Volume 35 No. 3 1985

the telecommunication journal of Australia

50th Year Golden Jubilee 1935-1985

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- Batteries for Telecommunications
- Information Networks
- Equipment Reliability
- Ericsson in Australia
- Remote Areas Equipment Accommodation

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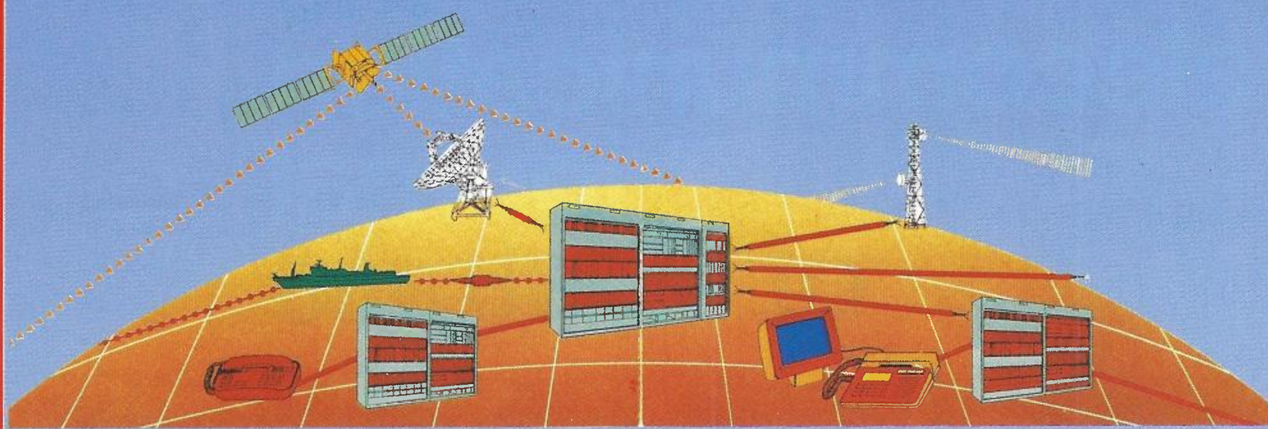
The world of Alcatel Thomson



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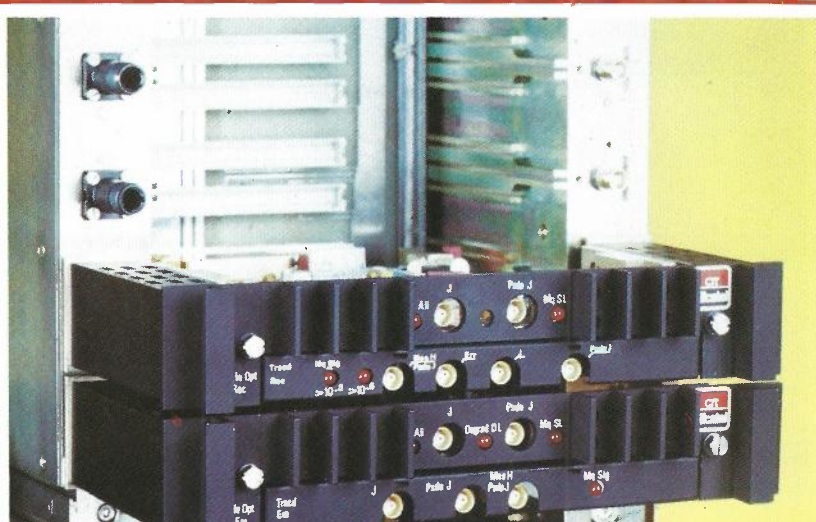

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NEW LOGO FOR TELECOMMUNICATION SOCIETY

The Telecommunication Society of Australia (TSA) is undertaking an extensive review of its operations so as to develop an infrastructure capable of more effectively and efficiently servicing its membership.

As a tangible sign of these changes it has been decided that the TSA needs a new logo and it seeks the assistance of its members in the development of this Logo.

The Council of Control of the Society is sponsoring a competition for the new logo and offering prize money of $200.

Eligibility for entry to the competition is limited to members of the Society.

The new Logo should represent the involvement of the Society in information technology and include within its framework the identity of the Telecommunication Society of Australia.

In preparing entries for the competition, members should understand that the Council of Control is seeking a logo which is flexible in its use. For example, the logo will be used on letterheads, banners and notices to identify activities of the Society. In addition the logo may be used on ties, scarves, cuff links, etc. to enable members to identify with the Society. Further, the logo may be attached to or embodied in special presentations to members and guest lecturers.

All entries to the competition must be in accordance with the Rules and Conditions provided by the Telecommunication Society of Australia in relation to this Logo Design Competition.

RULES AND CONDITIONS FOR ENTRY TO THE TELECOMMUNICATION SOCIETY OF AUSTRALIA LOGO DESIGN COMPETITION

1. THE COMPETITION

1.1 The competition is promoted and sponsored by the Council of Control of the Telecommunication Society of Australia.

1.2 The General Secretary of the Society will be responsible for the receipt of all entries and the forwarding of designs to the Judging Panel.

2. ELIGIBILITY TO ENTER

2.1 The Competition is open to all members of the Telecommunication Society of Australia.

2.2 There are no restrictions on the number of entries which may be made by persons eligible to enter the competition. Entries must, however, be submitted separately in the prescribed manner.

2.3 Individuals who are members of the Council of Control and members of their families, are not eligible to enter this competition.

3. SUBMISSION OF ENTRIES

3.1 Entrants shall submit their designs at their own expense and risk by mailing them to:

The General Secretary (Ian M. Mackechnie)
Telecommunication Society of Australia
Box 4050
GPO MELBOURNE VIC 3001
AUSTRALIA

3.2 Entries postmarked after midnight on Wednesday 31 August 1986 will not be admitted to the competition.

3.3 Designs are to be presented in the form of a coloured drawing on white paper not exceeding 300mm by 210mm and not smaller than 150mm x 105mm. Any suitable means of colouring will be acceptable eg. pencil, water colour, etc.

3.4 Each entry must be submitted on a separate sheet of paper and on the reverse side the name and address of the entrant should be clearly printed.

3.5 An entry will not be accepted if a mark or some other means of signifying the identity of the entrant is included on the design or included on the face of the paper on which the design in submitted.

3.6 A short supporting statement of less than 100 words explaining the design may accompany the entry.

3.7 By entering the competition, all entrants agree to be bound by the rules and conditions of entry.

3.8 The Council of Control as the Promoter of the competition accepts no responsibility for entries which are lost, delayed, mislaid or damaged in the post or posted for delivery insufficiently stamped.

3.9 Entries which are altered, illegible or not in accordance with the rules and conditions of entry may not be accepted; this at the complete discretion of the final Judging Panel.

3.10 The Promoter reserves the right to disqualify, at its absolute discretion, any entry where it is satiisfied that the submitted design is not an original design. Where it is discovered subsequent to the awarding of a prize that a winning design is not an original design, the prize awarded may be forfeited at the complete discretion of the Promoter. Any such forfeited prize money shall be repaid to the Promoter on demand.

3.11 All entries remain the property of the Promoter.

4. THE JUDGING PANEL

4.1 The Judging Panel of the competition shall consist of all members of the Council of Control of the Society in attendance at the time(s), specified for judging to occur.

5. JUDGING PROCEDURES

5.1 The Judging Panel shall decide its own rules as to procedures, quorums etc., to be adopted in carrying out the duties of the Judging Panel, provided such rules are not inconsistent with these rules and conditions of entry.

5.2 Entries will be examined by the Judging Panel for their aesthetic and functional qualities viewed against the spirit and objectives of the competition.

5.3 The Judging Panel may confer with such consultants as it may deem appropriate for the purposes of judging entries to the competition.

5.4 The Judging Panel shall, subject to condition 5.5, select one winning entry in the competition.

5.5 The Judging Panel may decline to declare a winning entry if in its opinion no design entered was of a sufficiently high standard.

5.6 The decision of the Judging Panel in all matters relating to the competition shall be final and binding. No correspondence or discussion will be entered into with any entrant.

5.7 Details of the winning entry will be published in the Telecommunication Journal of Australia and in such other publications as the Promoters determine appropriate for a competition of this nature. The entrants acknowledge that their name may be published in conjunction with this competition at the discretion of the Promotor.

5.8 The winning entrant will be notified by post of the decision of the Judging Panel.

6. PRIZES

6.1 A prize of Two Hundred Dollars will be awarded to the winning entrant as shown on the reverse side of the entry.

6.2 The Promoter, may at its discretion, award such additional awards as the Promoter shall think fit, in addition to that described in condition 6.1 above, if in the opinion of the Judging Panel there are designs entered in the competition other than the winning design which merit an award.

7. OWNERSHIP OF DESIGNS

7.1 Entrants to the competition expressly authorise the promoter to reproduce and use their designs without consideration to the entrants for the purpose of promoting the Telecommunication Society of Australia.

7.2 For the purposes of promoting the Society pursuant to condition 7.1 above, the Promoter reserves the right to reproduce a submitted design including altering or amending the design.

7.3 The entrants acknowledge that if their design is declared to be the competition winner the design shall forthwith become the exclusive property of the Promoter and the entrants acknowledge that the prize money referred to in condition 6.1 above shall be the full consideration for the transfer of all the property rights attaching to the design. The entrants further acknowledge that they shall do all such things and sign such documents as may be necessary to effect the transfer of such rights to the Promoter.

8. LIABILITY AND INDEMNITY

8.1 The Promoter and the Judging Panel shall be under no liability whatsoever for any loss, damage or injury to an entrant arising out of the entry of a design in the competition or the subsequent promotion of the design.

8.2 Each entrant shall indemnify the Promoter and the Judging Panel against all claims, actions and proceeding whatsoever which may be brought jointly or severally against the Promoter or the Judging Panel arising out of the entry of a design in the competition or the subsequent use of the design in the promotion of the Telecommunication Society of Australia.

THE TELECOMMUNICATION JOURNAL OF AUSTRALIA

ISN 0040 2486

Volume 35 No. 3 1985

50th Year Golden Jubilee 1935-1985

Cable Ploughing Tractor in action, ploughing in an optical fibre cable.

CONTENTS

OTHER ITEMS

Editorial

Chairman, Telecom Australia
R. W. BRACK

The tenth anniversary of Telecom Australia as a statutory corporation is an appropriate occasion to reflect on the developments of the past ten years as well as to consider the challenges and opportunities that lie ahead.

A heightened community awareness of the importance of efficient telecommunications service to the development of the Australian economy is perhaps the most important single factor which has impacted on our activities. With it has come a flowering of digital technology, and the convergence of computers and communications to produce an increasing range of new services.

Telecom has responded strongly to this challenging environment and we can be proud of our achievements in the first ten years of our operation.

Taking the price of our service as the bottom line indicator of our performance, our tariff index has remained a good five per cent below the CPI. In other words, our prices have reduced significantly in real terms.

If we consider staff per line as a measure of efficiency, we have seen an increase of 75 percent in network size with a three percent increase in staff and dramatic improvement in the speed of new service provision with average lead times falling from six to eight weeks in 1975 to less than ten days now. We have also introduced a vastly increased range of services including AUSTPAC, the digital data service. VIATEL, mobile telephony, the OO8 service, the Commander small business system and the Computerphone to name a few.

Financially, we are earning 11 per cent before interest on funds employed in the business and contributing to the Government some $600 million in interest payments, whereas in 1975 the telecommunications activities of the PMG Department were a charge of $255 million on the budget.

We are close to completing the task of making available to every Australian who wishes it a telephone service of world standard at an affordable price. This massive social responsibility has been made possible not only by our efficiency in operating profitably but is also facilitated by technological initiatives unique to Telecom Australia. We have applied solar power and digital radio techniques to remote area telecommunication systems in a way which has established us as a leader in the world in this field. By 1990 every part of Australia will be serviced with modern telecommunications infrastructure.

Looking to the future, there are two important aspects on which I would like to comment.

It is clear that if Australia is to continue to enjoy world class telecommunications services, and as an essential prerequisite, we are to keep up with and exploit the latest technological developments in our network, the responsibility for developing and operating the national infrastructure and services must remain with Telecom. By world standards we are not a large enterprise. We have six million customers and a huge continent to serve. British Telecom has 20 million customers and the Japanese NTT 40 million customers, whilst the smallest Bell regional operating company has ten million customers. These are the companies against which our performance is measured.

In addition to providing service, we have a commitment to foster the development of Australian research, development and manufacture in the area of telecommunications technology and systems. With an annual purchase of some $1,300 million from industry, 90 per cent of which is spent with local firms, Telecom is well placed to continue and develop its long standing policy of fostering in Australia a vital telecommunications industry.

Technologically, we have continued to build in the past ten years on the world reputation earned by the PMG Department for wise and timely technological judgment and new system integration. We are well advanced in the conversion of the network to digital operation with computer control of switching centres and with a massive national programme of optical fibre and digital transmission. The forthcoming introduction of a small digital rural exchange incorporating AXE switching technology is yet another example of Telecom's innovative skills and will further enchance our standing internationally. We face the challenge to derive from the new infrastructure an increasing range of modern value added services, thus allowing Australians in all walks of life to share in the opportunities of the information society.

Finally, as we look forward to the next ten years of challenge and opportunities, I would like to congratulate the Telecommunications Journal of Australia for being such an effective and high quality journal of record of the achievements and innovations of telecommunications in Australia. The Journal provides the means by which all in Telecom Australia and the telecommunications industry can keep up to date with the extensive range of new developments in our industry.

Every member of Telecom has just cause to be proud of the achievements of our first ten years and I am confident that the technological and service challenges that we face in the next ten years will be met and mastered with the same vigour and commitment.

Cable Design and Installation Technique for Direct Buried Non-Metallic Optical Cables

B.T. de BOER
R.W.A. AYRE
R.B. SCHUSTER

The use of non-metallic optical fibre cables for long-haul and rural routes has significant advantages in relation to lightning-induced damage, and on routes affected by power line proximity or other electromagnetic interference. The preferred installation technique for such cables is direct burial using cable ploughing techniques; however a number of difficulties were observed which were not previously encountered with traditional metallic cables. Detailed experiments and field trials were undertaken using sensitive fibre strain measurement equipment, and the parameters of suitable cable designs and installation equipment were estabished. As a result of successful developments in this area, Telecom Australia has standardised on non-metallic filled optical cables for all rural and long distance optical fibre installations.

INTRODUCTION

Like many other Telecommunication Administrations, Telecom Australia is faced with substantial demand for increased digital capacity in its long-haul trunk and rural networks. Single-mode fibre systems have now been established as a cost effective alternative to both coaxial cable and radio systems for these applications, and substantial trans-continental optical fibre links are now planned by Telecom Australia. **(Fig. 1)**.

The use of optical transmission also offers the possibility of a completely metal-free cable that is immune from lightning-induced damage. This is an important consideration over much of the Australian continent, as is the flexibility in route design offered by a cable not subjected to power induction and noise problems associated with power transmission lines. The installation of non-metallic optical fibre cables does however present some problems when compared to the techniques used for their traditional metal conterparts. In rural Australia, as in many other countries, cable ploughing techniques have been established as the most attractive method of installing long-distance directly buried cables. In general however, cable ploughing equipment and techniques have been developed with robust metal cables in mind, and their suitability with the smaller, lighter and more fragile optical cables requires detailed assessment.

CABLE INSTALLATION TRIALS

The use of conventional cable ploughing equipment and techniques designed for metal cables could impose excessive tensions on optical cables which in turn could lead to excessive short and/or long term strain levels in the fibres. Optical fibres are proof tested during manufacture to strain levels of typically 0.5% to 0.8% and may fail instantaneously if exposed to strain levels in excess of the proof-test value. A more insidious problem also arises, in that optical fibres within a cable are susceptible to failure through static fatigue if they are subjected to even small strain levels over a long period of time. **(ref. 1.)**

Whilst cables with extra strengthening materials and metal sheaths have proved successful for such applications, these items add to the cable cost and negate the attractive non-metallic features of the optical fibres themselves.

A series of trials was therefore conducted covering a range of non-metallic cable designs and using a variety of cable ploughing equipment. The elongation of fibres within each of the cables was continuously monitored during the cable installation period, together with a number of other parameters. The results were then interpreted in terms of the variations in cable structural features and differences in the type of cable ploughing equipment used.

Measurement System: The theoretical basis for the measurement system has been established by other authors. The elongation of an optical fibre can be determined from the change in the propagation time of an optical signal along a fibre. Methods employing phase-delay measurements with sine-wave modulated optical sources (references 2-4), and time delay measurements with pulse modulated sources (references 5-7) have been reported. Due to features of the experimental technique employed, it was found that greater resolution of fibre elongation was achieved with the phase-delay method.

The measurement system (reference 8) is illustrated in **Fig. 2.** A loop is formed by splicing two fibres in the cable at the far end (i.e. on the cable drum). A laser diode produces an optical signal which is coupled to one of the fibres. The optical signal is modulated at 200 MHz by a signal from a frequency synthesiser. The returning signal on the second fibre is detected by an avalanche photodiode, and a vector voltmeter measures the phase difference between the transmitted and received signals

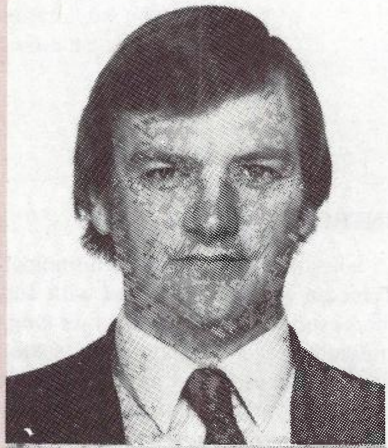
The equipment thus described is capable of measuring the fibre elongation relative to its initial state. In order to determine the strain corresponding to this elongation, it is necessary to know the length of cable installed. This was measured by a follower wheel mounted on the cable plough. As each extra metre of cable was ploughed, a data word, representing the cumulative installed length, is relayed by radio from the tractor to the measurement station and entered into the calculator's data record. The stored results can be used to generate a number of records, such as fibre elongation and strain of either residual (steady-state) or transient nature, changes in attenuation, length of cable installed at various times, and cable ploughing speed. In addition, a real-time plot of average strain against length of cable installed can be displayed so that the installation progress can be monitored and installation techniques modified if necessary.

Cables Installed in Trials: Six different cable structures were used in two series of trials in an attempt to establish the effect of cable design parameters on the installation process. The cable structures are shown in **Fig. 3** and brief details are as follows:

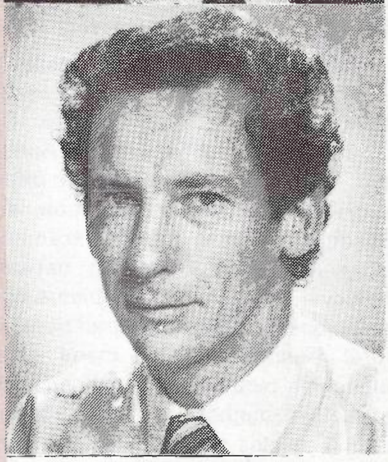
A: Loose tube structure with fibre reinforced plastic (FRP) central strength member and kevlar peripheral strengthening.

B: Tight stranded structure with six nylon jacketed fibres (0.9mm) and six dummy fillers around a FRP strength member.

C: Spacer-type cable with six nylon jacketed fibres laid loosely in plastic channels between spacers. FRP strength member.



Bob de Boer is currently head of the External Plant Inter-Exchange Networks Branch at Telecom Australia. He joined Telecom Australia in 1972 after graduating in Electrical Engineering from Monash University in Victoria. He has has extensive experience in areas of telecommunications cable design, specifications and provisioning, as well as in the installation of External Plant. He currently has Headquarters responsibility for all external plant aspects of optical fibre systems within Telecom Australia.



Robert W.A. Ayre received the BS degree in Electronics from the George Washington University, Washington DC in 1967, and the BE and M.E.Sc. degrees from Monash University, Melbourne in 1970 and 1972 respectively. In 1972 he joined the Research Laboratories of Telecom Australia, initially working on video signal processing techniques and transmission systems. Since 1977 he has been working on optical transmission systems and optical fibre measurement techniques. He is currently Head, Optical Systems Section, Telecom Australia Research Laboratories, Melbourne, Australia.

Richard Schuster joined Telecom in 1982 after graduating from the University of Queensland. He has had substantial experience in external plant installation activities associated with cable ploughing equipment and procedures.

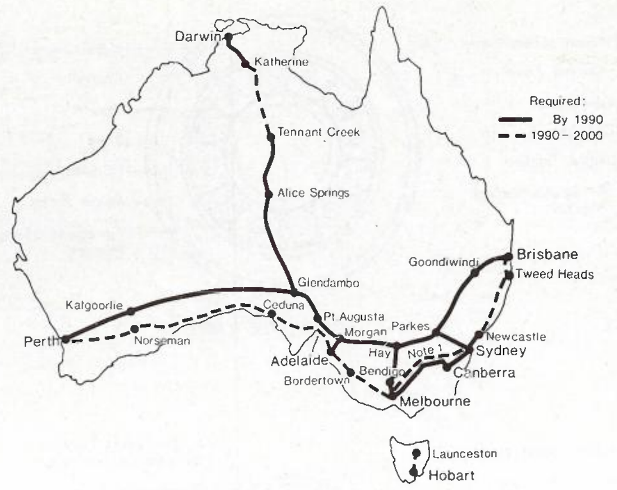


Fig. 1. Optical Fibre Cable Implementation in the Australian Inter-Capital Trunk Network.

D: Integral type cable with fibres housed in closed slots within a polyethylene cartwheel-like structure. FRP strength member.

E: Slotted core structure with FRP strength member.

F: Grooved spacer type cable with FRP strength member.

Most of the cables used on the trials contained filling compounds. All cables were fitted with an additional nylon outer jacket which is traditional in Australia for protection against ants and termites.

Cable Ploughing Equipment: Trials were conducted using various systems and modifications on existing cable ploughing tractors (typically Caterpillar D9 type) to reduce tensions on cables during installation.

The modifications included:

- Additional tension operated drive capstan at the top of the cable plough box.
- Hydraulic cable drum braking system.
- Automatic Catenary controlled cable drum drive system.
- Teflon lining within the cable plough box.

RESULTS OF FIELD TRIAL

The field trials demonstrated that optical cables with only minimal strength design can be successfully installed using modified cable ploughing equipment without introducing strain levels that might prejudice the fibre lifetime. Two significant cable design features were identified in the trial:

(a) Cables in which fibres are housed loosely, and which may include some small excess fibre length, provide a degree of protection against transient strains.

(b) Cables with high flexibility can be installed with smaller residual strain levels than stiffer cables.

With regard to installation equipment, conventional ploughing equipment was found to be less than suitable particularly with cables that did not meet the above criteria. Whilst large residual strains were almost totally attributed to the cable parameters of flexibility and strength, transient strains were heavily dependent on the ploughing equipment. **Fig. 4** shows the elongation of the spacer-type cable (Figure 3C) plotted against the corresponding length of cable installed. This cable showed the highest residual elongation totalling approximately 600 mm over the 920 metres of cable installed. The observed elongation is considered to arise as a result of the tension required to pull the cable around the 90 degree bend at the lower end of the cable plough-box. This cable was quite stiff and radial reaction forces are produced at points where the cable makes contact with the guiding surfaces of the plough-box. These in turn cause friction forces to act on the moving cable at these

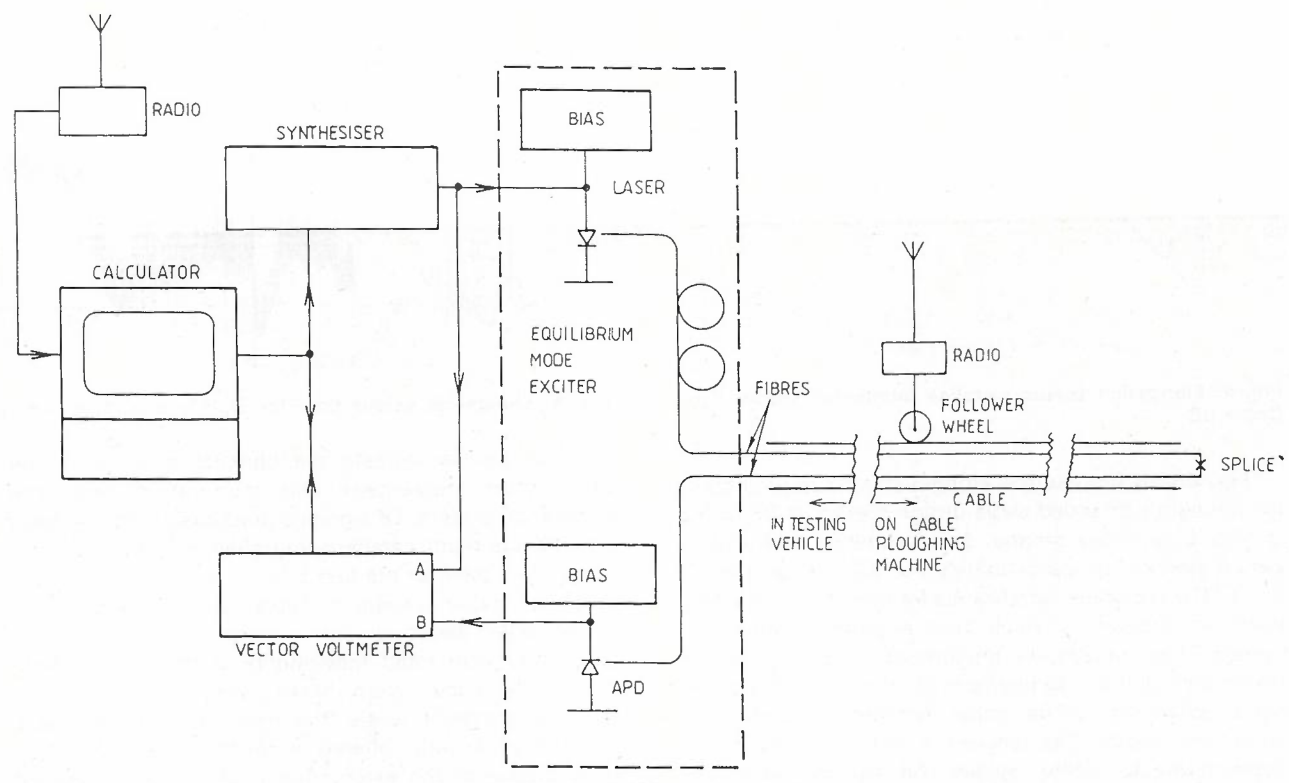


Fig. 2 Fibre Strain Measurement System

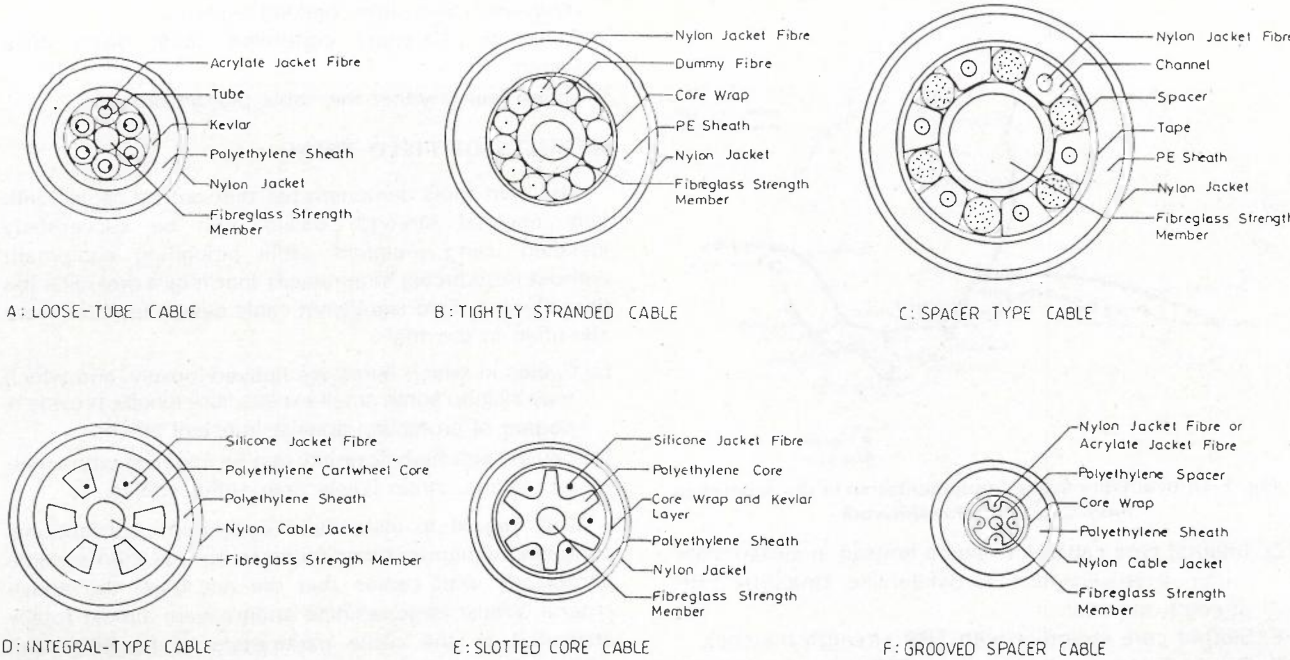


Fig. 3. Cables Installed in Field Trials.

points of contact, and in overcoming the friction forces, the cable is left with a residual tension. The use of a more flexible cable, or a plough box with increased radius of curvature, would allow the cable to be placed at a lower tension, and hence a lower strain level. Alternatively additional cable strengthening could be used.

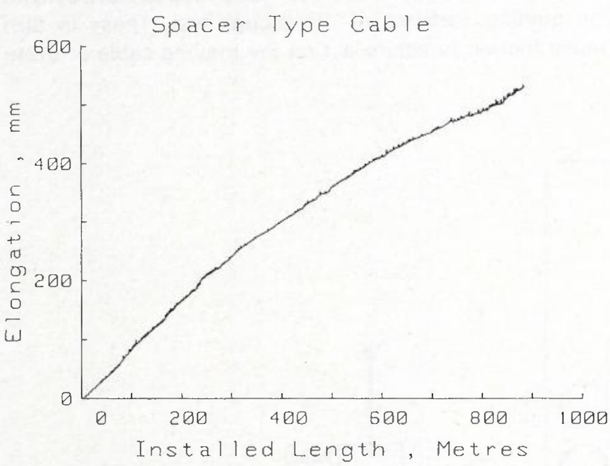


Fig. 4. Elongation versus installed length for Spacer Type Cable 3C

Fig. 5 and 6 show the elongation versus time curve for the tightly stranded cable design shown as 3B in Fig. 3. Fig. 6 provides greater detail showing a 2 minute period starting at approximately the 20 minute mark of Fig. 5. The feature of significance for this cable is the high transient elongations which show as peaks at regular intervals. The installation equipment in this particular experiment did not use any form of drum drive. The peaks occur as tension in the cable increases, and diminish when the tension has reached a level that causes the cable drum to rotate, spilling off excess cable. The elongation values plotted occur basically over the short distance between cable drum and plough box and are values averaged over 2 second measurement intervals. The actual instantaneous elongation values would therefore be higher than those indicated and correspond to a transient strain of up to approximately 0.5%

As this level is close to the proof-test level, some action to reduce the transient strain is necessary.

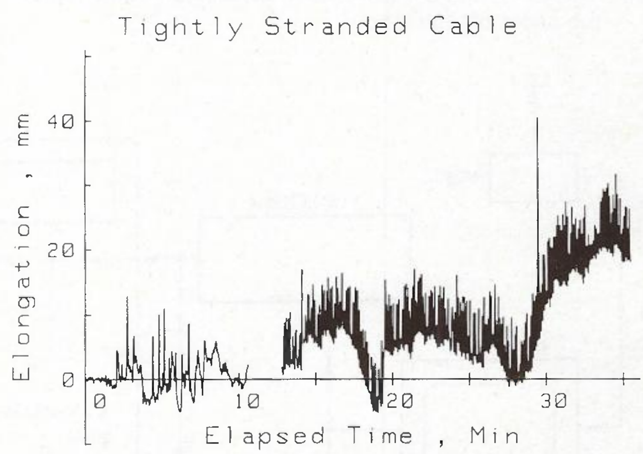


Fig. 5. Elongation versus time for Tightly Stranded Cable

These results indicate the benefits of isolating the cable drum movement and momentum from the installation system. Of significant success in this respect was the automatic catenary controlled drum drive system which was used for the first time in these trials. The use of a reasonable amount of cable slack in the catenary would also assist in diminishing any other effect associated with rapid movements in the tractor itself. Whilst the cable drum brake was of assistance in reducing transient levels, the new catenary controlled drum drive system offered a further improvement in performance to the extent that it effectively concealed any differences in the behaviour of individual designs.

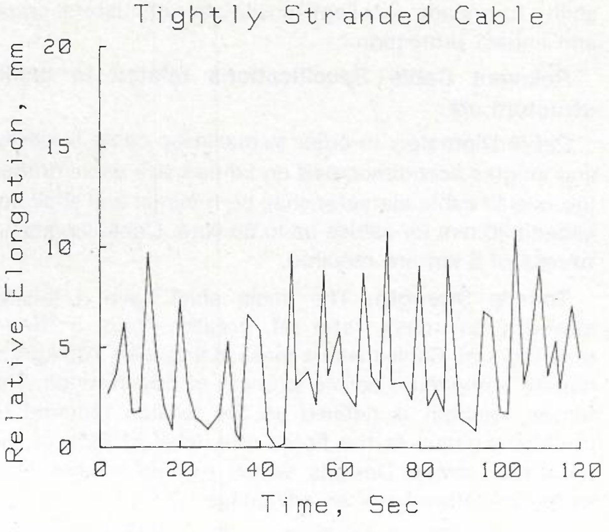


Fig. 6. Expansion of the Figure 5 plot over a two minute interval.

MODIFIED CABLE INSTALLATION EQUIPMENT

The aims in selecting and developing installation equipment were specifically directed towards absolute strain free installation, should this be possible, rather than accepting small strain values, either long-term or transient. As a result of the trials, and with the above aim in mind, the automatic catenary controlled drum drive equipment was chosen as standard equipment for optical fibre cable installation.

Cable Feed Control System

The cable drum driving system that was developed monitors cable demand and then adjusts the speed and direction of rotation of the cable drum so that a constant slack loop of cable is always maintained. The overall configuration of the cable feed control system is shown in Figure 7.

The basic function of the slack catenary loop of cable is to decouple the cable already in the ground and flowing through the cable plough box from the high inertia of the cable drum. The sag in the cable catenary is sensed by a spring-tensioned sensing arm attached to a rotary position transducer which indicates the position of the cable loop. Any deflection of the sensing arm from its normal operating angle results in a signal which causes the electro-hydraulic drum drive to either pay out or wind in cable in order to return the sensing arm to its 'normal' angle, and thus maintain the desired sag in the slack loop.

The cable drum, preferably a steel drum, is driven on both flanges via vulcanised rubber wheels. Firm contact between drive wheels and flanges is ensured by two hydraulic cylinders housed within the cable drum carry arms. The control system offers excellent response time between sensing arm deflection and cable payout or wind in. Drum acceleration from 0 to 6 KPH (tractor speed) is possible in only 0.1 seconds through use of the following components:

- A pressure compensated, axial piston pump which is driven off the tractor PTO (Power-Take Off).

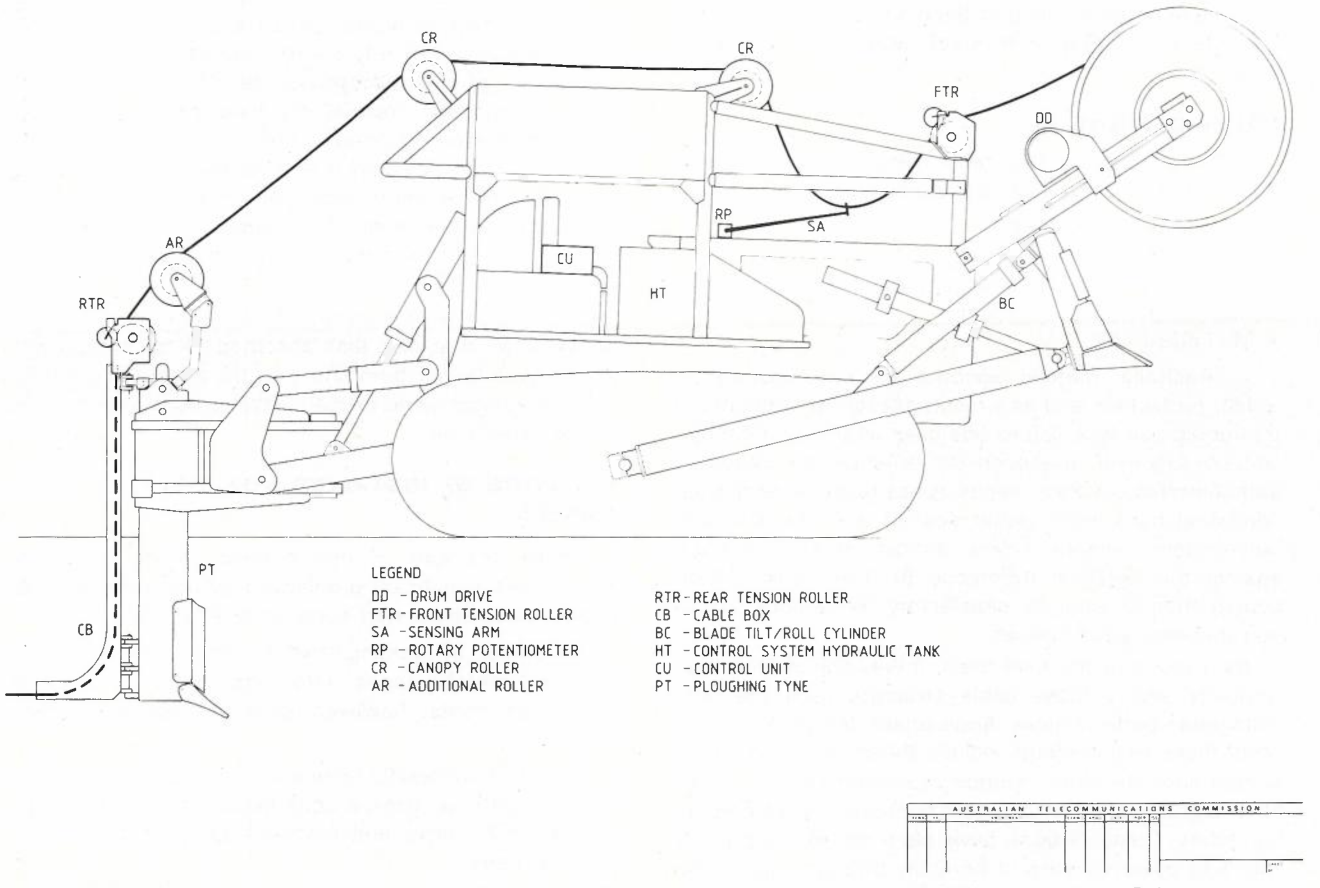


Fig. 7. Schematic Diagram of Modified Cable Ploughing Tractor with Automatic Catenary Drum Drive.

- Two high-torque, low speed radial piston motors which rotate the vulcanised rubber drive wheels and thus the cable drum.
- Solenoid operated servo valves mounted directly onto the motor ports. Full hydraulic system pressure is applied to these valves during the cable feed operation, ensuring the fastest possible response of the motors to input control signals.

Overall, this arrangement yields the quickest possible motor reaction to movement of the sensing arm.

The control system has other secondary features:

i. The operator can manually override the system. This is necessary for initial set-up of the cable drum and feeding of the cable through the apparatus.

ii. Tractor autostop. Should the control system malfunction, the tractor transmission is automatically shifted into neutral and the brakes are applied before excessive tension can be applied to the cable.

Other Tractor Modifications: Several other components mounted onto the tractor contribute toward mimimised tension during ploughing of cable:

a. The cable drum is mounted on a hollow spindle rotating on sealed roller bearings.

b. Hydraulically driven rollers in the cable path at the front and rear of the tractor assist the passage of the cable into the plough box. These roller motors develop only a very small torque and are easily stalled. Their overall effect is to keep unwanted slack out of the cable on the tractor, and to balance frictional drag in the feeding path.

c. Stainless steel is used to line the plough box. The expense of teflon lining of the plough box, and the difficulty in securing it to steel, was found not to be warranted.

CABLE DESIGNS

The requirements of a cable design for use in direct buried long distance and rural applications were set as:

- Non-metallic and filled.
- At least 5 km drumlengths.
- Able to be installed by cable ploughing techniques.
- Appropriate crush resistance.
- Minimised cost.

In Australia, metallic sheaths are not required for rodent protection, and as a result the standard sheath on traditional pair type cables has been all plastic. Of major concern however, has been the potential for attack by ants, termites or other insects. It has been found that an additional hard nylon jacket applied over the standard polyethylene sheath offers almost total protection against this problem (reference 9). This same sheath construction is seen as satisfactory for directly buried non-metallic optical cables.

As a result of the field trials, it was shown that high flexibility and a loose cable structure gave the best installation performances. Appropriate designs known to meet these requirements include those based on single slotted core concepts (multiple fibres per slot for higher fibre counts) or loose tube constructions (multiple fibres per tube). These designs have been shown to provide excellent characteristics of flexibility through small cable diameter (ie. high fibre packing densities) and have the ability to provide excellent tensile strength, lateral crush and impact protection.

Relevant Cable Specifications related to cable structure are:

Cable Diameter: In order to maximise cable flexibility and lengths accommodated on limited size cable drums, the overall cable diameter shall be minimal and shall not exceed 20 mm for cables up to 60 fibre. Cable lengths in excess of 5 km are required.

Tensile Strength: The cable shall have a tensile strength to mass ratio of greater than 5 Newtons/(kg/km). Cables with a mass of less than 100 kg/km require a minimum tensile strength of 500 Newton. The tensile strength is defined as the tension required to produce a strain in the fibres at a level of 30% of the proof-test strain. Designs which include excess fibre length therefore have an advantage.

Minimum Bending Radius: The cables shall be capable of meeting the following minimum bending radius requirements without experiencing cable or fibre damage or attenuation increase:

- 10 times cable diameter at no load
- 20 times cable diameter at maximum tensile strength.

Crush Resistance: Cables must be capable of withstanding a long-term crushing force (i.e. Statically applied lateral laod) of at least 10 KN/m, and a short term (1 minute) crushing force of at least 20 KN/m without experiencing fibre damage or attentuation increase.

Filling Compound Barrier:

One aspect, which is still under evaluation, is the inclusion of an all-plastic barrier material between the cable core and the cable sheath to prevent absorption by the sheath of oils and other materials contained in the filling compounds. Several materials show promise for this application through their properties of low permeability to oils, and it is proposed that appropriate laminated plastic tapes made from these materials would be bonded to the inside of the polyethylene sheath in a similar way to existing aluminium moisture barrier laminates.

The requirement for these filling compound barriers arises from concerns that absorbed filling compounds may have a longer term effect on the sheath of the non-metallic optical cable or may leave voids or water paths in the cable core.

LOCATION OF INSTALLED NON-METALLIC CABLES

Whilst the use of non-metallic cables will have advantages, significant problems may occur when these cables must be located some time after installation.

A number of locating systems have been examined including metallic tapes, wires and cables layed above the optical cable; however none of these has proved satisfactory.

The most successful technique, which will be used on early intallations, uses a combination of marker posts, buried plastic tape, and electronically detectable transponder pegs.

The highly extendable, non-metallic plastic tape is simultaneously plouged in about 500mm above the cable. The tape has warning markings, and is designed to attract the attention of anyone digging above the cable.

A marker post system will also be used. Each post will include a sign denoting optical fibre cable, as well as an accurate, permanent sketch plan showing the cable alignment in relation to the post. The sketch is made just after the tractor passes the post location.

In addition, relocatable passive transponder pegs will be buried above the cable at significant changes of direction, and at pre-determined spacings. The pegs can be accurately located to within 50mm, using a special detector.

It is expected that this combination of systems will ensure that the cable is adequately marked and protected, and able to be accurately located after installation.

CONCLUSION

In countries or areas where metallic cable sheaths are not required for mechanical or rodent protection reasons, non-metallic optical fibre cables can offer significant advantages in relation to lightning damage and on routes affected by electromagnetic induction problems. The costs of these cables could however become excessive if high tensile strengthening elements must be incorporated into the cable designs to cope with the rigours of installation.

As a result of an extensive set of field trials, Telecom Australia has developed cable specifications and installation equipment which will allow low cost non-metallic cables to be installed successfully, and specifically without residual fibre strain. An extensive program of installation of such cables is now underway and will extend well into the 1990s.

ACKNOWLEDGEMENTS

Many people rendered valuable assistance in the design and conduct of the experiments and trials and their help is gratefully acknowledged. Special acknowledgement is given to the staff of the Optical Systems Section of the Telecom Research Laboratories and to staff in the Queensland Automotive Plant Section.

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Information Transfer News

TELECOM SETS UP SPECIAL OFFICE TO HELP AUSTRALIAN MANUFACTURERS

Telecom has opened a Technical Liaison Office to provide Australian companies with technical information to assist in the development and manufacture of new telecommunications products.

Mr Bob McKinnon, Telecom's General Manager, Network Engineering, said "We want to encourage more Australian research and development. Not only do we need new products for our own network, we would also like to see Australians exporting the latest in telecommunications technology."

"Telecommunications technology is advancing rapidly and becoming more complex," Mr McKinnon said. "We need to help companies identify opportunities, be aware of relevant standards and specifications and have the chance to develop Telecom designs and industrial properties."

The Technical Liasison Office will be at Telecom's national headquarters:-

3rd Floor, 172 William Street, Melbourne

Contact: Mr Tim Gurrie for general enquiries. Telephone: (03) 606 5068.

Contact: Mr Jeff Levers for technical enquiries. Telephone: (03) 606 6806.

Its service will include

* Assistance in the interpretation of information, such as tracing Telecom specifications back to CCITT, CCIR and Australian Standards.
* Provision to industry of information about the telecommunications network and the standards to which it operates.
* Arranging seminars for industry on developments in the composition and character of the national and international network.
* Advice to industry when opportunities arise for Telecom designs or industrial property to be commercially exploited.
* A directory service for smaller Australian manufacturers who may have products to offer Telecom but may not be aware of how to access the Telecom purchasing system.

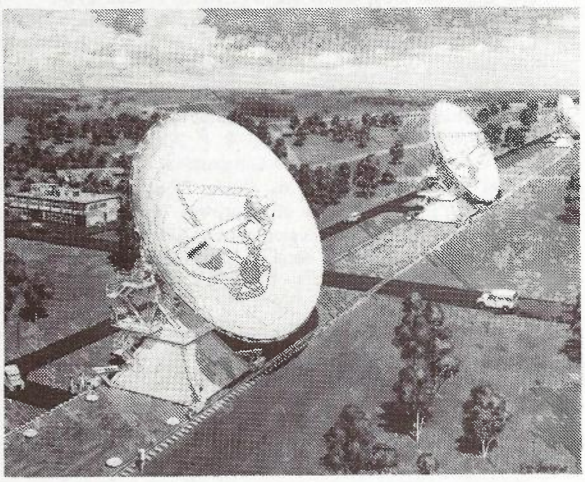
Local Firms Play Key Role in Australia Telescope

The excitement generated by Halley's Comet is focussing attention on the next major event in Australian astronomy — the construction of the Australia Telescope.

Scheduled for completion in 1988, the $32 million Australia Telescope is claimed to be the most versatile radio telescope in the world and its design breaks new ground in telescope manufacture.

Over 80 per cent of this innovative telescope will be manufactured in Australia by Australian companies, a significant vote of confidence in the local electronics and communications industries, according to Mr. G. (Bill) Page-Hanify, chief exective of the Australian Electronics Industry Association (AIEA).

Australia Telescope will not be a single telescope as such, but rather an array of telescopes or antennas, which can operate as one to simulate a telescope as large as the distance between the furthest antennas — 300 kilometres.



Map showing the layout of the Australia Telescope antennas, including the new ones to be built at Culgoora and Siding Spring and the existing 64m antenna at Parkes.

It will comprise six new moveable antennas, each 22 metres in diameter, at Culgoora near Narrabri, a new fixed 22 metre diameter antenna at Siding Spring Mountain near Coonabarabran and the existing 64 metre diameter telescope at Parkes.

The seven new antennas are the key elements of the Australia Telescope and represent about half its capital cost.

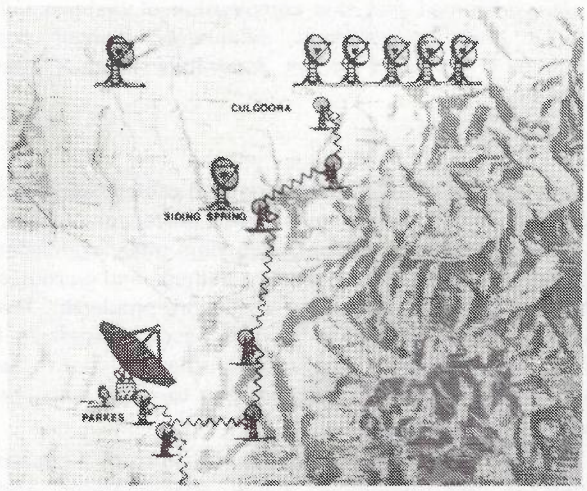
The $15 million contract to build these antennas has been awarded to local company Evans Deakin Industries, which in turn has sub-contracted other local companies.

They are working to designs conceived by the CSIRO's Division of Radiophysics.

The Australia Telescope is intended to provide Australian scientists with an advanced tool to use in the 1990s and beyond.

Radio astronomy — the study of the Universe by radio waves — has a history of discovering surprising new classes of celestial objects. Quasars, the explosive cores of young galaxies, and pulsars, incredibly condensed spinnning, dying stars, are two such notable examples.

Australian astronomists have been at the forefront of these discoveries. The Parkes telescope, for example, identified the first known quasar and has identified more pulsars than any other telescope.



Artist's impression of the compact array of antennas which will form part of the Australia Telescope at Culgoora, NSW.

The Australia Telescope is expected to play a significant role in the exploration of the galaxy — the nature of the nucleus, the birth of stars, the debris of exploded stars and other phenomena.

One of the greatest advantages will be the quality of its images. In the past, radio telescopes have suffered from their inability to match the resolution of optical telescopes. The Australia Telescope's resolution, however, will be 50 times greater than that of ground-based optical telescopes.

The special design of the Australia Telescope — with the new antenna array at Culgoora and the long baseline linking the Culgoora and Siding Springs antennas with Parkes — will also give the Parkes telescope a new lease of life.

In the ordinary course of events, the usefulness of the Parkes telescope would be rapidly diminishing each year, as the direction of astronomical research changes from discovering new objects to learning what makes them tick.

This change has led to the need for telescopes that are not only capable of detecting vanishing small quantities of radio energy — called seeing "faintly" — but of discerning fine detail in those faint objects described as seeing "finely".

The Australia Telescope will be able to do both — the long baseline incorporating Parkes will see "faintly" and the compact array at Culgoora will see "finely".

Communications Equipment Accommodation in Remote Areas

A. J. WISHART

The range of transportable and small fixed buildings in use in rural and remote areas in Australia and their thermal characteristics are described in this paper. Many of those buildings have been designed to varying degrees with features to promote the natural transfer of heat from the equipment room to its surroundings and to limit the room temperature rise to an acceptable level. Heat dissipation from digital type equipment of about 0.5 to 5 kW is becoming the norm whereas in the past the room heat loads with analogue equipment have not exceeded about 1.8 kW. The need for a more detailed knowledge of passive heat transfer mechanisms to economically accommodate the larger heat loads is evident. Developments in that area are discussed.

Introduction

The telecommunications network covering the large Australian continent spans many thousands of kilometres. Capital cities and major towns are spread up to 1500 km apart. The network links those cities, towns and the south-eastern coastal regions which have the majority of settlement. Broadband radio replay and coaxial cable links replaced open wire systems many years ago but are still reaching into remote locations to provide new or improved services to subscribers. Complete encirclement of the continent by the broadband network is imminent. The network will soon be complemented with single mode optical fibre cable links which will ultimately span the length and breadth of Australia.

Many of those links must pass through remote and desolate regions which harbour harsh environments where no reliable commercial power supply exists. Climatic conditions in those regions cover the extremes in temperature, humidity, wind, dust, rainfall, sunshine and radiation intensity as well as small diurnal variations concurrent with high temperatures and considerable periods of calm.

On-site primary power generation is therefore a necessity.[1] Operating transmission equipment located in those areas should not wherever possible be dependent on mechanical cooling plant so that the cost of on-site power generation can be kept to a minimum. Telecom Australia is consequently keen to use passively cooled or low energy consuming buildings in remote areas. Similarly, on-site construction costs in remote areas are usually prohibitive so functional transportable or at least prefabricated building designs must be conceived.

This paper describes the range of unattended transportable and small fixed buildings in use in Australia and their thermal characteristics. In many cases, innovative designs have been created to ensure that the reliability of the equipment room environment is better than that of the equipment it protects.

Transportable Equipment Accommodation In Australia

Early Developments

The widespread use of unattended transportable buildings commenced around 1950 when rural automatic exchanges, RAXs, were first installed to serve the needs of country subscribers. RAXs were basically designed for structural integrity to survive transportation over rough roads. There was a minimal need for environmental control for the step-by-step equipment installed in RAXs.

The advent of the cross-bar switching system and the development of the ARK 511 (90 line) and ARK 521 (400 and 800 line) exchanges in the early 1960s brought about the development of transportable ARK buildings. The original ARK building type was designed to provide a satisfactory environment for the essentially traffic dependent heat load of cross-bar equipment even in the hotter parts of Australia. The buildings have well insulated walls and roofs to block solar radiation heat gain and originally had a sheet steel floor as the main area to release heat during the cooler night-time period. Their overall heat transmission or U-value is around 0.7 W/m^2 °C.

As the network grew during the 1960's and 1970's, the ARK type building was put to many other uses including housing of additional equipment such as multi-channel carrier which has a generally continuous heat dissipation. The thermally thin floor was covered by 20 mm thick timber to facilitate the fixing of ironwork to the floor and caused a degradation of the thermal performance of the original ARK building.

However, variations such as the provision of thermally thin surfaces tended to improve their performance. Some buildings are fitted with sun shade panels and have an uninsulated sheet steel south facing wall. Others are built with an uninsulated sheet metal ceiling protected by an insulated safari roof between which there is free air movement.

Early ARKs were timber framed. Insulated steel or aluminium framed construction became popular in the 1970s and raised the overall U-value to around 2.3 to 3.3 W/m² °C. This has some benefit in reducing internal temperature rises to under 5°C above outside ambient for light coloured buildings housing up to 40 W/m² floor area.

Buildings For Rural and Remote Areas

Many specially designed transportable and small fixed buildings have been produced to satisfy the particular requirements of the installed equipment, usually performing non-switching tasks such as radio and long line transmission and TV translation.

Those buildings generally fall into two classes — thermally thin light-weight construction or heavy-weight construction with high thermal inertia. There are some 280 thermally thin buildings currently in use apart from many thin walled ARK types. Of the heavy-weight type buildings, some 150 are small permanent types and over 200 are underground shelters.

Both classes of building have been in use in Australia for at least 15 years and have effectively served the equipment they protect. This has been achieved by the passive heat transfer paths being inherent in the building structure.

Remote Area Design Day Conditions

The room temperature upper limit for reliable operation of communications equipment is the most important parameter in the design of passively cooled buildings. That temperature limit determines the type and size of building required in conjunction with the maximum outside shade temperature likely to be experienced.

Electro-mechanical switching equipment in use by Telecom Australia is designed to operate in an ambient room temperature up to 45°C measured 1.5m above floor level and 0.5m from the equipment. Both broadband radio repeater and modern line transmission equipment have an upper operating limit of 50°C. At a limit of 55°C the equipment is to remain operational without suffering permanent damage or permanent degradation of performance.

The maximum design day condition used for most outback regions is based on climatic records. They indicate that the design maximum outside shade temperature is 50°C concident with the maximum solar load and a breeze of 8 km/hr. Lower design day temperatures are of course used to suit other regions where appropriate. At 45°C the breeze is 3 km/hr and at 40°C it is near calm.

The majority of remote area transmission systems completed over the past 10 years in Australia are capable of operating with some slight loss in performance on a 50°C day which on average will occur 0.1% of a year. The upper room temperature limit of 55°C has therefore left the thermal design engineer with the challenge of achieving a room temperature rise of no more than 5°C using passive heat transfer techniques.

Heavy-Weight Buildings

Above Ground Buildings

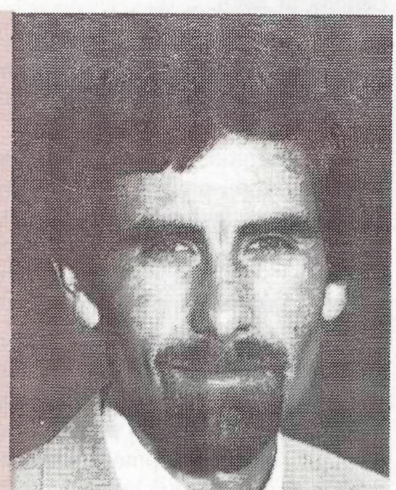
Small unattended standard heavy-weight buildings were developed around 1960 for the Sydney-Melbourne coaxial cable telephone system and for a number of other major routes. Since power is fed along the coaxial cable to many repeaters and daily room temperature variations were limited to under 2°C, a heavy-weight type of building was designed. Its main features are the ability to attenuate considerably the diurnal changes in outside air temperature and to minimise the effects of solar radiation. It utilises the large thermal storage effect of the building itself to provide passive temperature limiting.

Fig. 1 shows such a building designed to accommodate 600 W. The design day temperature is 45°C. The maximum internal temperature is 3°C above the maximum outside shade temperature and occurs close to the ceiling. The maximum difference in air temperature between any two positions in the building rarely exceeds 3.5°C (excluding positions immediately above ventilation outlets of equipment racks or heat sinks). **Fig. 2** shows the typical mild heatwave performance for peak outside shade temperatures of 33-36°C.

Allan Wishart joined the PMG Department as a Cadet Engineer in 1972. He graduated from Monash University with the Degree of Bachelor of Electrical Engineering in 1974 and from the RMIT with a post graduate Diploma in Control Engineering in 1977.

He joined the Buildings Branch, Victoria, in 1974 as an Engineer Class 1 and was involved in the planning, design and provisioning of electrical, mechanical and fire protection services for buildings in that State. In 1977 he joined the Buildings Division, Headquarters.

He is currently a Senior Engineer in the Engineering Standards and Design Section. Much of his work currently concerns the design of equipment shelters, cooled passively or by low energy consuming plant, for Telecom.



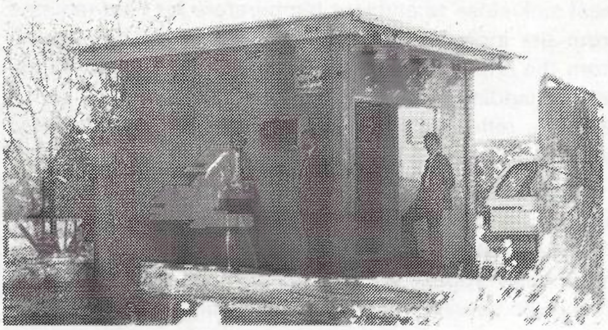


Fig. 1 — Sydney-Melbourne Coaxial Cable Repeater Building.

The buildings are constructed from prefabricated concrete panels suitable for quick erection at localities away from centres of normal building activity where brick construction has been used instead. The walls comprise separate 150 mm thick outer and 100 mm inner panels with a 50 mm air gap between them. The roof comprises galvanised steel decking, 75 mm of insulation and a 100 mm thick concrete slab. The roof is separated from the ceiling by a 230 mm clear air space through which outside air can flow. The ceiling is a 100 mm slab covered externally by 25 mm of insulation. At all sites except those raised above flood level, 32 copper rods, 1475 mm long and 25 mm diameter provide an improved thermal conductance path from the floor slab to the natural ground.

The Coen-Mossman radio relay system repeaters are housed in prefabricated buildings constructed from one or two 100 mm thick rectangular concrete units each providing a 7 m x 2 m floor area. The buildings are protected by sheet steel radiation screens treated on the inside for low emittance. **Fig. 3** shows one of the double unit buildings.

Their thermal inertia as measured by their mass, some 20 tonnes, is about half that of the Sydney-Melborne buildings. This reflects in the inside-outside temperature difference being about 5°C for a 250 W load in the worst case.

An analogue computer was used to develop a building thermal network to assist in the design of the Sydney-Melbourne route buildings. These days, appropriate programs operating on digital computer are used to estimate thermal performance of such buildings.

Underground Shelters

Underground shelters offer excellent temperature stability and are therefore classed under heavy-weight type buildings. The shelters housing radio repeater equipment are steel cylinders generally 2.4 m diameter and 2.6 m high. Entry is via a conning tower which at a number of solar powered sites reaches up to the floor of the above ground power and battery shelter. Some systems employ double shelters comprising two cylinders welded together and connected by a doorway opening. They house both radio relay and television transmitter equipment.

Heat released from the equipment is transferred primarily by convection to the shelter walls where it dissipates to the surrounding earth. Soil temperatures at floor level, about 3 m below the surface, vary only around 5°C over a year. At the top of the shelter 0.5 m or so below the surface the soil temperature varies in the order of 15°C over a year. The equipment therefore sees, on a daily basis, its surroundings as essentially unchanging at floor level and exhibiting an attenuated diurnal swing at ceiling level. Internal loads up to 500 W can be housed without the internal temperature normally exceeding 40°C unless the manhole entrance is unshaded.

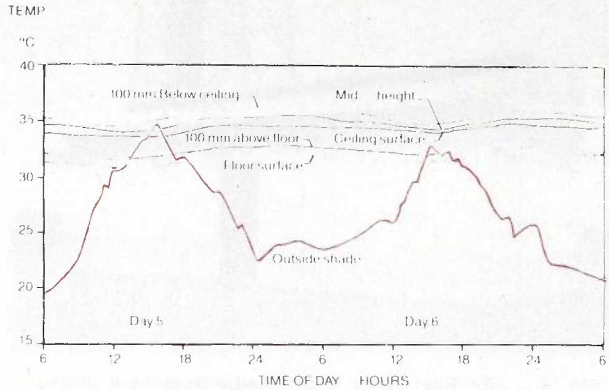


Fig. 2 — Sydney-Melbourne Coaxial Cable Building Temperature Response. Days 5 and 6 of Heatwave.

Proper thermal models for underground shelters need to be developed and validated. The basic thermal conductance model relating heat flow Q at the shelter wall and temperature T is:

$$Q = -kA \frac{dT}{dr} \qquad (1)$$

where k is the soil thermal conductivity, A is the shelter surface area and r is the radial distance away from the wall. It can be misleading unless the soil temperature at some distance r from the wall and k itself are known. Internal air temperature gradients of up to 10°C exist so more useful models might be found by studying the mechanisms of heat transfer from the equipment to the shelter wall.

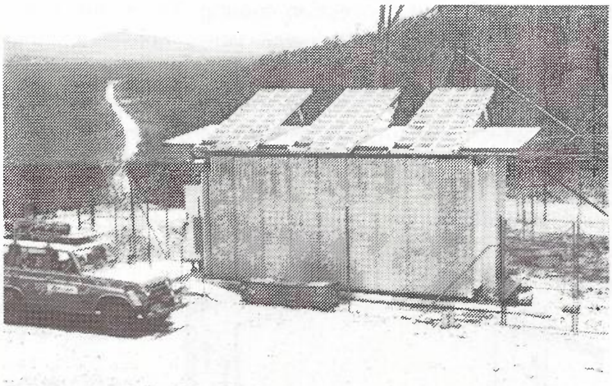


Fig. 3 — Coen-Mossman Radio Repeater Building

Thermally Thin Buildings

The development of the naturally cooled thermally transparent building concept began in 1964 with research on the performance of physical models in environmental chambers and in the field. Two years later a full size experimental building was located at Kalgoorlie in Western Australia for summer testing with internal heat loads up to 1 kW (90 W/m² floor area). The outcome of that work was the provision of 51 such buildings in 1969 for the East-West broadband radio relay system running 2400 km between Port Pirie, S.A. and Northam, W.A., including 1500 km across the desolate Nullarbor Plain. **Fig. 4** shows one of those buildings. The equipment room was designed for 1.6 kW of internal load.

Fig. 4 — An East-West Radio Relay System Building

The naturally cooled thermally transparent shelter type has the property of maintaining a small room-outside temperature difference for high equipment heat loads without the assistance of additional passive heat removing devices. The internal temperature therefore closely follows the outside temperature and so generally experiences the diurnal temperature swing.

Fig. 5 is a cross-section through a typical transportable shelter. The inner equipment room is as far as practicable thermally transparent and dust proof.

The outer shell comprises radiation and solar screens arranged to promote air circulation over the inner room. The ridge vent serves as a solar screen as well as an exit vent for convection air currents during periods of calm. Outside air will be drawn over the walls and ceiling of the equipment room by wind entering via the various vents and causing forced convection cooling. The shelters are normally located with the wall vents normal to the prevailing winds.

The roof and outer walls of the shelter are radiation screens which prevent solar radiation from impinging on the equipment room and provide on their inside surface a heat sink close to ambient temperature for heat radiated from the inner room. Convection cooling removes heat from the radiation screens. The screens consist of an external cladding, ideally gloss white in colour, an air gap of 25 mm, reflective foil, 50 mm mineral wool insulation and an internal cladding.

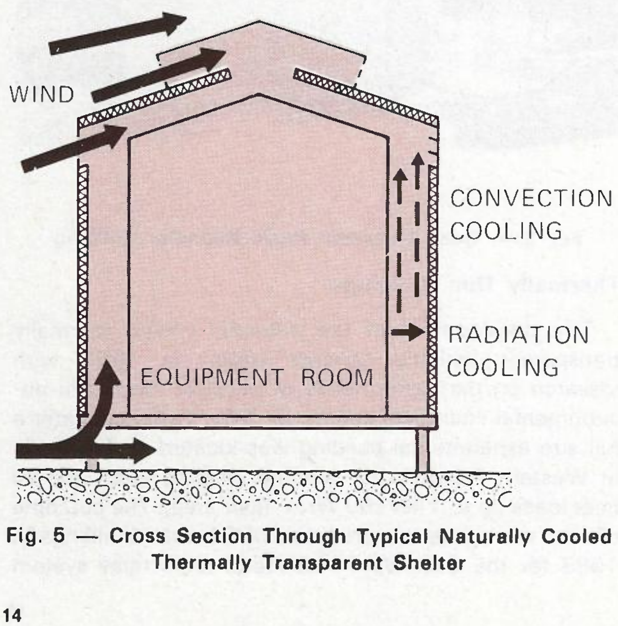


Fig. 5 — Cross Section Through Typical Naturally Cooled Thermally Transparent Shelter

Over 260 of those naturally cooled shelters of various sizes are in use on the East-West, Moomba-Peterborough (SA), Darwin-Mt. Isa and Perth-Dampier radio relay routes as well as for the Remote Area Television service receiving/transmitting stations.

Fig. 6 shows two of the 98 shelters recently provided along the Perth-Dampier natural gas pipeline. One shelter at each site houses pipeline supervisory and control equipment and the other houses equipment for extension of the broadband network. They can each accommodate 1.2 kW internal heat loads.

Thermal Performance

The thermally transparent shelters are usually designed to provide an equipment room mid-height temperature which will not exceed 55°C at any time on a 50°C day.

Their thermal performance is governed by the size of the shelter and the internal heat load. From field experience and with the assistance of a mathematical model, the 55°C limit can be readily achieved using a heat dissipation density of 20 to 25 W/m² equipment room free surface area. **Fig. 7** indicates the typical performance of thermally transparent shelters as measured on two Remote Area TV shelters which have a 750 W internal heat dissipation.

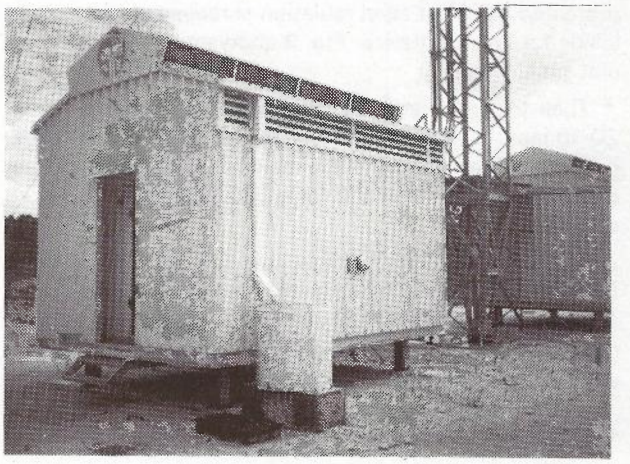


Fig. 6 — Perth-Dampier Radio Equipment shelters

The mathematical model used for the design of new shelters has been validated by field tests to an outside shade temperature of 43°C. (Hotter weather has not occurred whilst temperature data loggers were recording). The model is built on the simplified convection and radiation heat transfer coefficients for each side of the equipment room walls, floor and ceiling. For the worst case situation of laminar flow, the convection coefficient h_c is

$$h_c = a \left(\frac{\theta}{\ell}\right)^{0.25} \text{W/m}^2\text{K} \qquad (2)$$

where 1 is the surface characteristic dimension and 0 is the temperature difference over 1. The constant a is 1.42 for walls, 1.32 for the ceiling and 0.59 for the floor. For example, the surface area weighted average value of $a/1^{0.25}$ for the Remote Area TV shelter is 1.0 so

$$h_c = 1.0\left(\frac{\theta}{\ell}\right)^{0.25} \text{ W/m}^2\text{K} \quad (3)$$

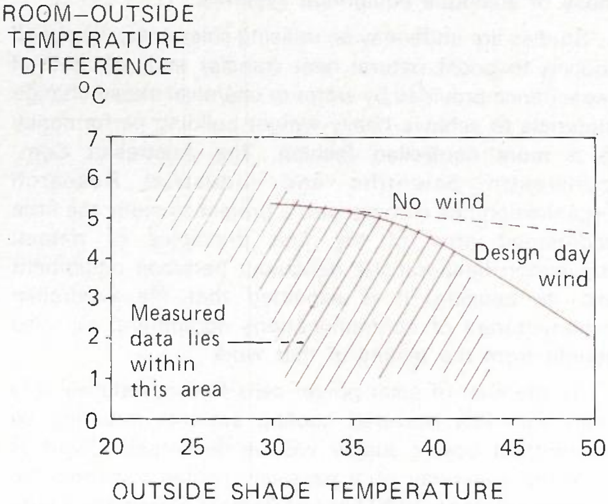


Fig. 7 — Measured And Calculated Temperature Performance of Naturally Cooled Thermally Transparent Shelters

Under calm conditions, the internal value h_{ci} and the external value h_{ce} of the convection coefficient are taken to be equal to h_c in Equation (3).

The radiation heat transfer coefficients h_{ri} and h_{re} in terms of the average room temperature TR and outside ambient TO, assuming the wall temperature is halfway between the two, are:

Internal:

$$h_{ri} = \varepsilon\sigma\left(2TR - \frac{\Delta T}{2}\right)\left[TR^2 + \left(TR - \frac{\Delta T}{2}\right)^2\right] \quad (4)$$

External:

$$h_{re} = \varepsilon\sigma\left(2TO + \frac{\Delta T}{2}\right)\left[TO^2 + \left(TO + \frac{\Delta T}{2}\right)^2\right] \quad (5)$$

where Δ = TR - TO, $\sigma = 5.67 \times 10^{-8}$ W/K^{4}m^2 (Stefan-Boltzmann constant), $\bar{\varepsilon}$ is the surface emissivity and h_{ri} and h_{re} are in W/m^{2}K.

The overall heat flow coefficient, U is the combination of the convection and radiation coefficients in parallel for each side of the wall. Assuming that $\Theta = \Delta$ T,

$$U = \left(\frac{1}{h_{ci} + h_{ci}} + \frac{1}{h_{ce} + h_{re}}\right)^{-1} \text{ W/m}^2\text{K} \quad (6)$$

The average room temperature may be found for a given internal heat dissipation, Q, from

$$UA(TR - TO) = Q \quad (7)$$

where A is the free surface area of the thermally transparent equipment room containing Q.

A heat flow balance based on equations similar to (2), (4), (5) and (6) may be established for a shelter by using suitable computer programs. Where necessary, the emperically derived natural convection relationships involving the non-dimensional Rayleigh and Nusselt numbers can be used instead of equation (2).

The free convection heat transfer coefficients may be adjusted by a suitable multiplier to account for forced convection by the design day breezes. The multipliers produce values of h_{ce} which are approximately two thirds of that suggested by the ASHRAE formula for forced air convection.

$$h = 7.34\, V^{0.8} \text{ W/m}^2\text{K} \quad (8)$$

for a shelter wall cavity airspeed of V m/s.[2] This should allow for the fact that not all surfaces will necessarily experience forced air movement at any one time. At 50°C ambient a wall cavity draught of 3 m/s is assumed and a multiplier of 10 is used. Similarly, at 45°C the draught and multiplier are 1.2 m/s and 4 respectively. At 40°C and near calm a multiplier of 1.7 is assumed. Alternatively, heat transfer coefficients for forced convection may be derived from emperical relationships involving Reynolds and Nusselt numbers. However, multipliers determined from field measurement may still be required for some shelter types.

The two curves superimposed on the measured performance of the Remote Area TV shelters in **Fig. 7** are model estimates of their performance. The model which takes into account the effect of the prevailing breezes provides a useful estimate of the maximum room temperature for a given outside ambient.

Cabinets

The Digital Radio Concentrator System will by way of over 1200 repeater sites make the network available over the next six years to almost all people in the outback areas currently beyond its reach. Each repeater will be housed in a cabinet designed to provide a maximum air temperature around the equipment of 55°C on a 50°C day. A prototype cabinet was recently tested in an environmental chamber with the design internal heat dissipation level of 250 W to confirm the design.

The cabinet comprises an equipment compartment and a battery compartment, each accessed separately from opposite sides. Sheet metal screens protect the two compartments from solar radiation on all walls and the roof and allow free flow of air within the wall and ceiling cavities. Figure 8 illustrates the cabinet construction and the relative sizes of the equipment and cabinet.

The design philosophy used was to arrange the heat dissipating equipment so as to enhance the natural inter-

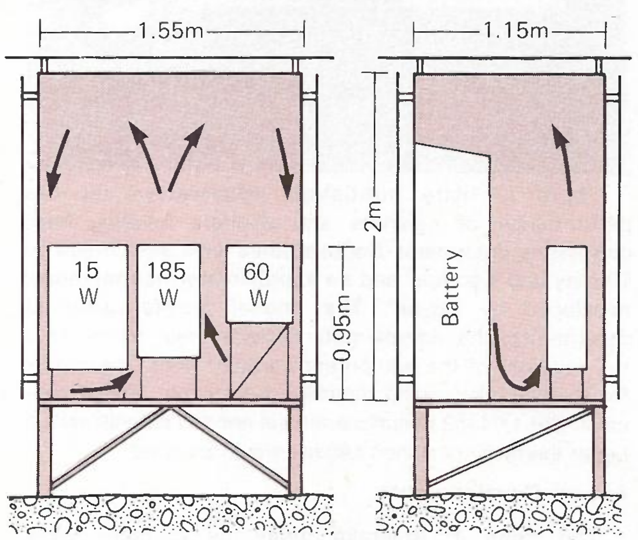
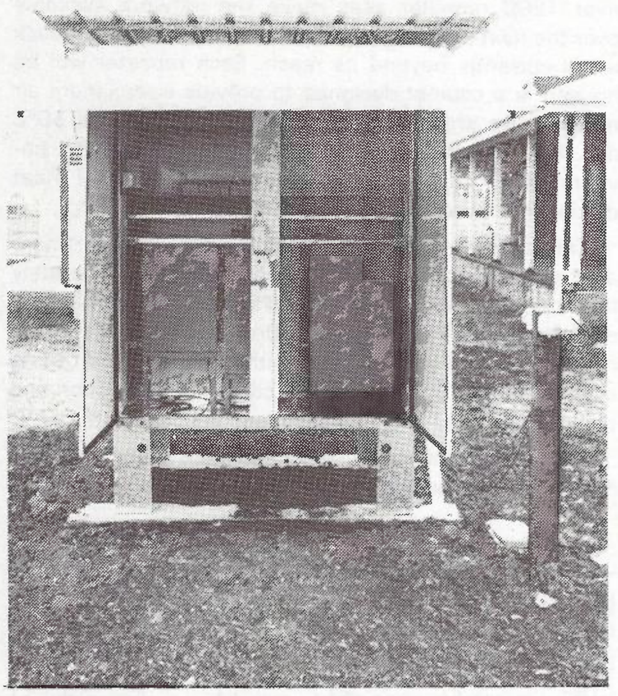


Fig. 8 — Repeater Cabinets

nal convection air currents. Hot air confined in an enclosure must recirculate to transfer its heat to the cooler areas of the cabinet walls. Sufficient space above the top of the equipment cubicles has been provided for rising heated air to establish the necessary temperature driving force to cause heat transfer to the outside air at the ceiling and walls. At the walls, heat is lost by convection and radiation to the sunscreens not exposed to the sun. On sunny days, the roof sunscreen temperature is normally close to that of the ceiling so heat is mainly lost to the outside air by convection. On some days it is expected that there will be a minor radiated heat inflow of around 20 W at the ceiling.

The repeater cubicle was originally located against a side wall to ensure the best formation of a rotating air cell. Cable length limitations for interconnections between adjacent cabinets, when required, caused the repeater to take the centre position as shown in **Fig. 8.** It is likely that two smaller air cells would form.

The cabinet is simple and of low cost but functional. A smaller version would probably be achievable by using a pitched ceiling and ridge vent, an insulated roof sunscreen and streamlined cavity inlets for calm day situations. However, the cabinet cost would then exceed that of the more basic but larger version adopted. Figure 9 is a view . . .



There is little published information on the performance of cabinets and shelters housing heat dissipating equipment. Some studies have been made by Tierney and Koczkur[3] and an approximate thermal model developed by Coyne[4]. That model proved useful in determining the approximate surface area, some 14.3 m^2, required of the equipment compartment. The model for the naturally cooled thermally transparent shelter indicates that 11.4 m2 of surface area is needed but assumes a better thermally designed cabinet would be used.

Future Developments

The trend in Australia today, as in many other countries, is towards the rapid expansion of an integrated digital network. The task we have in Telecom Australia is that of developing much better remote area transportable or small unattended buildings capable of accommodating virtually constant heat loads up to five times larger than those of analogue equipment systems.

Studies are underway on utilising solar energy induced cooling to boost natural heat transfer and of thermal capacitance provided by water or chemical phase-change materials to achieve heavy-weight building performance in a more controlled fashion. The Australian Commonwealth Scientific and Industrial Research Organisation has commenced a project to study the little understood area of the first principles of natural convection heat transfer behaviour between equipment and its housing. It is expected that the Australian manufacturers of communications equipment will also benefit from the results of that work.

As the cost of solar power cells further reduces, it is likely that low powered cooling systems requiring an intermittent power supply will be developed.[5] Work is currently underway on a passively cooled transportable building for up to 2000 lines of Remote Subscriber Stage switching equipment.

Conclusion

Accommodating digital technology communications equipment in remote and rural areas of Australia is a demanding task for which a solution must always be found. The experience gained over the past twenty-five years in housing analogue and some digital type equipment in passively cooled transportable buildings has provided an extensive base of designs and proven concepts.

The need for on-site primary power generation will continue to be a constraint in remote areas and encourage further innovation in the design of passively cooled accommodation for the current era of digital technology equipment.

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Wideband Integrated Services Networks

J. F. CONNORS

This paper reviews current practices in the provision of trial networks of wideband integrated services and examines trends in technological developments that will impinge on these networks.

1. INTRODUCTION

Telecommunications authorities all over the world are moving towards the provision of an integrated services network bringing a wide range of services to individual business and domestic subscribers. This facility will be introduced into the Australian network in the 1980s. The availability of optical fibre techniques now introduces the possibility of a wideband integrated services network, bringing wideband transmission capacity into business offices and homes. The services that could be made available within the "wired city" of the future appear limitless and would include —

High Quality Broadcast Video and Audio Services
Videophone and Teleconferencing
Video Library Services
Electronic Mail and Banking
VIEWDATA and TELETEXT
Data Transmission

2. NETWORK CONFIGURATION[1]

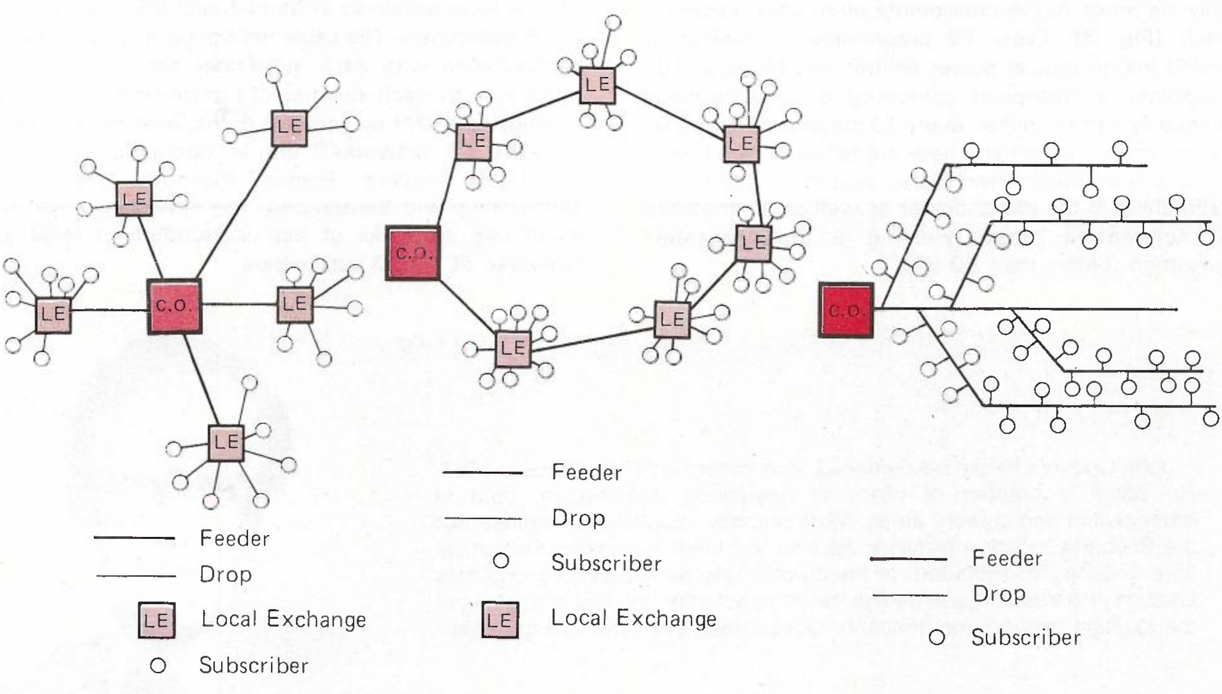
Possible configurations for a wideband services network are shown in **Fig. 1(a), (b) and (c).**

2.1 The Star Network

The Star network of Figure 1(a) is the most flexible for the provision of a wide range of analogue and digital services. It can also readily cope with changes in the distribution of demand. In this structure, each subscriber is connected to a local exchange. Several exchanges are connected to a higher order exchange (CO) and so on, thereby creating a hierarchy of exchanges. A Star network requires long lengths of cable, mainly in the connections from the local exchange to subscribers. However, because the level of multiplexing in this part of the network is low, savings can be achieved in the number of fibres required per cable and hence, in the total cost of the network.

2.2. The Ring Network

The basic ring structure consists of a transmission line looped from an exchange, through all subscribers' premises, back to the exchange. Each subscriber extracts messages from the line and inserts his replies for transmission on around the ring. Although this



a A Star Network b A Hybrid Star-Ring Network c A Tree Network

Fig. 1

structure offers savings in the total length of cable required in the network compared with a Star structure, it is not attractive because of the serious reliability problems involved in the cascading of electro-optical interfaces and the inflexibility of the network.

A variation of the ring network uses a hybrid star-ring structure as illustrated in Figure 1(b). Here the ring passes through a series of local exchanges, where messages are extracted for distribution to individual subscribers over dedicated connections. Star-ring networks can best serve small groups of subscribers within a small area.

2.3 The Tree Network

The basic tree structure is illustrated in Figure 1(c). Signals originating from a CO are broadcast over a network of transmission lines to subscribers, with each subscriber receiving the same signal.

These networks are ideally suited to CATV distribution but are difficult to adapt to switched private distribution.

3. TRIAL SYSTEMS

Moderate transmission ates between the local exchange and the subscriber have been achieved in a number of countries to date using optical fibre techniques to service small trial networks.

3.1 Philips Telecommunicatie Industrie Trial

One such trial reported from the Netherlands[2] describes a system in which wavelength division multiplexing (WDM) is used to provide four TV channels, 30 stereo channels, as well as telephony and data links (**Fig. 2**). The TV selection capability for up to 30 programmes is achieved by distributing the signals optically via fibres to the crosspoints of an opto-electronic switch (**Fig. 3**). Every TV programme transmitter is coupled via an optical power splitter and fibres to 100 crosspoints, a crosspoint consisting of a photo-diode followed by a preamplifier. Every 10 preamps are coupled to a summation amplifier. These are followed by a limiter driving a laser transmitter. Signal switching is achieved by switching of the photo-diodes as well as the preamps and summation amps, yielding a high crosstalk attenuation (better than 80 dB).

An optical power splitter distributes the optical signal from a TV programme transmitter. The light emitting core of its input fibre is projected onto a bundle of output fibres by means of a plano-convex lens. A power distribution over at least 100 fibres as proposed requires a splitter with an impractically large number of output fibres. Therefore a 1-8 and a 1-19 splitter are used, connected in series, to yield a 1-152 split.

Fig. 4 shows the configuration of a 5-channel wavelength division multiplexer and demultiplexer. Wavelengths of 820, 850, 880 and 1 300 nm are used for transmission from the local exchange to the subscriber and 1 200 nm is used in the reverse direction. Interference filters are used both in the multiplexer and the demultiplexer for wavelength-selective combining and separating of the light signals.

The power budget for this system, as shown in Table 1, indicates that with a system margin of 6 dB and a 3.5 dB/km cable, a transmission distance of 6.5 km should be possible.

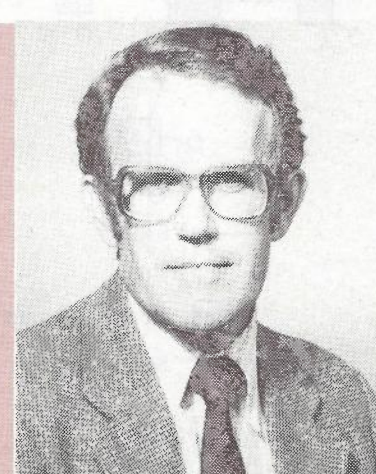
TRANSMITTER OUTPUT POWER	0 dBm
WDM DEVICES	9 dB
30 SPLICES at 0.3 dB	9 dB
6.5 km FIBRE at 3.5 dB	23 dB
RECEIVER SENSITIVITY	-47 dBm
SYSTEM MARGIN	6 dB

Table 1 — Power Budget at 850 nm

3.2 Other Trials

The equipment layout described above is typical of the techniques employed in other trials of wideband services networks. The BIGFON project in the Federal Republic of Germany, for example, uses a similar configuration to service local networks in Munich and West Berlin, each of 28 subscribers. The cable network is arranged in a star configuration with each subscriber connected via two fibres (one for each direction of transmission) or one fibre (employing WDM techniques) to the local office. Trials of at least 26 networks[3] are in operation in Canada, Denmark, England, France, Germany, Japan, The Netherlands and Switzerland. The networks range from small ring networks of four subscribers to large star networks of 1 500 subscribers.

John Connors began his career as an engineer in trunk service in 1967. He spent a number of years in operations engineering, both in metropolitan and country areas. More recently, as planning engineer for the Brisbane Junction Network, he was involved in planning the optical fibre network for Brisbane. In his current role as supervising engineer junction and transmission design, he is responsible for design aspects of the junction network for Brisbane, Gold Coast and surrounding areas.



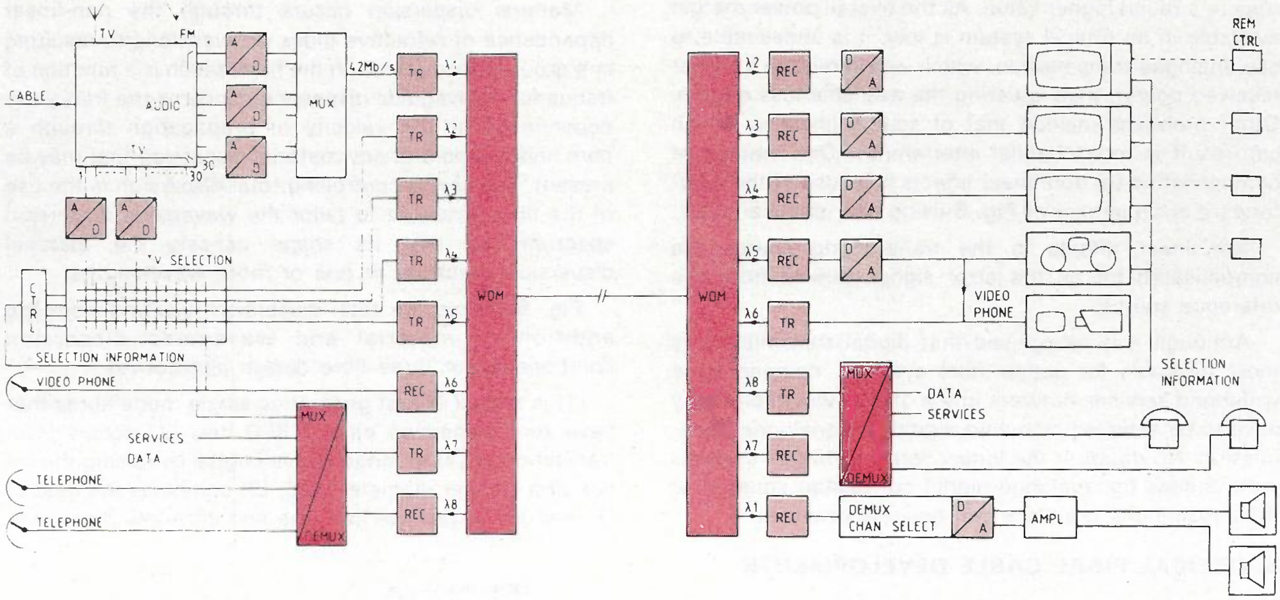


Fig. 2 — Trial System, The Netherlands

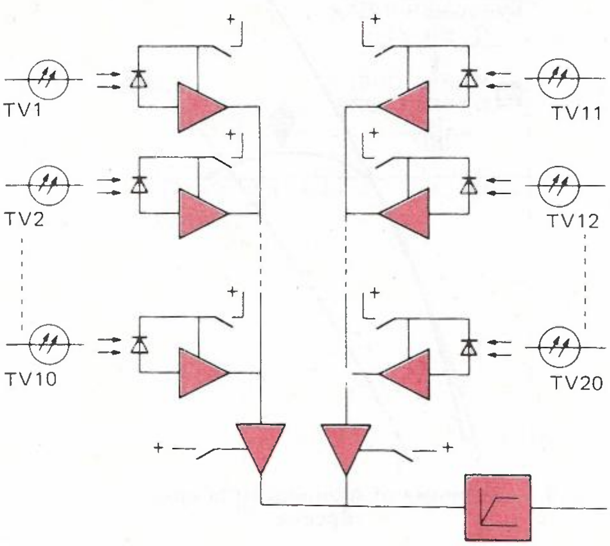


Fig. 3 — Electro-Optical Switch

4. DIGITAL MULTIPLEXING TECHNIQUES

While wavelength division multiplexing techniques on the line from the local exchange to the subscriber appear to dominate current trials, it has been suggested[4] that the use of a large number of wavelengths may not be ideal. The incorporation of many lasers, including their control and surveillance circuits, leads to very complex local exchanges. Further, the subscriber's receiver equipment would also be complex. For these reasons and to provide transmission capacity for future services (eg high definition television), a time division multiplex (TDM) system operating at high bit rates may be a better alternative.

For subscriber lines of less than 10 km a bit rate of 1.12 Gbit/s has been suggested for the next generation of integrated services subscriber lines. A large system margin can be expected and the component requirements can be relaxed, yielding a lower total cost. This system could be supplemented by the application of WDM with only a few wavelengths.

5. DIGITAL vs ANALOGUE TRANSMISSION

Current trials of wideband services networks involve hybrid digital and analogue transmission. While analogue transmission is possible, it is not the most suitable for optical systems. It can be shown[5] that satisfactory digital transmission over an optical fibre system can be obtained with a S/N ratio at the receiver of 21.6 dB while direct analogue transmission at baseband would normally

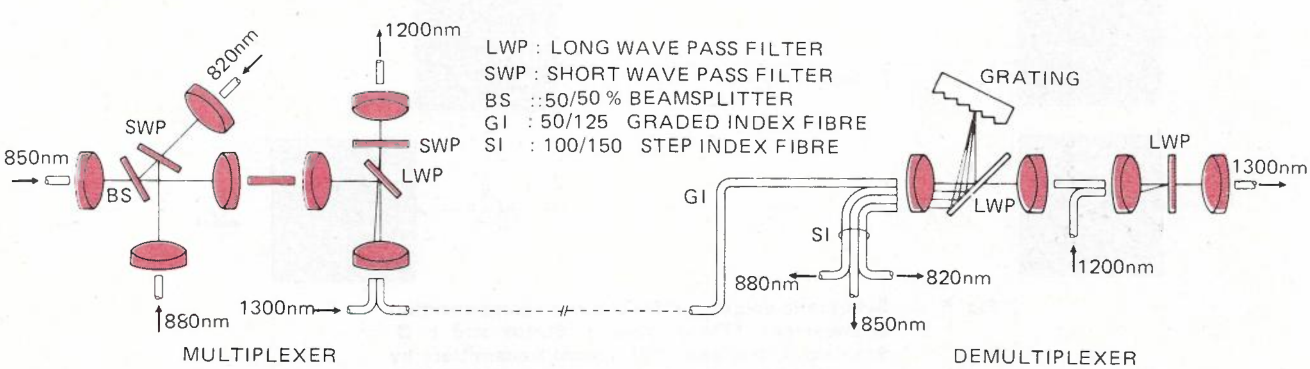


Fig. 4 — WDM Configuration

require a much higher value. As the overall power margin available in an optical system is low, it is undesirable to use analogue transmission, which would require a higher received power, thus lowering the available loss margin. Other problems include that of source linearity, which can result in inter-channel interference. One method of compensating for non-linear effects is by use of the feed-forward arrangement of **Fig. 5** using two identical LEDs.

Non-linear effects in the transmitting source are compensated for by the error signal derived from the reference source.

Although it is recognised that digital transmission is most desirable for optical fibre systems, demand for a wideband services network in the 1980s would probably have to be satisfied by hybrid digital and analogue transmission. No doubt in the longer term, all-digital systems with codecs for analogue-digital conversion situated at the subscribers' premises will become practical.

6. OPTICAL FIBRE CABLE DEVELOPMENTS

Existing trials of wideband services networks in general employ wavelength division multiplexing techniques to provide a number of services on the one fibre or fibre pair. Wavelengths in the vicinity of 850 nm and 1 300 nm are multiplexed onto graded-index fibres, and transmitted over maximum distances which are determined by the fibre loss at 850 nm. Through the use of single mode fibres, it is possible to provide lower losses and dispersion at longer wavelengths. Ultra-broadband fibres[6] are now proposed. These are capable of providing low losses and extending the near-zero dispersion region over a very wide wavelength range that can simultaneously encompass 1 300 nm and 1 550 nm. Such fibres would be useful for wavelength division multiplexing many high bit rate information channels onto the same fibre, providing capacity for services not as yet envisaged and/or allowing reduction in the number of fibres necessary in the subscriber distribution network.

Design of ultra-broadband fibres involves the minimising of dispersion. Chromatic dispersion in single mode fibres is the sum of two effects.

Material dispersion occurs through the non-linear dependence of refractive index on wavelength, resulting in a group velocity through the fibre which is a function of frequency. Waveguide dispersion concerns the frequency dependence of the velocity of propagation through a fibre, independent of any material dispersion that may be present. The key to controlling total dispersion is the use of the fibre structure to tailor the waveguide dispersion spectrum so that its shape cancels the material dispersion spectrum at one or more wavelengths.

Fig. 6 shows the total dispersion resulting from the addition of material and waveguide dispersion components for three fibre design alternatives.

(1) is typical of first generation single mode fibres that have zero dispersion near 1 300 nm; (2) occurs from translation of (1) to longer wavelengths by raising the index of a smaller diameter core; (3) combines the best of (1) and (2) to provide low loss and ultra-low dispersion

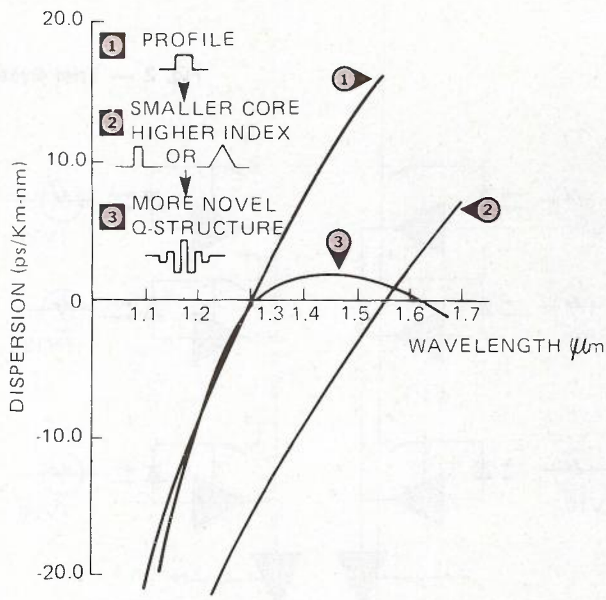


Fig. 6 — Examples of Alternative Chromatic Disperson Spectra

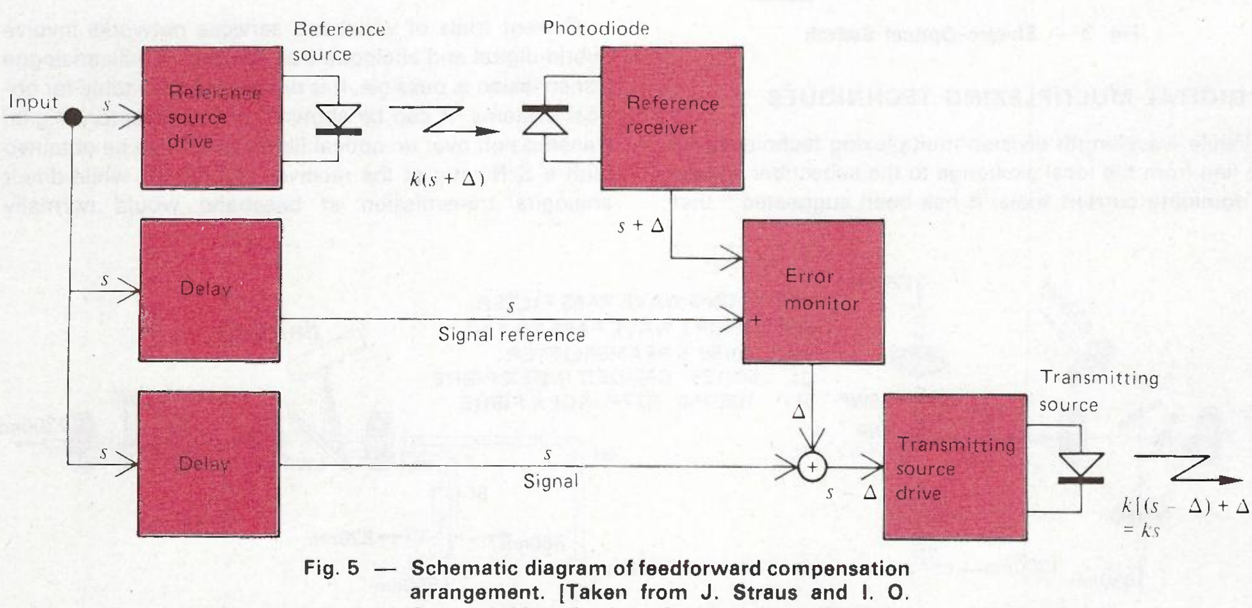


Fig. 5 — Schematic diagram of feedforward compensation arrangement. [Taken from J. Straus and I. O. Szentesi, Linearisation of optical transmitters by a quasifeedforward compensation technique, Ets Letts 13, 158-9, (17 Mar. 1977).]

near 1 300 and 1 550 nm. This requires a more novel quadruple-clad structure with a core surrounded by four concentric claddings.

Fig. 7 compares fibre profiles for ultra-broadband applications. The double-clad structure (the W-profile fibre) has a large waveguide dispersion effect which can be tailored to cancel material dispersion over a broad wavelength range, but high losses occur in the 1 550 nm region. The quadruple-clad structure compensates for the long wavelength loss problem. It has a core-guiding region and two index wells separated by an annular ring guide in the second cladding and can be optimised to achieve low loss and dispersion. In particular, the core and inner index well can be used to control low dispersion while the remaining second, third and fourth claddings can be used to maintain low losses at long wavelengths.

7. OPTICAL SWITCHING[7]

The function of the local exchange within a wideband services network is to separate the different services required and to set up connections subscriber-subscriber as well as subscriber-host computer. The use of optical switching will

- minimise opto-electronic conversions;
- allow transmission of analogue or digital signals;
- provide the largest possible bandwidth.

In the last few years optical switching systems have been the subject of many studies. They can be broadly divided into two main categories —

Space-division Systems
Time-division Systems

7.1 Space-division Systems

Space-division systems can be subdivided into
Guided Optics
Free Space Beams

7.1.1 In guided optics systems, the light beam is guided continuously from end to end through the exchange centre. At times, the light must be relaunched from one guide to another. These systems can be classified as ynamic or static.

In dynamic systems, mechanical movement aligns one fibre with another. Accurate alignment of fibres can be obtained by tightly fitting the fibres into V-grooves. Static systems are based on the principle of energy transfer from one guide to an adjacent guide by modifying the electrical characteristics of the guides. This principle implies a long enough interaction length and a very precise geometry to minimise the losses due to leakage and crosstalk. These switching units require the adoption of integrated optics technologies (see Section 8).

7.1.2 Free space beams switching systems involve the deviation of a beam transmitted from a fibre

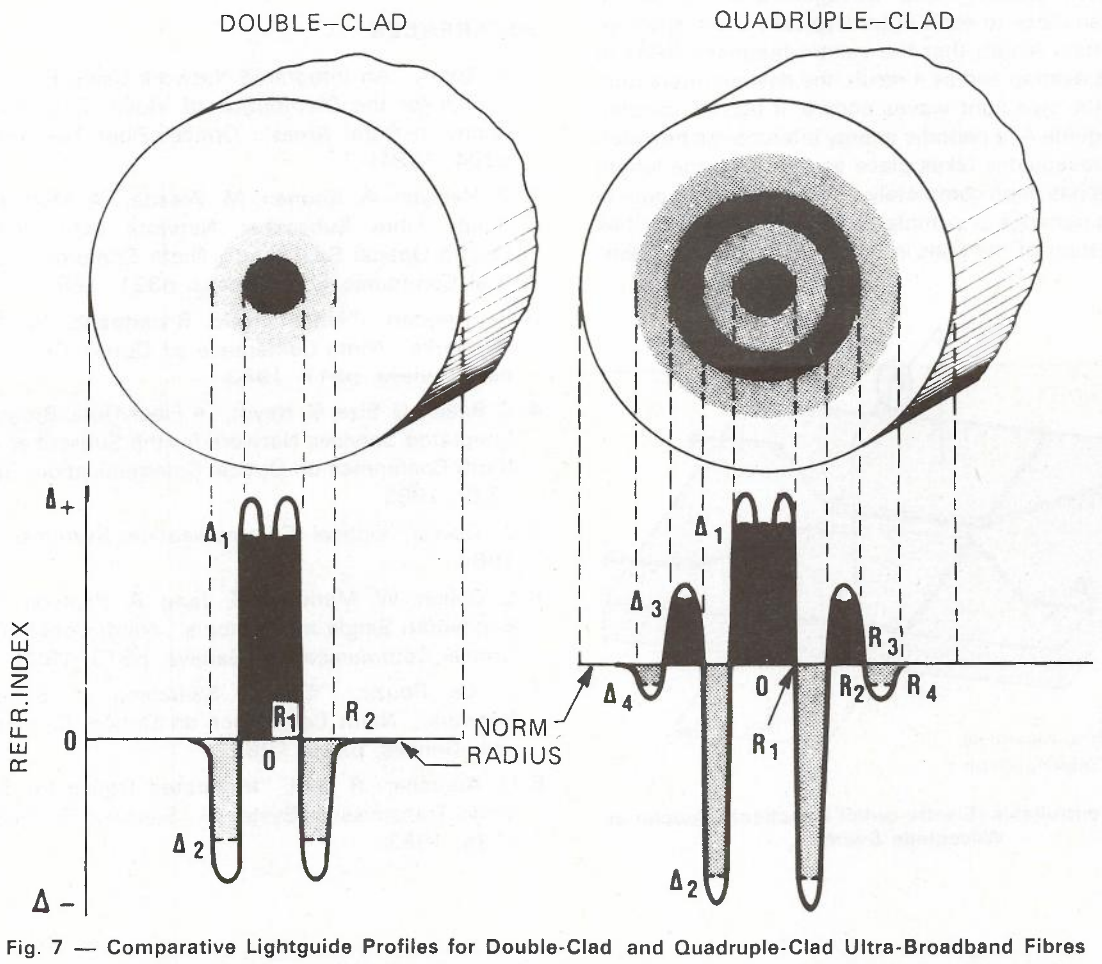


Fig. 7 — Comparative Lightguide Profiles for Double-Clad and Quadruple-Clad Ultra-Broadband Fibres

and its relaunching into another fibre for retransmission. Similarly, as for guided optics devices, these systems can be classified as dynamic or static.

With dynamic systems, mirrors or prisms may be used to effect the deviation of the beam or the fibre may be moved in the focal plane of the beam collinating lens. The latter method produces a larger capacity with moderate losses. Static systems are at the early laboratory stage and results concerning the performances of complete systems do not exist. One development concerns the use of nematic liquid crystals which in the off position reflect the incoming beam and which pass the P polarisation when placed in an electrical field.

7.2 The principles of time division techniques are similar to electronic time division techniques. They are very promising for the future but much development work remains to be done.

8. INTEGRATED OPTICS[8]

A gradual integration of optical and electronic components (analogus to that which has already occured in electronics) is to be expected in future optical communication systems. The anticipated advantages are compact, robust and reliable components, fewer interconnections and economies of production.

Of particular interest in the development of the integrated services network is the use of integrated optics for optical switching. An optical switch is shown in **Fig. 8**. Two identical strip waveguides A and B are arranged so close to each other (typically 3 um spacing) over a certain length that the electro-magnetic fields of the waves overlap and as a result, the desired interaction between the two light waves occurs. If light is coupled into waveguide A, a periodic energy interchange between the two waveguides takes place so that after the length L_o the light has been completely transferred to waveguide B. This interchange is complete only when the velocities of propagation of the light in both waveguides are identical.

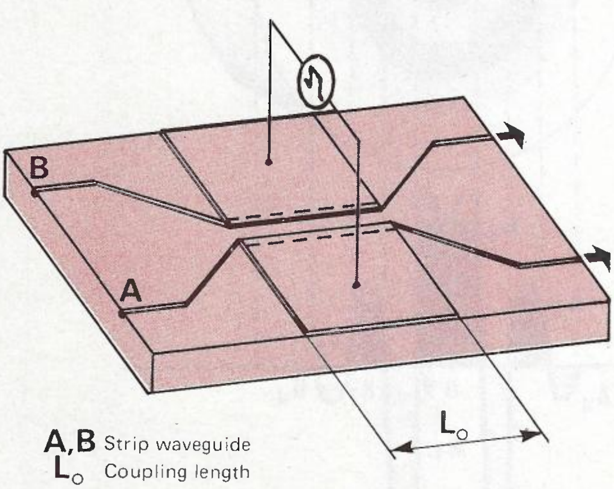


Fig. 8 — Controllable (Electro-optic) Directional Coupler as Waveguide Switch

With differing refractive indices and consequently differing velocities of propagation for the light in the two waveguides, there is only a partial interchange. The refractive index difference is produced by electric fields in opposing directions excited in the two waveguides via electrodes. At a certain voltage at the electrodes, the small fraction of light coupled from A to B is coupled back into A after a length L_o. Thus with voltage applied, the light emerges from A and without applied voltage from B. Consequently an optical switch has been realised. Such switches have already been operated at speeds in excess of 3 Gbit/s.

By suitable design of the coupled waveguides in Figure 8, the light transfer can be made strongly dependent on wavelength, resulting in a filter with electrically tunable pass band. Such filters could be used for the multiple use of optical fibres by wavelength division multiplexing.

9. CONCLUSION

The development of optical fibre components has reached the point where optical techniques can be used to expand telecommunications capacity almost without limit. Although the current state of development is satisfactory for the provision of operational wideband integrated services networks, future trends in optical techniques will ensure economies of installation and enable services to be provided which are currently not envisaged, thus contributing to the viability of such networks.

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Long Term Network Development of TACONET

PETER FLANAGAN and RON HAWKINS

Telecom Australia's computer network, TACONET, has rapidly grown in size and range of facilities over the past ten years. This rapid growth is predicted to continue through the rest of this century. A long term network strategy is outlined, illustrating the improvements in performance and functionality required in addition to the user demand for increases in the numbers of workstations connected.

Introduction

At a series of meetings from September 1984 to February 1985, the Information Management Group, a high level strategic planning committee in Telecom, endorsed proposals for an appropriate Computer Processing Architecture for Telecom. (Ref. 1). The development of such an architecture provides the opportunity to offer a greatly improved TACONET (Telecom Australia Computer NETwork) service to its users. The efficient and effective use of digital communications is an essential part of providing this improved service. It is the link joining the user's workstation to Telecom's data repositories and processing facilities.
user's workstation to Telecom's data repositories and processing facilities.

The Architecture

A previous article (Ref. 2) outlined communications plans and options for TACONET growth for the period ending June 1986. By this time, TACONET will have grown to about 7,500 workstations. (The average growth rate has approximated 50% per annum over the last 10 years). A long term strategy is necessary to guide this continuing expansion to the tens of thousands of screen-based devices that will be in use in the 1990s. (**Figs. 1 and 2** illustrate this growth in number of workstations and processing power).

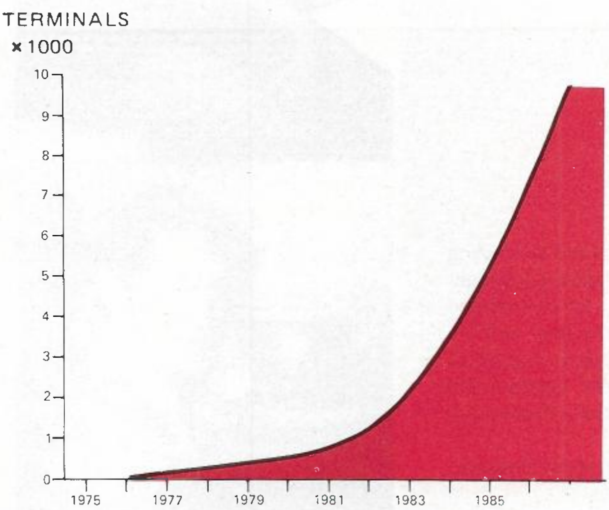


Fig. 1A. Timeshare Terminals on Taconet Recent History

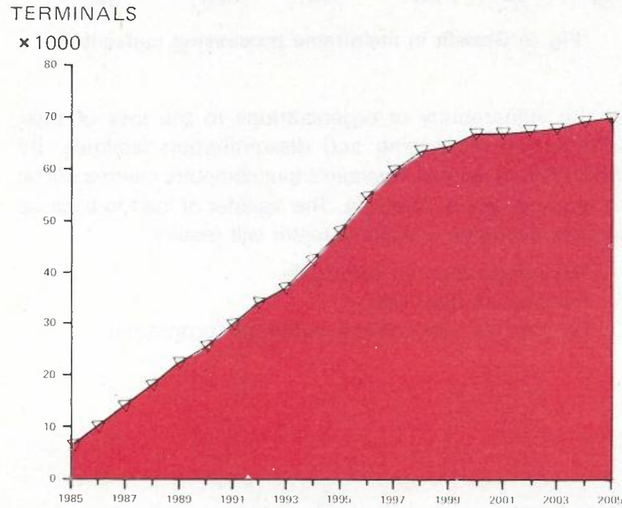


Fig. 1B. Timeshare Terminals on Taconet Predicted Long Term Development

Enhancements to the existing network will provide for an enriched connectability of data terminals to TACONET host systems. Within the constraints of security, by mid-1987 any user requiring access to multiple applications on TACONET will be able do this from one terminal no matter whether the applications run on different host types or whether those host systems are geographically separate **(Figs. 3 and 7)**.

To provide improvements in reliability and performance, new technologies will be adopted and computer facilities dimensioned such that users will obtain decreased response time to terminal commands and increases in throughput for the batch component of their work over that which is currently provided.

The computer equipment will be deployed in four computer centres; in closely located pairs of centres, one each in Melbourne and Sydney. This disposition allows for uniformity of support and management as well as economies of scale in the numbers of management and support staff required — areas where there has long been a shortage of qualified staff. In addition, this arrangement will yield an improved resilience to disasters. A complete centre could be lost without seriously interrupting Telecom's essential day-to-day operations.

Recent disasters, such as the Sydney Stock Exchange flood and the National Library fire, provide an indication

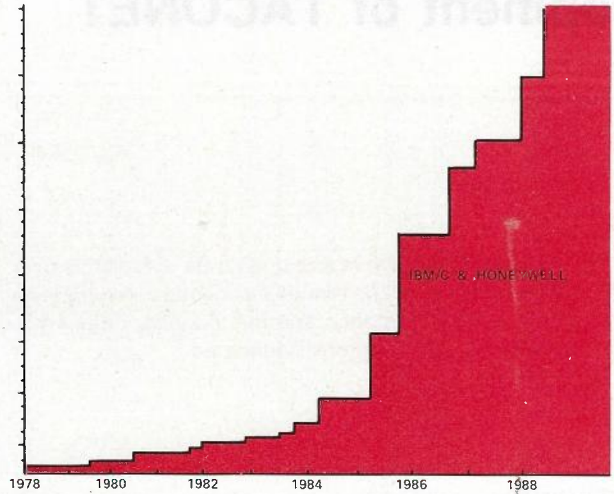


Fig. 2. Growth in mainframe processing capacity

of the vulnerability of organisations to the loss of their information processing and dissemination facilities. By 1990 **(Fig. 4)** each of Telecom's four computer centres will be as large as any in Australia. The transfer of load to back-up facilities following a major disaster will require:

1. Reconfiguration of terminals.
2. Transfer of data files.
3. Transfer of applications software (programs).

It can be seen that the improvement in the resilience of TACONET depends on establishing an excellent network between the centres. To provide automatic switching around failed links additional, dedicated links will be provided and permanently configured. During normal operations they will be operated in a lightly loaded state, ready to take on additional traffic as required.

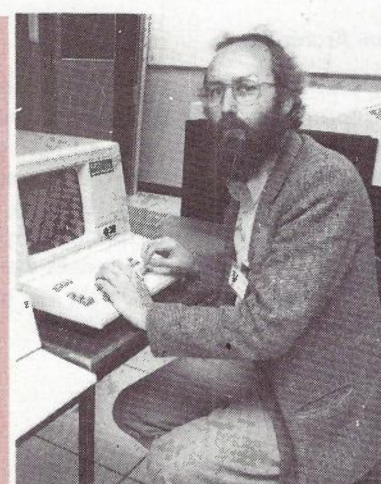
To facilitate the management of the network as well as the production of network plans within the overall strategy, the concepts of Primary, Secondary and Tertiary networks have been developed. To a large degree they can be said to be analogous to aspects of the telephone network but on a much smaller scale.

A Schema has been drawn up to consider the range of network connections required so that they can be dimensioned. This Schema is represented in **(Fig. 5)**.

Network Strategy

The Primary network consists of the high speed links joining the major processing centres and linking concentration centres to them. Currently using 48 kbits/s Datel and DDN links, these wil ultimately use multi-megabit per second channels over optical fibre or copper pairs. This is analogous to the interexchange bearers.

The Secondary network links the individual user sites (subscribers) to the Concentration centres (exchanges). These links are typically 9.6 Kbps Datel or lower speed dial-up.



PETER FLANAGAN joined the Australian Post Office as a Cadet Computer System Officer in 1975. Since then he has furthered his qualifications in Data Processing and Business Administration. After some years providing support to TACONET users, he transferred into a planning area, initially assisting in the development of the Network Plan for TACONET. In 1984 he joined the Systems Planning Branch where, as Manager, Facilities and Information Technology Planning, he is responsible for strategic planning activities associated with the end-user and major processing facilities for TACONET.

RON HAWKINS joined Telecom (then the P.M.G.) as a Programmer-In-Training in 1973. He commenced work in the systems software group, becoming manager for utility programming in 1975. He assumed responsibility for transaction processing software administration in 1978 and was closely associated with the introduction of several large T.P. systems. Since 1981 he has been engaged in strategic planning of Telecom's data processing computer network, mainly in the area of networking. He is currently Manager, Data Communications Planning in the Systems Planning Branch.

Mr Hawkins has a B.Sc from the University of Western Australia and a Graduate Diploma in Data Processing from C.I.T. (now Chisholm Institute).

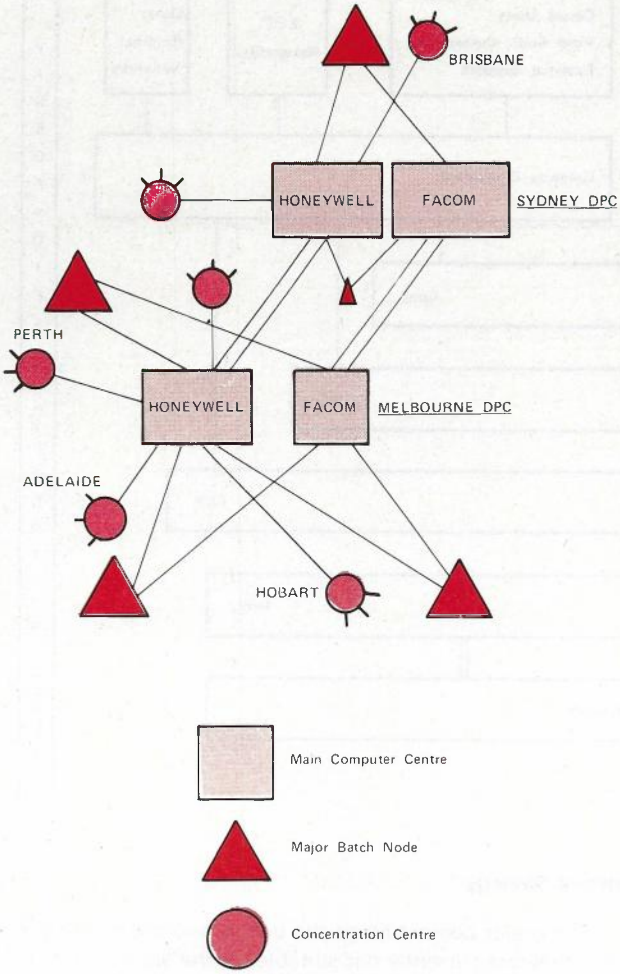


Fig. 3. Taconet 3 in 1986 — before Gateways

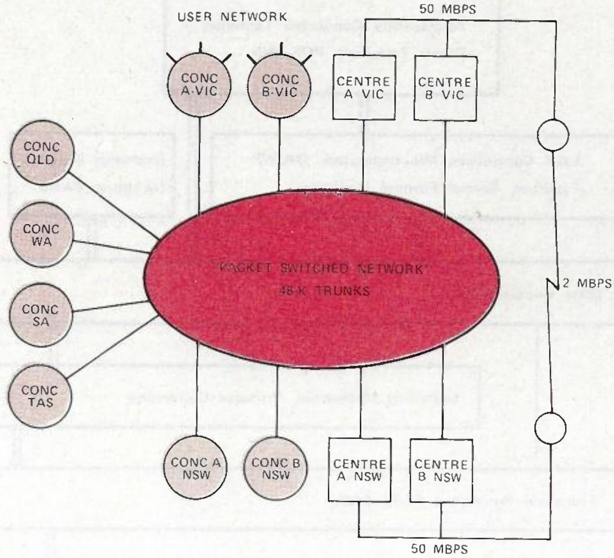


Fig. 4. Taconet 4 1990

The Tertiary network provides further reticulation within a particular building or site. The technology currently involves the use of workstation clusters — multiplexed or multidropped. The first sophisticated Local Area Networks (LANs) are also being installed. The Tertiary network is analogous to the use of a PABX within an organisation.

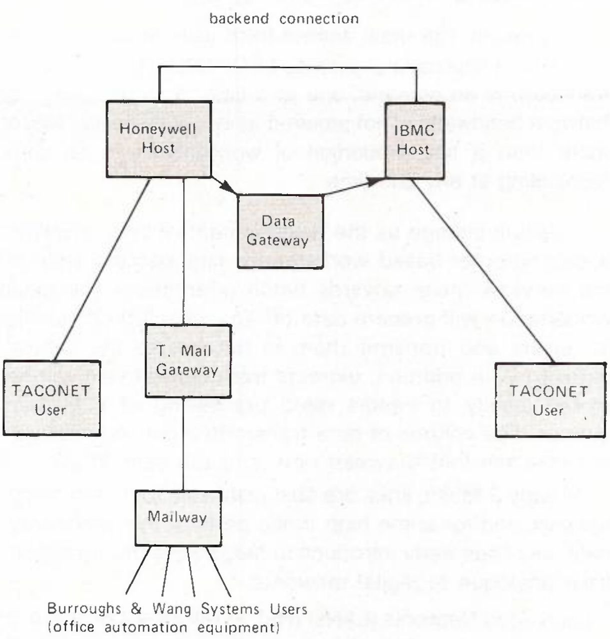


Fig. 7. Use of Gateways in Taconet (1986)

As in the PABX case, communications facilities must be standardised within a site to enable individual users to communicate directly without having to traverse the wider parts of the network first. To this end, LAN policies are being developed to complement specifications already drawn up for the Primary and Secondary networks. Such tertiary network specifications and policies will continue to be necessary even when the ISDN (Integrated Services Digital Network) allows the compounding of voice, data, text and image communications onto a single transmission network (**Fig. 6**).

The User Workstation

Grosch's law (Ref. 3) arose as an intuitive assertion in the 1940s. It took the form of:

$C = fW^{0.5}$

where C = cost of the computer system
and W = processing power of the system

The implication of this is that bigger computers provide much better processing value for money than smaller ones. This has been proven in practice for over 30 years — until the advent of microcomputers.

Currently microcomputers offer price/performance advantages over mainframe computers of the order of between 10 and 40 to one. This is partly because of an oligopolistic mainframe supplier situation and partly because of the huge economics of scale in building vast numbers of microcomputer chips. Development costs can be very quickly amortised.

Already microcomputer workstations are being built with the processing power of an early 1980s mainframe computer at a price (in $ terms) of about 1/100 of the original price of that processor unit. Admittedly the systems are only as fast as their slowest peripherals, the human mind interfaced by the eye and hand data transfer devices, but they are powerful systems. Currently the installed processing power of microcomputers connected

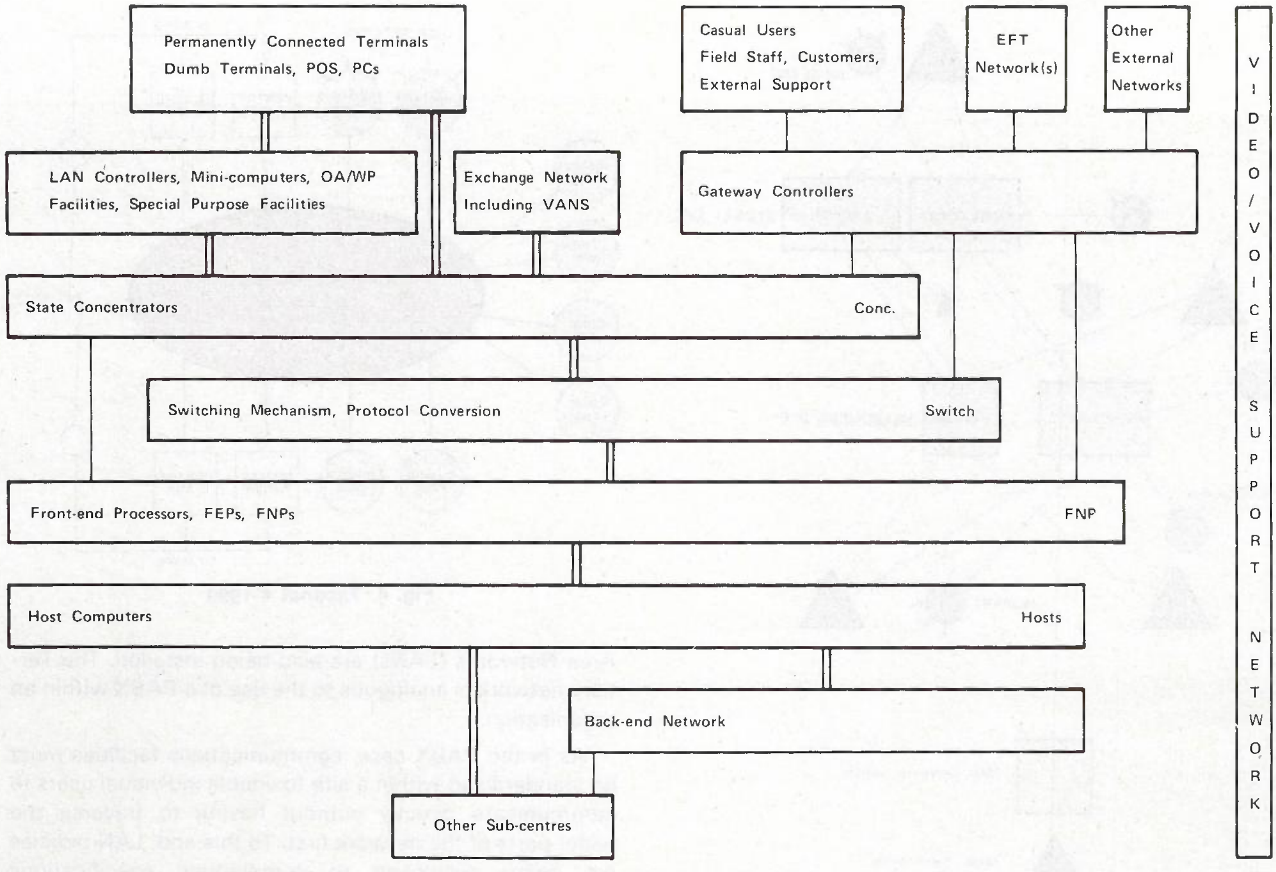
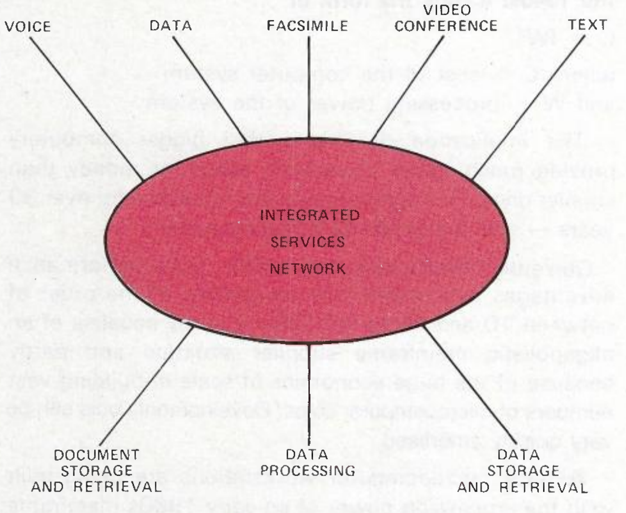


Fig. 5. Schema for Network Strategy

to TACONET mainframes exceeds the power of those mainframes by about five to one.

Whether the power of microcomputers is realisable is a moot point. The large mainframe with its ability to handle hundreds of simultaneous users and operate continuously, day and night, shows a better use of available resources than the single user microcomputer used by one person for perhaps three hours per day.



NOTE: "DDS FACILITIES" now extend to all user areas with ISDN (INTEGRATED SERVICES DIGITAL NETWORK)

Fig. 6. Taconet 1995

The major constraint on the use of microcomputers is that they are currently not suitable for the storage of vast quantities of corporate data that will be stored on and transferred around TACONET. The protection of this data from error, loss or illegal access requires centralisation of the highly trained support function in a small number of secure data repositories — the central nodes of TACONET.

The Changing Workstation Connection

At present, the main access from user workstations is interactive. Applications such as LEOPARD (Ref. 4) process transactions on demand, one at a time. A large secondary network bandwidth is not required as it is statistically rare for more than a tiny proportion of workstations to be communicating at any one time.

This will change as the development of very powerful microcomputer-based workstations changes the style of the network more towards batch orientation. The local workstation will prepare data off-line, check them locally for errors and transmit them in batches to the central repository. In addition, extracts from central files will be stored locally to handle rapid processing of individual queries. The volume of data transmitted per terminal will increase ten-fold between now and the year 2000.

Already 2 Mbit/s links are cost justifiable for the primary network and for some high traffic parts of the secondary network. Their early introduction helps ease the transition from analogue to digital networks.

Local Area Networks (LANs) (Ref. 5) will be all pervasive in the work place by 1990. Individually they will not need a high bandwidth; 10 Megabit per second would be adequate for some time. The most important specification for Telecom's choice of LAN will be whether an acceptable standard is used. At present, some 1000 different LANs are on the market. Within two years less than a dozen will remain viable. than a dozen will remain viable.

PBXs will not compete directly with LANs, but will be used as an adjunct for external communications. PBXs cannot provide the high bandwidth necessary for file transfers. They can, however, provide connection to mainframes and protocol conversions. Most of their lines will be used for telephony, even if this does become digital telephony. The corollary of using LANs for voice services is also possible. Digitised voice can easily be transported via a LAN. However, it may prove more appropriate to separate the services into dual networks within the building. The duration of individual connections, voice, is typically minutes while data is hours, may preclude the eary integration of these services.

The external communications (Ref. 6) will probably be 2 Mbits/s tie-lines to other PBXs and ISDN to computer systems. The advantage of ISDN is that the same cabling is used, but a 64 kbits/s connection is available if the devices at the user end are changed.

Digital communications will have to advance quite a long way to eliminate the use of paper in Telecom. While a single 30 cm platter laser disk can store, in image form, some 60,000 A4 pages, to transmit **one** page at 64 Kbit/s would take about ten seconds. One laser disk platter would store the equivalent of six four-draw filing cabinets of paper. The whole of TACONET's on-line file store is only about 300 Gigabytes. Telecom's paper files would contain hundreds of times the information stored there.

The Migration to New Networks

The Datel network of dial-up and leased connections have been used on TACONET for well over 10 years. However, our users have always had higher expectations of availability, reliability, resilience and performance. We are, as a consequence, seeking:

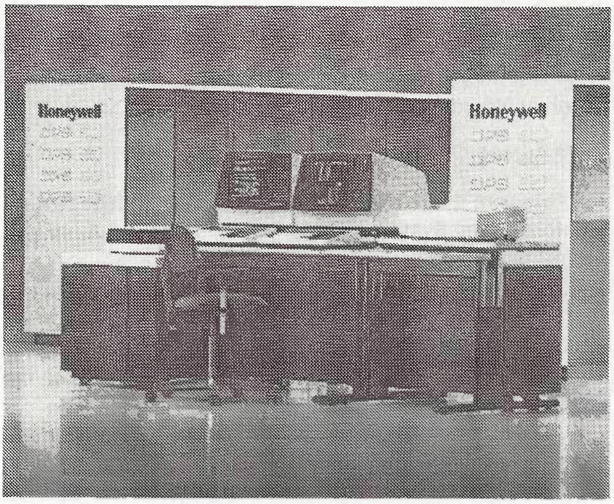
1. Higher transmission rates on the secondary network.
2. Better back-up for failed links.
3. Low error rate on transmitted data.
4. Higher data carrying capacity for the primary network.
5. More automation for the line switching function during back-up primary links.

The answers to these requirements lie in the plans for the use of DDN services and the introduction of TACONET Concentration Centres.

With the use of high speed communications over optical fibres and twisted copper pairs, the components of a computer centre can be divided. In the long term strategy the processing control and I/O (Input/Output) functions of a computer centre will be separated — perhaps into individual buildings on one site or a number of sites. The high speed links between separate computer centres will then allow the rapid transfer of data to match user requirements with available processing capacity.

The Integration of Separate Networks

Currently, separate data networks have been built, using different architectures, for our Honeywell (DSA and NPS) and IBMC (FNA/SNA) TACONET computer facilities. These will soon be linked for file transfer by a 50 Mbit/s backend network. This capacity should be sufficient until the mid-1990s. Connection at the user end currently involves separate communications lines to clusters of terminals or, alternatively, separate terminals for each type of access. Integration to simplify user access and reduce unnecessary redundancy in data lines is a worthwhile goal.



Honeywell DPS 90 Computer System

The use of DSA potentially allows every terminal connected to a Honeywell host on TACONET to access them all. Only one network is then needed — not four as was once the case. Similarly FNA allows the same facility with the IBMC systems.

Another important step taken by Telecom towards this objective involved the integration of TACONET with Mailway (the electronic mail product used on Telecom's 50 Wang OIS and VS model wordprocessing systems). This enabled text documents to be created and transferred between TACONET workstations and the 500 Mailway workstations.

Subsequent to this the linking of these facilities to our second Office Automation (OA) supplier's equipment will be made through gateway systems **(Fig. 7)**. The first stage of this super-network of interlinked networks will be in operation during 1986.

The TACONET data gateway may become redundant in the early 1990s as concentration/switching facilities become more advanced. Currently, concentration is performed separately in both the Honeywell and IBMC part of TACONET by powerful minicomputers. These facilities could be replaced by fault tolerant super-microcomputers serving **both** networks. Network management software would also be included.

In the early 1990s, starting in the business districts at first and later in metropolitan and country areas, there will be ISDN. This service, in providing an all digital subscribers' network, will allow any form of intelligence to be transferred between network stations regardless of the character of the information. The only constraint will be whether the receiving device can reproduce the packet stream into the appropriate analogue signal (e.g., voice, image, text).

In addition to the network connection, a common link level protocol such as DSA or SNA could be used. When this is finally achieved, protocol conversion will no longer be needed. Connection to networks external to TACONET would be via OSI standards. A single data terminal would come into being.

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GLOSSARY OF TERMS

Availability
: A measure of the amount of time a system is in an operational state and able to be used by its users.

Datel
: A facility for data transmission using standard voice grade lines (analogue transmission). Both permanent and dial-up links are available.

DDN
: (Digital Data Network) A dedicated digital network for carrying data marketed as Digital Data Service (DDS) for permanent connection and Austpac for casual connection.

IBMC
: (IBMC Compatible). A computer facility capable of executing with minimal change an applications package that was originally written for an IBM computer.

ISDN
: (Integrated Services Digital Network). An all digital communications network over which all types of communications traffic will ultimately travel.

LAN
: (Local Area Network). A high speed link joining local work stations, often using twisted pair or coaxial cable, allowing them to transfer data or text between themselves and to share expensive resources or network peripherals such as storage and printer devices.

LEOPARD
: (Local Engineering Operations Processing Analysing and Recording of Data) A TACONET-based application replacing the paper records and manual handling procedures in Services Assistance Centres (SACs) and Fault Despatch Centres (FDCs) with computer records and Video Display Units (VDUs).

Mailway
: A private network which allows the transfer of documents and messages between two Telecom word processing systems.

Office Automation
: That body of computer applications and facilities other than data processing that have wide application in the office environment. These include word processing, electronic mail, document storage and retrieval, telex and facsimile.

PBX
: (Private Branch Exchange). Sometimes referred to as PABX for an "automatic" PBX.

Primary Network
: That part of TACONET interlinking main computer centres with each other and with concentrator centres.

Reliability
: A measure of how infrequently a system fails to the extent of causing a noticeable interruption to work.

Resilience
: A measure of the ability of a system to survive a major disaster.

Secondary Network
: That part of TACONET linking user sites with concentrator centres.

TACONET
: (Telecom Australia Computer Network). An internally used network of large scale computers, communications processors and user workstations used for data entry, storage, processing and retrieval.

Tertiary Network
: That part of TACONET confined to a single user site.

T. Mail
: A gateway between the Mailway text network and TACONET which allows the transfer of documents between the two networks.

Some Trends and Developments in Information Networks

PAUL A. KIRTON, B.E.(Hons), Ph.D.

The information age has exciting prospects for making new and more convenient services widely available. To achieve this, many different systems will need to interwork in a compatible manner and on-line directory services will be required to store information about the various distributed information resources.

This paper discusses a variety of developments and trends that the author considers significant in the provision of economic, efficient, pervasive and user friendly information services. Topics discussed include the ARPA-Internet, office automation, electronic mail, network interconnection and routing, integrated directories, protocol performance, packet voice and integrated networks.

INTRODUCTION

Computer and communication technology is rapidly advancing. Many new information applications are coming to reality; electronic mail, videotex access to remote data bases and electronic funds transfer (EFT) to name some of the most important. To bring the information age to the user a large number of different systems and communication procedures must interwork efficiently. In particular, standardised application protocols are required, different communication networks must be interconnected, and a good on-line directory service is needed.

There are many important technological developments that will contribute to the information age. This paper discusses several topics that the author considers important. Most of the thoughts are a result of the author's experience while working at the University of Southern California Information Sciences Institute (ISI) in Los Angeles. ISI is a computer science research institute that has been involved with the United States Defense Advanced Research Projects Agency (DARPA) in developing advanced information technology. DARPA experience is used throughout to indicate future trends in commercial information networks.

The paper discusses the ARPA-Internet, office automation experience at ISI, electronic mail, computer communication network interconnection and routing issues, integrated directory services, performance issues, packet voice and video, and some anticipated trends in integrated networks.

Because of the benefits available information terminals will become as ubiquitous as the telephone. The first area where this will occur is in the office.

Electronic mail will have a large impact on the way people conduct business and will produce great improvements in efficiency. Some migration of telephone traffic to electronic mail can be expected.

In order to make information services widely available the many different private and public networks must be interconnected. In many cases large networks will be interconnected at a variety of points so that advanced routing strategies will facilitate fault recovery and network expansion.

Given a large number of distributed information resources such as people, computer mailboxes and data bases, it is essential from the user's viewpoint to have a friendly scheme for naming the resources and a good directory service for retrieving information about them to facilitate communication.

Many of the current international standardisation activities in new information applications are concerned mainly with the logical operation of new services and not as much with their performance. Once trial services are implemented, performance will become a major concern. Performance affects both the users' acceptance of new services and the economics of providing the service.

With the developments of the Integrated Service Digital Network (ISDN) customers will have access to a wide range of information services from a single access line. However, a variety of networks will then be available such as the circuit switched digital telephony network and packet switched data networks. In order to more economically use such alternative network resources, new developments will occur to integrate the various applications onto a single network. This is leading to investigations of packet voice and packet video switching and transmission techniques.

THE ARPA-INTERNET

The ARPA-Internet includes more than 900 host computers and 100 computer networks, all interconnected for a variety of resource sharing applications. The networks and computers are operated by U.S. Department of Defense establishments and DARPA contractors, which are typically universities, research institutes and corporations which are developing information technology.

The computers come from a variety of vendors, and range in capability from personal to main frame computers. There are also many different network types from numerous vendors. The major wide area networks are ARPANET, a 56 kbit/s terrestrial network which spans the United States, and SATNET a 64 kbit/s transatlantic satellite network interconnecting the USA and Europe. There is also an experimental wideband (3 Mbit/s) satellite network, WBNET, which spans the United States. These networks interconnect a variety of local networks, including rings and buses, and a packet radio network of mobile hosts. There is also a gateway to TELENET, a public network, which interconnects with other international public networks.

The main user applications operating over the ARPA-Internet are mail, file transfer and remote terminal access. These have been operational for more than 12 years, although their specifications and implementations have evolved. The ARPA-Internet is a realisation of the objectives of Open Systems Interconnection (OSI) currently being pursued by ISO (International Organisation for Standardisation) and CCITT (International Telegraph and Telephone Consultative Committee). But, as the DARPA protocols were developed earlier, they are different from the ISO standards.

ARPANET is the major wide area network around which the ARPA-Internet has grown. It was originally conceived to enable the sharing of remote computer resources including the ability to access remote data bases, files and special purpose computing facilities, and to utilise computers in different time zones for load sharing. Today, computer mail has become the dominant application, yet this was hardly mentioned in the initial plans and not foreseen as a significant use. But once early systems became operational, as early as 1972, its use spread rapidly. Thus as it turns out, human ideas are the main resource that is shared.

Mail is of great benefit in enabling co-operation between distributed project groups. Most of the DARPA projects involved many different organisations. Nationwide special interest group mailing lists facilitate discussion on particular design issues, protocol implementations and problems, and specific computer systems, plus many more. Queries to such lists can be used to rapidly access many of the experts in the USA There are mail links between the DARPA mail network and many other mail networks such as CSNET (U.S. Computer Science Network) and UUCP (Unix network) which in turn are connected to ACSNET (Australian Computer Science Network).

Two other very useful user services are WHOIS and FINGER. WHOIS accesses a centralised directory to retrieve information about human users, such as organisation affiliation, electronic mailbox, postal address and telephone number; and information about computers, networks and organisations, such as contact people. FINGER allows the current status of any user on an ARPA-Internet computer to be remotely determined. The information typically includes last login time, last time mail read, last mail item received and the contents of a user's "plan" file which allows a user to leave a message about his activities or time away from the office etc.

OFFICE AUTOMATION

The University of Southern California Information Sciences Institute is one of the many organisations attached to the ARPA-internet.

Trends in office automation are typified by developments at ISI. This section describes the information processing facilities at ISI, the way people utilise these facilities and some future developments.

Information Processing Facilities

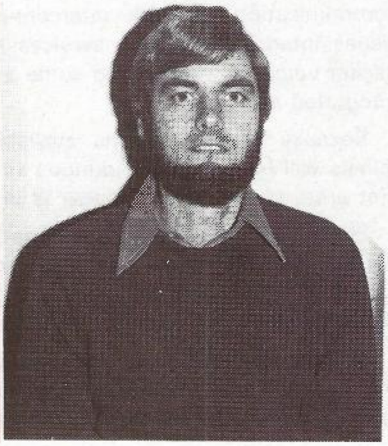
The majority of ISI's information processing is provided by centralised time-sharing systems that are interconnected via local area networks and the ARPA-Internet.

Both clerical and technical staff have computer terminals, and the majority of staff have terminals, provided by ISI, at home as well.

High quality laser printers provide letter-quality hardcopies.

Many of ISI's computing facilities, are presently overloaded. With such a large dependence on computing resources the cost of waiting for service on a large time-sharing system can be quite high. It has been decided that the most cost effective solution is to evolve towards a new computing environment that will consist predominantly of personal workstations interconnected by high speed local area networks (LAN) to shared print servers, file servers, mail servers and gateways to external resources. This is a result of processor and memory costs dropping far more rapidly than the cost of mass storage and output devices.

PAUL KIRTON received the B.E. and Ph.D. degrees in Electrical Engineering from Monash University in 1974 and 1981. He joined the Switching and Signalling Branch of the Telecom Research Laboratories in 1978. Until 1982 he worked on microwave and linear-phase filter design, monitoring instruments for computer controlled telephone exchanges, protocol specification techniques and Open Systems Interconnection protocols. From 1982 to 1984 he worked at the University of Southern California Information Sciences Institute under a Telecom Development Award. While at ISI he worked on name server and gateway projects. He is currently a Principal Engineer with the Data Switching Section where his research interests include computer network interconnection and advanced packet switching.



Personal workstations provide graphics as well as text so complete documents can be prepared easily.

The possibility of having a preferred workstation was considered but was finally rejected as no single workstation could best meet the needs of communication program development, artificial intelligence research and document preparation. A variety of workstations will therefore be selected, however, they will be required to interwork using DARPA protocols. This support will need to be available from the supplier or a third party, or ISI will have to do the development.

A high speed packet interface is most appropriate for access to servers as there are many simultaneous users and much of the connect time for file transfer and mail access can be the user thinking. When a file is transferred a low delay is required. Also, non-blocking access, possibly with delay, is required. Thus interconnection via a high speed LAN is more appropriate than via a digital circuit switched PABX.

The trend to personal workstations and shared servers interconnected by high speed LANs is occurring throughout the United States. For example, at the Massachusetts Institute of Technology there were 400 hosts interconnected by 40 LANs in 1984, but by 1990 they expect to have 10,000 hosts and 200 LANs.

From the User's Viewpoint

Local and nation-wide application services at ISI include electronic mail, file transfer and remote terminal access, WHOIS directory service and FINGER. Computers connected to the ARPA-Internet anywhere can be accessed. Most computers have public access accounts to make public files and programs available. These facilities enable the sharing of computer programs and resources, and co-operative developments by geographically remote parties.

Having accounts on several computers is beneficial if one is scheduled to be down for routine maintenance. Files can be transferred to another so that work can proceed without undue interruption. Output can be sent to the printers from most machines.

Almost all internal mail is electronic. The majority of external mail, and document and program transfer is electronic. Mail can be received at any machine and will be forwarded automatically to the user's nominated mailbox.

Extensive use is made of electronic mail internally for general queries and announcements. Electronic mail means fast message delivery, messages can be received by people working in remote locations or at home, fewer attempts to contact people by telephone and fewer interruptions as non-urgent requests can be deferred to a convenient time. Telephonists and secretaries also have terminals, so telephone messages are easily forwarded and clerical requests conveniently submitted.

There is no typing pool. Reports are composed directly on the author's terminal. Project assistants provide clerical and typing support if needed. Their work variety and skill level is therefore greater than a pure typist's.

Electronic mail is also used for project co-ordination. A report on ARPA-Internet research and development activities is prepared monthly. Contributions are submitted from throughout the network to ISI, by more than 10 organisations and the final report delivered to all people on the electronic mailing list with an overall delay of only a few days.

Extensive use is made of an electronic bulletin board for making announcements. Because it is so easy to post and read messages, electronic bulletin boards are more readily used and are more effective than hardcopy bulletin boards. The bulletin boards are accessible by electronic mail so that people at other organisations can submit messages to ISI's bulletin board.

There are also many special interest group mailing lists, both locally and nation-wide. Topics include project developments; new computer and workstation developments; communications and network developments; plus several more general topics such as music and science fiction.

Most documents and manuals are available in electronic form. If new manuals are required, good quality copies can be printed on a laser printer.

A key requirement to be able to use electronic information efficiently is an on-line directory. Library catalogues are available on-line. There are also on-line diaries of events and seminars, staff information lists, and telephone and computer directories.

Future Developments

Smarter user interfaces are currently being developed. Workstations will eventually be able to accept natural language requests in either voice or text form.

User applications such as electronic mail and calendar need to be able to interact. For instance, it is desirable to be able to send a message to all people attending a meeting noted in a user's calendar. These topics are currently being investigated at ISI.

New applications involving voice such as voice messaging, voice annotation of documents, and voice input to terminals will require integrated voice and data terminals.

NEW INFORMATION SERVICES

Many new information services are now being offered or under development for public use. I believe the most significant will be electronic mail, remote database access, such as provided by videotex, and electronic funds transfer (EFT). This section discusses some of these services.

The vast majority of Australian homes have a telephone and television. Considering this and the falling cost of home computers we can expect all offices and almost all homes to eventually have intelligent terminals for accessing new information services.

Extensions to Electronic Mail

Many of the advantages of electronic mail have been discussed above.

Electronic mail will evolve from text to mixed mode formats including images, graphics and voice. I believe point-to-point document exchange services like Teletex will be incorporated into electronic mail. This is because of the greater versatility of electronic mail whereby the user can send a message independent of whether the recipient's terminal is active. Facsimile will be used as a means of converting hardcopy documents into electronic form but will generally be sent within an electronic mail message. Messages could be printed on local facsimile machines or laser printers, after appropriate processing.

At ISI, a multi-media electronic mail system has been developed and is currently operational. Mail messages may include text, voice or bit-map images. Appropriate conversion facilities are provided for converting between facsimile and bit-maps to facilitate the inclusion of documents from hardcopy form. Multi-media mail is particularly important with the trend toward bit-mapped display terminals with graphics capabilities, and integrated workstations with both voice and data facilities.

Electronic mail has very broad applications. Documents can be rapidly exchanged. It can also be used for queries and requests that do not require immediate response. Examples include querying an account; requesting information such as an insurance proposal, which avoids waiting for service while telephone lines are busy or locating the appropriate person; delivering accounts and invoices, which can then be paid via EFT; or ordering products or spare parts.

New applications can be built on top of electronic mail. For example, the DARPA custom integrated circuit design service is implemented above the electronic mail system. Users can query the status of their designs by electronic mail. The queries are automatically answered without the need for operator intervention. This service effectively uses the electronic mail as a data transport service. Electronic mail has the greatest penetration of DARPA data services and the greatest interconnection with non-DARPA services.

The use of electronic mail will cause a migration of some traffic from the postal service and the telephone service. The number of electronic mail messages will probably exceed the number of telephone calls once there is wide penetration.

Significant use of electronic mail will have an impact on the characteristics of public networks and in particular the dimensioning of future ISDN's. Electronic mail messages are generally fairly short (less than one typed page) hence call holding times are short compared to telephone calls. For example, a typical one page message would take less than half a second to transmit at 64 kbit/s.

Other Information Services

Remote data bases will provide up-to-date information both internal to a business and externally. Electronic databases will provide classified advertisements. For example, if you are looking for a car and know the model, price range and age range, you can specifiy this and only receive those advertisements that meet your requirements. Telephone directories, travel time tables and entertainment programs will also be electronic. Educational material such as encyclopaedias will be available electronically from libraries. There will also be new public service information data bases that could assist people in selecting things as diverse as schools and physicians.

In the retail market with the introduction of efficent EFT systems far more purchases can be expected to be done electronically than are currently done using credit cards.

Home terminals will also be used to access business computers by people now able to work from home for an increased portion of time. After hours use will increase as many people who previously arrived home late may now have the option of continuing work at home.

Another important domestic information market will probably be entertainment. Many video games could be played by remote participants across a network.

NETWORK INTERCONNECTION

The above considered some new information services and their use in the local environment. To gain the maximum benefit from these services they must have wide penetration. Many information systems will be attached to different networks, including local area networks, wide area private networks, national public networks and international public networks. To achieve full user access to information services the various networks must be interconnected.

The proliferation of local area networks and personal computers is resulting in a change in the typical communication topology. Whereas wide area networks, like ARPANET, mainly connect directly to hosts and terminals, the trend now is for each organisation to have several local area networks which interconnect their hosts, and a gateway to the wide area network for external communications. This trend has rapidly increased the number of networks that need to be interconnected and consequently, the number of gateways.

Another change is the introduction of alternative wide area networks, such as satellite networks, as well as terrestrial networks. These often have different characteristics such as delay and throughput capability.

Currently, one of the main areas of concern within the DARPA community is ensuring that the ARPA-Internet can cope with this expansion in a manageable way.

ISO and CCITT are also very concerned with network interconnection. They have defined a global Network Service (Ref. 1) as part of their Reference Model of Open Systems Interconnection (Ref 2). The Network Service may be connection oriented (Ref. 1) or connectionless (Ref. 5). For the connection oriented case a virtual circuit is first established which preserves the sequence of packets. In the connectionless case each packet is independently routed as a datagram.

If two networks provide a consistent functional service, but not necessarily a consistent quality, they can be interconnected by gateways. ISO have structured the Network Layer of the Reference Model into three possible protocol sublayers to facilitate network interconnection, as shown in Fig. 1 (Ref. 3). Not all sublayers will necessarily be present in a particular implementation. The first, the Subnetwork Access Protocol (SNAP), provides access to a particular subnetwork; the second, the Subnetwork Dependent Convergence Protocol (SNDCP) enhances the subnetwork functions up to some standard service, but is dependent on the particular subnetwork; and the third, the Subnetwork Independent Convergence Protocol (SNICP) brings the network functionality up to the global Network Service, but is based on some other standard service and not the characteristics of a particular subnetwork. In the case of a gateway, the third sublayer also includes Routing and Relaying functions to provide

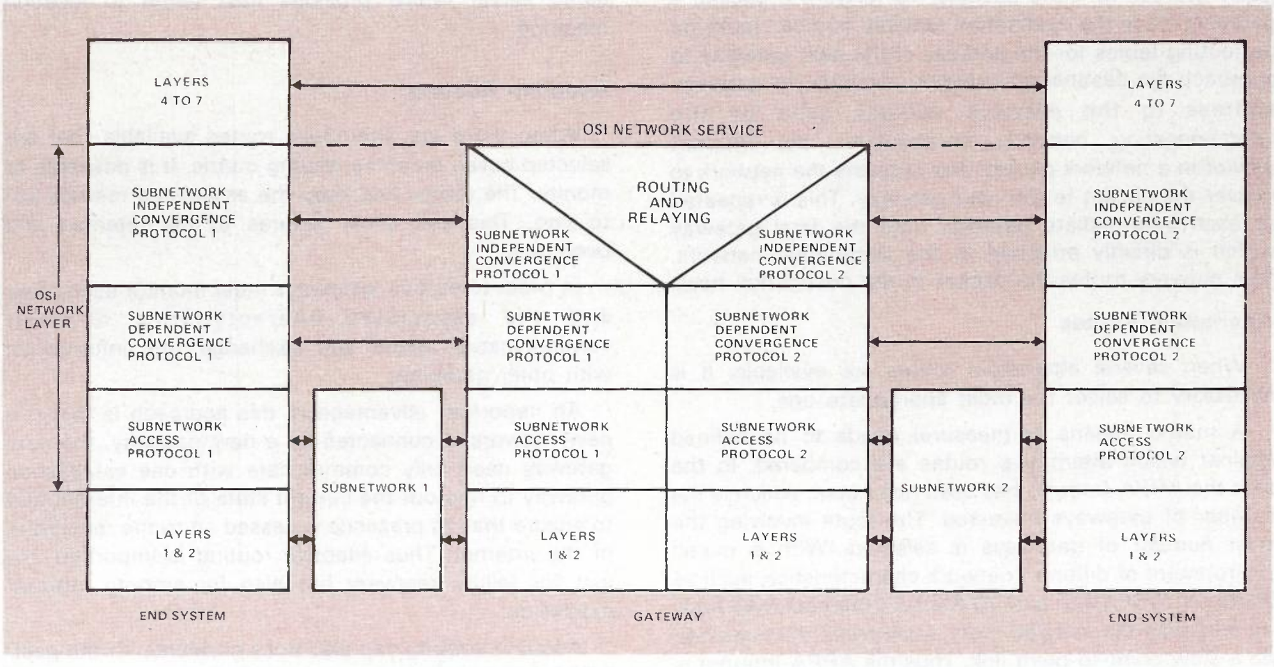


Fig. 1 — Subnetwork interconnection and gateway structure

information forwarding and routing between interconnected networks.

As an example, consider the provision of the Connection Oriented Network Service above a datagram (or connectionless) subnetwork, such as used in the Canadian Datapac network. The SNAP is a datagram protocol, a subnetwork specific protocol (SNDCP) is used to provide CCITT X.25-1980 packet level service, and an ISO SNICP (Ref. 4) is used to provide the full Connection Oriented Network Service above X.25-1980. X.25 has been enhanced in the 1984 version to meet the requirements of the full connection oriented network service, mainly by the inclusion of extended addressing information in the facility field, extended interrupt packets that allow 32 octets of data, call progress signals, and multilink procedures. In the above example, if the SNDCP provided X.25-1984 service, an SNICP would not have been required.

To provide the Connectionless Network Service, the ISO connectionless network protocol (Ref. 6) could be used as a SNICP. A SNDCP would not be required as the connectionless network protocol assumes minimum functionality from the subnetwork. The ARPA-Internet uses a connectionless mode of interworking. The ISO connectionless network protocol was derived from the DARPA Internet Protocol.

The primary difference between a gateway that interconnects computer networks and a terminal host is internet packet routing. Other important gateway functions are packet fragmentation and congestion control, and possibly protocol conversion. As internets expand the effect on routing is of particular concern and is considered further below.

Different networks may have different addressing schemes. ARPA-Internet addresses are 32 bits, Ethernet addresses are 48 bits, and CCITT X.121 addresses are 14 decimal digits. ISO is developing a standard for address specification that allows a variety of network address formats (Ref. 7). Internet routing is facilitated if there is a global internet addressing scheme which is mapped to the appropriate network addresses by intermediate gateways. The mapping between different addressing schemes is often called address resolution and is a network layer directory function.

Different networks may have different maximum packet sizes. Thus packets that are too large for a particular network must be fragmented into smaller packets by the connecting gateway.

Congestion control is usually simpler when connection oriented networks are interconnected as the flow control mechanism of the network layer protocol can be applied on a per virtual circuit basis. This will result in flow control propagating back to the appropriate source application process. In the connectionless case, special source quench control messages can be returned to source hosts. Appropriate adjustment of transport protocol parameters will then help. But it is more difficult to identify an offending host and it is up to that host to determine the offending application process. Gateway congestion can result from a misbehaving host that does not correctly respond to source quench messages. The DARPA community are currently researching improved methods of internet congestion control.

Internet Routing

Internet routing in the ARPA-Internet (Ref. 8) is done by gateways connecting different networks. It is independent of the routing between two gateways which is done by the interconnecting network's own routing algorithm. Thus there are two levels of routing decision, network routing which is confined to a single network and internet routing which selects a path via gateways that interconnect networks.

Each network has a network number which forms the first part of a global internet address of all hosts. The network numbers form a flat address space that the gateways use to route packets. To forward a packet, a gateway reads the destination network number, looks up its routing tables for the address of the next gateway to approach the destination network, converts the gateway address to the network address used by the interconnecting network, encapsulates the internet packet in a network packet, and requests the network to deliver the packet to the next gateway. This is repeated at each intermediate gateway until the final gateway which is directly attached to the destination network. This network routes the packet to the destination host.

Alternative Routes

When several alternative routes are available, it is necessary to select the most appropriate one.

A metric (means of measure) needs to be defined against which alternative routes are compared. In the past the ARPA-Internet has used hop count, which is the number of gateways traversed. The route involving the least number of gateways is selected. With a mixed environment of different network characteristics, such as 56 kbit/s ARPANET and 10 Mbit/s Ethernets, two hops via fast networks may be more appropriate than one hop via a slow point-to-point link. Thus the ARPA-Internet is planning to use delay as the main metric in the future.

Type of Service Routing

An internet can be a collection of networks of diverse characteristics, such as delay, throughput and error rates. For instance, wideband satellite networks typically provide higher throughput but larger delay than terrestrial wide area networks. Since traffic types differ in their service requirements internet routing needs to take account of more than one constraint depending on the type of service.

If information is maintained about multiple routing metrics such as delay, throughput or reliability, then separate routing tables can be calculated based on each or some combination. Thus packets can be forwarded over the most appropriate route according to the type of service indicated. This is being considered for the ARPA-Internet.

Network Partitions And Mobile Hosts

A network partition occurs when failures divide a network into two disjoint parts that are unable to communicate. It may be possible to route around such partitions via other networks. If routing is based on the destination network alone this cannot be achieved, as the different parts need to be differentiated. An alternative approach is to use gateway-based routing. In gateway-based routing each host associates itself with a gateway that it can communicate with. If internet routing uses this destination gateway rather than the destination network, network partitions can be routed around. One penalty of gateway-based routing is that routing tables are generally larger. Gateway-based routing is going to be used in part of the ARPA-Internet in future, as the military is concerned with robustness in a hostile environment. This approach is not being considered by CCITT or ISO.

Gateway-based routing is also more appropriate for mobile hosts. Rather than a host considering itself part of a network, it associates itself with a gateway. If the host moves out of communication range with that gateway it associates itself with a new gateway with which it can communicate. The new host location is advised to the name server which provides host name to location mapping.

Adaptive Routing

When there are alternative routes available that are selected based on some routing metric, it is desirable to monitor the routes and keep the associated metrics up-to-date. This will allow failures to be detected and overcome.

In order to do this, gateways must monitor each other and the associated characteristics of their communication paths and exchange this information with other gateways.

An important advantage of this approach is that if a new network is connected by a new gateway, the new gateway need only communicate with one established gateway to find out the current state of the internet and to ensure that its presence is passed on to the remainder of the internet. Thus adaptive routing is important not just for failure recovery but also for smooth internet expansion.

Adaptive routing can also pose problems. In the past, ARPA-Internet gateways monitored all other gateways on a common network. Thus, the gateway-to-gateway message overhead increased as the square of the number of gateways, which caused problems as the internet expanded. Under the new scheme only "next-door" gateways will be monitored and these will just pass on changes to other gateways.

Another problem is routing loops. If a failure occurs on a route and an "alternative" route is selected which also depends on the failed equipment, a routing loop can result. The current ARPA-Internet routing algorithm updates its routing information based on routes computed by its neighbour gateways. Thus, the presence of the failed equipment in this route cannot be known. Under the new algorithm, gateways will compute routes based on a complete knowledge of all gateways along the route. Thus routing loops will not occur. This is a similar approach to the new ARPANET routing algorithm (Ref. 9).

Exterior Gateway Protocol

Under the old ARPA-Internet routing algorithm any new gateway could immediately commence routing information exchanges with other gateways without prior authorisation. Faulty new gateways could easily cause erroneous routing information to be propagated throughout the internet. Thus some form of access control and a means of filtering suspect routing information is required. Also, the participation of gateways of different designs and maintained by different organisations in a common routing algorithm makes fault isolation and protocol changes difficult.

For these reasons, gateways have been divided into autonomous groups which are managed by a common organisation and use their own interior routing algorithm. Routing information to allow full internet connectivity is exchanged with other autonomous gateway groups via an Exterior Gateway Protocol (EGP) (Ref. 10, 11). EGP has an establishment phase which facilitates access control. EGP exchanges need only be conducted with one gateway of a different autonomous group sharing a common network. This reduces the route management traffic.

Future Routing Between Private and Public Networks

Public networks do not at present provide flexible routing procedures for private network interconnection. In general, each private network interface is treated as if it was a single host. But this is changing. The following discussion draws on DARPA experience to suggest some possible future advances in private/public network interconnection and routing.

There are many different topological arrangements for private and public network interconnection. In the case of a LAN, there will usually be only one point of interconnection with a public network. Thus a single public network interface will be used for routing all calls to the private network. In the case of large private networks, there may be several points of interconnection with the public network, such as in different cities, or in the same city for load sharing. In these cases several different public network interfaces can be used for routing calls to the private network.

Addressing in public data networks is specified by CCITT Recommendation X.121, but this only provides the address of an interface to a public network. **Fig. 2** shows the breakdown of an X.121 address into a four digit Data Network Identification Code (DNIC), which identifies one network from the global community of public networks, followed by a Network Terminal Number (NTN) of up to 10 digits to identify a particular public network interface. Typically, the NTN will include an area code to facilitate routing. The 1984 version of X.25 for accessing public data networks by packet terminals allows additional source and destination terminal addresses to be included in the Call Request Packet facility field. Thus, when routing to a private network, the public network interface address will be used in the destination address field and the terminal address will be used in the facility field.

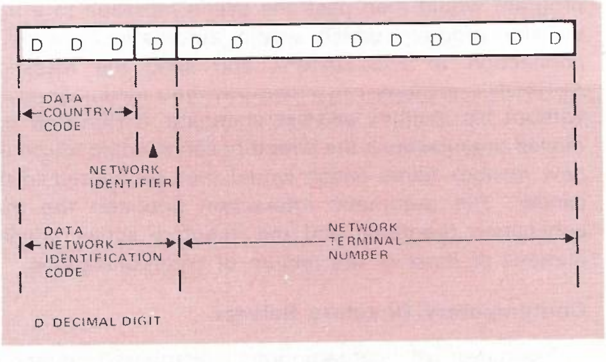


Fig. 2 — CCITT X.121 Address structure

There are different ways to identify private networks. In the case where a private network is attached to a public network in only one place it is simplest to use the X.121 interface address to identify the private network. If there are multiple public network interfaces, it is desirable to assign a single network number to identify the private network. The ISO Network Layer addressing standard (Ref. 7) has a subset that permits non-geographic, organisation-based addressing which could be used for large private networks.

In order to route calls to a private network with multiple public network interfaces, the appropriate public network interface address must be determined from the destination address information. In the case of geographically diverse interconnection points the closest operational public network interface would typically be selected to minimise the use of public network resources. This selection depends on the location of the source. If the interfaces are co-located for load sharing or reliability purposes, quality of service requirements may be a basis for selection.

When there are multiple interconnections to private networks and a failure occurs on the preferred route, it is desirable to be able to route to an alternative interface. To implement these types of routing decisions requires up'to-date information about the status of gateways and the networks that are reachable beyond them.

In some cases, private networks may consist of several different interconnected private subnetworks with different private network numbers. In order to minimise the use of public network resources it may be desirable to be able to select the nearest public network interface to any of the subnetworks when routing to any other of the subnetworks.

When routing to a private network via concatenated public networks the public network routing is based on the X.121 DNIC in the destination address of the Call Request Packet. In the case of international connections it is desirable for the call to be first routed to the destination country where a public gateway would examine the full destination address in the facility field in order to select the exit public network interface address. To implement such a scheme a special NTN needs to be chosen to indicate that only the DNIC is significant and that the full destination address is included in the facility field.

To make the flexible routing decisions described above, up-to-date routing information is required. In the ARPA-Internet all gateways maintain full routing information about all networks. This is required to provide adequate response in a connectionless environment. In the public network case where virtual circuits are used, a distributed internet routing server could be satisfactory. Hosts and gateways would query the routing server when they set up an internet connection. The results could be cached (temporarily stored) for a period of time so that subsequent connections to the same destination would not incur the extra delay. Only routing information about frequently used routes would therefore need to be stored, thus considerably reducing the size of routing tables. The internet routing service could consist of several distributed servers. These would maintain up-to-date routing information by periodically monitoring gateway interfaces, accepting messages from private networks about preferred routes, and exchanging routing information with each other. This would allow the internet to adapt to failures as well as the introduction of new gateways and networks. As all gateways do not exchange this information, the amount of route management traffic can be controlled.

If a gateway or host uses cached routing information and the connection request fails it could then contact the routing server to check that the route is still current. Timeouts on cached routes would ensure that the preferred route is eventually reverted to after it comes up.

As different gateways may be maintained by different organisations appropriate access controls will be required for routing information exchange. The separation of function provided by the Interior/Exterior Gateway Protocol approach of DARPA may be appropriate.

INTEGRATED DIRECTORY SERVICES

The previous section discussed several issues related to the interconnection of computer networks to allow distributed information resources on different networks to communicate. Before communication can be initiated with any resource its address and possibly other information need to be determined. For instance, with the increasing use of electronic mail there will be vast numbers of mailboxes. In order to send a message we need to know the appropriate computer supporting the mailbox, its address and the particular mail protocol it supports. An efficient on-line directory service is required to provide such resource information.

As the number of computers, computer networks, and network interconnections increases, so does the number of shared resources, such as hosts, mailboxes, file servers, and data bases with which communication is possible. A uniform naming convention is required to unambiguously identify these resources within the directory service. Because the directory service associates resource information with resource names it is sometimes called a name service.

With the transition to the ISDN, customer access to services will be integrated. Many offices and homes will have terminals for computer or videotex access. It will be desirable for public networks to provide an integrated on-line directory for all their services. Such a directory service should be provided in a consistent manner for various services, such as telephone, telex and data, so users see a consistent interface.

With different organisations being responsible for different resources, it is difficult to ensure that the information in any central directory of resources is current. Thus, it is preferable if each organisation provides an up-to-date directory service for its own resources. The directory service provided by public networks also needs to be distributed on a geographical basis to reduce cost and improve performance. User agent programs in user hosts access the distributed directory service on behalf of applications. A user agent and the various distributed directory servers need to be able to co-operate with each other to determine which directory server is responsible for the required information. The structure is shown in **Fig. 3**. For example, when contacting a large organisation like a university, their on-line directory would be accessible in the same manner as the public directory. In the case of a telephone call, this would avoid the need to first contact a central operator.

This directory service is different from the routing service discussed in the previous section. The directory service associates resource information with the name of each resource for use by end systems, whereas the routing service associates routing and intermediate

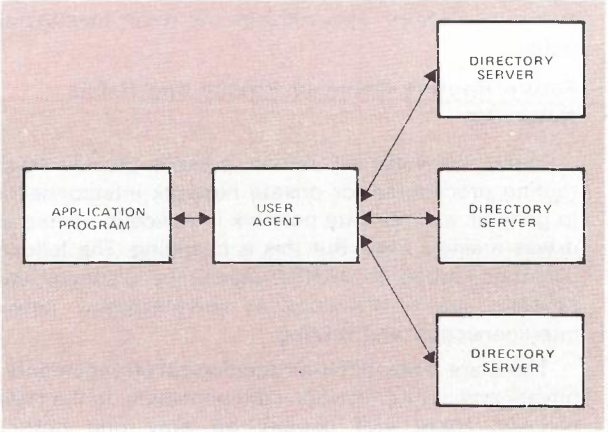


Fig. 3 — Distributed directory service structure

addressing information with destination addresses for use by the internet.

Names provide a friendly means for human users to refer to resources. It is easier to remember a natural language name for a computer than its 14 digit X.121 address. Names also allow applications to delay the binding (association) of resources with their locations. Applications refer to resources using names that are bound, by contacting the directory service, only when the application needs to access the resource. Since this binding is performed just before the resource is used, the application always uses the most up-to-date binding. This means that application software need not be changed when a resource is moved.

For example, to send mail to PERSON at ISI, whose mailbox is on the ARPA-Internet, the only address required to be supplied by the human sender is PERSON@ISI.ARPA, which is quite easy to remember. The user interface mail program then contacts the directory server automatically to determine that the mailbox is on computer F.ISI.ARPA, that its address is 167903284 and the mail protocol is DARPA SMTP (Simple Mail Transfer Protocol) by default. The user interface mail program would then pass the user's message to a mail transfer program which would automatically make a connection to F.ISI.DARPA and send the message. PERSON's mailbox can move between machines at ISI without his mailbox address changing. If PERSON had moved organisations the directory server could return the new mailbox name which would then be passed to the sender. The automatic interaction between the mail application programs and the directory server relieves humans of most of the tedium of communications.

Contemporary Directory Servers

Examples of contemporary distributed directory services are the Xerox Clearinghouse (Ref. 12), the DARPA Domain System (Ref. 13), the CSNET (US Computer Science NETwork) Name Server (Ref. 14, 15), and the International Federation of Information Processing (IFIP) directory service (Ref. 16). Brief descriptions of the last three are given below to illustrate the types of facilities provided.

The ARPA-Internet currently maintains a centralised host table of network addresses and other host information. Each host in the ARPA-Internet periodically makes a local copy of this table. Because the ARPA-Internet is large and complex, the size of this table and the frequency of updates is near the limit of managability. Also, under the present system, there is no universal scheme for distributing mailbox names. A distributed directory service called the Domain System is being developed. It defines a uniform, variable-level hierarchy for name syntax which is independent of resource type. For example a name may be of the form RESOURCE.SUB-DOMAIN.ORGANISATION.TOP-DOMAIN.

Hierarchial naming domains allow responsibility for naming to be distributed. Names can be allocated independently within a domain without regard for the names in other domains. Resource information retrieval is simplified because not all the name space need be searched. The DARPA system also defines a protocol for retrieving information about the resources. The information database is distributed among several directory servers. Each directory server includes pointers to other servers which hold different sections of the database. The directory servers communicate with each other to locate information. A user may request that the search be done by the directory service itself or may determine the location itself by using the pointers to closer directories returned by each unsuccessful request. As well as retrieving information about a known resource, the service allows partial names to be provided and all matching names to be returned to the user. Initially, the main information to be provided will include host internet addresses, mailbox locations, mail forwarder locations, mailing lists, and replacement mailboxes. The service will begin production service in 1985.

The CSNET Name Server provides information about human users. The system became generally available in 1983, and augmentation is underway. The basic service is a mapping from a person's name to a mailbox address. Other information is also included such as postal address, organisational positions and titles. Copies of the complete database are stored on two centralised redundant sites, with users requesting database alterations for their own entries. Because a person's name can be ambiguous, searches may include additional keyword parameters to resolve ambiguities. An abbreviated name capability is provided for each user within their user interface programs.

When sending mail a user need only supply the abbreviated name by which he personally refers to the recipient. The mail program automatically translates this into the full global address. If the recipient has moved, the mail program automatically queries the name server for the new address, updates the abbreviated mailbox address table and informs the user. The name server is accessible by electronic mail so that the name service is available as wide as the electronic mail extends. This includes many other mail networks such as the ARPA-Internet, the Xerox internet, UUCP (based on Unix protocols), BITNET (based on IBM protocols), and ACSNET (in Australia), which provide international coverage.

IFIP is developing a naming scheme and directory service primarily to support international electronic mail services. Names are composed of unordered components, where each component consists of a type and a value. For example, a business name may be of the form (Country = "US", Organisation = "Conway Steel", PersonalName = "John Smith"). By using unordered, optional, or redundant components, names are more user friendly. The directory service will name human users, mail distribution lists, and machine processes and will provide information to enable communication. The work of IFIP will form a basis for the development of CCITT recommendations for Directory Systems under CCITT Study Group VII.

With electronic directories security of the information and accuracy of the responses is an important consideration. For instance, if a directory query was intercepted and a false mailbox location returned, then mail could be intercepted.

Privacy is also of concern. With electronic access, people can readily get electronic copies of directory information such as for use in junk mail lists.

PERFORMANCE

With OSI protocols now standardised, much effort will be required to maximise their performance. Implementation guidelines will be desirable in cases where compatible strategies at both ends of a connection can improve performance, network performance information may need to be made available to end systems, and standards may need to be modified.

The ultimate measure of a protocol implementation is the performance achieved relative to the maximum achievable. With protocols designed to work under adverse conditions, it is easy for inefficiencies to be masked. Human users may not even be aware of this as they often do not know what to expect. Thus performance testing and tuning is an important responsibility of the implementer.

Overall performance of an application is affected by many things, such as network characteristics, host operating system features, how the protocols are structured in relation to the operating system, and the transport protocol flow control and retransmission strategy. In the case of transport protocols, performance can be improved if complementary implementation strategies are used by the two ends of the connection.

To assess performance, good monitoring facilities need to be built in from the start. In particular, error recovery actions such as retransmissions need to be monitored. It is preferable to set alarms when critical thresholds are exceeded as robust protocols mask errors from users. It is important to monitor the performance of internal network links as well as network interfaces and end-to-end protocols.

Performance has been a major concern of the DARPA community and they have gained much experience (Ref. 17, 18, 19, 20).

PACKET VOICE AND VIDEO

Great improvements are being made in voice and conference quality video compression.

CCITT has already standardised 32 kbit/s voice with comparable quality to the now standard 64 kbit/s voice, and is currently considering 16 kbit/s voice. Further transmission savings can be achieved by using digital speech interpolation (DSI) to utilise silent intervals. With a variety of voice digitisation rates and the use of DSI, packet switching, with its greater flexibility, may prove to be the most appropriate switching technique for voice.

Video compression techniques now give conference quality at 384 kbit/s and 64 kbit/s is anticipated in the 1990s. Instantaneous transmission rate requirements increase with the level of movement. Packet switching provides a means of varying the instantaneous data rate and hence should be able to produce improved video quality for a given average data rate.

ADVANCED INTEGRATED NETWORKS

With the advent of ISDN, a single customer access line will provide access to a variety of information services. Initially both circuit and packet switched networks will be used. Circuit switching is still the most economic approach for 64 kbit/s voice which will be the dominant application for many years. But packet switching is the most economic approach for interactive data applications. For instance, many interactive data applications may have average data rates of only 100 bit/s yet require peak data rates of 100 times this during the transfer of a full page of information. This would result in very poor utilisation of a circuit switched 64 kbit/s channel as used in the digital telephony network.

There are economic advantages in integrating all information transfer, including voice, onto a single network. Advantages are economies of scale in providing networks, the need for only a single network management strategy and the need for less total network capacity as traffic peaks occur at different times for different services.

In future, with the increase in variety of user services, particularly data applications; the bursty nature of interactive data, voice and video conferencing traffic; the low effective transmission rates of interactive data applications; and the variety of voice coding rates it is possible that the most appropriate and economic method of integrating voice, data and video conferencing into the telecommunications network will be by packet switching and transmission.

Today's packet switched networks are unsuitable for voice and video applications because their end-to-end delay is too great and they usually use link-by-link error recovery procedures. The main source of delay is queuing and link transmission delay. If trunk transmission rates are increased from around 50 kbit/s at present to 2 Mbit/s, delay should not be a problem. With optical fibre links error rates should be such that end-to-end error recovery techniques will be sufficient for applications requiring high accuracy. This will simplify packet switches and make the internal network service application independent. These developments along with developments in high capacity multi-processor packet switches may make packet switching the most appropriate method of providing the range and type of network services required by future information applications.

CONCLUSION

The information age has exciting prospects for making new and more convenient services widely available. To achieve this, many different systems will need to interwork in a compatible manner and on-line directory services will be required to store information about the various distributed information resources.

New methods of office working and interaction will come about and new services such as electronic mail will take some of the traffic from existing services like the telephone and post.

Of particular importance is the need to interconnect different communication networks. The development of advanced routing strategies will facilitate private network interconnection, alternative routing for reliability, and internet expansion.

New developments are required to achieve true integration of voice, data and video conferencing services on a single network.

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HEWLETT-PACKARD MODEL 410A VACUUM TUBE VOLTMETER

(Manufactured in Palo Alto, California)

This unit was one of four voltmeters sold by John Warmington to the Postmaster-General's Department Research Laboratories in 1949.

At that time he was a salesman for George Sample and Sons, which had just taken on a distributorship for the fledgling American company, Hewlett-Packard.

Little did John Warmington know then that he would go on to set up and head an Australian subsidiary of HP, stepping down as the company's managing director in 1981.

The voltmeters were to become a major electronic measuring instrument, and those purchased by the PMG 36 years ago are today still in service at Telecom Australia.

TYPE 84 EQUIPMENT PRACTICE

'The move from analogue transmission and exchanges to the new digital technology includes the redevelopment of the Line Transmission Construction Practice.'

Making this statement, Rodney Reynolds, Engineer Class 5, Design Standards, Line Transmission Branch, HQ, said that by replacing the Type 72 practice introduced some 15 years ago, the new Type 84 practice provides a general uniformity of transmission equipment accommodation.

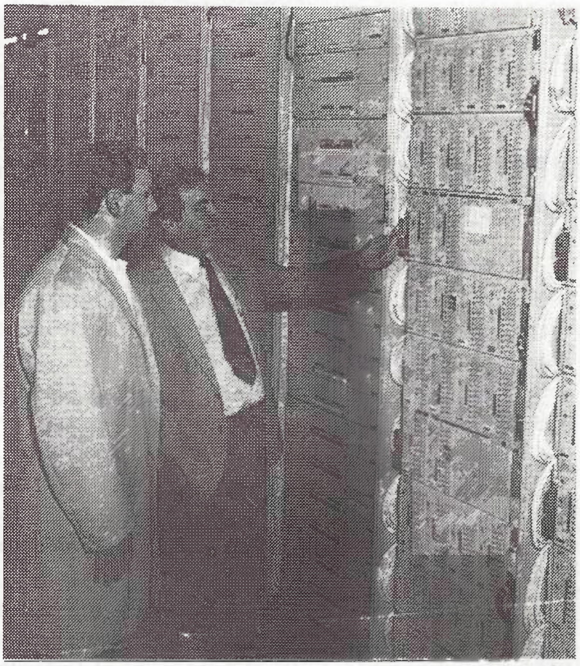
'It sets new standards for equipment mounting, cabling, power and alarms which is expected to satisfy Telecom's needs well into the 1990s,' he said, pointing out that as digital transmission has developed over the last few years it has proved to be rather different in physical form and ancilliary requirements from the equipment the new technology replaces.

'Digital equipment produces more waste heat and has an increased cabling volume. Greater integration with the exchange equipment and the need for higher technical performance compounded problems that were experienced when the earlier Type 72 practice was used.'

Mr Reynolds stated that so extensive were the needed modifications to the Type 72 practice that the resulting practice was given the title, Type 84. 'There has been a history of naming long line racks after the year of their conception or introduction or some significant two number digit. There have already been 19 inch, even though the actual size is larger, Types 52, 66, 72 and 74. Thus Type 84 fits nicely with the added tongue-in-cheek reference to George Orwell's noted work. Needless to say most of the basic development work was done during 1984.

'For the technically minded,' he continued, 'the Type 84 practice is centred on four main considerations. The most obvious feature is the rack system itself. There are two versions having different heights, 2750 mm for normal use and 2100 mm for use in restricted height applications such as RSS buildings and remote above ground repeaters. Both versions are about 10% deeper than Type 72 and the panels are off-set slightly providing up to 30% more cabling volume. The total equipment volume is about the same but the new panel depth is more convenient when internal ventilation is used.

'In some physical respects there is little difference between the two practices and with only minor inconvenience, the equipment designed for one practice could be used in the other. The practice operates



John Cairns, STO3 Line Transmission Branch, HQ, points out a detail on the existing Type 72 practice racks to Santi Isgro, Maintenance Technical Officer, at the Lonsdale exchange in Melbourne.

the equipment panels directly from 48 VDC instead of using 24V converters. The new system with its associated power and alarm panel is also arranged to operate directly from the Hi-ohmic power distribution system which is standard in the Ericsson AXE digital exchanges.

'The new power and alarm panel provides for the development of alarm and surveillance systems. A printed circuit board can easily be changed to provide the associated control equipment and there is sufficient space for a microprocessor based system if needed in future,' noted Mr Reynolds, adding, 'There are a number of environment changes. Individual racks will be able to exhaust more heat through the use of through ventilation and the overall limits will be building rather than equipment based. With the change to digital transmission the electromagnetic radiation limits will be reviewed to meet digital requirements.

'The Type 84 practice was developed in the Line Transmission Branch (formerly LTEC) within Headquarters in the Practices Section,' he said, noting that there were a number of developments occurring at present in the Line Transmission practices area towards standardisation of connectors and cables for example which in time will probably be called Type 84 practice.

'Since all development is towards the use of digital techniques, it can be said with some justification that digital transmission practice is Type 84 practice.'

Reliability of Electronic Telecommunications Equipment

J. R. TAYLOR — QE
Quality Systems Engineer

The sources of Reliability, and the Variability which leads to unreliability, are subjects of concern to all who work in telecommunications. The concepts of reliability and electronic component "wearout", as well as the "Chance failures" which lead to MTBF failures are discussed. The structure of the "bathtub" curve and its mathematical basis are treated along with some failure characteristics of Integrated Circuits.

What is Reliability?

Reliability is to many an abstract concept that usually means goodness of the item concerned. Goodness varies from person to person, and is not a suitable measure of reliability for engineering usage. Engineers, through the use of mathematical statistics, have given Reliability an exact meaning. Not only can it be exactly defined, it can be calculated, objectively designed and produced into items of equipment, as well as measured and verified.

Reliability, stated simply, is the capability of an item of equipment to continue in its operational mode without failure. When complex systems of equipment work well, and work each time they are called upon to carry out their intended functions, they are said to be reliable. Though reliable equipment should never fail in operation, experience shows that the best possible design, production and maintenance efforts do not completely eliminate the occurrence of equipment failures. We can categorize the types of failures of modern electronic telecommunications equipment into three classes. These are:

(i) There are failures which occur during the early part of an equipment item's operational life. These are called 'early failures' or 'infant mortality failures.' In most cases these early failures result from poor production or quality control techniques during the time the equipment was being manufactured. The complex system of controls designed, implemented and maintained by human beings can never be perfect. Even in the best of control systems some poor workmanship characteristics such as no-solders, cold-solders or short circuits, as well as the occasional sub-standard component, will filter through into equipment being produced.

Early failures can often be greatly reduced, and almost eliminated, by 'debugging' processes, or by 'burn-in' of the equipment. Burn-in programmes must be well designed to take into consideration the time spent during burn-in as this time will detract from the operating life of the components. A similar subtraction must be made from anticipated operational life of the equipment when 'power up' debugging practises are used.

(ii) The second class of failures are what we call 'Chance' failures. No amount of burn-in or debugging will remove the components with chance failure-causes in them. These failures are caused by random and often sudden stress accumulations or rises that exceed the strength of components in the equipment. These stress accumulations or raised intensities may stem from poor surface cleaning, mechanical structure, thermal fatigue, and marginal connections, as well as other causes.

No one can predict when chance failures are going to occur. We know, however, that these components will obey certain rules of collective behaviour permitting us to predict that the long term random failures will occur at a constant rate.

(iii) The third class of failures are what we call the wearout or degradation failures. These are caused by the 'wearout' of parts. Here many of us must adjust our views of the phenomenon of WEAR. We are accustomed to thinking of wear as something which results from abrasion in mechanical systems. In the semiconductors of the electronic component environment, as well as the non-active resistors, capacitors and joins, we have now to think of 'WEAR' as consisting of drift or shift in part characteristic values within some design-defined range toward non-operate limits. The parts are wearing, and once outside the limits are 'Worn Out'.

Electronic component wear may occur due to such things as high cyclic heat stresses, the presence of surface contaminant that progressively acts in a chemical way on the part, inadequate design derating factors for the part in the operating environment, or successive buildup of contamination from the active element environment. This environment may be due to leaks in the part housing or protective cover, or it may be due to an adverse environment enclosed with the part during manufacture, active elements of which continue to act on the device.

As infant mortality or 'early failure' components among the weaker members are replaced, other components have characteristics which continue to gradually 'Wear Out' with time and use. As their characteristics drift or shift closer and closer to the 'non-operate' limits for the parts, environmental stresses they withstood before are now too great, and these components begin to fail in much the same way 'Early Failure' components needed replacement during the early years of equipment use. In this way the 'Chance' failure rate continues to remain more or less constant during the entire life of the equipment.

Electronic parts wear, which occurs when a part characteristic changes value relative to some specified limit, is invariably traceable to changes in the solid state nature of the materials of the part. It is for this reason that the discipline of Engineering Materials Science has assumed so important a position in the understanding and control of reliability of electronic equipment. Studies show the older concept of fixed polycrystalline solids, unchanging throughout their lives, is grossly wrong. Surface atoms are constantly changing position, and concentrations of chemically active materials can develop and continue their activity throughout the component lifetime. From these material changes comes component wear, and the need for equipment maintenance.

From the above we see that Reliability is best expressed as a Probability of Success. It is obtained by selecting stable components, constructed appropriately of stable materials, and operating these under sufficiently low levels of stress, by derating, so that rates of characteristic change are acceptably low. Let us next consider the two principal failure density functions with which we are concerned.

The Failure Density Functions

Early Failures and Chance Failures comprise the first two classes of failure discussed above. When system burn-in and debugging have successfully accounted for the early failures, the chance failures remaining will usually be more or less constant for long operating periods. The reliability in this situation is defined as:

$$R_t = e^{-ft} \tag{1}$$

Where: R = the Reliability
t = the time interval in hours
f = the chance failure rate
e = the natural logarithm base

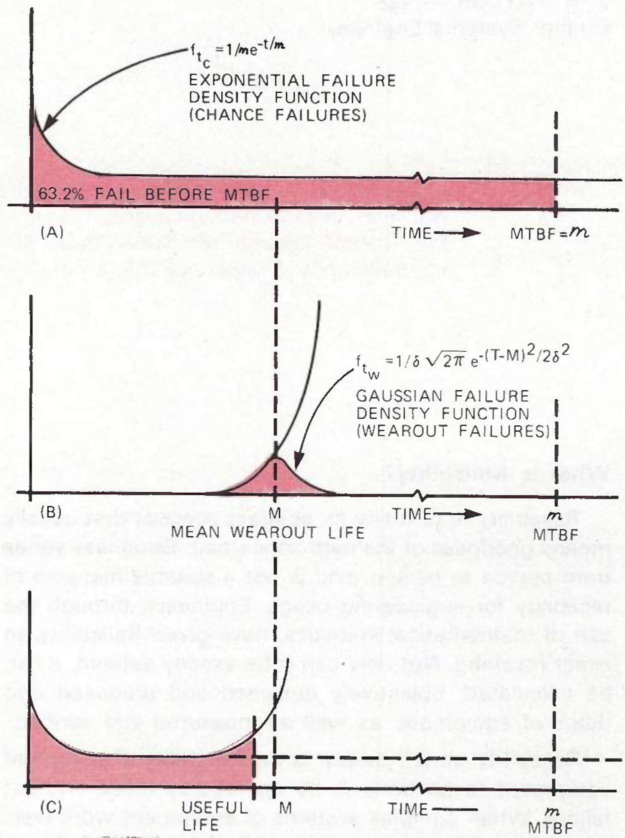


Fig. 1. Relatiionship between Failure and Useful Life.

There are two failure density functions which usually characterize the principal failure categories of interest. For the purpose of planning manpower, down times, and operational availability of systems it is essential to have information on the frequency of chance breakdowns. These type breakdowns may occur at any time from the beginning of life on through the operational life of the system. They will not, however, normally result in the ultimate failure and replacement of the system. Chance failures, therefore, do not determine the end of useful life.

JIM TAYLOR has been a professional Quality and Reliability engineer for the last 30 years. He obtained his tertiary education in Australia where he attended RMIT and the University of Melbourne. He has worked for more than 20 years in Engineering Design, Laboratory Management, and Engineering Management with U.S. Telecommunications and Electronics Companies before joining the Australian Post Office in 1972. He has been Telecom Australia's representative with the Standards Association of Australia where he is the representative on both Quality and Reliability. He is a Principal Engineer in the HQ Materials Inspection and Quality Assurance Section where he has designed, documented and established the Approved Firms Scheme and the Approved Inspection Scheme now in use. He is the author of the document, QA-4001 "Quality Assurance Systems for Provisioning Supplies".

Chance failures normally assume an exponential distribution according to the equation:

$$f_{tc} = 1/me^{-t/m} \quad (2)$$

Where: f_{tc} = Failure rate over time (t) for chance failures denoted by (c).
t = time
m = Mean Time Between Failure (MTBF)

As may be seen in **Fig. 1 (A)** the MTBF for an exponential failure density function occurs at 36.8% of the density magnitude on a time basis. From this we see that 63.2% of the chance failures take place BEFORE the MTBF time as denoted by M on the curve.

Not all failures are chance failures, and the class of system faults which characterize the WEAROUT of the system tend to conform to a Gaussian or normal failure density function. Wearout failures are caused by changes in the materials of the part or system which take place over longer time intervals as compared to chance failures that result from sudden or rapid change when strength is exceeded by stress. Wearout failure may be caused by progressive longterm stressing of parts near their failure point, gradually pushing the part characteristic value closer and closer to the non-operate limit where failure occurs. There are other wearout mechanisms however, including gradual chemical attack from contaminants, such as from residual or gradually built-up surface contamination, or from built-in stresses which gradually relieve themselves under the thermal operating environments established for the parts in use. These can be accelerated toward a shorter life by design operate temperatures of a higher nature; or the failure may become a chance failure when the cooling system fails and the part temperature suddenly surges upward.

Gaussian failure density functions take the normal bell shaped curve of **Fig. 1 (B)**. Though it is possible to conceive of a part where the mean (M) of the normal wearout failure density function will be greater than the value, in time, of the Mean Time Between Failures, (MTBF), this seldom occurs in practise. The reason is that we try in our components design and manufacture to push the MTBF as far outward as possible, in order to minimize the frequency of failure and amount of maintenance that will be required. In reliability engineering, the problem becomes one of seeking to minimise the frequency of chance failure, while prolonging the operate life as long as possible by reducing the rate of wearout.

We have been particularly successful in pushing the MTBF for modern electronic solid state components out in time. It is not uncommon to achieve demonstrable MTBF's for integrated circuits with small numbers of transistors and other internal components that are 500,000 to 1,000,000 hours, (57 to 114 years), when these parts are used in fixed positions in environmentally controlled buildings. These MTBF's fall drastically when the parts are used in mobile equipment, or in equipment subject to the full range of temperature and humidity cycles of the nation. Typically a component with an MTBF of 50 years in Melbourne, would have an MTBF of 12 years in Darwin when used in the same equipment installed in non-airconditioned buildings.

We have been far less successful, internationally, in achieving major extensions to the Wearout Life of electronic components, as compared to our success with their MTBF's. It is common to find that in mobile, or non-airconditioned operating environments, electronic solid state devices will have a wearout life of only some 10% to 15% of their MTBF. This means that an integrated circuit (MOS for example) where adequate care has not been taken in either its manufacture, or in its design derating and application environmental factors, can have a 50 year MTBF but can only be expected to continue giving satisfactory service for five years before it will wear out.

The above condition can be greatly improved by selection of components which have had proper controls throughout their design and production, which have had proper test programmes specified and carried out for them, screening out the weaker members before they are placed in use, and for which appropriate derating of stresses applied has been used in equipment designs. The importance placed on the use of strong Quality Controls during all phases of the component's manufacture and use may be seen in the U.S. Department of Defense use of Q L multiplying factor of 0.1 for the learning curve gone through by a production facility during the first year of its production of the part concerned. In the reliability model this reduces the wearout life to one tenth of its anticipated lifetime after the Quality Controls have been made operational.

In **Fig. 1 (B)** the normal failure density function has the mathematical equation:

$$f_{tw} = 1/\sigma \sqrt{2\pi} \exp(^{-(T-M)^2}/2\sigma^2) \quad 3$$

Where: f_{tw} = Wearout failure rate over time, t.
M = the mean of the wearout failure distribution.
T = actual wearout lifetime
O = the standard deviation for the normal wearout density function.

From the above we see that the mean time between failures MTBF of very good components operated in carefully chosen environments can be several hundred thousand to a few million hours. Seldom, however, will the wearout lifetime for discrete components be longer than a few tens of thousands of operating hours. In the case of Integrated Circuits we must think of these components as systems, for they typically contain thousands of components. We must expect that systems will have even shorter wearout lifetimes than will the individual components within them. We shall consider this further in **Fig. 4**.

In **Fig. 1 (C)** we see how the usual bathtub failure distribution curve is constructed as a composite of the exponential chance failure density function and the standardised cumulative failure curve resulting from the population of the Gaussian failure density function of wearout. Due to economic considerations preventive maintenance programmes must plan on replacement by the end of the 'useful life' time in order to maintain system availability.

Reliability Prediction in Telecommunications

Modern electronic telecommunications equipment uses a broad range of components which can be grouped into a relatively few classes, from a reliability viewpoint. The major classes are:

(i) Random logic semiconductor devices, with sub-classes being Hermetic Sealed, and Non-Hermetic Sealed.

(ii) Microelectronic semiconductor ROMs, with subclasses being Hermetic Sealed, and Non-Hermetic Sealed.

(iii) Microelectronic semiconductor RAMs, with subclasses being Hermetic Sealed, and Non-Hermetic Sealed.

(iv) Microelectronic linear devices, with sub-classes being Hermetic Sealed, and Non-Hermetic Sealed.

(v) Discrete Semiconductors, with sub-classes being Hermetic Sealed, and Non-Hermetic Sealed.

(vi) Resistors, with sub-classes being Fixed and Variable.

(vii) Capacitors, with sub-classes being Fixed and Variable.

(viii) Inductors (including Transformers).

(ix) Electromechanical (including motors, relays, etc.)

(x) Mechanical, active (switches, plug and socket, etc.) and passive, (Printed Boards, etc.).

(xi) Connections (Solder, Welds, Pressure, etc.)

(xii) Tubes, or Valves, etc.

There are a number of sub-sub-classes within most of the above major classes. For example, each Microelectronic ROM or RAM class has sub-sub-classes related to the number of bits per device; the Resistors, and Capacitors, have sub-sub-classes based on the material and structure designs used, etc.

Reliability predictions for electronic telecommunications systems can be carried out easily with the use of equation — 1 of this paper and a knowledge of the:

a) component class failure rate for each of the classes used in the design.

b) number of such components of each class used in the system design.

c) environment in which the system is to be used.

This type of reliability prediction is called the PART COUNT method, and is used when evaluating tenders for equipment it is intended to purchase for use by Telecom. The method is particularly useful on the more complex systems such as Exchange Switching Systems, PABX's, Packet Switching Systems, Radio and Broadcasting equipment, etc.

In general, the PART COUNT method of reliability prediction is not satisfactory when carrying out design work which must execute an ongoing programme of tradeoffs between system characteristics in order to arrive at a system which will meet all the Operational Performance Specification requirements, while still giving satisfactory reliability. The method most often used in this work is called the PARTS STRESS ANALYSIS method, and requires much greater amounts of data about the components, data which is not available when preparing tenders or quotes in the first instance.

Some Failure Causes in Components

It is not possible to consider all, or even most of the failure causes which lead to the end of wearout life for the components used in telecommunications equipment in a short paper such as this. We shall, however, consider some of the major failure causes found by defect analysis in microelectronic semiconductor ROM's and RAM's. Certain of these failure causes are also endemic to many of the other semiconductor devices used in modern electronic equipment. For this purpose let us look at **Fig. 2.**

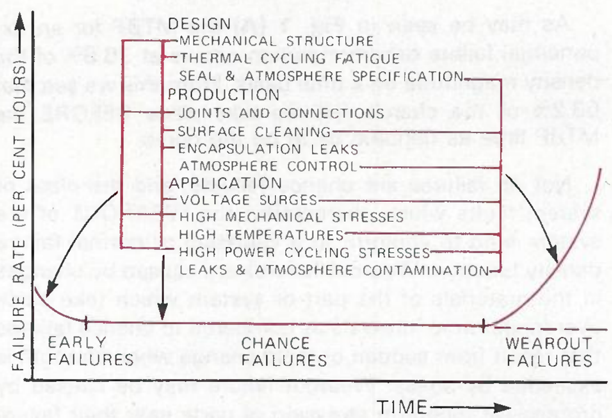


Fig. 2. Relationship between Failure Rate and Time.

Transistors used in switching circuits generally have longer lifetimes than when they are used in analog circuits. This is because the operation of the transistor in a switching mode is less critically related to operating characteristic range and greater spacing between tolerances can be used. The wearout of semiconductor devices comes not from excessive use of the device within its operating range, but rather from having its operating characteristics shift due to changes in the device. **Fig. 2** shows some of the things which go wrong that cause short wearout lifetimes, versus the chance failure causes of the exponential relationship.

Fig. 3 shows, on one set of axes, both the chance reliability function and the normal wearout function. The figure depicts a wearout lifetime of some 25 per cent of the MTBF time. For example, a 40 year MTBF component would have a 10 year wearout life, figures which are typical of modern integrated circuits. Where, in the 1970s for example, plastic encapsulated ICs could be expected to last 5 to 6 years, their lifetimes have been at least doubled by better materials and manufacturing knowledge and controls. Hermetic sealed devices characteristically last longer than non-hermetic devices, due to the fact that they have fewer wearout causes, and more stable structure.

Some typical failure rate relationships for microelectronic devices, operated in exchange environments, are compared in Table 1.

It may be seen that the failure rate increases with the complexity of the system, as there are more potential failure causes. These data represent the technology of the 1980s.

We see in **Fig. 4** the graphic representation of what would happen to a system failure rate when 1000 discrete transistors are connected together. One discrete component with an MTBF of 10^6 hours and a 1980s wearout life of 90,000 hours will yield a system wearout life before first failure of only some 12,000 hrs. by putting the 1000

NUMBER OF BITS OR GATES	COMPONENT CLASS	HERMETIC SEALED	NON-HERMETIC SEAL (PLASTIC)	PERCENT INCREASE
BITS 1-320	ROMs-MOS	0.02	0.03	50
38001-74000	ROMs-MOS	0.33	0.84	154
BITS 1-320	RAMs-MOS	0.03	0.04	33
38001-74000	RAMs-MOS	1.30	3.90	200
GATES 1-20	LOGIC-MOS	0.016	0.018	12.5
15001-20000	LOGIC-MOS	0.85	3.40	300

Table 1: Typical Failure Rate Relationships for Microelectronics Devices (in unit of failures/10^6 hours)

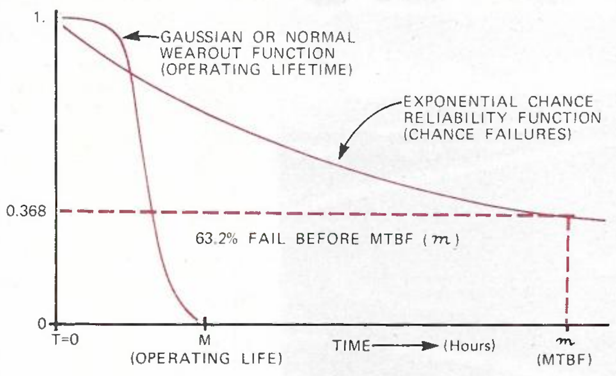


Fig. 3 — Refer to Text.

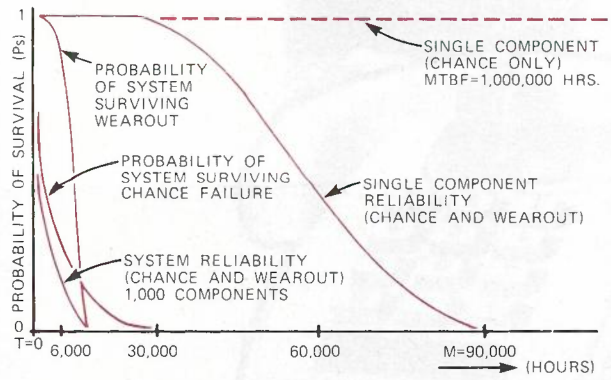


Fig. 4 — Refer to Text.

transistors on a single chip, with greater quality of reproduction, an anticipated lifetime closer to one half that expected for the individual component can be anticipated.

Because some components have shorter wearout lives, or lower MTBF and hence greater chance failure frequencies, the designer takes great care to position these in the electronic system where they can be more easily removed for replacement. When the sub-assembly is an IC this is considered as a component and the total 1000 transistors are replaced. Preventive maintenance programmes should be planned around the components with shortest wearout lives, and/or highest frequencies of chance failure (Lowest MTBFS). When needed, reliability growth is achieved by replacing components with different devices having higher MTBFs and/or longer wearout lives.

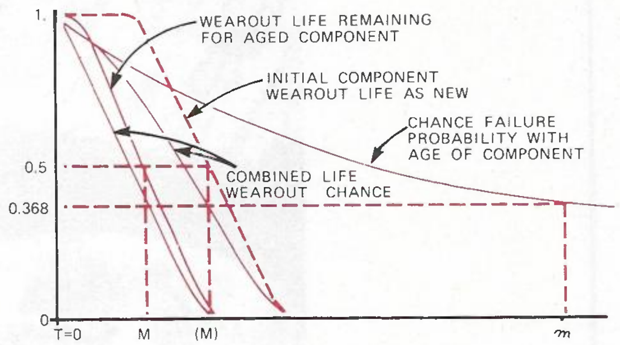


Fig. 5 — Refer to Text

Fig. 5 shows what happens as the part goes through life. When we burn-in a component the wearout life is partly used up. Burn-in programmes must therefore be planned so that a proper tradeoff is obtained in eliminated early failures versus life lost from the good components that then go into the equipment. The same consideration exists when the completed equipment is put through burn-in. As we see, the chance failure rate for the population of components does not change significantly during life. The wearout date steadily gets nearer as the system is continued in use, with the mean wearout life point M steadily shifting nearer to zero life remaining. The effect of the chance failure modes on the wearout lifetime can also be seen in **Fig. 5**. The effect is sufficiently small that in most preventive maintenance programmes it may be ignored, unless there is quite specific wearout lifetime known for the part concerned.

Summary

Reliability in modern electronic telecommunications equipment means lower maintenance effort during the early lifetimes of equipments. As the equipment becomes older, however, times will be reached when the amount of wearout becomes proportional to the rate at which the equipment was installed, and the amount which was installed in the earlier years. This will require spares calculation formulae to make allowance for increased rates of repair and replacement once the equipment begins to wear out. There is a demanding need for increased awareness of wearout and lifetimes in modern electronic equipment used by Telecom Australia so that continued intelligent control can be maintained of the Commission's business.

Small Traffic Recorder

INTRODUCTION

EDL Australia Pty. Ltd., with the support of Telecom Australia, has developed a new microprocessor based instrument for telephone traffic measurement. The unit measures the seizures, average hold-time of 128 individual circuits and group occupancy of 16 analog (traffic resistor) groups. 'Up to eight days of traffic statistics can be stored on an integral digital tape cassette!'

The unit is portable and thus finds particular application in periodic measurements at small exchanges and PABXs, and where other traffic measurement equipment is not installed, and also for special test studies and analysis of network performance.

The Small Traffic Recorder (STR) has an integral alphanumeric keyboard and display for use in programming study parameters and also to analyse study results. The unit also has three RS232C serial interfaces to provide an expanded local display, or printout, and to allow the unit to be integrated into existing and future automated traffic data processing systems.

The STR unit may be programmed in advance with the necessary study parameters, such as the circuits included in the study, the times of day that the study is to be performed, analog scan rate and software groupings of individual inputs. These are stored in non-volatile memory. At the programmed study start time and date, the unit commences to scan all the programmed inputs and store their traffic data on cassette each half hour.

BACKGROUND TO TRAFFIC MEASUREMENT

Telephone traffic information is vital to network planning and maintenance. The information gathered is used to plan network expansion, to relieve congestion problems and provide a better telephone service and to analyse revenues, tariffs and market trends.

For some years, Telecom Australia has been implementing computer based traffic measurement systems. These include CENTOC which records daily traffic at 3 minute intervals via telemetry links, DETRAM which processes data from Traffic Data Equipment and Decadic Dispersion Recorders, TRAXE to process data from AXE exchanges. Data from all these minicomputer systems is processed regularly by the processing program STRAP (Secondary Traffic Processor) and is subsequently transferred to the central traffic data base TADMAR (Traffic Data Management Analysis and Reporting).

CENTOC is installed in major exchanges and provides a macroview of general problem areas, on a continuous basis. Traffic Data Equipment (TDE) is generally set up in each major exchange every 2 years for a 5 day detailed study. Small and country exchanges have previously had no automatic traffic measuring equipment. In the past, traffic from these exchanges has been measured by means such as chart recorders which being mechanical are maintenance intensive and which are not compatible with automated data processing.

The EDL Small Traffic Recorder has been developed for use in these smaller exchanges and PABXs, and also to perform special traffic studies and for field engineering diagnostics. STR is portable, and simple and economical to set up. Its serial outputs are compatible with traffic engineering computer systems, and remote control and data acquisition. Its storage media, digital cassette tape, is very convenient to despatch to central processing terminals, where the data can be loaded directly into a secondary processing system for automatic production of traffic reports.

The STR has two important features which are generally not found in existing equipment and similar equipment developed overseas:

1. It enables the staff setting up the study to check and verify the data prior to, during, and after the study, before the data is forwarded for further processing. This facility is also extremely useful for network maintenance field engineering.
2. It provides computer legible data output, for economic production of traffic reports.

STR FACILITIES

The STR unit provides 128 individual circuit inputs, 16 analog group inputs and 8 software groups. The software groups enable any of the 128 individual circuit inputs to be combined as a group to provide route traffic statistics.

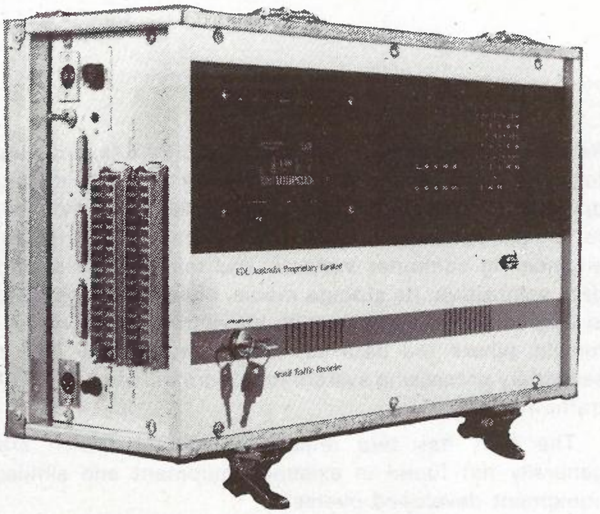
The basic input range of each analog group input is 0 to 63 Erlangs, with a resolution of 0.25 Erlangs. This range may be expanded to 200 Erlangs by the use of external resistors and a selectable value conversion program table. The scan rate for individual inputs is 100 milliseconds; the scan rate for analog group inputs is programmable 10 seconds or 180 seconds; the scan rate for the software groups of individual inputs is 10 seconds. Software debounce period for individual inputs is programmable from 20 to 990 milliseconds.

The unit has 3 RS232 serial interfaces set to 9600 bps (VDU), 1200 bps (modem) and 300 bps (printer) respectively. The unit can be controlled and programmed via the VDU or modem serial interface, and can be instructed to output its study data via any of the serial channels.

The unit contains an 8 character alphanumeric display and a 30 key alphanumeric plus special function keyboard. These may be used to set the study parameters, or to examine the individual and analog group inputs, or to display the recorded study data.

To facilitate setting up and verifying study inputs, the STR unit is provided with "Value" mode of operation, which can be used to display the idle-busy status of individual inputs and traffic value (Erlangs) of analog group inputs. To check the progress of a traffic study, the unit has 2 additional modes of operation: "Test Study" which performs a short study immediately and makes the results available for checking; and "Print Mode," where the study results are output to the printer channel at the end of each hour during a study.

To verify study data before it is forwarded to further



View of Small Traffic Recorder

processing or for network maintenance analysis, the study data recorded on the cassette may be recalled to the integral display, using the unit's "Find" mode. Data corresponding to any individual circuit, analog group or software group from any half hour in the study period may be located and displayed. The display can be used to display values for a series of different circuits within a half hour, or can "lock-on" to any selected circuit and display its study values over a series of half hours.

The inbuilt digital cassette tape unit has the capacity to record approximately 360 half hours of study data.

A special version of the unit (Small Traffic and Data Recorder) has been developed which can also be used to record ASCII data from other traffic engineering measurement systems and terminals. This feature can be used to provide a computer legible data recording and transfer medium for measurement systems and terminals which do not have their own recording facility. Record, erase, playback may be selected on the units control pannel, or from a terminal or processor via one of the serial data channels.

STUDY DATA PROCESSING

The unit scans all 128 individual circuit inputs every 100 milliseconds. During a study, the unit accumulates the total hold time for each circuit, and counts the number of seizures and the number of releases. At the end of each half hour, it divides the total hold time by the number of releases for each circuit, and records the results as Average Hold Times, together with the Number of Seizures. Circuits which are always busy or always idle are flagged.

Where a number of individual circuits input are programmed to form a Software Group, STR accumulates the data for the grouped circuits. The total busy time is divided by the number of 10 second scans and the result for each software group is recorded as its Average Occupancy. The total of the total hold times of all the circuits in the software group which release in the half hour is divided by the sum of the number of call releases in the group and stored as the group Average Hold Time. The unit also stores for each software group, the Total Number of Seizures, the Maximum Traffic, the Minimum Traffic and the Number of Maximums Read.

For each of the 16 analog group inputs, the STR unit calculates and stores the Average Traffic, the Number of Scans, Maximum Traffic, Minimum Traffic and the Number of Maximums Read.

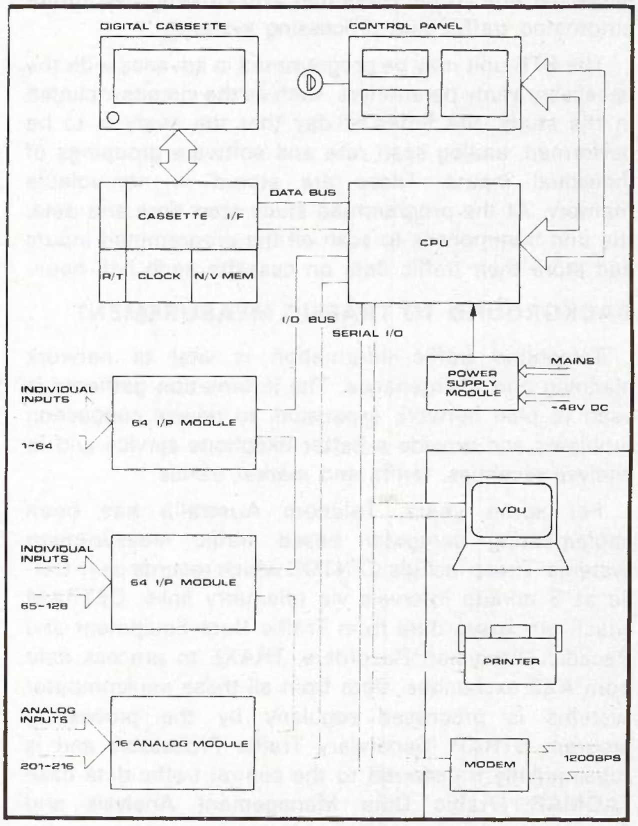
IMPLEMENTATION

The STR unit is mounted in a portable carry case 500 x 320 x 250 mm and weighs only 18 kg. It can be operated from 240V ac mains power or 48V dc supply.

The operation of the unit is controlled by an 8085A microcomputer with approximately 20K bytes of firmware. The other main cricuit modules are 2 off 65 individual input modules, an analog input module, 48 volt and mains power supplies and digital cassette interface and control, plus keyboard and display module.

Input connections for the 128 individual circuits and the 16 analog groups are provided by two 80 way knife jacks mounted on a recessed connector panel at one end of the unit. This panel also houses the connectors for mains and dc supplies, and 3 D-connectors for the 3 RS232C serial channels.

Opening the lid of the instrument provides access to the control panel which contains the digital cassette unit, alphanumeric display and control keyboard, and the Program/Study mode keyswitch.



Small Traffic Recorder Block Diagram

TECHNICAL FEATURES

The Small Traffic Recorder uses advanced technology and contains a number of features of technical interest:

1. The use of English language interactive "dialog" with the user. (user "friendliness"). Full alphanumeric key entry plus approximately 20 special controls and symbols is achieved using only 20 pushbuttons (with 2 directions of shift). The user programmable study parameters include study period, session times, exchange code, individual circuit activations, software

groups, analogy scan rate, individual antibounce time and busy/idle thresholds.

2. The individual inputs busy/idle thresholds may be programmed in the range -48V to + 10V. This extends the measurement range of the instrument to include logic levels (e.g. in "electronic" exchanges and PABXs) and also subscribers' lines. LSI technology together with optoisolated input multiplexors and digital to analog threshold converters is used to achieve 64 individual inputs with these features in a compact 238 x 114 mm module.
3. Each individual input module has its own on-board input processor. These processors scan their 64 inputs every 10 milliseconds, and are in turn polled by the main Traffic Recorder processor every 100 milliseconds. The input processors perform the following "anti-bounce" progressing algorithm: 'Changes of state are ignored until the input has changed to the opposite valid state for a user programmed number of 10 millisecond scans'. As well as anti-bounce and noise immunity, this allows the unit to be programmed to ignore short duration changes such as dial impulses.
4. The 16 analog group inputs measuring circuits are referenced to -48V dc. Level shifting to ground reference is achieved by a unique current mirror circuit. A VMOS FET connected is a current feedback path sinks the analog input current and at the same time, the circuit balances to sink a proportional current via a resistor chain which translates the signal back to logic reference ground. The ground referenced signals are then connected to an analog multiplexer and processor controlled analogue to digital converter.

The current mirror circuit saturates at approx. 40 mA input current sink, to provide automatic input current limiting and short circuit protection. The voltage reference signal to the analog to digital converter is ratiometric with respect to the -48V supply to the unit, so that the traffic measurements are independent of the -48V supply voltage.

5. The digital cassette control unit is connected directly to the buffered address and data busses of the main STR processor. Data is transferred between the cassette recorder and the main processor at 24 k bits/second.

The STR processor has a separate I/O bus for transfer of data between it and the individual and analog input modules. This is a high speed parallel bus with handshake, capable of data transfer rates up to 500 K bits/second. This provides adequate facility for input expansion in subsequent instruments.

6. The STR microprocessor design is flexible and easily adapted to a host of measurement applications including, for instance, in the telephone traffic measurement field: decadic dispersion and traffic Data Equipment (TDE) data recording.

CONCLUSION

The Small Traffic Recorder developed by EDL Australia Pty. Ltd. with the support of Telecom Australia Traffic Engineering is a flexible and powerful addition to the tools of Traffic and Field Engineering.

EDL is continuing to develop improvements and additions to the Small Traffic Recorder and its range of traffic measurement instruments.

REFERENCES:

1. G. A. Benjamin: "Telephone Traffic Measurement in the 1980 s" TJA Vol. 33/3 1983.
2. Traffic Engineering Section, Planning Services Branch HQ: "A Course in Teletraffic Engineering" Telecom Australia 1978.
3. EDL Australia: "Small Traffic Recorder EDL Type 414 Operator Manual" August 1983.

Operator Defined Parameters

```
STUDY START DATE - 09 22 83
EXCHANGE CODE - T STUDY
ASSIGNMENT TABLES
SELECTED INDIVIDUAL AND ANALOG CIRCUITS

001 128
201 216
SOFTWARE GROUP - 130
001 016

SOFTWARE GROUP - 140
017 032

SOFTWARE GROUP - 150
033 048

SOFTWARE GROUP - 160
049 064

SOFTWARE GROUP - 170
065 080

SOFTWARE GROUP - 180
081 096

SOFTWARE GROUP - 190
097 112

SOFTWARE GROUP - 200
113 128
SESSION START AND FINISH TIME - 15 00 00    16 00 00
CHAR DATE AND TIME -            09 22 83    15 22 24

STUDY DATA
```

CIRCUIT	NUMBER	HOLDTIME
001	0000000	000000.0
002	0000001	000142.0
003	0000001	000121.7
004	0000001	000101.4
005	0000001	000081.1
006	0000001	000060.8
007	0000001	000040.5
008	0000001	000020.2
126	0000001	000060.8
127	0000001	000040.5
128	0000001	000020.2

CIRCUIT	NUMBER	HOLDTIME	TRAFFIC	MAX	MIN	NO. MAX
130	0000014	000081.1	000005.6	014	000	002
140	0000014	000081.1	000005.6	014	000	002
150	0000014	000081.1	000005.6	014	000	002
160	0000014	000081.1	000005.6	014	000	002
170	0000014	000081.1	000005.6	014	000	002
180	0000014	000081.1	000005.6	014	000	002
190	0000014	000081.1	000005.6	014	000	002
200	0000014	000081.1	000005.6	014	000	002
201	020		000002.0	002	002	020
202	020		000006.0	006	006	020
203	020		000010.0	010	010	020
204	020		000014.0	014	014	020
205	020		000018.0	018	018	020
206	020		000022.0	022	022	020
207	020		000026.0	026	026	020
208	020		000030.0	030	030	020
209	020		000002.0	002	002	020
210	020		000006.0	006	006	020
211	020		000010.0	010	010	020
212	020		000014.0	014	014	020
213	020		000018.0	018	018	020
214	020		000022.0	022	022	020
215	020		000026.0	026	026	020
216	020		000030.0	030	030	020

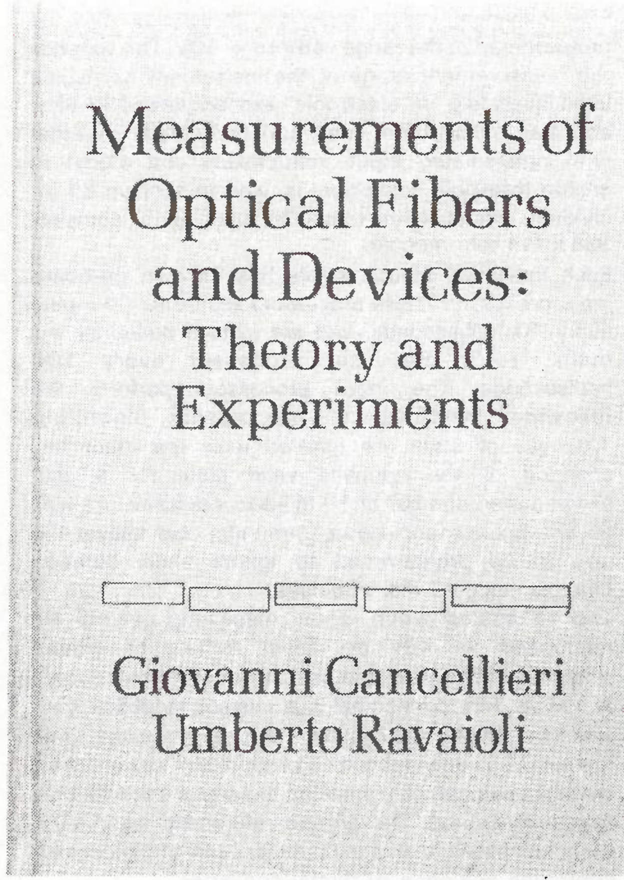
Book Review

MEASUREMENTS of OPTICAL FIBRES and DEVICES: THEORY and EXPERIMENTS.
Authors: Giovanni Cancellieri and Umberto Ravaioli
Publisher: Artech House Inc.
Published: 1984 xvi + 496pp. US $66.00

This is one of a number of books released in recent years concerning Optical Fibres and Devices. It is essentially a theoretical approach to the subject and will have a limited audience. It commences with a theoretical treatment of light transmission in the medium of fibres. It then deals with the limitations and parameters of real fibres going into such details as the effect of discontinuities in the fibres and introduces some models which were previously effectivly applied to lens systems. This is followed by a relatively short section on optical transducers covering most if not all the transducer types that were available in 1984.

The general subject of measurements on fibres and components is then dealt with. Three excellent appendices are included. The first covers optical instruments used in fibre measurements, the second the electrical instruments used and the third is a treatment of the practical preparation of cut fibres. One of the features of this publication is the excellent lists of references which are placed at the end of each chapter. Overall, the book provides a sound background for Scientists and Engineers entering the design world of Optical Fibres and Systems.

Reviewed by R.A.J. Reynolds.

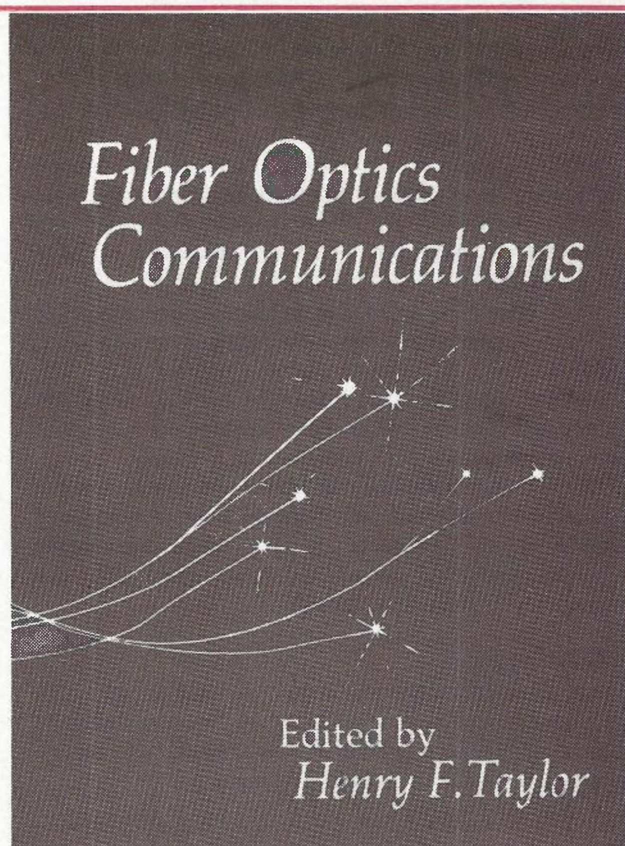


Book Review

FIBER OPTICS COMMUNICATIONS.
Editor: Henry F. Taylor.
Publisher: Arteeh House Inc. 1983.
US $54.00 xiv + 332pp

This book is a reprint of 53 papers on general optical fibre technology published between 1977 and 1983 in several journals but dominated by IEEE publications. The general classification of the articles is: industry reviews, fibre fabrication, fibre buffering and cables, connectors and splicing techniques, light sources and transmitters, photodetectors and receivers, multiplexing components and switches, system related noise effects, system design and experimental systems and field trials and operational systems. The reprints are achieved using photographic techniques and the general quality and hence legibility is quite good. It is an excellent gathering together of important papers of the period, and could save an individual considerable literature searching.

Reviewed by R.A.J. Reynolds.



Ericsson in Australia — a Quarter Century Story

ERICSSON Australia

This article traces the history of Ericsson in Australia, and looks at the extent to which the company has become involved in the development of telecommunications in Australia.

Looking back over the last three decades it is quite clear to see that the late fifties were a turning point for public telecommunications in Australia. Until then, the Australian Post Office (APO) had largely followed British practice in the development of the public telephone network.

The Telephone Plan of the mid-fifties, however, established the forward-looking and innovative approach that has characterised Australia's telecommunications strategy ever since.

One of the main features of the Plan, for example, was an all-figure national numbering plan that was to become the model followed by other countries including the UK. It also looked forward to the day when all Australian subscribers would have automatic service, and automatic access to each other through subscriber trunk dialling.

This Plan also led more or less directly to a decision that was a landmark for Ericsson in Australia. After a detailed technical evaluation of telephone switching systems available from the major international suppliers, the Ericsson crossbar system was selected as the system upon which the future Australian network would be based.

It was a major breakthrough for Ericsson in Australia. Not only in commercial terms, but strategically as well. To observers around the world, the decision would be seen as a 'seal of approval' for Ericsson's crossbar technology.

Yet it would be wrong to assume that this represented the start of Ericsson's involvement in Australian telecommunications. In fact, the story of Ericsson in Australia began 70 years earlier, before the turn of the century. That was when the Swedish company started supplying telephone instruments for the Australian network.

The ornate 'biscuit barrel' desk set and the more common 'coffee grinder' telephones were the earliest to be imported. The central battery wall telephones in handsome wooden cases appeared on the scene in the 1890s, and remained in service for some 50 years.

An interesting statistic that highlights the scale of Ericsson's trade with Australia in those early days is the fact that in 1900, sales of Ericsson telephones were greater in Australia than in Sweden itself.

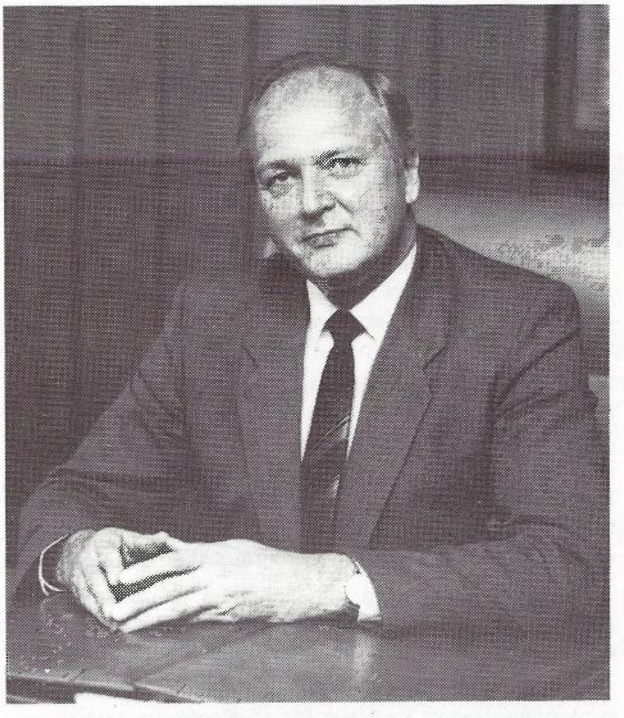
After the First World War, there was a lull in Ericsson's sales to Australia. It was not until the APO's momentous decision to standardise on Ericsson's crossbar switching system that this trade grew again.

And grow it did. Australia became the largest market in the world for the Ericsson crossbar system. By 1981 there were over 4 million lines of crossbar in service in the Australian public network, and another 2 million on order. Even today, with crossbar production being phased out as all-electronic exchanges take over, Ericsson has crossbar orders in hand worth $20 million for Australia.

For Ericsson, there was a big difference in the turn of the century trade with Australia, and the situation after 1960. In 1900, Ericsson was selling in Australia telephone equipment made in Sweden. After the crossbar decision in 1959, however, a large local development, engineering and manufacturing facility was established in Australia, as Ericsson became a major employer in the Melbourne area. Not only that, but Ericsson crossbar exchanges were also manufactured under licence by two other Australian companies.

It established a pattern that was to be repeated 20 years later, when Ericsson technology — in the form of AXE — was again chosen as the all-electronic switching system for the Australian public network. The basic technology was Swedish developed, but virtually all manufacturing, and a considerable amount of software and hardware development to meet the needs of the Australian market was to be carried out in Australia, by a largely Australian workforce.

Lars Estberger, now Managing Director of Ericsson Pty (EPA), remembers the 1959 decision well. At the time, he was one of the three people who made up the entire Ericsson sales office in Australia. The other two were Les Rowe, now Chairman of EPA, and their secretary.



Lars Estberger, Ericsson Managing Director.

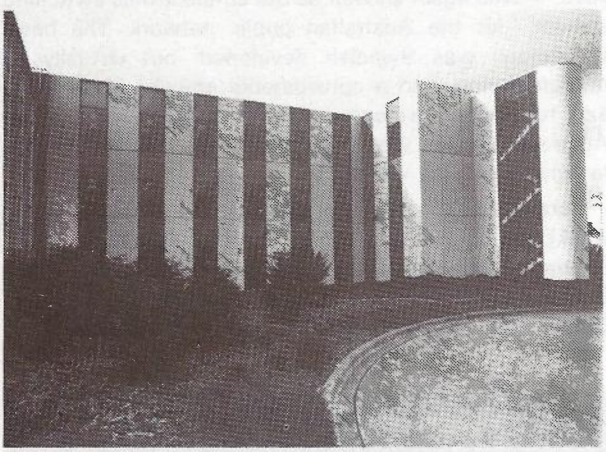
It was a very modest beginning for the Melbourne based company that now employs some 2,100 people, not only developing and manufacturing equipment for the Australian telecommunications market, but also for export markets.

The early Ericsson crossbar exchanges for the Australian network were manufactured by two established companies — TEI and STC — with some deliveries direct from Sweden, to get things off the ground.

This is what 'CAA' says. My notes say Templestowe and Sefton are the first. Advice please.

In 1963, a new manufacturing plant was started on a 'greenfields' site at Broadmeadows, on the northern outskirts of Melbourne. That grew to its present 48,000 square metre capacity. Along the way, in 1977, Ericsson acquired the remaining property it didn't already own on the block, when it took over the former Thorn plant in order to house the expanding printed circuit board manufacturing facilities.

Just recently, the plant was expanded again, when the Minister for Communications officially opened the new Design Centre, a $4 million development project housing, among others, the joint Telecom/Ericsson team working on a new member of the family for rural applications.



Ericsson Design Centre, Broadmeadows.

The magnitude of the move from step by step technology to crossbar, with its fundamentally different concept of common control, cannot be over-emphasised. Mel Ward, who was a cadet engineer with the then Australian Post Office when the first crossbar equipment started arriving, said 'The move from step by step to common control crossbar switching was more traumatic than the subsequent move from crossbar to SPC.

In 1974 came another decision by the APO that had important implications for Ericsson. This was the announcement of plans to upgrade many of the existing ARF crossbar exchanges to what Ericsson called ARE 11. It meant adding Stored Program Control (SPC), in a move that would take the network one step nearer to the all-electronic exchanges that were already being considered.

Meanwhile, during this period, Ericsson also contributed to the development of the telex network with ARM and ARB telex exchanges.

By the mid-seventies, as the APO considered the implementation of its plans for all-electronic exchanges, Ericsson once again found itself in the running for a major 'system choice'.

The rest, as they say, is history. This system choice was noted with considerable interest by other telephone administrations around the world, who were themselves trying to plan for future network development. Australia's reputation for correctly anticipating trends in public networks, together with its technological expertise, made the Australian decision a strategically important reference for Ericsson.

It will never be known to what extent PTTs around the world were influenced by Australia's decision to standardise on AXE, but the system has been remarkably successful in the years that followed. To date, no fewer than 62 other countries — including the UK — have chosen to use AXE exchanges.

Once again, the Telephone Administration now Telecom Australia, insisted that a second Australian manufacturer should be licensed to produce the system. The first bulk orders were placed with Ericsson in 1981, and to date orders worth A$250 million have been awarded. From now on, there will be open tendering for all AXE orders between Ericsson and STC.

The first AXE exchange was installed at Endeavour Hills, a suburb of Melbourne, in 1981. This exchange was equipped with an analgoue group selector stage. Together with a model AXE exchange at Telecom, it was used to gain experience of all-electronic equipment and establish working practices. By the time the first bulk orders were placed, in 1981, the digital group selector was specified as standard, so that the Endeavour Hills exchange is the only exchange in the network with an analogue group selector.

Indeed, it says much about Telecom Australia's planning expertise that the tender document of 1975 for SPC exchanges referred to the possible introduction of digital operation. This was at a time when the world telecommunications industry as a whole had not yet acknowledged the inevitability of digital networks.

The AXE switching system was also chosen by OTC for international service, to supplement the ARM and AKE international exchanges that entered service in the late sixties and early seventies. The first AXE international exchange will be installed in 1986 in Melbourne, followed by Sydney. They will be equipped with the powerful APZ212 central processor, which will give the exchanges a call handling capacity of 800,000 busy hour call attempts (BHCA).

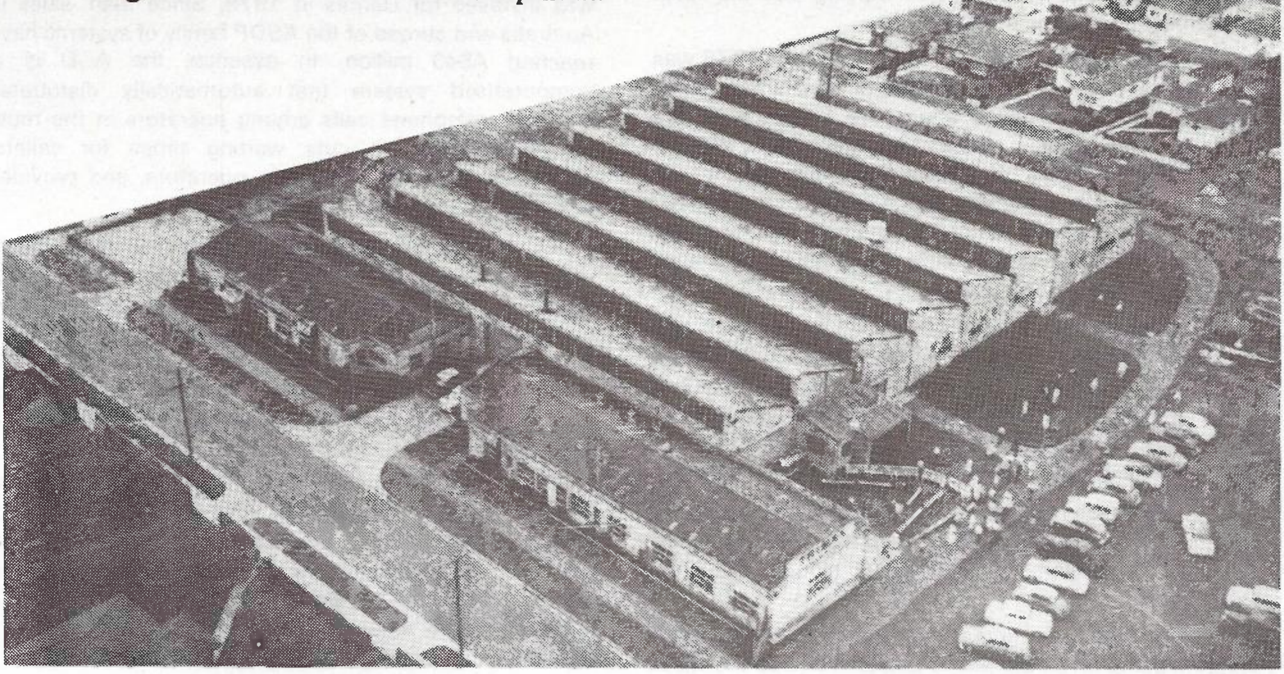
Another switching application for which the AX family was chosen was in the telex network. This mirrored events in the telephone network, since Ericsson had supplied the crossbar telex exchanges that had formed the basis of the automatic telex network since 1966. Ericsson also supplied the Sydney international telex exchange.

The AOM 101 computerised operation and maintenance centre concept is also being applied by Telecom Australia to the network, to facilitate the day to day running of the network. By 1986, it is expected that nine AOM centres will be installed.

The most recent application for AXE in Australia is in the planned cellular mobile telephony network. More details are given later in this article.

Behind these symbols

lies a wealth of experience in the manufacture of Telecommunications Equipment, Transformers and other components.



An early aerial view of the L. M. Ericsson factory at North Coburg, reproduced from a rare Trimax brochure.

Ericsson, Australia and exports

The principal reason for the establishment of Ericsson Pty (EPA) in Melbourne was to meet the needs of the Australian telecommunications market. In recent years, however, the company has built up a steadily increasing export market. Exports are seen as increasingly important for EPA, and considerable resources are being invested in this area. By 1988, exports from EPA are expected to reach A$50 million annually.

In the public switching field, exports started in 1965, when the company sold a rural crossbar exchange to Papua New Guinea. Sales to this country have continued, and today virtually all the exchanges in service were supplied by EPA. This includes an international ARM exchange at Lae.

In the mid-seventies, EPA delivered a number of containerised ARF and ARK crossbar exchanges to Oman — a contract that resulted from the experience gained in supplying large numbers of transportable exchanges for Australia.

Most recently, Fiji made a system choice in favour of AXE, and these exchanges are being engineered and supported by EPA.

Currently, a project for which considerable export potential is seen is the new digital small rural exchange being jointly developed by EPA and Telecom Australia. It could be an ideal product for the Pacific islands, with their unique geographical problems, and there has been considerable interest shown by telephone authorities in Europe and South America.

In the private sector, one of the enormous export successes is the Ericsson Automatic Call Distribution (ACD) system — also referred to as a Queueing System. Some 80 man years of development — worth AS$4.5 million at today's prices — went into the system, which has notched up strong sales in several countries including the UK and Sweden since its launch in 1978.

Exports account for 70% of the A$40 million sales of ACD systems to date.

One of the showcase installations of the Ericsson ACD system is in the Jockey Club of Hong Kong. Reckoned to be the biggest ACD installation in the world, this has 1600 operator positions, handling a peak rate of 48 calls per second. There are four systems which together have the equivalent capacity of a local exchange with 180,000 subscribers.

The latest development of this ACD system, a version tailored to suit the needs of dealer positions in the money markets, is expected to continue the export success of the product.

Another new development for the financial community — a transaction terminal unit for EFTPOS (electronic funds transfer at the point of sale) schemes — is also seen as a big potential export earner.

Australian development

In the early seventies, a dedicated team of Ericsson design and development specialists worked at a place called 'the bakery'. It sounded odd, and the premises themselves were certainly unexpected, literally right over a bakery. Yet from this engineering hothouse came a stream of innovative ideas that were often ahead of their time. (The tradition of unlikely locations was continued when the development team moved from the 'bakery' to the 'flour mills' in 1974, before moving into the main Broadmeadows plant in 1980.

The ACD system launched on the market in 1978 was one of the earliest applications of real-time, multi-processing. It says much about the elegance of the hardware and software design that even today, with all the various upgrades that have been carried out, the system still works within the 64K memory of the original design. A novel design feature for the mid-seventies was the use of both assembly level language and a high-level language in the same system.

The work on advanced digital systems being carried out by this group also led to an important contribution to the AXE programme. The first stage of the digital group switch for AXE was developed in Australia, and there is little doubt that as a result of this, the Ericsson group had a head start in the implementation of digital switching.

The APN162 processor used in several Ericsson Telecom systems was developed in Australia, and was one of the first processors in the world to use bit slice techniques.

At the moment, there are several development projects going on in the public sector. Perhaps the most important of them is a joint project between EPA and Telecom Australia that by mid-1986 will have produced a small digital AXE exchange for rural applications.

To be known as AXE 104, this will be a completely containerised and autonomous exchange for a maximum of 2000 subscribers. Present indications are that most of the AXE 104 exchanges needed for the Australian network will be smaller than 128 lines.

This project is seen as a significant venture by both Ericsson and Telecom Australia. The result will be twofold — a new small exchange that will exactly meet the needs of the Australian rural network, and a potentially exportable product that will deliver financial benefits to both Ericsson and Telecom Australia. As well, of course, as creating employment in the Broadmeadows plant.

Some 11 Telecom engineers are working at Ericsson's Broadmeadows plant, alongside Ericsson specialists. The schedule is that the first field trials of the new exchange will start in September 1986. They will run for six months, and by the middle of the following year there will be a further 21 of the exchanges installed.

Development work at the Broadmeadows plant is also taking place into two aspects of data communications. One is the development and manufacture of equipment for the Australian Digital Data Network (DDN) under a contract awarded in 1983. The first deliveries of equipment — including network terminator units and multiplexers — were in June 1985.

Another project, being undertaken at Broadmeadows for Ericsson Sweden, is a Time Division Cross Connect facility that will enable existing AXE exchanges to be used for data traffic. It will be offered to AXE users in any country, and the first systems are expected to be supplied to the Swedish telephone authority.

The private sector

Queueing systems

The first ACD system produced at Broadmeadows was installed for Qantas in 1978. Since then, sales in Australia and abroad of the ASDP family of systems have reached A$40 million. In essence, the ACD is a computerised system that automatically distributes incoming telephone calls among operators in the most efficient manner. It cuts waiting times for callers, distributes calls fairly between operators, and provides valuable management information.

An interesting question is: 'why did Australia in particular come up with such a system, rather than one of the other Ericsson subsidiaries, or even the parent company?'. Whatever the reasons, there is no doubt that it was a far-sighted development. The original system has been updated several times, to add, for example, management information facilities, MFC signalling, and call metering.

Telecom Australia use a network of Ericsson ACD's to handle directory assistance calls for the whole of Australia. Telephone administrations in other countries also use the system for the same purpose. One of the features of the ASDP system is the ability to integrate it into the public network so that the directory enquiry operators can be situated anywhere in the network.

Callers requesting assistance in the Melbourne area could be talking to an operator up to 1000 km away. It gives the administration immense freedom in recruitment strategies.

Now, seven years after the original system was introduced, a new enhancement is expected to take the Ericsson ACD into the financial world in a big way. What is in effect a completely new product has been developed for use in financial money market dealer positions.

In a similar field, EPA has become involved in the newly-emerging field of EFTPOS. It dates back to about three years ago, when the company started working with Westpac, the largest Australian bank, to develop a national, totally accessible service.

A new transaction terminal unit developed jointly by EPA and Ericsson in Swedan was the result, and there are now 1500 of them in service with the bank. It makes Westpac and EPA leading companies in the practical implementation of EFTPOS on a national scale. In September this year, the company received its first order for these terminals from the retail petrol sector.

In the PABX field, EPA started selling crossbar PABX's at the same time as they were supplying crossbar public exchanges to Telecom. Since 1979, EPA have been selling the ASB family of electronic computer-controlled PABXs. There are more than 3000 ASB systems amongst the total EPA installed base of over 10000 PABXs. EPA are now supplying the "third-generation" PABX, the MD110 — a system which is the cornerstone of Ericsson's office automation strategy, and excels in switching voice, data and text for today's modern businesses and corporate networks.

Most computer companies see office automation as word processing' is how EPA sees the situation. 'We see communications as the starting point, and MD110 is the basic building block of our offerings in this sector'. Complementing the PABX and ACD systems, EPA is introducing onto the Australian market some of the Ericsson computing products, like the Alfaskop IBM 3270-compatible terminal, and the Ericsson IBM-compatible PC.

Principal targets for these are corporate users rather than the single users or small businesses, although there are now three retail outlets selling the PCs together with communications equipment.

The company sees ergonomic considerations as particularly important in office automation, and one way to reduce the incidence of repetitive strain injury (RSI) in Australian offices.

Other activities

EPA produces transformers for professional equipment in Telecoms and similar fields. These are produced at Broadmeadows, alongside specialised power supplies such as switched mode power supplies.

Railway and road signalling equipment is another area where Ericsson is active in Australia — the company supplied the signalling system for the Melbourne Metropolitan Underground Loop.

Cellular radio

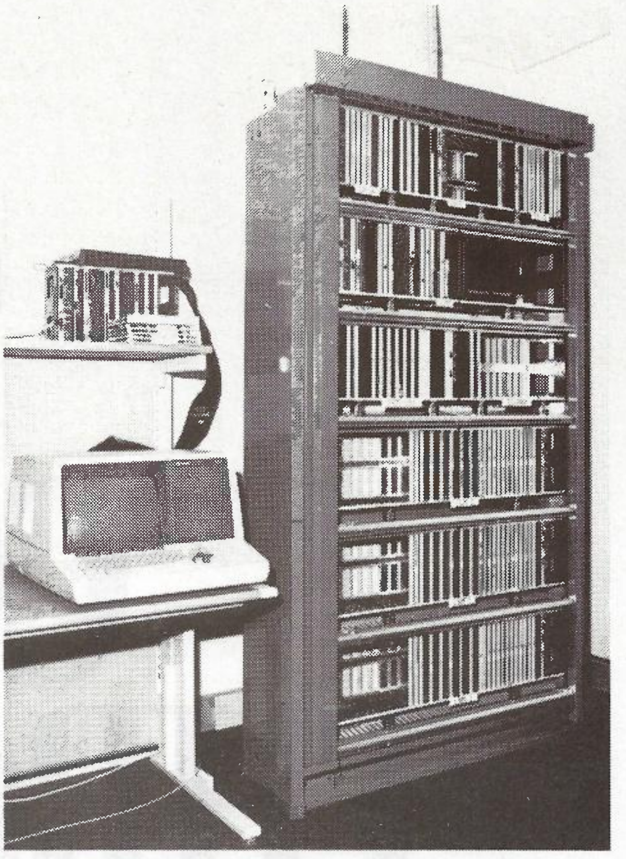
In the summer of 1985, EPA received another contract from Telecom Australia that represents a third milestone for the company in Australia. This was for a cellular mobile telephone network. Australia thus became the 20th country to choose the AXE-base cellular system. It will be using a system based partly on the US FCC standard, and partly on the UK TACS standard.

The first phase of the network is scheduled to enter service in Sydney at the end of 1986, and over the next 10 years the network is expected to grow to around 40 exchanges, serving over 100,000 mobile subscribers.

The future

According to Lars Estberger, Managing Director of Ericsson Pty, the company has a clear view of its role in the future of Australian telecommunications.

"Firstly, we will have the products and systems that deliver the greatest user value. Secondly, we will increasingly develop and manufacture them in Australia. Thirdly, we will take positive steps to build up exports.



The Ericsson AXE-Rural exchange under test in the design centre.

"The development facilities we have here in Broadmeadows are among the largest in the Ericsson group outside Sweden. We have already developed some very successful products for Australian and export markets — now we are going even further. An export division is being formed, and we have the freedom within the Ericsson group to market our products in other countries. We expect exports to rise substantially over the next few years.

"Investment in manufacturing at the Broadmeadows plant is also considerable — currently running at about A$8 million annually. We have some of the very latest and most advanced equipment, including CADCAM, robotics and laser cutting equipment.

"The joint development project with Telecom Australia on the new small rural digital exchange, we see as a quite unique demonstration of the way a state enterprise and a commercial organisation can successfully collaborate in a venture that could reap rewards for both parties.

This article was provided courtesy of Ericsson Pty. (EPA).

"The Acid Test" — Batteries for Telecommunications

N. K. THUAN,
Telecom Australia Headquarters

The reliability of telecommunication services depends on the provision of a reliable and stable power supply. The lead-acid battery, as the primary storage medium for this power supply, has long been a faithful servant.

Often ignored because of their apparent simplicity, lead-acid cells have nevertheless been developed over many years in Telecom to a stage where the positive pasted plate pure lead cells now have an excellent record of operational performance.

An understanding of some of the technical considerations of batteries in telecommunication service is vital. This understanding, including the requirements for storage in solar photo-voltaic systems, underscores the detailed design that has brought the lead-acid battery to the present advanced state.

INTRODUCTION

In Australia today, power supplies for telecommunications are designed to meet the demands both of high technology and of unique geographical and climatic conditions while remaining cost effective.

The range of telecommunications power supplies have included diesel driven generators, solid state power conversion equipment and systems, uninterruptible power supplies, and alternative energy systems such as wind driven generators, Ormat energy converters and solar power plants.

Each of these systems is made up of three basic components: generation and/or standby, conversion and storage.

The performance of any telecommunications network can be judged by the availability of the services and the degree to which uninterrupted operation is achieved. For high priority telecommunications services, the power supply system must be designed to cope with every conceivable interruption in the ac commercial supply. For lesser priority services, occasional interruptions of the supply could be tolerated.

Lead-acid batteries are one of the most important components in any telecommunications network as they provide the necessary energy storage which supplies a no-break power source to the telecommunications network under all conditions.

This paper describes the requirements, operations and applications of lead acid batteries in the National Telecommunications Network. The paper also discusses some problems Telecom has experienced with a range of batteries and the various solutions.

ENERGY STORAGE IN TELECOMMUNICATIONS POWER SYSTEMS

Secondary lead acid cells are used to store electrical energy in the majority of telecommunications power supply systems as shown in **Fig. 1**. The diagram represents the various power supply options, their applications and typical output characteristics. Appendix 1 shows a number of typical telecommunications power installations for various applications.

The main requirements of batteries are as follows:

- to ensure a no-break source of power under all conditions when the normal power source cannot be maintained e.g. interruption of the commercial mains, no output from solar arrays during night time.
- to maintain the reliability of power systems in the event of a failure of the main power source.
- to provide "peak lopping" during load variations.
- to provide a standby source of power for starting of other power systems.
- to provide filtering and smoothing effect for the overall power conversion system.
- to provide energy to clear fuses and faults in power systems.

As lead acid batteries are made up of individual 2V cells, or monoblocks of 3 cells (6V unit), or 6 cells (12V) unit), of a particular rating, they are usually arranged in series and paralleled to obtain the desired capacity at the correct system voltages (24 volt, 48 volt, 220 volt, 450 volt, etc). Large batteries are always made up of many banks in parallel to allow for maintenance and reliability.

To meet the stringent requirements of telecommunications services, lead acid batteries and cells must be designed to comply with the following system design considerations:

Long Life

Under float duty which constitutes the majority of telecommunication applications, the batteries are required to last more than 15 years under normal operational conditions.

Maintenance Consideration

The batteries should require minimum maintenance for this type of application. The cells must be housed in transparent plastic containers to allow visual inspection of electrolyte, plate assemblies and seals.

Explosion Prevention

To safeguard against explosion, all lead acid cells designed for telecommunications use must be fitted with a special safety vent that prevents "flash back" into the cell from hydrogen gas ignited outside the battery.

Packing, Transport and Handling

Batteries are inherently caustic and heavy components. They must be properly packed, handled and transported to all parts of Australia to prevent risk of injury to personnel or damage to batteries.

Low Loss (Low Self-Discharge)

The batteries must have a low self-discharge rate: less than 3% of the capacity per month if the batteries are left on open circuit. This is particularly important for batteries used in rural and remote applications.

SERIAL 177 TELECOM BATTERIES — DESIGN AND CONSTRUCTION

Australian battery manufacturers and Telecom Australia (formerly the PMG's Department) pioneered the Telecom Serial 177 "pure lead positive plate, long life" battery in 1953 to meet Telecom system requirements. The Telecom Serial 177 type of battery was designed for stationary use and is best suited for operation under constant voltage float conditions. They are still being used by Telecom and nearly all major authorities in many standby applications.

A design feature of Serial 177 batteries is the material of the positive plate grid. This grid is made from pure lead (99.99% purity) which results in minimum corrosion at the positive plate and ensures long life of the battery. The batteries are, however, not suitable for mobile applications as vibration would cause rapid deterioration of the positive plates. Furthermore, under cycling duty, these batteries have a service life directly dependent on the number of charge and discharge cycles (800 cycles at the 10 hour rate).

Telecom Australia positive pasted plate cells were developed to provide a simply manufactured low cost battery and are used extensively in the network and other applications in Australia, within and outside Telecom. The industry is standardised around Telecom Australia Serial 177 cells which marks the difference between the Australian practice and overseas practices. The cells comply fully with the requirements of Australian Standard AS 1981.

Tables 1 and 2 show a range of Serial 177 cells including the newer, larger units, 1440 Ah, 2170 Ah and 3200 Ah, and overall cell dimensions. **Fig. 2** shows a group of Serial 177 cells and **Fig. 3** is a typical Serial 177 cell in a clear copolymer of styrene and acrylonitrile (SAN) plastics container.

In this construction, the positive plate has a machine moulded grid made of commercially pure lead with the same pure lead extending through the busbar and posts. The absence of any alloy metal ensures that no contamination of the negative plates will occur. The positive grid is thicker than the negative grid which has higher mechanical strength due to antimony lead alloy being used (6% antimony).

Dual separators consisting of a fibreglass mat and a chemically inert high porosity low resistance polymer are used to prevent metallic contact between the adjacent negative and positive plates. They also help retain the active material in the positive plates and prevent lead growth from plate to plate.

SOME TECHNICAL CONSIDERATIONS

● Capacity versus Battery Reserve Concept.

The nominal voltage of a cell is 2 volt while the nominal voltage of a system is 2 x n (n = number cells used) i.e. for a 24 cell system, the nominal voltage is 48 volt.

The nominal capacity of a cell or the whole battery is given in ampere hours at the 10 hour rate to an end voltage of 1.85 volt/cell. The corresponding electrolyte density should be 1240 ± 5 kg/m^3 at 25°C (AS 1881, Sections 1 and 2).

In Telecom, batteries are seldom used at the 10 hour rate but at intermediate rates to meet particular requirements e.g. in telephone exchanges, 3 hour rate down to 1.85 volt/cell: in computer centres, 15 minute rate down to 1.70 volt/cell: in solar power repeaters, 15 days (360 hours) down to 1.85 volt/cell. These are the commonly used "battery reserves" in Telecom. These define how long the service will function before the system will shut down or be interrupted. A clear

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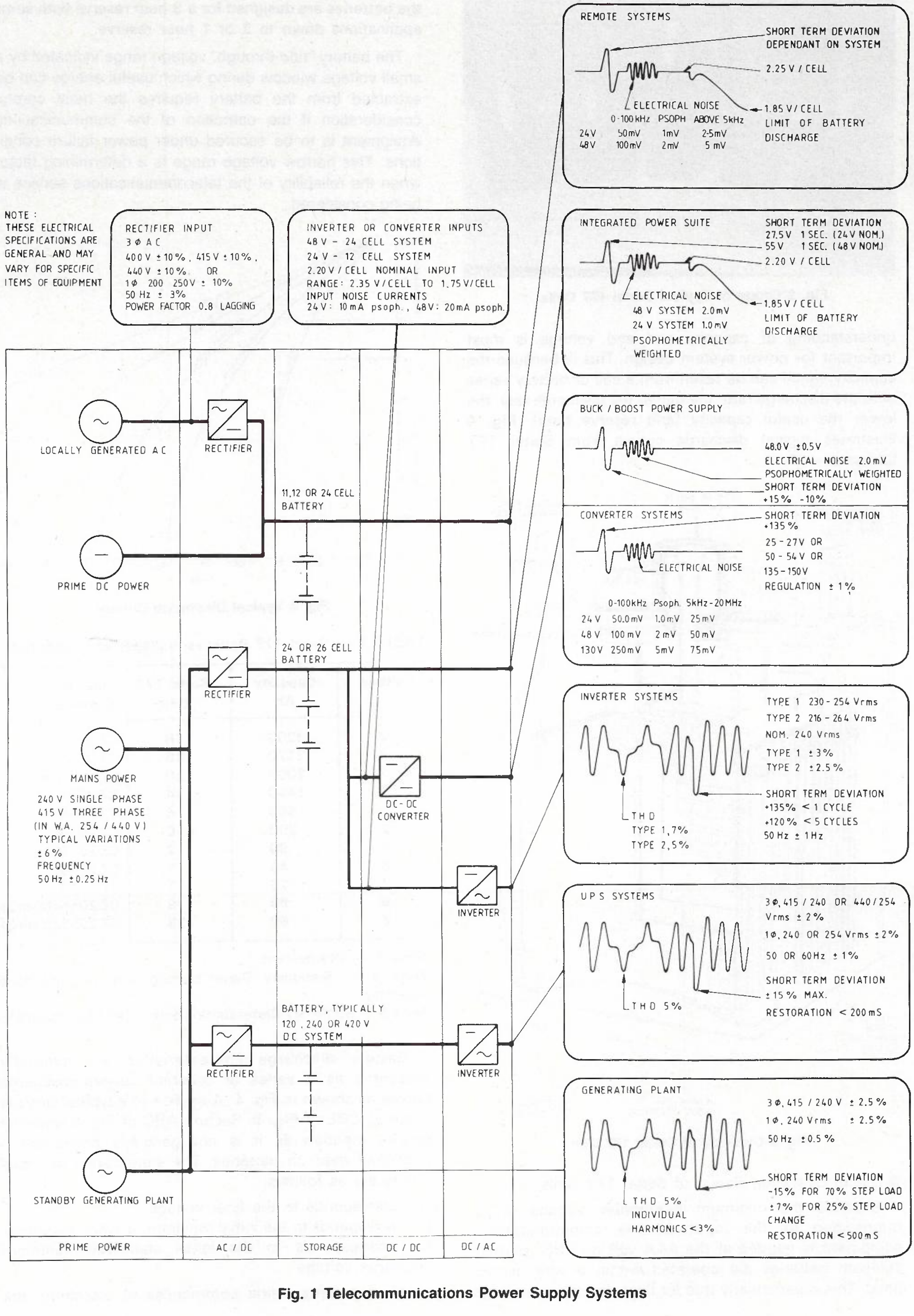

Fig. 1 Telecommunications Power Supply Systems

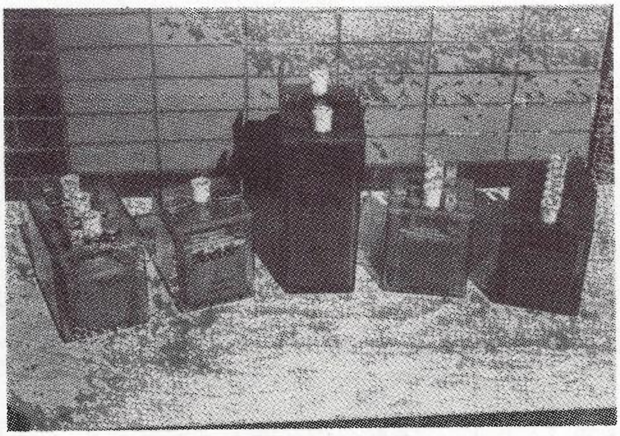

Fig. 2 Group of Typical Serial 177 Cells

understanding of capacity and end voltage is most important for power system design. This is because the capacity which can be taken from a cell or battery varies with the discharge rate; the higher the discharge rate, the lower the useful capacity (and reserve time). **Fig. 4** illustrates typical discharge curves from Serial 177 batteries.

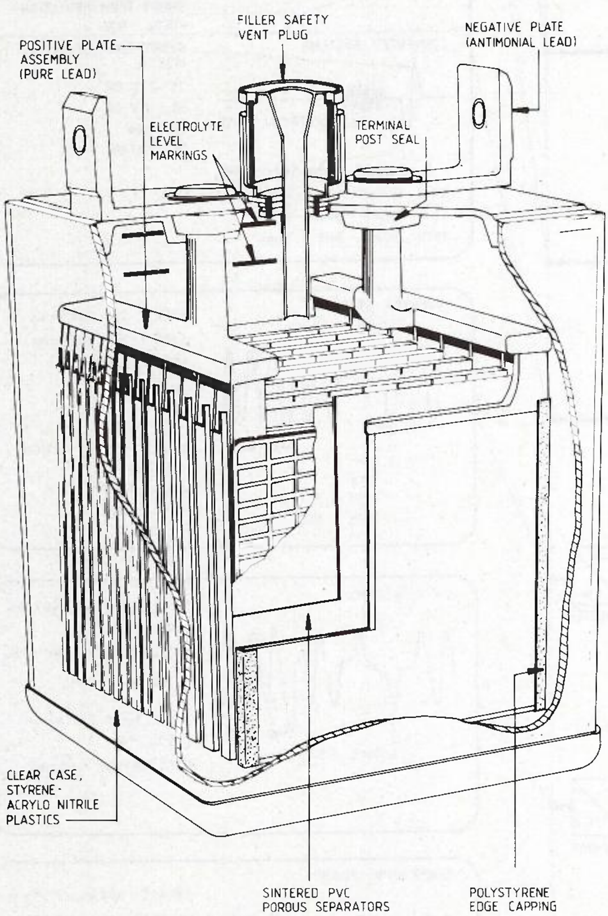

Fig. 3 Cutaway of Serial 177 Cell

● Useful Operating Range of Serial 177 Cells

Because the minimum permissible voltage to be maintained at the input of the communications equipment is pegged at the 44.4 volt or 1.85 volt/cell, Telecom batteries are operated within a very narrow band. This is particularly true for float operation in a large number of telephone exchanges. For these applications, the batteries are designed for a 3 hour reserve with some applications down to 2 or 1 hour reserve.

The battery "ride-through" voltage range indicated by a small voltage window during which useful energy can be extracted from the battery requires the most careful consideration if the operation of the communications equipment is to be secured under power failure conditions. This narrow voltage range is a determining factor when the reliability of the telecommunications service is being considered.

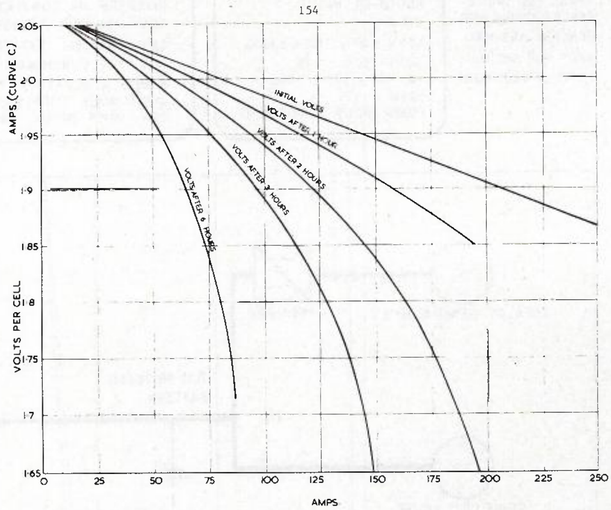

Fig. 4 Typical Discharge Curves

TABLE 1 — Serial 177 Batteries. Voltages and Capacities:

Voltage	Capacity Ah	Serial 177 Item	Telecom Drawing
2	3200	18	CZ 2054
2	2170	16	CZ 2054
2	2000	20	CZ 2019 (Note 1)
2	1440	14	CZ 2054
2	500	4	CZ 2019
2	200	6	CZ 2019
6	90	2	CZ 2019
6	45	1	CZ 2019
12	25	7	CZ 2019
6	80	19	CZ 2055 (Note 2)
6	80	23	CZ 2055 (Note 3)

Note 1 — Obsolescent
Note 2 — Stationary Diesel starting only — right hand assembly
Note 3 — Stationary Diesel starting only — left hand assembly

Battery discharge characteristics are generally presented as a series of constant current discharge curves as shown in Fig. 4. A section of a typical curve is given as CDE of **Fig. 5.** Section ABC of Fig. 5 warrants special mention as it is not generally presented in published data on batteries. The significance of these points are as follows:

A - corresponds to the float voltage
B - corresponds to the initial minimum discharge voltage
C - corresponds to the initial stablilized minimum discharge voltage

When a battery first commences to discharge, the

TABLE 2 — Serial 177 Batteries. Overall Dimensions:

Nominal Capacity (Ah)	No. of Cells	Nominal Voltage	Approximate Overall Dimensions (mm)			Serial 177 Item No.	Telecom Drawing No./Sheet
			Width	Depth	Height		
3200	1	2	585	368	673	18	CZ 2054/5&6
2170	1	2	483	368	673	16	CZ 2054/3&4
2000	1	2	375	337	583	20	CZ 2019/6
1440	1	2	306	368	673	14	CZ 2054/1&2
500	1	2	190	292	483	4	CZ 2019/5
200	1	2	194	197	280	6	CZ 2019/4
90	3	6	286	183	274	2	CZ 2019/3
45	3	6	185	197	274	1	CZ 2019/2
25	6	12	298	182	293	7	CZ 2019/1
80 Note 1	3	6	290	183	274	19/23 Note 2	CZ 2055/1

Note 1 — For stationary diesel engine starting use only. Must not be used for mobile application as vibration would cause plate disintegration.
Note 2 — For 24 Volt starter battery, use 2 - 6 V right hand (Serial Item 19) and 2 - 6 V left hand (Serial Item 23) assemblies.

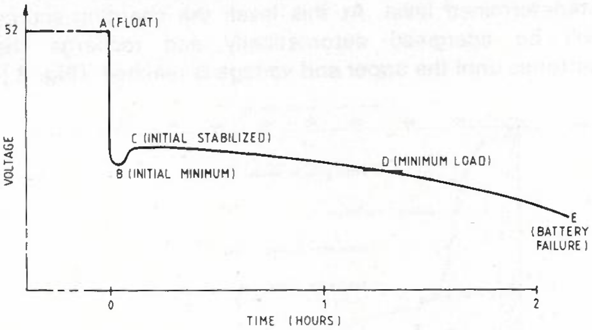

Fig. 5 Typical Voltage Dip

voltage falls rapidly from A to B then recovers to C. This process of dip and recovery (A to C) is completed typically in the first two minutes of discharge and is observed most readily in the float operation (Thuan, 1978).

The points shown in Fig. 5 are presented in **Fig. 6** for a family of constant current discharge curves. Based on a 24 cell floated battery system (Thuan, 1978) it can be seen from Fig. 6 that there is only a small voltage window during which useful energy can be extracted from the battery.

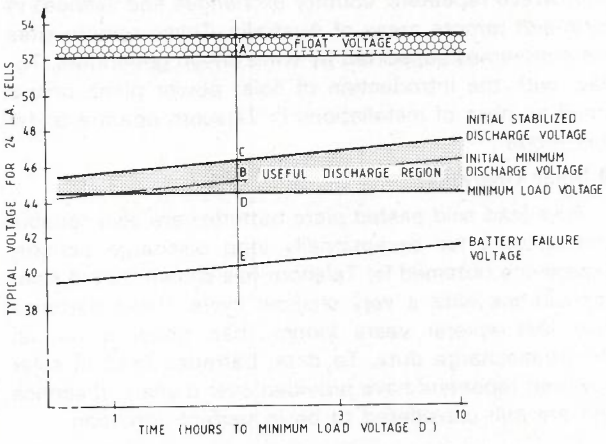

Fig. 6 Useful Operating Window

The voltage boundaries for this window are defined by the initial stabilized discharge voltage and the minimum load voltage.

● Temperature Effect on Capacity

The performance of lead acid batteries is dependent largely on their electrolyte temperatures. An increase in temperature will cause a rise in the potential directly proportional to increase in temperature. This increase in temperature will also cause a decrease in the electrolyte resistance.

An increase in the rate of diffusion of electrolyte will also occur at higher temperatures. The combined effect of the temperature increase will bring about an apparent increase in capacity of the battery under discharge. If corrections for temperature are not considered, it is probable that a battery which would fail to pass the capacity test at the standard temperature level of 25°C to appear quite normal at a higher temperature. Temperature effects on battery capacity, while not critical in well protected buildings, could be more significant in rural and remote applications where batteries are usually housed in low cost thin walled shelters or containers.

BATTERY OPERATION — DUTY CYCLE

● Float Operation

Float operation is a method in which the batteries are theoretically kept in a fully charged state. This is achieved by maintaining all cell voltages above but close to the true open circuit voltage of the cell.

This type of duty is the most common one in Telecom Australia and is always used where a continuous source of electrical power is available. This source of power comes from commercial ac supplies or continuously running diesel driven generators or alternators.

In this operating mode, the battery could consist of a single bank of cells or a number of banks of cells in parallel.

For low priority services, a simple battery would be used and operate with the charging source balancing the load and maintaining the battery in a fully charged state except that in a peak load period, or during mains supply failure, the battery would partially discharge. The charge lost will be recovered in the lightly loaded periods.

Typical installations of this type of application are PABX, Small Country Automatic Exchanges, Small Business Systems and Diesel Alternator Starter Batteries.

For most other priority services, in particular in medium to large telephone exchanges, long line and radio repeater stations, telex exchanges, etc, two or more banks of batteries are connected in parallel across the communications load with the charging source (rectifiers or diesel driven generators) balancing the load and maintaining the batteries in a fully charged state: all cells are kept just above the true open circuit potential (Thuan 1978).

In the event of a charging source failure, or mains supply interruptions, the batteries discharge to maintain the communications load. When the charging source is again re-established, the batteries would be substantially recharged at the float voltage. A manual boost is usually required to restore the batteries to a fully charged state if the period of discharge has been prolonged.

For almost 20 years, Telecom batteries were floated at 2.17 volt per cell, which is about 0.03 volt above the true open circuit voltage of the cell. This has the benefit of prolonging the life of the batteries. Many Telecom battery installations have been operating successfully since the early 1960s i.e. in excess of 20 years. This ideal float level was, however, revised in the early 1980s and raised to 2.20 volt/cell, which is now the standard float level in Telecom Australia.

The new float level helps to reduce the frequency of manual boost charging and maintenance of batteries — a very costly and time consuming practice. Any likely drawback is considered minor, and may result in a slight reduction in battery life. It is yet too early to gauge the full benefit of this revised float level; some maintenance is still needed.

Voltage variations of float operation of a typical power system used in Telephone Exchanges are shown in **Fig. 7** which also indicates the behaviour of lead acid batteries under manual boost charge conditions.

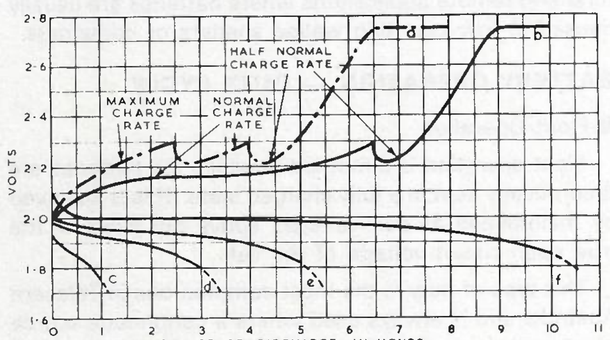

Fig. 7 Float Operation & Boost Charging

For economy, convenience, simplicity and standardisation, all rectifiers used in Telecom Australia are designed for constant voltage charging instead of constant current charging. The general trend is to reduce the amount of field work on batteries without affecting the high order of reliablility provided by the batteries. In recent years Telecom has been buying batteries fully charged (100% charged upon delivery) to avoid costly cycling on site. With electronic exchanges and constant load equipment, the old concept of letting the battery gain its full capacity after 12 months or so in operation is now no longer acceptable. Furthermore, it would be more economic for battery manufacturers to form the plates in the factory instead of on site.

● Charge/Discharge Operation

The charge/discharge operation or cycle operation of batteries is a method in which the batteries are taken through a process of discharge and recharge. This operation could be a deep cycle, in which the discharge is allowed to go beyond 50% of the 10 hour rated capacity, or a shallow cycle, in which the discharge is not allowed to go beyond 50% of the 10 hour rated capacity.

This mode of operation is not preferred, as it will result in a very short battery life (3 to 6 years). It will also necessitate frequent battery replacement and maintenance. It is usually used in areas where continuous power is not available from a commercial ac supply or when continuously running diesel alternators/generators are not justified.

The batteries are connected in parallel to support the load and the charging source is operated on an automatic charging cycle. During discharge operation, the batteries supply the load until the output voltage drops below a predetermined level. At this level, the charging source will be energised automatically and recharge the batteries until the upper end voltage is reached. **(Fig. 8.)**.

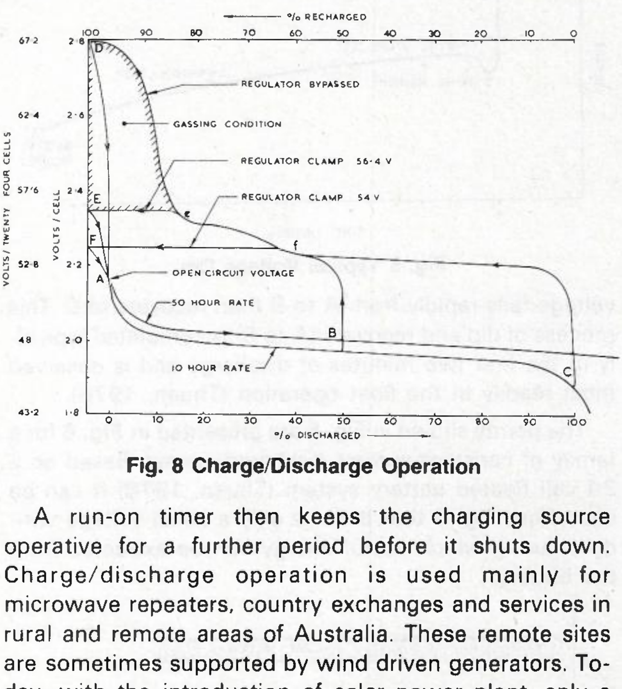

Fig. 8 Charge/Discharge Operation

A run-on timer then keeps the charging source operative for a further period before it shuts down. Charge/discharge operation is used mainly for microwave repeaters, country exchanges and services in rural and remote areas of Australia. These remote sites are sometimes supported by wind driven generators. Today, with the introduction of solar power plant, only a small number of installations in Telecom operate under this mode.

● Solar Operation

Pure lead acid pasted plate batteries are also capable and suitable for exceptionally long discharge periods. Experience obtained by Telecom has shown that in solar applications with a very shallow cycle, these batteries may last several years longer than under a normal charge/discharge duty. To date, batteries used in solar powered repeaters have provided over 6 years of service and are still considered to be in perfect condition.

As the battery must provide energy to run the communications equipment night and day, throughout the year, it must be designed to cope with seasonal changes in solar radiation and site weather conditions.

This mode of operation of battery in solar applications is quite unusual and often unpredictable (Mack 1978). Beside a very shallow daily cycling, the battery will undergo a gradual, relatively deep annual discharge (**Fig. 9.**) The annual notch in the battery state of charge curve is typical in many areas of Australia, particularly in the southern and non-tropical regions where solar energy varies through a summer and winter cycle.

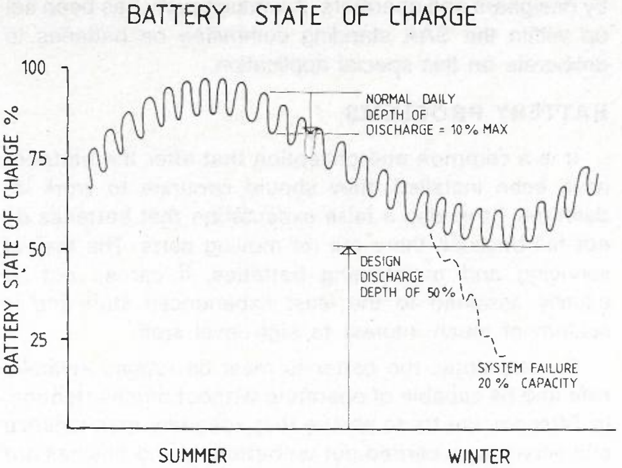

Fig. 9 Solar Operation

Design policies in Telecom to date have aimed at providing enough solar panels to keep the battery in a reasonable charged state with the minimum level of about 50% during the winter months. Minimum battery reserve could be achieved by deliberately inclining the array to face the winter sun. Excess summer radiation is usually wasted as the output of the solar arrays is usually cut back by the regulators to avoid gassing the battery excessively.

Telecom foresaw that the batteries may remain in a state of charge below 100% for several months during the year and made a very conservative estimate of battery life on "solar" duty (5 years approx.) Recent field experience from a number of radio repeater sites throughout the outback of Australia has, however, brought about a change in our belief in the suitability of "pure lead batteries" for solar applications. The gentle, low rate and shallow depth of discharge has not caused a shortening of battery life as observed in the charge/discharge operation. It is now predicted that Serial 177 batteries will last up to 10 years in solar applications. This is a significant improvement from 3-6 years' life of batteries obtained in charge and discharge system.

Every year of extra life of a battery for applications in remote area means large savings on manpower and expenditure to the Service. In extreme cases, where the location of the installation is difficult to get to, for example, Thursday Islands, Torres Strait: the cost of replacement of a battery is several times the cost of the battery itself. Besides the additional replacement cost, service reliability and availability of the communications equipment will also be affected.

Telecom Australia now has about 200 kilowatt peak of solar power systems in the network; most of these are at remote microwave repeater sites. Some of these sites belong to the Kimberley Microwave System — WA, the longest solar powered microwave link in the world. The first and world famous solar powered link is the Alice Springs-Tennant Creek System which has now been in operation for 6 years without any interruptions. The combination of pure lead pasted plate batteries and solar arrays has supplied a continuous source of power to radio equipment and required minimum maintenance; site visits are required about once a year.

Increased pressure is, however, being put on lead acid batteries for solar applications. There are three main reasons which give rise to the new requirements:

Balance of system cost

Battery cost is very significant in comparison to system cost. Furthermore, while the cost of solar cells has decreased markedly in the last few years, the cost of lead acid batteries has not.

Telecom Australia has modified its dimensioning rule recently for solar power plant to allow for a lower solar battery reserve and a simpler control system to reduce the cost of less critical services.

Competitiveness of Pure Solar Plant for Load above 300 Watt.

At present, solar power plants are economically viable for continuous loads up to 300 watt. For larger loads, wind assisted, or diesel driven assisted solar power systems may be required. A hybrid power plant consisting of solar modules and a wind driven generator (Wind Solar Energy System, WSES) or solar modules and a diesel driven generator (Diesel Solar Energy System, DSES), etc. as charging sources has drawn considerable interest in the communications industries both in Australia and overseas.

The new hybrid system will enable the powering of larger communications loads such as digital radio systems at non-mains powered sites without all the disadvantages of charge/discharge systems.

Battery Transport and Handling

Pasted plate batteries are prone to damage during transportation over long distances because of the weakness of the pure lead positive grids. Special care must be taken in the packing and transporting of the cells to prevent damage. Unfortunately, these measures are not always successful. The cells, being flooded type, must be transported to sites, installed and charged as soon as possible to prevent deterioration.

New developments in lead acid batteries may overcome and provide an alternative solution to this shortcoming. The new recombination batteries, which are dry and compact, could lead to "fully factory assembled" solar power systems instead of "site assembled" systems.

- High Current Constant Load Operation

This operation is identical to that discussed under float operation except that under discharge the batteries are required to deliver very large currents, several hundred amperes or thousands of amperes, in a relatively short time.

Because of high current demands, the batteries must

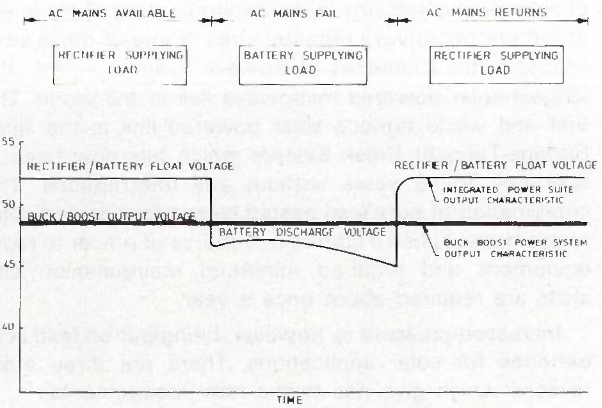

Fig. 10 High Current Constant Load

be capable of high rate discharges. There are three distinct applications for batteries operating under this mode:

Constant Load Demand - In this mode, the battery must supply an increased current during the discharge period, which is usually about 1-3 hours. The increase in current is to compensate for the drop in battery voltage as the power supply regulates to maintain a constant ouput voltage.

These are buck/boost power plants, which were introduced into the Australian Exchange Network in 1978 and are now the standard power systems for many electronic switching equipments (Thuan 1979).

Most of the larger buck/boost power systems will eventually operate on about a 1 hour battery reserve. This operation requires that the battery be capable of discharging at high currents without dropping its ouput voltage excessively. The lumped internal resistance of the battery must therefore be quite low, not more than 3.25 milliohm for a typical 2170 Ah battery.

Energy Flywheel Effect - To enable a regulated power supply such as the buck/boost power system to ride through a mains interruption without instability and excessive output voltage swings, an energy reservoir which acts similarly to a bank of capacitor, is provided across the power supply output. A specially designed high rate discharge 225 Ah battery has been used for this purpose and can discharge up to 1000 A for 60 seconds without dropping its voltage below 1.60 volt per cell. It can, with the large amount of energy stored, assist in controlling the transient voltage to about ± 5% of the output and clear fuses under fault conditions.

Uninterruptible Power Supply Operation - Batteries similar to the "Energy Flywheel" high rate discharge type are required in Uninterruptible Power Systems (UPS).

It is a normal requirement in Telecom Australia to provide UPS equipment for a wide range of computer controlled equipment and centres where real time on line processing and switching is required. The primary role of UPS is to provide a clean, transient free no-break power source for computer equipment, and to isolate this essential equipment from unpredictable disturbances in the commercial mains supply.

The batteries provide energy to enable the UPS to ride through mains interruptions and must discharge at large currents for 15-30 minutes before other circuit components come into play or system rescue can be carried out.

At Telecom's largest computer centres in Sydney and Melbourne, UPS systems with installed capacities of 1.65 Megawatt of 60 Hz output and 600 kilowatt of 50 Hz output will be installed to operate a large number of computers 24 hours a day. A massive battery capacity with over 1000 individual cells will be installed ultimately. This operating mode of battery is the least understood, the most demanding and has to be handled with extreme care both by designers and operators. A working party has been set up within the SAA standing committee on batteries to deliberate on this special application.

BATTERY PROBLEMS

It is a common misconception that after the batteries have been installed, they should continue to work indefinitely. It is also a false expectation that batteries do not fail because there are no moving parts. The task of servicing and maintaining batteries, if carried out, is usually assigned to the least experienced staff and is seldom of much interest to high level staff.

Consequently, the batteries must be rugged, reliable, safe and be capable of operating without much attention. In Telecom, we try to ensure that adequate maintenance and servicing is carried out on batteries, and this has not been without great difficulty. Because of manpower constraint and the massive size of the communications network, alternative and radical system design and servicing policies have been used to reduce battery maintenance without causing reduction in system reliability.

There are problems with batteries, however, that are beyond the capabilities of staff expertise and control; these problems surface from time to time and pose great challenges both to the manufacturers and Telecom in the search for solutions. Some of these problems are briefly outlined below.

- Road Transport Problems

Transportation of batteries over long distances is always a problem. With care, strict package design and control, handling and transportation, batteries can survive very long and arduous trips to outback Australia.

There were recently specific occasions when batteries suffered an unacceptably high level of damage while being delivered within the Capital Cities.

The plates of one make of batteries had moved sideways during transport; the positive and negative plates were dislodged by vibration and moved in opposite directions. There were also severe cracks in the pasted grids of negative plates. Investigation into the problem revealed that the absence of locating lugs on the base of plates could be the main contributing factor.

Another problem plagued a range of high capacity and heavy batteries when cracks developed in the SAN containers in the area of the wall near the ribs supporting the weight of the assemblies.

Extensive vibration tests carried out by the Government Aircraft Factories on behalf of Telecom Australia revealed that the cause of the problem was a combination of poor cell design, transportation stress, the adverse affect of plastic support pallets and poor packaging. The risk of damage was minimised by modifying the cell plate support system to allow the plate mass to rest on loose sludge ridges instead of the fixed moulded ribs and improving the method of packing, transporting and handling of these large cells.

● Battery Corrosion and Contamination

Impurities in the battery electrolyte originating from contamination can cause severe corrosion to the positive plates of the cell. Telecom has been studying the effects of perchlorates in battery electrolyte to determine whether the PVC separators are responsible for the initial contamination. Telecom is also considering the use of Daramic separators, made from the polyethylene group of materials, as a replacement for the current range of Porvic separators (sintered PVC).

Lack of quality control during production processes can have disastrous results. A slight corrosion problem was recently detected during a recent routine battery inspection. The magnitude of the problem soon became apparent when the fault was traced to the production line. An innocent change in material supply had an adverse effect on the plate forming process. The change apparently culminated in the formation of organic acid in the forming tanks and led to widespread corrosion.

● Battery Explosion

A 48 volt 500 Ah lead-acid battery housed in an all metal cabinet exploded while the battery was being commissioned at a Telecom exchange in WA. A staff member was cleaning the residue of "Corium" sealing compound from around the terminal lugs when the explosion occurred.

The explosion damaged seven cells; two cells had shattered cases and five others had cracked or broken cases. Acid damage was caused to the wall and floor of the area, and to a general purpose power outlet on the wall.

Investigations into the cause of the explosion showed that the blast may have been due to a faulty safety vent. Samples taken from the installation have been found to be without effective sealing at the base of the porous membrane and the outer cup, thus providing no barrier to external ignition.

Improvements to the rubber seals beneath the vent were also required. The seals became distorted when clamped in position and could cause leakage of electrolyte.

● Fused Lead Connections

The practice of using a "Pyro-bit" (carbon rod) to lead burn cell connections can be hazardous. This was proven recently during the commissioning of a 48 V lead-acid battery.

The operator was using the partly installed battery to power his Pyro-bit tool. Unfortunately some hydrogen gas had become trapped in the cell and it had sustained an internal fracture above the electrolyte level prior to installation. The particular cell exploded when the high surge of current, drawn by the lead burning tool, ignited the volatile gas.

NEW DEVELOPMENT — SEALED LEAD-ACID BATTERIES

A new type of sealed dry lead-acid battery operating on the recombination electrolyte principle is available in the world market and promises potential for early application in Telecom. Because these batteries do not contain any free liquid electrolyte (aqueous sulphuric acid), they are spill proof, leak proof and can be installed in close proximity to electronic equipment without posing a hazardous condition. Currently there are about six manufacturers specialising in recombination cells: Gates (USA), Chloride Industrial (UK), Yuasa (Japan), GNB Batteries (USA) Chloride (Aust.), General Electric Company (USA), Hawker Siddeley (UK) and Steco (France).

From the chemical reactions governing lead-acid batteries, it can be shown that during discharge, electrolyte is used to convert the active materials (PbO^{2}) to lead sulphate ($PbSO^{4}$) and water ($H^{2}O$) with the liberation of electrons. During charge, this process is reversed.

In conventional wet or flooded cells, the positive plates are less efficient in the charge acceptance than the negative ones, hence oxygen is always evolved at a lower state of charge at the positive, and hydrogen is only evolved from the negative when the cell becomes fully charged. In other words, the oxygen evolution occurs before the hydrogen evolution. This feature is used in the design of sealed lead-acid batteries.

In the sealed recombination batteries, under normal operating conditions, the negative plates do not become fully charged, hence the evolution of hydrogen is suppressed. The positive plates, on the other hand, do become fully charged and the oxygen evolved during charge or overcharge recombines at the negative plates.

The separators are specially designed to allow for the diffusion of oxygen from positive to negative plates where it is recombined.

The net effect is a fully-sealed oxygen cycle system without water loss. In the case of abuse, where pressure could build up because of severe overcharge, a self resealing safety vent will release the pressure.

The manufacturers have claimed that the recombination cells are suitable for both float duty and deep cycle duty. These characteristics will make the cells ideally suited to applications in rural and remote areas as well as the conventional float operation in switching and transmission stations.

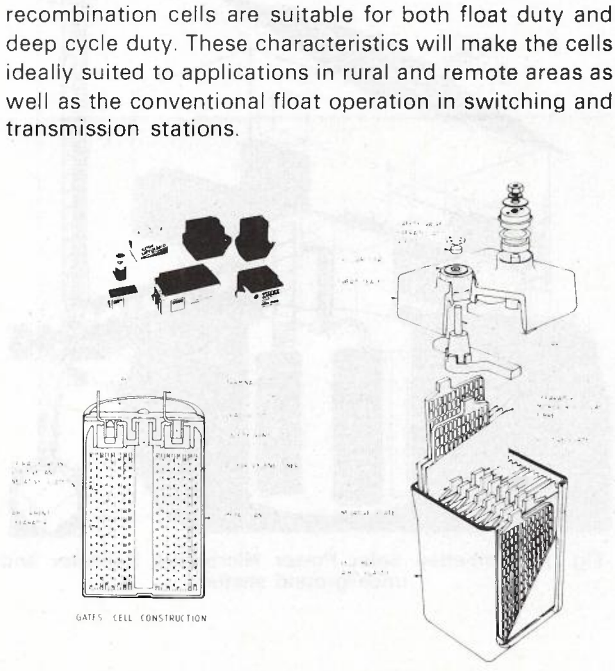

Fig. 11 Recombination Batteries

There are three types of construction (**Fig. 11**) for recombination cells to date: the spiral cylindrical pure lead type manufactured by Gates Energy, Denver (USA); the prismatic flat-plate antimonial alloy configuration by GNB Batteries Inc, Langhorne (USA) and the flat-plate ternary lead alloy type by Chloride Industrial (UK), Yuasa (Japan) and Chloride (Aust.)

The main advantages of recombination cells are:

- maintenance free (no addition of water during the normal operational life;
- no gassing, no corroded terminals)
- small and lighter than wet cells
- high energy density
- low internal impedance
- no stratification; no periodic equalisation
- improved charge/discharge characteristics
- low self discharge, long shelf and storage life
- improved performance over a wide range of temperatures
- suitable for both float and cyclic operation
- leak and spillage proof; office compatible and clean
- rugged and have good vibration resistance
- can be operated in any position
- can survive being frozen
- can be transported by air

The main disadvantages of recombination cells are:

- low capacity (400 Ah maximum)

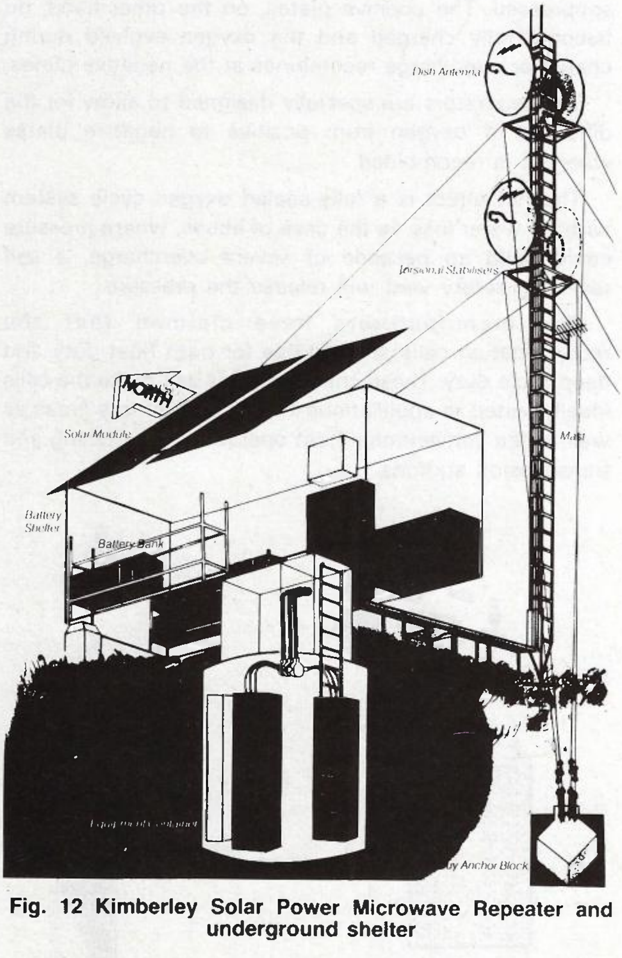

Fig. 12 Kimberley Solar Power Microwave Repeater and underground shelter

- shorter life than wet cells
- relatively high float voltage
- relatively expensive for small capacity

The recombination cells are especially attractive for many applications, from rural and remote power supplies, small uninterruptible power supplies, to business communications and transportable applications. The technology is somewhat in its infancy and further development is needed to improve the performance and characteristics, to increase the rating and to lower the price of the cells.

CONCLUSION

Lead-acid batteries, dry or wet, are probably the most important power supply component in the national telecommunications network. Without them, we would not be able to achieve the high level of reliablility of the telephone services as we have today.

In comparison with batteries used in overseas communications networks, Telecom batteries, conceived and produced in 1953 by Australian Battery Manufacturers and Telecom engineers are the most economical type; they offer performance and reliability that matches any kind of comparable design in the world today.

With the future emphasis on compactness, office compatibility and minimum maintenance, the new range of recombination lead-acid cells will fill the gap at the bottom end of the capacity range. In these new applications, we will see packaged modularised power plants with batteries being physically integrated into the power system.

As a companion to the latest high frequency switching techniques used in modern power supplies, sealed lead acid cells will be used in the home, office, underground communications shelters, computer rooms, PABX and Small Business Systems. They are emerging as the preferred batteries for business communications applications despite the fact that the estimated life is only half that of conventional wet cells at the present time.

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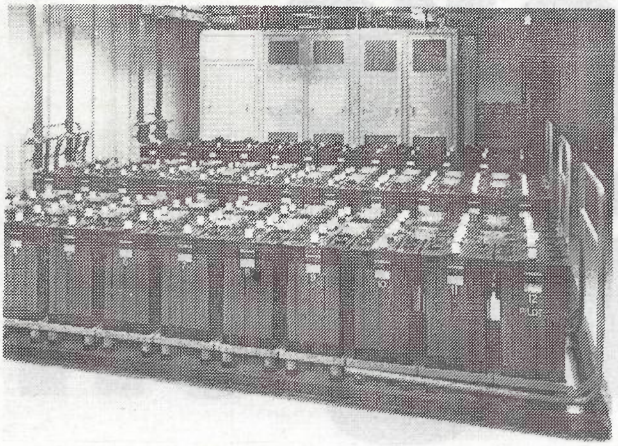
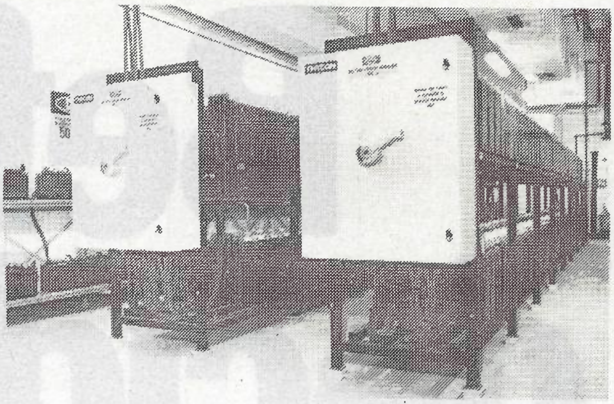
ACKNOWLEDGEMENT

Thanks are due to Messrs J.J. McNally, Senior Engineer and A.C. Swift, Swinburne TAFE Student, for their assistance in the preparation of this paper.

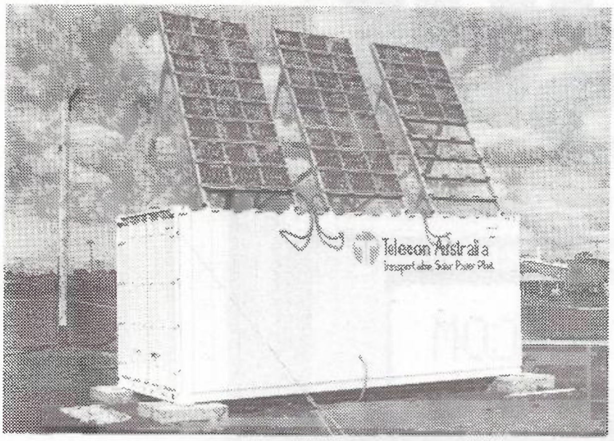
Appendix I — Typical Telecommunications Power Supply Installations



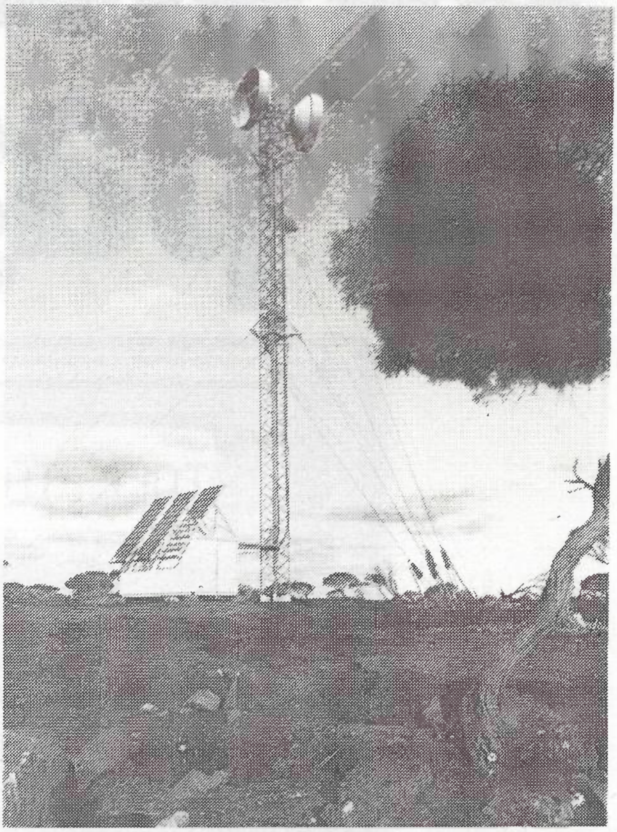
1. Power System for Telephone Exchange — 10C Trunk



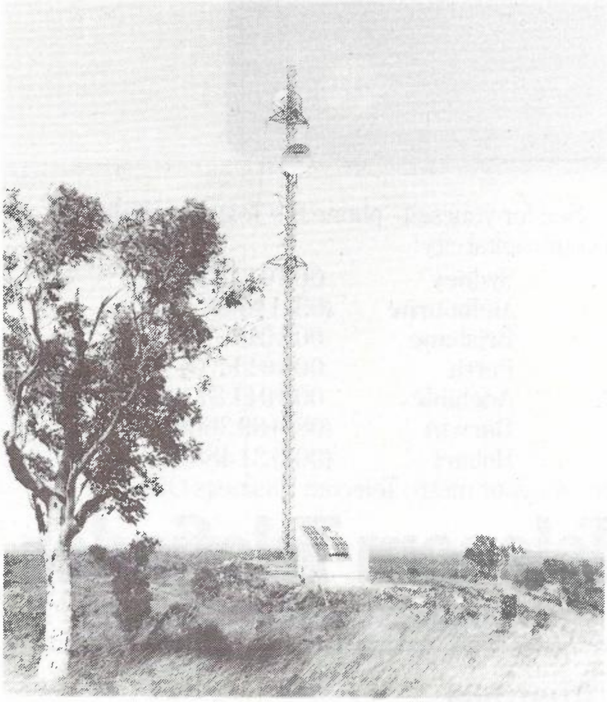
2. Batteries for Computer Centres



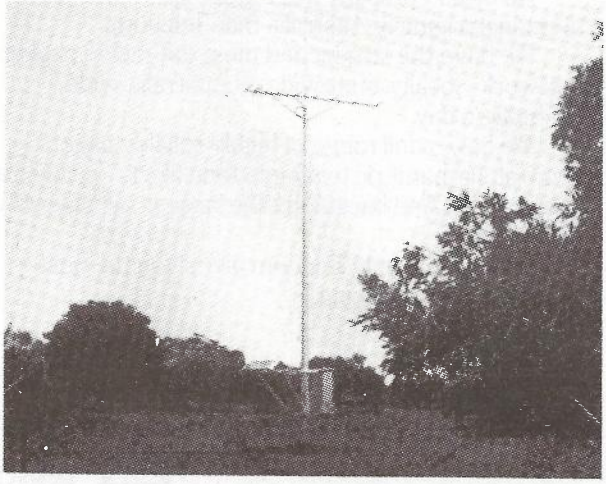
3. Transportable Solar Power Plant



4. Solar Powered Repeater Station — Alice Springs-Tennant Creek



5. Kimberley Microwave Repeater and Underground Shelter



6. Solar Powered VHF Subscriber Radio Telephone

Rural and Remote Customer Networks: Which Technology and Why?

Telecom Australia

The choice by Telecom Australia of the Digital Radio Concentrator System (DRCS) as the mainstay for providing services to outback Australia has raised wide interest.

This paper provides some background to this decision by way of discussing the DRCS and the main alternative, a satellite system. The characteristics of these two alternatives are discussed and a comparison is made on the basis of cost. This comparison, based on the latest industry figures, reveals that the DRCS is still the most cost-effective means of providing services in outback Australia by 1990.

INTRODUCTION

The publicity surrounding the Australian domestic satellite, AUSSAT, has led many individuals and organisations to enter the telecommunications technology debate. Some are at a loss to understand why Telecom Australia is using terrestrial systems to provide outback telecommunications rather than using the satellite; others claim that the satellite is preferable because it could provide a fuller range of services, or it is cheaper, or both. Many of these claims involve false assumptions and misconceptions about telecommunications systems, their capabilities and cost structures.

What is often omitted in these discussions is the context of the choice of one telecommunications system over another. Frequently the question of how best to provide telecommunications services in Australia's remotest areas is reduced to the comparative cost of satellite systems and Ditigal Radio Concentrator Systems (DRCS), one of the main terrestrial systems Telecom has chosen for remote areas. Although comparative cost is a central issue in the choice of a telecommunications system, the current and future customer benefits each system provides are also taken into account.

In choosing a telecommunications system or technology to provide services in a particular market, Telecom Australia considers many factors including the characteristics of the market and the range of services/products to be provided, as well as the characteristics and costs of alternative telecommunications system which might be used. The aim is to provide the required services and products in the most cost-effective manner.

RURAL AND REMOTE SERVICES

In rural and remote areas, the provision of world standard telecommunications services is a high priority for people living and working in some of the harshest country in the world.

In providing these services, Telecom Australian must meet technical design standards which are set internationally to govern the quality and integrity of the world's telecommunications networks: compliance with these standards allows customers to make ISD calls to anywhere in the world and to interconnect computer systems and other equipment to world information, financial and management networks.

The nature of Australia's outback and the characteristics of its settlement vary widely. However, the general low population density and great distances between its inhabitants — on pastoral stations, Aboriginal communities or mining ventures — have presented great difficulties in the provision of world standard telecommunications services. With the recent availability of appropriate and acceptably priced telecommunications systems, Telecom Australia has made the commitment to provide world standard services to those areas by 1990 through its Rural and Remote Areas Programme (RRAP).

Telecom's commitment to the $400 million Rural and Remote Areas Programme is unique in that it is the only such endeavour by a comparable telecommunications organisation anywhere in the world. In other countries the uneconomic nature of rural and remote networks makes them a low priority for telecommunication businesses seeking a profit. For Telecom Australia, these expanding networks are an expression of its mandate to serve all Australians wherever practicable: this national social mandate leads to the cross-subsidisation of Australia's rural and remote networks from areas where costs are not as high.

These varying circumstances of Australia's outback settlement have necessitated the use of a range of different systems and technologies by Telecom Australia in the RRAP. Modern automatic terminal exchanges give rural and remote customers access to the national and international network through the latest microwave transmission technology and soon through optic fibre routes, From the terminal exchange to the customers' premises (ie the customer network), Telecom has continued the use of underground cable systems in towns where exchanges are located. Further from exchanges (the distance depending on the terrain and the comparative cost of alternatives), customers' services are provided by means of radio systems. These may be single or multiple channel radio systems or may involve concentrators, as with the Analogue Radio Concentrator Systems (ARCS). Although radio telecommunication systems have been available for years, it is only in comparatively recent times that advances in digital transmission have produced systems which would enable the national switched network to be extended to provide a full range of services to remote areas at an acceptable cost.

Apart from the cost, telecommunications planners must take account of a system's construction, operation and maintenance characteristics when considering its use in the network. The most important consideration is that the system meets the customer's requirements for reliable services of a standard comparable to those in the major urban centres, that it can carry the traffic required of it, and that it can reasonably meet new demands into the future.

To bring telecommunications services to the rural and remote market not already served, Telecom engineers designed a new radio system (the DRCS) which could span sparsley settled areas, while still providing a world standard service up to 600 km from the terminal exchange.

DIGITAL RADIO CONCENTRATOR SYSTEMS

The Digital Radio Concentrator System (DRCS) was conceived and specified to meet the needs of this market and, following development and production by the Nippon Electric Company (NEC), is arousing interest in countries with markets of similar characteristics. The DRCS will fill a gap in rural telecommunications markets worldwide.

A DRCS has three major building blocks: the customer station, the repeater station and the exchange unit. The radio path is taken out to customers by radio repeater stations about 40-50 km apart. Up to 13 repeaters can be used in any one line in a DRCS, giving up to a 600 km distance between exchange and customer (see **Fig. 1**).

Each customer on a DRCS is either cabled for service from a nearby repeater (less than 4.5 km) or connected to it by radio to his customer station, located on his premises and within line of sight (about 30-40 km) of the repeater tower. It can be seen that by locating repeater stations to suit the spread of customers and the terrain (viz, using raised ground where available), a DRCS can serve customers over a vast area.

(**Fig. 2** shows two DRCSs which have been installed in WA in 1984/85, stretching out from Meekatharra and Mt Magnet exchanges. To put it into perspective, the size of the area served by these systems has been compared with a superimposed map of Tasmania).

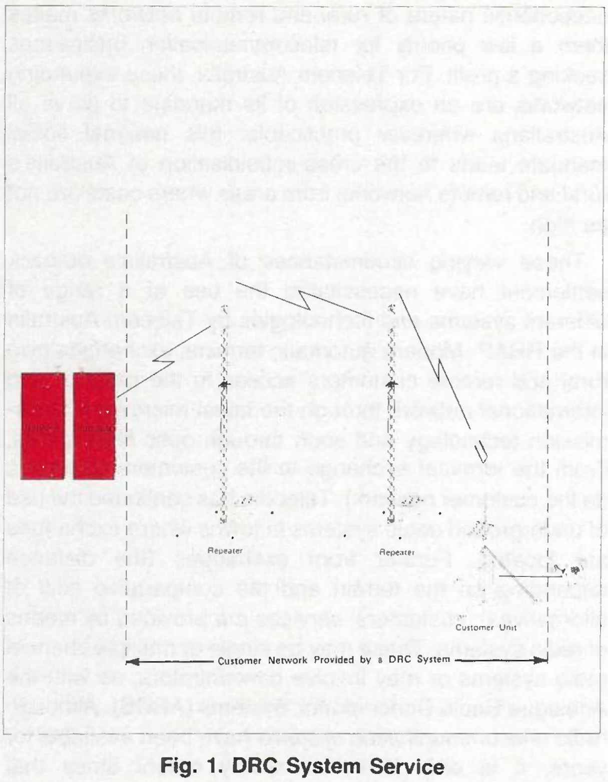


Fig. 1. DRC System Service

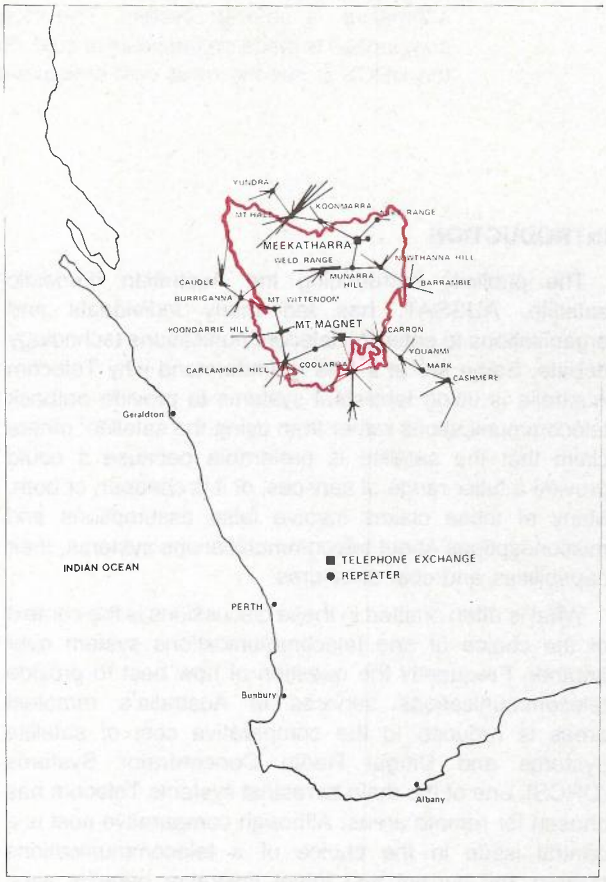


Fig. 2. Mt. Magnet and Meekatharra DRC Systems

The DRCS delivers a wide range of modern telecommunication services and allows the connection to the network of a full range of facilities. Through DRCS, remote customers can have access to services such as ISD, STD and 008.

Besides providing world standard telephone services, DRCS is also capable of providing videotex, telex, telememo, facsimile and normal 2400 bit/sec data services. Data can be transmitted at the speeds required to accommodate the services needed in remote areas. For example, DRCS will support electronic funds transfer (EFT) which will make such things as home shopping, home banking and computerised stock selling etc. possible.

The DRCS allows the full range of applications seen elsewhere in the Australian telecommunications networks: in business and government, in health, education and welfare services, the network's capabilities for conferencing, transmission of written material and computer interaction will greatly reduce the effects of isolation in Australia's rural and remote areas.

The DRCS was designed for this particular purpose — to provide world standard telecommunications services to Australia's outback. It is not surprising therefore that it is the most cost-effective means of providing these services available at present. Furthermore the digital radio concentrator systems installed under RRAP provide the basic network infrastructure for expansion or development when the population (and the demand for telecommunications services) grows in particulars areas.

At present some 187 separate digital radio concentrator systems are planned, providing a total of about 10,000 telephony services. Each of these systems can cater for up to 127 customers (depending on traffic levels) or can be expanded without affecting other DRCSs technically or commercially.

Expansion of each system can be achieved by various means, all making use of the basic network repeater stations and associated infrastructure, extra radio concentrator systems can be doubled up on the existing system, or truck radio systems can be used to connect a new exchange back to the network, thereby "thickening" the network and allowing its further growth from a new nodal point. For example, a new exchange might be installed in a remote Aboriginal community when the demand for services reaches a certain level. This network expansion can be undertaken in a local area according to demand with no significant impact on the network as a whole and at relatively low additional costs.

SATELLITE COMMUNICATIONS SYSTEMS

At present satellite communications offer the only feasible alternative to digital radio concentrator systems for provision of telephone services to remote and sparsely settled areas of Australia. Geostationary communications satellites have some unique characteristics which offer both advantages and disadvantages when compared with other telecommunications systems or technologies. Putting the basic question of cost aside for the moment, it is relevant to examine the characteristics of satellite systems and how they are utilised in the world today.

The satellite is essentially a radio-repeater placed in orbit at an altitude of 36,000 km above the equator. At this altitude, the orbital period is exactly 24 hours and so the satellite appears to be fixed in the sky (ie, it is geostationary). The satellite receives radio signals from individual sources on earth — transmitting earth stations — amplifes and retransmits those signals back to earth to be received by appropriate earth stations within the areas covered by the satellite's antennas, sometimes called the satellite "footprints".

The radio signals repeated by the satellite are usually in the microwave frequency range, and use much of the technology employed in terrestrial microwave telecommunications systems. In the case of the AUSSAT system, transmissions from earth stations to the satellites (called "uplinks") are in the frequency band 14.00-14.50 GHz[1] and transmissions from the satellites ("downlinks") are in the 12.25-12.75 GHz band. This frequency allocation is sometimes called the 12/14 GHz or Ku-band. The three AUSSAT satellites being launched during 1985 and 1986 are being placed in geostationary orbit above the equator north of the Solomon Islands to Australia's north-east.

Satellite communications have three characteristics which may offer potential advantages over terrestrial techniques for certain applications.

Firstly, the satellite can reach all parts of the country with more or less equal effectiveness, and that includes nearby islands and offshore mineral exploration and extraction sites. Thus, communications services can be located anywhere for roughly the same cost.

Secondly, once a signal has been beamed up to the satellite, it can be received at as many locations as needed simply by adding the receiving equipment in the required locations. Depending on the network size and location, the satellite can broadcast a signal more cheaply than by using a land line to each place. This broadcast capability can also be used in the reverse direction where, for example, the satellite is used to act as a concentrator to collect data from many widely distributed locations and transmit the information to a single point; though in general, transmitting earth stations are considerably more expensive than receive only ones.

Thirdly, a channel through the satelite may be used now between two locations, then between another two locations, and later still, between yet other locations. This rapid flexibility is a feature which terrestrial systems do not have.

Beyond these three characteristics, the satellite has two other features which complement terrestrial technology. Once the satellite has been launched, individual services may be rapidly provided simply by setting up the appropriate facilities at ethier end of the link. In long-haul systems, this can be done very much faster than, for example, installing a microwave, coaxial cable or optical fibre transmission system.

In addition, a satellite may be used for improving the reliability of communications. It is, quite simply, an alternative technology. At present, Telecom utilises alternative technologies in many situations: copper cables, coaxial cables, radio and optical fibre systems are some of the terrestrial technologies currently in use. The satellite offers a further alternative with the advantage that it would be very unlikely that both satellite and terrestrial systems would fail at the same time.

Satellite communications systems also have characteristics which pose particular problems for two-waycommunications. The first of these is due to the satellite's orbital position some 36,000 km above the equator: at this distance, radio signals take about a quarter of a second to travel between the transmitting and recieving earth stations. Thus, for two-way communications, a round-trip delay of about half a second exists. In voice communications this delay can impede the free flow of conversation and can cause echoes requiring the use of echo suppressors and cancellers for satisfactory telephone communications. The situation becomes worse if a two-hop connection is required. The round-trip delay can also cause a substantial reduction of throughput for data communications unless protocols specially designed for satellite transmissions are used.

*1. 1 GHz (Giga hertz) * 1,000 MHz * 1,000,000,000 Hertz or cycles/sec.*

Yet another characteristic of satellite communications is the phenomenon known as 'sun outage', due to the geometry of the earth station, satellite and the sun. Any earth station pointed at a geostationary satellite will, at certain times of the year, also be pointed directly at the sun. When this occurs, communications are lost as the radio noise from the sun drowns out the wanted signal. Luckily the duration of this occurrence is short — only for a few minutes a day for a period of about a week, twice a year. The occurrence of this phenomenon is entirely predictable and so communication requirements can be scheduled around these periods.

The use of satellites for the provision of telephone telecommunications requires earth stations which can both receive and transmit signals of high quality, anywhere in the satellite footprint. The high costs associated with two-way satellite voice communications have limited its use to-date to long distance trunk applications, particulary over sea or difficult terrain (eg tundra in North America).

One of the earliest of satellites, leading to the formation of Intelsat, was for international telephone links across the world's oceans. The terestrial alternative (viz — sub-marine cables) was very costly and the satellites were, and remain, a cost-effective substitute currently providing approximately 50% of transoceanic telephone links.

For domestic telecommunications, satellites' largest application has been for television programme distribution. In the USA alone, there are approximately 800,000 TV receive-only stations in operation and this is expected to rise to one million by the end of 1986. In comparison, also in the USA, there are currently some 1,250 transmit/receive earth stations in operation. This total of 1,250 stations includes stations for television and data applications as well as for voice.

In 1973, Canada commenced operation of one of the world's first domestic satellite communication systems, owned and operated by Telesat Canada. Currently, Telesat has some 150 earth stations in operation providing television, data and telephone service across the nation. The Canadian continent is a vast area with many isolated communities in the frozen north of the country. Apart from TV, the satellite is used to provide some of these remote communities with telephone services. In the main, the satellite technology is used for trunking between the remote terminal exchange and the terrestrial network. Telesat has some 85 earth stations nationwide providing telephony services at a total investment of approximately C$150M, or close to an average of C$2M per telephony earth station.

There are a number of other countries with domestic satellite systems which are usually used to provide communication links to isolated regions. For example, Indonesia's population (approx. 160 m people) is spread over some 3,000 islands and their Palapa satellites are being used to link some of the islands with administrative centres.

Australia is also characterised by a vast continent and a harsh climate in most of the remote regions. However, in contrast with other countries using satellites for telephony, most of the population without or inadequately serviced with telecommunications is thinly spread. Unlike Canada, where a single earth station can serve a community of a few hundred people, the requirement in Australia would be for earth stations serving single homesteads with a handful of services. It can be appreciated that for an Australian RRAP applications, a very different system design and associated cost structure is required from that used in other domestic telephony applications around the world.

REMOTE TELEPHONY SATELLITE SYSTEMS

Any satellite communications system consists of two major components:

a. the satellite transponder;

b. the transmitting and receiving earth stations.

The communications capacity of a transponder is a function of both the transponder and earth station characteristics. In general, the more sensitive the earth station (larger and more expensive installations), the greater the transponder capacity. In order to optimise the cost of a satellite communications system, the total cost of both earth and satellite components needs to be taken into account. Thus, for international communications where one or two gateway earth stations serve an entire country, it is worthwhile investing in very large expensive earth stations in order to maximise the capacity obtained from a transponder. The Moree and Ceduna Australian Intelsat earth stations have antenna diameters of 30 metres and cost many millions of dollars each.

If, instead of a thick route network as in the international case, a network with a large number of earth stations is required, it becomes economic to sacrifice some transponder capacity in order to reduce the size and cost of the transmit/receive earth stations. Each particular network requirement will have a different optimum design, and cost minimisation of the earth station will usually result in a very high transponder channel cost component.

Put another way, there is a point where the increasing costs (in manufacture, transportation, installation, etc) of bigger earth stations are greater than savings achieved due to the larger number of channels derived from a transponder. That is, the per customer cost of a particular satellite telephony system begins to increase again once a certain size customer earth station is passed. This point can be seen as the lowest in the graph in **Fig. 3.**

For remote satellite telephony, costs are associated with the remote customer earth stations, the proportional transponder usage and major network together with a central control, monitoring and switching functions. **Fig. 4** shows the satellite customer network.

In the case of the Telecom Iterra Network Service, the optimal size of customer earth stations is 3.5-4.0 m, giving 200 satellite channels. More channels could be derived by using larger earth stations but these are not only more expensive but also quickly become unwieldly, requiring special transportation, extra supports and mechanised adjustment for directing at the satellite. As rain attenuates the radio signal in the Ku-band, larger antennas and more powerful transmitters are needed in higher rainfall areas if continuous service is to be provided, increasing the average per-customer cost.

The 200 INS channels can support around 2,000 customers (at relatively low traffic levels) through the use

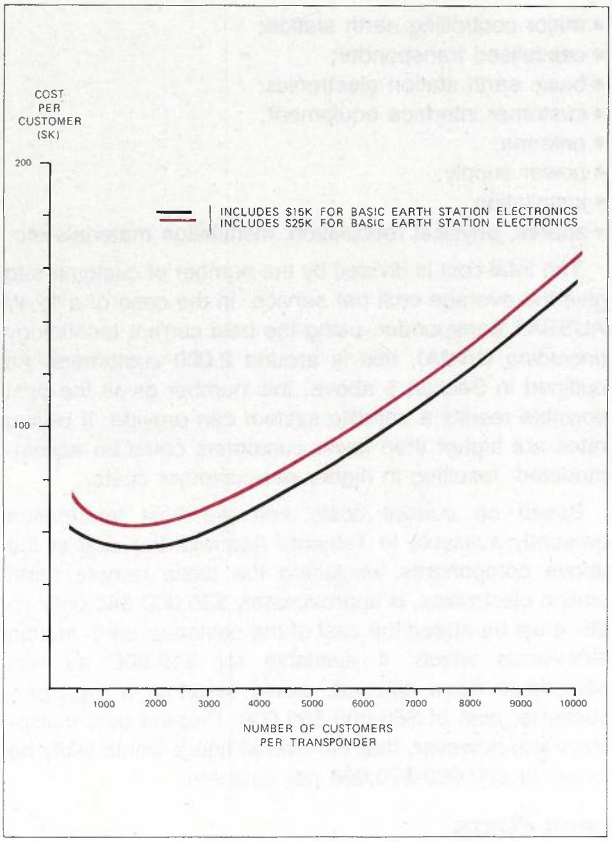


Fig. 3. Satellite Costs Per Customer

of a flexible system of channel allocation called Demand Assigned Multiple Access (DAMA). Each customer is only allocated a transponder channel as he requires it, rather than its being permanelty assigned; in this way the satellite system acts as a large radio concentrator.

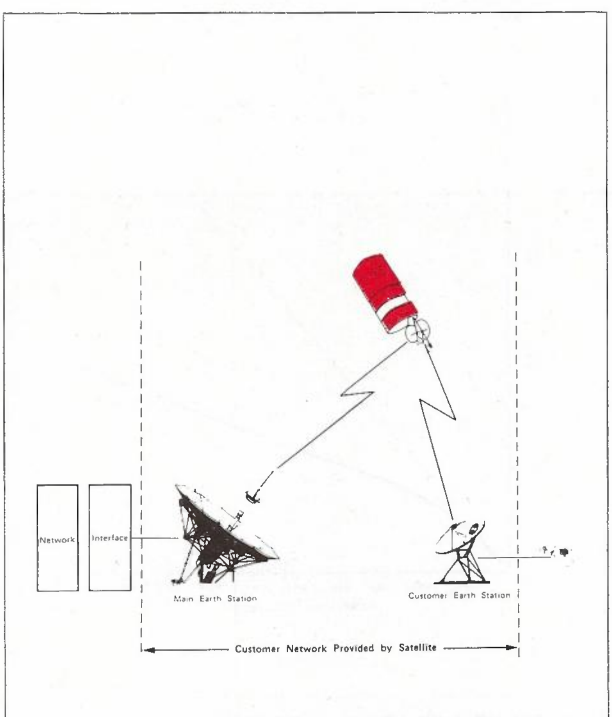


Fig. 4. Remote Telephony Satellite Service

Providing up to 2,000 satellite telephone services could require up to 2,000 single-channel earth stations. If customers are co-located, larger multiple-channel earth stations could be used. Each of these earth stations must be equipped with electronic interface equipment which caters for the DAMA system, the switching and metering of telephone calls and may also need to vary the signal strength to compensate for any rain attenuation. This complexity contributes to the overall higher cost of two-way switched telephony earth stations.

Because of the higher costs of both earth stations and transponders it is desirable to fully load a transponder to obtain the optimal financial return; the per-customer cost of a transponder is lowest when it is fully loaded with around 2,000 low-traffic services. Clearly, if this per-customer cost is low enough the satellite-switched telephony system will be preferred to any terrestrial option serving the same number of customers.

Once the capacity of a single transponder has been reached then if more traffic is to be handled another transponder would be required. This then means a stepwise increase in overheads, rather than any substantial saving in additional cost which happens with terrestrial networks. An accurate forecast of telephony traffic is therefore critical for a satellite system's financial optimisation. Furthermore, as this transponder needs to be on the same satellite, costs are incurred in reserving capacity for future use.

MULTI-PURPOSE CUSTOMER EARTH STATIONS

The potential for satellite systems to provide a range of services by use of their capability to relay radio signals to large receiving areas on earth (viz, footprints) has led many people not familiar with the complexities of communication electronics to assume that these services might all be readily available through a small multi-purpose earth station located anywhere in outback Australia. Unfortunately, this is not the case.

To give greater flexibility in their use, each of the three AUSSAT satellites (located 4° apart in space) is divided in four (4) 30 watt transponders and eleven (11) 12 watt transponders[3]. The transponders can be individually switched to give the footprint necessary for a particular communications purpose (**Fig. 5** shows the various footprints available). In addition, the flexibility and capacity of the satellite can be increased by polarising the radio signal[5]: A vertically polarised beam can be transmitted along with a horizontally polarised beam of the same frequency and the two can be detected and received separately, doubling the amount of information which can be sent or received in a particular bandwidth.

The different satellites, transponder polarisations and footprints allow a wide range of services to be provided via the AUSSAT system. Some of the powerful transponders (30 W) will be used to provide the ABC's HACBSS TV service. This greater transponder power allows reception of a signal through small (1-1.5 m), comparatively cheap

2. See "Where Satellite Technology Gets Down to Business." Telecom Australia, 1985, Section 8, for an outline of DAMA.
3. See "Where Satellite Technology Gets Down To Business" for a full explanation of these relationships.
4. Ibid
5. Ibid

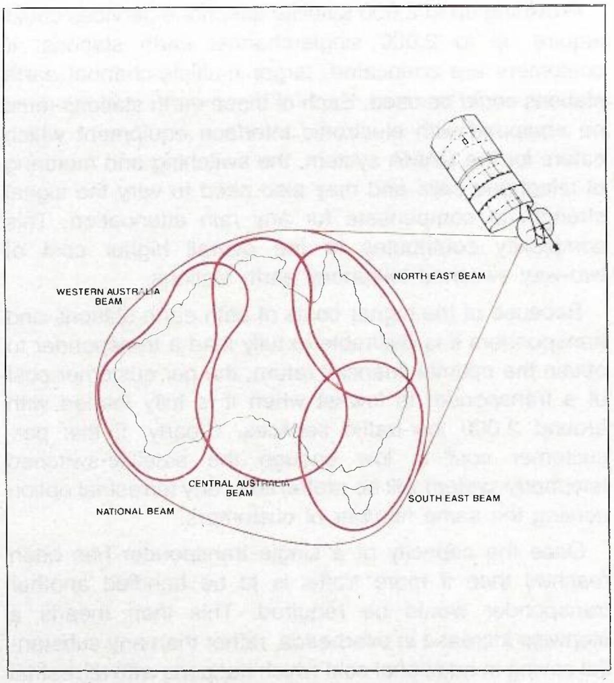


Fig. 5. Aussat's Satellite Coverage Areas

($2,000-$3,000) earth stations in the footprint of the transponder using that frequency and polarisation. In each case the customer's earth station must be pointing at the particular satellite where the transponder is located.

These small dishes cannot readily be adapted to simultaneously receive signals from other satellites and transponders or signals from the same satellite on a different polarisation. To give them that capacity, given the numbers of combinations of satellite and transponder serving each footprint, would destroy the economies of scale achieved by mass production of earth stations dedicated to each respective purpose — be it HACBSS, education services or switched telephony.

In fact, as a general rule the situation is so complex to make the design and production of multi-purpose earth stations a very expensive exercise, where practicable at all. This is further exacerbated if the earth stations are to transmit as well as receive in the way outlined in the above discussion of remote telephony satellite systems.

COMPARATIVE COSTS OF DRCS AND SATELLITE

As it is planned to provide some 10,000 services by means of Digital Radio Concentrator Systems (DRCS) it is appropriate to compare the cost of these systems with costs of a satellite system. The less costly solution allows Telecom to complete the provision of services to all remote areas more quickly as it allows more services for a given annual expenditure in the Rural and Remote Areas Programme.

To provide a customer with service, a connection must be made between the customer's premises and the switched network. It is these customer access networks provided by the DRCS and the satellite respectively that must be compared in cost.

SATELLITE COSTS

The total cost of the customer satellite network is made up of the following component costs:

- major controlling earth station;
- capitalised transponder;
- basic earth station electronics;
- customer interface equipment;
- antenna;
- power supply;
- installation;
- spares, physical reticulation, installation materials etc.

The total cost is divided by the number of customers to give the average cost per service. In the case of a 12 W AUSSAT transponder, using the best current technology (including DAMA), this is around 2,000 customers. As outlined in Section 5 above, this number gives the best possible results a satellite system can provide: If calling rates are higher then fewer customers could be accommodated, resulting in higher per-customer costs.

Based on current costs and the best information presently available to Telecom Australia the cost of the above components, excluding the basic remote earth station electronics, is approximately $35,000-$40,000. To this must be added the cost of the customer earth station electronics which, if available for $15,000 as has sometimes been claimed, would result in a total per-customer cost of $50,000-$55,000. Present cost indications are, however, that the overall figure would likely be closer to $60,000-$70,000 per customer.

DRCS COSTS

The installed capital cost of DRCS services includes the following component costs:

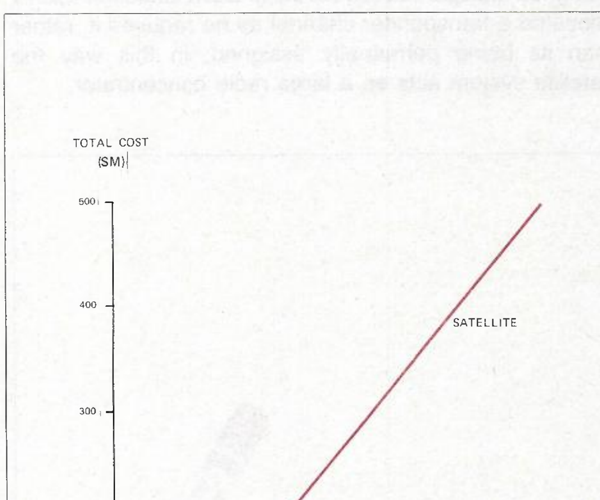


Fig. 6. Total Satellite Costs vs Total DRCS Costs. (Satellite costs based on optimum per customer cost as shown by the lowest point on the graph in diagram 3).

- radio equipment at customer stations, exchanges and repeater locations;
- mast, antenna and feeder costs;
- power supplies;
- site works (surveys, acquisition, access roads);
- installations;
- spares, physical reticulation, installation materials, etc.

On this basis the cost of the 10,000 services to be provided under the Rural and Remote Areas Programme by means of DRCS is estimated at $200M: ie, at an average $20,000 per service over the whole programme.

CONCLUSION

The graph **(Fig. 6)** of comparative costs shows that at the best satellite performance (approximately 2,000 customers per transponder) the average cost per satellite service is approximately $55,000, compared with the average cost of $20,000 for DRCS.

It is important to note that although it is a significant cost the cost of each satellite customer earth station is only a proportion of the overall per-customer cost. Even comparatively large reductions in cost of the customer earth stations will not greatly affect the total per-customer cost.

The cost used for the purpose of this comparison (ie, $15,000) is much lower than tendered costs on contracts let by Telecom to date. It remains to be seen if this figure would be achieved over the development and manufacture of a new customer earth station. Current discussions with manufacturers put a figure of $25,000 per earth station at the bottom end of manufacturing cost targets. This figure would give an average per-customer cost of $65,000.

On the other hand firm contracts are in place for DRCS, the system is in production, a number of systems are installed and operating and estimates have been checked against actual costs. The actual costs for the most expensive 2,000 DRCS services will be approximately $31,000 per customer.

Even if the highest actual cost for DRCS services (viz, $31,000 per customer) is compared with the lowest estimated cost for satellite services (viz, $55,000 per customer) the result is still clear-cut; ie, DRCS-provided services are far less costly than those provided by satellite. As a result, the use of the DRCS will allow Telecom to provide services to outback Australia within a timeframe that is unachievable if the satellite were to be used.

ELECTRONICS INDUSTRY SPENDS MILLIONS ON 'CLEAN ROOMS'

Local electronics companies are investing tens of millions of dollars in the construction of controlled environment areas to allow production of technologically advanced equipment for specialised hi-tech applications.

The increasing number of these 'clean rooms' is a clear indication of the growing sophistication of the local electronics industry, according to a spokesman for the Australian Electronics Industry Association (AEIA).

'Clean rooms' — areas that are often more sterile than hospital operating theatres — are vital in the manufacture of miniature electronic components and of equipment that has to operate for years in environments where it cannot easily be repaired, such as underwater or in outer space.

The reliability of this type of equipment depends on the rigid control of all possible contamination, from clothes' fibres and hair to street dust, and from static electricity during their manufacture.

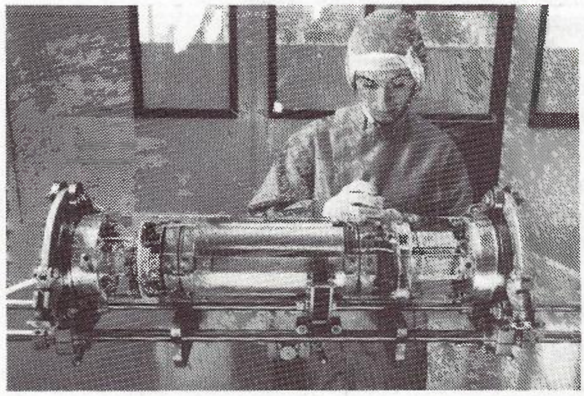
Clean rooms guarantee this control with special air-conditioning and filtering techniques that extract all dust and pollutants larger than 6 microns from the air. (A micron is a millionth of a metre.)

Inside these rooms, which are built from special non-shedding materials, the temperature is kept constant and humidity is never allowed to rise above 75 per cent.

Many also have special anti-static work stations and static dissipative flooring to control static electricity discharges. A static electricity charge to a semiconductor device can either destroy it completely or, even worse, damage it so that it fails in the field after passing 'in-house' tests.

Many of these components are damaged by discharges as small as 150 volts, far below the threshold of human awareness. The characteristic jolt felt from a doorknob or a metal cabinet, for example, is about 3500 to 4000 volts.

Staff in these clean air environments are specially gowned in non-linting, static dissipative gowns and are forbidden to wear cosmetics or to smoke or eat in the area. Often, staff are gloved and capped for even better protection.



Assembling and testing complex submarine repeaters at STC's "clean room" factory at Liverpool, where conditions are as sterile as a hospital operating room.

Twenty years ago there were no clean rooms in Australia. Today there are about 60. Many of these have been built for the local electronics industry as it gears up to meet the demand for increasingly complex components and equipment.

Companies that have invested heavily in these hi-tech factories include AWA Microelectronics, Standard Telephones & Cables (both AEIA members), Qantas and Burroughs-Wellcome.

STC built a $10 million clean room factory to manufacture undersea repeaters for the 14,000 kilometre ANZCAN undersea communications cable from Sydney to Vancouver, opened in November, 1984. Subsequently the clean air factory was used for the production of similar repeaters for the AIS (Australia, Indonesia, Singapore) cable, linking Perth, Djakarta and Singapore, as well as for the manufacture of harness coupling for satellites.

Products for these projects are expected to operate in 'hostile' environments for up to 25 years without servicing or repairs; hence the vital need for highly reliable components manufactured in a dust-free environment.

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The Telecommunications Journal of Australia

Abstracts: Vol. 35, No. 3

CABLE DESIGN AND INSTALLATION TECHNIQUE FOR DIRECT BURIED NON-METALLIC OPTICAL CABLES: B. T. de Boer, R. W. A. Ayre and R. B. Schuster, Telecom. Journal of Aust., Vol. 35, No. 3, 1985, Page 3.

The use of non-metallic optical fibre cables for long-haul and rural routes has significant advantages in relation to lightning-induced damage and on routes affected by power line proximity or other electromagnetic interference. The preferred installation technique for such cables is direct burial using cable-ploughing techniques: However a number of difficulties were observed which were not previously encountered with traditional metallic cables. Detailed experiments and field trials were undertaken using sensitive fibre strain measurement equipment and the parameters of suitable cable designs and installation equipment were established. As a result of successful developments in this area Telecom Australia has standardised on non-metallic filled optical cables for all rural and long-distance optical fibre installations.

COMMUNICATIONS EQUIPMENT ACCOMMODATION IN REMOTE AREAS: A. J. Wishart, Telecom. Journal of Aust., Vol. 35, No. 3, 1985, Page 11.

The range of transportable and small fixed buildings in use in rural and remote areas in Australia and their thermal characteristics are described in this paper. Many of those buildings have been designed to varying degrees with features to promote the natural transfer of heat from the equipment room to its surroundings and to limit the room temperature rise to an acceptable level. Heat dissipation from digital-type equipment of about 0.5 to 5 kW is becoming the norm whereas in the past the room heat loads with analogue equipment have not exceeded about 1.8 kW. The need for a more detailed knowledge of passive heat transfer mechanisms to economically accommodate the larger heat loads is evident. Developments in that area are discussed.

WIDEBAND INTEGRATED SERVICES NETWORKS: J. F. Connors, Telecom. Journal of Aust., Vol. 35, No. 3, 1985, Page 17.

This paper reviews current practices in the provision of trial networks of wideband integrated services and examines trends in technological developments that will impinge on these networks.

LONG-TERM NETWORK DEVELOPMENT OF TACONET: P. Flanagan and R. Hawkins, Telecom. Journal of Aust., Vol. 35, No. 3, 1985, Page 23

Telecom Australia's computer network, TACONET, has rapidly grown in size and range of facilities over the past ten years. This rapid growth is predicted to continue through the rest of this century. A long-term network strategy is outlined, illustrating the improvements in performance and functionality required in addition to the user demand for increases in the numbers of workstations connected.

SOME TRENDS AND DEVELOPMENTS IN INFORMATION NETWORKS: P. A. Kirton BE., Telecom. Journal of Aust., Vol. 35, No. 3, 1985, Page 29.

The information age has exciting prospects for making new and more convenient services widely available. To achieve this many different systems will need to interwork in a compatible manner and on-line directory services will be required to store information about the various distributed information resources.

This paper discusses a variety of developments and trends that the author considers significant in the provision of economic, efficient, pervasive and user-friendly information services. Topics discussed include the ARPA-Internet, office automation, electronic mail, network interconnection and routing, integrated directories, protocol performance, packet voice and integrated networks.

RELIABILITY OF ELECTRONIC TELECOMMUNICATIONS EQUIPMENT: J. R. Taylor QE, Telecom. Journal of Aust., Vol. 35, No. 3, 1985, Page 41.

The sources of reliability and the variability which leads to unreliability are subjects of concern to all who work in telecommunications. The concepts of reliability and electronic component "Wearout," as well as the "Chance Failures" which lead to MTBF failures are discussed. The structure of the "Bathtub" curve and its mathematical basis are treated along with some failure characteristics of Integrated Circuits.

SMALL TRAFFIC RECORDER: Telecom. Journal of Aust., Vol. 35, No. 3, 1985, Page 47.

Ericsson in Australia — a quarter century story: Telecom Journal of Aust., Vol. 35, No. 3, 1985, Page 51.

This article traces the history of Ericsson in Australia, and looks at the extent to which the company has become involved in the development of telecommunications in Australia.

THE ACID TEST — BATTERIES FOR TELECOMMUNICATIONS: N. K. Thuam, Telecom Journal of Aust., Vol. 35, No. 3, 1985, Page 57.

The reliability of telecommunication services depends on the provision of a reliable and stable power supply. The lead-acid battery, as the primary storage medium for this power supply, has long been a faithful servant.

This paper describes the requirements, operations and applications of lead acid batteries in the National Telecommunications Network. The paper also discusses some problems Telecom has experienced with a range of batteries and the various solutions.

RURAL AND REMOTE CUSTOMER NETWORKS WHICH TECHNOLOGY AND WITTY: Telecom. Journal of Aust., vol. 35, No. 3, 1985, Page 69.

The choice by Telecom Australia of the Digital Radio Concentrator System (DRCS) as the mainstay for providing services to outback Australia has raised wide interest. This paper provides some background to this decision by way of discussing the DRCS and the main alternative, a satellite system.

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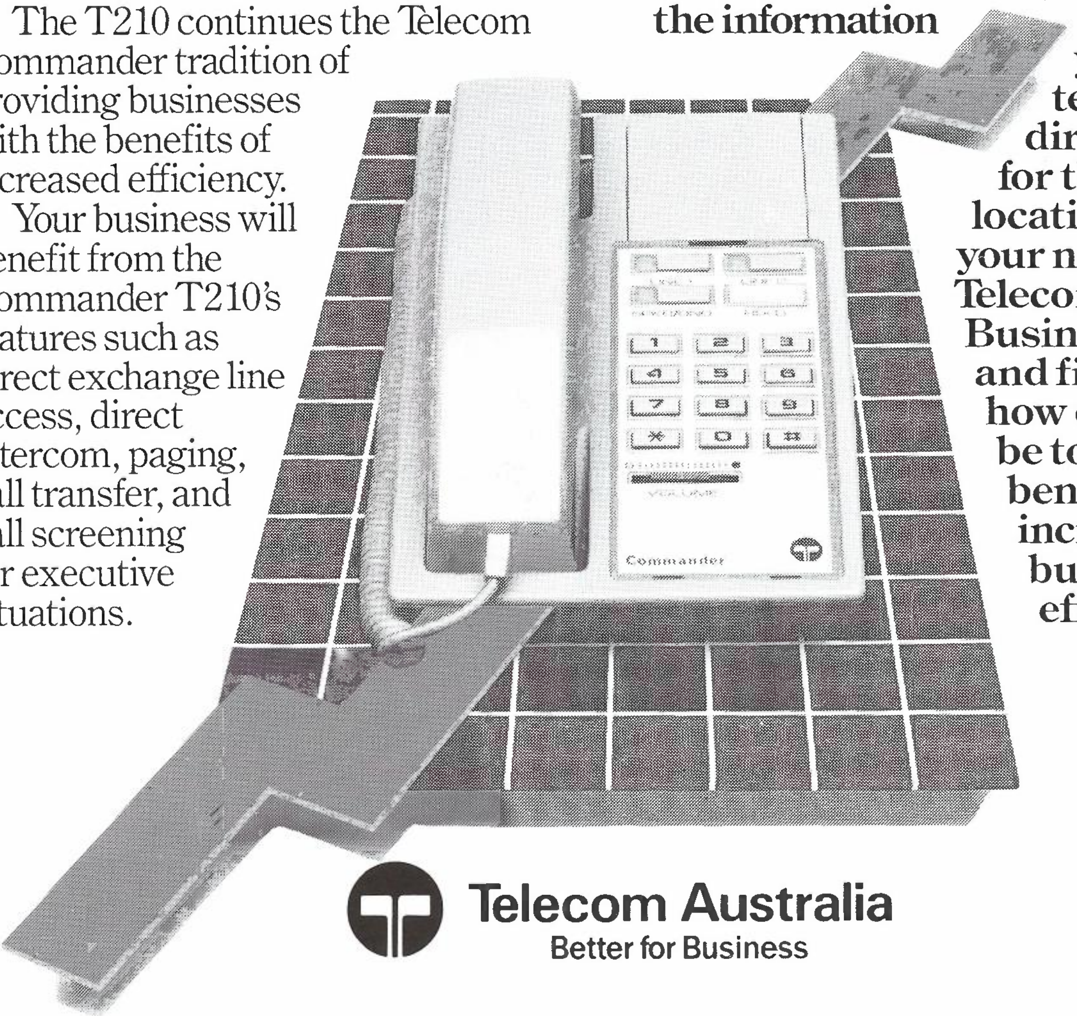

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