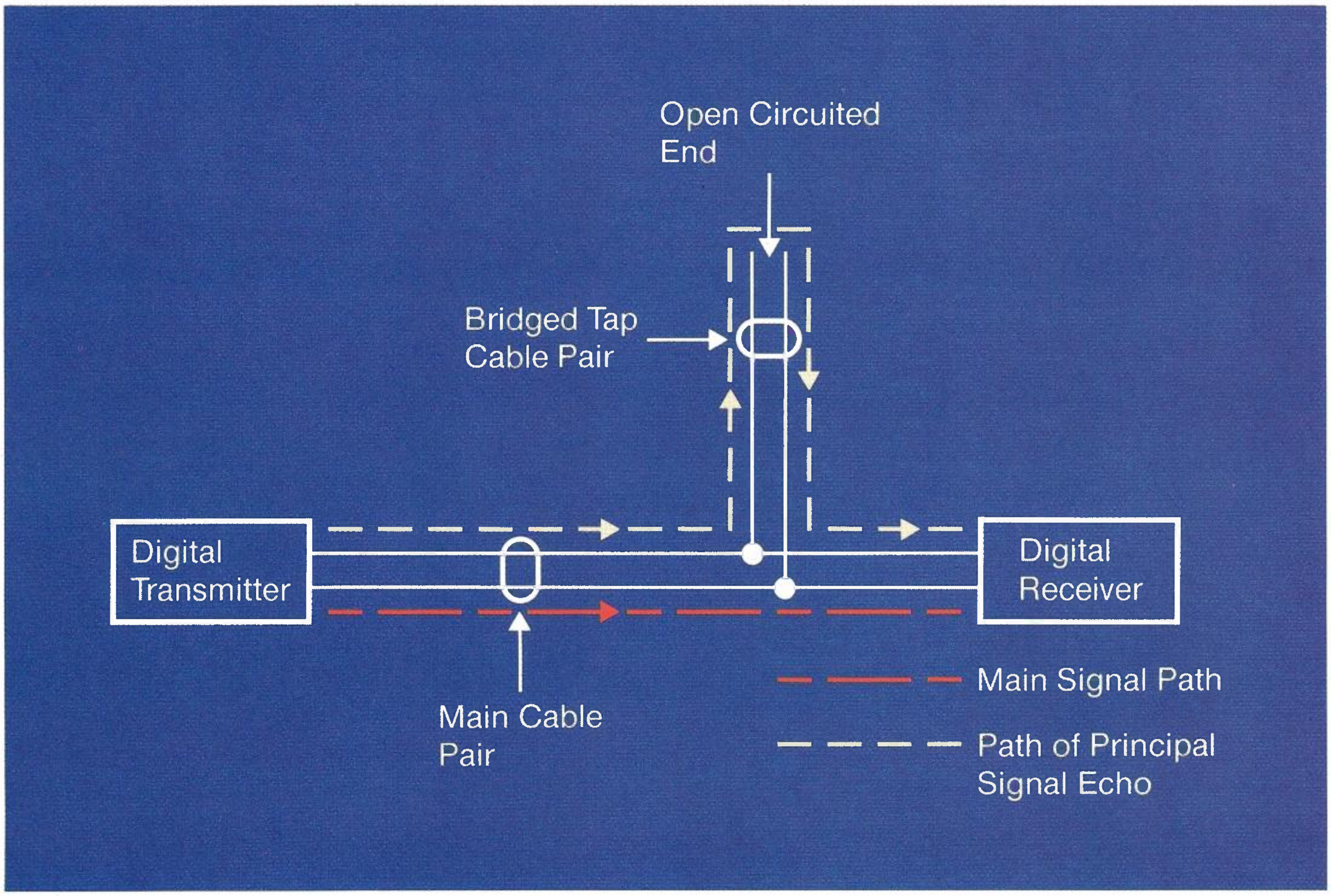
The Effects of Bridged Taps on the Transmission of Baseband Digital Signals

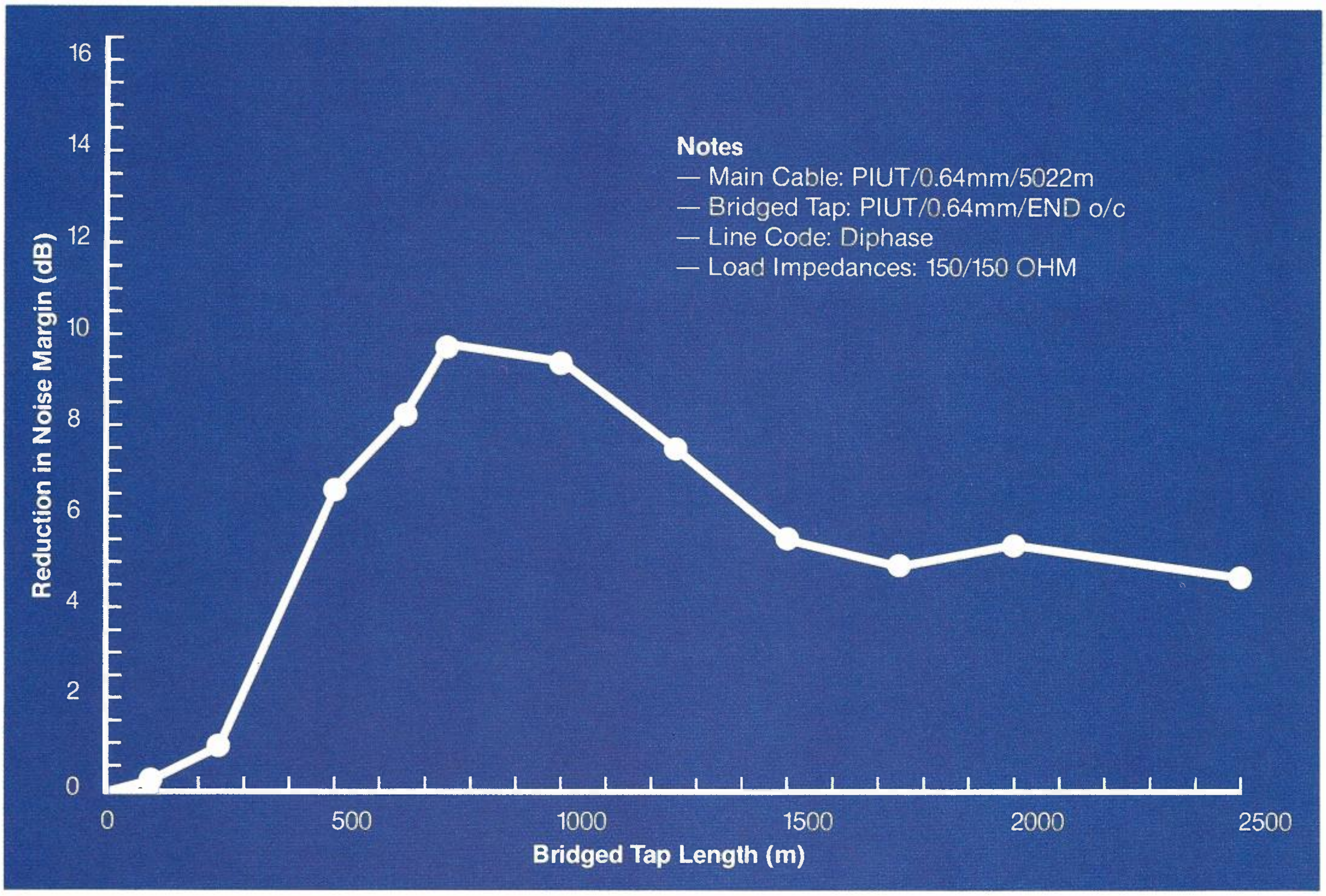
Past cable layout and installation practices used by Telecom Australia have resulted in a significant number of cable pairs in the subscriber cable network with one or more additional cable pairs bridged across some point along their length. These additional pairs are known as "bridged taps", "tees" or "multiples", and they are provided to give the subscriber network a degree of flexibility in providing future or additional services to customers. However, only one of the outgoing pairs from the bridging point is used at any given time; the ends of the other pairs are left open-circuited. Although these bridged taps cause no perceptible interference to voice signals, they can degrade the transmission of digital signals.

With the recent development of Telecom Australia's Digital Data Service (DSS), baseband digital data modems are being installed in increasing numbers in the subscriber cable network. Although at this stage cable pairs free of bridged taps are generally available, it will become increasingly difficult to avoid pairs with bridged taps in the future as the number of DDS customers increases. Consequently, a study was undertaken in the Research Laboratories to quantify the effect of bridged taps on the operation of the baseband data modems used for the provision of the data communication links in the DDS. Particular emphasis was placed on investigating the impairment produced on the operation of the 72 kbit/s modems used by Telecom, since these modems were considered potentially the most vulnerable to the effects of a bridged tap. The results obtained from the investigations at 72 kbit/s were extrapolated to predict the effect of bridged taps on the operation of the DDS modems used at the lower line rates of 3.2, 6.4 and 12.8 kbit/s.

A three-pronged approach was used in the investigation. An initial theoretical analysis was performed to provide a basic insight into the effects caused by bridged taps and to establish the relative importance of the various parameters involved. The insight was obtained by modelling the signal reflections up and down the bridged tap and the consequent signal impairment caused by the superposition of the echoes produced. The transmission impairment produced in an actual 72 kbit/s modem was then quantified by experimental measurements performed on a drum of 0.64 mm PIUT cable. Finally, these experimental results were complemented by simulation studies. An extensive range of simulation results was obtained with the aid of a comprehensive computer program to cover a representative selection of cable types, gauges and bridged tap conditions.

Digital transmission in subscriber cable network with bridged taps





Computed reduction in noise figure of 72 kbit/s baseband modem due to bridged taps of various lengths

The results of these investigations indicated that 72 kbit/s modem operation can be significantly degraded by greater than 10 dB reduction in noise margin if the bridged tap length, for typical cable types, is about 650 metres; however, longer and shorter lengths cause less signal degradation. For example, the reduction in noise margin produced by bridged taps longer than 1500 metres asymptotes typically to about 3.5 dB reduction in noise margin; and bridged taps shorter than 300 metres cause less than 2 dB reduction in noise margin. However, since information obtained from a subscriber loop survey suggests that most bridged taps in Telecom's subscriber network are less than 300 metres in length, the majority of cable pairs with bridged taps are still useable for the provision of 72 kbit/s data links for the DDS service, provided acceptable levels of impulse noise and crosstalk apply.

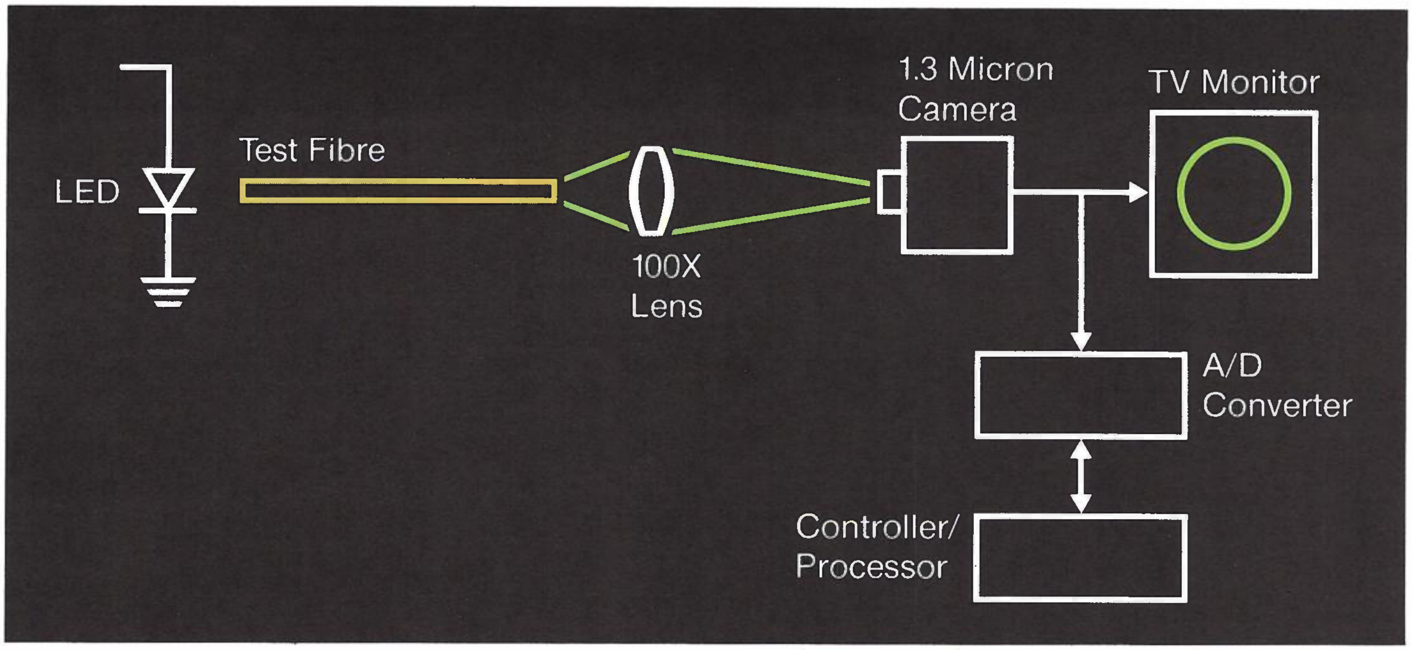
At the lower DDS modem line speeds, the correspondingly longer bridged taps required to cause significant interference are of greater length than nearly all bridged taps encountered in the network. At these lower speeds, bridged taps therefore cause insignificant transmission impairment. Furthermore, these longer bridge tap lengths cause relatively higher attenuation to the echoes produced, which in turn causes less signal degradation.

Single-mode Optical Fibre Studies

Single-mode optical fibres offer exciting possibilities for long haul trunk applications because of their superior transmission properties, which allow transmission rates of 140 Mbit/s and above over repeater section lengths in excess of 30 km. To ensure that timely advantage is taken of transmission systems utilising single-mode fibres in the Australian network, both laboratory and field trials are being undertaken.

A major objective of the laboratory studies is to investigate and develop methods of characterising the fibres as an input to the preparation of cable specifications. A measurement facility is being developed for the important fibre parameters. These include the attenuation of the cabled fibre, the effective cut-off wavelength, a mode spot description of the fundamental mode field and the dispersion. One approach being implemented for the mode spot description is digital processing of a TV image of the magnified near-field power distribution. This approach provides a spot size which is easily used in estimating transmission performance. It is also planned to measure the geometry of the fibre cladding and its relation to the mode spot location, by using the same equipment facility.

In the field studies, the Research Laboratories are participating in an Engineering Department field trial

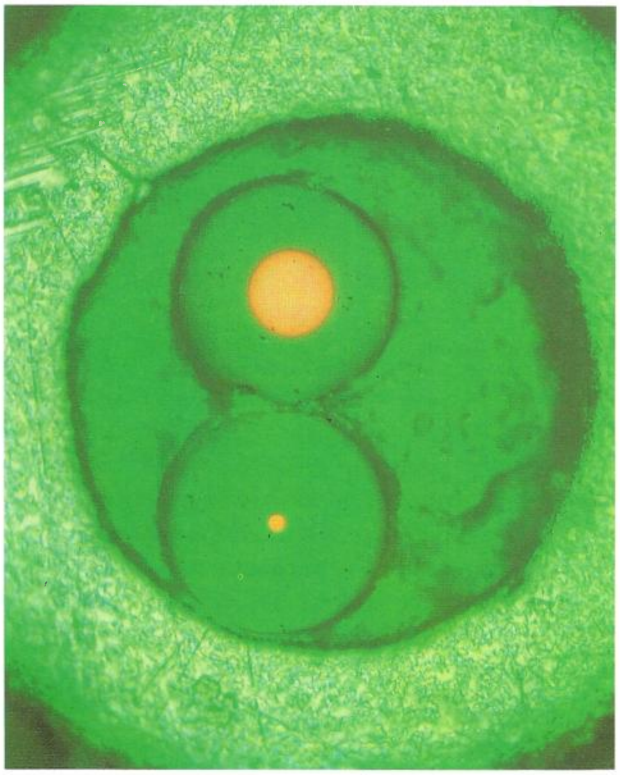


Near-field measurement technique for single-mode optical fibre spot parameters

of a single-mode optical fibre system which is being installed over a 76 km route between Melton and Ballarat in Victoria. A major component of these studies is an investigation of the effect of cable installation techniques on fibre lifetime.

Optical fibres are susceptible to failure through static fatigue if they are subjected to a high level of residual stress. The time-to-failure of an optical fibre can be many tens of years if it is installed and left in a lightly stressed state, or only a few months if subjected to a higher residual stress. Strain is more easily determined than stress, and it can be used in making lifetime/time-to-failure estimations. Consequently, an examination of the ploughing techniques used to install conventional cables in rural areas is being undertaken, and the Laboratories are developing prototype equipment for measuring the strain imposed on an optical fibre cable during installation. This equipment will be used in preliminary ploughing trials to assist in the selection of a suitable structure for the cable and to verify that the installation technique is satisfactory.

In parallel with this work, a research and development contract has been placed with Australian industry for the development of robust optical fibre strain measuring equipment suitable for field use.



Comparison of multi-mode and single-mode fibre cores

Ultra-low-noise Optical Pre-amplifier

Future optical fibre digital transmission links for long junction and trunk network applications will operate in the long wavelength region above one micron to exploit lower fibre loss and dispersion.

To improve receiver sensitivity and hence increase maximum repeater section lengths, the Research Laboratories have developed an ultra-low-noise PIN diode optical pre-amplifier suitable for operation in the long wavelength region, where at present, low-noise avalanche photo-diodes are unavailable.

In receivers employing PIN diodes, the receiver sensitivity is set by the pre-amplifier noise and its design is critical. The total pre-amplifier noise has two dominant components, namely the first stage device noise and the feedback resistance noise. In all feedback designs in current use, the pre-amplifier bandwidth is related strongly to the feedback resistance, and it is therefore impossible to reduce the overall noise by increasing the feedback resistance without a subsequent reduction in bandwidth. The optimum feedback design developed in the Laboratories eliminates this interaction and allows the feedback resistance noise to be reduced to negligible proportions, while still maintaining the desired bandwidth. The total pre-amplifier noise therefore approaches its theoretical minimum value, which is that set by the first stage device.

The optimum feedback configuration has already been implemented in the laboratory in hybrid thick film technology. This laboratory prototype is being used as a state-of-the-art general purpose optical pre-amplifier for the many special purpose laboratory measurement instruments used to characterise and investigate the properties of optical fibres and line transmission equipment.

It is intended to develop the circuit further by investigating and using thick film technology to improve the noise performance, thereby extending the bandwidth beyond that presently achievable using discrete components.

Electrical Simulation of the Impulse Response of Multi-mode Graded-index Optical Fibre

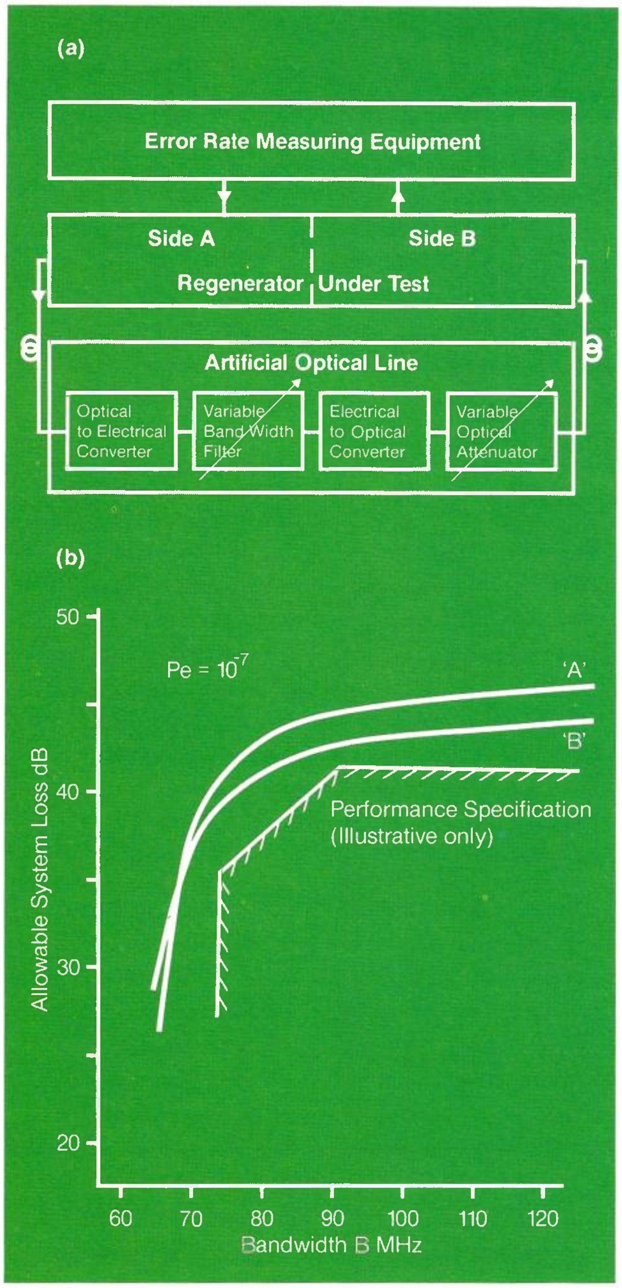
Telecom Australia is currently installing first generation optical fibre digital transmission systems operating at 34 Mbit/s and 140 Mbit/s over graded-index multi-mode optical fibre. These links will be used to provide high capacity digital circuits in the junction network and to digital radio terminals of the trunk network. In the years ahead, many of these optical fibre systems will be installed, particularly where a rapidly increasing demand for digital transmission capacity is expected.

The error rate performance of an optical regenerator depends on both the fibre attenuation and bandwidth. A feature which distinguishes optical fibre transmission systems from conventional metal bearer systems is that, even with perfect equalisation of the received signal to eliminate intersymbol interference, the error rate increases as the fibre bandwidth decreases. This is due to the signal dependent nature of the noise produced in optical to electrical conversion.

To design an optical fibre link, two of the many parameters describing the line transmission equipment that must be known are the receiver sensitivity and the minimum operating bandwidth to achieve a specified bit error rate. A useful measure of this performance is the dispersion power penalty, defined as the additional optical power required to maintain a constant error rate when a fibre of infinite bandwidth is replaced by one having a finite bandwidth. The receiver sensitivity can then be expressed as the sum of the receiver sensitivity for a fibre of infinite bandwidth, S dBm, and the dispersion power penalty, P dB.

To measure the dispersion power penalty, independent control over the fibre bandwidth and attenuation is required. To achieve this, the Research Laboratories have developed an artificial optical fibre line which simulates electrically the impulse response of long lengths of multi-mode optical fibre. The artificial line comprises an optical to electrical converter, a variable bandwidth electrical filter, an electrical to optical converter and a variable optical attenuator. A Gaussian impulse response was chosen for the filter after extensive measurements performed on long lengths of multi-mode optical fibre revealed a near Gaussian impulse response.

The receiver sensitivity for a particular error rate and the dispersion power penalty can be subtracted from the transmitted power to give an "allowable system loss", a parameter which uniquely specifies the regenerator performance. This parameter includes a component that varies with bandwidth, and



Characterisation of optical line transmission equipment
(a) Schematic of test facility
(b) Allowable system loss for typical regenerators

represents the maximum loss between transmitter and receiver that can be tolerated for a particular fibre bandwidth. In a transmission system, this is equal to the sum of the spliced fibre loss, connector losses and the system safety margin. The allowable system loss can be directly measured using the artificial optical line and conventional error-rate measuring equipment.

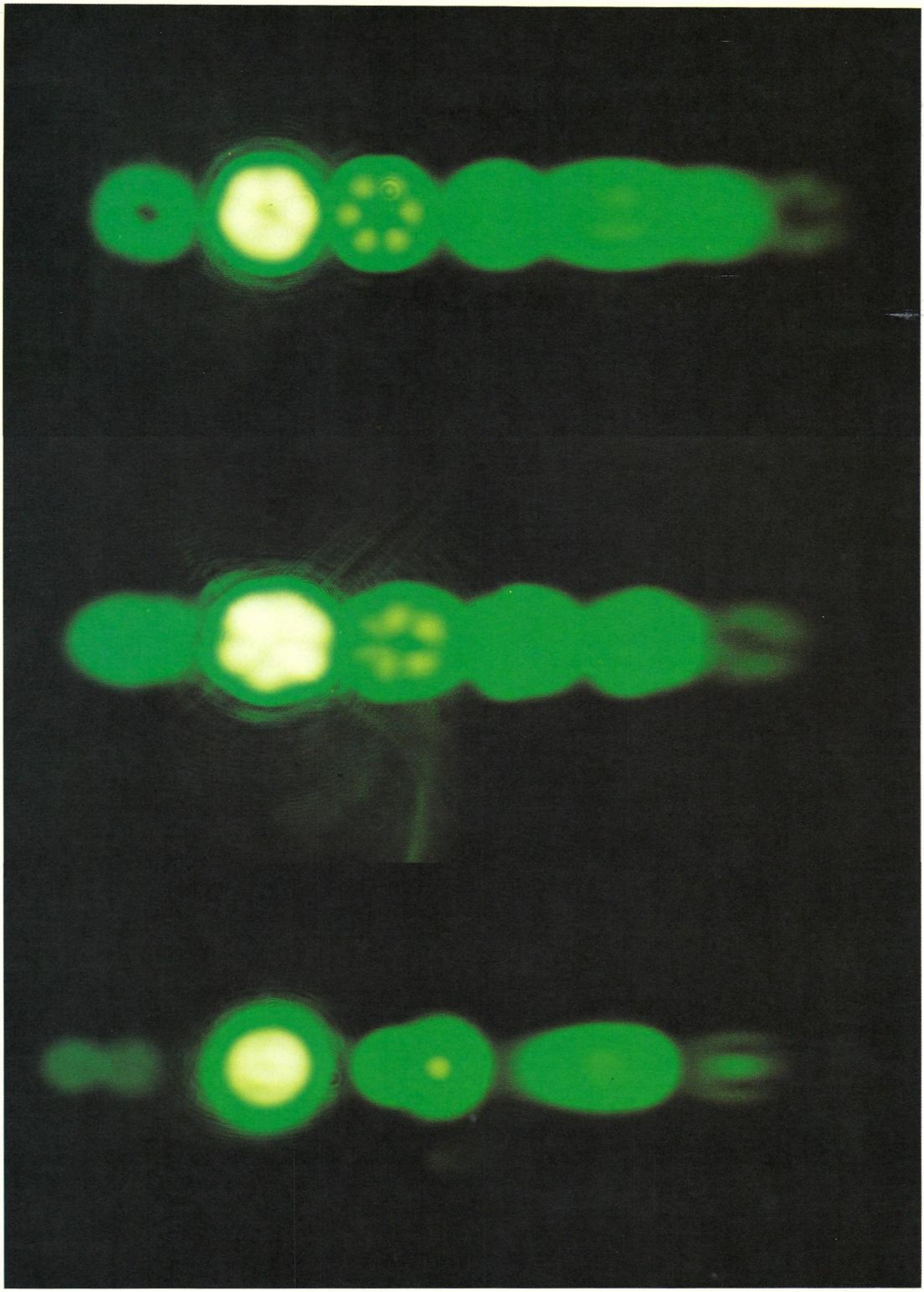
The characterisation of optical line transmission equipment using the artificial optical line provides invaluable information to system planners and allows efficient optical fibre transmission links to be designed with confidence, obviating expensive, over-conservative design.

Four Photon Mixing in Optical Fibres

If monochromatic light is passed through an optical fibre, a detailed examination of the light spectrum at its far end will reveal new frequencies which are produced in the core material as a result of the non-linear movement of the electric charges in the electromagnetic field of the light. It is by the movement or vibration of these charges that the light propagates through the fibre, and for materials such as silica, the non-linearity is extremely small. For this reason, the distortion products pass unnoticed in most optical systems. However, when sufficiently high optical power is coupled into a small diameter fibre, producing a high intensity in the core material, a variety of non-linear products can be observed in the output spectrum.

This phenomenon may provide the basis of a measuring technique for application in the quality control of optical fibres, since the associated spectrum depends on fibre geometry. The basic effect is due to the third-order non-linearity of charge movement with respect to field strength, which of itself is not frequency sensitive. The frequency selectivity, and consequent spectrum, results from the way in which certain combinations of fibre modes can compensate for the material dispersion which would otherwise prevent the continuing in-phase addition of the distortion products along the fibre. Thus, the speed of propagation in each mode will in general be different, and if laser light is launched into appropriate modes, the products formed at any point are in phase with those travelling at a particular frequency difference. It can be shown that light in up to four modes can take part in the process and it is from this feature that the name Four Photon Mixing is obtained. In effect, two laser photons, which may be in two different modes, disappear — to be replaced by two other photons which may be in two other modes.
Energy conservation requires that the sum of the new frequencies is twice the laser frequency, or in radio engineering terms, upper and lower sidebands are produced equally displaced from the carrier.

In the Laboratories, four photon spectra have been observed in fibres intended for single mode operation in the 1.3 μm to 1.5 μm region, by using a frequency-doubled Nd:YAG laser at 0.53 μm. At this shorter wavelength, several modes can propagate and a variety of spectra can be observed, depending on which modes are excited. As each line in a spectrum results from the phase matching condition and has a particular mode pattern, information is obtained about the relative speed of the fibre modes.
In comparison with direct observation of the fibre core geometry, the frequency shifts can be measured with considerable accuracy, and for this reason, the effect may have applications in detecting lack of fibre uniformity and fibre-to-fibre variations.



Four photon mixing : light from a fibre dispersed by a prism for three different launch conditions

Signal Processing Using Switched-Capacitor Circuits

Switched-capacitor signal processing is an analogue technique using only operational amplifiers, switches and capacitors to perform filtering and equalisation in transmission systems. First developed for voice-frequency applications such as in telephone codecs and PCM channel filters, the technique is now finding application for digital transmission systems at 200 kbit/s and higher. Its principal advantage is that it allows fully integrated MOS realisation of these formerly cumbersome functions without the high power consumption of digital signal processing.

The Research Laboratories have been investigating the potential of this technique for application in local digital reticulation. Since existing customer lines have high attenuation and are highly dispersive, the equalisation of these lines is particularly difficult. An adaptive equaliser is a desirable solution in this application.

A switched-capacitor equaliser has been developed in the Laboratories for this application. It is based on traditional equaliser structures transformed to the switched-capacitor technique. In this way, some of the advantages of the traditional structures, such as low sensitivity to component variations, are maintained. At this stage, a laboratory prototype of the equaliser has been developed and further work is under way to proceed to full integration of the equaliser.

By varying the capacitor values of the switched-capacitor circuits, variable and adaptive circuits can easily be obtained. In this way, adaptive equalisers can be designed to deal with line variations. The capacitor values can be controlled digitally, thereby combining the advantages of digital techniques with the switched-capacitor technique.

VLSI Design and the Multi-project Chip

There is little doubt that very large scale integrated (VLSI) circuit devices will form the basic components of many items of future telecommunications equipment. Such circuits can comprise up to 100 000 transistors on a tiny piece of silicon, or "chip", providing increased speed of operation, circuit density and reliability at reduced power consumption and cost per circuit element.The Laboratories are conscious of the need to maintain expertise in this important area of technology, so that Telecom Australia can be given timely and relevant advice on the many aspects of integrated circuit applications in the telecommunications context. They are also aware of the very sophisticated and expensive facilities required in the large volume production of VLSI devices and of their limited availability in Australia. These factors present the would-be Telecom Australia designer of custom-designed VLSI devices for special low volume telecommunications applications with difficulties in realising his designs as economical devices.

One possible means of overcoming these difficulties lies in the combined adoption of the Mead and Conway VLSI circuit design methodology and the multi-project chip (MPC) concept for integrated circuit device fabrication. The Research Laboratories have been investigating the value of such an approach.

The design methodology devised by Professor Carver Mead of the California Institute of Technology and Dr. Lynn Conway of Xerox Research Centre, California has been disseminated widely throughout Australia by the CSIRO Division of Computing Research, with which the Laboratories have been collaborating since 1981. The Laboratories were among the groups from Australian industry, academia and Government laboratories which were invited by the CSIRO to participate in Australia's first VLSI multi-project chip (MPC) programme, dubbed AUSMPC 5/82.

The Mead and Conway methodology uses VLSI circuit design techniques which are based on a conservative set of design rules and very basic transistor models, to produce geometric layouts for each of five masks required in the fabrication process. The techniques allow designers who have little or no knowledge of semiconductor physics to successfully design their own integrated circuit layouts. Extensive computer-aided design (CAD) tools are used to design and simulate the circuits before they are fabricated.

The MPC concept is a means of reducing the cost of realising a particular circuit on silicon, by sharing the mask-making and subsequent fabrication costs among many such circuits, each from different designers. This is achieved by merging the circuit designs into what is effectively a single, large chip for fabrication purposes. An economy of scale is thus achieved. After the chips are processed and packaged, each circuit designer receives chips in which only his circuit is connected to the package pins.

The technology used to fabricate the MPC circuits is a self-aligned, silicon gate nMOS depletion load process. This is a relatively simple process, using five mask levels to produce the enhancement and depletion mode transistors. It is used by many manufacturers.

During the year, Laboratories' engineers designed three circuits with experimental telecommunications applications, for inclusion on an AUSMPC 5/82 multi-project chip. These were:

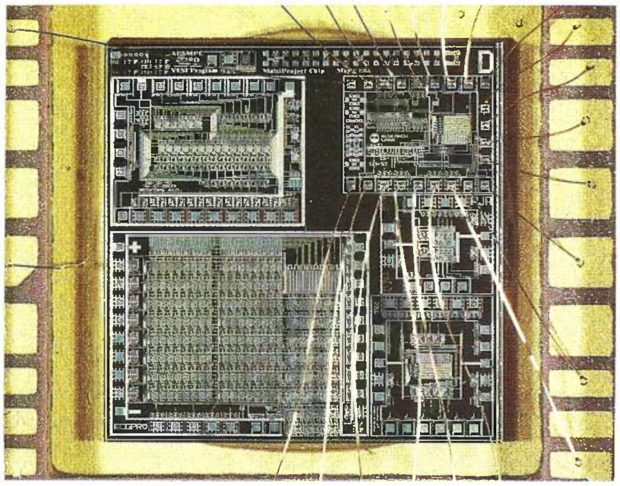
- a digital time division multiplexed switch
- an error rate monitor suitable for use in the front end of a CCITT No 7 signalling terminal
- a PCM signal and line code generator sub-system.

The digital switch is a 4-channel time division multiplexed switch, having 4 bits per channel. This circuit was designed using a symbolic layout language distributed by the CSIRO and verified by plotting the layers on a colour plotter. The error rate monitor uses a leaky bucket counting scheme to count errors on the signalling link, and indicates when the error count exceeds a preset threshold value. This circuit was designed using a black and white graphics system employing software layout tools developed in the Laboratories. The PCM signal and line code generator is a central component in a prototype instrumentation system developed in the Laboratories to enable the transmission performance of PCM regenerators in the presence of cable crosstalk to be verified prior to the installation of the regenerators in the field. This third circuit was designed using software design programs provided by the CSIRO in combination with the Research Laboratories' interactive computer graphics system.

All three circuits used about 1000 transistors, occupying an area of the silicon die of about 2 mm x 2 mm. The design time involved for each circuit was about 10 man-weeks.

The circuit devices were subsequently fabricated by a private company in USA and by AWA Microelectronics Pty. Ltd. in Australia. The results obtained from evaluations of the circuit designs and the performance of pre-production quantities of the devices were very encouraging.

The overall success rate of the MPC programme to date confirms the importance of this technique as a method of producing custom-designed integrated circuit devices. The continuing development of more advanced software design tools, both overseas and within Australia, will further simplify the ease of design and reduce the design time for future circuits. The Laboratories plan to keep in touch with developments in this area.



Fabricated MPC device, with a Laboratories-designed circuit connected to the perimeter package pins

Laboratories' engineers check MPC layout before fabrication

Characterisation of Semiconductor Materials Grown by Molecular Beam Epitaxy

The Molecular Beam Epitaxy (MBE) machine at the Laboratories is growing semiconductor epitaxial layers for research purposes. Interest centres upon semiconductor alloys made from such elements as gallium, arsenic, phosphorus, indium and aluminium. It is from these materials that the high performance lasers, transistors and diodes essential for telecommunications systems are fabricated.

A vital element in the semiconductor growth process is feedback concerning the quality and purity of the material produced. With this information, optimum control over crystal growth procedures can be maintained, ensuring high quality epitaxial layers for device construction. Both electrical and optical characterisation facilities have been established to provide feedback data.

Electrical Characterisation Facility

This facility is able to characterise a range of semiconductor compounds and structures (e.g. laser diode and high electron mobility) which the MBE facility is capable of producing. The detailed information required is the dopant density versus depth, the carrier mobility in the epitaxial layers, the degree of crystal perfection, and the identification of impurities and defects.

This information is obtained by incorporating a number of measurement procedures in the electrical characterisation facility. These are as follows:

- Electrochemical capacitance-voltage profiling. This measurement procedure gives a dopant depth profile of the epitaxial layers grown.
- Hall mobility and resistivity measurements. The analysis of Hall mobility and resistivity measurements are made over a temperature range of 77°K to 300°K, providing details about the crystal quality donor and acceptor concentrations, and the mobility of majority carriers. Both the material grower and the device fabricator find this information essential.
- Deep level transient spectroscopy (DLTS). This measurement technique is carried out over a temperature range similar to that used in Hall mobility measurements. The purpose of the DLTS technique is to measure the density of crystal imperfections and to identify them by their characteristic energy. This information is important, as it can be used to optimise MBE growth conditions.

The above measurement procedures have been largely automated to facilitate experimental control and data collection. Once the data has been collected and stored, processing routines are applied to filter out specific information about the semiconductor under test.

Optical Characterisation Facility

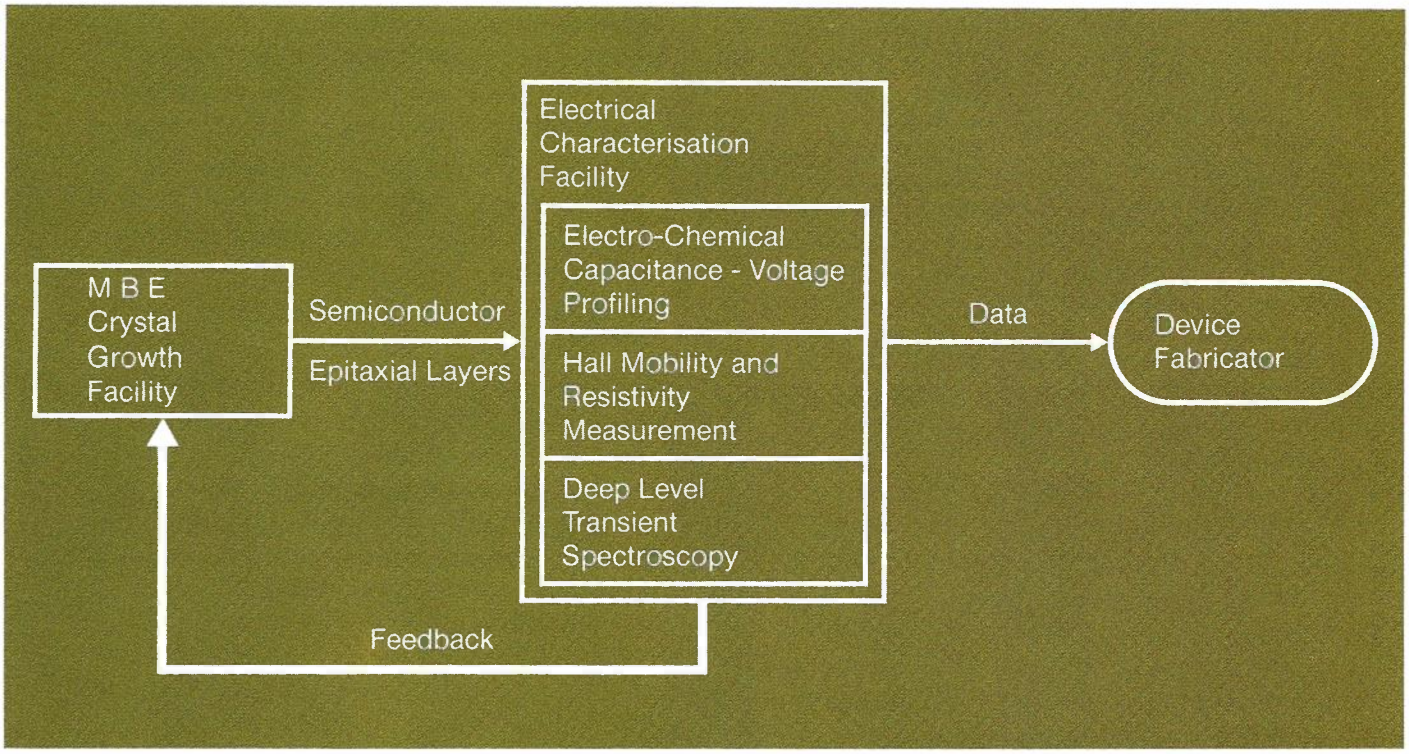
This facility is based upon photoluminescence (PL) spectroscopy, i.e. the spectroscopy of the visible and infra-red radiation emitted following the excitation of a material by light. If a semiconductor is illuminated by radiation of sufficient energy, electrons and holes are injected into the conduction and valence bands respectively. For gallium arsenide, this illumination must be by light of wavelength less than about 800 nm. Because of their Coulombic attraction, many of these excited electrons and holes pair up, forming hydrogen-atom-like entities known as excitons. These are highly mobile in the perfect crystal, but bind readily to crystal imperfections and chemical dopants in the excited volume. Thus, even in the most perfect and high purity crystals, virtually all of the electron-hole pair recombination takes place at impurity or defect sites, giving rise to a spectrum of emitted light characteristic of the impurity energy states, even at concentrations of about 10 parts per billion or less. The spectrum also provides a very precise measure of the semiconductor band-gap, and thus of material composition in ternary and quaternary alloys. The technique is particularly suited to characterisation of epitaxial layers, as the exciting radiation is typically fully absorbed in a depth of 1 to 5 microns, thus sampling the epitaxial layer only.

Experimental requirements are:

- very low sample temperatures to freeze out shallow impurities and eliminate thermal broadening of optical processes
- several laser sources for optimal excitation of different semiconductors
- sensitive optical detection and dispersion, since, with competing non-radiative de-excitation mechanisms, the emitted intensity can vary over many orders of magnitude.

The photoluminescence system developed in the Laboratories consists of:

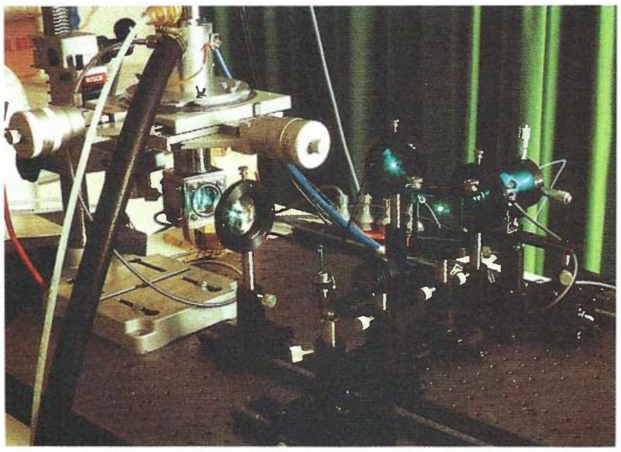
- helium-neon or multi-line argon ion lasers for the excitation source
- a variable temperature, liquid helium cryostat, to investigate the PL of a layer as a function of temperature in the range 4°K to about 300°K, and so measure such quantities as donor/acceptor ionisation energies
- a high resolution (<0.01 nm) spectrometer with a focal length of 1 metre
- a high sensitivity photo-multiplier tube coupled to photon counting electronics. This counting method is a digital version of traditional lock-in amplifiers, and has inherently higher long term stability and greater sensitivity (background noise levels of about 5 photons per second than the analogue approach)



Schematic illustration of the role of the electrical characterisation facility

- microcomputer control of the system via the IEEE-488 bus.

The photoluminescence system is now in regular use in the Laboratories, providing feedback to the MBE growth process and assisting continuing investigations into the conduction and optical processes in gallium arsenide and aluminium gallium arsenide.



In the photoluminescence spectroscopy facility, laser light introduced via an optical fibre (right rear) is focused onto the semiconductor sample mounted in the cryostat

High Resolution Low Energy Electron Spectrometer

To assist in-house research into semiconductor device technology, the Laboratories have recently designed, developed and commissioned a high resolution low energy electron spectrometer. The instrument is now being used to characterise semiconductor-vacuum and semiconductor-metal interfaces. The former is important during growth by molecular beam epitaxy and the latter is the heart of ohmic contacts and Schottky barriers which are essential to all semiconductor device technology. Such interfaces are poorly understood and are a chief cause of failure of these devices. The spectrometer provides information on the surface structure, crystallography and electronic interfacial properties.

The spectrometer was developed in the Laboratories because no suitable apparatus was commercially available. The development task presented a number of interesting challenges related to material choices and their machining and magnetic characteristics; the electrical insulation of metallic parts; the use of ruby balls as spacers and bearings; and the requirement that, if dismantled, the equipment could be easily and accurately re-assembled to its original configuration. To meet these challenges, new techniques for the machining and welding of some unusual materials were developed and special care was taken with fabrication tolerances. Since it is important that magnetic fields should be less than one milli-Gauss in the ultra-high vacuum application of the spectrometer, all parts of the spectrometer, and particularly the machined stainless steel components, were subjected to magnetic measurement, and de-Gaussing where necessary, during fabrication.

The apparatus comprises a spectrometer and a monochrometer, which are mounted on a stable carriage. The monochrometer is mounted on a shaft so that it can be rotated relative to the spectrometer over a calibrated range of incident angles. The whole carriage can, in turn, be moved on slides within the vacuum chamber to free the semiconductor surface under investigation for other operations or to allow exchange of test specimen.

The monochrometer is mounted on a stainless steel shaft which can be rotated on ruby ball bearings housed in bearing supports attached to the carriage base plate. The monochrometer is mounted at one end of the shaft in precise alignment with the spectrometer and their relative angular position is indicated by a rotating calibrated scale attached to the shaft and a fixed pointer. The spectrometer is mounted in a fixed position relative to the shaft. A drive coupling and counter-balance weight are attached to the other end of the shaft, allowing the assembly to be smoothly rotated and then held stable in the desired position.

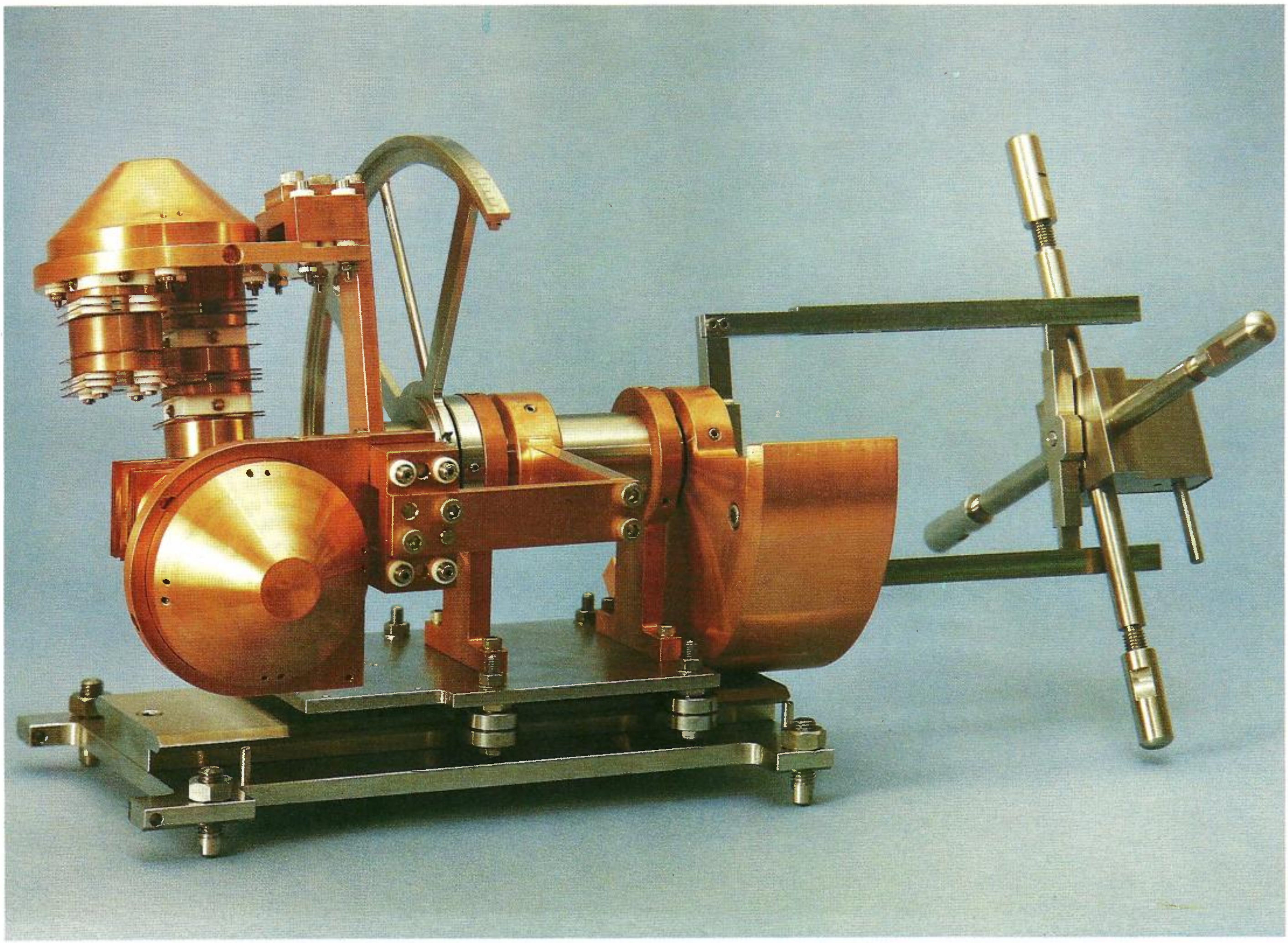
The spectrometer and monochrometer are mirror images of each other, apart from the different composition of the stacks protruding from their baseplates. The stacks consist of a number of lens plates, deflector assemblies and several other sub-assemblies to position and align the stacks.

Each metallic piece is insulated from the others because they are individually positively charged. A convex and a concave hemisphere are located on the reverse side of the baseplate, and a uniform gap is provided between the two. Both hemispheres sit upon 3 mm diameter ruby balls to give the required "stand-off" gap to provide the correct electric field around the assemblies. Each hemisphere is also electrically insulated from surrounding parts of the assembly.

One of the main objectives in the fabrication of the apparatus was to ensure that if dismantled, it could be easily and accurately re-assembled to its original configuration. By employing close tolerance machining, stainless steel and ceramic dowels and hollow silica tubes to align components on the lens stacks, and ruby balls on the hemispheres, this requirement was met.

The development of the apparatus by the Equipment Engineering Section of the Laboratories has been successfully concluded, all specifications having been fulfilled. The apparatus is now in use in the Solid State Electronics Section.

High resolution low energy electron spectrometer



High Vacuum Evaporation System

Thin film technology is fundamental to the fabrication of many microelectronic, opto-electronic and optical devices. Since such devices find application in telecommunications systems and equipment, the Laboratories are conducting research into thin film technology to provide in-house knowledge of the fabrication processes and their effects in device performance and reliability, and also to fabricate small numbers of advanced devices for use in Laboratories' experiments which are equipment or system-oriented.

In thin film technology, a circuit device is built up layer by interconnecting layer on an inert substrate material by successive cycles of masking the substrate and depositing a thin film of material in the designed pattern of each layer. In thin film evaporation, the masked substrate is placed in a high vacuum chamber, where the material of the film to be deposited is heated until it evaporates as an atomic or molecular stream. This stream then condenses onto the exposed substrate where it forms a thin film of the material in the presence of reactive gases.

With the growing complexity of thin film devices, multilayer structures of varying materials, including compounds and alloys, must be fabricated. To meet the physical demands placed on these structures, automatic process control techniques must be used to ensure the integrity of the film layers.

To provide the necessary facilities for research in this field, the Laboratories have recently procured and commissioned the first microprocessor-controlled, dual-beam electron gun, high vacuum evaporation system in Australia.

The system has a capability of automatically evaporating up to four different materials in a thin film structure of up to 24 layers. A special feature of the system is its large cryogenic pumping capability, which condenses the evaporated gas molecules onto cold plates. The system also has a high water vapour and hydrogen pumping capability, which is desirable in the deposition of refractory metals.
Mass spectrometry is utilised in the analysis of the chamber gases.

Microprocessor-controlled high vacuum evaporation system

Semiconductor Device Failure Analysis

The repeated service failure of a particular semiconductor device in a telecommunications plant application leads to speculation as to whether the device is inherently poorly designed, or whether it has been subjected in its particular application to environmental and electrical stress conditions which were severe enough to have markedly reduced its expected life. When such failures occur, the Laboratories are often called upon to determine the precise mechanism of the component failure.

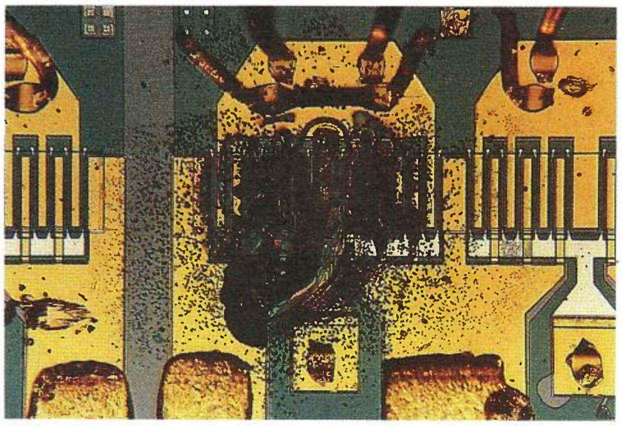
A selection of advanced measurement and analysis techniques are applied in such investigations in the Laboratories. The following outlines of two recent failure analyses illustrate the application of several of these techniques, which have become available with recent instrumentation procurements.

In one recent case, a new type of microwave radiocommunications system placed into service by Telecom Australia failed three times over a short time interval, with significant loss of service on each occasion. The seat of the failure was identified on each occasion as a particular type of semiconductor power device used in the system. The device employed state-of-the-art field effect transistor (FET) technology. As Telecom planned to introduce more systems of this type into service, failure analysis was undertaken. The failed devices were opened and inspected, revealing severe burn-out of one of the four parallel transistors in each package. Only one transistor of the four was damaged; the other three were working correctly. A literature survey indicated that random, spontaneous self destruction may occur in devices of imperfect quality, but the observed failures differed in appearance from those so described. After investigating the remaining good transistors in the packages, it was found possible to trigger a similar failure by stressing the transistors with a slight electrical overload. A study of the complete operating environment of the component indicated that such stress levels might occur under field conditions. This case exemplified a situation where the device was sound but its operating electrical environment was in need of modification.

In the second example of a failure analysis, the Laboratories sought to determine why transistors in certain types of switchboard located in lightning-prone areas failed due to excessive leakage. In this case, a more advanced failure analysis technique was applied. It involved the use of electron beam induced currents (EBIC) and the observation of the devices with a scanning electron microscope (SEM). Visual inspection of the transistor devices had revealed a large number of scratches and defects on the chips, but suggested no obvious failure site.

Using the EBIC technique in the scanning electron microscope, all superficial chip defects remain dark on the observed image, but the leakage paths are highlighted. The EBIC technique utilises the capability of a high energy beam of electrons to create electron-hole pairs in a semiconductor and so produce excess current. As the beam scans the specimen, the current collected from one of the device terminals is amplified and used to control the intensity of a video screen image of the specimen. An area of excess current, corresponding to the defect, produces a bright spot in the video image.

In the case under discussion, such defects were found in the base regions of the failed transistors. By SEM examination of the topology of this region of the device, it was concluded that the physical nature of the fault was an oxide rupture caused by electrical overstress.



Failed gallium arsenide power FET

Facilities for the Evaluation of Solar Cell Modules

During the past year, a new facility has been completed by the Laboratories which will enable comprehensive evaluations to be made of the performance and reliability of solar cell panel modules in the range of environments likely to be found in Australian applications of the modules. The facility involves both special laboratory and field site installations. The establishment of the facility has been funded, in part, by a grant from the Australian National Energy Research, Development and Demonstration Council (NERDDC).

Telecom Australia is currently one of Australia's largest purchasers of high reliability solar cell modules in a narrow range of sizes. It uses these principally to power radiocommunications equipment providing trunk and subscriber links in the more remote rural and outback areas of Australia. The Laboratories have therefore developed expertise in recent years in solar panel evaluation to assist these Telecom applications.

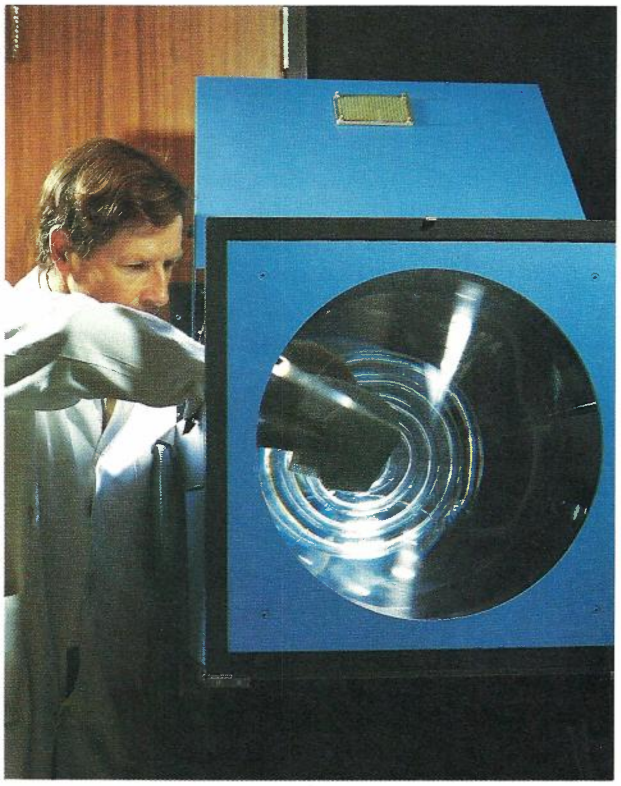
With the new facilities, the Laboratories will expand their role to a national level and increase the scale of their activities in this field to provide more comprehensive evaluations of solar cell modules over a wider range of sizes and intended applications. Test samples of modules will be provided by a number of Australian and Japanese manufacturers and test results will be made more widely available to interested organisations and persons.

The major item of equipment in the laboratory is a pulsed solar simulator and its associated data acquisition system. Using this simulator, the electrical characteristics of solar cell modules, in the form of a current-voltage (I-V) curve, can be accurately measured under fully controlled conditions of irradiance and temperature. It will be possible to determine these characteristics at any time in the laboratory, regardless of outdoor weather conditions, thus enabling the effects of various accelerated environmental and mechanical tests and of the field site exposures to be monitored. Accelerated testing is performed in temperature and humidity-controlled ovens, and purpose-built equipment is used to perform tests under controlled conditions simulating wind loading, hail impact, and cell shadowing (hot spots). Outdoor facilities to determine the Nominal Operating Cell Temperature (a measure of a module's ability to shed unconverted radiation) have been set up on the Laboratories' campus.

Outdoor exposure sites have been installed at the Laboratories at Clayton, Victoria – in a temperate climatic region; at Innisfail, Queensland – in a hot and wet climatic region; and at Cloncurry, Queensland – in a hot and dry climatic region. The Clayton site was set up first and, as well as providing data on the performance of modules in a temperate climate, it was used to establish the feasibility of the associated automated data logging procedures and to debug the equipment and software, prior to the installation of identical equipment at the other distant locations.

At all sites, modules are mounted facing north and inclined at the latitude angle to the horizontal. Pairs of each manufacturer's modules are connected as a small array to their own regulator, storage battery and constant current load. The data collected at each site includes frequent readings of solar irradiance array currents; load currents; temperatures of the modules, associated batteries, the outside air and of a black body in full sun; relative humidity; rainfall; wind speed and direction; and battery cell voltages. Each day at about noon, data for a 30-point I-V curve of each module is recorded, enabling daily monitoring of other aspects of module performance. Each night, the data collected during the day is automatically transmitted over telephone lines to a computer at the Laboratories, where it is processed to allow easy monitoring of all parameters of interest.

When sufficient data is accumulated, it is analysed to correlate changes in module performance with the climatic exposure conditions. It is expected that, within three to five years, these field site exposures will have yielded sufficient results to enable some correlation with the results obtained from accelerated laboratory testing.



Light source of pulsed solar simulator showing coiled Xenon arc tube through the Fresnel lens

Fabrication Techniques for Solar Cells

With growing applications for solar cells as a means of powering telecommunications equipment, particularly unattended equipment in the more remote parts of Australia, the Research Laboratories have been investigating several of the processing techniques used for the fabrication of solar cells. The objectives of this work are to evaluate ways of simplifying the fabrication process or of increasing solar cell efficiency, and thereby to contribute to the development of solar cell technology.

Two techniques have been studied in the laboratory, namely:

- screen printing techniques to fabricate the ohmic contacts on the silicon surfaces of solar cells
- chemical treatment of the silicon surface to increase the output power of solar cells.

Screen printing techniques, similar to those used in making thick film hybrid circuits, offer promise as a means of providing solar cell ohmic contacts on the silicon which are both more economic and provide a simpler fabrication process than for conventional vacuum evaporated ohmic contacts. Specially formulated commercial thick film pastes intended for solar cell contact applications are readily available. However, laboratory experiments have shown that special care must be taken in their use, since higher contact resistances can occur with the screen printed paste technique than with vacuum evaporation of metal contacts. The increase in contact resistance causes a decrease in solar cell output power.

In the screen printing technique, the pastes are fired and yield a contact which comprises a mixture of sintered metal particles suspended in glass. The technique has fundamental restrictions on the minimum printable line width and on the cross-sectional shape of the line. As line widths are decreased, the contact resistance increases more rapidly than for lines produced using conventional vacuum evaporation techniques.

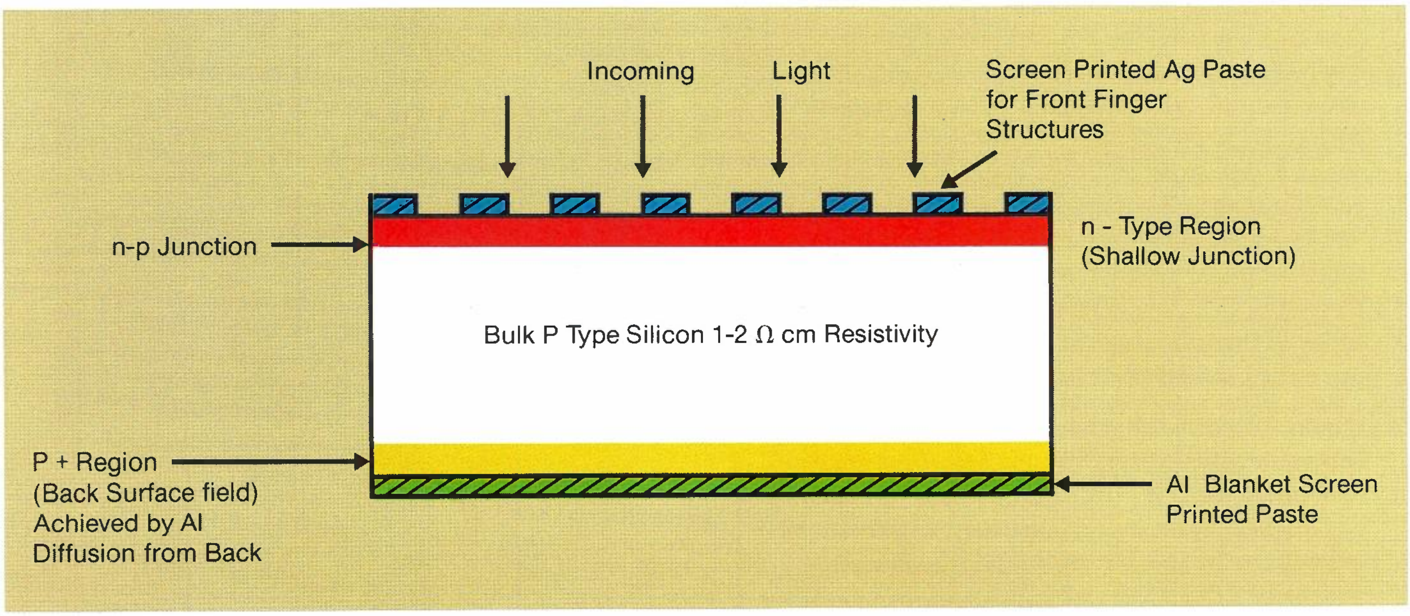
A number of solar cells have been fabricated in the Laboratories using screen printed ohmic contacts. A variety of contact patterns were tested and their specific contact resistances were characterised. The experimental results show that, with careful processing, satisfactory contacts can be achieved on both the front and back surfaces of the cell.

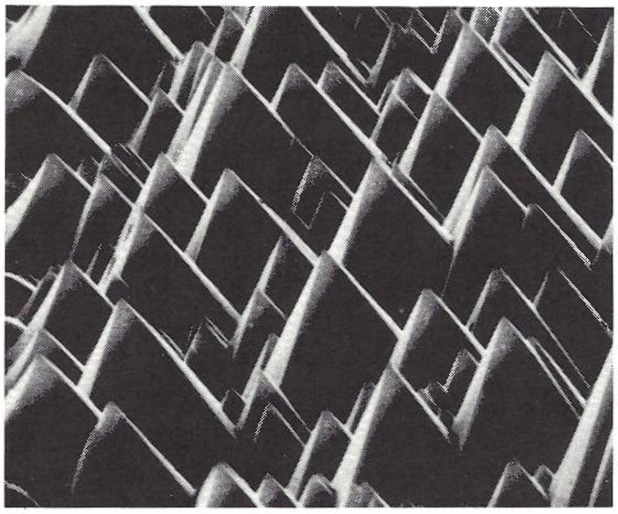
In other experiments, the surfaces of solar cells have been chemically etched to yield a surface texture which reduces reflection of incident sunlight and thereby increases the output power of the solar cell.

In the experiments, an anisotropic etching treatment has been used to selectively etch "pyramids" on the silicon surface of the solar cell. The overall effect of these closely packed pyramids is to provide multiple reflection paths for the incoming light, thus coupling a larger fraction of this light into the solar cell. Typical reflection losses of polished untreated silicon surfaces are as high as 35%. These losses can be reduced to a few percent by surface texturing, thus allowing a further increase in conversion efficiency. The colour of the texturised cells appears dull black since little light is reflected from the surface. Only at oblique angles can some reflection be seen.

These studies, together with those concerned with the evaluation of the performance and reliability of solar cell modules in the range of environments found in Australia, are intended to keep Telecom Australia abreast of solar cell technology.

Typical cross-section of experimental thick film solar cell fabricated in the Laboratories





Texturised silicon surface of experimental solar cell (approx. X4000 magnification)

Wind Load Testing Apparatus for Solar Cell Modules

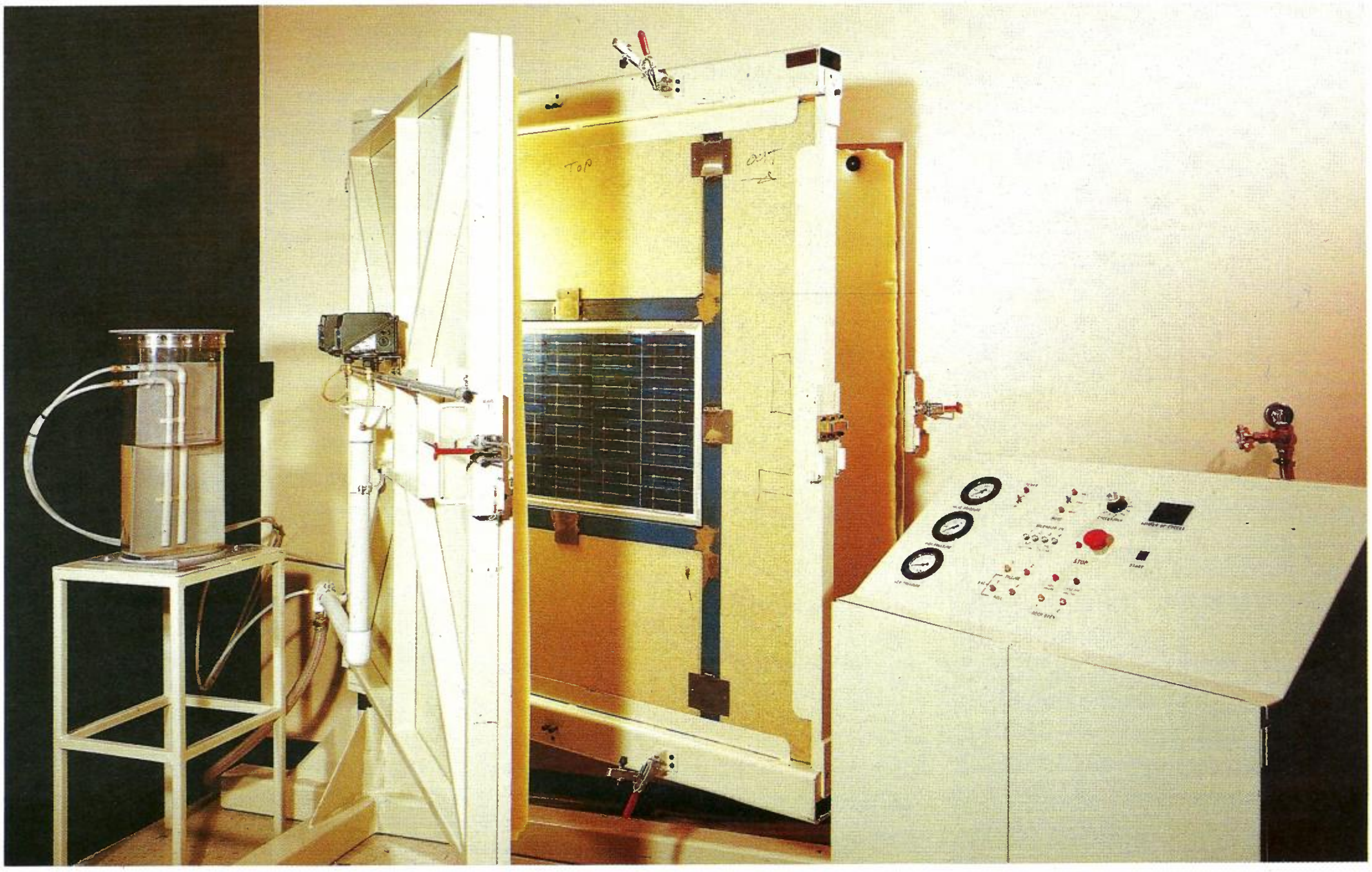
A programmable Wind Load Simulator has been designed and constructed in the Laboratories to provide a specialised, purpose-designed facility which is now being used in laboratory studies of the reliability of solar cell panel modules. Simulated wind load testing is one of a suite of tests being applied in this work.

The simulator provides a facility for cyclically subjecting solar cell panel modules to stresses equivalent to wind gusts of up to 160 km/h. The test program requires these stresses to be applied 20 times per minute, and the performance reliability of the modules is assessed against their ability to withstand 20 000 test cycles. This test program enables the general physical robustness and other design features of the modules to be assessed. These features include the mechanical construction of the modules, their mounting arrangements, the types of materials and sealants used in their construction, and the means and materials used to establish internal and external electrical connections.

The simulator enables each module under test to be fitted to a rigid frame, using the inbuilt mounting arrangements of the module. The module is then sandwiched securely between two doors.
An inflatable bag covers the inside surface of each door, with a layer of low density polyurethane foam separating the surface of the bag and the solar module. When inflated, either bag simulates an evenly applied wind load, whilst the foam layers ensure that any sharp feature on the module does not puncture the bags.

By means of an electro-pneumatic control system, either or both bags can be inflated to a pressure of up to 2.6 kPa and then deflated. With cyclic inflation-deflation, the loading effects of wind gusts up to 160 km/h can be simulated. Alternatively, static loading effects on either side of a module can be simulated by manual operation of the apparatus.

Wind load testing apparatus



Safety precautions and electrical interlocks have been built into the control system logic and the mechanical engineering design features of the simulator, to ensure that testing forces are not exceeded and that operating staff are not exposed to hazards resulting from the considerable forces applied within the simulator when the bags are inflated. Safety features ensure that, for any fault condition, the air supply is switched off and air in the console and test unit is bled to atmosphere. A column of water is used as the final fail-safe over-pressure device. A continuity test of the module circuitry is maintained and any brief open-circuit will halt a test.

The design also allows for one door to be opened and a safety frame fitted in its place so that the deflections in a module can be measured under static load conditions.

Automated Control and Data Analysis System for Battery Testing Facility

Telecom Australia has a large investment in secondary storage batteries in the no-break power supplies of exchanges and other equipment stations throughout its network. The quality control and reliability aspects of battery technology have been under study in the Laboratories for some years and various aspects of this work have been reported in previous editions of the Review of Activities. Recently, to improve the efficiency of battery testing in the Laboratories, an automated, fully instrumented battery test facility has been developed in the Laboratories.

The facility automatically cycles batteries of varying capacity through specified charge-discharge routines, measuring a variety of parameters related to battery performance and subsequently analysing them.

The control system for the facility comprises seven sub-controllers, each of which controls the test program for batteries of a particular capacity. The seven sub-controllers are themselves controlled by a Hewlett Packard desk-top computer type 9845B via a general purpose interface bus to IEEE Standard 488(1978). This computer can commence a series of tests via any sub-controller as well as process the collected test data.

Because battery testing is a continuous process over many days, a special multi-tasking software program was written for the computer which would collect the data from the sub-controllers when necessary, while allowing the operator to obtain results of current or previous tests in either tabular or graphical form. The data received from the sub-controller contains header information about the test, measurements of cell voltages, positive and negative half cell voltages, and cell temperature for each cell being tested, as well as battery ampere hours and circuit test current. The sub-controller uses the service request line (SRQ) on the interface bus to communicate to the computer that data is waiting to be sent. The computer responds to the SRQ by interrupting its present task, carrying out a serial poll, reading and formatting the data block containing some 500 to 3000 bytes. It immediately stores the data block into a selected file on the Winchester disk memory of 16 Mbytes capacity. A separate file is used for each particular test run and it is independent of the source sub-controller. These files can each contain up to 2000 data blocks on 0.5 Mbytes of disk storage.

While the data is being collected, other data collected and analysed from current or past tests can be presented as a graphical display either on a CRT screen or by means of a multi-pen plotter. These displays can be presented for either a complete or a partial test. The screen image can be modified using the digitising facilities of the computer to home in on a particular part of the test of special interest.

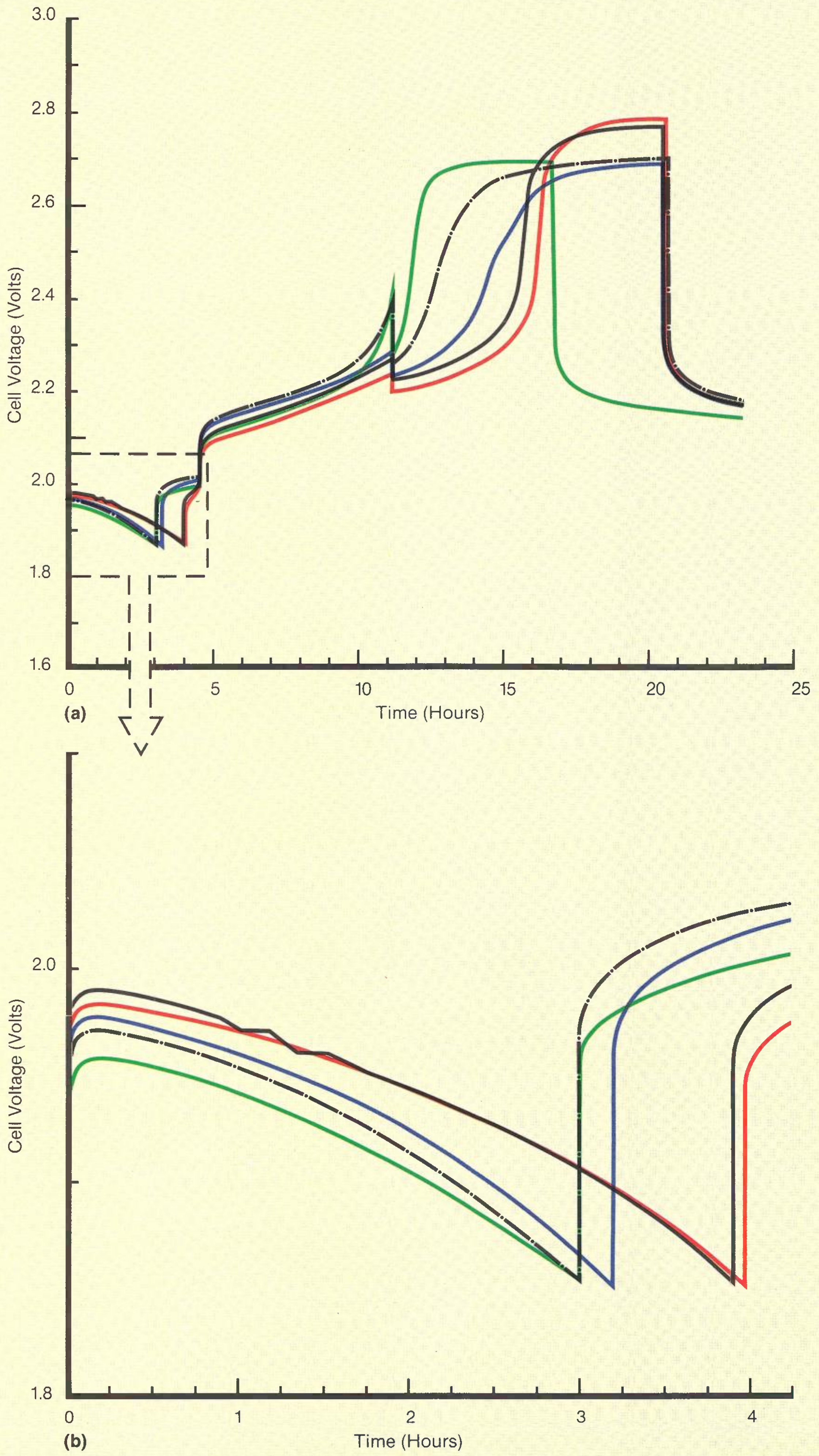
In the design of the control system software, a number of standard BASIC programming statements could not be used because they did not allow for data interruption. For example, statements such as "INPUT" were replaced by an interruptable sub-program which utilised the live keyboard facility of the computer to achieve a similar result.

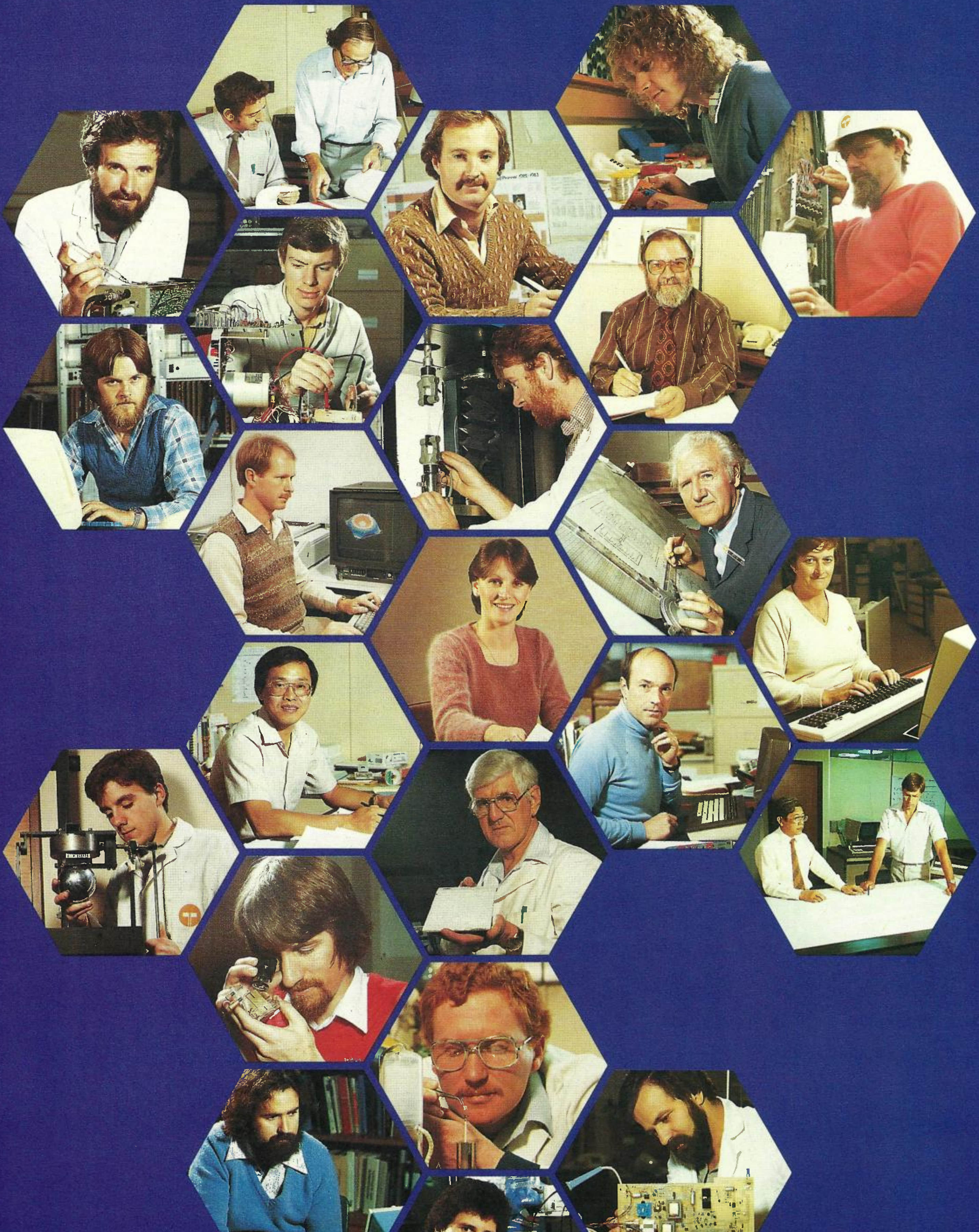
Program operation is by means of 10 different sets of special function key overlays. The 8 key definitions for each overlay in use can be displayed on the CRT screen, together with a detailed description if required. Other elements of the program are operated either by menu selection, form filling or the special input routine. Provision has been made for utility programs, in the form of sub-programs, to be loaded into memory as required to perform non-standard tasks.

The main program, which contains 88 kbytes of code and occupies 140 kbytes of computer memory, has been running successfully for 6 months collecting data from the two installed sub-controllers. An additional 80 kbytes of overlay programs and 17 kbytes of data for look-up tables are stored on disk. These are fetched as and when required.

The Laboratories' battery test facility has now been automated to a degree which allows an extensive program of battery testing to be performed with greatly increased efficiency.

Typical cell voltage characteristics of five batteries during discharge-charge tests:
(a) over one complete discharge-charge cycle
(b) expanded portion of (a) showing discharge cycle in greater detail (See diagram opposite)


3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
Cell Voltage (Volts)
0
5
10
15
20
25
(a)
Time (Hours)
2.0
1.8
Cell Voltage (Volts)
0
1
2
3
4
(b)
Time (Hours)



CONSULTATIVE ACTIVITIES

The Laboratories are continually developing expertise and laboratory facilities in the engineering and scientific disciplines which are somewhat special and uniquely concentrated in Telecom. As can be seen from the earlier sections of this Review, these are necessary for the pursuit of the major technical and scientific research projects which cover the whole range of advanced materials, components, equipment and systems which make up the network by which Telecom provides Australia's national telecommunications services.

In addition to performing larger project-scale research investigations in an on-going work program, the staff of the Laboratories are often called upon by other Departments of Telecom to give ad hoc consultant advice and assistance on problems which arise in their day-to-day activities and which can be quickly and effectively solved by such calls. Such assistance provided by the Laboratories ranges from advice on the design and specification of equipment; to assessments of the reliability of materials and components; to evaluations of the effects of particular manufacturing process technologies on equipment performance and reliability; or to assessments of the likely causes and effects of problems arising in field operations through component or equipment failures, through the adoption of particular operational practices or as the result of accidents or equipment malfunctions.

These smaller scale tasks do not attract the same prestige as the larger-scale R&D projects, in terms of their contribution to major corporate decisions. Nevertheless, they are regarded as an essential part of the Laboratories' role to provide cost-effective and speedy assistance, where possible, to other Departments of Telecom – to avoid or solve minor, but often costly, problems arising in the operation of a large telecommunications network. Brief details of some of the consultative activities of the Laboratories during the past year are given in the following pages.

Electromagnetic Interference and New Technology

A diverse range of new generation semiconductor-based equipment is continually being introduced into all areas of Telecom Australia's operations. The widespread application of this new technology can pose a variety of operational problems resulting from the effects of electromagnetic interference (EMI). These problems would have gone unnoticed or would not have arisen in the operation of earlier generation equipment utilising electro-mechanical relay-based technology.

The successful operation of semiconductor-based equipment can be threatened by EMI conducted or radiated from a variety of sources. Alternatively, semiconductor-based equipment has the potential to become a source of EMI which degrades the operation of other equipment providing telecommunications services. The interfering equipment and the equipment interfered with can belong to Telecom or to other organisations or persons.

These changing aspects of EMI and the need for electromagnetic compatibility (EMC) of equipment have been recognised by Telecom Australia and formal arrangements are being made within Telecom to co-ordinate activities to minimise EMI problems. Telecom is aware that the successful operation of new generation equipment requires control of its electromagnetic environment as much as its physical environment.

For some years, the Research Laboratories have been providing consultative advice and investigative assistance to other Departments of Telecom to identify and overcome EMI problems arising in network operations. The Laboratories are also researching new techniques and solutions to mitigate EMI effects in anticipation of a future need for Telecom to develop new technical specifications, standards and methods of measurement in relation to EMI.

Recent EMI investigations performed by the Laboratories have centred upon computer-controlled telephone exchanges, new generation PABXs, microprocessor-controlled small business telephone systems, data processing computer installations and microprocessor-controlled telex equipment.

AUSTPAC Technical Working Party

Telecom Australia's introduction in December 1982 of its public packet switching data network, AUSTPAC, will have a potentially far-reaching impact on the Australian community. Opportunities now exist for creation of new services and applications by interconnecting computer equipment and terminals via AUSTPAC. For example, economical, nationwide access could be provided to computer databases, powerful data processing systems and electronic message systems. The realisation of these opportunities depends on the common understanding between equipment vendors, potential service users and providers and Telecom Australia about the many aspects of possible applications of the AUSTPAC network in relation to new or existing services, including the technical requirements for connection of equipment to the AUSTPAC network.

To encourage the ongoing exchange of information about applications of the AUSTPAC network, Telecom Australia convened the AUSTPAC User Group in December 1981. The User Group has since provided a forum for general discussion of AUSTPAC services between equipment vendors, potential users of AUSTPAC services and Telecom Australia.
A Technical Working Party, which is a sub-committee of the User Group, provides a forum for more detailed discussion of technical aspects of AUSTPAC services.

To ensure reliable data transfer, computer equipment connected to AUSTPAC must conform to standardised data communications procedures known as the X.25 interface. The Technical Working Party concentrates on a range of technical issues concerning this interface, including explanation and clarification of the AUSTPAC implementation of X.25, techniques for testing conformance of user equipment to X.25, and interconnection of private data networks to AUSTPAC.

Officers of the Research Laboratories acted as Chairman and Secretary of the Technical Working Party for the first year of its operation and continue to provide technical consultative support.
An important outcome of the deliberations of the Working Party to date is the submission to the CCITT of proposals for standardisation of a new interface and an expanded addressing scheme for interconnection of private and public data networks.

Digital Data Service Cross-connect Switch

Telecom Australia's Digital Data Service, which was inaugurated in December 1982, operates over a pre-provided network of digital transmission links. Field staff connect these links in series as and when needed to provide services for customers wishing to lease semi-permanent data circuits. Initially, the interconnections are being established manually by "jumper" wiring, but this method is planned to be replaced by digital cross-connect switches controlled by simple keyboard commands sent from operations centres.

With this future objective in mind, the Laboratories have been assisting the Data Division of the Headquarters Commercial Services Department to evaluate the requirements of a digital cross-connect switch for this application. A joint feasibility study concluded that the application of digital cross-connect switches would offer significant savings in total equipment costs and provide very useful operational advantages which are not available with the use of the manual wiring technique.

In the light of these conclusions, a functional specification of a digital cross-connect switch for this application was prepared for inclusion in Telecom's public call for tenders from the telecommunications industry for the supply of suitable equipment to Telecom Australia.

Transmission Performance Assessment of Business and Intercom Telephone Systems

Telecom has recently introduced three new telephone systems for small users which replace and enhance the facilities provided by various older style intercommunication telephone systems. All of the new systems are of overseas design, and Telecom experienced some difficulty in interpreting the manufacturers' transmission performance specifications for these systems because there is no common internationally agreed method for rating telephone transmission performance by a simple objective method.

Because the Research Laboratories maintain internationally recognised reference standards of telephone transmission and voice-ear facilities for undertaking subjective determinations of telephone instrument performance, it has been possible to assess samples of each type of telephone relative to Telecom's specified transmission requirements.

Telecom's new business telephone systems for which transmission performance ratings have been established

Where necessary, the manufacturer was subsequently required to modify the telephone performance. In some instances, it has been possible to define and rigidly specify an objective measuring technique based on the manufacturer's measuring facilities, and to provide an associated correlation factor so that the manufacturer can continue to use a simple objective test to achieve the required transmission performance in telephone production.

Failure of Parafil Tail Rope on Radio Mast

On January 1982, one of eight Parafil tail ropes attached to the capacitative top loading wires of the medium frequency (567 kHz) broadcasting mast at radio station 6PH, Port Hedland, failed in winds of approximately 100 km/h. Examination of the remaining wires revealed that a further four Parafil ropes had deteriorated sufficiently to require replacement.

The Parafil tail ropes are attached to eight 15.2 m lengths of copper wire spaced around the top of the 41 m high Port Hedland mast at 45° intervals. The ropes are composed of a core of longitudinal strands of terylene (polyethylene terephthalate) fibres covered with a continuous jacket of black, low density polyethylene. Each Parafil rope is connected to the copper wires at its top end by a porcelain insulator and terminated at its bottom end by "standard Parafil terminations" comprising epoxy-resin-filled metal cylinders.

A Laboratories' examination of the failed rope showed that:

- a break had occurred in the rope at a point adjacent to the insulator
- many small protruding bubbles were distributed randomly along the length of the polyethylene jacket
- welding of the polyethylene jacket had occurred where it had been brought together after encircling the porcelain insulator and held with metal clamps
- severe cracking of the jacket had taken place at the top end of the loop through the porcelain insulator.

The bubbling and welding was considered to have been the result of dielectric heating in the section of Parafil rope adjacent to the insulator and situated in the mast's radio frequency field. Since terylene shows some response to dielectric heating and polyethylene none, it was postulated that insufficient heat was generated in the terylene fibres to cause melting of the fibres themselves (melting point 258° C), but that the temperature attained was high enough to soften, and in places melt and weld, the polyethylene jacket (melting point 105° C) with which it was in close contact. That the polyethylene was heated by conduction from the inside was evidenced by the appearance of once-molten polyethylene having forced its way through from the inner to the outer surface of the jacket and by the impregnation of the surface layer of terylene fibres within the jacket with black polyethylene at these points.

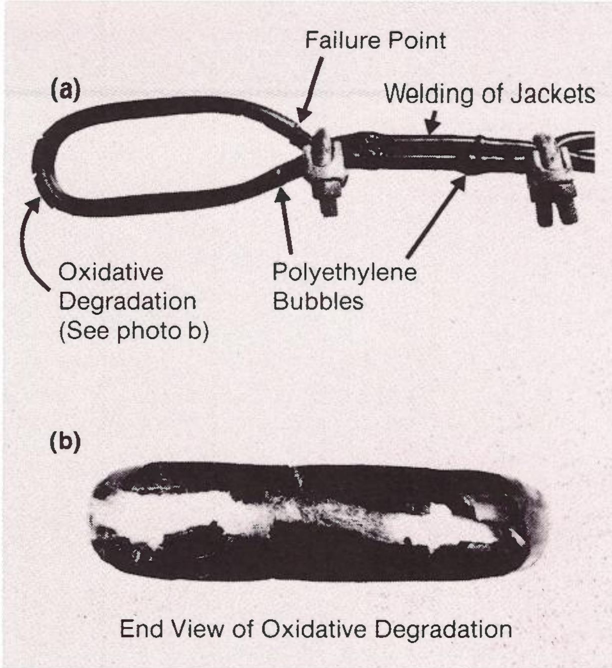
It was concluded that the rope had broken as a consequence of a reduction in the strength of the terylene fibres at the resulting operating temperature, which must have been well in excess of 105° C to cause bubbling and welding of the air-cooled polyethylene jacket.

The cracking of the polyethylene jacket at the top end of the loop through the porcelain insulator was considered to be caused by a different phenomenon, namely, by oxidative degradation as a result of ozone being produced from atmospheric oxygen by corona discharge across the copper wire, in the salt-laden atmosphere of Port Hedland.

The fact that five out of the eight ropes required replacement after 13 years of exposure in service indicated that:

- either their plastics components were inadequate for the particular application, or
- the strength of Parafil rope in the chosen size was inadequate at the top end of the rope.

These conclusions were highlighted in the report of the Laboratories' investigations to assist the choice of a replacement for the ropes.



Photographs show faults in failed Parafil rope

Inter-layer Compounds for Jacketed Cables

For many years, the inter-layer compound applied between the sheath and jacket of composite cables used by Telecom Australia has comprised a mixture of vacuum distilled resin and mineral oil. Doubts about the compound's effectiveness under field conditions led to a recent laboratory investigation. The investigation confirmed the validity of these doubts. It was found that, during cable manufacture, prolonged heating of the compound in the application tank degrades the resin component to a non-tacky, powdery, isomeric form. It was also found that the amount of the compound applied to the cable during manufacture was often too sparse to completely fill the void between sheath and jacket.

Alternative materials were therefore investigated and the results showed that compounds based on blown asphalt are clearly superior in heat stability and have a greater tenacity toward polyethylene, making possible the application of heavier coats of the compound in the cable manufacturing process.

Cable Filling Compounds

Compounds based on oil-extended waxes (petroleum jellies) have been successfully used in numerous countries around the world for many years to fill the cores of multi-pair cables and so prevent water entry into them. Telecom Australia has been using this type of "filled" cable since 1975 and has standardised on the filling compound, Insogell A2852.

A new filling compound based on the concept of an oil-extended polymer containing approximately 90% oil has been developed in the Bell Laboratories, USA. The material has been called Flexgel because of its rubbery nature. Experimental cables filled with Flexgel have been evaluated in the Research Laboratories to determine whether they can withstand the rigours of Australian climatic conditions and operational practices.

To date, the tests suggest that the cables filled with Insogell are superior to those filled with Flexgel, particularly as regards the retention of their electrical properties on ageing. These properties deteriorate with migration of the oil extending into the cable components.

Further development work is being pursued in the Laboratories to modify the Flexgel formulation to satisfy Australian requirements.

Grouting Materials for Tower Anchor Rods

In 1967, an investigation was commenced by the Research Laboratories to ascertain the suitability of alternative grouting materials to the standard Portland cement/sand type of grout. The latter has many deficiencies, amongst which are deterioration in water-logged and/or acidic situations. One such situation arose during the installation of the TV translator tower on Mt. Owen in Tasmania during 1967, when an epoxy resin grout was substituted for the cement grout in a highly acidic rock face.

In order to follow the ageing characteristics of specific materials, two synthetic grouts (epoxy and polyester), a modified cement grout and a standard cement grout were used to install prepared rods in rock in an experimental exposure trial at Dunn's Hill, Victoria, in 1967. The rods were installed at various depths in holes which were dry or which contained either water or a water/clay slurry.

During 1982 and after 15 years of field exposure, controlled attempts made to extract the rods showed that, under the non-chemical conditions prevailing in the Dunn's Hill experiment, the performance of the epoxy resin, standard cement and modified cement grouts was approximately equivalent and that these three grouts were superior to the polyester resin grout.

Over-voltage Tests on AXE Exchange Equipment

Results of over-voltage tests performed on discrete components or individual circuits in the laboratory cannot be always used to predict reliably the performance of equipment composed of a number of such component parts – because of possible interactions – particularly under abnormal load conditions. In view of this, some items of equipment must be tested in their final form of use and under actual field service conditions.

Such tests were recently performed on circuits of a working GSS-D type (digital group switching) AXE exchange to determine whether the exchange complied with its over-voltage specifications. Portable test equipment, designed and constructed in the Laboratories, was used to simulate potentials which might occur in the communications network as a result of lightning discharges, induction from electrical power distribution grids or direct contact with mains power electrical distribution lines.

The AXE exchange circuits tested passed all of the prescribed tests without the exchange developing any functional faults or detectable changes in transmission characteristics.

Failure of Fire Sprinkler System

Telecom Australia's storage warehouse complex at Clayton, Victoria, has a sophisticated fire detection and protection system. A central design feature of the system is its use of temperature sensing elements in the form of a continuous twisted pair of spring steel wires, insulated with a low melting-point plastic insulation. The wires are installed throughout the steel rack system in the warehouse to give an extensive protection system. In the case of fire, the resulting temperature rise causes the plastic insulation of the sensing wires to melt, causing a short circuit. Sensitive sensing means then determine the precise location of the short circuit and activate detonators in sprinkler heads to spray high pressure water jets in a predetermined pattern to contain the fire. It is a feature of the system that only the actual fire area is sprayed, thereby avoiding serious water damage to goods not at fire risk.

However, false triggering of the system has occurred in recent years, leading to some water damage. Investigations have not yet been able to identify positively the cause of these malfunctions. Laboratories' examinations of the plastic insulation have shown that its melting point and other physical characteristics complied with the manufacturer's claims, and known summer temperatures in the warehouse were not high enough to melt the plastic.

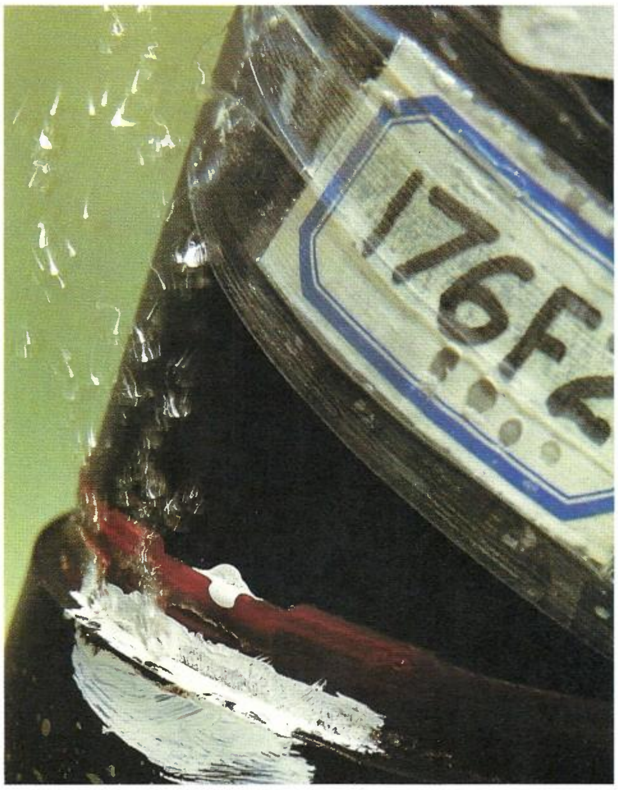
Long term thermal stressing of part of the fault-prone sensor wire was therefore carried out in the Laboratories. The wire was cycled between 0° and 90° C, but no measurable physical change occurred. Examination of wire insulation failures which had occurred in service showed that, in most cases, the wires had been subjected to enough mechanical force at the point of the short-circuit to leave a permanent indent in the plastic sheath. However, no evidence existed to identify positively the manner in which the sensor wire had been so marked. It was concluded that the false triggering of the system was probably due to manufacturing defects in the cable or the application of an excessive force at some points along the sensor cable during installation.

Assessment of Heat-shrinkable Cable End Seals

Large size air-pressurised cables must be protected during storage, prior to installation, by sealing each of their ends to retain pressurisation as a safeguard against the entry of potentially harmful vapours and gases. Many methods of sealing the cable ends have been tried for a variety of cable types.
For lead-covered cables, a wiped lead cover is used. Although reliable, the cover is expensive to fit. Polyethylene cable is sealed by butt-welding discs against the cable ends using a heat welding technique. In an endeavour to introduce a universal method, a plastic cap sealed and secured by a screw clip has been used. More recently, improvements in heat-shrinkable plastics have led to their adoption as the preferred method of sealing cable ends.

In a recent Laboratories' assessment of the adequacy of heat-shrinkable plastics in this application, samples of heat-shrinkable end caps from four manufacturers were tested in a comprehensive evaluation program. The program also involved the fitting of the end caps by personnel of three cable companies as a further test of the reliability of the operator/end cap combination.

Environmental tests involving cable samples fitted with various caps were carried out by subjecting the samples to cyclic temperature changes in a controlled manner to simulate climatic conditions expected during storage. Further stressing was introduced by causing cyclic air pressure changes in the capped cables during environmental testing. The measure of the reliability of an operator/end cap combination was determined by measuring the air leakage rate for each combination at regular intervals throughout the testing period. The test program demonstrated that only one type of heat-shrinkable end cap was successfully applied by all operators. The success of the preferred end cap/operator combination was ascribed to a thermo-chromic indicator incorporated in the heat-shrinkable cap. This allowed the operator to assess both the temperature and uniformity of heating as he applied the caps to the cable. All other combinations included in the test programme lacked the thermo-chromic indicator, and they yielded seals of inconsistent quality, regardless of the operator/end cap combination.



Heat-shrinkable Cable End Seal immersed in water showing air escaping from faulty joint

X-ray Microanalysis of Faulty Soft Magnetic Iron

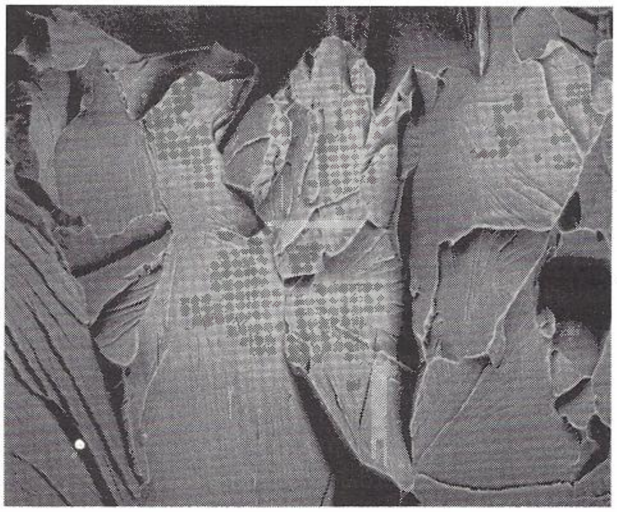
Soft magnetic iron is a ferrous material with a high magnetic permeability which is used in the manufacture of electro-mechanical relays. Extremely large numbers of such relays are used in Telecom Australia's telephone exchange installations, and investigations related to the quality control of soft magnetic iron have therefore been pursued in the Laboratories for some years.

In a recent investigation, the Laboratories were called upon to assist in the solution of a problem encountered by an Australian relay manufacturer in machining relay parts from soft magnetic iron. The manufacturer had observed that a particular batch of soft magnetic iron obtained in coil form from the steelmaker was causing severe and premature blunting of the machining tools. There was no immediately apparent reason for this phenomenon as there was no obvious significant difference between the iron from the particular batch and that from other batches from the same steelmaker. These other batches were not causing the machining problem.

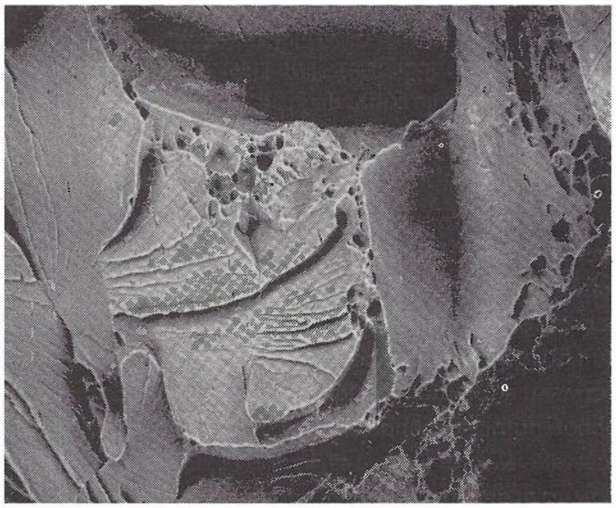
A detailed analysis of samples of the soft magnetic iron was made in the Laboratories.

A disparity between the materials was demonstrated when samples of iron both from the normal batches and the batch causing the problem were fractured at liquid nitrogen temperature and examined using a scanning electron microscope equipped with an X-ray microprobe analysis facility. The cleavage of the normal material resulted in a uniform transcrystalline brittle fracture, whereas cleavage of the faulty material revealed areas with a dimpled structure around most of the grain boundaries. Many of the dimples contained small spheroidal inclusions and X-ray microanalysis of these areas indicated traces of several elements. The elements included silicon, which is the principal de-oxidiser used in steelmaking. Further detailed chemical analysis confirmed a small excess in the silicon content of the faulty soft magnetic iron.

The presence of silicon as hard silicon dioxide inclusions in the soft magnetic iron explained the rapid blunting of the machining tools.

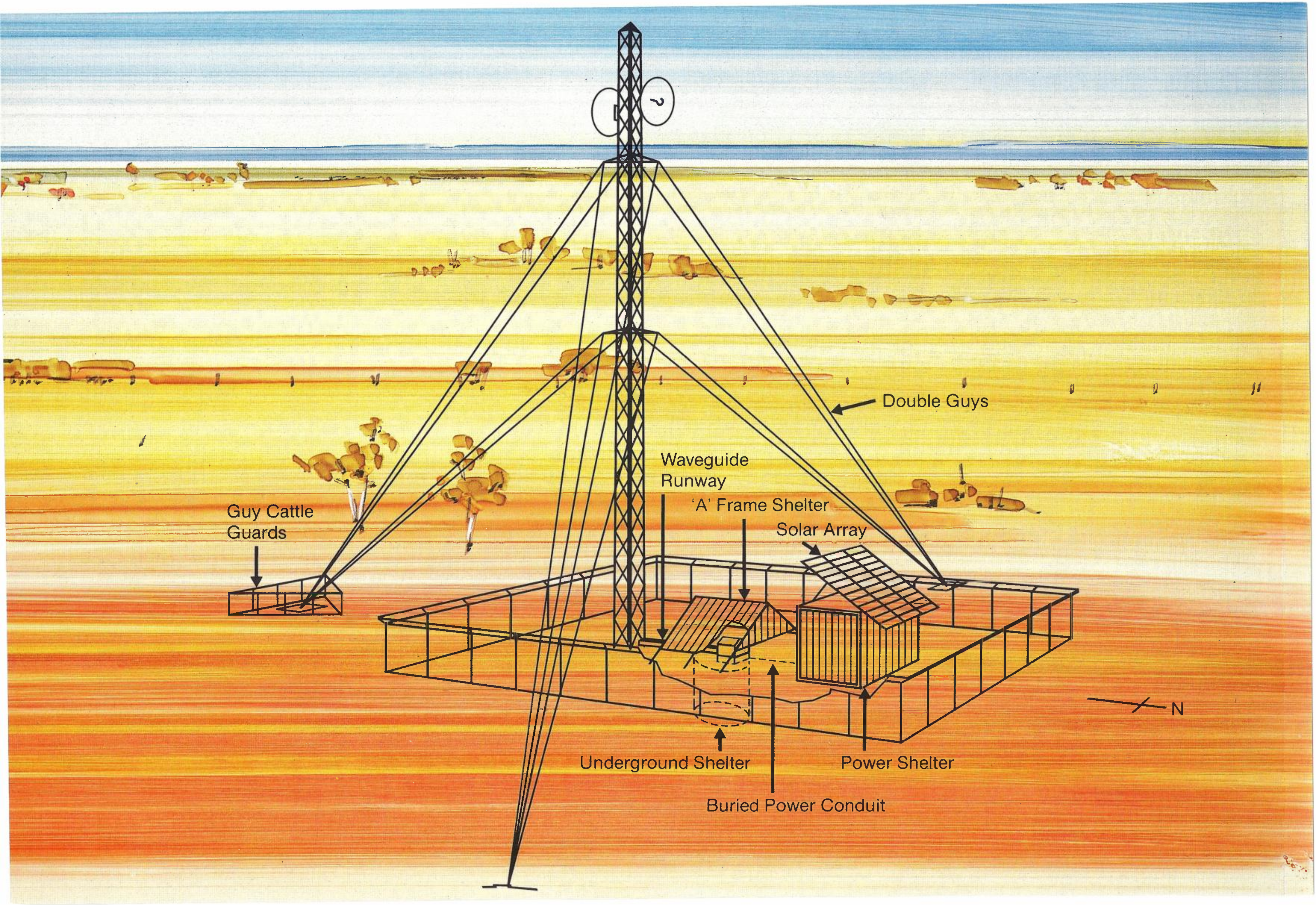


(a)



(b)

SEM photographs (500 mag.) show cleavages of:
(a) sample of normal soft magnetic iron
(b) faulty sample with dimpled structure at grain boundaries due to excess silicon



Double Guys
Waveguide
Runway
'A' Frame Shelter
Solar Array
Guy Cattle
Guards
N
Underground Shelter
Power Shelter
Buried Power Conduit

Soil Analysis at Microwave Radiocommunications Sites

Microwave repeater installations are situated at locations governed by radio propagation factors rather than site accessibility or the geo-mechanical properties of the local soils. The more remote repeater sites require maximum utilisation of materials from the immediate surroundings for the preparation of stable structural footings and for use as backfill earthworks around foundations and equipment shelters. In some instances, these shelters may be buried for thermal stability.

It is necessary therefore that a chemical assessment of the soil at particular repeater sites be performed within the period between the completion of the ground surveys which are used to determine a radio route and the calling of tenders for the construction of the equipment stations sited along the route, to enable preventative steps to be taken against accelerated corrosion of above ground structures or aggressive chemical attack on foundations.

The Laboratories have provided soil analyses for some of the major radio-communications network extensions in the north and west of Australia, such as the Port Hedland-Derby-Kununurra route. Rock, gravel and soil samples have recently been tested and assessments provided to assist structural design and specifications for construction projects encompassing repeater sites along the Kingston-Jalara and Darwin-Jabiru routes.

Many of the soil tests have been performed on samples of relatively small size because of the logistical problems surrounding collection and transportation of rock and gravel samples from remote sites to the test laboratory. Despite this, sufficient data has been derived to enable civil engineering designers to forecast potential problems with consolidation and compaction of earthworks, with reaction with concrete under wet or dry seasonal conditions, or with possible metal corrosion.

Typical microwave repeater station layout shows the scope for soil analysis in its structural design
(See diagram opposite)

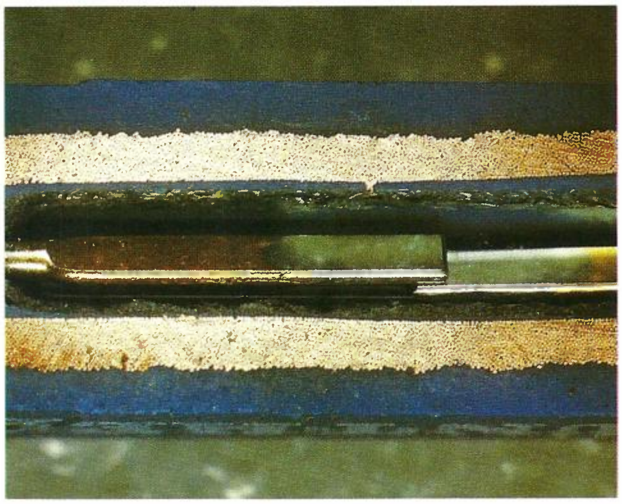
Relay Evaluation

Although solid state relays have to some extent replaced electro-mechanical relays, the low on-resistance, high current handling, good electrical isolation and multiple circuit control capabilities of electro-mechanical relays will ensure their continued use in many telecommunications applications.

In on-going Laboratories' evaluations of component reliability, a range of miniature flatpack and dual-in-line relays, suitable for mounting on printed circuit boards, has been subjected to a range of electrical, mechanical and environmental tests. The tests have demonstrated the reliability of many new miniature relay designs. The results have confirmed the desirability of selecting contact material appropriate to the electrical loads, using bifurcated contacts, and choosing sealed versions of the relays for use in harsh environments.

Although mechanical endurance tests have proved to be the most effective in promoting failures, more specialised tests such as electrical leakage, solvent resistance and elevated temperature tests have also revealed shortcomings due to both poor design and inadequate quality control during manufacture.

This particular Laboratories' evaluation has identified a number of reliable, pin-compatible miniature relay alternatives in both flatpack and dual-in-line formats which are suitable for telecommunications applications in the Australian environment.



Magnified view of contact set of miniature relay

Failure of Gas Conversion Power Plant-Moomba Gas Pipeline Communications System

Communications systems along the Moomba gas pipeline, which runs from the Moomba gas field to Spencer Gulf in South Australia, rely on electrical power generated using gas conversion plants. One plant recently failed when air entered a stainless steel refrigerant return pipe, causing a loss of vacuum in the system. The Laboratories were asked to assist in the identification of the cause of the failure.

The Laboratories' investigations showed that the failure was due to the ingress of air through a corrosion pit in the stainless steel refrigerant return pipe. Energy dispersive X-ray analysis detected the presence of an abundant quantity of chlorine around the perforated areas and inside the corrosion pits. It was concluded that this was the corrosive agent as the grade of stainless steel used for the pipe was known to be susceptible to pitting in the presence of chloride ions. The source of the chlorine was found to be the foamed neoprene-hypalon insulation used around the pipe. This plastic insulation is known to decompose over a period at temperatures above 70° C, forming hypochlorous acid in the presence of moisture. As the gas conversion plant reaches operating temperatures around 90° C, it was concluded that insulation decomposition and the formation of solutions containing chlorine caused the fault. It was recommended that the insulation in question be removed from all gas plants and replaced with a more inert type of insulating material.

Evaluation of Through-hole Plated Printed Circuit Boards

During equipment manufacture, the components on a printed circuit board are wave-soldered to conductor pads on the board. Solder resist is usually applied to the board before soldering to protect conductors and to reduce the probability of solder bridging between conductors. Hence, the adhesion of the solder resist to the conductors is important.

A new production technique uses chemical oxidation to facilitate this adhesion. Since the technique is likely to be used increasingly in the manufacture of telecommunications equipment purchased by Telecom, the Laboratories have evaluated sample printed circuit boards whose manufacture involved the application of this technique.

The boards were assessed according to surface cleanliness requirements (MIL-P-28809). Insulation resistance was determined in both normal and humid environments, and the conductors were also cross-sectioned to examine the effect of the chemical treatment.

The general cleanliness of the boards was satisfactory, with the test results indicating that contamination from readily soluble ionic species introduced through handling or flux residues was quite low. When the boards were exposed to 90% relative humidity, the insulation resistance of the laminate and surface resistance satisfactorily remained greater than 400 megohms.

White corrosion products were formed during the humidity test and subsequent analysis showed these to be lead chloride. The halide impurity present was most probably the result of a highly activated flux residue remaining on the solder pads after the re-flow process. Preferential attack to the lead-rich dendrites in the lead/tin alloy occurred during exposure.

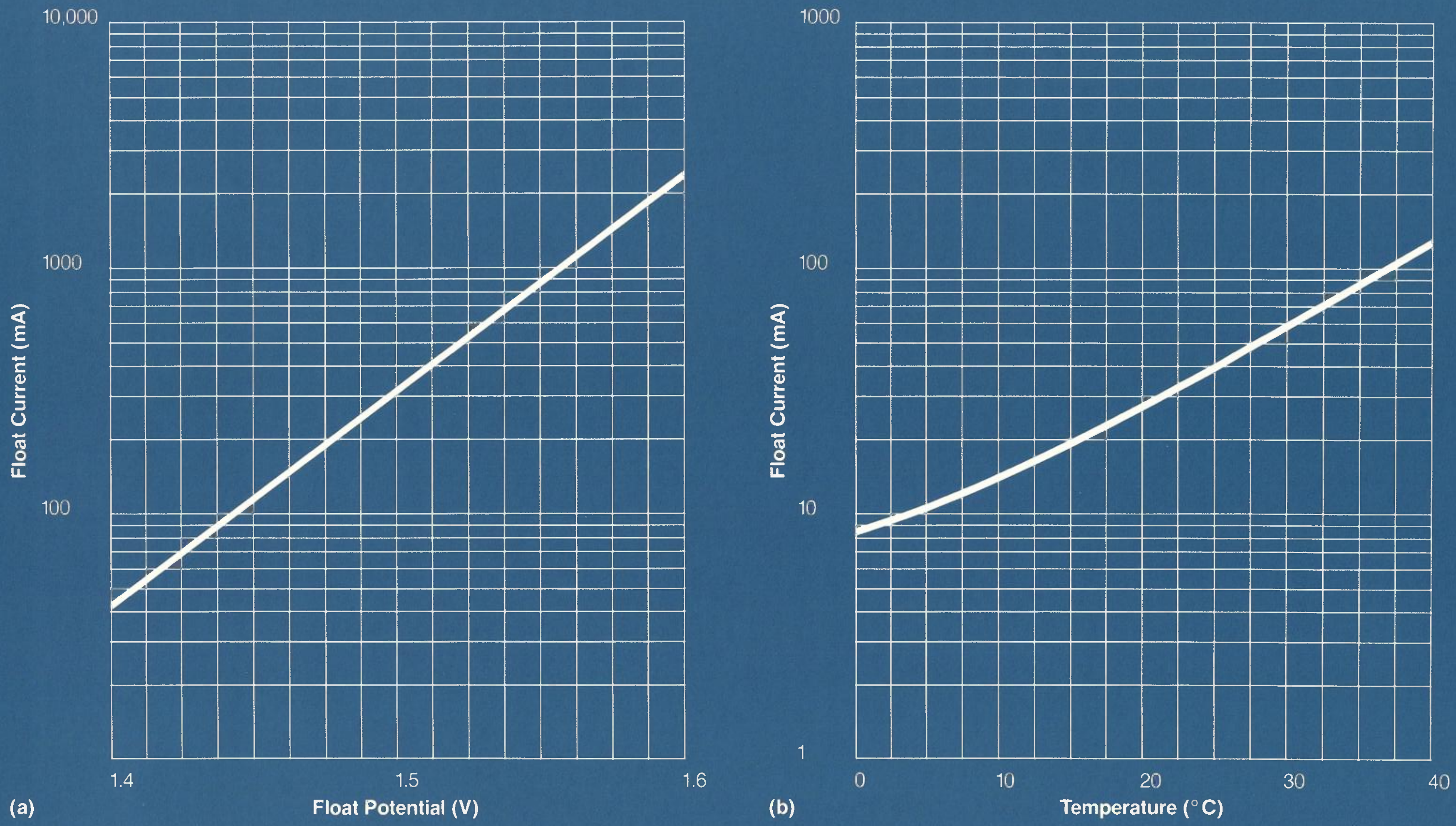
The laboratory evaluation concluded that the technique provides good protection to the copper conductor during soldering, but suggested that impurities left on the exposed conductor pads could be a problem, particularly in high humidity environments.

Nickel-Cadmium Battery Testing

Depending on their design, vented nickel-cadmium batteries can be used for heavy duty cycling or high current discharges, such as diesel engine starting. It is also claimed that they are suitable for float operation as well as for light duty cycles when both current loads and depth of cycles are only moderate. Batteries are exposed to this latter type of service condition when used for power back-up in hybrid power systems based on solar cells.

Several batteries intended for such a solar power system application were examined in the Laboratories recently, because it appeared that a considerable part of the expected capacity had been permanently lost. The first of several charge-discharge cycles carried out at the nominal 10-hour rate increased the initial capacity. However, after a further three cycles, the capacity of the batteries fell to a level which was well below their expected nominal value. Extended charging time and high current pulse charging techniques did not improve this condition. Battery cell self-discharge was initially very high during the first 24 hour rest period, but the discharge rate reduced

(a) Float current versus float potential at 25° C for a 100 Ah Ni-Cd cell
(b) Float current versus electrolyte temperature at 1400 mV for a vented 100 Ah Ni-Cd cell
(See diagram opposite)


10,000
1000
100
Float Current (mA)
1.4
1.5
1.6
(a)
Float Potential (V)
1000
100
10
1
Float Current (mA)
0
10
20
30
40
(b)
Temperature (°C)

asymptotically until, after four or five days, it had reached an acceptable level. The float current was found to be a logarithmic function of cell potential between 1.4 V and 1.6 V, but the actual values were temperature dependent.

It was concluded that the reduced capacity was due to positive plate passivation, which, in turn, was the result of high iron impurity. Energy dispersive X-ray analysis using a scanning electron microscope showed that the iron impurity had an affinity for the surface of the active nickel oxide crystals in the positive paste. The overall conclusion was that, for float operation or for shallow cycling duties, the negative pocket and any other mild steel battery components exposed in the electrolyte should be nickel plated to reduce the possibility of iron contamination.

Advanced Traffic Engineering Course

A two-week residential course in advanced traffic engineering was held from 12 to 24 September, 1982. The course was presented under the Engineer Development Programme administered by the Training Group of the Headquarters Engineering Department. All lecturing and tutorial staff were members of the Traffic Engineering Research Section of the Research Laboratories.

This course was originally developed in 1967. Since its establishment, it has been held at approximately two-yearly intervals, with a major revision and updating of the course syllabus being carried out in 1978. The 1982 course was the eighth in the series, and it was attended by 29 participants from the Headquarters and State Administrations of Telecom and from Hong Kong, Malaysia and Sri Lanka.

The course was opened by the Director, Research, who welcomed the participants and stressed the importance of teletraffic engineering principles and methods to the accurate dimensioning of telecommunications networks.

The course syllabus included fundamental traffic theory models and their application to the analysis and dimensioning of the increasingly complex telephony and data switching networks. Traffic measurement and forecasting methods were also covered in considerable detail, since reliable traffic data is an essential prerequisite for optimum network design and accurate dimensioning of every traffic route.

The course format included lectures, tutorials, discussion sessions, seminars and syndicate projects. It ended with the presentation of five syndicate reports on current traffic engineering projects and a panel discussion about new problems awaiting solution.

Basic Digital Transmission System Theory Course

Staff of the Transmission Branch of the Laboratories joined with academic staff of the Electrical Engineering Department of Monash University to present a two-week course on digital transmission theory to 26 Telecom engineers during May 1983. The course was held at Monash University and it was the fifth presentation of the course.

The course was developed and first presented in 1981 as a collaborative project by the Laboratories and the University. Its objectives are to provide Telecom engineers with a comprehensive knowledge of the principles and theory which are fundamental to digital transmission systems and to demonstrate their application to the evaluation, design, specification and performance assessment of a variety of transmission systems, both line and radio.

The course covered time and frequency domain analysis of linear systems; probability theory applied to random time processes and, in particular, to the determination of the power spectra and the response of digital transmission systems; and digital transmission theory and techniques, with illustrations of their typical application in cable, radio and optical fibre transmission systems.

The course comprised lectures and tutorials in about equal proportions. Participants were provided with comprehensive lecture and tutorial notes and an up-to-date reference textbook, to assist them not only to assimilate knowledge during the course but to apply it in their subsequent day-to-day professional engineering activities within Telecom.

In the five presentations of the course since 1981, 127 Telecom engineers have been given the opportunity to obtain a comprehensive understanding of the topic. It is expected that in future the course will be presented about once each year to maintain Telecom's pool of expertise in this increasingly important field of network technology.

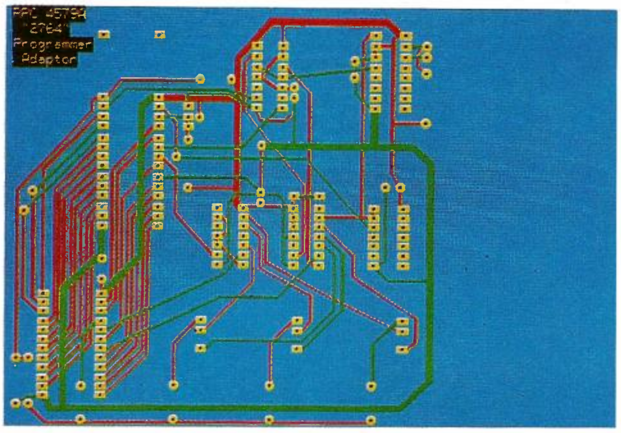
Interactive Computer Graphics Techniques

Many engineering and scientific investigations conducted throughout Telecom now rely heavily on the use of computers for modelling the characteristics of telecommunication systems or for the analysis of large volumes of data. Often, an appreciation of the results of these investigations is most effectively obtained through graphical presentation. In addition, interactive computer graphics techniques which support direct input of graphical data and manipulation of the displayed image at the terminal can increase the efficiency of the analysis process itself. This results from a more immediate interaction at the visual level, for example, avoiding repetitive conversions to an alpha-numeric description when evaluating the effect of parameter changes.

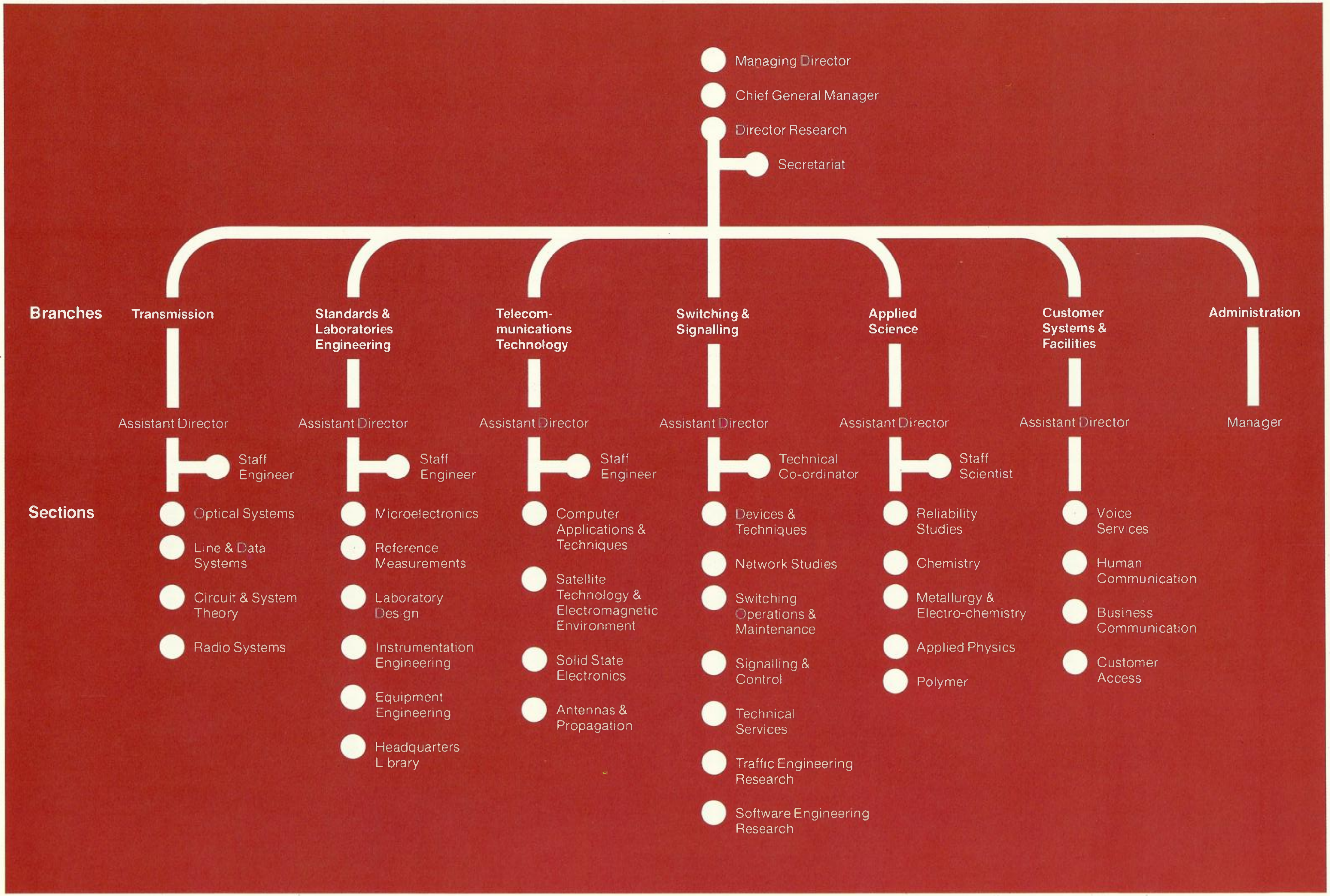
Some areas of design and production activity (e.g. electronic circuits, printed circuit boards, mechanical parts) benefit greatly from the adoption of computer graphics techniques and are best served by special-purpose computer systems. However, in order to investigate the benefits of interactive graphics capabilities for the majority of Telecom engineering applications, the Laboratories have installed a Tektronix Inc. implementation of the United States Graphics Standards Planning Committee's Core system on the Telecom computer network, TACONET. This software provides advanced, device-independent graphics capabilities which enable application software to produce images on a wide range of terminals and plotters. The device-independence exploits the local features of intelligent terminals while emulating advanced terminal facilities in software for more primitive graphics terminals.

Features of the graphics system include:

- three-dimensional graphics support, enabling the display of three-dimensional surfaces at arbitrary orientations
- image shading capabilities
- graphics text composer, with special purpose character fonts (e.g. mathematical, cartographic and electronic symbols)
- line smoothing, for the production of smooth curves from a minimum of data points
- retained segments – user-generated graphics objects within an image, which are named and can be repeatedly altered and re-displayed as a single entity (e.g. functional blocks within a logic circuit diagram).



Colour display of a double layer printed circuit board layout generated using TACONET graphics software



The Research Laboratories' Organisation

OVERALL OBJECTIVES OF THE LABORATORIES

- Maintain a position at the forefront of knowledge in communications science and technology, in order to provide expert participation in the formulation and implementation of policies for the introduction of advances in science and engineering of relevance to Telecom Australia.
- Conduct specific development and design projects and scientific and engineering investigations related to telecommunications problems.

ORGANISATION

The Research Laboratories are a Department at Headquarters. The Director, Research, heads the Laboratories' organisation. He is responsible to the Chief General Manager, who in turn is responsible to the Managing Director of Telecom Australia. The Laboratories comprise a Secretariat attached to the Director's Office, an Administrative Services Section and thirty scientific and engineering Sections, grouped into six Branches. The scientific and engineering Sections comprise, professional, technical and clerical support staff, with each Section possessing expertise in particular areas of the engineering and scientific fields.

PROFESSIONAL AND SENIOR STAFF

The names given below are those of the actual occupants of the positions (appointed or acting) at 30 April 1983.

Director: E.F. Sandbach, AM, BA, BSc, FTS.

Secretariat

Objectives
Provide executive assistance to the Director, Research, in the management of the Research Department, in matters relating to:
- corporate planning and work programming;
- technical information services and external relationships;
- staff development;
- industrial property.

Head, Secretariat: F.W. Arter, BEE, MEngSc.

Senior Engineers:
L.N. Dalrymple, Dip Elec Eng, Grad IE Aust.
O.J. Malone, BEE.

Executive Officer: A.B. Conroy
Senior Technical Officers:
P.F. Elliott
A.K. Mitchell
W.W. Staley

Administrative Services Section

Functions
The Administrative Services Section provides administrative and clerical support to the Laboratories.

This includes information and advice on various matters relating to:
- manpower, organisation and establishment
- budgets, finance and supply and
- staff industrial and general personnel services eg. registry and typing.

Manager Administration: B.M. Douglas
Senior Planning Officer: T.W. Dillon
Project Officer: B.F. Donovan
Budgets Officer: R.J. Beveridge
Staff Services Co-ordinator: P.G. Rodoni

Transmission Branch

Objectives
In the field of transmission, conduct research, exploratory developments, system applications and field experiments, contribute to specifications, assist in the assessment of tenders and provide advice and recommendations as appropriate relating to:

- the technical aspects of signal transmission within the Telecom Australia network;
- new transmission systems, and systems which are extensions of present techniques, with particular reference to their integration into the existing network;
- mutual compatibility of the various services and systems within the network;
- cost sensitivity studies.

Assistant Director: R. Smith, BE(Hons), ME, MIEE, SMIREE.
Staff Engineer: R. Horton, BSc(Hons), PhD, AMIEE, FIREE.

Branch Administrative Officer: M.J. Holmes

Circuit and System Theory Section

Functions

- Provide information, advice, consultancy and recommendations as defined in the Branch objectives.
- Conduct research into the theory and design of response shaping circuits which optimise the performance of transmission systems.
- Conduct research into the analysis and synthesis of filter-type circuits, including active and passive filters, equalisers, impedance simulating and compensating circuits, etc.
- Develop mathematical tools for the measurement, analysis and design of transmission circuits and systems.
- Provide a design and consultant service for filter-type circuits.

Section Head: I.M. McGregor, BE(Hons), MEngSc, PhD.

Senior Engineers:
A.J. Jennings, BE(Hons), PhD, MIEEE.
L.J. Millott, BE(Hons), MEngSc, MIEEE.

Engineer: B.R. Clarke, BE(Hons).

Senior Technical Officer: R. Owers

Radio Systems Section

Functions

- Provide information, advice, consultancy and recommendations as defined in the Branch objectives.
- Conduct research into transmission systems which utilise radio bearers.
- Investigate the interworking of such systems with other parts of the transmission and switching network.
- Investigate and develop appropriate bearer and system testing methods.
- Develop appropriate systems and testing apparatus which are not otherwise available.

Section Head: R.P. Coutts, BSc, BE(Hons), PhD, MIEEE.

Principal Engineers:
W.S. Davies, BE, MEngSc(Hons), PhD.
I.C. Lawson, BEE.

Senior Engineers:
J.C. Campbell, BE, MEngSc, MIEEE.
A.L. Martin, BE, Grad IE Aust, SMIREE.

Engineers:
P.R. Hicks, BE, BSc(App Maths).
P.V. Kabaila, BSc, BE, PhD.
B.J. McGlade, BE(Hons).

Scientist: J.L. Adams, BSc(Hons), PhD.

Senior Technical Officers:
M.J. Durrant
R.L. Reid
D.J. Thompson

Line and Data Systems Section

Functions

- Provide information, advice, consultancy and recommendations as defined in the Branch objectives.
- Conduct research into transmission systems which utilise metallic bearers.
- Conduct research in modulation and multiplexing techniques and applications.
- Conduct research into methods of data transmission with particular reference to Datel type services and to dedicated data networks.
- Investigate the interworking of such systems with other parts of the transmission and switching network.
- Investigate and develop appropriate metallic bearer and system testing methods.
- Conduct exploratory development of appropriate systems and testing apparatus which are not otherwise available.

Section Head: B.M. Smith, BE(Hons), PhD, MIEEE.

Principal Engineers:
A.Y.C. Quan, BE(Hons), ME, AMIEE.
G.J. Semple, BE(Hons), MEngSc.

Senior Engineers:
F.G. Bullock, BE(Hons), Grad IE Aust.
N. Demytko, BE(Hons), BSc, M Admin.
P.G. Potter, BE(Hons), PhD.

Engineers:
M.J. Biggar, BE(Hons).
J.S. Spicer, BE(Hons).
A.R. Urie, BE(Hons).

Senior Technical Officers:
L.W. Bourchier
R.B. Coxhill
J.L. Kelly
R.I. Webster

Optical Systems Section

Functions

- Provide information, advice, consultancy and recommendations as defined in the Branch objectives.
- Conduct research and exploratory development into the transmission characteristics of optical media.
- Conduct research into transmission systems which utilise optical media.
- Evaluate the potential applications and utilisation of such systems using such media for the transmission of telecommunications services in the local, junction and trunk networks.
- Investigate the inter-working of such systems with other parts of the transmission and switching network.
- Develop and advise on new techniques for the measurement of transmission properties and characterisation of optical systems.
- Maintain an awareness of and evaluate and advise on emerging techniques relating to optical systems transmission.

Section Head: A.J. Gibbs, BE(Hons), ME, PhD, SMIEEE, SMIREE.

Principal Engineer: R.W.A. Ayre, BE(Hons), BSc(Hons), MEngSc.

Senior Engineers:
E. Johansen, BE(Hons), PhD, SMIREE.
G. Nicholson, BE(Hons), MEngSc, MIEEE.

Engineer: T.D. Stephens, BE(Hons), MEngSc.

Senior Technical Officers:
J.B. Carroll
J.H. Gillies

Standards and Laboratories Engineering Branch

Objectives

To ensure a sound scientific basis for all measurements made by and within the Australian Telecommunications Commission by arranging traceability of accuracy of measurement of fundamental engineering and physical quantities to the Australian National Standards.

Conduct studies, exploratory development and field experiments, contribute to specifications and provide advice and recommendations as appropriate relating to:

- development and application of standards of electrical quantity, time and frequency within the field of telecommunications;
- telecommunication instrumentation and equipment engineering practices;
- development and application of microelectronics components.

Provide a mechanical, electrical and/or electronic equipment development facility for Telecom Australia.

Provide a laboratory design and instrumentation facility for the Research Department.

Provide a comprehensive library service to all Departments and Directorates at Headquarters.

Assistant Director: G. M. Willis, FRMIT, MIE Aust, SMIREE.

Staff Engineer: A.J. Stevens, BE, MIEE, MIEEE.

Branch Administrative Officer: T.H. Brown.

Reference Measurements Section

Functions

- Plan and oversight the implementation, operation and further development of a system of engineering references and calibration facilities for Headquarters and all States.
- Operate, maintain and calibrate the Commission's central engineering references in terms of the Australian National Standards of Measurement.
- Develop improved engineering references, calibration and measuring techniques and procedures to meet the Commission's developing technology and operational needs.
- Develop special techniques, systems and equipment for the application of measurement technology to the solution of engineering plant problems.
- Operate as a Verifying Authority and Signatory in accordance with the requirements of the National Standards Commission and the National Association of Testing Authorities.
- Liaise with other sections of Telecom Australia to ensure that all standards of reference have an appropriate authenticity of calibration as required by the Weights and Measures Act.
- Liaise with other national and international measurement laboratories and authorities, particularly the International Telecommunications Union, Union Radio Scientific Internationale, the Standards Association of Australia and the National Association of Testing Authorities.

Section Head: J.M. Warner, BSc, MIEE.

Principal Engineer: R.L. Trainor, BSc.

Senior Engineers:
R.W. Harris, BSc(Hons), BE(Hons), BComm.
E. Pinczower, Dip Elec Eng, MIE Aust.

Engineers:
J.P. Colvin, BE, Dip Elec Eng.
D.A. Latin, BE.
R.W. Pyke, Dip Elec Eng, BE(Hons), MIE Aust.
B.R. Ratcliff, Dip Comm Eng.

Senior Technical Officers:
J.B. Erwin
C.R. Flood
A.L. Forecast
J. Freeman
R.H. Yates

Laboratory Design Section

Functions

- Plan and specify, in conjunction with other Telecom Australia staff, accommodation requirements of the Department in future and existing buildings; liaise with construction authorities and contractors as appropriate; plan and co-ordinate the occupation of new accommodation.
- Maintain special laboratory buildings, fittings, services and facilities; liaise with Buildings Sub-Division to arrange all buildings and building services, repairs and maintenance required within the Department.
- Co-ordinate all safety, security, and fire protection matters within the Department.

Section Head: D.S. Geldard, MIEE, MIE Aust.

Engineer: R.J. Day, Dip Elec Eng, Dip Mech Eng, MIE Aust.

Senior Technical Officer: J.T. Blake

Instrumentation Engineering Section

Functions

- Study instrumentation trends relevant to present and future Telecom Australia applications; design and develop novel instrumentation systems for specific Telecom Australia needs which cannot be obtained from commercial sources.
- Develop and maintain facilities, including calibration standards, required for the calibration and maintenance of advanced laboratory test equipment and apply these facilities to ensure the high standard of performance required of the Research Department's instrumentation.
- Conduct the procurement programme for all new equipment for the Department, including preparation of technical specifications, tender evaluations and technical reports; perform acceptance testing of new equipment.

Section Head: A.M. Collins, BSc.

Senior Engineers:
G. Heinze, Dip Electron Eng, BE.
F.R. Wylie, BE, MIEEE.

Engineers:
I. Dresser, BE.
N.A. Leister, BE, Grad IREE.
P. Standaert, BE(Hons).

Senior Technical Officers:
S.P. Curlis
P.J. Dalliston
D.R. Daws
P.S. Dawson
D.C. Diamond
B.K. Eley
D.G. Marshall
K.L. Rogers

Headquarters Library

Functions

- Provide a comprehensive library service to all Departments and Directorates at Headquarters.
- Co-operate with State Administrations and provide consultative services in regard to common standards and systems.

Principal Librarian: H.V. Rodd, BA, Dip Lib.

Senior Librarian: D.J. Richards, BA, Dip Lib.

Librarians:
G. Chua, BAppSc, ALAA.
M. McAllister, BSc(Hon), Dip Lib, ALAA.
P. Millist, Dip Lib, ALAA.
E.M. Spicer, BA, Dip Lib.
G.A. Lawson, BA, Grad Dip Lib, ALAA.
J.A. Smith, BA.
B.A. Wilson, BA, LLB, Grad Dip Lib.

Equipment Engineering Section

Functions

- Conduct research into the application of new materials, components fabrication and assembly techniques applicable to the design and construction of mechanical, electrical and electronic equipments and tools required within the Research Department and elsewhere in Telecom Australia.
- Provide for Telecom Australia a specialist design facility, including mechanical and electromechanical engineering design of the hardware aspects of telecommunications models; arrange for production of these designs within Telecom Australia or industry or, when necessary, within the Section; establish specification criteria for performance and quality, and the necessary measuring equipment, and employ these to ensure adequate performance of the items produced.
- Oversight the on-the-job training of apprentice artisans and trainee technical staff in the mechanical engineering field for the Research Department.

Section Head: F. Wolstencroft, CEng, MIMech E.

Senior Engineer: P.F.J. Meggs, Dip Mech Eng, ARMIT, Grad Dip IM, MIE Aust.

Engineers:
A.R. Gilchrist, Dip Mech Eng, BE(Hons), Grad IE Aust.
W.F. Hancock, Dip Elec Eng, MIE Aust.
K. Ho-Le, BSc, BE(Mech Hons), MIE Aust.
R. Proudlock, BE.

Senior Technical Officers:
J.D. Kisby
D.J. McMillan
W.L. Reiners

Microelectronics Section

Functions

- Conduct research studies into the design and physical realisation of electronic circuitry, in particular that involving miniature and microminiature techniques and components, and into interconnection and mounting of these circuits.
- Provide in-house facilities for the production of prototype microelectronic circuits in experimental quantities; specify and develop test criteria and techniques for the control of quality and reliability of these circuits.

Section Head: D.E. Sheridan, Dip Elec Eng, Dip Mech Eng.

Principal Engineer: G.J. Barker, Dip Mech Eng, MIE Aust.

Senior Engineers:
G.K. Reeves, BSc(Hons), PhD, MIE Aust.
H.S. Tjio, BE(Mech), Dip Electron Eng.

Engineers:
A. Brunelli, Dip Electron Eng, BE(Comm).
J.L. Chester, BE(Hons).
C.D. Knowles, BSc, BE(Dist).
D.R. Richards, BE, MIEEE.

Scientist:
Z. Slavik, Dip Eng, ARACI.

Senior Technical Officers:
G. Brinson
M. Crarey
F. Gigliotti

Telecommunications Technology Branch

Objectives

Conduct studies, exploratory development and field experiments, provide advice and recommendations, and contribute to equipment specification and assessment relating to:

- the application of newly emerging, extended or improved technologies in telecommunication engineering;
- the characteristics and properties of new devices, circuits and techniques in communications applications;
- the impact and compatibility of new technology and new applications of existing technology with those already in the Telecom Australia network;
- the forecasting and evaluation of developing trends in telecommunications technology particularly suitable for application in Australia;
- maintain and develop liaison with appropriate research establishments in Australia and overseas to provide information and advice on emerging technologies of interest to Telecom Australia.

Assistant Director: W.J. Williamson, BE(Hons), PhD.

Staff Engineer: N.F. Teede, BE(Hons), PhD, Dip Mgt,

Branch Administrative Officer: C.J. Chippindall

Satellite Technology and Electromagnetic Environment Section

Functions

- Provide information, advice and consultancy as defined in the Branch objectives.
- Conduct research into, and advise on applications of communication satellite technology in Australia from system and technique studies, hardware development and experimentation.
- Conduct research into the utilisation of the frequency spectrum by satellite systems, including frequency re-use, and their coexistence with terrestrial radio services.
- Investigate interference effects of radio frequency radiation on telecommunications equipment and make recommendations on electromagnetic compatibility as appropriate.
- Establish and maintain a knowledge base on the biological effects of electromagnetic radiation and evolve design practices to take account of best available information, in consultation with and with inputs from experts in relevant medical specialities.

Section Head: G.F. Jenkinson, BSc, SMIREE.

Principal Engineers:
R.K. Flavin, BSc, MSc.
I.P. Macfarlane, BE, ARMTC, MIEEE.

Senior Engineers:
A.J. Bundrock, BE(Hons).
D.J. Kuhn, BE, MEngSc.

Engineers:
P.R. Murrell BE
S. Iskra, BE(Hons).

Senior Technical Officers:
D.K. Cerchi
D.M. Farr
B.C. Gilbert

Computer Applications and Techniques Section

Functions

- Provide information, advice and consultancy as defined in the Branch objectives.
- Conduct fundamental studies on and recommend or implement as appropriate, modelling and simulation methods, as applicable to telecommunication systems and techniques, and related activities.
- Investigate and make recommendations concerning processor technology, techniques and applications as they relate to telecommunications engineering.
- Investigate and make recommendations on methods of mathematical analysis best suited to the application of computers to problem solving in telecommunications engineering.
- Develop and provide computing facilities including hardware and software to meet special needs within Telecom Australia. Co-operate with the Instrumentation Engineering Section and Information Systems Department in provision of items of computer hardware for the Department's needs.

Section Head: P.J. Tyers, BE(Hons), BSc, MIEEE.

Senior Engineer: K.F. Barrell, BE(Hons), PhD.

Engineers:
L.A.R. Denger, ENSEMN, MIEEE, M Soc Fr de Elec, Grad IE Aust.
R. Palmer, BE(Hons), PhD

Senior Technical Officers:
D. Drummond
I.J. Moran

Antennas and Propagation Section

Functions

- Provide information, advice and consultancy as defined in the Branch objectives.
- Conduct research and exploratory development in the field of freely propagated electromagnetic waves, including the study of propagation phenomena and of the interrelation of meteorological and other mechanisms, and make recommendations in relation to the performance and design characteristics of radiocommunication systems.
- Conduct research, undertake exploratory development and make recommendations on antennas for launching and receiving electromagnetic radiation, for application both in the design of antennas for experimental and practical engineering projects.

Section Head: J.H. Reen, BEE, MIE Aust.

Principal Engineers:
J.V. Murphy, BE(Hons), BA.
S. Sastradipradja, BE.

Senior Engineers:
R.A. Harvey, Dip Rad Eng, BSc, AMIREE.
E. Vinnal, BE(Hons).

Engineer: W. Lobert, BE(Hons), MEngSc.

Scientist: P. Turner, BSc(Hons), PhD.

Senior Technical Officers:
E.D.S. Fall
R.J. Francis
S.J. Hurren
B.W. Thomas

Solid State Electronics Section

Functions

- Provide information, advice and consultancy as defined in the Branch objectives.
- Investigate and advise on the properties of materials and components that are applicable to the development and fabrication of devices and circuit elements which have functions based on the exploitation of these special material properties; conduct exploratory development and fabrication of such devices.
- Investigate and advise on active and passive circuit configurations, employing such devices for the generation, amplification, modulation and processing of signals and their application, especially in microwave and optical circuits and sub-systems.
- Develop and provide specialised facilities in the realm of engineering materials and devices arising from the above.

Section Head: P.V.H. Sabine, BSc, BE(Hons), PhD.

Principal Engineers:
Y.H. Ja, BE, PhD.
G.E. Rosman, BEE, ME.

Senior Engineers:
J. Hubregtse, Dip Comm Eng, MIREE.
G.O. Stone, BE(Hons), MEngSci, PhD, MIEEE, MIREE

Engineer: A.M. Duncan, BSc, BE(Hons).

Principal Scientist: G.L. Price, BSc(Hons), PhD, MAIP, MAPS, MIEEE.

Senior Scientist: P.C. Kemeny, BSc(Hons), PhD, Grad APS.

Scientists:
B.J. Linard, BSc(Hons), PhD, Grad AIP.
B.F. Usher, BSc(Hons), Dip.Ed, PhD, MAIP

Senior Technical Officer: B.P. Cranston

Switching and Signalling Branch

Objectives
In the fields of switching and signalling, conduct studies, exploratory development and field experiments, contribute to specifications and provide advice and recommendations as appropriate relating to:

- technical aspects of switching and signalling within the Telecom Australia network;
- new switching and signalling systems which use extensions of present techniques, or new techniques with particular reference to their integration into the existing network;
- compatibility of switching and signalling systems;
- cost sensitivity studies;
- traffic engineering.

Assistant Director: F.J.W. Symons, BE(Hons), PhD, DIC, MIE Aust, AIEE.

Technical Co-Ordinator: J.L. Park, BE(Hons), MEngSc.

Branch Administrative Officer: S.J. Chalk.

Network Studies Section

Functions

- Conduct research into the basic nature of switching networks and the manner in which changes in network parameters influence the technical and economic characteristics of the network.
- Assess the potential of future systems in relation to network needs.
- Provide specialist consultative advice and assistance in relation to the progressive integration of new switching systems into Telecom Australia's networks.
- Examine requirements for switching and signalling systems in future environments and conduct feasibility studies of possible approaches.

Section Head: R.J. Vizard, Dip Elec Eng, BEE.

Principal Engineer: G.J. Champion, BE.

Senior Engineers:
J. Billington, BE (Hons), MEngSc, MIEEE.
K.S. English, BE(Hons), MEngSc, MIEEE.
M.C. Wilbur-Ham, BE(Hons).

Research Officer: G.R. Wheeler, BSc(Hons), MSc.

Signalling and Control Section

Functions

- Study the characteristics and potential of new approaches in the field of control and signalling.
- Develop models to validate theoretical studies of new control signalling systems and techniques.
- Conduct field trials to assess the performance of new approaches and techniques in the field of control and signalling.
- Provide specialist consultative advice in matters pertaining to control and signalling.

Section Head: P.H. Gerrand, BEng(Hons), MEngSc, MIE Aust.

Principal Engineers:
M.A. Hunter, BE(Hons), MIE Aust.
M. Subocz, BE, MIE Aust.

Senior Engineers:
P.A. Kirton, BE(Hons), PhD, MIEEE.
G.K. Millsteed, Dip Elec Eng, BE(Hons).
B.T. Dingle, Dip Elec Eng, BE(Hons).

Engineers:
H.K. Cheong, BE(Hons) PhD.
S.M. Jong, BE.

Research Officer: I.P.W. Chin, BSc(Hons), AIEE.

Switching, Operations and Maintenance Section

Functions
Within the fields of switching and signalling:

- Study the characteristics and potential of new approaches in the field of operations and maintenance.
- Develop models which will be used to validate theoretical studies of new operations and maintenance systems and techniques.
- Conduct field trials to assess the performance of new approaches and techniques in the field of operations and maintenance.
- Provide specialist consultative advice in matters pertaining to operations and maintenance.

Section Head: E.A. George, ASTC, PostDip Elec Comp, MIE Aust.

Senior Engineers:
G.J. Dickson, BE(Hons), MEngSc, MIEEE.
J.C.N. Ellershaw, BSc, BE(Hons), PhD, MIEEE.
J.L. Snare, BE(Hons), MEngSc.

Engineers:
C.J. O'Neill, BE(Hons).
K.T. Ko, BE(Hons), MIEEE

Devices and Techniques Section

Functions

- Assess the potential of new devices and techniques for application in switching and signalling systems.
- Develop new techniques to exploit the latent potential of new switching technology.
- Participate in the design and assessment of field trials of new switching systems and equipment which use novel devices and techniques.
- Prepare recommendations for the adoption or trial of new devices and/or techniques.

Section Head: R.A. Court, BE(Hons), BSc, MEngSc, MIEEE.

Senior Engineer: E. Tirtaatmadja, BE.

Engineers:
D.M. Harsant, BE(Hons).
J.G. Hollow, BE(Hons), PhD, MIEEE.

Scientist: C.J. Scott, BAppSc, Grad AIP.

Software Engineering Research Section

Functions

- Conduct research and investigations and develop new techniques in fundamental areas of the application of computer systems to telephony and data switching and signalling.
- Study the characteristics and potential of new approaches in the field of SPC programming and software technology.
- Participate in the design and assessment of laboratory and field trials of new switching and signalling systems using novel software engineering and programming techniques.
- Provide an SPC system programming and software specification, analysis, design, production and testing capability for the Switching and Signalling Branch.
- Make recommendations concerning the provision of the Branch processor complex, provide a comprehensive software support capability, and co-ordinate the day to day operation of the Branch processor complex.
- Provide specialist consultative advice and assistance in relation to the progressive integration of new SPC programming and software technology into the network.

Section Head: R.H. Haylock, MACS.

Senior Computer Systems Officers:
E.M. Swenson, MSc. Grad Dip Data Processing, MAIP, AACS.
J.S. Drake
G.P. Rochlin, BSc, MACS.

Computer Systems Officers:
J.B. Cook
S.A. Dart
R. Liu

Traffic Engineering Research Section

Functions

- Serve as a national reference authority for traffic engineering theory and education.
- Investigate the traffic characteristics and traffic capacity of new switching and signalling systems adopted or being considered for adoption by Telecom.
- Recommend traffic performance standards for, and contribute to specifications for new switching and signalling systems being considered for adoption by Telecom.
- Serve as a consultant for the dimensioning of special systems and networks for Telecom's larger customers.
- Maintain a constant review of world developments in traffic theory and its application to telecommunications networks.

Section Head: J. Rubas, ARMTC, MIE Aust.

Senior Engineer: R.E. Warfield, BE(Hons), PhD.

Scientist: R.J. Harris, BSc(Hons), PhD.

Engineer: G.A. Foers, BE(Hons).

Research Officers:
M. Rossiter, BSc(Hons).
S. Choy, BSc.

Technical Services Section

Functions

- Provide field and laboratory planning, provisioning, investigational, developmental, production, testing and evaluation support for Branch activities.
- Install, operate and maintain equipment in field experiments.

Section Head: W. McEvoy, AAIM.

Senior Technical Officers:
R.L. Backway
S. Dovile
P. Ellis
H.G. Fegent
L.P. Lucas
H. Meijerink
P.C. Murrell
B.J. Wilson

Applied Science Branch

Objectives

Conduct studies, exploratory development and field experiments, contribute to specifications, assist in the assessment of tenders and provide advice and recommendations, as appropriate, relating to:

- the properties of materials, components and equipment;
- the causes of degradation and failure, and the establishment of remedial measures;
- the influence of the environment on staff and plant and the required protective measures;
- the development and application of new materials and of new scientific test methods;
- the reliability of components and devices;
- participation in committees, conferences, etc., both national and international, and liaison with universities and research organisations.

Assistant Director: R.D. Slade, Dip Met, FIM, MAIMF.

Staff Scientist: G. Flatau, FRMIT

Principal Engineer: A. Fowler, MIE Aust.

Surface Characterisation Group

Senior Scientist: J.R. Lowing, Dip Sec Met.
Scientist: C.G. Kelly, BAppSc, AAIP, MAXAA, MAXS
Solar Module Evaluation Group

Group Leader: D. McKelvie, BSc(Hons).
Senior Scientist: A.J. Murfett, BSc(Hons).
Branch Administrative Officer: M.A. Chirgwin

Metallurgy and Electro-Chemistry Section

Functions

- Provide information, advice and consultancy as defined in the Branch objectives.
- Conduct exploratory research and investigation in the fields of metallurgy and electro-chemistry to the depth necessary to enable this scientific knowledge to be applied to the solution of Telecom Australia's problems.
- Perform scientific studies involving electrochemical phenomena in the fields of corrosion and electrical power sources.
- Conduct scientific studies into the properties of metals and alloys and their application.
- Develop appropriate test methods and specialised equipment as required.
- Conduct research into surface phenomena and electro-deposition; develop practices for the satisfactory protection of equipment and plant.

Section Head: K.G. Mottram, Dip Met Eng, AMAIMM.

Senior Scientist (Metallurgy Group):
T.J. Keogh, Dip Sec Met.

Scientists:
J.R. Godfrey, Dip Met.
K. Keir, Dip Met Eng.

Senior Scientist (Electro-Chemistry Group):
J. Der, BSc, ARACI.

Scientists:
P.J. Gwynn, Dip App Chem.
R.F. May, MSc, Dip Sec Met.

Engineer:
J.A.A. Lyimo, BE(Hons).

Senior Technical Officers:
F.M. Hamilton
M. Jorgensen
J.W. Smith

Polymer Section

Functions

- Provide information, advice and consultancy as defined in the Branch objectives.
- Conduct exploratory research and investigation in the chemistry and application of polymeric and associated materials to the depth necessary to enable this scientific knowledge to be applied to the solution of Telecom Australia's problems.
- Carry out scientific studies of the properties of polymeric materials and develop methods for their application.
- Develop polymer materials with special properties for particular applications as required.
- Develop appropriate test methods and specialised equipment as required.

Section Head: H.J. Ruddell, Dip App Chem, FPIA, ARACI.

Senior Scientists:
D.J. Adams, Dip App Chem, Grad RACI.
B.A. Chisholm, MSc, Dip App Chem, Grad PRI, Grad RACI.

Scientists:
R.J. Boast, Dip App Chem, Grad Dip Pol Sc, Grad RACI.
G.I. Christiansz DipEd, Bsc(Hons), PhD.
P.R. Latoszynski, Dip App Sc, Grad RACI. Grad Dip Analyt Chem.
D.T. Miles, C Chem, MRSC, MRSH.

Reliability Studies Section

Functions

- Provide information, advice and consultancy as defined in the Branch objectives.
- Conduct exploratory research and investigation into the reliability of components, devices and assemblies to the depth necessary to enable this scientific knowledge to be applied to the solution of Telecom Australia's problems.
- Conduct scientific studies into the causes of failure or degradation of components, devices and assemblies.
- Conduct research leading to the statistical prediction of the life expectancy of components, devices and assemblies.
- Design and develop specialised test equipment.
- Develop special analytical techniques for failure analysis.
- Conduct scientific studies into the properties of materials and components.

Section Head: G.G. Mitchell, BSc(Hons), MSc.

Senior Scientist: S.J. Charles, BAppSc.

Senior Technical Officers:
R.A. Galey
J.F. Pidoto
R. Wilkinson

Chemistry Section

Functions

- Provide information, advice and consultancy as defined in the Branch objectives.
- Conduct exploratory research and investigations in the field of chemistry to the depth necessary to enable this scientific knowledge to be applied to the solution of Telecom Australia's problems.
- Conduct scientific studies into chemical phenomena and hazards.
- Develop specialised techniques and equipment for the analysis of materials.
- Provide the scientific backing for the operations of the Australian Government Stores and Tender Board, including the formulation of new specifications and approval testing of all relevant types of material and consumer products.

Section Head: F.C. Baker, Dip App Chem, Dip Chem Eng, ARACI, AAIST, C Chem, MRSC.

Senior Scientist: R.N.M. Barrett, BSc(Hons), C Chem, MRSC.

Scientists:
T.J. Elms, Dip App Sc, Grad Dip Analyt Chem, Grad RACI.
P.W. George, Dip App Sc(App Chem), Grad RACI.
S. Georgiou, BAppSc(App Chem), Grad Dip Analyt Chem.
F.M. Petchell, Dip App Chem, ARACI.

Senior Technical Officer: R.R. Pierson MAIST Grad Dip Res Cons Stud.

Applied Physics Section

Functions

- Provide information, advice and consultancy as defined in the Branch objectives.
- Conduct exploratory research and investigation in the field of physics to the depth necessary to enable this scientific knowledge to be applied to the solution of Telecom Australia's problems.
- Conduct scientific studies into the physical properties of materials and components.
- Conduct research into the effects of the natural and man-made environment on staff and plant; devise means of protection from any deleterious influences.
- Conduct research into high voltage phenomena and its effect on staff and plant; devise protection methods as appropriate.
- Design and develop specialised testing and measuring equipment as required.

Section Head: I.A. Dew, BSc, MSc.

Senior Engineer: I.K. Stevenson, BAppSc, (Dip Electronic Eng) Grad AIP, Grad IE Aust.

Senior Scientists:
E.J. Bondarenko, Dip App Phys, BApp Sc, LAIP, SMIREE, FRAS.
G.W.G. Goode, BSc.

Scientists: D.E. Thom, Bsc, DipEd Grad Dip(Process Computer Systems).
E.E. Gibbs, BSc(Hons), PhD.
Engineer: P.W. Day, BE(Comm).

Senior Technical Officers:
M.C. Hooper
S.R. McAllister
I.M. Tippett

Customer Systems and Facilities Branch

Objectives

Conduct studies, exploratory development and field experiments, contribute to specifications, assist in the assessment of tenders, and provide other advice and recommendations as appropriate relating to:

- the needs and potential needs for communication within the community considering both human and technical aspects;
- user facilities and equipment which are new or which represent extensions of existing services;
- the interaction between users or users' equipment and the Telecommunications system;
- performance criteria for user communication.
- cost sensitivity studies.

Maintain an awareness of:

- community and commercial initiatives in the area of customer facilities and equipment;
- actual and potential community needs for new, extended or improved customer facilities and equipment;
- local and overseas technical developments relevant to the provision of new, extended or improved customer facilities and equipment.

Assistant Director: R.J. Morgan, BSc(Eng Hons), PhD.

Branch Administrative Officer: G.N. Galvin

Voice Services Section

Functions

- Provide information, advice and consultancy as defined in the Branch objectives.
- Conduct studies and exploratory development of new telephone facilities and customer apparatus for voice services, taking account of switching, signalling, and multiplexing requirements of the telecommunication system.
- Provide standards for telephone transmission and make recommendations on the transmission performance criteria for voice services.
- Investigate the generation, transmission, perception, synthesis and recognition of speech signals in telecommunication networks.
- Conduct studies into audio frequency acoustic signal propagation and noise.
- Advise on methods for the quality control of the performance of customer equipment.

Section Head: E.J. Koop, Dip Elec Eng, BE, MAAS.

Principal Engineers:
P.F. Duke, Dip Maths, BTech.
R.A. Seidl, BE(Hons), PhD.

Senior Engineer: P.L. Nicholson, BE, MIEEE

Engineers:
J.P. Goldman, Dip Rad Eng, Dip Comm Eng, Grad IE Aust.
N.H. Duong, BE.

Senior Technical Officers:
J.E.W. Lucas
T.R. Long

Customer Access Section

Functions

- Provide information, advice and consultancy as defined in the Branch objectives.
- Conduct studies of methods of providing customer access with particular reference to service and terminal requirements.
- Develop approaches towards the standardisation of customer access (electrical interfaces and logical procedures) which will enable maximum interworking of network terminals and services.
- Prepare recommendations regarding customer access standards.
- Assess the potential and limitations of proposed approaches towards customer access as they relate to terminal equipment and services.

Section Head: N.Q. Duc, BE(Hons), PhD, SMIREE, MIEEE.

Senior Engineer: E.K. Chew, BE, MEngSc, PhD, Grad IE Aust.

Engineers:
P.I. Mikelaitis, BE, MEngSc, MIEEE
D.M. Blackwell, BE.
A.H. Al Tarafi, BSc(Hons), Phd

Business Communication Section

Functions

- Provide information, advice and consultancy as defined in the Branch objectives.
- Provide specialist advice and assistance in the use of television and record systems.
- Conduct studies and exploratory development of integrated multi-functional business communications systems.
- Investigate hardware and software techniques relevant to the provision of customer information systems.
- Investigate questions of technical compatibility arising when new facilities are added to existing business systems.
- Conduct studies and exploratory development of terminal equipment for the generation and display of TV and record signals.
- Undertake investigations and exploratory development of the processing of visual and record signals so as to facilitate their transmission within the Telecom Australia network.
- Study and develop techniques for the conversion between various forms of visual and record signals.

Section Head: P.S. Jones, BE MEngSc.

Principal Engineers:
R.I. Davidson, BE.
G.K. Jenkins, BSc, BE(Hons), ME, MACS.

Senior Engineers:
A.R. Jenkins, ARMIT.
W.E. Metzenthen, FRMIT, ME, MIREE.
P.F. Frueh, BE, MEngSc.

Engineers:
P. Bernhard, BE.
R. Exner, BSc, BE(Hons), MAppSc, MIEEE.
G.R.G. Smart, Assoc Dip Radio Eng, MIREE, ARMIT, JP.

Senior Technical Officers:
B.W. Booth
P.D. Jackson
A.M. McDonald

Human Communication Section

Functions

- Provide information, advice and consultancy as defined in the Branch objectives.
- Undertake fundamental studies of the processes of human communication.
- Undertake the design, exploratory development and experimental assessment of group and other novel communication facilities.
- Investigate the social and organisational implications of such facilities.
- Investigate, develop where necessary, and apply the techniques of the social sciences to the assessment of the effectiveness and acceptability of communication facilities.
- Investigate the effects of signal transmission, presentation and processing on human communication, including the interaction between telecommunication technology and user perception and behaviour.
- Conduct studies and exploratory development of communication devices and techniques which meet the special needs of the handicapped.

Section Head: G.D.S.W. Clark, BEE(Hons), MSc, MIE Aust.

Senior Engineers: J.K. Craick, BE(Hons), BSc.
D.Q. Phiet, BE(Hons), PhD.

Engineer: P.H. Newland, BE.

Senior Psychologist: L.A. Albertson, BA(Hons), Dip Ed.

Psychologists:
L. Perry, BA(Hons), MAPS.
R.W. Hyland, BA(Hons).

Senior Technical Officers:
A.H. Borg
D.R. Potter

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 contribute papers to Australian and overseas scientific and technical journals and present papers to learned societies both in Australia and overseas. This list shows those papers, lectures, talks and reports presented or published during the last 12 months.

Papers

Albertson, L.A. & Perry, L.	"Configuration or Channel? A Conceptual Challenge to the Type Allocation Model as a Basis for Teleconferencing Systems", 6th International Conference on Teleconferencing and Interactive Media, Madison, Wisconsin, USA, May 1982.
Albertson, L.A.	"The Wired World of Tele-Education", Telecom News, No. 77, August 1982.
Albertson, L.A.	"High Hopes for Rural Tele-Education", School Bell, The Official Journal of the Victorian Council of School Organisations, October 1982.
Albertson, L.A. & (Galloway, J.J., Macquarie University)	"Netmapping the Diffusion and Adoption of Teleconferencing Facilities", 14th Pacific Science Congress, Dunedin, New Zealand, February 1983.
Albertson, L.A.	"Telelink Rescues Housebound", Australian Society, November 1982.
Albertson, L.A. & L. Perry	"Configuration or Channel ? A Conceptual Challenge to the Type Allocation Model as a Basis for Teleconferencing Systems", Proceedings of the 10th International Symposium on Human Factors in Telecommunications, Helsinki, April 1983.
Baker, F.C.	"Cold Ashing of Plastics by R.F. Plasma", Joint Meeting of the Analytical Chemical and Polymer Groups of the Royal Australian Chemical Institute - Theme: Analysis of Polymers and Polymer Additives, Melbourne, May 1982.
Barrett, R.N. & Baker, F.C.	"Estimation of Titanium Dioxide Pigment in UPVC Pipe", Joint Meeting of Analytical Chemistry and Polymer Groups of the Royal Australian Chemical Institute - Theme: Analysis of Polymers and Polymer Additives, Melbourne, May 1982.
Billington, J.	"Comments on 'Model of a Connection' The Network Service Definition, February 1982", CCITT Study Group VII, Q27, Working Document 27/7L/11, Melbourne, March 1982.
Billington, J.	"Specification of the Transport Service Using Numerical Petri Nets", The Second International Workshop on Protocol Specification Testing and Verification", Idyllwild, California, USA, May 1982.
Billington, J.	"Transport Service Definition using Labelled Numerical Petri Nets", Contribution to CCITT Q.27/VII and Q.39/VII Meetings in December 1982, Geneva, November 1982.
Billington, J.	"Proposed Major Change to ISO/DP8072", Contribution to ISO/TC97/SC16/WG6, January 1983.
Billington, J.	"Transport Service Specification using Labelled Numerical Petri Nets", contribution to ISO/TC97/SC16, February 1983.
Blackwell, D.M. & Chew, E.K.	"Local Communications over the D-Channel", Delayed Contribution DXI/6-174, CCITT Working Party XI/6 Meeting (Digital Subscriber Line Signalling), Melbourne, April 1983.
Blackwell, D.M. & Chew, E.K.	"Extended Addressing in the D-Channel", Delayed Contribution DXI/6-175, CCITT Working Party XI/6 Meeting (Digital Subscriber Line Signalling), Melbourne, April 1983.
Bundrock, A.J.	"Simultaneous Transmission of TV and Sound Channels Through a Satellite Transponder - An Investigation of Intermodulation", Australian Telecommunication Research Vol. 16, No. 1, 1982.
Campbell, J.C. & Coutts, R.P.	"Outage Prediction of Digital Radio Systems", Electronics Letters, Vol. 18, No. 25/26, December 1982.
Chew, E.K., Duc, N.Q. & English, K.S.	"Multiple LAP-D Addressing in OSI Framework", CCITT Delayed Contribution to Working Party XI/6 (Digital Subscriber Line Signalling), Geneva, November 1982.
Chew, E.K. & Subocz, M.	"Layering of s-Type Signalling Protocols in D-Channel", CCITT Delayed Contribution to Working Party XI/6 (Digital Subscriber Line Signalling), Geneva, November 1982.
Chew, E.K. & Subocz, M.	"Architecture for PABX Access Protocol", Working Party XI/2 PABX Access Meeting, Paris, November 1982.
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Barrell, K.F.	"Graphical Investigations", Department Computing Research, CSIRO, Canberra, February 1983.
Billington, J.	"Protocol Verification Methodology and Example", Presentation to Monash University Department of Computer Science, July 1982.
Billington, J.	"Labelled Numerical Petri Net Specification of the Transport Service", Seminar to CSIRO, Division of Computing Research, Canberra, November 1982.
Boast, R.J.	"Thermal Analysis of Polymeric Materials", Chisholm Institute of Technology, Melbourne, October 1982.
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Findlay, R.J. & Gibbs, A.J.	"Telecom's Single Mode Field Experiment", 7th Australian Workshop on Optical Communication, University of New South Wales, December 1982.
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Linard, B.J. & Rosman, G.E.	"The Solid State Electronics Section of the Telecom Australia Research Laboratories: Some Semiconductor and Optical Projects", Department of Physics, University of Tasmania, March 1983.
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Stephens, T.D.	"An Ultra-Low Noise Optical Preamplifier", 7th Australian Workshop on Optical Communication, University of New South Wales, December 1982.

Stone, G.O. & Silvester, P.P. (McGill University & Gorghani, B. Infolytica Corp.)	"Programming Newton-Raphson Finite Elements for Axisymmetric Vector Fields", Presented at COMPUMAG Conference, Genoa, Italy, 30 May – 2 June 1983.
Stone, G.O.	"Nonlinear Optical Communications Applications of the Finite Element Method", CADL Seminar, McGill University, October 1981.
Stone, G.O.	"Pascal-Implemented 2D and 3D Finite Element Sorting Algorithms with Minimal Mass-Storage Operations", CADL Seminar, McGill University, February 1982.
Stone, G.O. & Silvester, P.P., (McGill University)	"Augmented Axisymmetric Finite Element Formulation for On-Axis Magnetostatics", CADL Seminar, McGill University, November 1982.
Stone, G.O.	"A New Finite Element Formulation for a Class of Piezoelectric Waves in Crystals" CADL Seminar, McGill University, February 1983.
Tyers, P.J.	"The Current State of Computer Technology", Seminar at the Australian Administrative Staff College, June 1982.
Vizard, R.J.	"Wideband and ISDN", Presentation to CTV Task Force, Melbourne, December 1982.
Williamson, W.J.	"Solid State & Quantum Electronics Research in Telecom Australia", Electrical Engineering Department Seminar, University of Western Australia, 15 June 1983.
Wragge, H.S.	"Future Developments in Telecommunications", Bendigo Branch IE Australia, Bendigo, May 1982.

Reports

Report No	Author	Title
7225*	A. Brunelli	Micro Camera Alignment Procedures
7236*	E. Johansen	Optical Fibre Tap Couplers
7372*	J.R. Grimwade	The Participation Model of Teleconferencing: A Pilot Study
7391*	G. Dhosi	A High Speed 8-11 Mbit/s Jitter Test Set
7407* Addendum 1	K.G. Mottram	The Solderability of Bare Copper Wire
7419*	H.S. Tjio	IDS-2: System Architecture and Programming, Part 2 – Data Structure
7421*	M. Crarey	IDS-2: System Architecture and Programming Part IV – ICT Assembler and Practical Aspects
7445*	E. Tirtaatmadja	The Second US/Southeast Asia Telecommunications Conference and Exhibition, Singapore – December 1980 – An Overseas Visit Report
7452* Addendum 1	P.W. George	Evaluation of Adhesives
7472*	M. Subocz	Overseas Visit Report – April 1981 – The CCITT No. 7 Common Channel Signalling System Developments
7473*	S.A. Dart, N.Q. Duc & P.A. Kirton	Use of SDL as a Formal Description Technique for Open Systems Interconnection Specifications
7480*	M.A. Hunter & R.J. Vizard	IST/RSU Project – Project Overview
7482	M.A. Hunter	IST/RSU Project – RSU Control Link Design
7483*	M.A. Hunter	IST/RSU Project – Equipment Practices
7496	B.R. Ratcliff	Civil Time Transmitter
7504*	P. Gwynn	Examination of Methods for Evaluating Rosin-Based Soldering Fluxes
7510	T.J. Keogh, J. Godfrey & P. Galvin	The Effect of Surface Finish on the Strength of Sling Chain
7512*	J.C. Campbell & R.P. Coutts	Mean Square Error Analysis of QAM Digital Radio Systems Subject to Frequency Selective Fading
7514*	Y.T. Tan	Local Area Networks – A Survey
7515	E.K. Chew	Performance Modelling of the CCITT No. 7 Common Channel Signalling System
7517	R.A. Seidl	Communications Software for the NOVA Minicomputer
7521*	W. Lobert	Testing of the Marysville and Mount Wellington Antenna Radomes
7522*	A.J. Stevens	Automated Battery Testing
7524*	I.K. Stevenson	Overseas Visit – Telecommunications Component Evaluation
7525*	A.J. Jennings & R. Swinton	Prototype Variable Equalizers for the Digital Data Network
7526*	M. Hayes	An Analogue Adaptive 2-Wire 4-Wire Terminating Set for Unloaded Subscriber Lines
7527*	W.L. Reiners	Development of a Variable Height VDU Work Station
7532	D.J. Adams	Equivalent Temperature – Its Derivation and Use
7533*	M. Subocz	Overseas Visit, Nov-Dec 1981 – CCITT Meetings in Geneva and Related BTM & AT&T Visits
7535*	G.J. Barker	Overseas Visit Report – September-October 1981 – Thin Film Technology
7536	K.S. English	A FORTRAN Program for Global Minimisation of a Function of One Variable
7539*	D.B. Albert	Design and Implementation of a Data Acquisition System for the Digital Radio Field Experiment
7540*	E.M. Swenson	Important Features of SPC Software for Switching Systems
7542	G.W.G. Goode	Software for a Cable Pressure Monitoring System

7545*	R.P. Coutts, R.L. Reid & D.J. Thompson	Signature Measurements on 13 GHz 34 Mbit/s Digital Radio Equipment
7546*	J. Thompson	The Feasibility of using Standard Devices to determine the Electromagnetic Susceptibility of Integrated Circuits
7547*	G.K. Reeves	Overseas Visit Report - Microelectronics Circuit and Device Technology
7548*	J.L. Adams & E. Johansen	Wave Length Division Multiplexing Bi-directional Operation of Optic Fibre
7549*	I.E. Long	An Evaluation of Printed Wiring Board Mounted Flatpack Relays
7550*	J. Pidoto	An Evaluation of Miniature Dual-In-Line Switches
7551*	N. Demytko	The Topology of the Australian Urban Subscriber Loop Network
7552	E. Tirtaatmadja & C.J. Scott	Non-volatile Semiconductor Memory - A Review of EEPROM Techniques
7554*	J.L. Snare, N.Q. Duc, F.J.W. Symons & P.A. Kirton	An Introduction to Selected Data Communication Standards: The Reference Model: - X.25 - the Transport Service
7556*	G.W.G. Goode	United Electric Flow Transducer Type J4P Model 12160
7557*	D.R. Richards	The Caltech Intermediate Form Conversion Routine for the Gerber IDS-2
7561*	D.A. Jewell	Time Marker Generator
7563*	R. Haylock	Report on Overseas Visit to Investigate Developments in the Specification, Design, Production and Testing of Software for Stored Program Control Systems
7564*	F. Gigliotti & G.K. Reeves	Thick Film Design Guidelines
7566*	R. Smith	Digital Systems and Networks - A Report on an Overseas Visit, June 1982
7567	K.S. English	A Least-Squares Approach to the Analysis of Multipath Propagation Data
7568*	A.Y.C. Quan	Some Transmission Aspects of Local Area Networks for Distributed Data Processing
7570*	I.K. Stevenson	A Functional Comparison of Sockets for Dual In-Line Packaged Integrated Circuits
7571*	G.W.G. Goode	Heat Shrink Sleeving of P.E. Cable having a Wax-based Filler
7577*	D. McKelvie	Solar Cell Module Manufacture and Evaluation Visit to Japan - May 1982
7580	E.K. Chew & M. Subocz	An Introduction to the CCITT No. 7 Common Channel Signalling System
7582*	P.F. Duke	Overseas Visit - 1982 - Trends in Voice Services
7595*	W. Hancock & Kong Ma	Accidental Detachment of Flexible Hoses from Insert Fittings

Note: The reports marked * are classified as "Telecom Australia Use Only", in addition 12 "In Confidence" reports with restricted distribution were produced.

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 (Educational)

Technical and Further Education Board, Victoria
Science Laboratory Standing Committee — F.C. Baker
Applied Science Joint Standing Committee — F.C. Baker

University of Melbourne
External Member - Faculty of Engineering — E.F. Sandbach

Monash University
Research Associate - Department of Electrical Engineering — P.H. Gerrand

Footscray Institute of Technology
Course Advisory Committee — H.S. Wragge, G.F. Jenkinson

Chisholm Institute of Technology
Course Advisory Committee — R.J. Morgan

Royal Melbourne Institute of Technology
Course Advisory Committee — R.D. Slade
Communication and Electronic Engineering Course Advisory Committee — P.H. Gerrand
Industrial Fellow — P.H. Gerrand

National & State Professional Bodies

Australian National Committee for Radio Science — W.J. Williamson

Radio Research Board — E.F. Sandbach

Australian Computer Research Board — F.J.W. Symons

Victorian CSIRO State Committee — E.F. Sandbach

Australian Institute of Science Technology
Victorian Branch Council — F.C. Baker

The Institute of Radio and Electronics Engineers, Australia
Publications Board — R. Horton
Melbourne Committee — R. Horton

Telecommunications Society of Australia
Council of Control — E.A. George, G.F. Jenkinson

Board of Editors: "Australian Telecommunication Research" — H.S. Wragge, J. Billington, G.D.S.W. Clark, G. Flatau, P.H. Gerrand, A.J. Gibbs, M.A. Hunter, I.P. Macfarlane, G.K. Reeves, H.V. Rodd

Board of Editors: "Telecommunication Journal of Australia" — D.A. Gray

Institute of Electrical and Electronic Engineers
Victorian Sub-Section Committee — R.A. Court, R.P. Coutts, A.J. Gibbs
Secretary/Treasurer Region 10 — A.J. Gibbs

University of Queensland
Microwave Technology Development Centre — W.J. Williamson

Standards Association of Australia (SAA)
Council of Executive and Staff Committee — E.F. Sandbach
Telecommunications and Electronics Standards Board and Executive Committee — G. Flatau, E.F. Sandbach

Australian Electrotechnical Committee — G. Flatau, E.F. Sandbach

- Reliability of Components and Equipment — G. Flatau
- IEC Quality Assurance Scheme for Electronic Components — G. Flatau, E.F. Sandbach

Acoustics Standards Committee — E.J. Koop
Plastics Industry Standards Board — R.D. Slade
Co-ordinating Committee on Fire Tests — F.C. Baker
Metallography Committee — T.J. Keogh
Metals Standards Board — R.D. Slade

Technical Committees
Australian Welding Research Association Technical Committee: Panel 12 Welding of Plastics — H.J. Ruddell

Acoustic Standards
- Instrumentation and Techniques for Measurement of Sound — E.J. Koop

Australian Welding Research Association
- Panel 12 - "Plastics" — H.J. Ruddell

Chemical Industry Standards
- Adhesives — F.C. Baker
- Heavy Duty Paints — F.C. Baker

Computers and Information Processing
- Data Communications — G.J. Dickson
- Open Systems Interconnection — P.H. Gerrand

Electrical Industry Standards

• Plastics	G.W.G. Goode
• Lightning Protection	E.J. Bondarenko
• Indicating and Recording Instruments	J.M. Warner
• Electrical Insulating Materials	G. Flatau
• Electrolytes	F.C. Baker
• Control of Undesirable Static Charges	G.W. Goode
• Copper & Copper Alloy	K.G. Mottram
• Electrical Accessories	E.J. Bondarenko

Mechanical Engineering Industry Standards

• "Engineers" Hand Tools	P.F.J. Meggs
• Solders	K.G. Mottram
• Vibration & Shock ME Measurement & Testing	I.A. Dew

Metal Industry Standards

• Coating of Threaded Components	R.D. Slade
• Galvanised Products	R.D. Slade
• Electroplated and Chemical Finishes on Metals	R.D. Slade
• Metal Finishes Sub-Committee	T. Keogh
• Bi-metallic Corrosion	R. May

Plastics Industry Standards

• Plastics for Telecommunication Cables	H.J. Ruddell D.J. Adams
• Methods of Testing Plastics	G. Flatau
• Outdoor Weathering of Plastics	G.W.G. Goode
• Polytetrafluoroethylene	B.A. Chisholm
• Flammability of Plastics	D.J. Adams
• ISOTC 61 Plastics Advisory Committee	B.A. Chisholm H.J. Ruddell
• Safety Helmets	R.J. Boast

Safety Standards

• Industrial Safety Gloves	F.C. Baker
• Steel Wire Rope and Strand	T.J. Keogh

Telecommunications and Electronics Industry Standards

• Capacitors and Resistors	G. Flatau S.J. Charles
• Printed Circuits	D.E. Sheridan
• Wires and Cables	G. Flatau
• Semi-Conductors	I.P. Macfarlane
• Environmental Testing	G. Flatau
• Electro-Acoustics and Recording	E.J. Koop
• Hazards of Non-Ionizing Radiation	S. Sastradipradja

National Association of Testing Authorities (NATA)

Electrical Registration Advisory Committee	E.F. Sandbach J.M. Warner
Assessor for Environmental Testing	G. Flatau
Assessor for Laboratories Engaged in Testing Plastics	B.A. Chisholm
Assessor for Laboratories Engaged in Acoustical Testing	E.J. Koop
Assessor for Laboratories Engaged in Electrical Testing	J.M. Warner E. Pinczower J.B. Erwin

Victorian Post Secondary Education Commission

Engineers Education Committee	H.S. Wragge

International Bodies

The Laboratories participate in the activities of a number of international bodies and committees; these include:

- The International Telegraph and Telephone Consultative Committee (CCITT).
- The International Radio Consultative Committee (CCIR).
- The Australian and New Zealand Association for the Advancement of Science (ANZAAS).
- The Bureau International de l'Heure (BIH)
- The International Electro-Technical Commission (IEC).
- International Organisation for Standardisation (ISO).
- The International Federation of Documentation, Committee for Asia and Oceania (FID/CAO)

In particular, staff of the Research Laboratories held offices as listed in the following International Bodies during the year:

• IEC Joint Co-ordination Group - Optical Fibres, Working Group 4	A.J. Gibbs
• International Confederation for Thermal Analysis	F.C. Baker
• Teletraffic Engineering Training Project TETRAPRO, ITU/ITC	J. Rubas
• Special Rapporteur, CCITT SG XVIII	R. Smith
• IEC Quality Assessment System for Electronic Component Certification Management Committee	G. Flatau
• Special Rapporteur CCITT SG VII/39 (System Description Techniques)	G.J. Dickson
• Special Rapporteur CCITT SG XI/14 (Monitoring and maintenance of No. 7 Signalling Systems)	M. Subocz

INDUSTRIAL PROPERTY

It is a policy of Telecom Australia to protect its interests in any worthwhile industrial property, notably patentable inventions but also registerable designs, which might be generated by its staff in the course of their work. Many of the inventions patented by Telecom Australia have been made by Laboratories' staff, and the staff of the Laboratories also contribute to assessments of the novelty and likely usefulness of new ideas as they arise as possible subjects for patent or similar action. The list below summarises the portfolio of industrial property held by Telecom Australia. The property includes applications for letters patent and registered designs.

Patent Applications and Patents

Invention Title (Inventor/s)	PATENT APPLICATION NUMBERS Provincial Specification	Complete Specification	Patent No. (if granted)	Country
Method and Apparatus for Testing Subscribers' Telephone Instruments in situ under Service Conditions (J.F.M. Bryant & R.W. Kett)		233699	3261926	USA
Self Adaptive Filter and Control Circuit (L.K. Mackechnie)	65671/69	23649/70 98800	448805 3732410	Australia USA
Tip Welding Means (E.J. Bondarenko)	49395/70	10361/70 4714/71	455004 3657512	Australia USA
Analogue Multiplier (H. Bruggemann)	43033/68	43033/68 855543	414207 3629567	Australia USA
Apparatus for Routing Discrete Telecommunication Signals (A. Domjan)	61428/69	19808/70	448958	Australia
Apparatus for Monitoring a Communications System and a Detector Therefor (J.A. Lewis)	PA1474/70	29415/71	458997	Australia
Monostable and Bistable Devices (I.P. Macfarlane)	PA2298/70	32612/71	465242	Australia
Control of Operation of a System (N.W. McLeod)	PA2035/70	31550/71 166819	466670 3745418	Australia USA
Apparatus for Use in Feeding Alternating Electric Current to a Load and an Antenna including such Apparatus (R.P.Tolmie)	PA7174/71	49340/72	484853	Australia
Smoke Detector (L. Gibson & D.R. Packham)	PA9230/72	56513/73 367260	482860 3874795	Australia USA
Method and Apparatus for Detecting the Presence of Signal Components of Pre-determined Frequency in a Multi-frequency Signal (A.D. Proudfoot)	PB24/72	59138/73 387855 178402	480006 3882283 984068	Australia USA Canada
Nephelometer with Laser Source (L. Davidovits)	PC4286/75	20511/76	507518	Australia
Tamperproof Telephone Apparatus (C.M. Hamilton & J.A. MacCaskill)	PC5285/76	23264/77	502780	Australia
Fault Monitoring Apparatus (R.W.A. Ayre)		17251/76	504585	Australia
Optical Waveguides and a Method of Manufacture Therefor (P.V.H. Sabine & P.S. Francis)	PC4499/76	21232/77	507723	Australia
Method and Apparatus for Reducing Phase Jitter in an Electrical Signal (K. Webb)		24926/77	510034	Australia
Programmable Digital Gain Control System for PCM Signals (A.M. Fowler)	PD3192/78	43735/79	519441	Australia
Transversal Filter (K.S. English)	PD7273/79	54367/80 109589/80 00263/80	 4340875 	Australia USA Japan
Fibre Optic Termination (P.V.H. Sabine)	PD6157/78	50841/79 P2938649 G79271195 126329/79 266321	521528	Australia Germany Germany Japan USA

Noise Assessment of PCM Regenerators (A.J. Gibbs)	PD6790/78	52160/79 793025727	525766	Australia Europe (designating: France Germany Britain Italy Holland Switzerland)
		339841 148305/79 093228	1134915 4300233	Canada Japan USA
Tap Coupler for Optical Fibres (E. Johansen & E. Dodge)	PF0272/81	87251/82		Australia
Hydrometer (F. Bodi)	PF1183/81	89297/82		Australia
Apparatus and Method of Cable Hauling (J. Alcorn)	PF5293/82			Australia
Method and Apparatus for Testing Bells and other Electrically Actuated Devices (B. Sneddon)	PF5557/82			Australia
Etching (Z. Slavik)	PF7347/82			Australia

VISITORS TO THE LABORATORIES

The work of the Laboratories often calls for close liaison with various Australian universities and other tertiary institutes and with the research establishments of government departments, statutory authorities and private industry. Reciprocal visits are made by the staff of the Laboratories to these and other establishments for mutual participation in discussions, symposia 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 industry, professional societies, government departments and academia. This is achieved through arranged discussions, inspection tours and demonstrations 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 UN/ITU and Colombo Plan Fellows, whose visit to the Laboratories is a part of a more extensive period of training in Telecom Australia.

Some of the groups and individuals who visited the Laboratories during the year are listed below:

- Dr. N. Blevin, Chairman, National Standards Commission and Chief Standards Scientist, Division of Applied Physics, CSIRO - for discussion of measurement facilities and techniques used across the spectrum of Laboratories' activities
- Dr. E.B. Burton, Principal Scientist, Optical Services Section, and Mr. P. Ciddor, Group Leader, Length Group, National Measurement Laboratory, CSIRO - for discussion and inspection of Laboratories' activities in the field of optical fibres and devices and of the measurement techniques applied in this work
- Delegates attending the Melbourne meetings of Working Parties 3, 4, 5 and 6 of CCITT Study Group XI - for discussion of Laboratories' activities in the field of digital communications techniques, systems and networking standards
- Messrs Wan Xiding and Zhang Taiyuan, Senior Engineers of the PTT of the People's Republic of China - for discussions of planning processes, traffic forecasting and network dimensioning techniques
- Dr. L.T. Chadderton, Emeritus Professor of Physics and Chief of the Division Chemical Physics, CSIRO - for discussion of research in the materials science field, particularly that related to the growth of semiconductor materials and devices by molecular beam epitaxy
- Dr. P. Chorney, Vice-President, Microwave Associates Inc., USA, and Mr. J. Werner, Werner Electronic Industries, Australia - for discussion of developments in microwave technology
- Dr. H. Cookson, Chief Scientist, ITT, USA and Messrs P. Lane and W. Page-Hanify, STC, Australia - for discussion of major research activities and trends in Australian telecommunications
- Mr. H.P. Davids, Teleglobe, Canada - for discussion of major research activities and trends in Australian telecommunications
- Mr. H.A. d'Assumpcao, Chairman, Defence Research Centre, Salisbury, South Australia and a party of research engineers and scientists - for discussion of R&D topics of mutual interest, particularly in the fields of digital communications, radio propagation, digital signal processing and microelectronics
- Professor W.A. Gambling, Optical Communications Department, Southampton University, UK - for discussion of activities related to optical devices and fibres, semiconductor materials and devices and solar cell technology
- Messrs. Y. Higo, K. Shoji and Dr. M. Takahashi, Senior Engineers, NEC, Japan for discussion of optical fibres, devices and relevant developments in telecommunication systems
- Professor I. Ross, Dr. L. Wain and Mr. J. Ritchie, members of the Government Inquiry Team investigating Commonwealth Government Laboratories - for discussion of the functions, working relationships, work programme and research facilities of the Laboratories
- Dr. P.E. Ritt, Vice-President and Director of Research, Dr. E.B. Carne and Dr. W.F. Nelson of GTE Laboratories,USA, and Mr. J.T. Collinson and Mr. R. Cormish of GTE (Australia) - for discussion of R&D activities related to digital networks and services and to the evolution of the ISDN concept
- The Technical Co-operative Programme (TTCP) Panel JPT-12 (Fibre Optic Technology) - for discussion and inspection of activities related to optical fibre devices and techniques, and relevant microelectronics developments in telecommunications
- Mr. V. Mann, Plessey (UK) and Mr. I. Trayling, Plessey (Australia) - for discussion of R&D activities related to digital networks and services and to the evolution of the ISDN concept
- Mr. K. Swaminathan, Director, and Mr. R. Rangarajan, Telecommunications Research Centre, India - for discussion of the role of Telecom's Research Laboratories and major R&D activities
- Mr. H. O'Hara, Vice-President, Intel (USA) and Mr. W. Curt-Hallam, Intel (Australia) - for discussion of microelectronic device developments for telecommunications and computer networks and services
- Mr. H. Inagawa, NEC (Japan) - for discussion of research activities directed at reliability and performance assessment of components and devices
- Dr. C.A. Worrell, Electrical Research Association, UK - for discussion of polymeric materials and their applications to communications plant and equipment.

In addition, the Laboratories hosted visits by other parties from external organisations and academia and from within Telecom Australia for discussions of R&D topics of mutual interest.

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 an annual programme of overseas visits through which members of staff are enabled to interchange experience, technical knowledge, opinions and ideas with research personnel of other organisations. The visits are normally to other telecommunications 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:

R.W.A. Ayre
B.A. Chisholm
R.P. Coutts
S. Dart
G.J. Dickson
B.T. Dingle
N.Q. Duc
G. Flatau
R.K. Flavin
P.H. Frueh
A.J. Gibbs
J.R. Godfrey
R.J. Harris
R.W. Harris
J.L. Park
G.P. Rochlin
H.V. Rodd
J. Rubas
E.F. Sandbach
R. Smith
M. Subocz
P.J. Tyers

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 post-graduate 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 staff have been encouraged to engage in post-graduate studies:

- Dr. P.A. Kirton, Development Training Programme Award, Information Science Institute, University of Southern California, USA
- Dr. G.O. Stone, Development Training Programme Award, McGill University, Montreal, Canada
- Mr. R.G. Addie, full-time Study Leave without pay, Department of Mathematics, Monash University, research studies leading to the Degree of Doctor of Philosophy

The following staff member has been given an award to enable him to pursue full-time undergraduate study:

- Mr. H.A.J. Meijerink, Undergraduate Scholarship, Royal Melbourne Institute of Technology, course for the degree of Bachelor of Computer Science

SPONSORED EXTERNAL RESEARCH AND DEVELOPMENT

Telecom Australia is aware of the external R&D capabilities in telecommunications science and technology which exist in local industry, in academia and in specialised Australian research institutions such as the Commonwealth Scientific and Industrial Research Organization (CSIRO).
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 and the Australian Computer Research Board.

The Research Laboratories act as one channel for the provision of such support by Telecom, in particular, for research studies of telecommunications topics having potential application in the longer term development of the telecommunications network. The Laboratories also contract out development projects in specialised fields to meet an instrumentation or similar technical need which cannot be met from the usual sources of supply.

Current R&D contracts administered by the Laboratories concern the study topics or developmental projects listed below:

- Manufacturing Processes for Optical Fibres and Optical Fibre Cables
- Refractive Index Profiling Techniques for Optical Fibre Preforms
- Transmission Performance of Single and Multi-mode Optical Fibres
- Modulation Characteristics of Laser Diodes
- An Optical Parametric Amplifier
- Equaliser Structures for Optical Systems
- A Speech Level Measurement System
- Bird-proof Windows for Feeder Horns of Microwave Antennas
- Double Pulse Q Switched Ruby Laser Development
- Automated Plating Process for Printed Wiring Board Fabrication
- Correlation between the Physical Properties of Plastics and their Resistance to Termite Attack
- Automated Generation of Chill Codes from Call State Transition Diagrams and Other Pictorial Data
- Fault-tolerant Microcomputer Systems for Telecommunications Applications
- Lidar Sounding of the Troposphere
- Optimal Dimensioning of Circuit Switched Digital Networks
- A Digital Transmission Error Performance Analysis System
- Systems Engineering for a Remote Data Acquisition/Analysis System
- Microwave Solid State Amplifiers for Satellite Communications
- Modelling and Analysis of Electric Field Strength and Noise Distributions in Mobile Radio Communications
- Techniques for Full Duplex Digital Communications on Subscriber Lines
- Electrical Parameters of Lightning Surges Induced in Telephone Lines
- Interference Effects in Digital Radio Systems
- A Remote Controlled Digital Clock
- Gas Exposure and Weathering Chambers
- Bipolar Gate Array Technology
- A Digital Data Store
- Early Indicators of Electrical Deterioration of Polyethylene Spacers in Coaxial Cable
- Techniques for Group Delay and Attenuation Measurement
- Simulation of Numerical Petri Nets using Data-driven Computer Architectures
- Rules for the Production of Speech from Text
- Automated Systems for the Verification of Communications Protocols
- Teleconferencing Diffusion Studies
- A Digital Cross-connect Switch

In addition, the Laboratories occasionally participate in joint projects with other national and international bodies such as the Overseas Telecommunications Commission (Australia), the CSIRO, international standardisation bodies such as the CCITT and CCIR, and overseas telecommunications administrations.

Produced by the Graphic Design Group,
(Headquarters) Telecom Australia.

Photography supplied by the Photographic Section,
(Headquarters) Telecom Australia.

Photoset in Palatino and Helvetica by
The Composing Room, using text supplied electronically
by the Telecom Research Laboratories.

Photograph and Diagram text supplied by
Ultraset (Vic.) Pty. Ltd.

Printed by Valentine Graphics