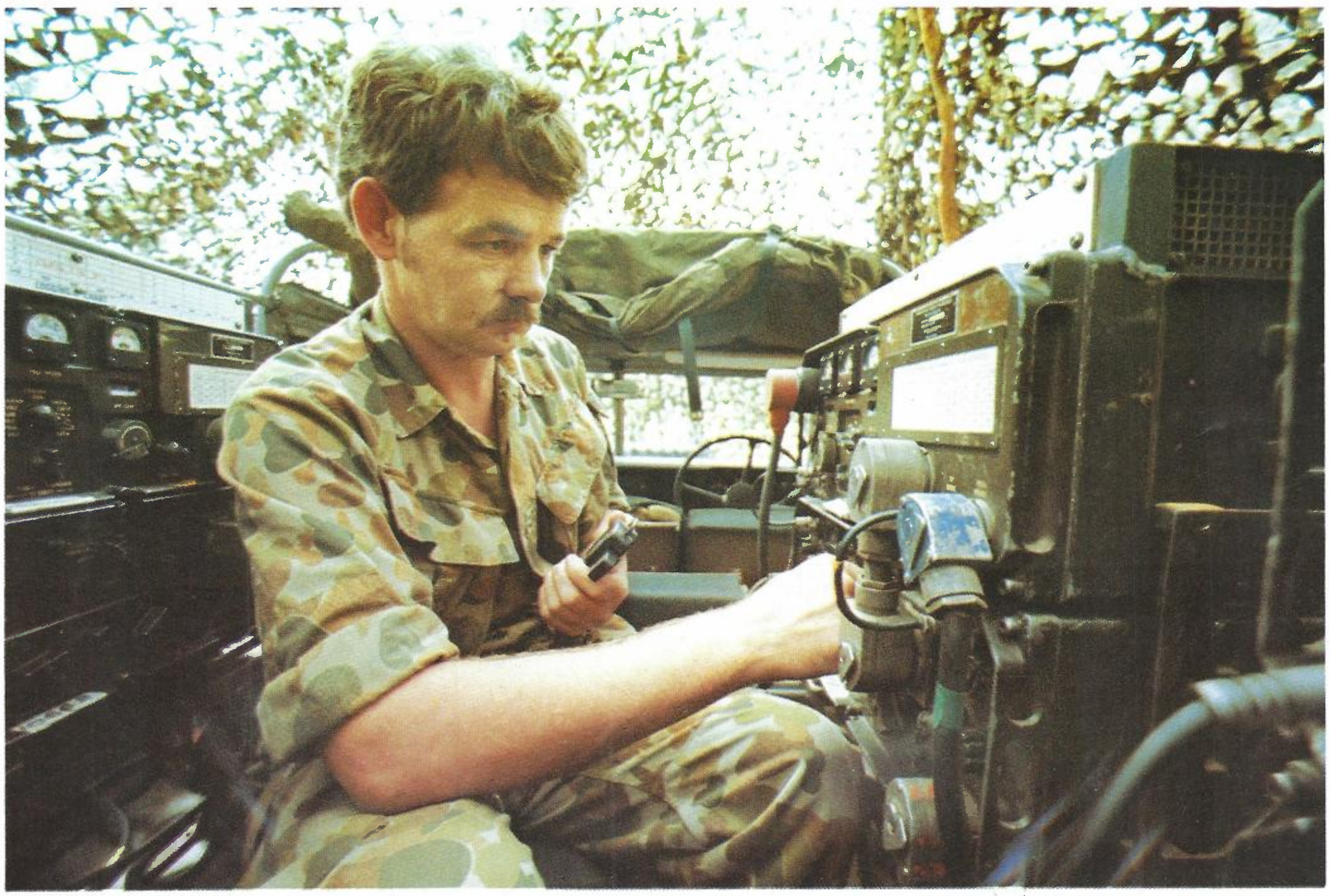
Volume 33, No. 2, 1983

the telecommunication journal of Australia



WORLD COMMUNICATIONS YEAR 1983

33/2

FEATURED IN THIS ISSUE:

- COMMUNICATIONS IN THE ARMY
- PLASTIC INSULATED CABLE PROBLEMS
- TRANSMISSION PERFORMANCE TESTER
- CCITT RECOMMENDATION X.25
- KALGOORLIE TO LEONORA RR SYSTEM

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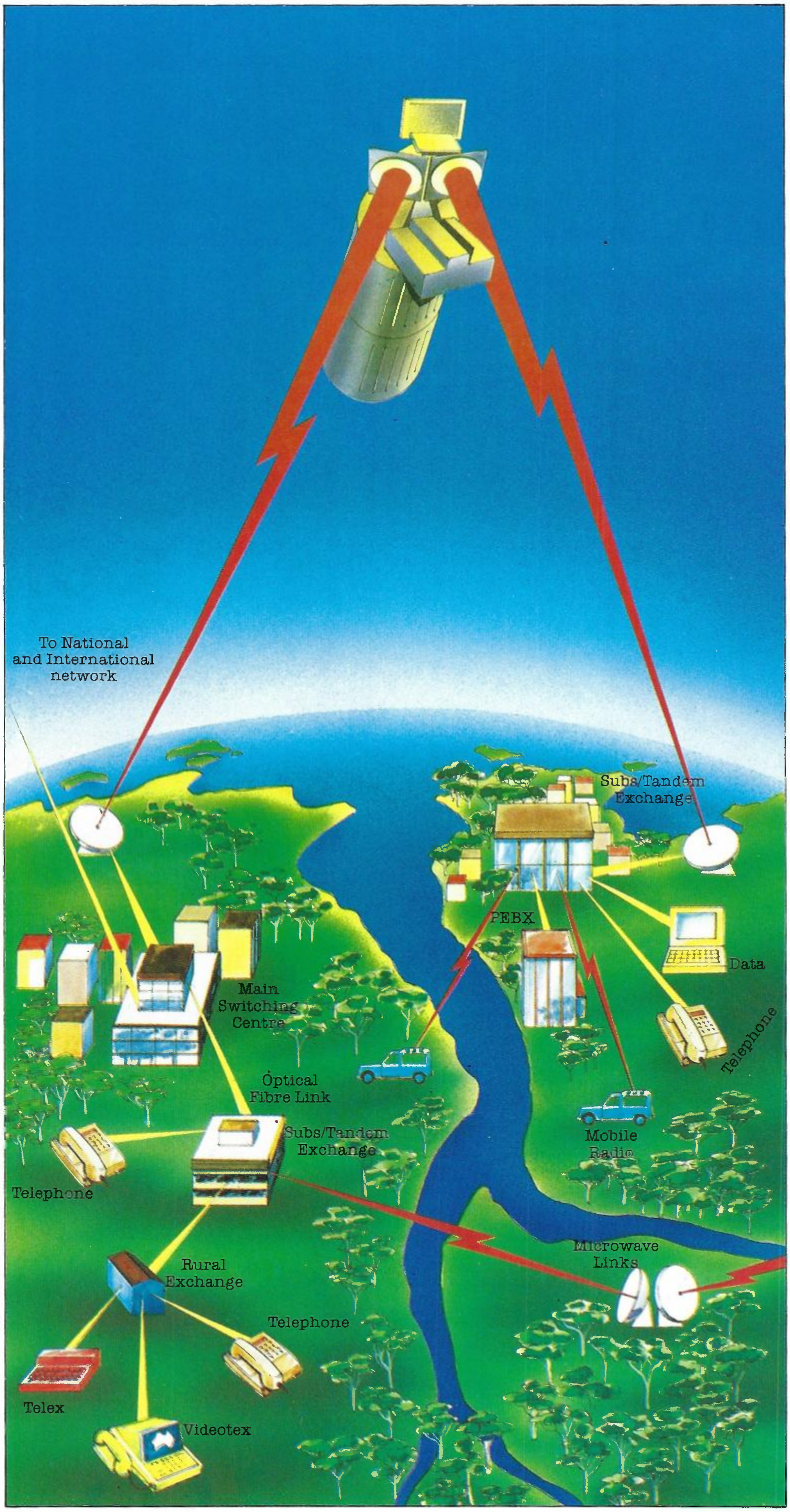

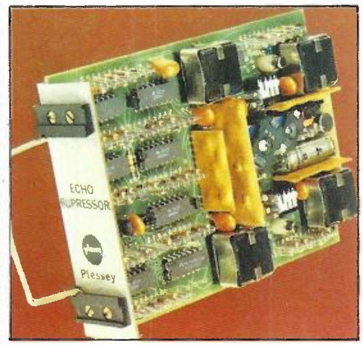

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THE TELECOMMUNICATION JOURNAL OF AUSTRALIA

ISN 0040 2486

Volume 33 No. 2, 1983

Cover:
Operating an Army portable radio set in back of ¾ tonne vehicle.

CONTENTS

OTHER ITEMS

Editorial

The Guest Editor for the May issue of the Telecommunication Journal of Australia was to have been the new Federal Minister for Communications, Mr Michael Duffy.

An Editorial in which the Minister was invited to outline the new Federal Government policies and/or changes in communication directions foreseeable for the future.

Unfortunately due to pressure of work, at the last instance, word was received that the Minister would be unable to provide comments in time for the May issue. At the same time printing deadlines had to be met, thus preventing an alternative Editor being sought.

RON KEIGHLEY
EDITOR IN CHIEF

Army Communications Looking Ahead

Colonel P.G. Skelton, AM, FRMIT, FIREE

This article describes the need for communications for command control of the Army. It summarises the various levels and types of communications provided and describes the elements which exist to provide these communications. The article looks forward indicating the type of communications and equipment which can be expected in the future.

INTRODUCTION

Communications are essential to enable the exercise of ***command*** and ***control.*** One of the responsibilities of a military commander at any level is to provide communications down to those he commands. To execute this responsibility the commander at each level in the Army is provided with a communications staff on his headquarters for planning and co-ordination, and a signal unit to provide the required communications.

There are many variations in the detailed implementation of this theme. There is also variety in the complexity, organisation and transportability of the signal units, depending on the level of the commander and the nature of his command. This summary of communications in the Australian Army today and towards Year 2000 illustrates that variety. The Army is a people, rather than equipment, oriented organization and the variety of interesting careers available in Army communications (both Regular and Army Reserve) can be inferred by the reader.

UNIT COMMUNICATIONS

Within units (that is within Infantry Battalions, Armoured Regiments, Artillery Regiments and so on) communications are provided by Regimental Signallers. These are members of those units who are primarily Infantrymen, Troopers, Gunners etc. and who have been given additional training to enable them to provide communications within their units. They provide VHF simplex voice radio networks (nets), HF simplex voice or CW (morse code) nets, and telephone systems based on small unit switchboards, magneto telephones and field cable. The key characteristics of equipment at this level are light weight, small size, reliability, and ability to withstand for long periods the full range of physical environmental conditions found anywhere in the geographical area of "Australia and its interests". Our emphasis in environmental performance is based on operations in hot wet and hot dry dusty (with high direct solar radiation) conditions, compared with our Northern hemisphere allies who are concerned with cold temperature performance. Electrical characteristics of importance are high frequency stability, clean emission and narrow channel spacing, to permit the required many hundreds of nets to operate in close physical proximity, plus compatibility with encryption devices and electronic counter counter-measures (ECCM) such as frequency hopping.

The Army has in service to-day, a variety of manpack and vehicle (both wheeled and tracked) mounted HF SSB and VHF FM radios, some of which were designed, and almost all manufactured, in Australia. These will all be replaced this decade by the family of radios being developed in Project RAVEN. The RAVEN family comprises a manpack HF transceiver, a manpack VHF transceiver, RF power amplifiers, and a common set of headsets, handsets, message entry device, power cables and so on **(Fig 1)**. RAVEN radios will be manufactured in Australia, with the HF radio entering service in 1987 and the VHF radio in 1989. They will not be much smaller or lighter than their predecessors, but are microprocessor controlled, have far better performance, will be more reliable despite the added complexity, and be easier to maintain.

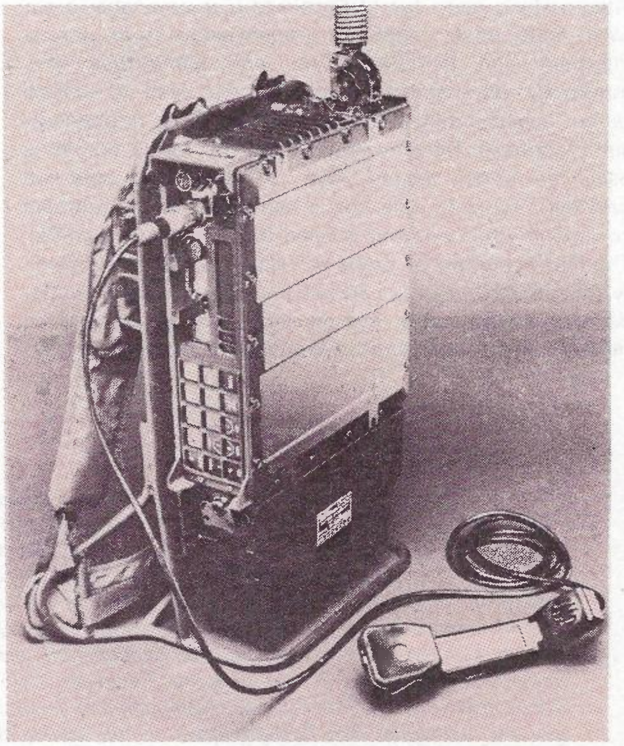


Fig. 1 — The HF manpack transceiver from the RAVEN family of radios. Note the lack of switches and dials. The keypad and screen indicate the greater flexibility of this new range of microprocessor controlled radios.

COMMUNICATIONS ABOVE UNIT LEVEL

Above unit level, communications are provided by the Royal Australian Corps of Signals (RA Sigs). To scope the variety of tasks undertaken by RA Sigs it is simplest to consider six general categories, namely:

- conventional field communications;
- Special Action Force field communications;
- fixed (strategic) communications;
- technical support;
- training;
- electronic warfare.

RA Sigs has approximately 2600 officers and other ranks (of which about 12.5% are females) engaged in these activities. In addition, about 30% of the officers at any one time are filling "non-Corps" appointments such as in operations, personnel management, logistic support, or material development and acquisition, as part of their career advancement and broader contribution to the Army.

Field Communications — Brigade

A Brigade is a grouping of two to four Infantry Battalions, an Artillery Regiment, a Signal Squadron, and other units, all under a Brigade Headquarters.

A Brigade Signal Squadron provides communications for the Brigade Commander to all units under his command, to the Brigade Headquarters on his right (when deployed in the field with other Brigades), and for various special purposes such as reconnaissance groups and commanders rover groups. The main means of communication is secure VHF FM voice radio with handsets remoted into command posts and with radios sited making good use of terrain to give coverage to our own units while shielding transmission from enemy intercept and jamming. One, and sometimes two, automatic retransmission stations are used to extend range, necessitating the use of up to three frequencies simultaneously for one simplex net. HF voice or CW is used for longer ranges. Two or more radio nets are provided. Typically one net is kept clear for operational command while another is used for more routine traffic. The RAVEN family of radios will also be used at this level. A switchboard of about 30 line capacity **Fig 2** serves the Brigade Headquarters. The current manual board will be replaced by an automatic one this year. Line is laid from Brigade to Battalion Headquarters when possible, such as in a defence position, to avoid use of radio which is susceptable to intercept and jamming. A communication centre containing teleprinters at Brigade Headquarters enables receipt of formal messages from Division Headquarters. Training has commenced on the new microprocessor based teleprinter **Fig 3** now replacing the aged electromechanical one. A Signal Dispatch Service (SDS) based on Dispatch Riders using vehicles or motor bikes supplements electronic communications and provides a means of delivering items such as maps. There are currently three Regular Army and six (soon seven) Army Reserve Brigade Signal Squadrons.

Field Communications — Division

When a Division is formed from several Brigades, a Divisional Signal Regiment provides communications for the Divisional Commander to all Brigades and other headquarters and units directly under his command. The general outline already described is repeated with secure VHF FM voice and HF voice/CW nets, in future using the RAVEN radios, and use of SDS. However at this level the main means is a multichannel trunk communications system **Fig 4(a and b)**. It is based on a 12/24 voice channel UHF radio relay sub-system using pulse code modulation (PCM) at 19.6 kbps. This carries common user and sole user voice circuits as well as teleprinter

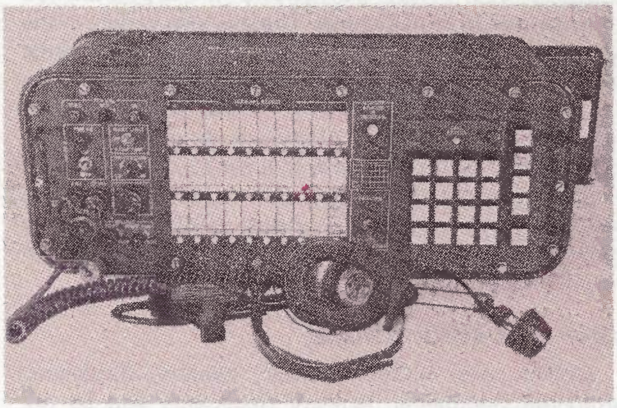
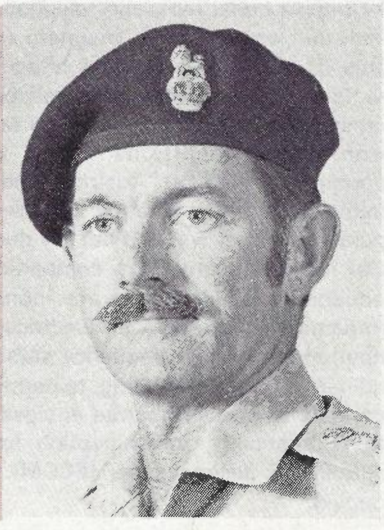


Fig. 2(a) — Switchboard SB-3614. This ruggedized 30 line microprocessor controlled switchboard is subscriber facility programmable and can be stacked to form a 90 line board. It is also approved for connection to the Telecom system.

Colonel Skelton graduated from the Royal Military College Duntroon in 1960 into the Royal Australian Corps of Signals. He attended RMIT gaining FRMIT (Comm Engr) in 1962. He then commanded a troop responsible for installation of HF transmitting and receiving stations. Following a period as Instructor at the School of Signals he went to Vietnam where he was responsible for communications support to HQ AFV, including in-country radio relay and HF back to Australia. He has had a number of regimental and staff appointments including Commanding Officer 2 Signal Regiment, Commander Field Force Signals and Project Officer for digital field radio relay equipment. In 1978-80 he was the Australian C-E Representative in the United States Joint Tactical Communications Project Office. He has attended the Australian Staff College, the Royal Military College of Science (UK), and US Armed Forces Staff College. He is now Director of Communications — Army.



circuits. The switchboard is a 150 line automatic board produced in Australia. It is a commercial PABX shock mounted in a "shelter" **Fig. 4 and 5** and modified physically and electronically to the minimum extent necessary to survive the environmental conditions and to interface with the radio relay and other equipments. A "shelter" **Fig. 6**, used widely at Divisional level and above, is a transportable room about 2.0 m x 2.0 m x 3.8 m carried on a truck or slung under a helicopter.

Message switching is still accomplished by manual torn tape relay but this will be replaced in 1986 by a small automatic, shelter mounted, store - and - forward message switch. Single channel secure HF teletype links provide an alternative connection when the radio relay is being moved. A medium power multichannel HF transportable terminal (MEDPORT) **Fig 7** now under production in Australia will replace the present equipment in 1984, as well as provide new capabilities.

The present array of terminal, switching, systems control, and transmission equipments, together with various short term expedient equipments about to be purchased, will all be replaced in the early 1990s with the all digital secure multimode (voice, data, facsimile, telegraph) system being developed under Project PARAKEET. A significant facet of PARAKEET which differentiates it from its overseas counterparts is the depth of investigation into integration of HF bearers into an otherwise wideband (16/32 kbps delta modulation)

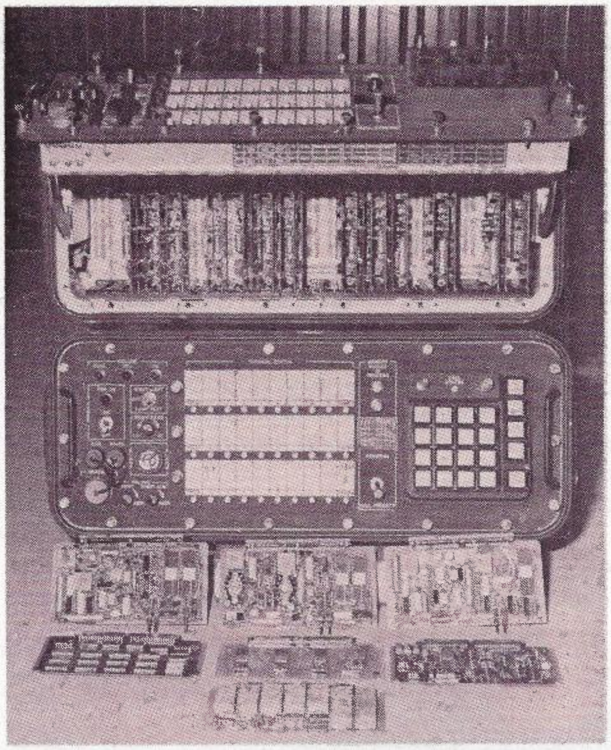


Fig. 2(b) — Another view of the SB-3614 showing: a. in the centre a complete SB-3614; b. on top another SB-3614 partly opened to show internal layout, and; c. at the bottom some of the cords removed from the top board.

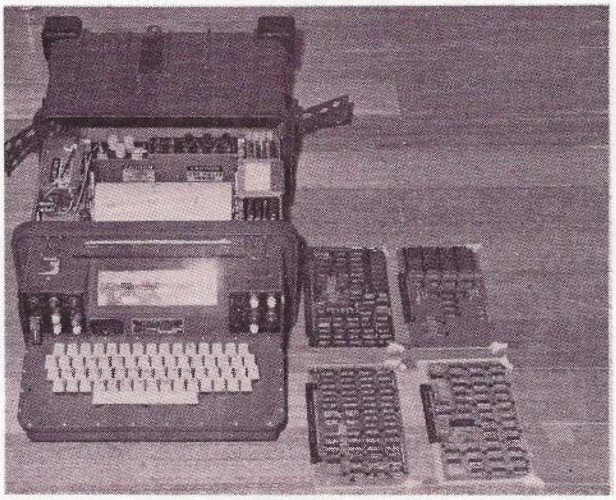


Fig. 3 — Field Teletypewriter AN/UGC-74 shown opened. The four PCBs visible in the right rear are also shown removed alongside.

Fig. 4(a) — Radio Relay Terminal AN/MRC-127.

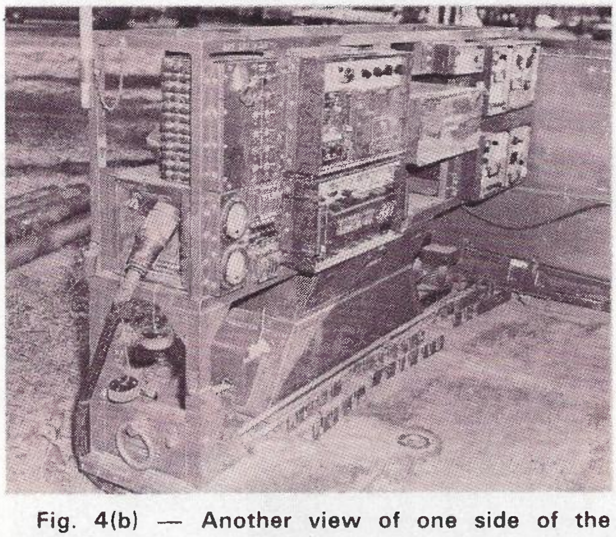


Fig. 4(b) — Another view of one side of the AN/MRC-127F1 radio relay pallet. Top left: signal cable connexion by binding post or (partly obscured) 26 pair cable lock. Bottom left: power cable and power panel. Top centre: 12 voice channel PCM time division multiplexer. Bottom centre: 12 channel telephone signal converter. Top and bottom right: UHF radio.

system. Although satellite links will doubtless be a part of PARAKEET, there are circumstances in our situation when HF will be indispensible.

Reverting momentarily to the present day, the reader can readily appreciate the difficulty in frequency management generated by a dynamic system in which users are mobile and require of the order of 300 nets for each Division of which many VHF nets need retransmission stations, with some HF applications ground wave and other skywave, plus a frequently reconfigured radio relay system. On top of this many stations are in close physical proximity, alternative frequencies are needed to allow immediate relief from enemy jamming, and the entire assignment must be changed at least daily for other electronic warfare reasons. To overcome the daunting effort in calculation of all the interference possibilities, making compatible assignments, and printing the results in a user useful form, the program FASTNET is used. It was developed and written within Army and is run on a desk top computer in 1st Signal Regiment. In addition to frequencies, FASTNET is used to assign radio call signs and code words which also change at least daily.

Field Communications Behind the Battle

Behind the Combat Zone is the Communication Zone in which are found the less frequently moving and larger logistic support elements of the Army. Provision of communications in this zone follows the same general pattern, with due allowance for high capacity, long range, and less frequent moves, but non-the-less responsiveness to electronic warfare and air attack. One such Signal Regiment currently exists and there are plans to shortly reopen membership of it to the Army Reserve. This unit will also be equipped with both RAVEN and PARAKEET, and already has a shelter mounted automatic store - and - forward message switch based on a commercial minicomputer **(Fig 8)**.

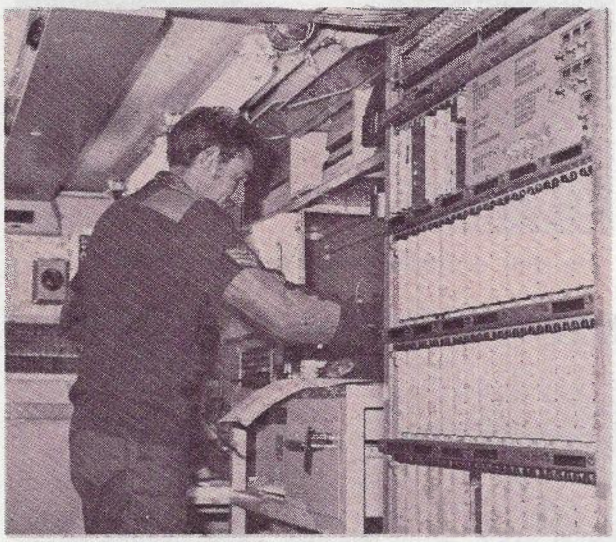


Fig. 5 — Inside the Field Automatic Telephone Switch shelter. It is an only slightly modified 150 line Australian made PABX.

Fig. 6 — Typical shelter.

Field Communications — Joint Operations

It is difficult to imagine an operation these days conducted by the Army in isolation. No matter how small or large the Army contingent deployed, it will almost certainly be as part of a Joint Force which would include Naval, Army and Air components. For such a Joint Force which included an Army component, Army provides the communications for the Joint Force Headquarters, with supplementation by communications personnel from the other services. The same building blocks as already described are used, and are practiced on the well known KANGAROO series of exercises, which also embrace interoperation with our allies. Multichannel long range communications to link such a headquarters with Canberra, or provide other long range links within such a force, are provided by a high power (10 kW) HF transportable terminal **(Fig 9)**, soon to be replaced by the new HIPORT terminals.

Computer Assistance

At all headquarters there is scope for computer assistance for both staff procedures involved in information management (such as own force and enemy

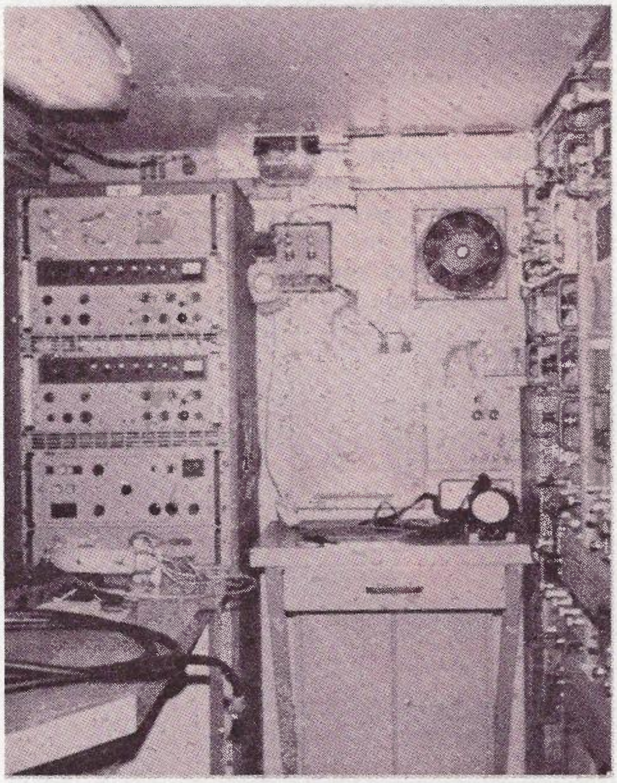


Fig. 7 — Inside the MEDPORT shelter, which is smaller than the other shelters. MEDPORT is based on a 1kW HF ISB transmitter carrying one voice and four teletype circuits.

organizations and locations) logistics and other calculations, as well as communication of key information between headquarters. The AUSTACCS 86 project is developing such a computer assisted system for use at Division and Brigade level. Data channels will be provided by both RAVEN and PARAKEET.

Conventional field communications as outlined above serve the bulk of the Army operations. There are however some interesting special requirements such as described below.

Special Action Force Communications

Special Action Forces (SAF) in Australia comprise the Special Air Service (SAS) Regiment, and a Commando Regiment. Regional surveillance units such as NORFORCE, (based in Darwin) have some similar communications requirements. The nature of SAF operations calls for specialist trained RA Sigs officers and soldiers, a contingent of whom form an integral part of all SAF units.

Some SAF communications, such as those deployed on the familiar commando raids, use similar single channel radio equipments and techniques for command and control as those used by conventional Army units in the Combat Zone. A different challenge for the SAF communicator is the maintenance of the vital links between a patrol base and its small patrols operating for protracted periods under adverse conditions up to several thousand km from their base. For the patrols, conventional communications are not always appropriate, differences are brought about by limitations on equipment size, weight and power output caused by their deployment techniques (from parachute to submarine and many in between) for long periods remote from support. The distances involved currently limit the patrol to HF radio. The need for security and speed, in dangerous operations, necessitates inconspicuous expedient antennas, burst code transmission techniques and minimal set up and tear down times.

The patrol base compensates for the limited resources of the patrol. A wide array of antennas, sensitive receivers and recording and cipher equipment collect the information, which is passed to the staff on the supported Headquarters. This information adds to the Commander's intelligence on the ground ahead and/or the enemy forces that occupy it.

Fixed (Strategic) Communications

Army provides manpower and operates major elements of the Defence Communications Network (DEFCOMMNET) and will continue to do so in DISCON (Ref 2). (Defence strategic communications are discussed in Ref 1 & 2). These elements include message switches, HF radio transmitting and receiving stations, commcens, radio relay and system control facilities.

Major Army units involved in the DEFCOMMNET are located in Sydney, Melbourne, Brisbane, Canberra and smaller facilities are operated in Townsville, Hobart, Adelaide and Perth.

Signal Corps trade structures and training are such that personnel can be employed in both fixed units and the field units already discussed.

DEFCOMMNET is mainly a common user message switched telegraph network which uses both Defence-owned and Telecom bearers but a facsimile service is also provided. In addition, Teleconference links can be established for military staffs, using telegraph facilities, between a number of headquarters.

Army is presently replacing aging electromechanical telegraph equipments with microprocessor based message terminal equipments at all of its commcens.

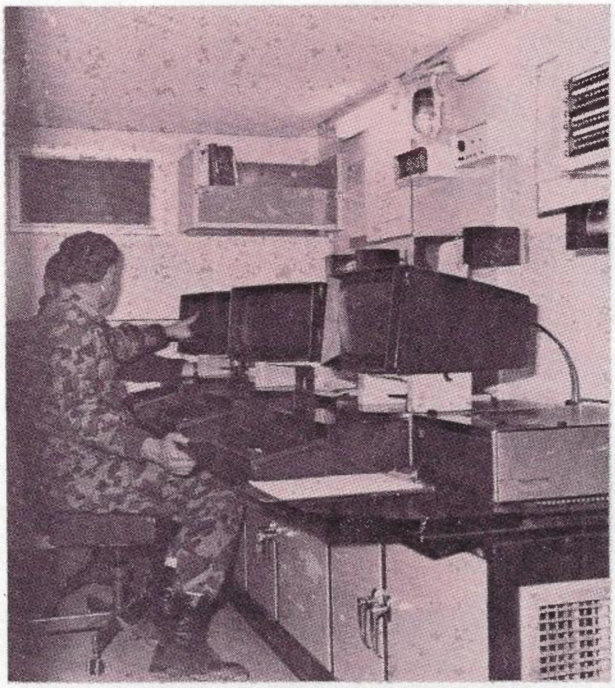


Fig. 8 — Field Automatic Message Switch. Store and forward switch handling 20 duplex teletype circuits. Photo shows interior of the control shelter with its supervisory positions. The fully duplicated minicomputer is in an adjacent shelter.

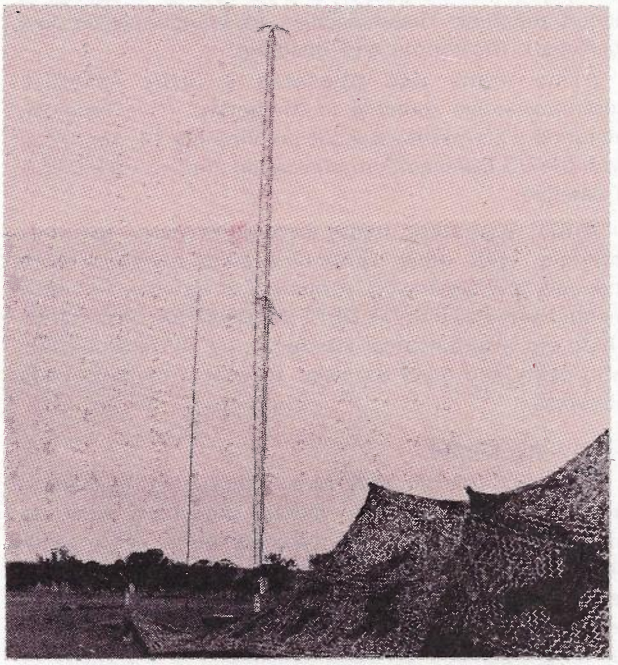


Fig. 9 — Transportable high power HF terminal AN/TSC-38A. Shelter containing one 10kW and one 1kW transmitters, dual diversity receivers, multiplexers and control equipment is under the camouflage net. The system includes two ship antennas and three sloping log periodic antennas.

These software based terminals provide assistance to the operator in formating, editing, routing, and traffic statistics. The terminals have a variety of memory capacities and numbers of keyboard/VDUs to enable tailoring to particular commcen traffic loads **(Fig. 10)**.

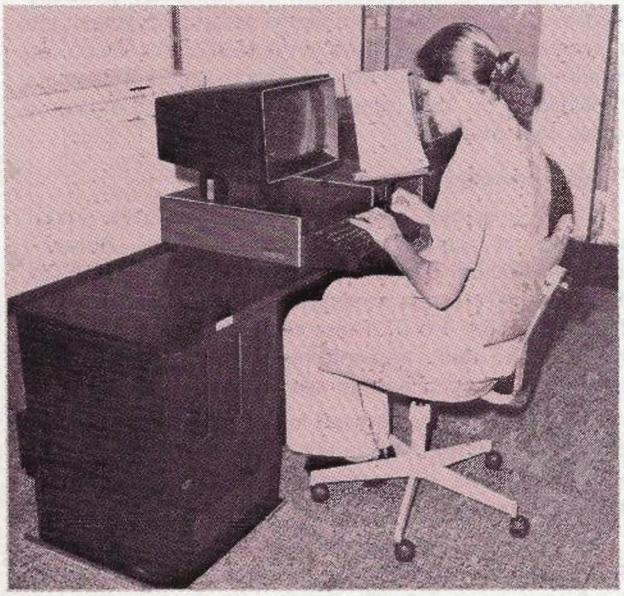


Fig. 10 — Fixed services tributory terminal (FIXSTT). The smallest terminal is shown with its single keyboard/VDU, single 3-disc 10 Mbyte memory unit and single high speed printer. The largest size has eight keyboard/VDUs, three memory units for a total 100Mbyte and four printers.

The HF radio facilities operated by Army are currently being upgraded. This has involved the procurement of new generation remotely controlled transmitters and receivers and the provision of a new range of special to circuit antennas. These facilities are being installed now in Hobart, Melbourne and Brisbane.

Army mans and operates a large satellite communications terminal in Melbourne. This terminal, featuring a 20 metre parabolic antenna **Fig 11**, interfaces with the US Defence Communication System via a DSCS II satellite.

Army operated fixed communication facilities interface with other communications networks both manually and electrically. A number of facilities provide a manual gateway into the DEFCOMMNET for Telex traffic. There are also electrical interfaces, by HF radio or line, with Army and other Services' tactical communications networks.

Electronic Warfare

Electronic Warfare (EW) is an integral part of modern warfare and has many facets. Activities such as monitoring enemy transmissions and using radio direction finding techniques to locate their emitters, are really quite akin to other more conventional forms of reconnaissance. Having located the enemy, using jamming against their communications is analogous to using any other kind of weapon. An EW squadron is allocated to support a Division by using all these techniques and Army currently has a major procurement programme to re-equip this squadron.

There are numerous other actions taken to limit the effect enemy EW activities will have on our own communications. These range from disciplined use of radio to minimise time on the air use of minimum power, directional antennas, and antenna siting — all to minimise accessibility of our communications to an enemy — use of codes and automatic encryption, and use of spread spectrum emissions.

Technical Facilities For Support of Army Communications

Army has two units which provide specialist technical support to other units in both the strategic and tactical communications networks.

The first of these units is a project squadron which is responsible for detailed engineering planning and installation of fixed communication facilities as well as some shelter mounted facilities for tactical units. In the strategic network such facilities include commcens, system control stations, message switch centres, HF radio stations, microwave radio terminals and antennas. This unit is also responsible for maintenance of antennas and masts in many parts of Australia. Its role should soon include a software development responsibility to enable the Army to maintain and develop its new computer based communications equipments.

The other unit operates a depot for receipt, storage and issue of a range of communications equipments and stores used by the first unit.

Training and Trade Structure

Army communications training is conducted mainly at the School of Signals located at Watsonia Barracks, outside Melbourne. It trains approximately 950 students per year. The School is organised into two trade training wings and support elements in line with the RA Sigs two

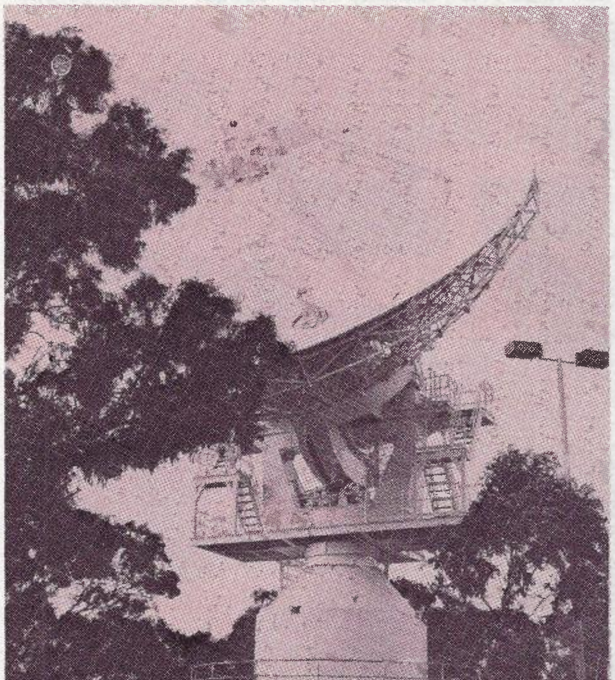


Fig. 11 — Satellite terminal. 20m antenna located at Watsonia Barracks Melbourne.

major career employment groups namely operators and technicians. In addition there is a third wing which is responsible for special signals training for officers and non-commissioned officers.

The operator trade wing conducts initial employment training and continuation training in keyboard, radio, communications security, procedural and management skills needed by the operator trade stream.

The technician trade wing also conducts initial employment and continuation training. The initial employment courses are for technicians electronic, technicians telegraph, riggers and linesmen. Advanced theory courses cover HF radio, radio relay, automatic switch and communications security equipments. The emphasis is to teach tradesmen the full theory of operation whilst also conducting specific equipment maintenance courses on the more complex equipments. Technical Supervisor training includes passing a 12 months certificate course at the Royal Melbourne Institute of Technology.

Fig. 12 — Fish eye lens view of 12 channel VHF radio relay terminal.

About 25% of young officers joining RA Sigs should do so with an engineering degree in electrical, electronics, computing, or communications. The remainder will, from 1983, attend early in their career a 12 month Telecommunication Systems Management Course at Swinburne Institute of Technology. All also attend courses at the School of Signals.

CONCLUSION

Although the variety of communications activities is clear there are several unifying features. These include deliberate adoption of complete systems design and management; our use of microprocessor based equipments using LSI chips arranged in a way amenable to rapid fault location and restoration of service; our preference for Australian design and manufacture; and our focus on developing people as the war winning factor.

REFERENCES

1. H. J. P. Adams, "Australian Defence Communications — A Complex Discipline" Telecom. Journal of Australia Vol. 33 No. 1, 1983.
2. I. H. Maggs, "The DISCON Project" Telecom. Journal of Australia Vol. 33 No. 1, 1983.

In Brief

AUSTRALIAN PRODUCT NUMBER

Australian Product Number (APN) symbols began appearing in Australia on groceries and other merchandise in 1979. Now, more than 60% of items crossing checkouts are symbol marked. Indeed, the rate of symbol marking has exceeded expectations.

The concept of a national product number and a symbol which can be automatically scanned was floated by an ad hoc committee of grocery industry representatives in the USA in 1970. The committee formulated its requirements and invited computer equipment manufacturers to come up with submissions. The symbol had to be printable on existing machinery and with dye based inks used in the packaging industry. Price was not to be included in the symbol as the identification would allow price to be retrieved from the in-store controller or mini computer.

In April 1973 the committee announced the symbol it had chosen. It was to be called the Universal Product Code (UPC) and was a refinement of the symbol proposed by IBM.

Steinbergs in Montreal became, in August 1974, the first store equipped with IBM scanning. Now there are over 5000 supermarkets scanning in North America and several hundred in Europe.

Spurred by the success of scanning in the USA, a European committee was formed in 1975. It found that the North American committee had not allowed enough capacity in the UPC for products to be numbered uniquely, world-wide.

IBM then proposed an extension of the APC, allowing the number to be increased from 12 to 13 digits but retaining the basic UPC symbology for 12 digits. The 13th digit was 'induced' by differing combination of two number systems in the left half of the symbol. Ten combinations yielded digits 0 through 9 which enabled countries to be assigned one or more 2 digit 'flags' or prefixes.

Although the UPC was developed first it became the subset and the EAN or European Article Number, the superset. At that stage the European Article Number Association (EANA) had 12 member countries with a Secretariat in Bruxelles.

Australia formed an ad hoc committee in 1978 which was later incorporated as the Australian Product Number Association and admitted to the EAN Association in 1979 with endorsement by the Australian Government to be the sole organisation responsible for administering the EAN system here. UPC, EAN and APN associations administer a voluntary standard funded entirely by subscription of member companies.

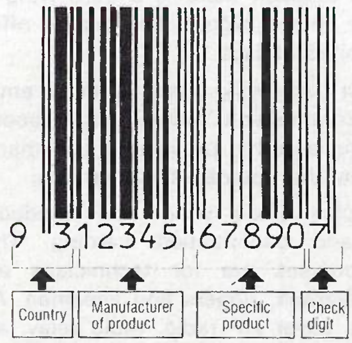
With non-European countries joining EAN, notably Japan and Australia, it was appropriate to change the name from the European Article Number Association to the International EAN Association. New Zealand was admitted in 1981, South Africa and Yugoslavia in 1982. There are now 18 member countries.

Thus a world-wide voluntary coding structure was created and made operational in less than a decade, a remarkable feat of international co-operation.

Coded products can now cross borders and be read by scanning equipment in the retail stores and warehouses of many countries.

One can easily recognise the country of origin of a bar coded product. A single zero or 3 halfway up on the left of the symbol indicates North America, 3 being for pharmaceutical items.

The EAN version has all digits along the base of the symbol. The first two digits represent the country flag. Australia is 93, New Zealand 94, UK 50, etc. In the 13 digit number the next 5 digits are allocated to manufacturers who then have control of the following 5 digits being their own product number. The final digit is a check digit, unique to the arrangement of digits in the rest of the number. Its purpose is to ensure that symbols will be



rejected if poor print quality or equipment failure cause errors in the decoding function.

For packs where the label area is very limited, there are shortened symbols available — the EAN (APN) 8 symbol.

The 8 digit symbol has only 5 digits to identify the product, consequently the manufacturer's identity is not necessarily a recognisable part of the 5 digits.

The country flag structure provides flag 20 for free use by retailers for in-store marking and within that structure price or weight can be encoded. Meat for example is weighed, packed and symbol marked with a readable price by packaging machinery within the store.

Another significant world-wide agreement covers the use of flag 978 for the symbol marking of books, with the existing International Standard Book Number (ISBN). Magazines, records and cassette tapes are also symbol marked in the USA.

Still to come is bar coding of the trade unit or 'outer cartons'. The basic number structure of EAN will be used but because of print quality and contrast problems on corrugated fibre board, a larger and simpler coding structure called 'interleaved 2 of 5' has been adopted in North America. There have been some alternative proposals from EAN countries which are being evaluated with compatibility in mind. Cartons therefore will be scannable as they move along conveyors in warehouses and receiving docks of stores.

Standard message formats to allow computers to talk to computers universally are also being defined and in fact undergoing testing in the USA.

EAN COUNTRY FLAG ASSIGNMENT

ASSIGNED FLAGS	ASSIGNED TO
00,01,03,04,06,09	UPC (USA, Canada)
2X	In Store Marking
30-37	France (Gencod)
40-43	Germany
49	Japan
50	United Kingdom
54	Belgium
57	Denmark
600	South Africa
64	Finland
70	Norway
73	Sweden
76	Switzerland
80-83	Italy
84	Spain
860	Yugoslavia
87	Netherlands
90-91	Austria
93	Australia
94	New Zealand

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Investigation of premature depletion of stabilisers from solid polyethylene insulation

B. L. Board, H. J. Ruddell

Early failure of solid polyethylene insulation jointed in above ground closures is a serious field problem in Australia in cables made between 1965-74. Analysis has confirmed thermal oxidation as the cause, resulting from inadequate initial stabilisation and rapid depletion of antioxidant in service. No failures have been reported in more recent insulation incorporating the current primary antioxidant/metal deactivator systems, as used in many other countries. However, these systems are also depleted prematurely, and current polymers are unlikely to provide the expected life. Several factors cause this depletion of stabilisers, including rapid migration to the polymer surface due to insolubility at all service and polymer storage temperatures, substantial extrusion losses, elevated service temperatures and reaction with colourants. The use of a secondary antioxidant appears beneficial, and triple component stabilisation systems, with components chosen for their excellent solubility and oxidative stability, are being evaluated.

INTRODUCTION

Polyethylene insulated and sheathed telephone cable was introduced in Australia in 1956. It featured solid low density polyethylene (LDPE) insulated copper conductors in an unfilled core, and was used initially in sizes up to 100 pairs in the subscribers distribution network only. Solid polyethylene insulation is currently used in Australia in all unfilled distribution cables, which remain the standard cables for all aerial and urban underground distribution installations, and in some tail cables. (Cellular polyethylene insulation is used on filled cables, the standard cables for the buried rural subscriber and minor trunk networks, and on unfilled underground pressurised junction and subscriber main cables).

In the earlier years following its introduction, many field problems occurred as a result of extrusion pinholes in the insulation. However, the oxidative stability was never questioned and insulation cracking was not reported until the mid-1970s. The initial failures occurred in exposed (i.e. non-sheathed) insulation in above ground joints. Further reports and analysis suggested thermal oxidation as the cause, and the stabilising system used in the approved insulants was changed in order to overcome the problems.

However, the number of reports of insulation cracking in the earlier cables continued to increase, revealing that a major problem existed.

As these reports came from most areas of Australia, Telecom Australia decided to carry out a national field survey to characterise the extent and features of the problem. In conjunction with this survey, a comprehensive laboratory investigation was undertaken to determine the causes and extent of stabiliser losses in insulation, including the earlier failed insulation, current production insulation, and developmental insulations containing various experimental stabiliser systems.

This paper was delivered by the authors to the 31st International Wire and Cable Symposium, held at Cherry Hill, New Jersey, USA on 16-18 November, 1982.

HISTORY OF INSULATION CRACKING PROBLEMS

Insulants Used In Australia

The various solid polyethylene insulants used by Telecom Australia from 1956 to the present are listed in **Table 1.** Trade names of stabilisers have been used for convenience; their chemical names are listed in Table 6. There is some uncertainty about the stabilisation of the early polymers, and at least some insulant was imported prior to 1963/64. Prior to 1976, Santonox R, in low concentrations, was the principal if not the sole stabiliser in all insulants.

Overseas Experience Of Thermal Cracking

The phenomenon of embrittled solid polyethylene insulation in above ground pedestals was first observed in the USA in 1970 in the Bell network and some independent networks [1-3]. Their conclusions were that the embrittlement of insulation occurring after 6-10 years' exposure in above ground jointing pedestals was due to the depletion of antioxidant by copper-catalysed air-oxidation at the elevated temperatures existing within the enclosures. It was also considered that the oxidation process was accelerated by the presence of a processing aid [2] and the pigment titanium dioxide (TiO_2) in the polymer, and by a reduction in the concentration of antioxidant by migration and by dissolution in water condensed within the pedestal.

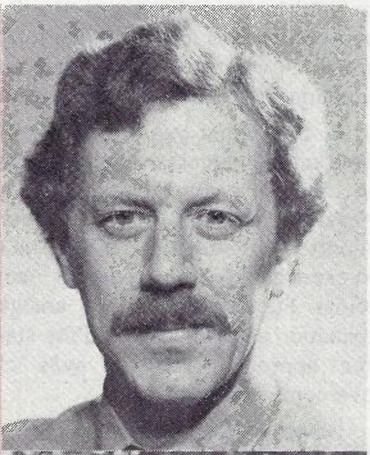
As a result, modifications were made in 1972 to the Bell System solid polyethylene resins for insulation of air-core cables. The stabilisation system was changed from a single primary (phenolic type radical scavenger) antioxidant, Santonox R, to a system with both a primary antioxidant, Irganox 1010, and a copper deactivator, Eastman Inhibitor OABH, to improve the thermo-oxidative resistance of the polymer (4). The polymer was changed from a 920 kg/m³ density resin to one with a density of 950 kg/m³ to improve physical properties of the insulation such as abrasion resistance (5). Alternative metal deactivators Irganox MD 1024 and Ube MD have since been approved. The above two-component stabiliser system is also used in the foam skin DEPIC insulation of filled cables. It is understood that these changes have resulted in an improvement in life expectancy of exposed insulation at joints.

Reports of similar insulation degradation in REA-sponsored cable networks (6) followed soon after the initial Bell reports. Many of the independent US telephone companies and their cable suppliers followed the Bell lead and introduced similar changes to their stabiliser systems.

Period	Supplier/ Local (L) or Imported (I)	Polymer Density (kg/m³)	MFI (g/10 min.)	Stabiliser System	Nominal Stabiliser Concentration	Comments
1956-60	UCAL/I?	918	2	Santonox R	<0.05%	
1961-63/64	UCAL/I?	918	2	Santonox R Nonox WSP	<0.05% ≃0.1%?	
1963/64-66	UCAL/L ICI/L	919 923	0.3	Santonox R	0.05%	Provided a higher mol. wt. polymer
1966-76	UCAL/L ICI/L	926-928	0.3	Santonox R	0.05%	Density increased to overcome pinholes
1976-82	ICI/L	926	0.3	Irganox 1010 Eastman Inh. OABH	0.1% 0.1%	Introduced to overcome thermo-oxidative cracking
1977/78-82	UCAL/L	927	0.3	Irganox 1035* Irganox MD1024	0.1% 0.1%	

UCAL = Union Carbide Australia Ltd.
ICI = ICI Australia Pty. Ltd.
* = Small concentrations of in-house processing stabilisers also incorporated.

Table 1 — Solid Polyethylene Insulation Compounds used by Telecom Australia



Bruce Board graduated in Electrical Engineering (Electronics and Communications) from the University of Queensland, Australia in 1971.

Following graduation, he worked as an external plant field engineer for Telecom Australia. In 1974 he joined Bell-Northern Research, Ottawa, Canada where he was responsible for the development and engineering of optical fibre systems in the outside plant. This included fibre cable design and specifications and all fibre outside plant hardware and practices.

In 1978 he returned to Australia and joined the Engineering Development Division of Telecom Australia Headquarters. He is currently Senior Engineer, Cable Design, responsible for the development and introduction of all new cable materials and new paired cables and optical fibre cables into the Telecom Australia network.

Hec Ruddell joined Telecom Australia Research Laboratories in 1955 as a Chemist after 19 years in private industry in the field of oils, general chemistry, rubbers and plastics. In 1966 he was promoted to set up the Polymer Section which is responsible for the investigation, development and application of all plastics, rubbers and adhesives in communications equipment. He was actively associated with the early manufacture and installation of plastics cable, including the development and formulation of epoxy resins and the epoxy resin field pack, the design of joints and the recent developments in filled cable, optical fibres, and stabilisation of polyethylene.

Mr Ruddell has been an Associate Member of The Plastics Institute of Australia since 1959 and was awarded a Fellowship of that Institute in 1982.

The Australian Experience

Some of the initial faulty joints observed in Australia in the mid-1970s were returned from the field for inspection. A preliminary analysis showed the embrittled unsheathed insulation to be depleted of Santonox R, consistent with the American findings. In order to arrest the manufacture of potentially faulty insulation, it was considered essential that the stabilising system be changed immediately. No detailed laboratory investigations were conducted at that time. Instead, as the symptoms of the degradation appeared identical to those observed several years earlier by Bell, Telecom Australia decided to adopt a similar stabilisation system. In mid-1976 this change was implemented. In fact, different stablisation systems were adopted by the two Australian polymer suppliers, as is shown in Table 1, to suit their base polymers. These respective systems have been used since then for both the solid and cellular insulants. However, in contrast to the Bell policy, no change was made to the density of the solid polyethylene.

Since that time, observations of cracked insulation have continued to be reported from many parts of Australia in increasing numbers. The 1978/79 national fault analysis system reported about 2700 faults in above ground joints due to degraded insulation. These reports showed a geographic dependence roughly consistent with the thermal environment. Such data, together with the field reports from various Australian States, prompted a decision in 1980 to investigate the problem in detail and determine its severity and any specific features.

NATIONAL SURVEY OF CRACKED INSULATION

The field survey [7] was conducted in late 1980 in all States except Western Australia. Joints were selected in both known trouble areas and in areas selected at random. Thus the survey showed some bias towards deteriorated plant.

The above ground joints [8] inspected included the standard above ground jointing post (a free-standing galvanised steel enclosure similar to the REA channel-type housing [6]), the pole-mounted untailed terminal box (a black LDPE closure for drop wire feeding) and various local custom housings. Some underground openable joints (non-encapsulated plastic distribution joints housed in pits) were also examined.

Of the 200 joints surveyed, involving 216 cables, the following conclusions were drawn, many supporting earlier US observations [1, 3, 4, 6]:

- 31% of all above ground joints exhibited some cracked insulation;
- no degradation was observed in the small number of underground joints inspected;
- the jointing post and untailed terminal box had similar incidence of embrittled insulation;
- all failures observed were in the end length from which the cable sheath had been removed. No cracking was in sheathed sections;
- pole-mounted joints facing east, north, and west showed higher fault incidence than those facing south;
- failures were observed in all but Tasmania, the most southern State. Thus all failures occurred north of 38° south latitude. However, in the hottest State surveyed, Queensland, 54% of joints were faulty. Correspondingly, the cooler areas showed failure rates less than the overall survey average. The results of above indicate clearly that the degradation is temperature-related;
- all insulation failures occurred in cables manufactured between 1965 and 1974 (see **Fig. 1**). This graph suggests that age in itself is not a critical factor;

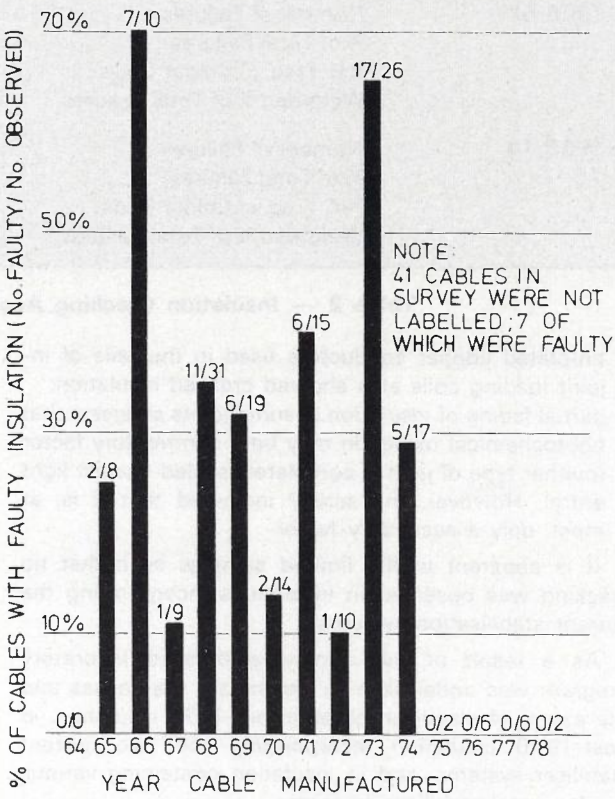


Fig. 1 — Distribution of insulation faults from field survey according to year of manufacture.

- the failures showed a dependency on colour. **Table 2** presents the failure data according to the insulation colour. This is separated into two periods during which different colour codes were used. Shown are the percentage of the total cracked wires accounted for by each colour, and also these percentages corrected for the frequency of the respective colours in the colour code concerned (i.e. weighted percentages). The results show that white and grey exhibit by far the highest failure rate, and black is virtually fault-free. The 1965-69 period also showed considerable blue faults [2]. It is probable that the blue pigment used during the 1965-69 period contained free copper and was responsible for the considerable number of faults in blue insulation;
- some joints displayed both cracked and uncracked insulation and, upon analysis, showed no antioxidant remaining in either state. Only the cracked insulant exhibited a decrease in molecular weight;
- excessive failures were observed in joints where the obsolete practice of twisting the two legs of a pair together tightly at the base of the joint had been carried out;
- the use of grease-filled sleeves appeared to give some protection to the insulation;

YEAR OF MANUFACTURE	SURVEY DETAILS	INSULATION COLOUR WHITE	RED	BLUE	ORANGE	GREEN	BROWN	GREY	BLACK	TOTAL
1965-67	Number of Failures	35	3	9	1	4	3	9	2	66
	% of Total Failures	53	4.5	14	1.5	6	4.5	14	3	100
	Rel. Freq. in Colour Code	5	5	1	1	1	1	1	5	
	Weighted % of Total Failures	21	2	26	3	12	9	26	1	100
1968-74	Number of Failures	241	30	14	13	8	4	106	—	416
	% of Total Failures	58	7	3	3	2	1	25	—	100
	Rel. Freq. in Colour Code	5	5	2	2	2	2	2	—	
	Weighted % of Total Failures	38	5	5	5	3	2	42	—	100

Table 2 — Insulation Cracking According to Colour (Field Survey Data)

- tin-plated copper conductors used in the tails of in-joint loading coils also showed cracked insulation;
- partial fading of insulation in some joints suggests that photochemical oxidation may be a contributory factor (neither type of joint is completely sealed against light entry). However, the survey indicated that it is, at most, only a secondary factor.

It is apparent in the limited samples seen that no cracking was observed in insulations incorporating the current stabilisation systems.

As a result of this survey, a detailed laboratory program was undertaken to investigate the causes and the extent of stabiliser losses in pre-1976 insulation, in post-1976 insulation incorporating the two current stabiliser systems, and in insulation containing various experimental stabiliser systems.

LABORATORY ANALYSIS OF PRE-1976 CABLE INSULATION

The results shown in **Table 3** were obtained on insulation from a 1970 cable submitted from Toowoomba, Queensland because the joint had severely cracked insulation. Tests conducted on all colours of both the exposed (cracked joint area) and unexposed (uncracked under sheath) insulations revealed levels of antioxidant concentration so low as to offer no protection to the polymer against oxidation. This finding is consistent with the field experience that joints fail in less than two years after being remade from insulation previously protected by the sheath.

The period of cable manufacture in which the insulation is prone to the above type of premature failure by cracking was clearly identified in the field survey (Fig. 1) as being 1965-1974. It was therefore of interest to determine what difference exists between cables made during this period and those made prior to 1965. Short lengths of cable were subsequently obtained for many of the years between the introduction of plastic cable in 1956 and up until 1975. **Table 4** shows the results of the tests conducted on the white insulated wire taken from beneath the sheath at least two metres from the end of all cables.

The cables had been manufactured by three cable companies using polyethylene from two local and one Japanese supplier. Consequently it was reasoned that no blame could be placed on any one of the cable or polymer manufacturers. Also, as faults were found in cables made in 1965, the consequent change made to the polymer density in 1966 cannot be considered a cause of failure.

The stabilising systems used in the polymer were identified by thin layer chromatography (TLC) and the remaining stabiliser concentration in the insulation determined by high performance liquid chromatography (HPLC) [9]. Santonox R, a sulphur-containing

Insulation Colour	Unexposed Insulation: OIT $t^{190°C}$ Al, O_2 minutes	Unexposed Insulation: Residual Santonox R % m/m	Exposed Insulation: OIT $t^{190°C}$ Al, O_2 minutes	Exposed Insulation: Residual Santonox R % m/m
White	6	0.0043	<1	<0.0005
Grey	5	0.0034	<1	<0.0005
Green	6	0.0044	<1	<0.0005
Brown	8	0.0021	<1	<0.0005
Blue	7	0.0089	<1	<0.0005
Orange	9	0.0029	<1	<0.0005
Red	6	0.0051	<1	<0.0005

Table 3 — Comparison of Exposed and Unexposed Insulation of 1970 Cable

Year of Manuf.	Stabiliser Type Present	Stabiliser Concentration: Initial by XRF* SR %	Residual by HPLC SR %	Residual by HPLC WSP %	Pigtail Test F_{20}^{+} days	OIT[10] t 190°C Al_2O_3 minutes
1956	SR	0.020	<0.001		10	<1
1958	SR	0.023	<0.001		9	<1
1961	SR & WSP	0.022	<0.001	0.046	148	17
1962	SR & WSP	0.019	<0.001	0.054	95	33
1963	SR & WSP	0.027	0.015	0.038	45	37
1963	SR & WSP	0.029	0.015	0.039	41	34
1966	SR	—	0.014		6	8
1966	SR	0.038	0.008		16	11
1966	SR	0.034	0.004		13	6
1967	SR	0.034	0.005		14	10
1968	SR	0.034	0.006		14	14
1969	SR	0.026	0.003		22	15
1969	SR	0.041	0.008		15	18
1970	SR	0.024	0.004		15	6
1972	SR	0.029	0.001		20	9
1973	SR	0.033	0.003		16	7
1974	SR	0.038	0.004		40	21
1975	SR	0.042	0.012		45	27

* Calculated from total sulphur concentration determined by ICI Australia Operations Pty. Ltd. using X-ray fluorescence techniques. It includes sulphur present on the insulation surface (i.e., the insulation was not wiped).

+ The F_{20} value approximates the 20% failure point. For a more precise definition, refer to Reference 9.

SR = Santonox R

WSP = Nonox WSP, now known as Permanax WSP (PQ).

Table 4 — Characteristics of unexposed (white) insulation taken from under sheath of field cables.

antioxidant, was found to be present in all insulations and its initial concentration (i.e. that at the time of compounding the polyethylene) was calculated from the total sulphur concentration, as determined by a quantitative X-ray fluorescence technique. This method is able to account for all sulphur present, be it in the form of unused Santonox R or its breakdown products. The determination showed Santonox to be present initially in very small amounts, frequently far below the stated nominal concentration of 0.05% at the time of polymer manufacture. The residual Santonox R concentrations in all samples were extremely low.

Another major finding from the cable analysis was the presence of the mixed stabilising system of Santonox R and Nonox WSP in insulation made between 1961-1963. These insulations were in good condition 19-21 years after manufacture, as demonstrated by excellent pigtail test [9] and oxidation inducted times (OIT) [10] when compared with the results for insulation made many years later. The amount of Nonox WSP remaining in the insulation (⩾0.04%) was very high compared to that of Santonox R (⩽0.015%). Unfortunately, no analytical technique is available to ascertain the concentration of Nonox WSP at the time of polymer manufacture in the same way as was possible for Santonox R.

STABILISER DEPLETION

As the Santonox R component of the double antioxidant system was lost from the insulation to the same extent as in the straight Santonox R systems, the better quality of the insulation containing the double system must have been due to the Nonox WSP component alone. It was at first thought that this may have been a result of its better chemical efficiency and that smaller amounts were consumed in protecting the polymer during processing and service life. However, thermal analysis conducted on LDPE containing these antioxidants did not support the above hypothesis as the oxidation induction time (OIT) for Nonox WSP was found to be only about half that of Santonox R [8], in general agreement with previously published data [11].

In view of the effectiveness of Santonox R in controlling oxidation, investigations were conducted to ascertain if the losses of Santonox R were the result of reactions with other additives or due to other causes, since depletion of an antioxidant from polyethylene can occur by both chemical and physical processes [12, 13]. The additives requiring study included pigments / opacifiers and their coatings, metals present as the conductor or as contaminants in the polymer from the production process, and other possible components of the colour and stabiliser masterbatches, including dispersants and low molecular weight polyethylene base polymers. Losses incurred during the processing of polymer compound to insulation on wire and during the storage of stabiliser masterbatch and compounded polymer prior to processing were also investigated.

ANTIOXIDANT LOSSES PRIOR TO PROCESSING

As mentioned previously, the polymer was considerably understabilised at the time of compounding. The familiar problems of ensuring that the specified levels of antioxidant are included in the compound have been considerable over the years. Recent improvements in measurement technique and equipment [9, 14] and greater understanding of stabiliser behavior have done much to overcome the uncertainties.

However, it has not been generally appreciated that a significant loss of stabilisers can occur from the stabiliser masterbatch or from the insulant from the time of manufacture through to extrusion. It is suggested that the loss may be particularly rapid from the masterbatch itself due to the high concentrations of stabilisers there, but no attempt has yet been made to verify this. However, the occurrence of losses from the compound during storage has been verified.

The results in **Table 5** show that the concentration of some antioxidants in polymers stored in a laboratory at room temperature, whether in the dark or exposed to light, diminishes at an alarmingly fast rate.

It is suggested that the major cause of such rapid loss under relatively moderate conditions is migration of the antioxidant to the polymer surface, where it is lost to the system. Stabiliser migration, and investigations to identify high solubility stabilisers, are discussed in detail later in this paper.

ANTIOXIDANT LOSSES DURING PROCESSING

Stabilisers are added to polymers for various reasons, one of which is to protect the polymer during processing. In the insulating process, the polymer is subjected to very high shear stress and temperature conditions. The amount of stabiliser consumed in chemical protection or lost by physical means (volatilisation) depends to a very large extent on the extrusion machine and operating conditions [14, 16].

Sample No.	Antioxidant	Time period stored	Loss during storage	
			in dark	in light
		months	%	%
1	Santonox R	28	47	
2	Santonox R	28	38	
3	Irganox 1010	37	54	
4	Irganox 1010	37	46	
5	Irganox 1010	37	47	
6	Irganox 1010	37	52	
7	Irganox 1010	38	57	
8	Irganox 1010	12		24≠
8	Irganox 1010	21		39≠
8	Irganox 1010	42		69≠

≠Ref. 15

Table 5 — Loss of Antioxidant from Polyethylene Stored in the Laboratory.

In order to determine whether the loss of the primary antioxidant was significant in cables supplied to Telecom Australia, an analysis was carried out in 1979 of samples of insulated wire and insulant pellets obtained from all three Australian cable manufacturers using the current approved commercial compounds. It was found that the loss of antioxidant was as high as 45%, with an average loss of 26% for all samples. The cellular insulant (MDPE) generally exhibited much higher losses than the solid compounds. Sheath samples were similarly analysed and the loss of stabiliser (Santonox R) averaged 15%.

In late 1980, an investigation was conducted with the three Australian cable manufacturers using four specially prepared compounds, each incorporating a different secondary antioxidant in addition to the normal dual component stabiliser system, to ascertain the effect of the additional antioxidant in controlling the loss of the primary antioxidant during extrusion. The results, shown in **Fig. 2**, reveal that an average of 34% of the primary antioxidant was lost, with the maximum being 54%. Also, it can be seen that, with each manufacturer, less primary antioxidant was lost when BHT or PEPQ was included as the third component than was lost from the other two triple stabilised compounds.

In 1981, samples of granules and insulation (HDPE, stabilised with Irganox 1010/Irganox MD 1024) were obtained from a Japanese cable manufacturer for a similar evaluation to verify that the considerable processing losses were not a local phenomenon. Although the solid insulation showed quite acceptable losses of antioxidant (<15%), the cellular insulation showed losses of 46%. The losses of the metal deactivator were considerably higher in both cases.

That extruder losses were not being monitored by any of the overseas cable companies visited by one of the authors during 1981 was therefore a great surprise. The assumption being made by manufacturers was that an adequate proportion of a nominated concentration of stabiliser in an approved polymer would always be present after processing!

Because of the magnitude of these extrusion losses, the use of a secondary antioxidant was proposed. It is now accepted generally that an effective primary antioxidant of high molecular weight and low volatility in combination with a metal deactivator in appropriate concentrations are required in order to obtain even moderate insulation lifetimes [2, 12, 17]. However, the need for a secondary antioxidant (hydroperoxide decomposer) is not widely accepted. In addition to interrupting the degradative cycle associated with the decomposition of the hydroperoxides in the on-going oxidation mechanism, an effective secondary antioxidant should also limit the comsumption of the primary antioxidant during extrusion, and prevent crosslinking of radical formations or chain scission, thus maintaining acceptable insulation surface finish and mechanical properties [17-20].

The results in Fig. 2 are in general agreement with those of Swasey [19]. In that work, BHT was found to be as good a processing stabiliser as the phenols, whilst DLTDP proved ineffective. However, P-EPQ performed extremely well in evaluations, showing a marked synergistic effect on both processing stability and long-term stability when used in conjunction with a phenolic antioxidant. BHT showed no such synergism with the phenols. Some of the organic phosphites have also demonstrated considerable synergism with the phenols in extending processing stability [20].

In spite of more recent investigations demonstrating that processing losses at Company C can be reduced to 10-15% with reduced extruder shear and tighter machine controls, such as improved temperature profiles, it is believed that the use of an effective secondary antioxidant is worthwhile. For the reasons given and also because BHT can discolour the polymer and has no long-term stability due to its volatility, Sandostab P-EPQ was chosen as the secondary antioxidant for use in compounds for the migration evaluations of developmental stabiliser systems.

Our studies have demonstrated the need to specify not only the stabiliser type, but its content in the polymer after processing onto wire. This must be of a level sufficient to provide a minimum life of 40 years under all service conditions. To meet this requirement, the cable manufacturer must ensure optimum extrusion conditions for compounds containing a sufficient extra amount of stabiliser to provide the specified concentration after processing.

MIGRATION OF STABILISERS

The performance of an antioxidant in protecting polyethylene from oxidation is a function of its solubility in polyethylene over the service temperature range, its tendency to diffuse or migrate out of the polymer, its chemical effectiveness in countering the degradation reactions, its volitility and of the polymer itself. Moisan [21] claims that the solubility is the most important property in determining the long term stability. Predictably, solubility and migration are intimately related.

Migration of antioxidants from polyethylene has been studied by many people [3, 11-13, 21, 22] but as stated by Roe [22] it appears that the "physical depletion of additives from polyolefins ... has not been given the proper attention that it deserves". The migration of stabilisers from low and medium density polyethylene was investigated by us as a function of both temperature and time, initially using moulded plaques and later using insulation on copper wire.

Relationship between migration and temperature

The degree to which a stabiliser diffuses to the polymer surface is related to its solubility in the polymer [11], and hence is dependent upon temperature.

The relationship between migration and temperature was studied using a 919 kg/m³ density polyethylene (UCAL DFDL 6005 unstablised) as the base resin into which the stabilisers given in **Fig. 3** were incorporated in masterbatch form on a two-roll mill. 0.5 mm thick plaques were pressed at 165°C from the crepe produced. The plaques were aged in air-circulating ovens at temperatures of 23, 40, 60, 80 and 100°C each for 28 days. The amount of exudate on the plaque surfaces was determined before and after ageing at each of these temperatures by immersing the plaque, 30 times in 30 seconds, in acetone (containing 10% v/v dimethyl formamide when determining the migration of Eastman Inhibitor OABH) followed by a wash and finally a wipe with cotton-wool wetted with a fresh amount of the same solvent type. The stabiliser content in the "wash" was determined by HPLC and the amount of stabiliser migration expressed as a percentage of the total stabiliser initially present in the sample.

The results are presented in Fig. 3 from which it can be observed that Nonox WSP and Eastman Inhibitor OABH did not migrate at any test temperature and that

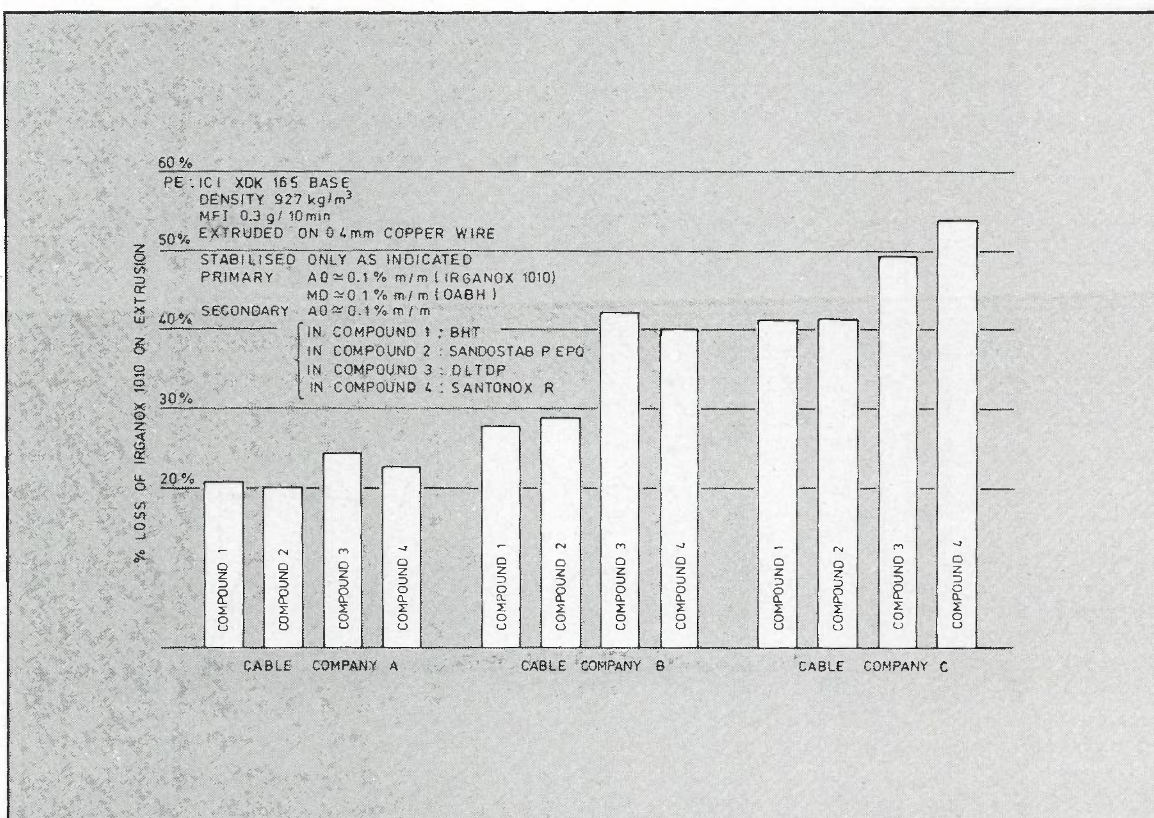


Fig. 2 — Loss of antioxidant (Irganox 1010) insulation extruded by different cable companies (1980/81).

maximum migration occurred at 60°C for 4 out of the 5 stabilisers that did show migration tendencies.

It should be noted that the above results are based on stabiliser concentrations of approximately 0.1% in LDPE. Different concentrations may result in different migration behaviour, this being determined by the solubility of the stabiliser in the polymer. Once the concentration exceeds the solubility limit of that stabiliser at a particular temperature, the stabiliser will exude until eventually it does not exceed that limit at that temperature (see **Fig. 6**).

The maximum value of 60°C for Santonox R agrees with Howard's conclusion [3] that migration of Sanotox R is most prominent in the region of approximately 50-70°C. 60°C is also close to the maximum temperature found in current above ground joint enclosures. Although it was recognised that 60°C favoured Irganox 1035 which migrates at lower temperatures, it was considered to be the temperature best suited for a single point determination. The investigation of the relationship between migration and time was therefore conducted at this temperature.

Relationship between migration and time

This study was conducted in two parts. Firstly, an investigation was carried out of the migration behavior of 4 primary antioxidants and 2 metal deactivators from 0.5 mm thick plaques of 919 kg/m³ polyethylene. Each antioxidant was used in a set of 3 systems: either as the sole antioxidant or combined with each of the two metal deactivators. The secondary antioxidant, Sandostab P-EPQ, was added to the systems containing the metal deactivators. Various colour masterbatches were used within each system, making a total of 39 plaques evaluated. Measurement of any migrated primary antioxidant or metal deactivator was determined before and after ageing at 60°C for 36 and 72 days, by the same technique as described earlier. No attempt was made to determine Sandostab P-EPQ, as energy dispersive X-ray analysis techniques indicated Sandostab P-EPQ was not present on the surface of the plaques before or after either ageing period, and it was therefore assumed to be non-migratory.

The most important results [8] arising from the plaque tests were that Nonox WSP, Irganox 1035, and Eastman Inhibitor OABH showed negligible migration at 60°C even after 72 days, whilst Irganox MD 1024 migrated rapidly. Santonox R and Irganox 1010, used on their own, also migrated readily. However, in combination with other stabilisers, the migration of Santonox R decreased whilst that of Irganox 1010 increased. Except for those stabilisers that migrated very rapidly, the quantity of exudate detected after 72 days ageing was often approximately double that for the 36 day period. The addition of colour masterbatch appeared to have no effect on the migration behavior of any system.

The second part of the study was to ascertain if the geometry, polymer morphology, or copper wire contact altered the behaviour pattern of the stabilisers. The same 4 antioxidants as before combined with Eastman Inhibitor OABH and Sandostab P-EPQ, were incorporated into the two approved 926-927 kg/m³ base polyethylenes and extruded as insulation on wire. Also evaluated were the two currently used solid insulating grade polyethylenes from the same two companies (see Table 1). As before, the incorporation of various colour

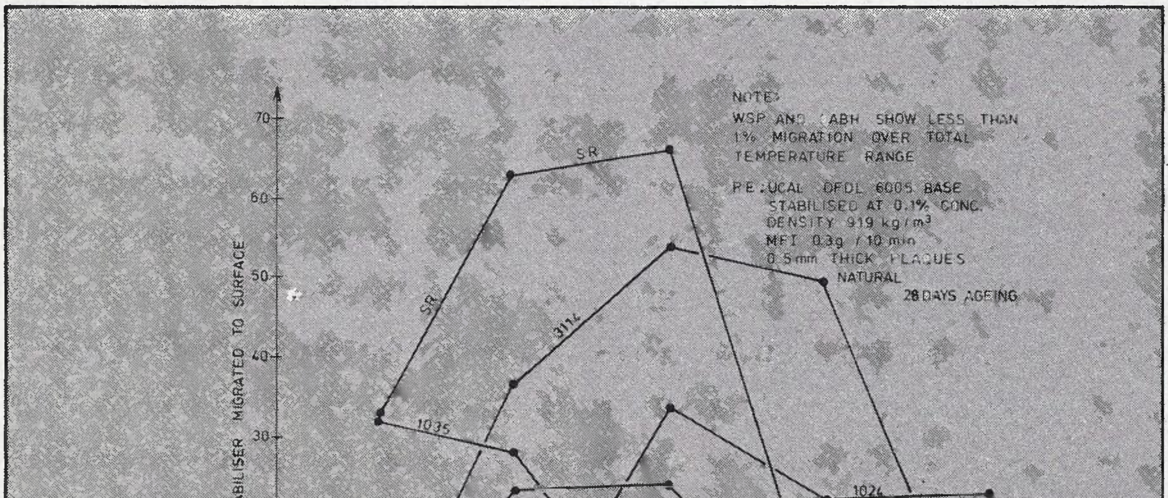


Fig. 3 — Migration of stablisers after 28 days at various temperatures.

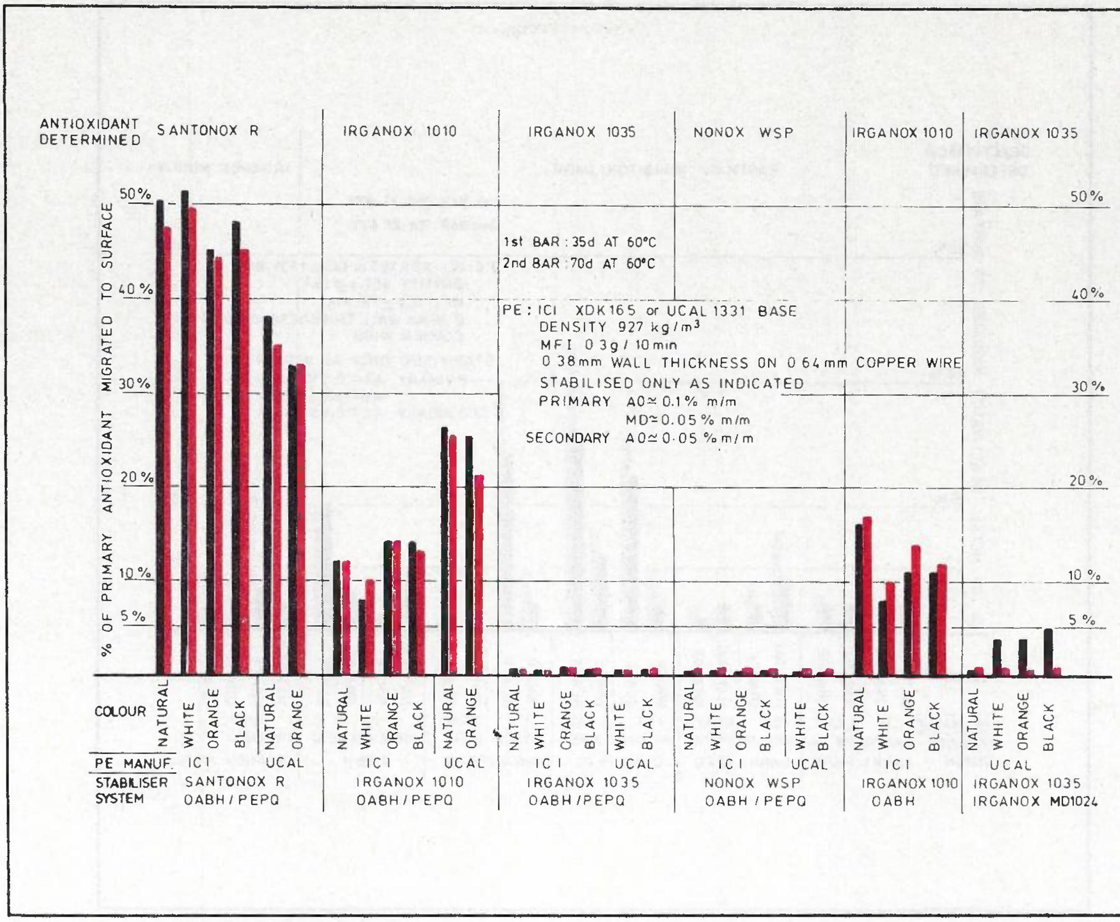


Fig. 4 — Migration of primary antioxidant from polyethylene insulated wire containing various stabilising systems.

concentrates was followed, making a total of 32 insulated wires examined.

The results for migration from the insulation are given in **Fig. 4 and 5.** When compared with the plaque results, several differences are apparent for which no technical explanations can yet be offered, although the different polymer densities of the plagues and insulation may be a factor. The significant differences are (i) an increase in the migration of Santonox R when in the presence of Eastman Inhibitor OABH, (ii) migration of Eastman Inhibitor OABH from black insulation and (iii) a decrease in the loss of MD 1024 when combined with Irganox 1035.

In contrast to Fig. 4 which expresses the percentage of antioxidant rejected by the polymers during ageing at 60°C, Fig. 6 shows the amount of antioxidant retained in the same two polymers after several months at 60°C. These values are in good agreement with the solubility data of Moisan [11] determined at the same temperature.

Accelerated Ageing Testing

The migration results have demonstrated a major reason for inaccuracies in life prediction when accelerated ageing test (OIT, oxygen uptake, pigtail, or elongation testing) are conducted at temperatures well above the actual service temperatures [3, 12, 18]. Hence any accelerated ageing test of insulation containing migratory stabilisers must incorporate a pre-conditioning program of forced migration [23] prior to ageing, carried out at that temperature within the service temperature range at which maximum migration occurs for the particular stabiliser system used. This ensures that the stabiliser concentration at the commencement of the ageing test does not exceed the effective net concentration during initial service. With non-migratory stabilisers, the forced migration step becomes unnecessary.

Some ageing tests have been completed on insulated wire containing several of the above stabiliser systems. These samples were pre-conditioned at 60°C for 70 days, then the surfaces were wiped prior to ageing at 100°C. Three measures of degradation have been used in these tests: OIT (on straight insulation), cracking stability (on insulation pigtails), and elongation at break (on straight insulation). These measures have yielded inconsistent results. No pigtails cracked, even after prolonged ageing such that the elongation and OIT values of similarly aged samples were both drastically reduced to unacceptable levels. Also, the elongation and OIT results did not correlate: although the OIT reduced with age, many samples with low elongation showed much higher OIT values than did other samples with greater elongation. This was true where the samples were different base polymers and where the samples were of the same base polymer but incorporated different stabiliser systems.

This was also observed in the field samples listed in Table 4: the OIT and pigtail results showed no uniform correlation with the residual antioxidant concentrations or with each other.

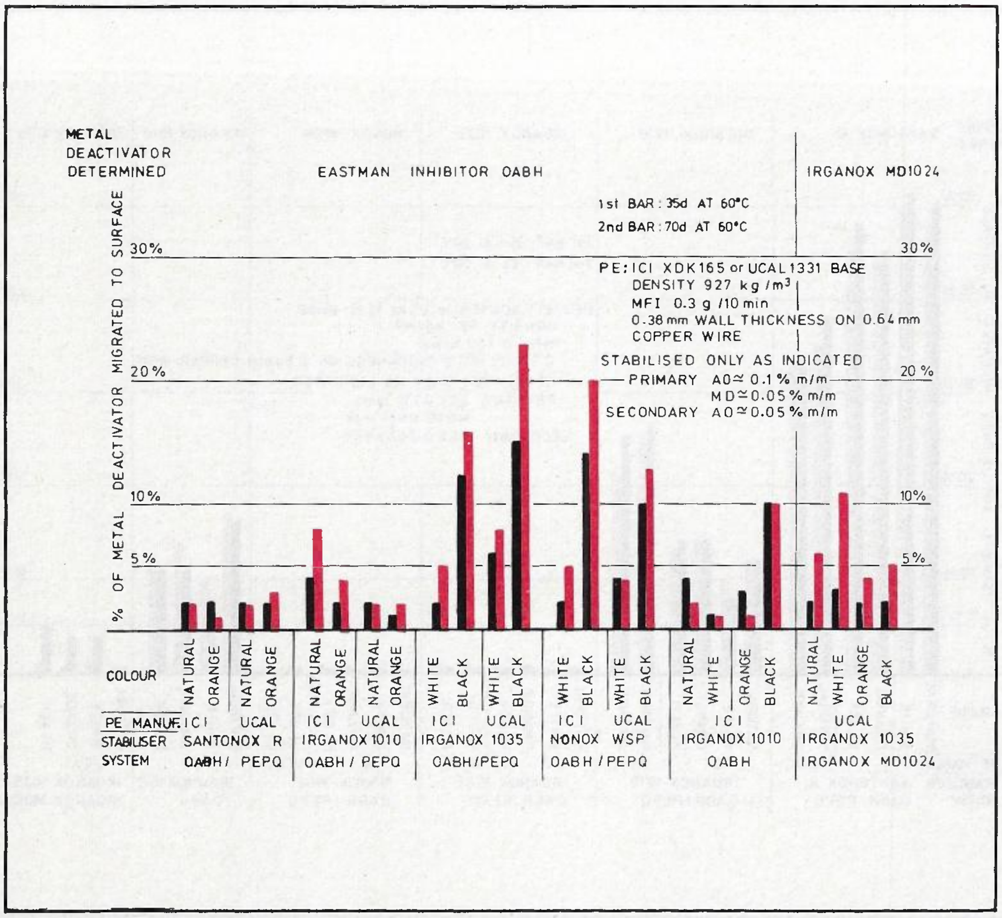


Fig. 5 — Migration of metal deactivator from polyethylene insulated wire containing various stabilising systems.

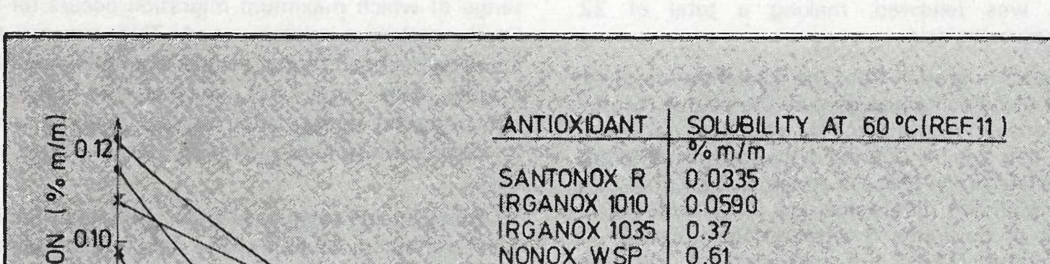


Fig. 6 — Percent antioxidant retained by insulated wire aged at 60°C

When a joint is re-entered, the insulation is subjected to dynamic stressing, and it must be elastic to survive. Pigtail tests do not imitate this stressing. Consequently, pigtail tests can give optimistic results, as observed above.

Elongation appears the most realistic measure of degradation, as it involves the transient stressing of the aged material. It is particularly appropriate for HDPE testing as it is claimed [23] that such polymer cracks before it oxidises.

Fig. 7 shows the results of ageing tests performed on MDPE base polymers from two suppliers containing two different stabiliser systems. The different performances of the stabiliser systems can be observed. However, the most substantial difference is that one polymer appears to be clearly superior to the other. This may be due to polymer morphology — molecular weight distribution, type and number of branch chains, degree of unsaturation etc. — and/or metal contamination. Further work is being performed to explore the polymer contribution to ageing performance as well as the stabiliser system and colour contribution.

DEPLETION OF ANTIOXIDANTS BY PIGMENTS AND OTHER POLYMER ADDITIVES

The field survey data on colour dependency of failure (Table 2) indicated that white and grey insulation were the most readily degraded colours, accounting for more than 75% of all failures (after weighting the results to allow for the relative frequency of appearance of the colours in the colour code). As all colour concentrates have been obtained almost exclusively from the one manufacturer since 1956, the only possible difference between the white and grey insulation and the other colours was the TiO_2 content. This was 40% and 30% for white and grey respectively compared to an average value of 10% for green, orange, blue and brown. Red and black contained no TiO_2 prior to 1974.

It is well documented [24-26] that reactions occur between primary antioxidants [2] (phenols, amines) and the reactive hydroxyl groups of TiO_2 pigment created as a result of the manufacturing process. These hydroxyl groups appear on the edges of the surface crazing of the TiO_2 particles [27]. Attempts to reduce the reactivity of the hydroxyl sites by applying 3 nm thick coatings of various metal hydrous oxides has been only partially successful since the coatings are never completely homogeneous. However, these coatings are also believed to react with antioxidant [3]. No zinc or zirconium oxide coatings have been used in the titanium pigments supplied (from one manufacturer only) for Telecom masterbatches to date. Silicon and aluminium oxide coatings have, however, been employed extensively in these coatings, together with some organic coating compounds in post-1967 pigment. Generally, the cable industry has not recognised that such reactions occur, and they should be considered when selecting pigments and antioxidants.

Thus, in the faults surveyed, it is highly probable that a Santonox R/TiO_2 reaction occurred. Since the white and grey insulations have greater loadings of TiO_2 than the other colours, higher reaction losses of Santonox R resulted. This left a lower concentration of Santonox R available to protect the polymer against oxidation, causing earlier degradation. Conversely, the good performance of black insulation (pre-1968 cables) could

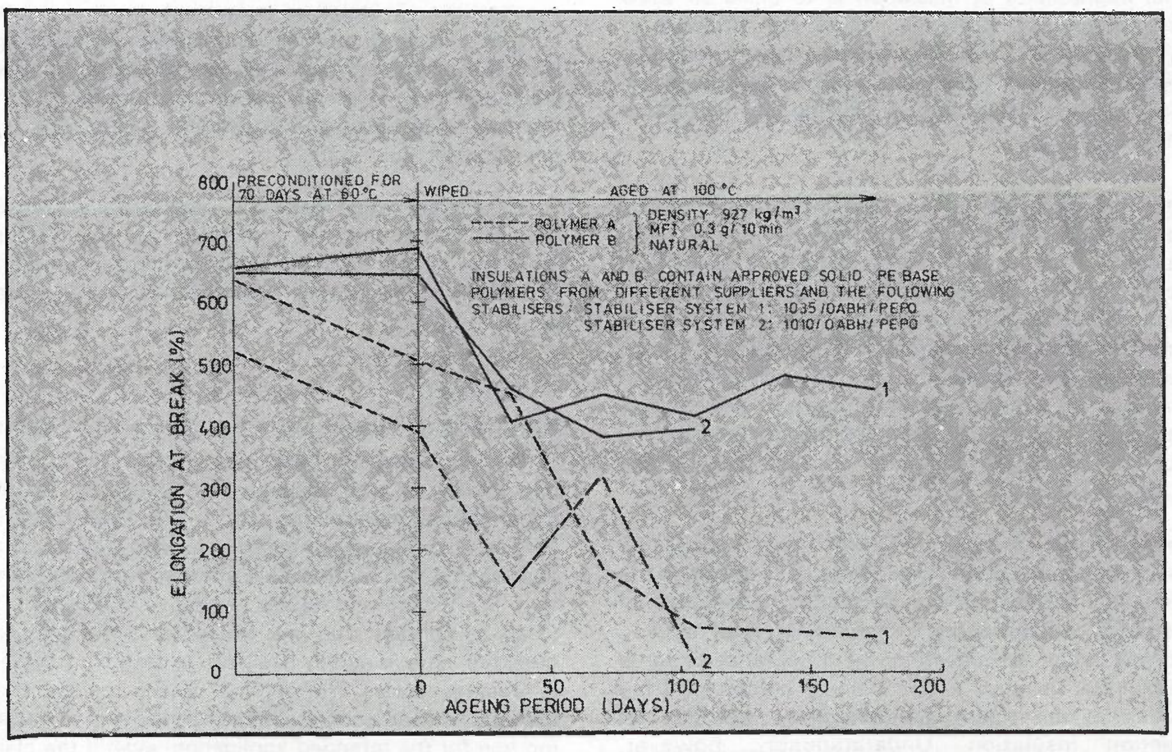


Fig. 7 — Accelerated ageing of experimental stabiliser systems.

be attributed to the absence of TiO_2, since the small amount of carbon black present would have provided little protection from oxidative attack.

It is believed that the other inorganic pigments used in masterbatches, particularly heavy metal pigments, may also react with antioxidants in a similar manner to TiO_2, though possibly at a slower rate [2]. In addition, at least some of these pigments are coated with similar hydrous oxides to those on TiO_2 to improve stability. These coatings also prevent agglomeration of the finely divided small pigment particles. Thus these coatings, too, can consume the stabiliser/s.

Siloxane is also commonly used as a lubricant or dispersing agent in pigment manufacture and metal stearates are often used in colour masterbatch preparation to aid dispersion of the particles throughout the polymer on which the masterbatch is based. Metal stearates and siloxane react with phenolic antioxidants [24, 25]. Fortunately, no metal stearates or other lubricants, including low molecular weight PE waxes, are used in either Telecom's colour masterbatches or stabiliser masterbatches. Only a minimal amount of siloxane ($<$0.5%) is present in the currently used titanium pigment.

Active metals can also be present in the insulant as catalyst residues of the polymerisation process, and can degrade the insulant stability [16]. However, the approved Australian insulants are produced by processes in which the catalyst residue levels are not considered significant.

CORRECTIVE FIELD PRACTICES AND HARDWARE

The obvious and possibly most effective solution to thermal degradation of insulation is to place all cable joints underground. However, this is not attractive in many Australian rural areas for several reasons. Therefore alternative techniques need to be considered to minimise degradation in both existing and new above ground installations.

Since the laboratory analysis confirmed that sheathed insulation adjacent to a degraded joint is virtually exhausted of antioxidant, little benefit is gained by stripping back the sheath and remaking the joint. It appears necessary to replace the affected cable/s back to the nearest underground joint. This may be a new underground joint installed at the base of the pole or jointing post to limit the length of cable to be replaced. Encapsulation of joints, whether degraded or satisfactory, is not an option as complete encapsulation is not practiced in Australia.

Colour-related changes are also being considered. These include the adoption of a colour code based on the susceptibility of the colours to oxidation, the reduction of masterbatch concentrations to a minimum level required for correct colour identification, the acceptance of some degree of translucency in the insulant colours and the relaxation of the colour standard limits specified on production insulation. Understandably, however, decisions on these aspects cannot be made until the analytical work planned for colour masterbatches and pigments is completed and the most suitable masterbatches for our insulants are identified.

The field survey indicated that the insulation cracking was temperature related. Loss of antioxidant by physical and chemical processes mentioned previously is also temperature dependent. Therefore temperature recording sites were established recently to measure the thermal conditions of joints over an extended period. The recording sites are near Mt. Isa, Queensland (a HOT DRY climate, 21st parallel south latitude) and at Melbourne, Victoria (a TEMPERATE MOIST climate, 38th parallel south latitude) (Koppen's Climatic Classification). These climates reasonably bracket the range of climates encountered by the cable network in Australia. The limited data [8] indicate that temperatures up to 15°C higher and 10°C higher than ambient shade temperature are reached inside the standard terminal box and jointing post respectively, the difference increasing with the ambient temperature. However, the use of white plastic covers or over-covers on these enclosures reduced the maximum temperatures inside the joints substantially. They also reduced the daily temperature fluctuations, thus verifying their insulating effect. No further significant reduction appears to be gained by venting the white covers, though some small improvement is obtained by venting the standard enclosures. Therefore, the design and use of white covers is being examined. Rigid PVC pipe over-covers are already a standard item for use on above ground jointing posts in some rural areas to prevent cable damage during grass fires. However, they are unlikely to be considered suitable for use in suburban locations.

The use of aliphatic polyurethane and butyl rubber insulation restoring sprays [28] and restabilising sprays [29] are not considered viable treatments. The mechanism of stabiliser migration to the insulation surface is likely to prevent restabilisation by spraying. At best, these approaches will extend the life of non-cracked insulation by a relatively short time. Additionally, their use raises significant occupational safety and health concerns for field staff.

Thick foam cover bags for joints are claimed [6] to provide some thermal protection to the insulation. However, moisture condensation in the bag and periodic low insulation resistance-related faults can be a feature of these bags.

SUMMARY

Insulation of Cables Manufactured prior to 1976

Our investigations have shown that the premature degradation of the polyethylene insulation of cables manufactured during the period 1965-1974 has been confined to installations in above ground joint enclosures, and was caused by thermo-oxidation, resulting primarily from insufficient and hence ineffective antioxidant (Santonox R) content. The low concentration of antioxidant detected experimentally has been caused by a number of interacting factors. The nominal 0.05% concentration in the unprocessed compound has been shown to be clearly too low for the intended application, even if the claimed concentration was ever present in the finished product.

Our measurements indicate that the true value since 1963 was on average about two thirds of the claimed value. It is also now clear that further Santonox R losses must have occurred during storage and extrusion, leading to a further reduction of at least 20% and perhaps as high as 50%. It is therefore not unreasonable to assume that the Santonox R concentration in the finished insulation was only about 0.02%.

Under the temperatures existing in above ground temperature enclosures, it has been demonstrated that Santonox R rapidly migrates to the polyethylene surface. Furthermore, reactions with heavy metal pigments and their coatings in the insulation colourants can lead to further significant losses, in particular with those colours containing a high concentration of TiO_2.

Consequently, it is evident that little or no Santonox R remained in the insulation after a relatively short time to provide protection against the normal oxidative attack. Once the available antioxidant had been used up, by reaction or exudation, the oxidative chain reaction proceeded under the catalytic action of the metal conductor and the acceleration in the reaction rate due to elevated temperatures in the enclosures, to the stage where severe cracking of the insulation occurred.

However, with Nonox WSP it has been shown that losses due to migration are negligible. Therefore any reduction in antioxidant concentration in the 1961-63 cables was probably caused by depletion in performing its expected function as a primary antioxidant. Thus the tendency of Nonox WSP not to migrate enables it to provide protection against oxidative attack for a much longer time span than does Santonox R, even though thermal analysis data suggests Nonox WSP to be inferior.

Insulation of Cables Manufactured after 1976

As described, two new stabilisation systems were introduced in 1976/77, both systems containing an antioxidant as well as a metal deactivator, both at 0.1% m/m, with the aim of improving thermal oxidative stability. Since then we have found that both Irganox 1010 and Irganox 1035 migrate significantly at service temperatures. Irganox MD1024 gave similar results for plaques but, for as yet unexplained reasons, exhibited low migration for a small sample of insulated wires. Eastman Inhibitor OABH showed a low tendency to migrate except in black coloured polyethylene. As these new systems have been in service for only a short time, no faults have yet been reported from the field, and it is still expected that insulation containing these systems will last longer than the insulation containing Santonox R. However, our results indicate that both systems will tend to lose their primary antioxidant. Also, the possible rapid loss of Irganox MD 1024 in one system could lead to early depletion of the primary antioxidant. Consequently the insulation containing either of these systems is still unlikely to achieve the specified 40 year service life, particularly in the hotter regions [3].

Future Insulation

Based on the studies carried out to date, it is believed that the following actions will prevent premature stabiliser depletion:

- ensure that an adequate amount of stabiliser is present in the polymer after extrusion of insulant on the wire. The processing losses must be allowed for in determining the required level of stabiliser in the polymer compound before extrusion;
- select stabilisers from those known to exhibit low volatility and little or no tendency to migrate over the entire service and storage temperature range when present in the required concentrations;
- choose a stabiliser system which will counter all possible thermal oxidation mechanisms. This can be achieved by the inclusion of suitable efficient primary and, possibly, secondary antioxidants as well as a metal deactivator;
- ensure that the stabiliser concentration is not significantly depleted by reactions with other additives, i.e. colourants. Limit the concentrations of reactive additives where possible;
- reduce the temperature inside the joint enclosure, as this will extend the insulant life due to the reduction in the stabiliser depletion rate. The optimum solution is to locate all joints underground. Where this is impossible or impractical, the use of white reflective covers on above ground joints appears effective.

To date, only a limited number of stabilisers have been evaluated in the laboratory, and of these the system of Permanax WSP (PQ), Eastman Inhibitor OABH and Sandostab P-EPQ appears to provide the best protection for our existing solid medium density polyethylene, the choice of components being in line with the 2nd and 3rd items above. Compounding and processing trials of the solid MDPE insulant containing the above stabiliser system at minimum concentrations of 0.09%, 0.09%, 0.05% respectively are currently in progress.

Further studies are planned to investigate other antioxidants and metal deactivators, particularly those of high solubility, in order to pinpoint the most efficient system for each base polymer and the optimum component concentration levels. Furthermore, a parallel study is required to identify the optimum stabilising system for cellular polyethylene insulation in both filled and unfilled cables. Finally, much remains to be done to characterise the reactivity of the various masterbatch pigments and their coatings, and the possible replacement of TiO_2 and other metal pigments by alternative non-metallic pigments. Such work will also necessitate a review of the current colour code and colour standards.

Through these combined and multiple actions, Telecom Australia expects to achieve a minimum 40 year service life for all future cables under the most severe operating environments.

Trade Name	Manufacturer	Chemical Name
Santonox R	Monsanto Co	4,4' - Thiobis (6-tert-butyl-3-methylphenol)
Irganox 1010	Ciba-Geigy Ltd	Tetrakis [methylene-3, (3,5-di-tert-butyl-4-hydroxyphenyl) propionate] methane
Irganox 1035	Ciba-Geigy Ltd	2,2' - Thiodiethyl-bis [3-(3,5-di-tert-butyl-4-hydroxyphenyl) propionate]
Permanax* WSP (PQ)	Vulnax International Ltd	2,2' - Dihydroxy-3,3'-bis (1-methylcyclohexyl) 5,5' - diphenylmethane
Goodrite 3114	Goodrite Chemicals	Tris (3,5-di-tert-butyl-4-hydroxybenzyl) isocyanurate
Eastman Inhibitor OABH	Eastman Chemical Products Inc	Oxalic acid - bis (benzylidene hydrazide)
Irganox MD 1024	Ciba-Geigy Ltd	1,2-Bis[3,5-di-tert-butyl-4-hydroxyphenyl) propionic acid] hydrazide
Sandostab P-EPQ	Sandoz Ltd	Tetrakis (2,4-di-tert-butylphenyl) 4,4'-biphenylenediphosphonite
BHT	—	2,6-Di-tert-butyl-4-methylphenol
DLTDP	—	Dilauryl thiodipropionate

*Formerly known as Nonox WSP

Table 6 — Chemical Identification of Stabilisers

REFERENCES

1. B. B. Pusey, M. T. Chen, W. L. Roberts, Proc. 20th Int. Wire & Cable Symp., 209, (1971).
2. W. L. Hawkins, M. G. Chan, G. L. Link, Polym. Eng. Sci., 11, 377 (1971).
3. J. B. Howard, Proc. 21st Int. Wire & Cable Symp., 329 (1972).
4. H. M. Gilroy, Proc. 23rd Int. Wire & Cable Symp. 42 (1974).
5. M. G. Chan, Proc. 23rd Int. Wire & Cable Symp., 34 (1974).
6. L. Ance, J. P. McCann, Proc. 23rd Int. Wire & Cable Symp., 82 (1974).
7. D. McInnes, E. T. C. Cole, Report of Field Survey to Telecom Australia Committee on Deterioration of Polyethylene Insulation, Engineering Department, Headquarters, Telecom Australia, 1981.
8. H. J. Ruddell, D. J. Adams, B. A. Chisholm, Plast. in Telecommun., 3rd Int. Conf., (1982).
9. Australian Standard 1049-1983.
10. E. Kokta, Proc. 24th Int. Wire & Cable Symp., 220 (1975).
11. J. Y. Moisan, Plast. in Telecommun., 2nd Int. Conf., 26.1 (1978).
12. H. E.Bair, Annu. Tech. Conf. — Soc. Plast. Eng., 19, 106 (1973).
13. H E. Bair, R. J. Roe, C. Gieniewski, Annu. Tech. Conf. — Soc. Plast. Eng., 20, 412 (1974).
14. J. Fech, A. de Witt, Proc. 29th Int. Wire & Cable Symp., 327 (1980).
15. A. C. Anderson, ICI Australia Operations P/L, Private Communication, 22 May 1980.
16. G. A. Schmidt, L. A. Bopp, Proc. 29th Int. Wire & Cable Symp., 331 (1980).
17. J. M. Farber, W. H. Brown, A. DiBattista, P. P. Klemchuk, Proc. 21st Int. Wire & Cable Symp., 361 (1972).
18. J. B. Howard, H. M. Gilroy, Polym. Eng. Sci., 15, 268 (1975).
19. C. C. Swasey, Proc. 25th Int. Wire & Cable Symp., 68 (1976).
20. Ciba Geigy Ltd., Basle, Switz., "Irgafos 168 in Combination with Irganox Antioxidants", Technical Information Bulletin, July 1978.
21. J. Y. Moisan, R. Lever, Eur. Polym. J1., 18 (1982) (to be published).
22. R. J. Roe, Org. Coat. Plast. Chem., 132 (1974).
23. G. A. Schmidt, Proc. 22nd Int. Wire & Cable Symp., 11 (1973).
24. R. Solvik, W. Wu, L. Krebaum, Mod. Plast., 78 (1974).
25. D. Holtzen, Annu. Tech. Conf. — Soc. Plast. Eng., 22, 488 (1976).
26. BTP Tioxide Ltd. Technical Service Report D8745GC (1976).
27. W. Hughes, Congr. FATIPEC, 10, 67 (1970).
28. J. W. Shea, Proc. 21st Int. Wire & Cable Symp., 70 (1972).
29. F. R. Wight, Proc. 28th Int. Wire & Cable Symp., 112 (1979).

Transmission Performance Tester

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The Transmission Performance Tester is used to monitor the performance of the Broadband Transmission Network for continuity, level variations and noise.

This article gives a general description of the system and the performance data it produces.

THE PURPOSE OF THE TPT

A minicomputer controlled Transmission Performance Tester (TPT) has been developed in South Australia by the Trunk Service Section, Telecom Australia. It provides a means of continuously monitoring the ability of broadband routes to reliably provide a transmission medium for trunk circuits.

The equipment monitors interruptions, outages, level variations and noise on selected voice frequency circuits of every bearer under test. It is capable of simultaneous and continuous monitoring on 24 broadband routes.

Outages, average noise power and level variations are important parameters when assessing the performance of telephony circuits. For non-voice traffic such as data or telegraphy, short term interruptions down to as low as one millisecond, and high level noise are considered to be better indicators of circuit quality.

Previous attempts to measure these parameters have led to many different methods with a wide selection of instrumentation. Consequently there existed very little uniformity in the analysis of the results which varied widely in presentation. Information was extracted from chart recordings which were generally difficult to interpret.

With the TPT, microprocessors are used to scan the outputs of circuits that monitor level and noise. This information is then transferred to the central minicomputer. Here it is used to create real time printed output for any alarm condition requiring immediate attention and also summary reports at predetermined intervals to indicate trends and highlight the need for maintenance.

Unsolicited output appears on printers providing a permanent record of network performance.

DEVELOPMENT

Development work on the TPT began with the design and construction of an analogue unit which, using discrete components, monitored interruptions, level and noise on a single bearer and displayed the information on a three pen chart recorder.

Only the most significant interrupt in a one minute period could be displayed and the noise circuit had a limited input range of 20dB. The chart recorder required continuous attention and extraction of information was both difficult and time consuming.

Under the guidelines of Telecom Australia's Research Development and Innovation (RDI) programme it was decided to design and build an automatic Transmission Performance Tester.

A prototype unit was built with a capability to monitor multiple bearers, with precise recording of all interruptions and, using digital techniques, to expand the noise input range to 40dB.

Drawings and associated documentation were prepared which enabled Telecom's Workshops to produce the final product and in May 1981, the first system was installed at the Adelaide Trunk Terminal. (See **Fig 1**) It was equipped to monitor 24 inputs and provided output at the trunk terminal, the main radio terminal, the service restoration and traffic control centre and the trunk service office.

By June 1982 seven systems had been installed in Adelaide, Melbourne, Perth, Darwin, Launceston, Brisbane and Sydney.

FACILITIES

Two reference voice frequency circuits on each bearer are removed from service and permanently connected to the TPT for surveillance. A 2kHz test signal of -10 dBmO is used on one circuit for interrupt and level measurements, while the 2nd circuit is terminated and left idle to facilitate induced noise measurements **(Fig 2)**.

The following parameters are continuously monitored:

- number of interruptions in each of four categories;
- number of outages;
- down time;
- level variations;
- noise power.

The 2kHz test tone is received in an amplitude detector which senses a drop in level by 6dB and records this as an interruption or loss of bearer continuity. All interruptions to the tone with duration in excess of one millisecond are recorded. Each individual interrupt is timed with a resolution of 1 millisecond and categorised into one of 4 categories as follows:—

- Category 1: 1 msec — 3 msec.
- Category 2: 3 msec — 30 msec.
- Category 3: 30 msec — 300 msec.
- Category 4: 300 msec — 10 secs.

An interruption of the 2kHz test tone for greater than 10 seconds is classified as an outage or major break to the bearer continuity. The total time of tone absence or 'down time' as a result of such interrupts and outages is recorded for each input.

Any variation in the level of the 2kHz test tone by 2dB either side of the nominal value of -10dBmO is considered as a level violation. All level violations are sensed and timed with resolution of one second.

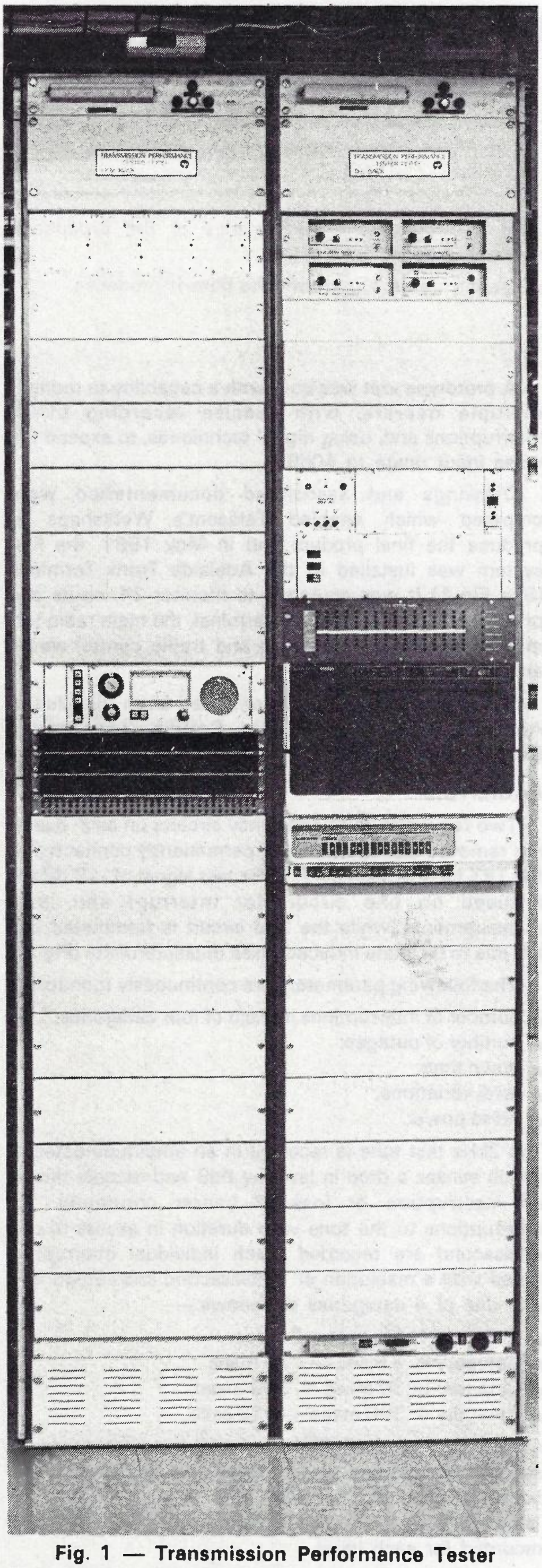


Fig. 1 — Transmission Performance Tester

The noise voltage induced into the idle reference circuit of each bearer is measured and integrated over a period of one minute to provide a mean noise power value. The noise voltage is first weighted in accordance with CCITT recommendations to provide psophometric noise readings. The resulting one minute mean psophometric noise power value is compared with two noise level thresholds and the number of minutes that the noise exceeds each threshold, is recorded.

Noise Level Thresholds are:—

- 3L+MUX pWOp
  where L = length of the monitored route in kilometers.
  and MUX = a noise allowance for multiplexing equipment, normally set to 700pW.
- 50000 pWOp.

TRANSMISSION PARAMETERS

Interruptions, level and noise are the basic criteria upon which circuit performance is evaluated. Short term interruptions down to as low as one msec are important in assessing the datel qualities of a particular circuit whereas for telephony, level variations and noise power are better indicators.

Interruptions

Table 1 shows how interrupt durations may be classified according to their effect on certain types of transmission.

Level

Long term level variations are controlled by automatic gain regulation on most broadband bearers. However, short term level fluctuations and variations outside the limits of the regulators are not corrected.

An increase in level may cause intermodulation distortion in the measured section or subsequent sections of a broadband route or at worst, could lead to a bearer overload. Both speech and data will be impaired.

Low level while not as serious, may result in degradation of the signal to noise ratio which can worsen as circuits are placed end to end to form a long interconnection.

Noise

Noise is an important parameter in determining the performance of a voice frequency (VF) channel with respect to the various functions for which it could be used. The predominance of purely telephone traffic on a broadband bearer is rapidly being reduced as digital data applications become more widespread. The noise characteristics of a voice frequency channel have an important bearing on the bit error rate in data transmissions and on the general quality of speech transmissions.

As a maintenance aid continuous monitoring of the above parameters enables rapid detection of poor performance and subsequent corrective action. From a planning viewpoint, continuous records which are readily interpretable and presented in a form suitable for further analysis provide performance trends in the light of increased traffic loading, different bearer utilisation and equipment aging. These factors assist in decisions related to provisioning of new services and facilities. Proper analysis of results obtained over a long period can show trends in performance and hence assist in determining maintenance effort required to ensure a certain satisfactory grade of service.

Type of Transmission	DURATION of BREAK			
	1-3ms	3-30ms	30-300ms	300ms — 10 secs
Data transmission and C.C.I.T.T. signalling system No. 6	Possible loss of information	Loss of information Possible loss of synchronization	Loss of information Loss of synchronization	Interruption of transmission
Telegraphy		Possible fault in character	One or more faulty characters	Release of circuit
Telephony			Switching error. Disturbance in conversation (clipping)	Subscriber may abandon the call

Table I — Classification of Interruption Durations

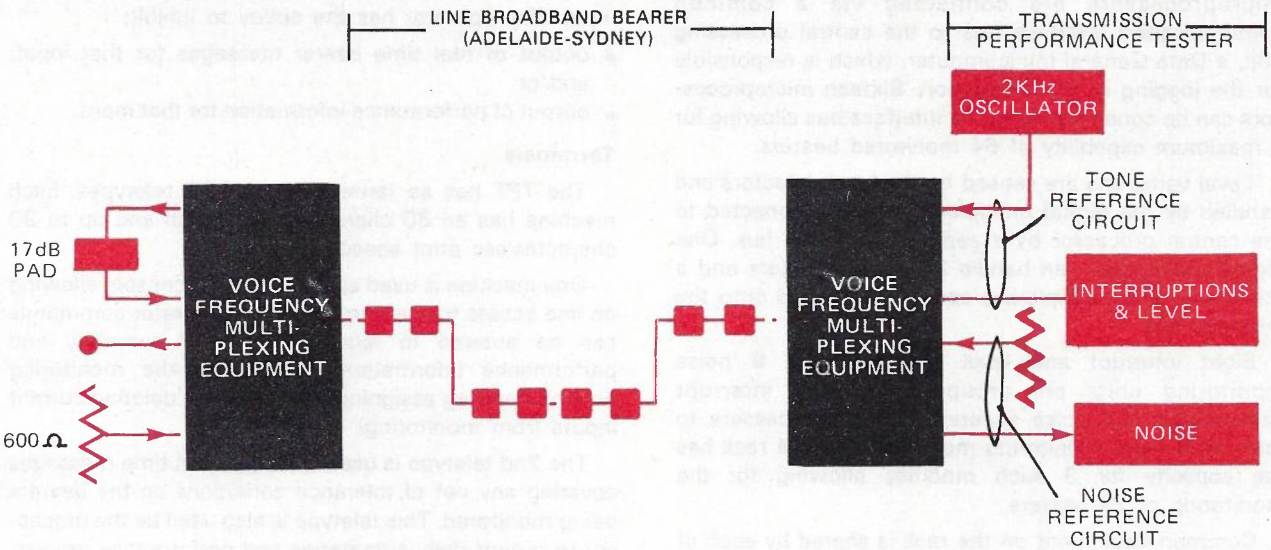


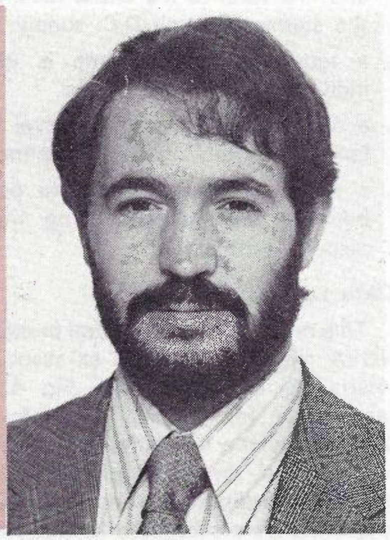
Fig. 2 — Reference Circuits

Jim Delinicolas graduated from the University of Adelaide with an Honours Degree in Electrical Engineering in 1974 and a post graduate Diploma in Computing Science in 1976.

He joined Telecom Australia in 1974 as an Engineer Class 1 in the Trunk Service Section, Adelaide and was involved with monitoring the performance of the main interstate broadband bearers.

In 1978 he was promoted to Engineer Class 2 and became the project engineer for the design and development of the automated Transmission Performance Tester.

He is currently acting in the position of Senior Engineer working with Line Transmission Equipment Construction Branch, Telecom HQ, on the automated video switcher project.



SYSTEM DESCRIPTION

The Transmission Performance Tester is housed in two racks:

1. The Transmission Performance Monitoring (TPM) rack.
2. The Data Logging (DL) rack.

Transmission Performance Monitoring Rack

This rack contains the measuring circuitry which interfaces to the broadband bearers under test. It consists of:

- interrupt and level detectors;
- noise monitoring units;
- microprocessors;
- digital multiplexer;
- common equipment — power supplies
  - — 2kHz oscillator
  - — meter panel
  - — patch panel

Microprocessors are used for interrupt analysis and noise measurements. Referring to **Fig 3**, eight interrupt detectors work into an interrupt categorising microprocessor while 8 noise monitoring units, function into a noise supervisory microprocessor. The microprocessors are connected via a common communication interface bus to the central processing unit, a Data General minicomputer, which is responsible for the logging of all information. Sixteen microprocessors can be connected onto the interface bus allowing for a maximum capability of 64 monitored bearers.

Level variations are sensed by the level detectors and handled by the digital multiplexer which is conected to the central processor by a separate interface bus. One digital multiplexer can handle 24 level detectors and a maximum of 8 multiplexers can be connected onto the interface bus.

Eight interrupt and level detectors and 8 noise monitoring units are grouped with the interrupt categorising and noise supervisory microprocessors to form an 8 input monitoring module. One TPM rack has the capacity for 3 such modules allowing for the monitoring of 24 bearers.

Common equipment on the rack is shared by each of the 24 inputs as follows:

- a power supply frame provides +5 volts, +15 volts and -15 volts to the entire rack. Input power is from the station -48 volt D.C. supply;
- a tone distribution frame is used to provide 24 individual 2kHz test signals;
- a common panel provides level and noise metering facilities on any of the 24 inputs;
- a patch panel is provided to permit a break point between the bearers being monitored and their respective detectors.

Data Logging Rack

This rack houses the central processor, a Data General NOVA minicomputer, and all associated peripheral and interfacing equipment (see **Fig 4**). The processor is responsible for logging all performance information provided by the detecting and monitoring circuitry and reporting to the operating staff any serious out of tolerance conditions which require further attention. Daily summaries are collated for each monitored input and these are stored onto a diskette unit which provides the processor with the bulk of its storage capability.

An input/output card frame is used to interface all monitoring hardware of the transmission performance monitoring rack to the processor. This card frame plugs into the processor's standard Input/Output bus connector thus eliminating any special prewiring to the minicomputer.

Status Panel

A status panel is located above the processor on the datalogging rack and is used to provide a visual indication of the current state of every monitored input.

The panel consists of a matrix of light emitting diodes and is updated by the central processor once every second.

Indications on the panel for each input are:

- bearer interruption;
- level variation greater than 2dB;
- noise;
- inhibit status.

The last indication is under operator control and reflects the status of the inhibit function for that bearer input. The operator has the ability to inhibit:

- output of real time bearer messages for that input; and/or
- output of performance information for that input.

Terminals

The TPT has as terminals two GEC teletypes. Each machine has an 80 character print width and up to 30 character/sec print speed.

One machine is used as an operator's console allowing on line access to the minicomputer. Operator commands can be entered to request output of summary and performance information or to alter the monitoring environment (eg assigning new inputs or deleting current inputs from monitoring).

The 2nd teletype is used to output real time messages covering any out of tolerance conditions on the bearers being monitored. This teletype is also used by the processor to output daily summaries and performance reports.

These reports together with the real time bearer messages form a permanent record of the performance of each monitored bearer. TPT error and warning messages created within the TPT's self diagnostics are also printed on this teletype. (these cover TPT equipment fault conditions.)

No input to the processor is allowed through the real time teletype and multiple copies of the output to this teletype can be fed through a 300 baud data modem to remote stations providing these areas with a copy.

REAL TIME BEARER MESSAGES

The real time printer is used to output information covering alarm conditions for each input. Whenever a serious out of tolerance condition is detected, a bearer message is compiled by the central processor and sent to the real time printer, accompanied by an audible alarm to bring it to the attention of the operator. The single line message takes the following standard format:

- bearer message sequence number (the sequence number is reset at the end of everyday);

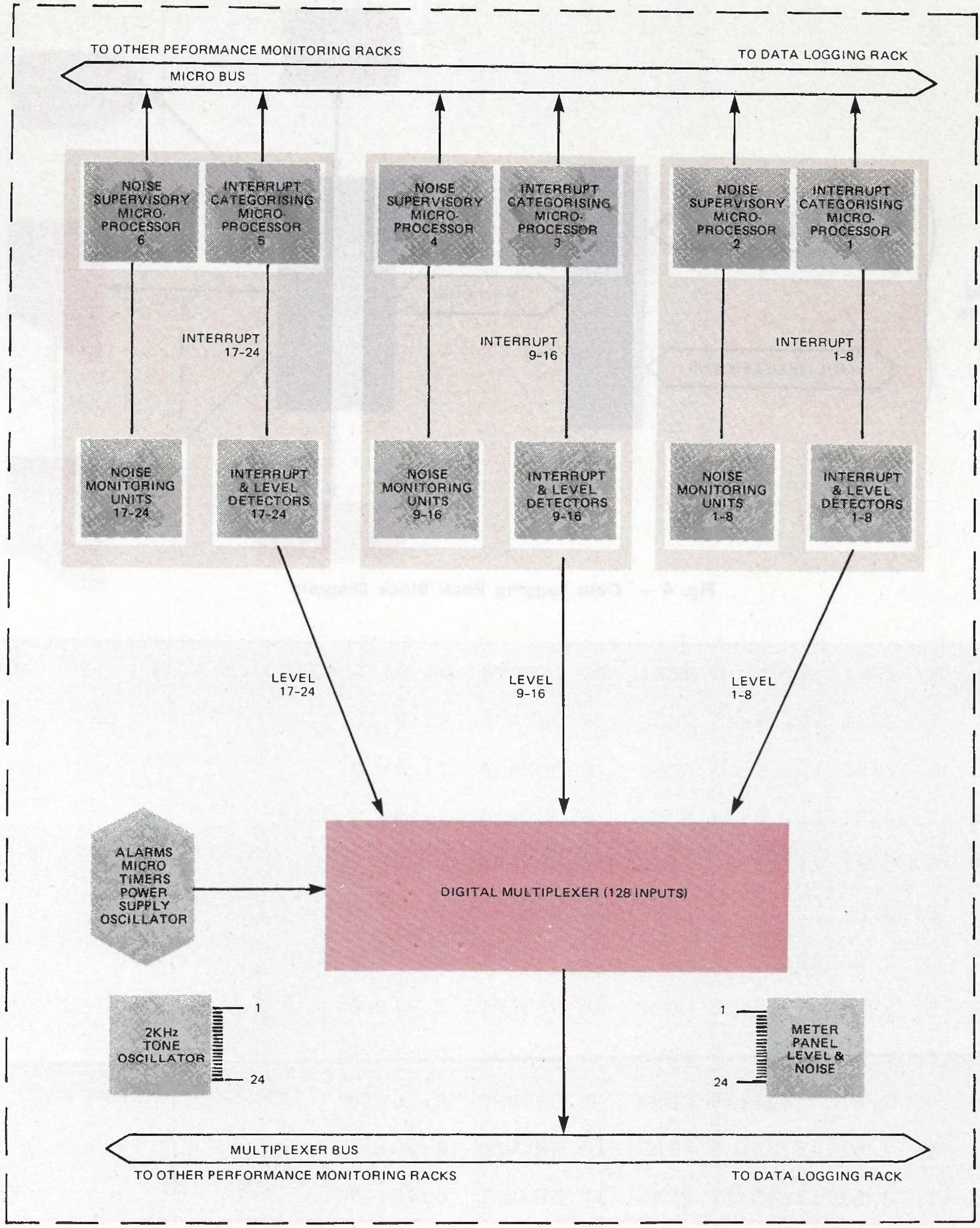


Fig. 3 — Transmission Performance Monitoring Rack Block Diagram

- the current date (day/month/year);
- time of the day (hours: minutes: seconds);
- bearer input descriptor;
- bearer input number;
- bearer message descriptor;
- duration (in hrs: mins: secs.msecs) of the out of tolerance condition.

There are two different types of bearer messages:

1. Alarm Message — to inform operator that an out of tolerance condition exists.
2. Return Message — indicates that the alarm condition has cleared.

To enhance the usefulness of these messages a time threshold is applied to all out of tolerance conditions. An alarm message will not result until the duration of the violation has exceeded the particular time threshold. These thresholds can be altered by the operator through

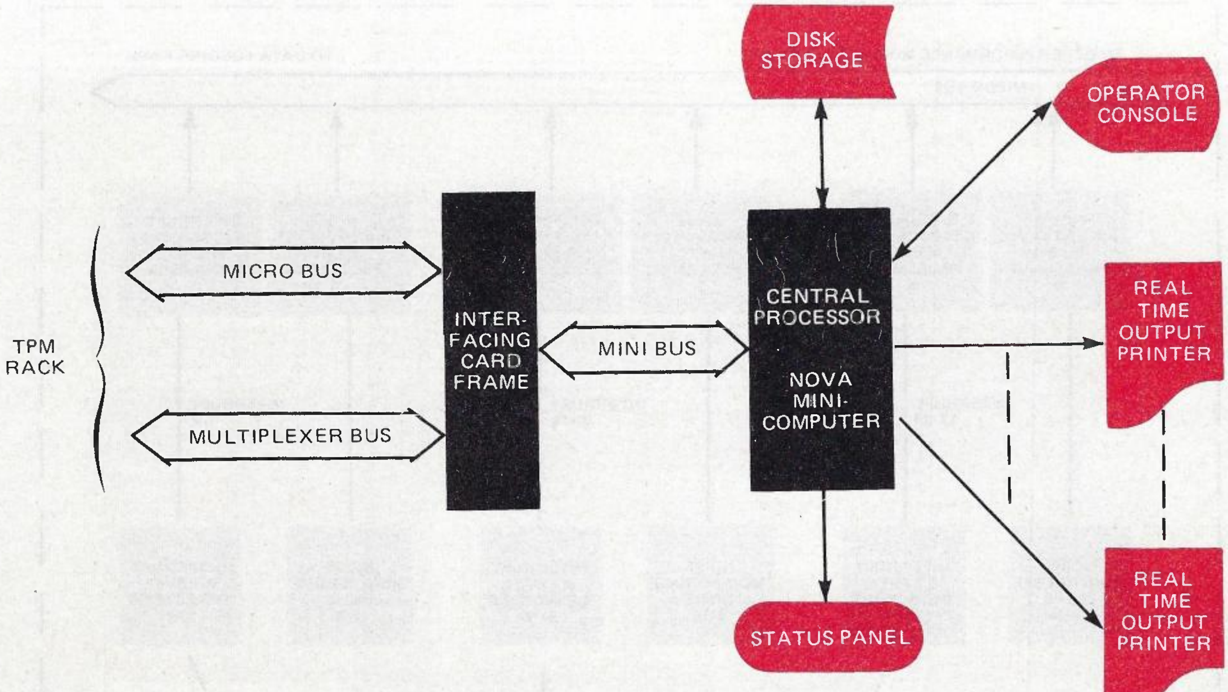


Fig. 4 — Data Logging Rack Block Diagram

```
 1  5/ 2/81  9:51: 0 BERI  11 INTRTN  0: 0: 5.538#   5   3   2   5
 2  5/ 2/81 10: 5:25 RUSC   6 OUTAGE  0: 0:10.
 3  5/ 2/81 11: 5:15 RUSC   6 OUTAGE  1: 0: 0.
 4  5/ 2/81 11: 8:20 RUSC   6 OUTRTN  1: 3: 5.373#
 5  5/ 2/81 12: 9:35 LONC  24 NS3LPW  0:30: 0.
 6  5/ 2/81 12:10:35 LONC  24 N50KPW  0: 1: 0.
 7  5/ 2/81 13:15:35 LONC  24 N50KRT  1: 6: 0.
 8  5/ 2/81 13:20:35 LONC  24 NS3LRT  1:41: 0.
 9  5/ 2/81 15:20: 8 CDNA   9 LEV-HI  0: 1: 0.
10  5/ 2/81 15:25:18 CDNA   9 LEVHRT  0: 6:10.
11  5/ 2/81 15:35: 5 PTAA  17 LEV-LO  0:30: 0.
12  5/ 2/81 15:45:12 PTAA  17 LEVLRT  0:40: 7.
```

Fig. 5 — Real Time Bearer Message Examples

his console and are individual to each parameter. Thus the real time printout **(Fig. 5)** covers only alarm conditions which require operator awareness.

There are 4 parameters associated with the bearer messages, these being:

- noise power;
- level;
- outages;
- interrupts.

Noise

The message descriptors associated with noise are:—

- NS3LPW — indicating that the minute mean noise power was greater than (3L+MUX) pWOp for a duration in excess of the time threshold.
- NS3LRT — is the return message, indicating the total duration of the out of tolerance condition in hours, minutes and seconds.

- N50KPW — indicating that the minute mean noise power was greater than 50000 pWOp for a duration in excess of the time threshold.
- N50KRT — is the return message, indicating the total duration of the out of tolerance condition in hours, minutes and seconds.

Level

The message descriptors associated with level are:—

- LEV-HI — indicating that the 2kHz test tone is being received 2dB above the nominal level for a duration in excess of the time threshold.
- LEVHRT — is the return message, showing the total duration of level high in hours, minutes and seconds.
- LEV-LO — indicating that the 2kHz test tone is 2dB below nominal level for a duration in excess of the time threshold.
- LEVLRT — is the return message, showing the total duration of level low in hours, minutes and seconds.

Outages

Message descriptors associated with a bearer outage are:—

- OUTAGE — indicating that loss in continuity of the 2kHz test tone has exceeded the time threshold of 10 seconds. Subsequent reminders are given at hourly intervals until the outage returns.
- OUTRTN — is the return message showing the outage down time in hours, minutes, seconds and milliseconds.

Interrupts

Interrupts do not have an alarm message. Interrupt activity is divided into 1 minute time slots during which all interrupts on every input are detected and categorised. At the end of each minute period and only if an interrupt has occurred on that bearer, an interrupt message is printed, which uses the following descriptor:—

- INTRTN — contains information on the total interrupt down time and a breakdowns of the interrupts into their respective categories.

- Category 1: 1-3 msec.
- Category 2: 3-30 msec.
- Category 3: 30-300 msec.
- Category 4: 300 msec-10 sec.

SUMMARY REPORTS

Summary reports are continuously compiled for every monitored input and cover information on noise, level high or low, interrupts and outages for each Bearer being monitored. Three types of summary reports exist:

1. Hourly Summary Report
2. Daily Summary Report (24 hours)
3. Period Summary Report (28 days)

These summary reports are all stored on diskette and are available to the user via the real time printer on an unsolicited basis. The operator can however request a report to be printed at any time via the operator's console.

Each summary report takes the following format (**Fig. 6**):

Heading:— contains the title of the type of summary, the date, period and day count.

Summary Information:— consists of one line of

TPT-ADELAIDE DAILY SUMMARY REPORT NO OF HOURS:24
2/11/82 PERIOD: 5 DAY:27

IN	NAV	N>3L	N>50K	LEVEL HI	LEVEL LO	CAT1	CAT2	CAT3	CAT4	OUTS	DOWN TIME
**	###	HHH:MM	HHH:MM	HHH:MM:SS	HHH:MM:SS	*****	#####	*****	#####	****	HHH:MM:SS.MSC
1	-59	4:53	0: 0	0: 0: 1	0: 0: 0	104	568	0	0	0	0: 0: 2.364
2	-60	0:13	0: 0	0:30:22	0: 0: 1	10	0	0	2	3	0: 1:29.219
3	-52	3:42	0:10	0: 0:37	0: 0: 1	100	44	5	0	1	0: 0:21.475
4	-50	10:34	0:12	0: 0: 6	0: 0: 0	1533	70	0	0	0	0: 0: 2.829
5	-58	0: 0	0: 0	0: 0: 0	0: 0: 0	0	1	0	0	0	0: 0: 0. 4
6	-59	0: 2	0: 0	0: 0: 4	0: 0: 0	0	2	0	0	0	0: 0: 0. 30
7	-65										
8	-57	0:31	0: 0	0: 0: 1	0: 0: 0	0	12	0	0	0	0: 0: 0. 75
9	-56	7:52	0: 6	0:33:39	0: 6:33	1	19	30	14	5	0: 6:14.625
10	-68										
11	-54	0:39	0: 0	0: 0: 0	23:58:29	9	11	2	0	0	0: 0: 0.186
12	-61	0:54	0:33	0: 0: 0	0: 0:23	5	2	0	0	0	0: 0: 0. 16
13	-63	0: 0	0: 0	0: 0: 0	0: 0:23	0	1	0	0	0	0: 0: 0. 5
14	-59	0: 0	0: 0	0: 0: 0	0: 0:23	0	1	0	0	0	0: 0: 0. 5
15	-62	0: 0	0: 0	0: 0: 0	0: 0:23	0	1	0	0	0	0: 0: 0. 5
16	-55	0: 1	0: 0	0: 0: 0	0: 0:23	17	29	0	0	0	0: 0: 0.278
17	-64	0: 0	0: 0	0: 8:26	0: 0: 0	0	0	0	0	0	0: 0: 0. 0
18	-100	0: 0	0: 0	0: 0: 0	0: 0: 0	0	0	0	1	0	0: 0: 2.260
19	-100										
20	-100										
21	-100										
22	-99	0: 0	0: 0	0: 0:33	0: 0: 0	0	0	0	0	2	0:54:44.755
23	-94	0: 0	0: 0	0:29:10	2: 0:22	12	28	8	13	5	0:59:54.177
24	-94	0: 0	0: 0	0: 0: 0	0: 3: 8	1	0	0	1	0	0: 0: 2.262

Fig. 6 — Daily summary Report

information for each input being monitored, each line has the following:

- input number;
- average noise value for the corresponding input in dBmOp;
- duration of time that noise was greater than (3L+MUX) pWOp;
- duration of time that noise was greater than 50,000 pWOp;
- duration of time that level was high;
- duration of time that level was low;
- the number of category 1 (1-3 msec) interrupts;
- the number of category 2 (3-30 msec) interrupts;
- the number of category 3 (30-300 msec) interrupts;
- the number of category 4 (300 msec-10 sec) interrupts;
- the number of outages;
- the total down time (= interrupt + outage down time)

PERFORMANCE REPORTS

A performance report presents information on noise, levels high or low, interrupts and outages for a particular route. There are two types of performance reports, namely:—

1. Daily Performance Report
2. Period Performance Report

Performance reports are similar in format to the summary reports except that they indicate for a particular input how the information is distributed over the day or period **(Fig. 7)**.

The performance reports are not stored on disk, but rather, are calculated from the summary reports. The minicomputer simply reads the required information for the relevant bearer from the summary reports on disk and produces a performance report for that particular bearer. These performance reports are available to the user via the real time printer on an unsolicited basis. The operator can however request a performance report for a particular bearer to be printed via the operator's console.

BENEFITS OF THE TPT

The Transmission Performance Tester is an accurate indicator of the broadband transmission network performance.

It is an early warning device to the maintenance staff and a powerful commissioning tool providing detailed fault analysis and performance information on both existing and newly installed bearers.

The TPT has improved the allocation of maintenance effort according to the requirements of individual broadband bearers and has provided an overall improvement in the service offered to the Telecom customer by the rapid detection and subsequent correction of faulty or substandard equipment.

TPT-ADELAIDE DAILY PERFORMANCE REPORT INPUT: 9 M WAYC-HMKX E01
2/11/82 PERIOD: 5 DAY:27

HR	NAV	N>3L	N>50K	LEVEL HI	LEVEL LO	CAT1	CAT2	CAT3	CAT4	OUTS	DOWN TIME
**	###	HHH:MM	HHH:MM	HHH:MM:SS	HHH:MM:SS	*****	#####	*****	#####	*****	HHH:MM:SS.MSC
1	-52	0:52	0: 0	0: 0: 0	0: 0: 0	0	0	0	0	0	0: 0: 0. 0
2	-51	1: 0	0: 0	0: 0: 0	0: 0: 0	0	0	1	1	0	0: 0: 0.995
3	-51	1: 0	0: 1	0: 0: 0	0: 0: 0	0	1	3	2	0	0: 0: 1.460
4	-51	1: 0	0: 0	0: 0: 0	0: 0: 0	0	0	0	0	0	0: 0: 0. 0
5	-56	0:13	0: 5	0: 7:56	0: 0: 0	0	7	26	6	4	0: 5:35.358
6	-51	0: 5	0: 0	0: 0:50	0: 1:41	0	0	0	2	0	0: 0: 6.738
7	-54	0:22	0: 0	0: 2: 0	0: 0: 3	0	0	0	0	0	0: 0: 0. 0
8	-54	0:22	0: 0	0: 1: 2	0: 0: 9	0	0	0	0	0	0: 0: 0. 0
9	-55	0:13	0: 0	0: 5:34	0: 0:19	0	0	0	1	0	0: 0: 6.173
10	-53	0: 5	0: 0	0: 0:50	0: 0: 6	0	1	0	0	0	0: 0: 0. 10
11	-56	0: 5	0: 0	0: 0:51	0: 0: 0	0	2	0	0	0	0: 0: 0. 12
12	-56	0: 0	0: 0	0: 0: 3	0: 0: 0	0	3	0	0	0	0: 0: 0. 23
13	-57	0: 2	0: 0	0: 0: 2	0: 0: 0	0	0	0	0	0	0: 0: 0. 0
14	-55	0:18	0: 0	0: 2:24	0: 0:20	0	3	0	0	0	0: 0: 0. 16
15	-56	0: 5	0: 0	0: 3:52	0: 0:21	0	0	0	0	0	0: 0: 0. 0
16	-48	0:27	0: 0	0: 3:21	0: 0:16	1	1	0	0	1	0: 0:12.199
17	-47	0:58	0: 0	0: 1:22	0: 1:26	0	1	0	0	0	0: 0: 0. 5
18	-54	0:12	0: 0	0: 1:57	0: 1:18	0	0	0	1	0	0: 0: 8.703
19	-53	0:31	0: 0	0: 3:58	0: 0:34	0	0	0	1	0	0: 0: 2.963
20	-57										
21	-56										
22	-57										
23	-57	0: 1	0: 0	0: 0:32	0: 0: 0	0	0	0	0	0	0: 0: 0. 0
24	-56	0: 1	0: 0	0: 0: 5	0: 0: 0	0	0	0	0	0	0: 0: 0. 0

Fig. 7 — Daily Performance Report

An Introduction to the CCITT Recommendation X.25

J. L. Snare, B.E., M. Eng. Sc.

This tutorial paper gives an introduction to the CCITT X.25 protocol for interworking between packet mode terminals and public packet switching data networks. A top-down approach is taken, with a description of the intended purpose of each of the three X.25 layers followed by a discussion of typical protocol procedures that are used to support these functions.

INTRODUCTION

This paper gives a tutorial introduction to the CCITT recommendation X.25 (Ref. 1) entitled "Interface Between Data Terminal Equipment (DTE) and Data Circuit Terminating Equipment (DCE) for Terminals Operating in the Packet Mode on Public Data Networks". It takes a top-down approach and discusses what the X.25 protocols can do in terms of the services provided and how the procedures in its layers work and combine to allow these services to be supported.

A user of an X.25 communications system will probably not see any of the X.25 protocol signals directly. However the user needs to know how to make sure that the system implementing the protocols is operating "appropriately". Options in X.25 and higher level protocols may influence the cost and performance of system usage. Hence an X.25 user needs to know enough about how communication protocols work to enable selection of options and parameters which will ensure that performance is adequate for an application while cost is minimized.

X.25 Application Example

Fig. 1 shows where the X.25 protocols fit into a data communications service. A typical application may be where there are several user processes at one location that may sometimes wish to communicate with some remote processes at remote locations. The X.25 protocols facilitate this communication and allow, for example, communication between processes A and A', B and B', and C and C' (Fig. 1) at some particular time. Another time this communication pattern may change. The X.25 protocols enable this communication to be achieved using a packet switching data network. To send information the following functions are performed:

- data is collected from the various user processes (which may be computer programs to implement higher level protocols or specific user functions);
- data from each source is grouped into message units and these are interleaved and statistically time division multiplexed on to a single network access link;
- information is attached to each message unit that enables the network entry mode to determine the desired destination of each message unit;
- messages delivered by the network to the destination site contain sufficient information to enable the original data to be restored to a form that can be used by the destination process.

The packet switching function is performed for each message unit using X.25 protocol information attached to each message unit. It should be understood that X.25 is not synonymous with packet switching. X.25 simply facilitates packet switching by enabling access to a packet switching network and says nothing about the complex functions performed within the network relating to call management, routing, network management etc. This paper assumes familiarity with the basic concepts of packet switching, i.e. the sharing of network resources by the dynamic allocation of transmission resources and the flexibility of the technique to provide a wide range of services.

Types of X.25 Service

X.25 defines 3 mutually exclusive types of service. The first type of service is the permanent virtual circuit (PVC) service where there is a permanent logical relationship between two users. A PVC is set up at subscription time and the connection is always logically available. Messages sent at any time on a PVC are guaranteed to be delivered in sequence to the destination user.

The second type of service defined in X.25 is the switched virtual circuit (SVC), or virtual call service. For this service, a call set-up phase is required to establish the logical relationship between two users at a particular time. Data is then transferred in sequence between the users until the call is terminated by a call clearing phase.

Finally, X.25 offers a datagram service where packets are transported independently. This is known as connectionless information transfer; however in X.25 the datagram procedures are widely regarded as unnecessarily complex and no commercial implementation of them is known to the author.

Summary of X.25 Services

Within the context of the X.25 services described in the previous section, the X.25 protocols provide procedures that support the following functions:

- multiplexing of user data onto a single network access link;
- signalling for set-up and clearing of switched virtual calls;
- signalling for control of permanent virtual circuits;

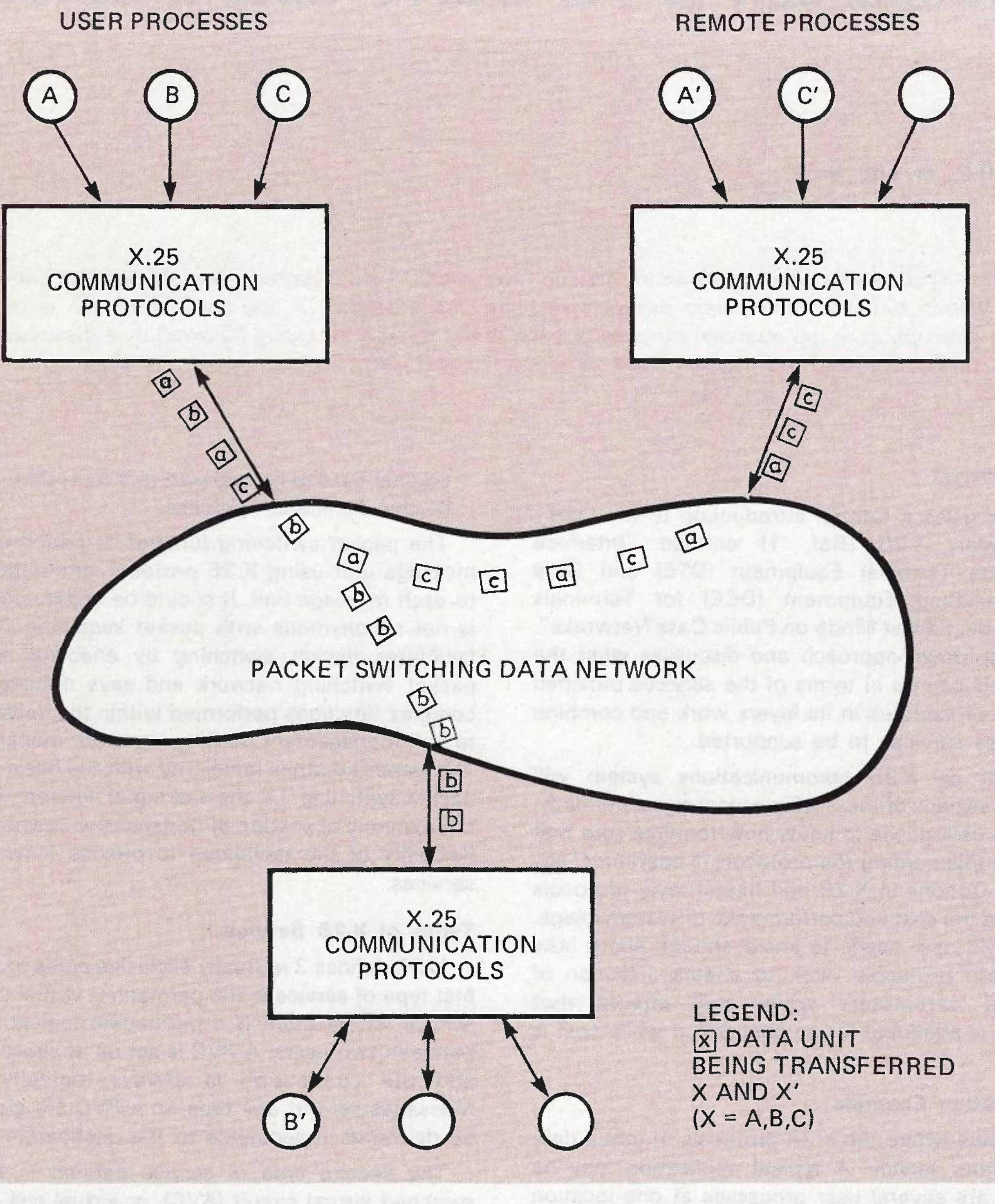
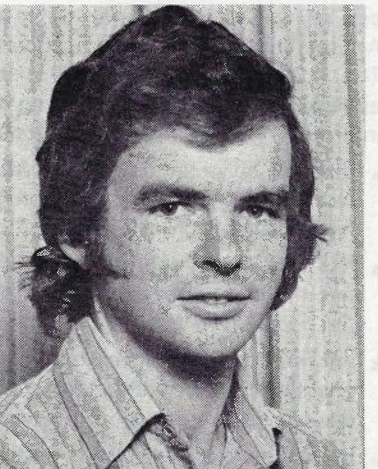


Fig. 1 — X.25 Application



John Snare received the Bachelor of Engineering degree with Honours in 1973 and Master of Engineering Science degree in 1982 from Monash University. From 1973 he has worked in the Transmission and Switching and Signalling Branches of the Telecom Australia Research Laboratories. He is currently a senior engineer in the Data Switching Section with research interests in the areas of data communications networks and protocols.

- signalling for the datagram service;
- access to network provided user facilities (Ref. 1, 2)
- reliable transmission of user data in sequence with low probability of undetected bit errors;
- flow control to match the data handling capabilities of each of the user processes.

Layering of X.25

X.25 defines protocols relevant to the lower 3 layers of the Reference Model of Open Systems Interconnection (Ref. 3) as shown in **Fig. 2.** The physical layer of the reference model is called the physical level in X.25, the data link layer of the reference model is called the link level in X.25, and the packet level of X.25 provides some of the functions of the network layer in the reference model. The X.25 packet level cannot be considered as a complete network layer because it does not describe routing or switching functions and it does not describe data unit manipulations that may be needed for compatability with the transport layer.

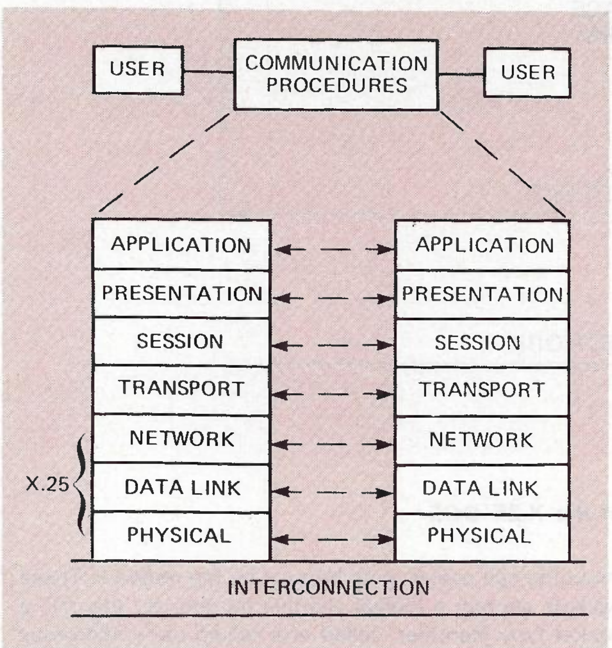


Fig. 2 — Partitioning

The layered approach helps to manage the complexity of the communications functions supported. This approach aids design because requirements can be partitioned into blocks of manageable size, and it aids testing and maintenance because of the functional modularity. Such an approach also results in system flexibility because not all layers may need to be changed for different applications.

The X.25 packet level provides the services described in the previous sections. The packet level is built on a link level service that provides information transfer with a low probability of undetected errors and in the correct sequence with no duplication. The link level in turn is built on a physical level service that provides synchronous, full duplex, serial transfer of information between the user and the network of rates of 2400, 4800, 9600, or 48,000 bits per second.

X.25 Data Transfer Principles

Similar data transfer techniques are used in both the link and packet levels of X.25 to achieve the functions of terminal synchronization, flow control, sequence control and error control. Signals for protocol initiatives are sent as commands. Commands are not considered to have been received until an appropriate acknowledgement has been received. At the link level, acknowledgements are of local significance only and indicate satisfactory transfer of information across the network access link. At the packet level the scope of acknowledgement varies, with some acknowledgements having local significance (e.g. call-clearing), some having end-to-end significance (e.g. call set-up) and others having local or end to end significance depending on context (e.g. data transfer).

The X.25 protocols are quite complex because of the procedures used to maximise communications performance. To utilise the delays involved between sending a data unit and receiving its acknowledgement, the protocol has mechanisms that allow several data units to be sent before acknowledgements are expected. To further improve communication efficiency, commands and acknowledgements can be combined within data units under some circumstances. The penalties associated with these performance enhancing features are that it is necessary to identify commands within a sequence of data units and resolve the acknowledgements that are perhaps combined with them. Additionally, if commands or acknowledgements get out of sequence or get lost, quite complex recovery procedures are necessary.

The Nature of Data Circuit-Terminating Equipment (DCE)

X.25 refers to the interface between data terminal equipment (DTE) and data circuit-terminating equipment (DCE). However the concept of DCE is not used in the usual way (or in accordance with the CCITT definition). For the purpose of this discussion, the DCE includes:-

- equipment in the users premises;
- transmission systems to a network node;
- software at a network mode to perform X.25 protocol functions at the link and packet levels.

This is illustrated **Fig. 3.** Throughout this paper, the terms "DTE" and "terminal" are used synonomously, and the term "DCE" is used synonomously with "network".

X.25 PACKET LEVEL

Packet Level Multiplexing

Emphasis in this discussion is on the X.25 switched virtual circuit service. The data unit used in this protocol level is the "packet".

The first service that the packet level provides is multiplexing to allow many calls to logically exist on a shared network access link. A logical channel number is assigned for each call at each network interface at call set up time. The network manages the relationships between the logical channels associated with the call. X.25 provides a logical channel address space from 1 to 4095, although it is unlikely that implementations would support simultaneous calls on each available logical channel.

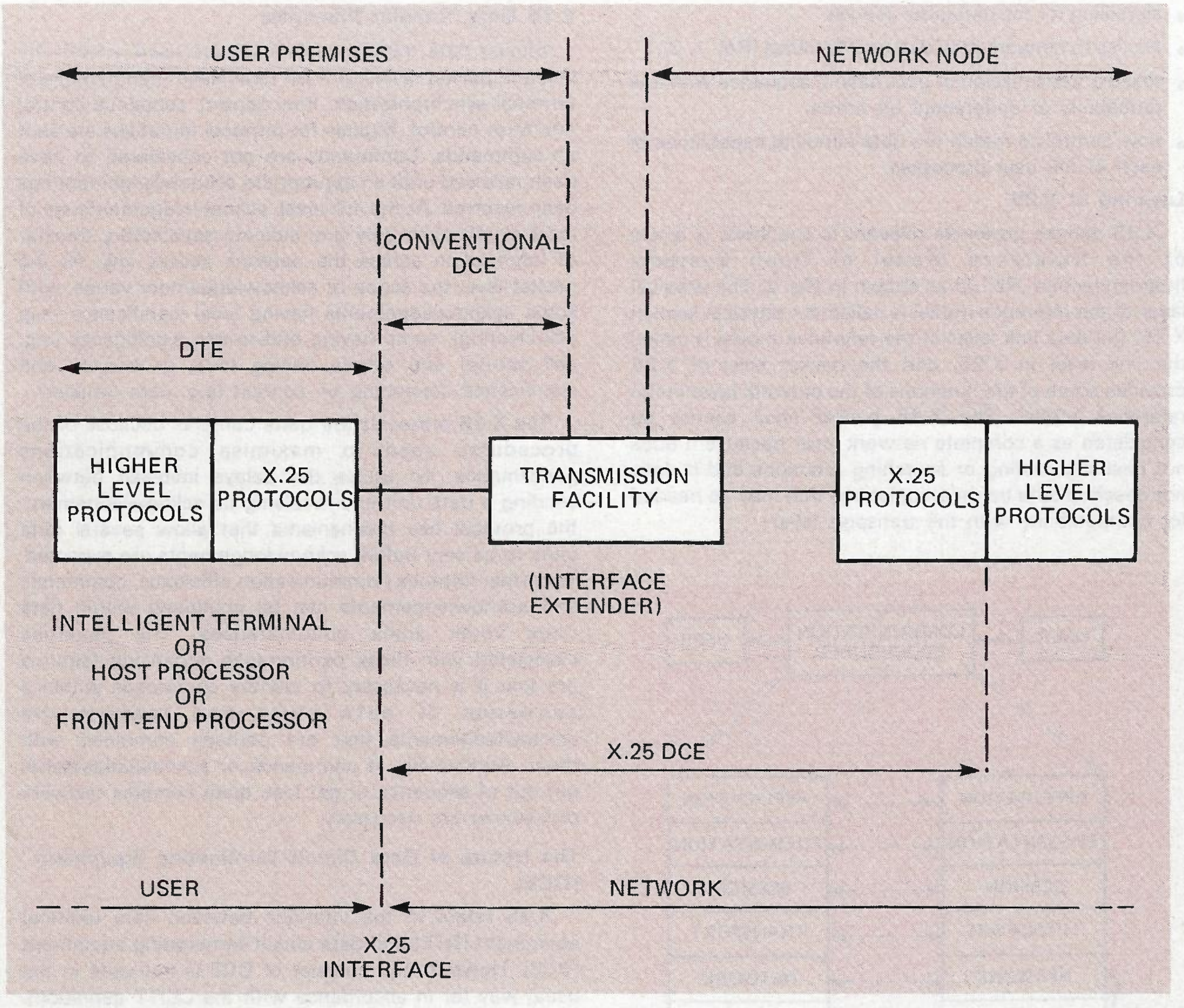


Fig. 3 — The Nature of the X.25 DCE

In the example shown in **Fig. 4**, a virtual call is set up from terminal A to terminal B. When a call is set up, the X.25 logical channel allocation strategy is that if the terminal is initiating the call it starts seeking a free logical channel from the highest number down. In this example, logical channel X is chosen by terminal A, so the call will be conveyed into the network on logical channel X. The network is then responsible for establishment of the call to the desired destination node. The network then selects a free logical channel on the X.25 interface to the appropriate user. X.25 specifies that the network selects free logical channels from the lowest channel number to minimise the possibility of both the network and the terminal trying to establish a call on the same logical channel. In the example, logical channel Y is allocated to the call at the B interface. The example thus shows the distinction between a logical channel which is local to a particular interface and a virtual circuit which is an end-user to end-user concept.

Packet Level Call Set-Up

The X.25 packet level provides signalling functions necessary to establish virtual circuits. To set up a call, a call request packet may be sent by a terminal or an incoming call packet may be sent by the network. These packets contain a logical channel number for the call, a packet type identifier, called and calling party addresses as appropriate, facilities required and up to 16 octets of user data. X.25 does not specify the use of the user data field, but it may typically be used to convey information about the higher level protocols used or log-on information.

In the example shown in **Fig. 5**, DTE A issues a call request packet and sends it to the network. The network then generates an internal signal that sends the call information towards its destination using the address information in the call request packet to make routing decisions. At the destination node, the network generates an incoming call packet which is sent to terminal B. Under normal circumstances, terminal B will then issue a call accepted packet that is relayed through the network resulting in a call connected packet being sent to the calling terminal. The virtual circuit is then ready for data transfer. During the call set up phase there may be some negotiation about X.25 services and facilities required during the call. If for some reason the call cannot be set up, a clear confirmation packet is

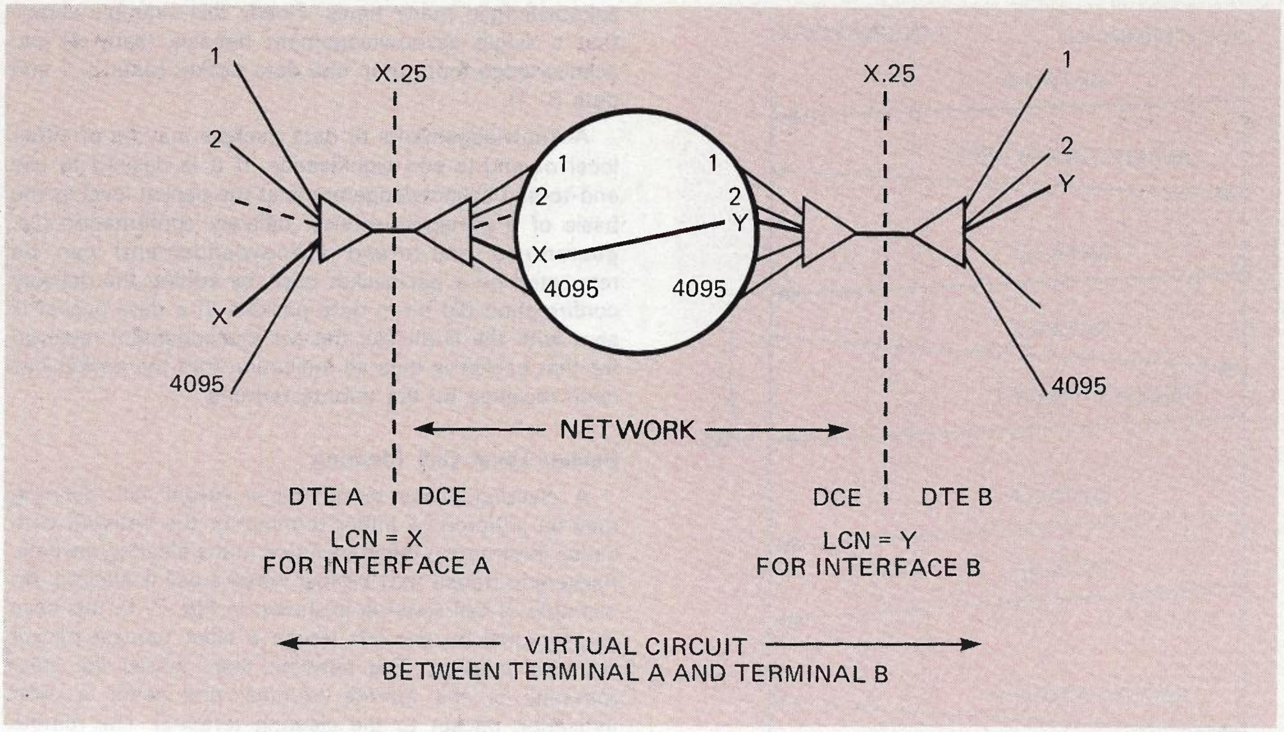


Fig. 4 — Packet Level Multiplexing

returned to the calling terminal containing the reason why the call attempt was unsuccessful.

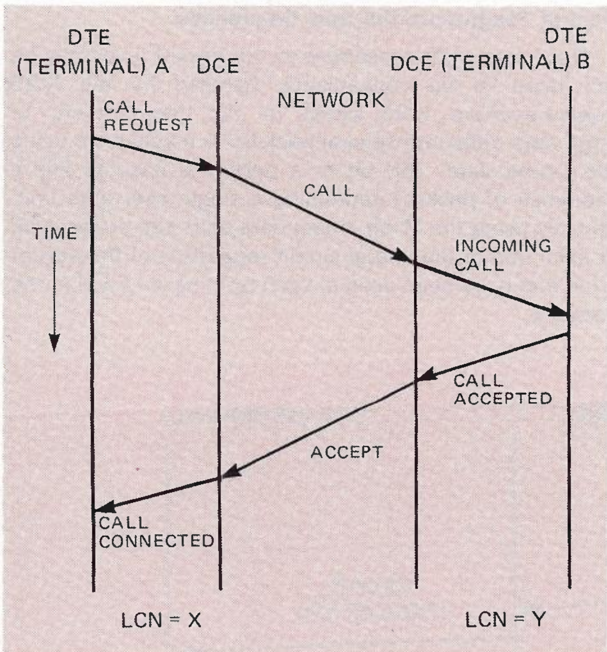


Fig. 5 — Packet Level Call Set-up

Packet Level Data Transfer

In the data transfer phase, data packets are sequence numbered modulo 8 and acknowledgements of packets can be used to implement flow control.

Because a modulo 8 numbering scheme is used, up to 7 unacknowledged packets can have their sequence unambiguously resolved, although typically 2 or 3 are generally sufficient outstanding unacknowledged packets to achieve satisfactory performance. X.25 allows optionally a modulo 128 numbering scheme for use on large delay links. Packet acknowledgements may be in special response packets or they may be "piggybacked" onto data packets travelling in the reverse direction. Flow control is achieved by either delaying acknowledgements or by sending a receive not ready (RNR) packet that requests that no more packets be sent until a receive ready (RR) packet is received.

The example shown in **Fig. 6** illustrates the X.25 packet level data transfer functions. The notation used in the example is that the packet type name is followed by one or two numbers. If only one number is present, as in the case of the receive ready packet, it is the receive sequence number (P(R)) which is an acknowledgement of all packets up to and including P(R)-1. This indicates that the next data packet expected by the receiver should have a send sequence number (P(S)) equal to the P(R) value in the acknowledgement. If two numbers are present, the first is the send sequence number (P(S)) of the packet and the second is a "piggybacked" acknowledgement receive sequence number (P(R)) which is interpreted as described above.

In the example, the terminal (DTE) first sends a data packet. The send sequence number indicates that this is data packet number 0, and the piggybacked acknowledgement indicates that the terminal expects the next data packet it receives from the network (DCE) to have sequence number 0. After the data packet has been received by the network, an acknowledgement is sent in due course. The delay between the network receiving a data packet and the sending of an acknowledgement depends on the internal condition of the network and the flow control requirements. In this example, a receive ready acknowledgement is sent indicating that data packet number 0 has been received and the next data

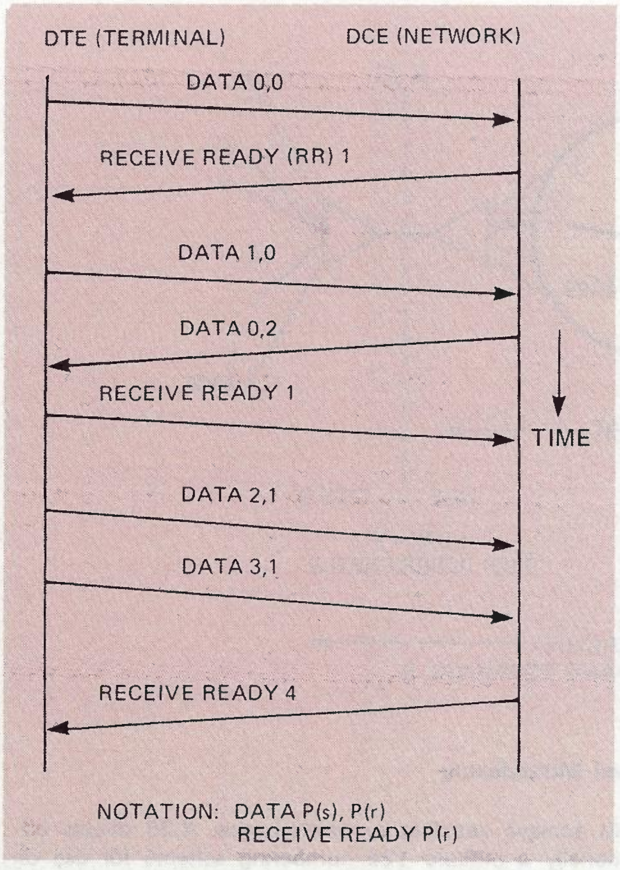


Fig. 6 — Packet Level Data Transfer

packet expected should have send sequence number (P(S)) equal to 1.

The example shown in Fig. 6 shows the use of "piggybacked" acknowledgements, with data packet 1, 0 from the terminal being acknowledged by data packet 0, 2 from the network. It can be seen that the receive ready 1, data 2, 1 and data 3, 1 packets from the terminal each acknowledge receipt from the network of packet data 0, 2, hence a data packet can, in general, be acknowledged many times. Finally this example shows that a single acknowledgement (receive ready 4) can acknowledge more than one data packet (data 2, 1 and data 3, 1).

Acknowledgements of data packets may be of either local or end-to-end significance. If it is desired to use end-to-end acknowledgements at the packet level as the basis of a transport service, delivery confirmation (i.e. guaranteed end-to-end acknowledgement) can be requested on a per-packet basis by setting the delivery confirmation (D) bit in data packets. If a data packet is sent with the D-bit set, the acknowledgement received for that packet is thus an indication that the packet has been received by the remote terminal.

Packet Level Call Clearing

A clearing phase terminates a virtual call. Clearing may be initiated by either terminal or the network with cause information being included in the clearing packets. Packets in transit may be lost when a call is cleared. An example of call clearing is shown in **Fig. 7**. In this case the terminal on the left issues a clear request packet initiating clearing. The network then passes the clear message to the remote terminal and sends a clear indication packet to the clearing terminal. The remote terminal issues a clear confirmation packet following the receipt of a clear indication packet. A clear confirmation sent by the network to a terminal may be of either local or end-to-end significance.

Packet Fragmentation and Sequences

User data units presented to the packet level may be too large to be conveniently handled by the X.25 implementation. X.25 allows for the fragmentation of large data units into several packets. A mechanism using the "more data" (M) bit in a packet is used to link a sequence of packets containing a single user data unit. Thus by using the M-bit, intact data units can be resolved at each end of the virtual circuit regardless of the packet sizes that have been used at each terminal and within the network.

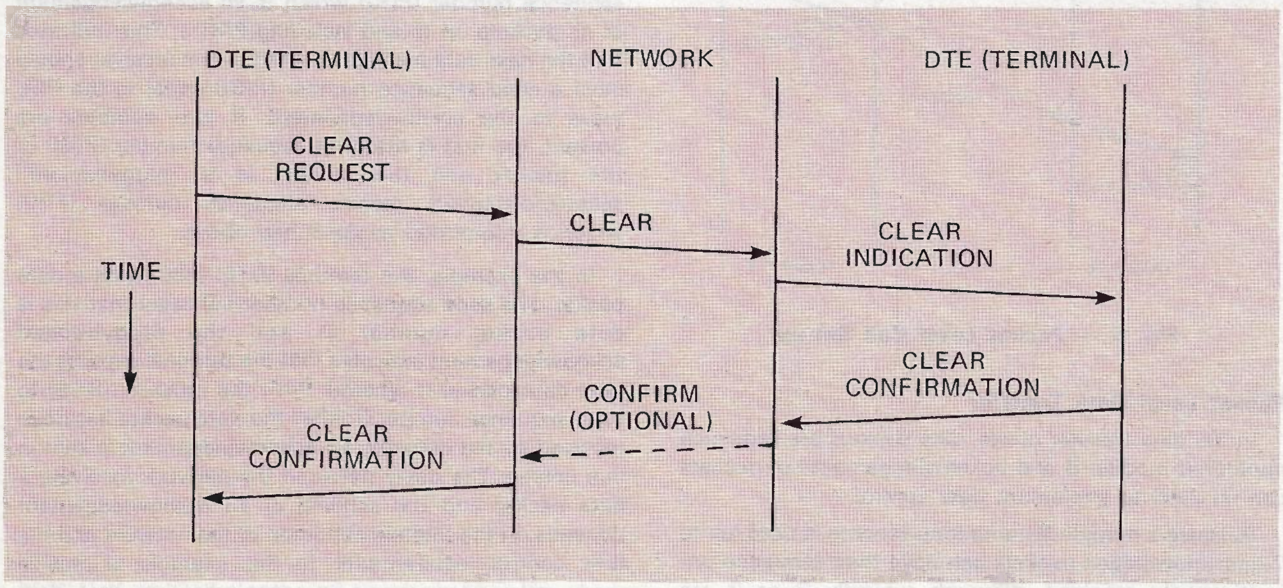


Fig. 7 — Packet Level Call Clearing

Packet sizes may thus differ at each terminal and within the network. A sequence of packets that is linked by the M-bit is known as a complete packet sequence and X.25 allows networks to store and forward data packets as complete packet sequences rather than on an individual packet basis.

Packet Level Signalling

X.25 provides two additional signalling procedures for signalling during a call: a data qualifier mechanism, and interrupt packet transfer procedures. Each data packet header contains a data qualifier (Q) bit. When Q = 0 it indicates that the packet contains normal user data. Q = 1 indicates that the packet data field contains control information for a higher level protocol. This mechanism is used when signalling to a packet assembler/disassembler communicating with an unintelligent asynchronous terminal. This Q-bit use appears to violate some of the layering concepts in the reference model because it allows the protocol at the packet level to have some knowledge of the contents of the user data field.

For out of band signalling, the X.25 packet level provides a special interrupt packet containing 8 bits of user data that may be used during a call. Only one outstanding interrupt sequence is allowed at any time. An interrupt packet is not sequenced and may thus be given priority over data packets, particularly under flow control blocked conditions. The use of the interrupt procedure does not affect the flow control or validity of normal data transfer. The example in **Fig. 8** shows an interrupt packet overtaking a data packet. The interrupt procedure could be used to investigate suspected congestion on a particular virtual circuit.

Packet Level Reset

Either the network or either terminal may detect error conditions that could disrupt a virtual call; for example, out of sequence packets may be detected. Under such conditions the packet level service on that virtual circuit cannot be assured (e.g. data may be lost) and reset procedures are initiated to logically resynchronise the virtual circuit. The reset request and reset indication packets contain information about the cause of the reset. The example shown in **Fig. 9** shows a resetting sequence initiated by a terminal. The reset confirmation sent by the network may be of either local or end-to-end significance. It is also possible that the network may initiate resetting.

Packet Level Restart

The packet level restart procedure is used to initialise all logical channels used across a particular network access link to a known state. Restart procedures may be initiated by either terminal or the network and other packets may be lost during restart. The restart packets contain information about the cause of the restart. Typically, restart procedures may be used for initialisation at terminal start-up, or following serious link level failures. **Fig. 10** illustrates the use of restart packets.

Packet Level Diagnostic

The X.25 packet level contains a diagnostic packet that may optionally be used by the network to indicate error conditions on a virtual circuit when it is appropriate to use reset or clear. The diagnostic packet contains a cause field. Some diagnostic causes are standardised while others are available for network specific use.

X.25 Link Level

The packet level services are supported by a link level service that provides reliable point to point communication between a terminal and the network.

Mechanisms are provided in the link level to:

- initialise the link;
- ensure that any message bit pattern can be transferred (transparency);

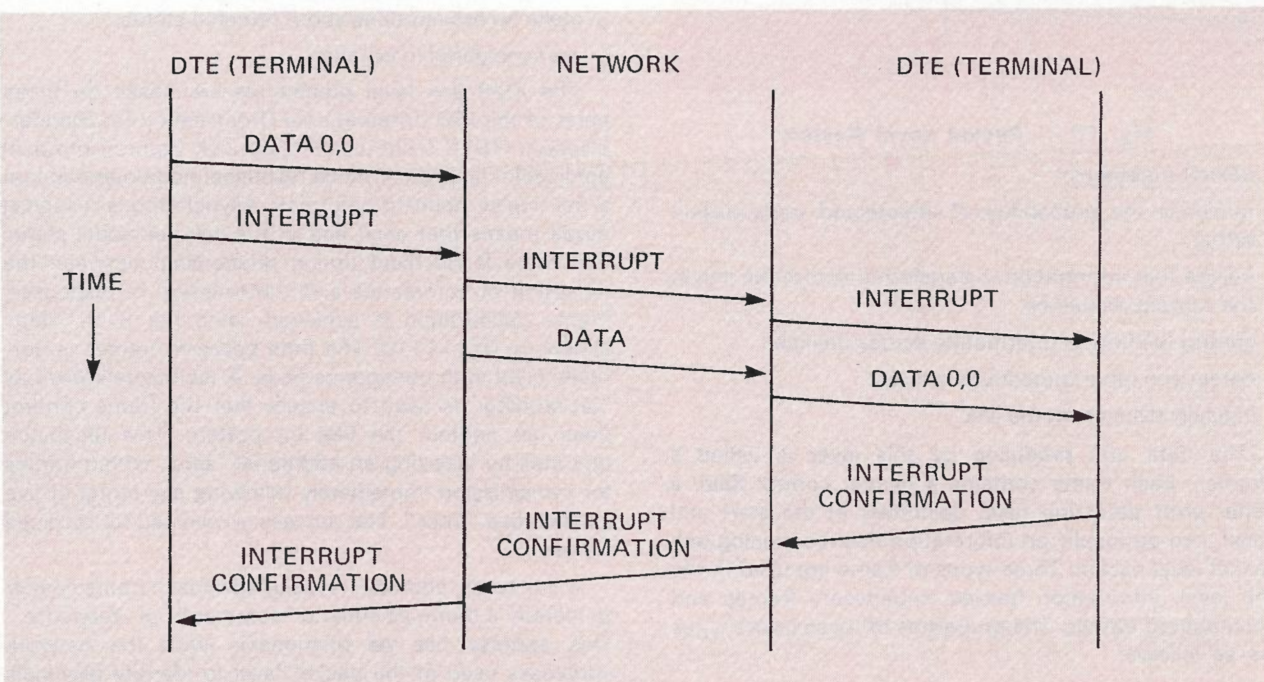


Fig. 8 — Packet Level Out-of-Band Signalling

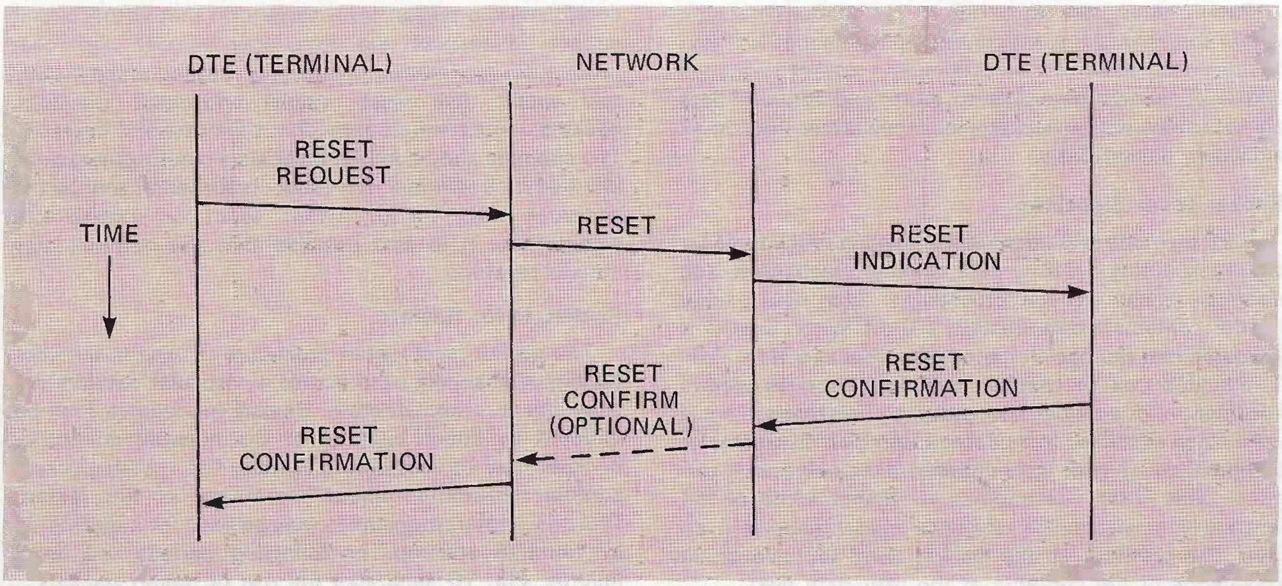


Fig. 9 — Packet Level Reset

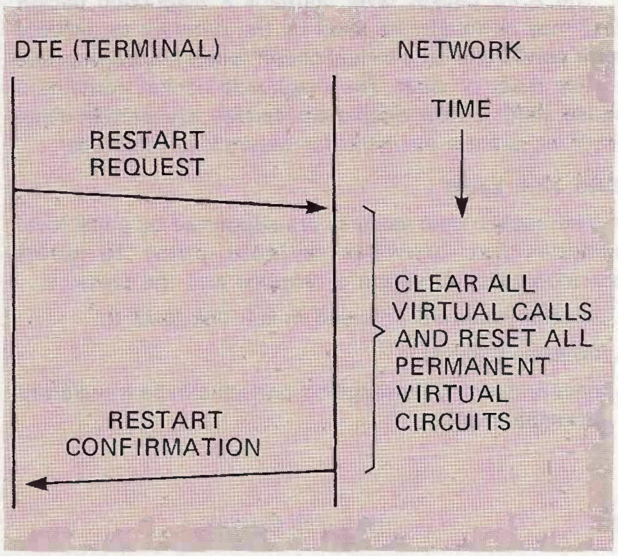


Fig. 10 — Packet Level Restart

- delimit messages;
- minimise the probability of undetected transmission errors;
- ensure that information is transferred across the link in the correct sequence;
- control the flow of information across the link;
- detect and report procedure failures;
- logically disconnect the link.

The data unit produced by this layer is called a "frame". Each frame contains a header control field, a trailer error detecting field, delimiters at the start and finish, and optionally an information field containing one packet level packet. Three types of frame are used in the link level, information frames, supervisory frames and unnumbered frames. The properties of these frame types are as follows:

Information Frames:

- contain 1 packet level packet;
- contain a send sequence number;
- contain acknowledgements of received frames;
- can only be commands.

Supervisory Frames:

- may be commands or responses;
- can request DTE or DCE status;
- can indicate DTE or DCE status;
- contain acknowledgements of received frames;
- are unsequenced.

Unnumbered Frames:

- are used to set up, clear or reset;
- may be commands or responses;
- make no assumptions about terminal status;
- are considered in isolation.

The X.25 link level procedures are based on those parts of the ISO (International Organisation for Standardisation) HDLC (High-Level Data Link Control) protocol applicable for asynchronous response mode operation on a full duplex point-to-point link. Asynchronous response mode means that each end of the link has equal status and there is no fixed timing relationship between the reception of commands and transmission of responses. Frame delimitation is achieved using the 8 bit "flag" sequence 01111110. The time between frames is normally filled with contiguous flags. A technique known as "bit-stuffing" is used to ensure that the frame content does not contain the flag bit pattern. This technique operates by inserting an additional "zero" within frames for transmission immediately following any string of five consecutive "ones". The process is reversed for received frames.

A link level "address" is included in each frame header to identify a frame as either a "command" or "response". This address has ***no*** relationship with the network addresses used at the packet level to identify terminals connected to a network.

Transmission errors in frames are detected using a 16 bit frame check sequence (or cyclic redundancy code) appended to each frame. This scheme reduces the probability of undetected bit errors in a frame by a factor of approximately 1 in 10^5. Procedures in the link level protocol provide for error recovery by retransmission.

X.25 describes two link procedures, LAP and LAPB. The LAP procedures were introduced in 1976; however they contain protocol problems that can lead to deadlock under some resetting conditions. To resolve these problems the LAPB procedures were introduced in 1978 for "Balanced mode" operation. The 1978 LAPB procedures contained considerable assymetries of operation between network and terminal. The 1980 LAPB recommendation has been expanded so that the link level behaviour of the network and terminal is largely symmetrical. The LAP procedures remain supported by X.25; however the LAPB procedures are described as preferred and are the only procedures required to be implemented by all X.25 networks. Examples presented in this chapter are based on the LAPB procedures. The notation used is similar to that in the packet level examples.

Link Set-Up

The set asynchronous balanced mode (SABM) unnumbered command and the unnumbered acknowledgement (UA) unnumbered response frames are used to set up and initialise a link using the LAPB Procedures as shown in **Fig. 11**. Both the network and the terminal maintain state variables V(S) (send state variable) and V(R) (receive state variable) which are set to the sequence number of the next information frame to be sent and the oldest unacknowledged information frame respectively. These state variables are initialised during link set-up.

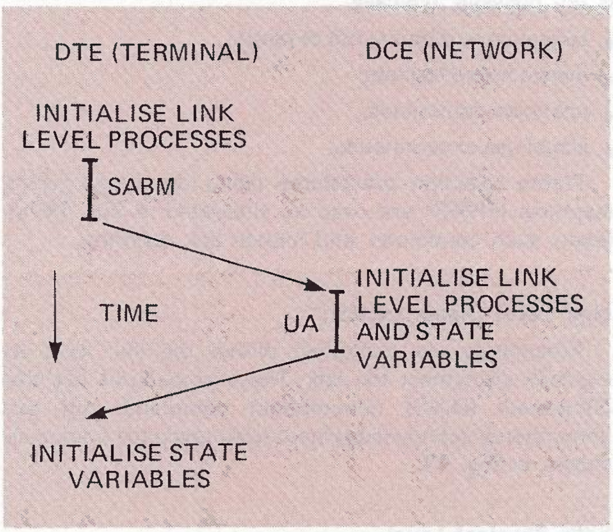


Fig. 11 — Link Set-up

Link Level Data Transfer — Sequence Control

Data transfer procedures in the link level are similar in operation to those described for the packet level. However, while the main purpose of the packet level is to control flow, emphasis in the link level is on sequence and error control.

The link level allows up to 7 outstanding unacknowledged information (I) frames to increase link utilisation. Each I-frame is numbered modulo 8 for sequence checking and error control. Frames can be acknowledged by either supervisory response frames or acknowledgements "piggybacked" onto command frames travelling in the reverse direction. One response can acknowledge more than one command ((I) frame) and frames may be acknowledged more than once provided the sequence of new acknowledgements is maintained. **Fig. 12** shows examples of information transfer with acknowledgement by supervisory response and piggybacking.

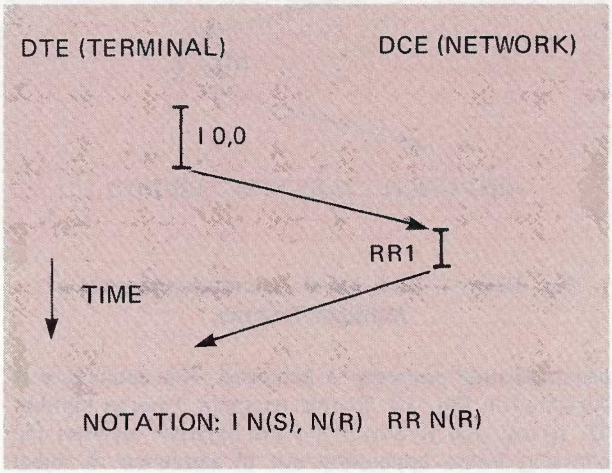


Fig. 12(a) — Link Level Acknowledgement by Supervisory Response

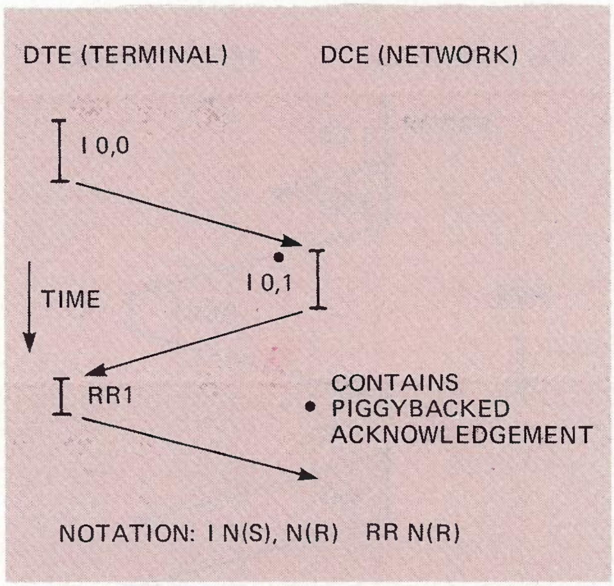


Fig. 12(b) — Link Level "Piggybacked" Acknowledgement

Link Level Data Transfer — Error Control

Frames received containing transmission errors are detected using the frame check sequence and discarded. The link level provides two error recovery procedures.

Firstly, if a frame is received out of sequence, it is assumed that the previous frame was discarded due to errors. In this case, a reject (REJ) response is sent requesting retransmission of all frames from a specified sequence number. Further out of sequence frames are

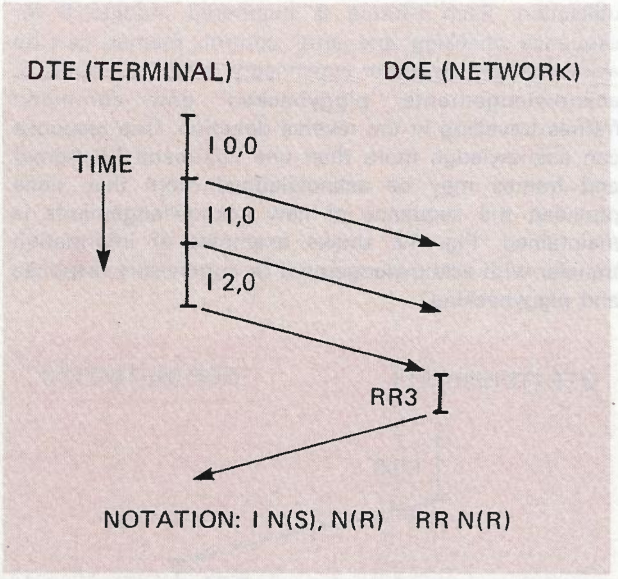


Fig. 12(c) — Link Level Acknowledgement of Multiple Frames

discarded until recovery is achieved. This procedure is illustrated in **Fig. 13.** In this example, I-frame number "O" is lost due to errors and the network receives the following frame apparently out of sequence. A reject response is thus sent requesting retransmission of all frames from and including "O".

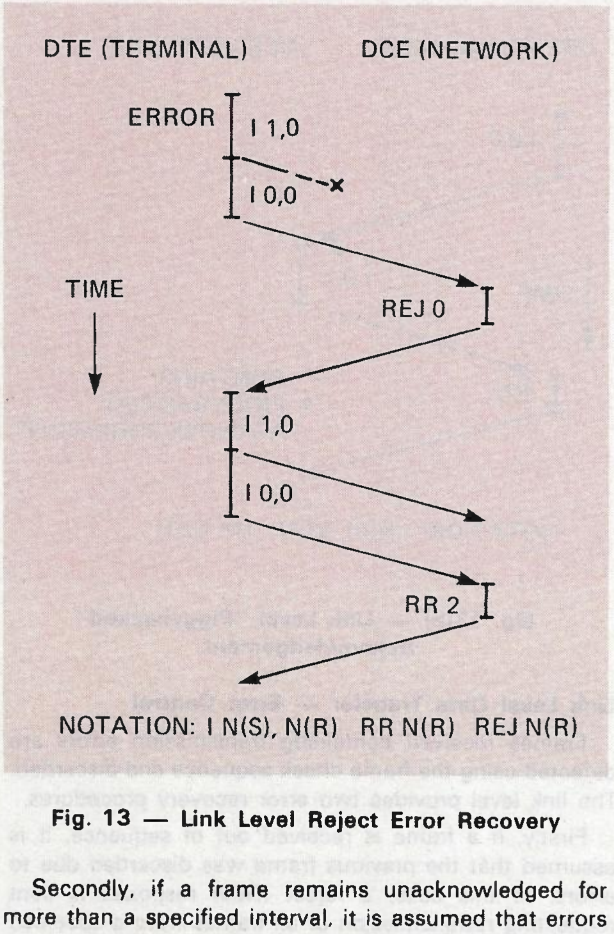


Fig. 13 — Link Level Reject Error Recovery

Secondly, if a frame remains unacknowledged for more than a specified interval, it is assumed that errors have interrupted transmission. A recovery phase is initiated that establishes which data has been successfully received, and retransmits all successive frames.

The time-out recovery procedures are synchronised using the poll/final mechanism. If a command is sent with the poll bit set, received responses are ignored until a response is received with the final bit set. Only one outstanding frame with the poll bit set is allowed. **Fig. 14** shows two examples of how time-out error recovery can be achieved. Alternative 1 shows the use of a polled supervisory command (RR) to establish what frames have been correctly received by the network. Alternative 2 shows the case where error recovery is achieved by retransmission of all unacknowledged frames, starting with the oldest which is sent with the poll bit set to establish the validity of such retransmission.

Link Level Data Transfer — Flow Control

The link level contains a flow control mechanism using a receive not ready (RNR) supervisory response frame as shown in **Fig. 15.** It is widely considered that the use of this link level flow control mechanism is undesirable because of possible adverse reactions with higher level protocols which may also be applying flow control. Use of the link level flow control procedures indiscriminately restricts the flow associated with all the multiplexed data streams using the link. Release of the flow restriction may cause instability if large amounts of data have been stored while the link is flow control blocked. The link level flow control mechanism should thus be used only in cases of extreme localised congestion.

Link Level Procedure Failures

Some error conditions can occur from which recovery is not possible, typically:

- sequence numbering out of range;
- invalid frame formats;
- unknown commands;
- illegal use of commands.

Frame rejection procedures using the frame reject response (FRMR) are used as illustrated in **Fig. 16** to report such conditions, and initiate link resetting.

Link Level Disconnection

Procedures are contained within the link level to logically disconnect the link. These procedures use the disconnect (DISC) unnumbered command and the unnumbered acknowledgement (UA) response frames as shown in **Fig. 17.**

X.25 Physical Level

The link level is built on a physical level that provides physical, mechanical and electrical conditions for the synchronous transmission of the bit-stream generated by the higher level protocols. The physical level interface is similar to those currently used for leased line data communications services such as V.24 or R.S.232. The X.25 physical level is specified by reference to parts of other interface recommendations, in particular to X.21 and X.21 bis. X.21 differs from X.21 bis, for this application in that fewer electrical circuits are used,

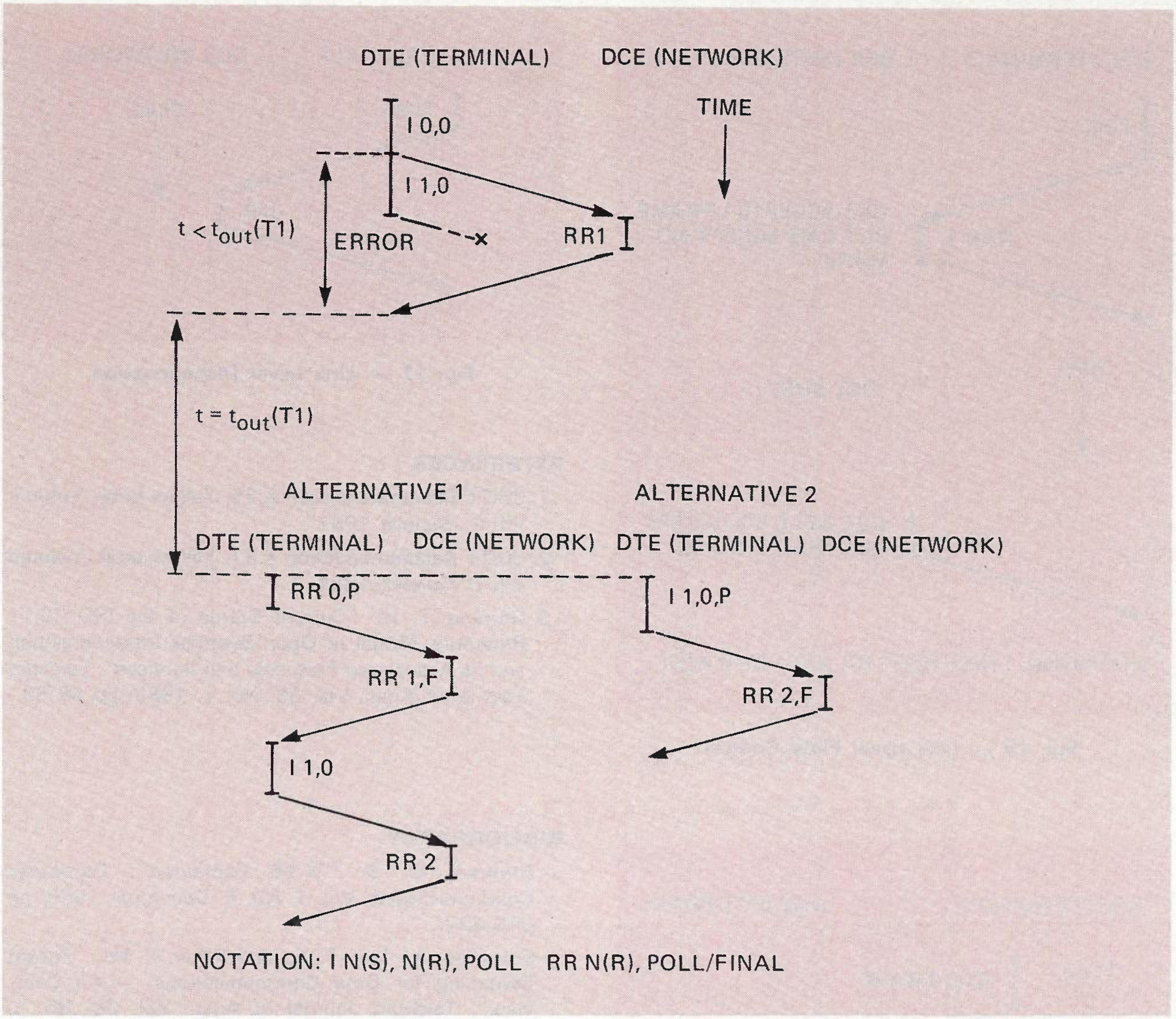


Fig. 14 — Link Level Time-out Error Recovery

electrical levels and signal detection criteria differ, and the time sequence of signals is important in X.21.

CONCLUSIONS

X.25 has evolved remarkably quickly for a CCITT standard. Although the 1980 CCITT X.25 recommendation has reached a considerable level of maturity, X.25 remains complex with many options. It gives a description of procedures but does not specify how they should be used and cannot be considered as a complete protocol specification because there are too many areas that are open for interpretation. X.25 lacks formal specification of the services it provides. Although X.25 is primarily concerned with network behaviour, some indication is given concerning suggested terminal behaviour. X.25 appears to violate some of the layering concepts of the reference model for open systems interconnection, particularly with the use of the packet level Q-bit and the options for end-to-end significance of interactions in some cases. The packet level service does not align completely with the network layer because it does not consider routing or data unit size management.

Many difficulties remain for users of X.25. For example, from a terminal point of view, it is difficult to know how to specify X.25 systems to ensure compatibility with other systems or networks and to ensure that an adequate level of service performance will be achieved. Similarly, from a network operator's point of view, it is difficult to establish user compatibility within an evolving network. It is necessary for a network operator to be able to ensure that one user will not be able to disrupt or degrade the service offered to other users. It is also necessary to ensure that the performance achieved by users with particular implementations will not be degraded when network protocol software is updated.

Despite these difficulties, X.25 is the only available suitable international standard for packet mode access to public packet switching networks. As such, it has received wide and increasing acceptance by computer systems manufacturers as well as public data network operators. Many public X.25 networks are now operational worldwide with a large number of X.25 users and a standardized capability for international X.25 calls.

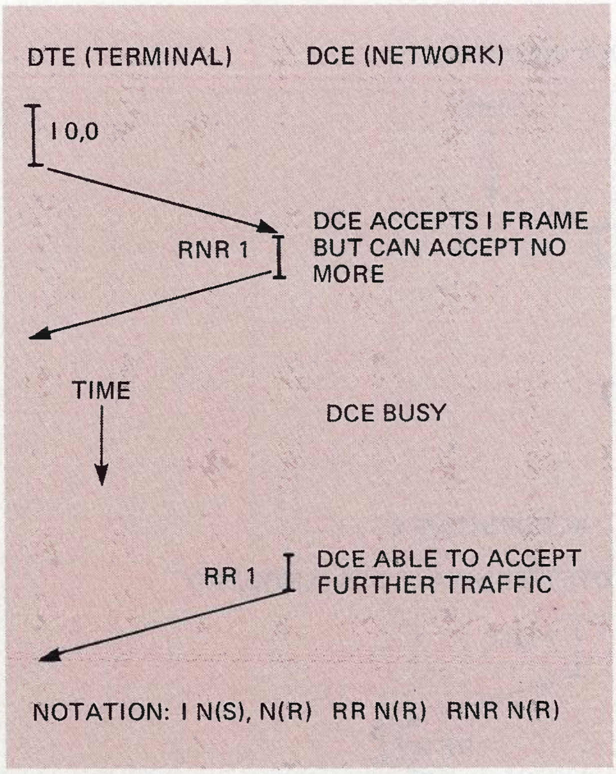


Fig. 15 — Link Level Flow Control

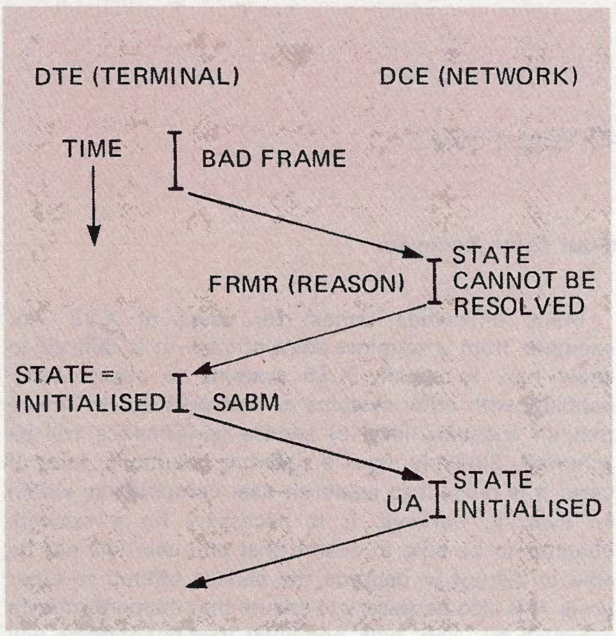


Fig. 16 — Link Level Reset Procedure

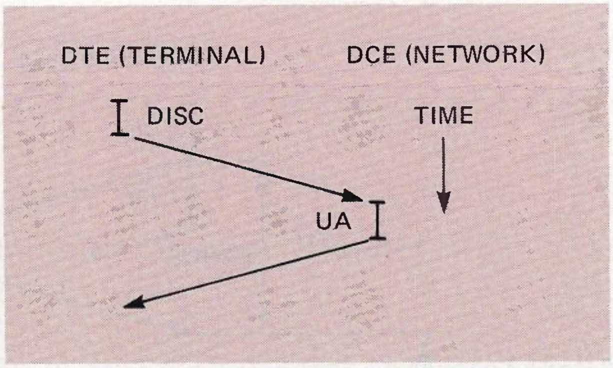


Fig. 17 — Link Level Disconnection

REFERENCES

1. CCITT Recommendation X.25, Yellow book, Volume VIII-2, Geneva 1981.
2. CCITT Recommendation X.87, Yellow book, Volume VIII-3, Geneva 1981.
3. Gerrand, P. H.: "Current Status of the ISO/CCITT Reference Model of Open Systems Interconnection and its Associated Protocols and Services"; Telecom Journal of Aust., Vol. 33, No. 1, 1983, pp 59-66.

BIBLIOGRAPHY

— Sloman, M. S.: "X.25 Explained"; Computer Communications, Vol. 1, No. 6, December 1978, pp 310-327.

— Edvi-Illes, A., Lee, F. Y., and Wion, F. W.: "Packet Switching for Data Communications — An Overview"; Telecom Journal of Aust., Vol. 30, No. 1, 1980, pp 26-33.

— Bertine, H. V. "Physical Level Protocols"; IEEE Trans. Communications, Vol. COM-28, No. 4, April 1980, pp 433-444.

— Harrison, M. J.: "Network Plan for AUSTPAC — The Australian National Packet Switching Service"; Telecom Journal of Aust., Vol. 31, 1981, pp 28-33.

— Harrison, M. J.: "DPS25: Distributed Packet Switching Technology for the AUSTPAC Network": Telecom Journal of Aust., Vol. 32, No. 1, 1982, pp 3-12.

— Symons, F. J. W., Duc, N. Q., Snare, J. L., and Kirton, P. A.: "An Introduction to Selected Data Communications Standards"; Telecom Australia Research Laboratories Report No. 7554, February 1983.

Remote Area (Satellite) Television in Queensland

V. L. CAVALLUCCI B.E. (Elec.)

Those of us who have had a choice of television programmes for many years may find it difficult to appreciate how those without television in remote areas feel about their isolation. The unique problems and dispersal of communities in this country has required pioneering efforts to extend the National Television Service coverage. The problem has always been the very high cost of relaying the programme as most of Australia outside the urban areas is sparsely settled with numerous small communities. Otherwise each could be easily served with a low powered transmitter, at reasonable cost.

This article outlines how services have been established at an "affordable" cost at many isolated localities in Queensland. The system utilises an existing satellite for the Australia-wide relay of television programmes.

INTRODUCTION

There have been a number of projects over the last ten years for expanding the National Television Service. Each project has brought television coverage to communities previously considered remote.

The availability of suitable transponders on the Intelsat IV Pacific Satellite and of "affordable" receive equipment has enabled television to be brought to even the most isolated communities via satellite. There are twenty communities in Queensland including such notable places as Birdsville, Thursday Island and Normanton which were the first to receive the National Television Service by satellite. The only source of television for these communities had previously been via private video tape replay units. Indeed the coming of real time television has been a milestone for these communities where time seems to otherwise have stood still. Over the last 100 years the motor car, electric power, refrigeration and the Flying Doctor Service have been the other main developments to reach some of these communities yet they are still waiting for sealed roads, radio broadcasting services and modern telecommunications services.

This paper will discuss the methods used and efficiency achieved in completing the remote area satellite project. Discussions and comments will also be offered on the technical and subjective performance attained over the satellite derived system.

The Remote Area TV (RATV) stations were designed and installed by Telecom Australia on behalf of the Department of Communications.

PROJECT MAGNITUDE

On current plans there are to be 62 satellite derived TV stations throughout Australia of which 20 are in Queensland.

In addition to the 20 Queensland satellite sites a further eight transmitters were provided which derived their program from terrestrial microwave systems. **Table 1** lists all sites included under the remote area TV (RATV) project in Queensland. The magnitude of the task can be appreciated by reviewing the numbers, location and time available for projects.

From the total of 28 services covered in the project, as many as practical were to be operational by December 1980. Twenty-two services were actually established by December 1981, and the remainder of services covered by the project were completed by November 1982.

A quick review of the geography of Queensland will show just how remotely the sites were located and how wide they were apart. Sites were located within 15 kilometres of the Northern Territory, South Australia and New South Wales borders and within 150 kilometres of New Guinea, representing an area of 1.5 million square kilometres.

Sheer physical or logistic aspects were not the only challenges.

Telecom was the first administration in the world to use a communications satellite as a "relay station" to serve a network of ground TV stations. To do this, a number of new features were necessarily introduced. These included:

- the extensive use of large diameter 6.5 to 7.5m but non-tracking earth station antennas;
- main station quality but low priced low noise amplifiers and receivers;
- television transmitters with new designs; and
- a new type of supervisory system.

These "novelties" as well as requiring introduction into satellite operation, demanded a very high degree of technical alertness and flexibility.

PROJECT IMPLEMENTATION

The majority of the sites in Queensland were completely new and undeveloped and all the work in establishing the services was performed by the project teams. This included the site preparations, excavations and foundations, erection of structures and antennas, and the installation and commissioning of all equipment. Vital services such as for the surveying of sites and the transporting of many large items of material to the sites were provided by other areas of Telecom.

The Remote Area TV project team was formed in January 1980 and was drawn from staff already working in the TV installation area. Teams were developed to cover the specific activities of the project and the organisation of the group as a fifth cell of the Radio Section was as shown in **Fig 1**.

During peak efforts towards the end of 1980 and for a number of occasions in 1981 a maximum of about 20 staff worked on the project.

The project commenced with the installation of terrestially-fed transmitters at already developed sites for the Surat, Capella, Jericho and Corfield services. Excavations and foundations work at satellite stations commenced in April 1980 at Cooktown, and proceeded according to the schedule listed in **Fig 2**. The structures and antenna erection party commenced as soon as material became available, towards the end of August 1980, closely followed by two equipment installation parties. By the end of September the stations at Cooktown, Normanton and Karumba were completed and placed into service with Exmouth, Onslow and Broome (WA) and Walgett (NSW) on 28th September 1980 — the official commencement date for the Intelsat fed RATS.

Over the 1980/81 financial year, which includes the usual annual Christmas recess of 4 to 6 weeks for field staff, 14 stations were fully commissioned. Such a rate of progress achieved by a relatively small number of staff reflects the considerable amount of project co-ordination, efficient work practices and enthusiastic efforts. The achievement compares very well with an earlier remote area TV project performed by contractors on a turn-key basis.

Again, reviewing the schedule of site works in relation to the geography and weather patterns of Queensland, will show that work flow was adjusted to run least risk of weather interruption. This arrangement was successful, as little wet weather time was lost by construction crews. For example, work was able to be recommenced at Aramac many weeks earlier than would have been possible at less accessible localities such as Birdsville.

A discussion of field work would not be complete without some explanation of the extent of the work carried out by each of the teams. This is summarised in **Table 2** and should be reviewed within the following background:

TELEVISION TRANSMITTER SERVICES OFF INTELSAT SATELLITE		
Aramac	Greenvale	Quilpie
Bedourie	Injune	Tambo
Birdsville	Isisford	Taroom
Boulia	Karumba	Thursday Is.
Cooktown	Mt. Molloy	Wandoan
Croydon	Muttaburra	Weipa
Georgetown	Normanton	

TELEVISION TRANSMITTER SERVICES OFF MICROWAVE LINKS	TELEVISION TRANSLATOR SERVICES
Camooweal	Dimbulah (UHF)
Capella	Miriamvale
Coen	Mt. Gravatt
Corfield	Rubyvale
Jericho	Texas
Laura	
Pentland	
Surat	

Table 1 — TV Services Included in 1980/83 Queensland RATV Programme

VINCE CAVALLUCCI graduated in 1971 with a Bachelor of Engineering (Electrical) degree from the University of Queensland. He has worked in the Radio area since then, in almost all its specialties. These have included . . .

— The Design, Survey and Installation of Radio Telephone Systems;

— The supervision of the contract installation of a major thin-line Microwave route for TV relay to transmitters.

— The upgrading of high powered TV stations and replacement of large TV transmitting antenna systems.

Over recent years his work has involved the installation of numerous TV translators and transmitter services which led to his appointment as Project Engineer for the Remote Area (Satellite) TV project.

- all excavations were carried out by project staff using whatever mechanical aids were available.
- concrete was mixed on site using a truck mounted agitator and other aids. Up to 40m³ of concrete was used at some sites. Aggregates were hauled to site from the nearest suitable source which for some sites was 650 km away. A typical plant consisted of an end-loader, a batching unit and an agitator truck. See **Fig. 3**.
- shelters, masts and other major materials were transported to sites by Telecom transports. **Fig. 4** shows work in progress on the fitting and alignment of earth station antenna petals at Cooktown.
- crated electronic equipment was delivered to site in the shelters.
- to adequately deal with the quantity and variety of new technology equipment, qualified and experienced office based personnel assisted with commissioning work. **Fig. 5** shows commissioning in progress at Birdsville in mid-summer. **Fig. 6** shows a completed installation at Normanton.

WORK PARTY	ACTIVITY	TYPICAL ON-SITE COMPLETION TIMES
Excavations and Foundations (4 men)	Prepare site, excavate footings, provide aggregates, set foundation inserts, set earthing hardware and lay concrete for Earth Station Antenna (E.S.A.), shelter, mast, security fence (20-40m³ required).	2-3 weeks
Structures and antenna erection (4 men)	Assemble and erect E.S.A. and mast, secure shelter, complete and test earth system, install Tx antennas and cables, install security fence.	2-3 weeks (depends on availability of crane for mast and E.S.A.)
Equipment Installation (3 men)	Install receiver (Rx) and transmitter (Tx) racks and mount equipment there-on; complete inter-rack wiring; fit ducting and terminate main cables; fit Low Noise Amplifier (L.N.A.), connect power to equipt., operate equipment and acquire satellite by pointing E.S.A. Install monitoring receivers; fit and interface supervisory equipment.	2-3 weeks
Equipment Commissioning (2 men)	Test the Television Receive Only Terminal (TVRO) and Tx; measure carrier to noise ratio; check overall performance, check radiation pattern; check antenna Voltage Standing Wave Ratio (VSWR).	1 week
Depot preparations. Despatch (3 men)	Prepare equipment panels and cabling; package materials site by site; despatch material and tools; back-up for installation and commissioning teams.	continuously Depot based.

Table 2 — Work Team Activities

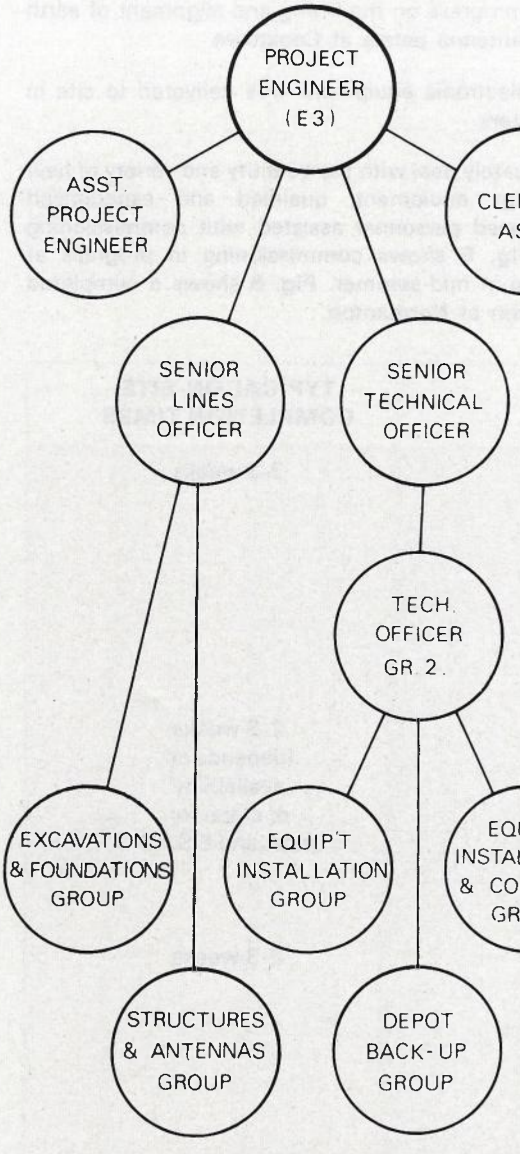


Fig. 1 — RATV Project Organisation

SYSTEM DESCRIPTION

Satellite TV originated as a means of extending national service coverage to more isolated communities more economically and at similar quality as video tape replay services prior to November 1982. Two programmes were relayed via a single transponder of the Intelsat IV and after that, two separate transponders were used on Intelsat IV-A satellite (which replaced Intelsat IV) Pacific Satellite. One programme is transmitted from the Overseas Telecommunications Commission (OCT(A)) earth station at Moree for the East Australia services (on AEST) and the other from the O.T.C. earth station at Carnarvon for the West Australia service (on WAST).

The antenna on the current satellite provides a hemisphere beam covering Australia with a minimum of 26.0 dbW effective radiated power (ERP) in the service areas. The receive band is in the 3.7 to 4.2 GHz range and is one of the standard communications bands. This poses frequency co-ordination difficulties with terrestrial microwave systems operating in the same general geographical area as satellite terminals.

The basic receive system as installed on the current remote area satellite derived television consists of the following items and is configured as on **Fig. 7**.

- 6.5m or 7.5m diameter satellite receive antenna.
- Low noise amplifier (typically 100°K).
- 4 0Hz TV receiver — demodulator.
- 10W 50W or 100 watt TV transmitter.
- Telephone based alarm system.
- 30m to 60m masts for transmitting antennas.
- Transportable equipment shelter.

The earth station antenna provides a signal at the low level of about -90 dBm to a low noise amplifier which boosts this level to an amount which can be processed by the 4 GHz TV receiver/demodulator. The antenna and low noise amplifier add very little noise to the signal, presenting a receive system noise temperature of 120°K (1.5 dB noise figure). The figure of merit (ratio of gain of the antenna receive system to noise temp.) for the combination of a 6.5m antenna and 100°K amplifier is 26 dB/°K. The antenna consists of a one-piece centre of 4.0m diameter surrounded by 18 (6.5m) or 24 (7.5m) petals to achieve the required size. The petals are fitted and aligned on site and the large centre transported to site by the contractor supplier using a special transporter. There is no tracking system used on these antennas even though their beamwidth is only about 0.5° between -1dB points.

The low noise amplifier is a fine example of advanced technology at an affordable price. The unit provided a gain of 50dB over the 500 MHz range of 3.7 to 4.2 GHz. It adds only 100°K noise temperature to the incoming signal using four stages of Gallium Arsenide, field effect transistors (GASFET) operated at ambient temperature. The unit is fitted in a relatively benign location at the base of the antenna and is hermetically sealed (at the factory) with dry nitrogen to reduce internal deterioration.

The amplified noisy signal is applied at a useful level to a microwave receiver for the demodulation of vision and sound signals. This whole system (antenna, LNA TV Rx-Demod) is commonly referred to as TV Receive Only Terminal (TVRO). Its design specifically suits the operating conditions that are optimum for the Intelsat IV satellite that is in use. The television receive only (TVRO) terminal used on this system (see **Fig. 8**) represents a price/performance breakthrough with unique features including a stable local oscillator switchable over the 3.7 to 4.2 GHz band in 0.25 MHz steps, a phase locked loop demodulator, and a very sharp band limiting, phase equalised intermediate frequency (IF) filter. The performance of the TVRO's is up to normal broadcast standards except for the signal to noise (S/N) ratio which is the system limiting factor. The video S/N ratio is generally adequate for local broadcast only and the signal can not normally be used as a "parent source" for another translator, for example.

Standard video and audio signals from the receive/demodulator are applied to conventional TV transmitters. To achieve the technical operating conditions specified by the Dept. of Communications, output powers of 10, 50 and 100 watts have been used over channels mostly in TV band III. The transmitters achieve the specified broadcast performance and the transmitted signal is limited only in the system noise. As with the earth station equipment, the TV transmitters are also endowed with some notable features not common in that class of equipment. Refer to **Fig. 9**.

Vestigial sideband transmission with minimum correction has been successfully achieved for what is believed to be the first time. The device used is a special filter using state of the art surface acoustic wave transmission. The other feature that is notable was somewhat less successful and involves the use of Radio Frequency (RF) amplifiers with Class AB biased stages. The manufacturer's endeavours to achieve the required linearity with such stages produced problems that resulted in some power amplifier failures.

The dispersal throughout the state of complex and sophisticated equipment such as the RATV system is most unusual. Monitoring and servicing such equipment is a daunting task but is made manageable by the use of a comprehensive alarm system. A television translator alarm system (TETRA) was adapted for use at RATV stations and is a permitted attachment to the telephone network, reporting changes of state automatically to a designated telephone service. The status of the station (16 alarms) may be interrogated by telephones from any point in the switched network.

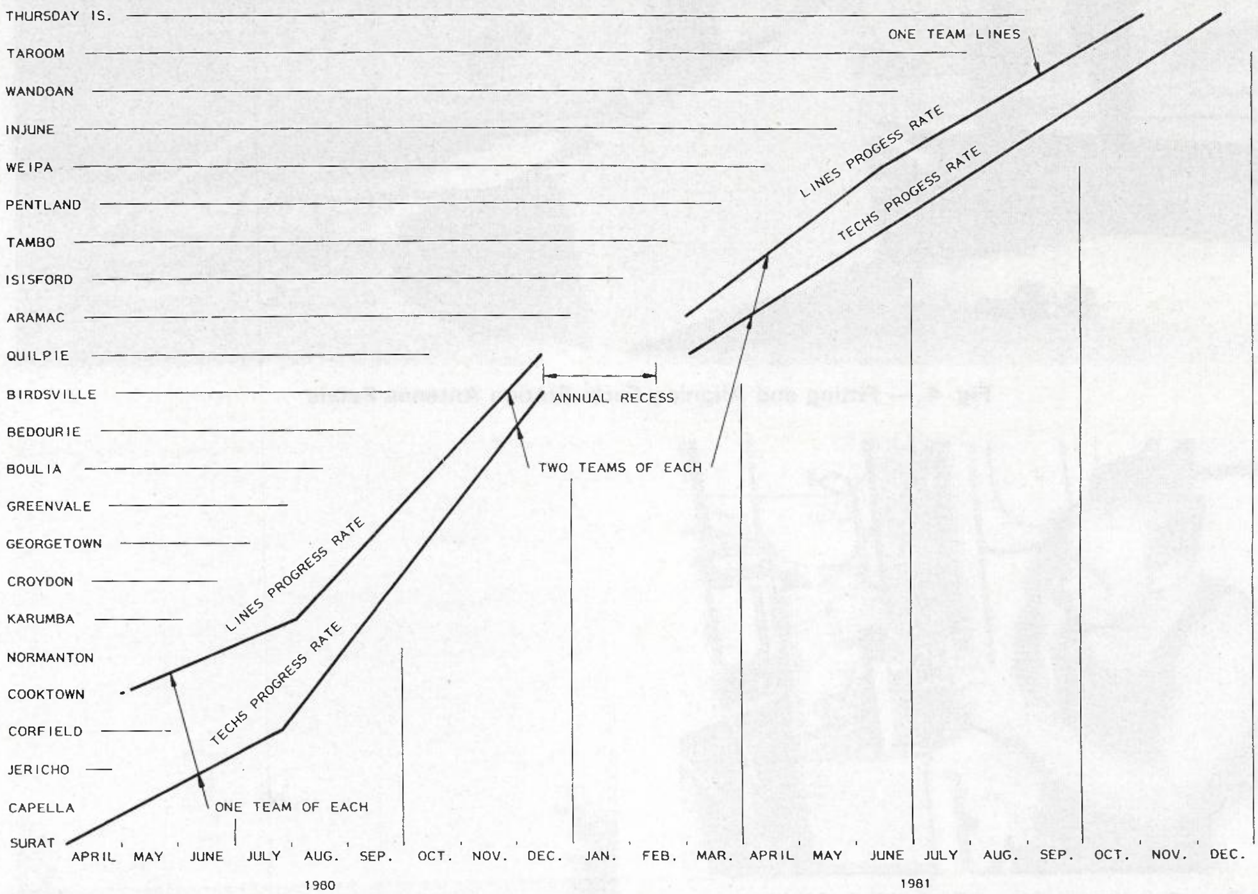


Fig. 2 — Progress Graph — RATV May '80 to Dec. '81.

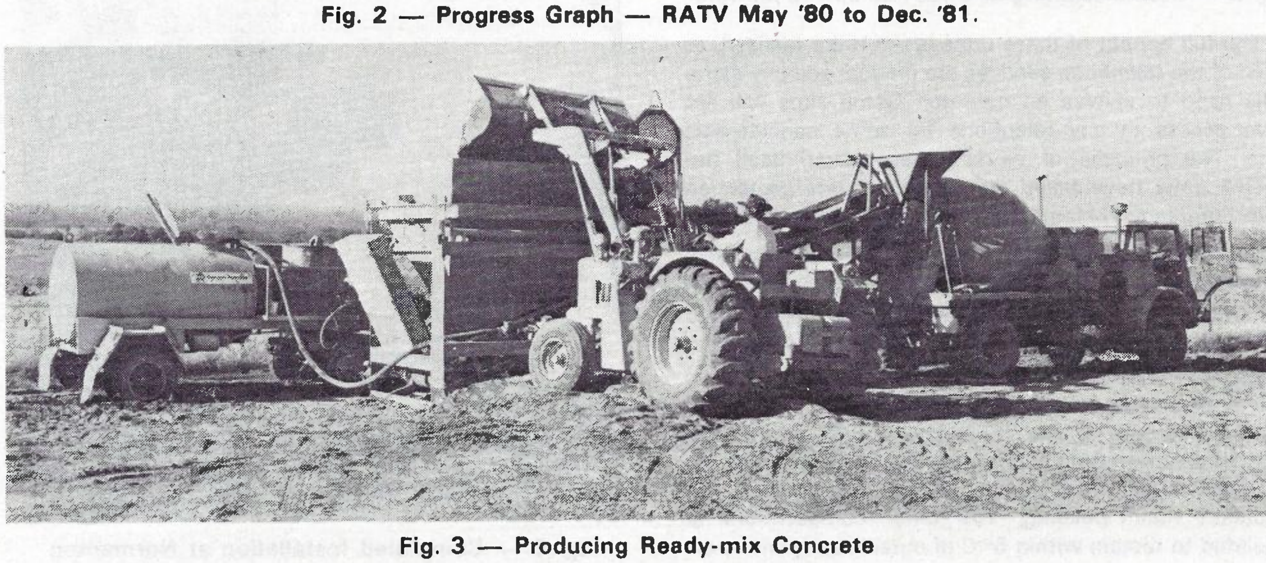


Fig. 3 — Producing Ready-mix Concrete

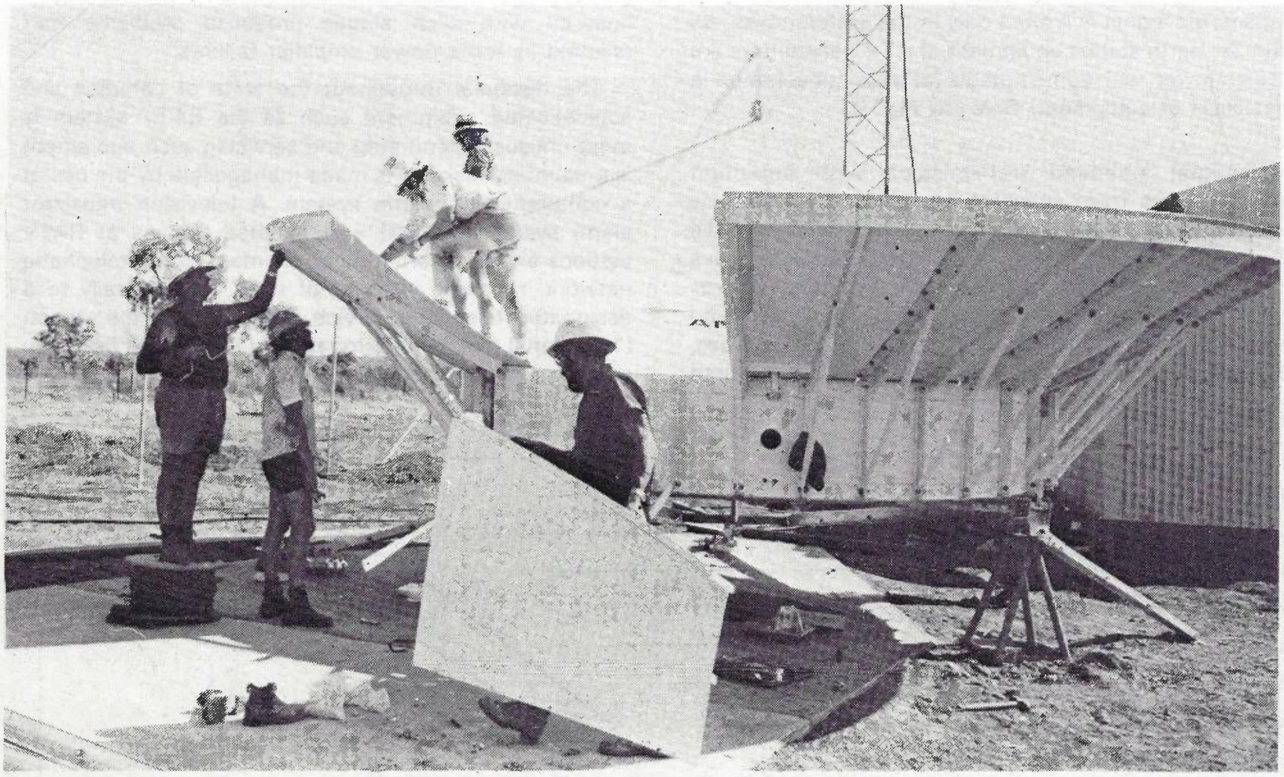


Fig. 4 — Fitting and Aligning Earth Station Antenna Petals

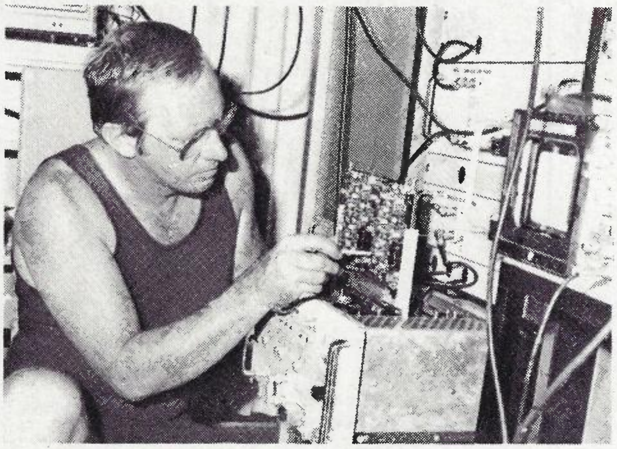


Fig. 5 — Commissioning at Birdsville in Mid-summer

The full benefit of these units is yet to be realised, as most of the telephone services are manual and any alarm calls need to involve an operator. Some sites will not have access to any telephone for some considerable time. The principle of working has proved itself but TETRA units have failed due to inadequate protection from lightning problems induced over telephone lines.

The requirements for antenna support structures have been relatively modest at heights from 30m to 60m with not more than four, corner reflector type, transmitting antennas. Guyed triangular masts with a side dimension of 610mm were used in most cases.

Use of a transportable equipment shelter with good thermal features is the remaining significant novelty introduced for the satellite project. The shelter houses the equipment within an inner shell enclosed within the insulated main building. The inner compartment is insulated to remain within 5° C of outside ambient by air

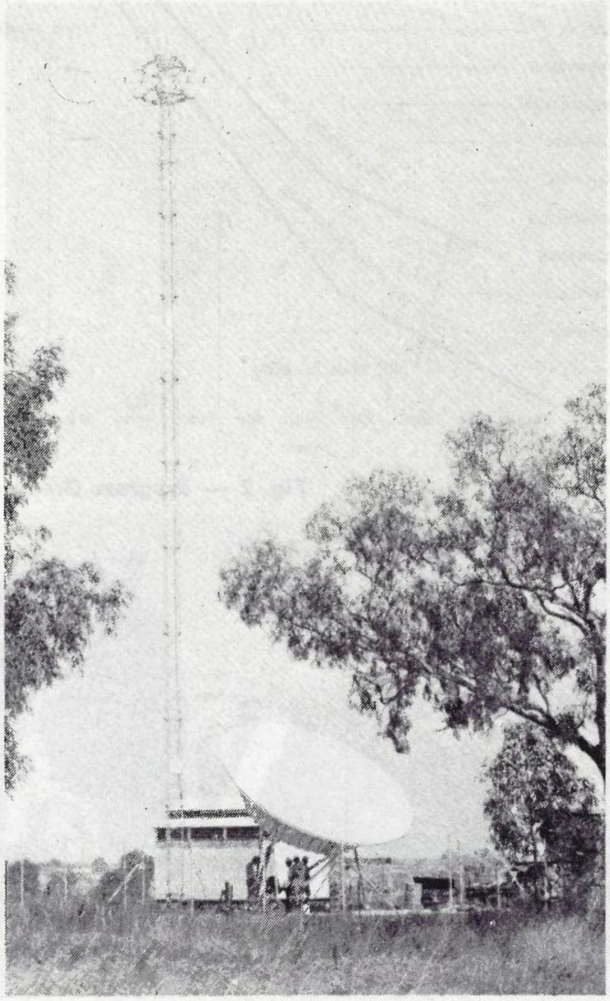


Fig. 6 — Completed Installation at Normanton

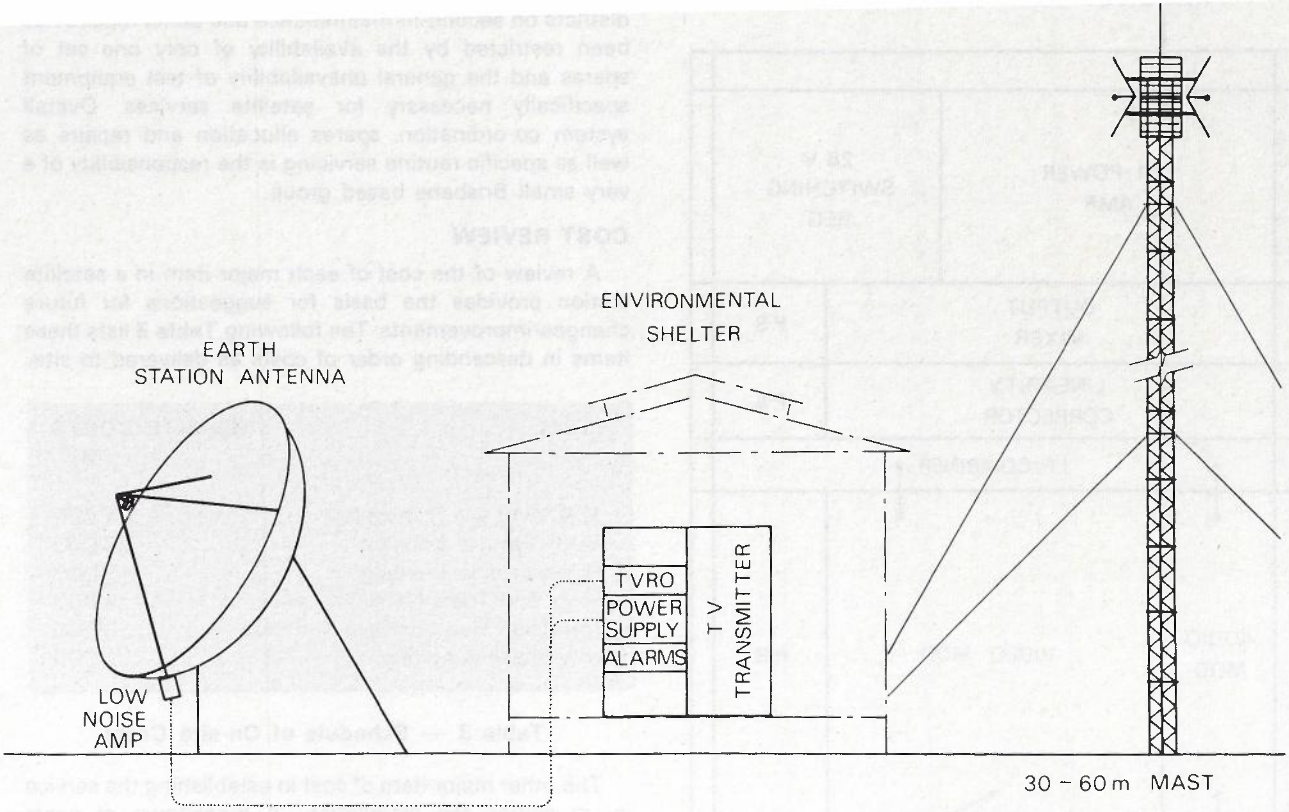


Fig. 7 — Typical RATV station Connecting Diagram

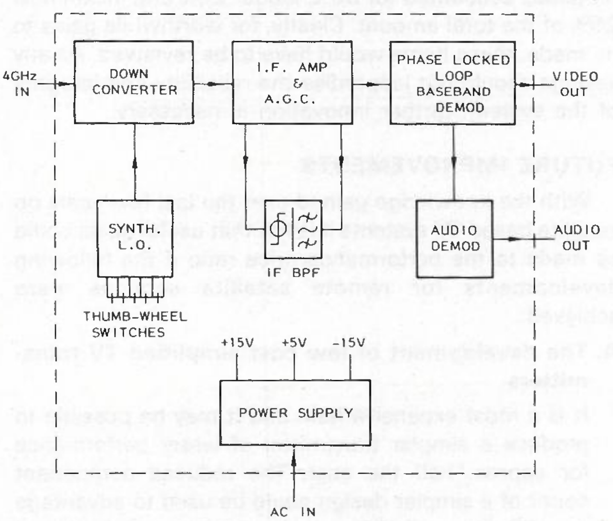


Fig. 8 — 4 GHz TV Receiver

which circulates in the large cavity between the walls. Although quite expensive for the usable floor area, the shelters function quite well even without room air-conditioners.

OPERATIONAL EFFECTIVENESS

In spite of the difficulties mentioned, the system has operated as designed and good reliability has been achieved even over the initial twelve months period. With a basis of comparisons comprising domestic video cassette recorders and very long distance (hundreds of kilometres) reception of main station services, assessment of the quality of the satellite TV service by viewers has been most favourable. The only comment on picture quality to be drawn from viewers of satellite TV has been on an unusual form of noise which occurs, and can be subjectively annoying on picture content, with fast rise-times or with high chrominance saturation. This type of noise has been termed "truncation noise" and produces a congregation of scintillations (black and white flecks) on fast transitions and random occurances on picture content with high color saturation. To achieve a subjectively satisfactory picture/sound quality on normal programme i.e. adequate S/N, an over deviated system is used to compensate for the fairly low carrier/noise receive ratios. Some frequency components are then rejected by the receive filter which results in signal distortion upon demodulation. The level of annoyance depends partly on the Carrier/Noise (C/N) ratio of the receive system and can result in less-legible programme credits and ABC time clock.

Another unexpected system difficulty which plagued some marginal services during the initial stages related to satellite position stability and pointing accuracy. Variations to these caused the received signal to go beyond the threshold range of the receiver and the narrow beam non-tracking earth station antennas at the edges of the satellite spot beam had to be re-pointed on one occasion. Eventually the satellite was maintained to within 0.1° of its nominal position and the recent introduction of a newer Intelsat IV satellite has also reduced all variations to insignificant amounts.

Fig. 10 shows a rare occasion of sun transit across the prime focus of an earth station antenna. During these minutes the satellite signal is swamped by radio signals from the sun.

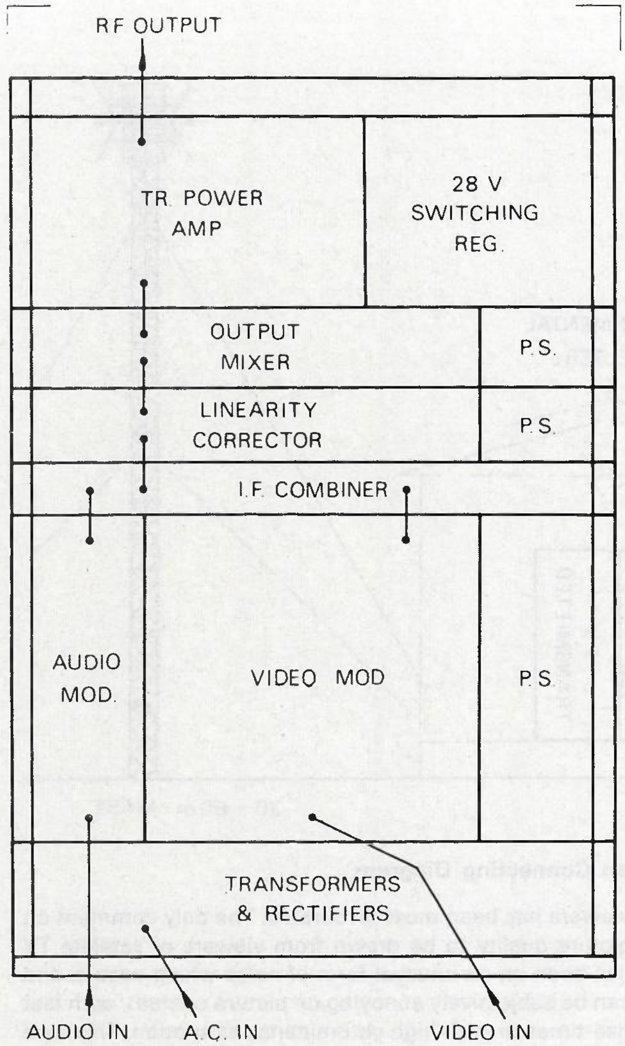


Fig. 9 — 100 watt Television Transmitter

MAINTENANCE

The maintenance of major new systems usually creates some conflict with established servicing practice and change is less readily accepted in those areas. Modern electronic equipment is so packaged and so reliable that personnel not skilled with the specific equipment can identify faulty panels and refit replacement units with a modicum of common sense and assistance from a control centre.

To achieve the best operational efficiency while retaining a high integrity of service requires a flexible approach which balances the requirements of the system with the available resources.

The number of control centres to supervise servicing of sparsely located stations is best determined on the basis of achieving the maximum number of stations per control centre. The location of the centre should match a node of the national transport routes. Such an arrangement minimises the cost areas of spare parts, test and servicing equipment, salary for highly trained personnel, and transport charges. Only one set of spare parts and equipment per State was supplied, with the future tendency being for further reduction.

The maintenance arrangements that have been set up use first-in maintenance by the local district telephone technician in the usual manner. The role of the Radio districts on second-in maintenance and panel repairs has been restricted by the availability of only one set of spares and the general unavailability of test equipment specifically necessary for satellite services. Overall system co-ordination, spares allocation and repairs as well as specific routine servicing is the responsibility of a very small Brisbane based group.

COST REVIEW

A review of the cost of each major item in a satellite station provides the basis for suggestions for future changes/improvements. The following **Table 3** lists these items in descending order of costs as delivered to site.

ITEM	ON-SITE COSTS $
100 Watt TV Transmitter	21 000
Earth Station Antenna	20 000
Transportable Building	17 000
Mast and Transmit Antennas	8 000
Television Receive Only Terminal	3 000
Low Noise Amplifier	1 500

Table 3 — Schedule of On-site Costs

The other major item of cost in establishing the service is, of course the installation. A breakdown of costs averaged over twenty installations indicates that materials accounted for 55%, labour 20% and incidentals 25% of the total amount. Clearly, for worthwhile gains to be made, these items would have to be reviewed. As any savings should not jeopardise the reliability and integrity of the system, further innovation is necessary.

FUTURE IMPROVEMENTS

With the knowledge gained over the last few years on satellite based TV systems it is felt that useful gains could be made to the performance/price ratio if the following developments for remote satellite services were achieved:

A. The development of low cost simplified TV transmitters

It is a most expensive item and it may be possible to produce a simpler transmitter of lesser performance for approx. half the cost. The reduced component count of a simpler design could be used to advantage to enhance reliability and reduce complexity of adjustments.

B. The development of lower cost mesh type satellite receive antennas

The earth station antenna is again up to full professional standards and has a solid surface. There would seem to be no reason why a mesh type could not be used at a size so as not to reduce available gain. An antenna of such a type could much more easily be transported in a knock-down form and would require much smaller foundations. A reduction to half the present cost could reasonably be expected.

C. The use of adapted commercial designs of buildings

Using an equipment building based on a number of

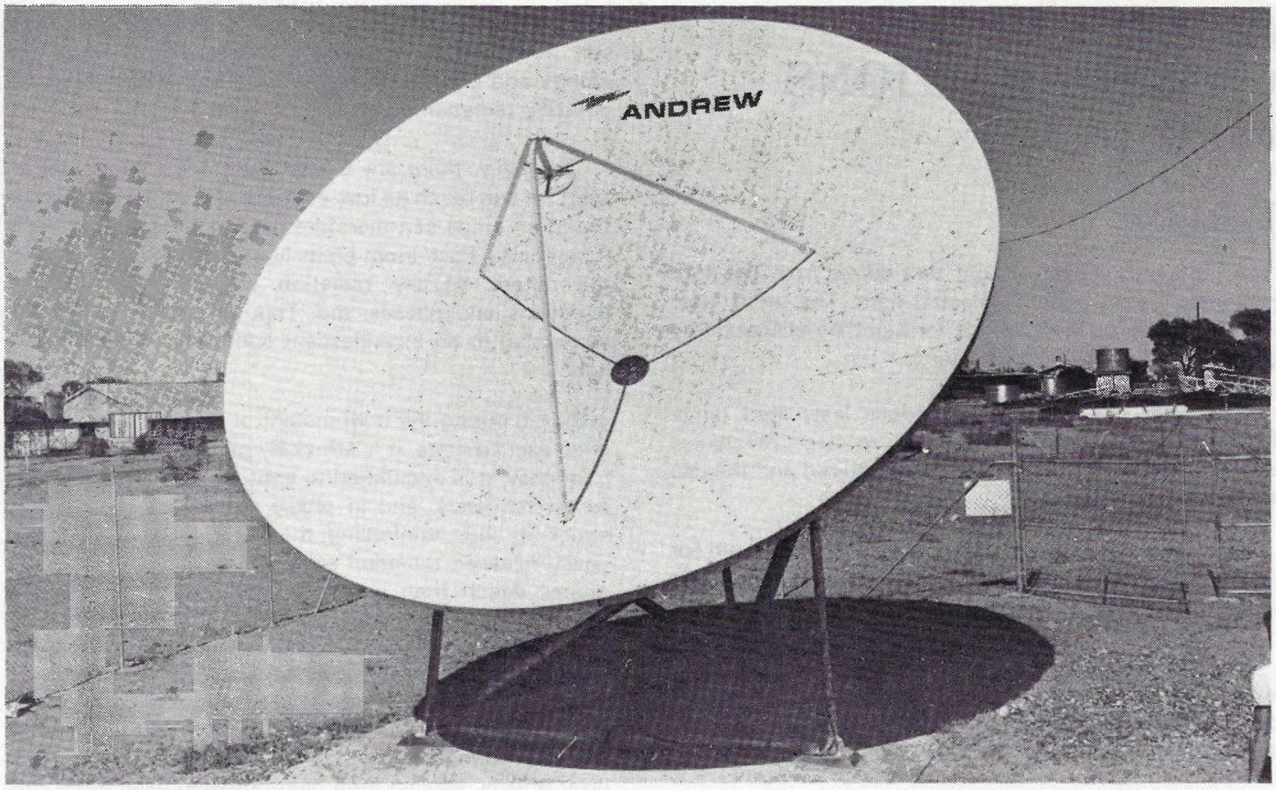


Fig. 10 — Sun Transit Across Antenna Prime Focus

commercial types sold in a knock-down form but adapted to include similar thermal qualities to the shelter currently in use would be expected to reduce total installed costs by approx. one third.

D. The incorporation of technological improvements
Other minor cost reductions due to improvements of other components of the system in the normal course of development.

If these measures are implemented it would be possible to bring satellite services to more communities in Queensland, at significantly reduced cost.

CONCLUSION

Developments in TV Broadcasting continue to occur with increasing rapidity. Equipment suppliers and users are not daunted by innovation. To extend services to more and more viewers the performance/price ratio will continue to be improved.

The achievements in the development of TV broadcasting throughout the world in a little over 10 years are quite startling; they have included the introduction of transistorisation, IF modulation; common amplification of sound and vision signals, transistorised amplification to hundreds of watts over 30% bandwidths; vestigial TV sideband filtering using virtually distortion-free surface acoustic wave filters. The introduction of Remote Area Satellite TV services to outback areas of Australia is another significant achievement in the development of TV broadcasting.

OPTICAL COMMUNICATIONS Pt. II

Lasers

A laser is a source of light that differs from the light produced by an ordinary electric light. The word laser itself is an acronym. It stands for Light Amplification by Stimulated Emission of Radiation.

The kinds of devices that produce laser light range from small semiconductor devices to large machines, depending on the kind of laser light required and the use to which it will be put.

Light emitted from an ordinary electric light bulb (or from any other source of white light) is chaotic and disordered. Another word for this is incoherent.

If there were some way to organise the light emitted so that it was all at the same frequency, all going in the same direction, and all in phase, then we would have an extraordinarily powerful beam of light.

That, quite simply, is what a laser does.

All of the light in a laser beam is of the same frequency, or of the same colour (monochromatic 'one colour').

All of the light is also going in almost exactly the same direction, and the beam spreads out very little. In fact, so directional is the beam that scientists have shone a laser beam at the Moon, nearly 400,000 kilometres away, and the patch illuminated by the beam on the Moon was only a few kilometres wide. So concentrated and so intense was the original beam that light reflected back from mirrors placed on the Moon by the Apollo astronauts was strong enough to be picked up again on Earth by powerful telescopes. Using this reflected beam, scientists are able to continually measure the distance from the Earth to the Moon to within centimetres.

The light in a laser beam is also in phase, that is, all of the crests of the lightwaves are in step with each other, and so reinforce the power of the beam. When suitably focused, laser beams can burn holes in solid steel.

Whereas an incandescent light bulb produces incoherent light, therefore, a laser produces a beam of coherent light.

All materials are made up of atoms, which are for practical purposes indestructible. Atoms in turn consist of a dense centre called the nucleus, surrounded by varying numbers of electrons, even smaller particles, which can be thought of as moving around the nucleus in an orbit the way a satellite moves around the Earth.

When a material is heated up or otherwise has energy pumped into it, the atoms of which it is made up become excited: the electrons of the atom exist in a high-energy state different from their normal low-energy state. You can think of this as being a higher 'orbit'. They lose energy and drop back down into a low-energy state by emitting radiation.

Ordinarily, there are a large number of ways that an electron can reach its low-energy state, and the radiation the atom emits can therefore be of a variety of different frequencies. Each atom emits light independently of all of the others, so the radiation emitted is at random directions and phases, too. This, of course, is what is happening in an incandescent light bulb emitting white light.

But if, during the brief instant of time that an atom is in its excited state, it is struck by radiation of a particular frequency, it is stimulated to emit radiation that is of the same frequency, and in phase with the radiation that struck it, thus reinforcing the incoming radiation. The newly-released radiation can in turn strike more excited atoms, which then are stimulated in turn. There is a snowballing effect going on that results in most of the atoms in the material emitting light of the same frequency, in phase. The result is a laser beam.

Something has to start off the process, of course, and there are various methods of getting materials to produce laser effects, varying from high-powered flash tubes (not unlike camera flash units) surrounding the material, to other lasers of a different type. Usually, there is an arrangement of mirrors to reflect any non-coherent light back within the material.

Many different kinds of material can produce laser action. The first laser ever operated, by Theodore Maiman in May 1960, used a ruby cylinder with its ends polished flat and silvered to make mirrors. But since then, tubes filled with certain gases, liquids including dyes, and jets of burning gas have all been stimulated to produce laser beams.

The frequencies of the laser beams so produced can vary considerably. In fact, the first demonstration of the principles involved was at microwave frequencies — producing a so-called maser (from Microwave Amplification by Stimulated Emission of Radiation). But the frequencies at which laser action has been demonstrated have been pushed steadily upwards, through visible light to ultraviolet radiation and beyond. It appears that an X-ray laser has been operated by the United States military, but details are still secret.

Apart from the still very improbable military uses of lasers, there are a host of uses for laser light. They have been used to drill holes in gems, to do delicate surgery on the retina of the eye, to provide an extremely accurate straight line in building and industry, to cut wads of material for clothing, to measure the drift of continents, and to create three-dimensional pictures.

They also have a major potential in communications as a source of light to beam down optical fibres, carrying hundreds of telephone conversations in the form of flashes of laser light.

(Part III, in the next issue, will be about Fibre Optics).

The Kalgoorlie to Leonora Microwave Radio-Relay System

A. Haime

The expanding requirement for communication services resulting from the discovery and exploitation of mineral deposits has made it necessary for Telecom Australia to extend its broadband network into remote and hostile areas. This paper presents an overview of the planning, design and construction of Western Australia's first major solar powered microwave link between Kalgoorlie and Leonora. An examination is also made of fading caused by strong specular reflections from an unexpected source, namely flat scrub-covered terrain.

INTRODUCTION

Telegraph Offices were opened in the Western Australian mining towns of Menzies and Leonora in December 1895 and September 1897 respectively. By 1910 both towns boasted a telephone exchange and by 1920 were served by open wire lines on the railway route. These were the boom years when the Eastern Goldfields contained more than half the State's population (Ref. 1). Leonora's importance continued when other centres began to decline and in the immediate post World War II years warranted the installation of a single channel carrier system, a terminal of which is shown in **Fig. 1(a)**. In 1963 the Sons of Gwalia mine ceased operations, bringing to an end an era of goldmining at Leonora.

In 1971 an important nickel deposit was discovered at Leinster, north of Leonora and other important mineral discoveries were taking place, including uranium at Yeelirrie, copper at Teutonic Bore, and nickel at Laverton. The importance of Leonora as a regional communications centre began to re-emerge. Despite an upgrade of open wire circuits on the railway route from Kalgoorlie, sufficient channels were not available to meet the growing traffic demand. There was also the requirement to extend TV programme from the Kalgoorlie "gateway" to Menzies, Leonora, and possibly beyond.

As a result the microwave system was planned. Due to the hostile nature of this sparsely populated route and other constraints, the design of the system offered a number of challenges all of which were overcome. Although based to a large extent on the Alice Springs to Tennant Creek microwave system (Ref. 2) the Kalgoorlie to Leonora system is significantly different. In addition installation and commissioning of the system was carried out entirely by Telecom W.A. staff.

This paper presents a brief summary of the system, discusses a number of the design constraints, and gives an outline of the system engineering details. The approach used to construct the internal and external plant is described. Mention is made of fading which occurred during commissioning, indicating a path reflection problem, and the action that was necessary to overcome this problem.

GENERAL DESCRIPTION OF THE SYSTEM

The planning requirements were for a 960 channel telephony system with one working or main bearer and one standby protection bearer in each direction between Kalgoorlie and Leonora, with possible future extensions to the mining towns of Leinster and Yeelirrie — **See Fig 2**. Provision was made for non-priority TV (NPTV) transmission on the protection bearer in the south to north direction. This extends National Broadcasting Service (NBS) coverage from the existing Kalgoorlie gateway to Menzies and Leonora. Additional 960 channel telephony bearers can be provided at a later date if required.

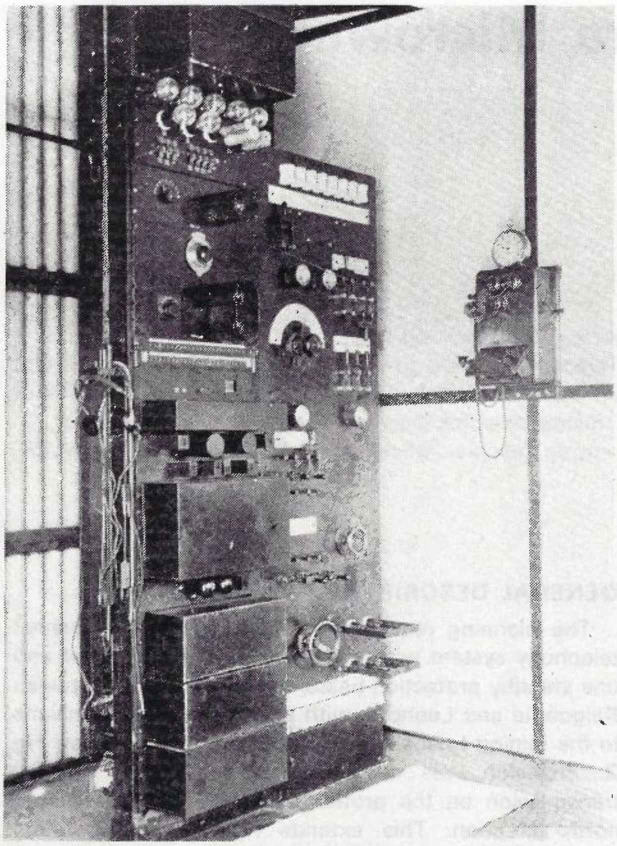
Due to the remoteness of repeater sites, power supply options were reduced to diesel-generators or photovoltaic solar arrays. It was determined that low power consumption 4GHz microwave equipment, identical to that used for the Alice Springs-Tennant Creek system, with solar powered repeaters, would be the most economical solution.

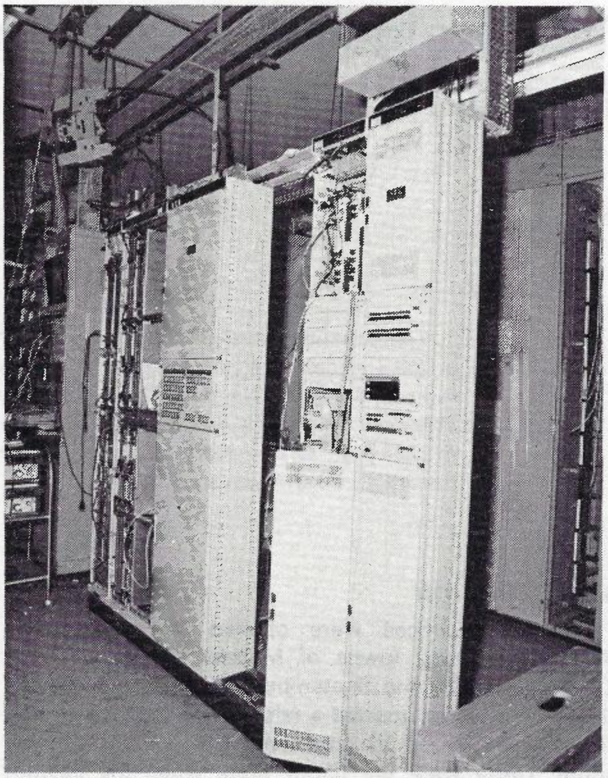
The 4GHz band was chosen for the following reasons:

a. It is the preferred band for 960 channel systems;
b. At the time, the 4GHz equipment power consumption was the lowest available to Telecom;
c. Possible mutual interference with the existing East-West 2GHz and proposed 6.7GHz radio relay systems would be avoided.

The southern terminal was located at the already established Kalgoorlie microwave site, a main repeater on the East-West system. Here an existing 45m tower was utilised **(Fig. 3)**. At Leonora a new terminal site was established approximately 3.3 km east of the townsite, in order to satisfy mast clearance requirements adjacent to the Leonora airport. A cable tail was provided to connect with the transmission line equipment building in the town. AC power was available at the site.

A 300 channel drop/insert facility from the main telephony bearer, and a TV drop from the protection bearer were provided at Menzies. The microwave repeater and tower were co-sited with the existing open wire repeater TLE building within the town. At Menzies and Leonora, NBS TV transmitters and antennas have been installed in the microwave equipment shelters and





(b) 960 Channel Microwave Terminal, Kalgoorlie.

Fig. 1 — The Old and New Terminal Equipment.
(a) Single Channel Carrier Terminal, Leonora.

on the microwave antenna support structures, respectively.

At the three intermediate solar powered repeaters underground equipment shelters were used to provide a suitable operating environment. Seatainers, containing the batteries and control equipment and with the solar panels mounted on roof frames, were placed over the top of the underground shelters. This avoided separate A-frame structures to shade the underground shelter as was used on the Alice Springs to Tennant Creek system. **Fig. 4** shows a solar power seatainer over the underground shelter. This configuration also provides additional security, as entry to the underground shelter can only be obtained via the seatainer which can be securely locked.

Another feature which makes the Kalgoorlie to Leonora system significantly different from the Alice Springs to Tennant Creek system was the provision of wayside customer facilities at the remote repeaters. The 0-252kHz range of the main bearer frequency spectrum referred to as the "sub-baseband" is available at every repeater. This will enable up to a total of 60 voice channels to be provided from the repeaters to the terminals as well as three service channels in the range 0-12kHz. Voice channel multiplex equipment has been provided for 12 channels in the band 12-60kHz. Direct-to-line (DTL) channel multiplex equipment will be used for future exploitation of the 60-252kHz band. Wayside services can be provided from the microwave repeaters to homestead, mining operations, public telephones, etc via cable or small capacity radio-telephone links, as shown in **Fig. 5**. The utilisation of the sub-baseband spectrum is shown in **Fig. 6**.

The wayside facilities reduce the spectrum available on the main bearer for terminal to terminal traffic to 312-4028kHz ie. supergroups 2 to 16 (900 channels). The

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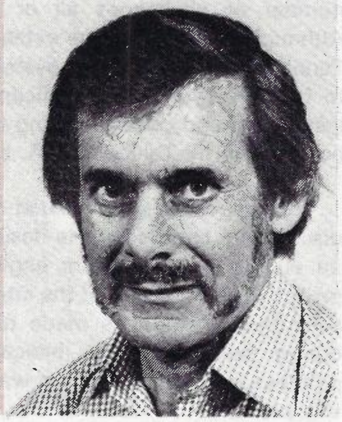
Mr Haime has had wide experience in the design and operation of radio-communication facilities in Western Australia. He was responsible for the design of the Kalgoorlie to Leonora microwave system. He is a Member of the Institution of Engineers (Aust.) and is currently the Supervising Engineer, Radio Section, Perth.



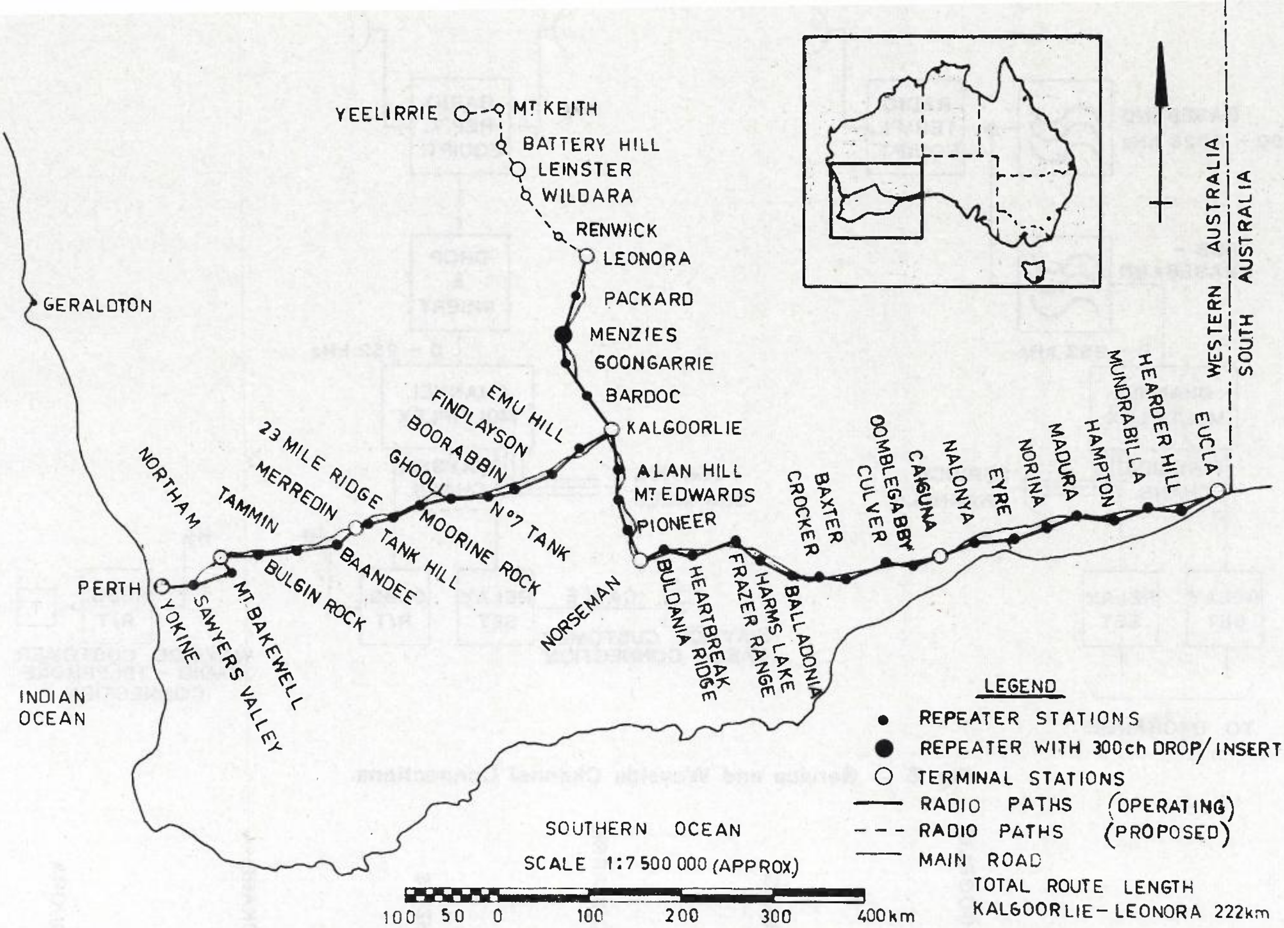


Fig. 2 — Route Map of Kalgoorlie to Leonora Microwave Radio Relay System.

Fig. 3 — Kalgoorlie Microwave Terminal. Leonora System Antenna is in Top Left Position.

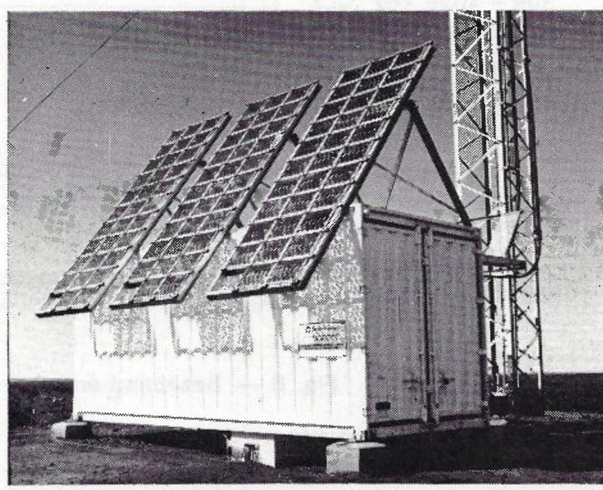


Fig. 4 — Bardoc Solar Power Seatainers. Portion of the Underground Shelter can be seen below the Seatainer.

252-300kHz portion of the spectrum is unusable due to the sub-baseband filter response.

Very low cost 4-wheel drive access tracks were provided to the remote repeater sites. A great deal of emphasis was placed on the provision of an extremely reliable system requiring only bi-annual routine maintenance visits and hence more extensive access roads were not justified. Local staff are equipped with

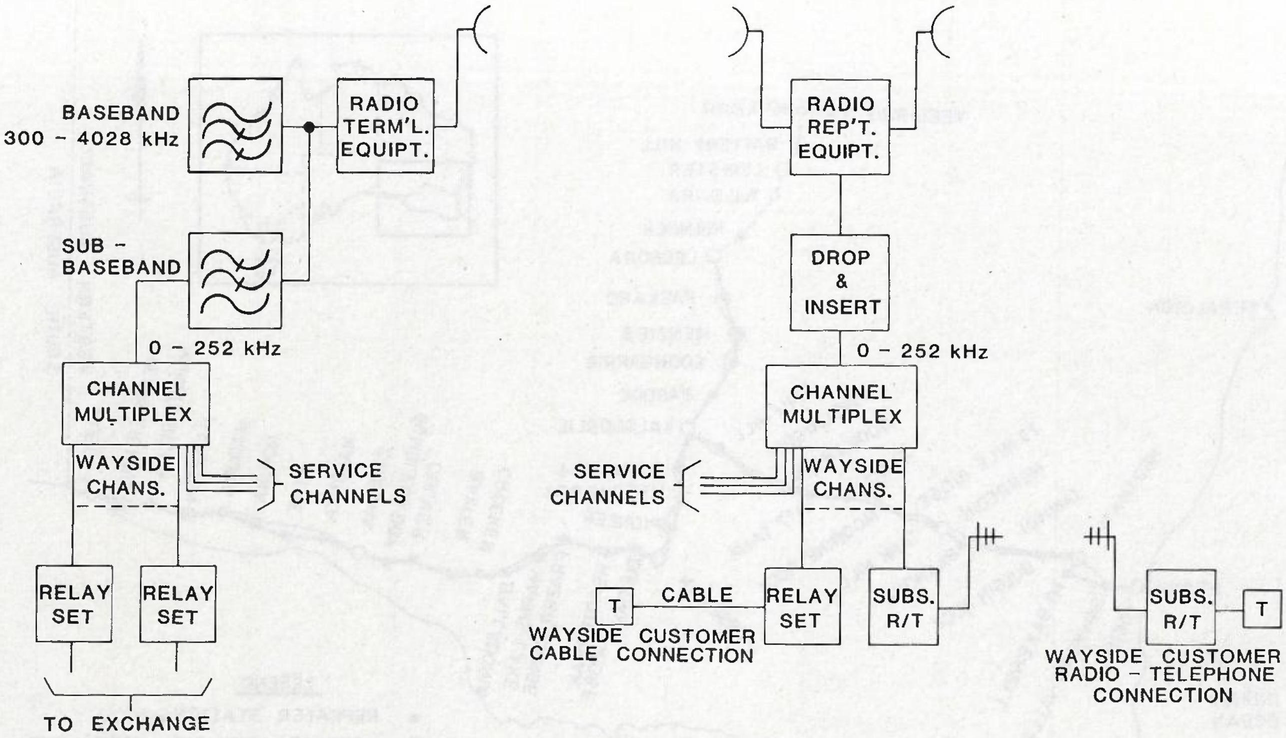


Fig. 5 — Service and Wayside Channel Connections.

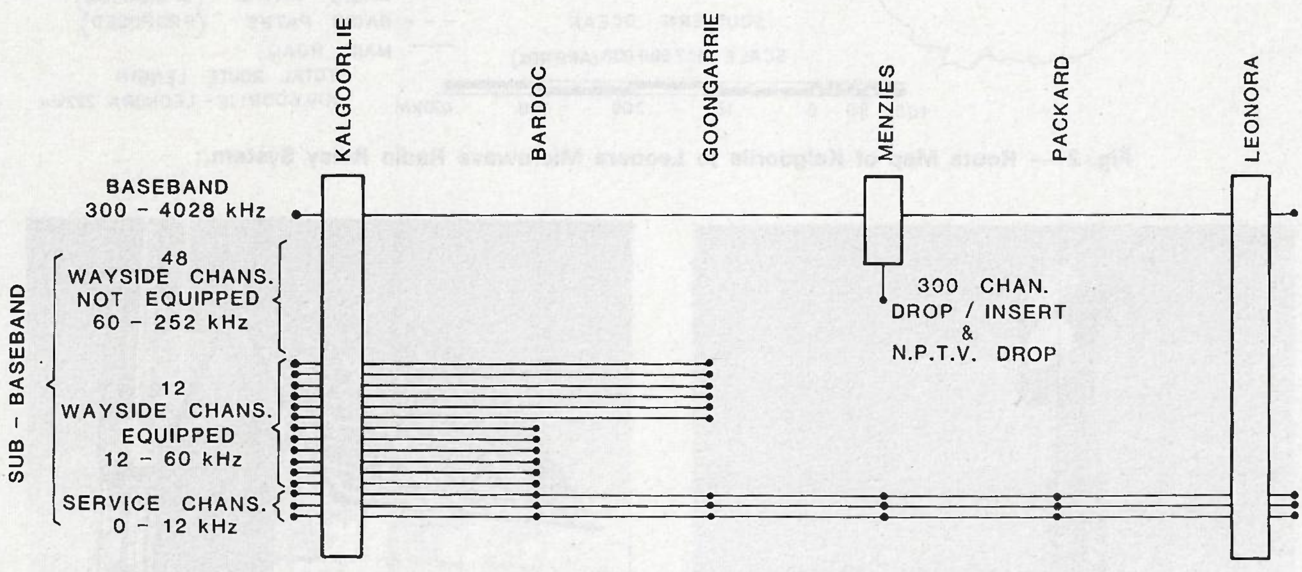


Fig. 6 — Baseband and Sub-baseband Spectrum Utilisation.

suitable 4-wheel drive vehicles which are a necessity for normal operations in the area.

ROUTE SELECTION AND DESIGN ASPECTS

The route selection was constrained by the requirement to avoid possible RF signal overshoot problems. Under conditions where atmospheric refractivity causes excessive downward bending of the RF signal path, referred to as a super-refractive atmosphere, or where ducting conditions exist, strong RF signals can be propagated over very long distances. Since, in order to preserve the RF spectrum, bearer frequencies are re-used on alternative hops as shown in **Fig. 7**, RF signals can overshoot two, four, six etc. intermediate repeaters and lead to excessive system noise. These are referred to as first, second, third, etc. order overshoots; generally only up to third order overshoots need be considered.

It is clear from Fig. 2 that the Kalgoorlie to Leonora route is essentially directly in line with four hops of the East-West microwave system. Although 4GHz is not presently used on the East-West route, its future use could not be entirely ruled out. Consideration therefore had to be given to potential overshoots within the Kalgoorlie to Leonora system, to the East-West system and also to the Leonora to Leinster and Yeelirrie extension. Sites had to be staggered to provide sufficient angular separation between all overshoot and wanted signal paths, to ensure the narrow beamwidth parabolic antennas would reject the unwanted overshoot signals. In particular, the Goongarrie site had to be located some

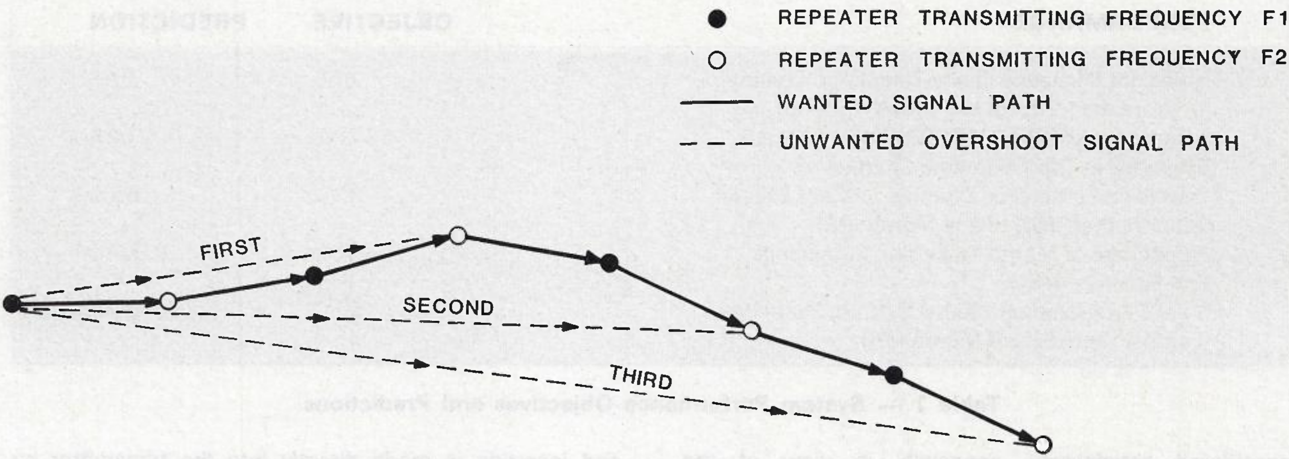


Fig. 7 — Overshoot Signal Paths in One Direction of Transmission.

15km west of the sealed main road, an apparently illogical choice in most other respects because of the access problem. A high performance antenna, with high angular discrimination against overshoot signal interference was also required at Bardoc.

The route selection was made very difficult by the overshoot constraints. A number of possible alternative routes well away from the main road were investigated and many abandoned gold mining towns which once had thriving populations were discovered; places with exotic names like Ora Banda or seemingly out of place Siberia. One wonders at the history of such places.

Fortunately contoured maps of the whole region were available which certainly made the design engineering and route surveying work a lot easier. Contrary to what might be imagined, parts of the route are quite heavily vegetated. The W.A. Drafting Section survey team appreciated the Design Engineer being able to nominate the critical path obstructions from the map beforehand, as this minimised the amount of survey work and "scrub bashing".

Airport clearance requirements placed further restrictions on site locations. The Leonora Aiport, a licensed strip operated by The Department of Aviation is quite close to the townsite which placed unacceptable height limitations on a tower at the Leonora TLE site. A new radio terminal site therefore had to be located sufficiently far out of town to comply with Transport Australia regulations. The situation is depicted in **Fig. 8.** which shows the region of air space to the side of the runways which had to remain unobstructed. At Menzies a similar situation existed but fortunately only a 44m tower was required at the TLE site. The owner of the airport (which is accorded the lower status of Approved Landing Strip), the Menzies Shire, had no objections to the structure.

The route traverses terrain which is dotted with many salt lakes which although mostly dry could cause severe ground reflections and hence two ray interference fading to occur. During the design, careful attention was given to potential path reflection areas to ensure that significant fading due to reflections would be avoided. Unfortunately, following commissioning reflections were found to occur on one path from a totally unexpected source — flat terrain covered with 2-3m high scrub. From previous experience with microwave paths, it was thought that the scrub would scatter the incident signal and reduce coherent reflections to an insignificant level, but this was not the case. Substantial corrective action was necessary before the system could be placed in service, as discussed later.

The system was designed to meet CCIR transmission objectives, which are shown in **Table 1** together with predicted design data. It can be seen that the objectives are easily met, except the short term telephony noise which is exceeded by a factor of two. This was

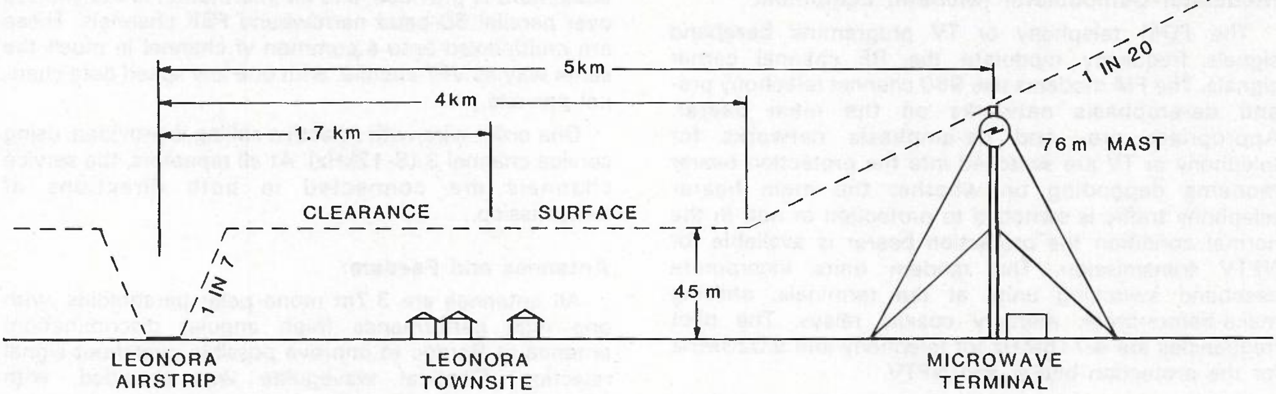


Fig. 8 — Airport Clearance Requirements, Leonora.

PERFORMANCE	OBJECTIVE	PREDICTION
Noise not Exceeded in any Telephone Channel for more than 20% of any Month (pWOp)	866	357
Percentage of Month 47500 pWOp of Noise Exceeded in Top Telephone Channel	0.012	0.023
Television Luminance Channel S/N not Exceed for more than 20% of any Month (dB)	62.0	65.4
Percentage of Month Television Luminance S/N Exceeds 44dB	0.0089	0.0046
Sound Programme Channel S/N not Exceeded for more than 20% of Month (dB)	55.0	65.5

Table 1 — System Performance Objectives and Predictions.

considered satisfactory, especially in view of the conservative prediction method used.

The system availability is expected to be ultra-high. Very reliable equipment has been used in a 1+1 protected bearer configuration and the power plant has been designed with considerable reserve battery capacity. Outages due to equipment or power supply failures will have a very low probability of occurrence. An alarm surveillance system with displays monitored on a 24-hour basis will ensure that fault conditions are promptly detected. Critical spares are held at Kalgoorlie and repair times, in the event of a failure, will be short. With the corrective action taken to overcome the effects of reflective fading, interruptions due to RF propagation are also expected to be negligible.

SYSTEM ENGINEERING

A summary of the salient system specifications is shown in **Table 2**. The major items of equipment are discussed under the following headings:

Radio Equipment:

The fully solid state equipment has a nominal transmitter output power of 1W and a transmission capacity to 1260 channels (although the system has been designed for a 960 channel requirement). By adding 4GHz RF power amplifiers, 1800 channel operation could be achieved. The receivers are equipped with FET RF pre-amplifiers which reduce the noise figure to typically 4.5dB. Particularly important is the relatively low power consumption of approximately 22W per transceiver. Differential absolute delay equalisation of the main and protection bearers was carried out at IF interconnection points. RF channels 2, 6, 2′ and 6′ are used for the main and protection bearers.

Modulator-Demodulator (Modem) Equipment

The FDM telephony or TV programme baseband signals frequency modulate the RF channel carrier signals. The FM modems use 960 channel telephony pre- and de-emphasis networks on the main bearer. Appropriate pre- and de-emphasis networks for telephony or TV are switched into the protection bearer modems depending on whether the main bearer telephony traffic is switched to protection or not. In the normal condition the protection bearer is available for NPTV transmission. The modem units incorporate baseband switching units at the terminals, utilising make-before-break mercury coaxial relays. The pilot frequencies are 4.715MHz for telephony and 9.023MHz for the protection bearer and NPTV.

Service and wayside channels are dropped at repeaters via low-powered non-duplicated demodulators, and insertion is made directly into the transmitter by modulating the RF carrier. At remote repeaters the drop and insert equipment can handle three service and up to 60 wayside channels for local traffic. Direct to line (DTL) multiplexing equipment will be used for future wayside channels. At Menzies a 300 channel drop/insert facility is provided with duplicated demodulators. At all repeaters switching units protect all drop and insert points when the main bearer fails and/or is switched to protection.

Switchover Control Equipment:

Bearer switchover is controlled by pilot and noise detectors incorporated in the switching units, and activated by an FSK tone transmitted over the 0-4kHz service channel band. Switchover of the drop and insert points at the repeaters is controlled by detecting the end-to-end FSK control tones generated by the switching control units at the terminals.

Service Channel and Supervisory Equipment:

Telesignalling transmitters with 32 alarm monitoring points are provided at all stations. Encoder local displays are provided at repeaters only. The alarm indications are extended to the Route Control Centre at Mt Yokine (Perth) where a 32 point decoder and display panel is provided for each station. The terminal stations at Kalgoorlie and Leonora are equipped to display the alarm indications of any two stations on an interrogatory basis, as well as a summary of the alarm status at all stations.

Remote control decoders are provided at Kalgoorlie, Leonora and Menzies with provision for the addition of decoders at the other repeaters if required. Up to sixteen ON or OFF control functions can be effected from Kalgoorlie or Mt Yokine. Service channel 2 (4-8kHz) is used to transmit the telesignalling and telecontrol information over the system. Low power consumption equipment is provided, and all information is transmitted over parallel 50 baud narrowband FSK channels. These are multiplexed onto a common vf channel in much the same way as VFT circuits, with one low speed data channel per site.

One order wire with selective calling is provided, using service channel 3 (3-12kHz). At all repeaters, the service channels are connected in both directions of transmission.

Antennas and Feeders:

All antennas are 3.7m mono-polar paraboloids, with one high performance (high angular discrimination) antenna at Bardoc to improve possible overshoot signal rejection. Elliptical waveguide was provided, with pressurisation from a low'power consumption compressor/desiccator unit.

PARAMATER	SPECIFICATION
RADIO EQUIPMENT	
Frequency Band	3770-4200MHz
TX Power Output	+30dBm (1W)
TX Deviation per Channel	200kHz
RX Noise Figure	4.5dB (typ.)
RX IF Bandwidth	38MHz
RX Threshold	-80dBm
Power Consumption per TX/RX	22W (approx.)
Operating Voltage Range	-20V to -28V
Operating Temperature Range	0°C to 45°C
ANTENNAS	
Type	3.7m Monopolar Paraboloidal
Gain	41dBi
-3dB Beamwidth	+-0.8°
-20dB Beamwidth	+-2.0°
WAVEGUIDES	
Type	Elliptical, Corrugated
Loss	2.62dB per 100m
Pressurisation	24VDC Compressor/Desiccator
ANTENNA SUPPORT STRUCTURES	
Maximum Wind Velocity	40m per second
Maximum Tilt and Torsional Deflection	+-.35° with 27m per second winds
SOLAR POWER PLANT	
Solar Module Peak Output	0.7A
Quantity of Solar Modules	
Bardoc, Goongarrie	96
Packard	78*
Battery Capacity	
Bardoc, Goongarrie	2000 AH
Packard	1500 AH

* To be increased to 96 modules when additional diversity equipment is provided.

Table 2 — Equipment Specifications.

Antenna Support Structures:

Torsionally stabilised guyed masts were used at all sites except Menzies where space is limited and Kalgoorlie where the existing structure was utilised. All structures were designed to a maximum tilt and torsional stability of +-0.35° in 27m/s winds and to withstand 40m/s maximum wind velocity, with full antenna loading.

Equipment Shelters:

At solar powered repeaters the equipment is housed in corrosion-protected cylindrical steel shelters, buried underground to obtain thermal stability. The internal dimensions are 2.4m diameter and 2.6m height. The power shelter is placed over the underground shelter to provided thermal shade, with access to the underground shelter through the power shelter. Above ground transportable shelters have been used at Leonora and Menzies, whilst the existing microwave terminal building at Kalgoorlie was utilised.

Power Plant:

Apart from Kalgoorlie, Leonora and Menzies, no commercial ac power is available along the route. Silicon photo-voltaic cell arrays and large capacity secondary storage batteries are capable of providing roughly 150W of continuous power at Bardoc and Goongarrie and 130W at Packard. Ninety-six solar modules with a maximum output of 0.7A each are connected in a series parallel configuration to charge nominal 2000AH 24V batteries at the former two sites, and seventy eight-modules are installed at Packard with a 1500AH battery bank. The battery capacity of the 11 cell positive earthed banks is not expected to drop below 50% of nominal value during winter, and a reserve of at least 10 days operation is expected from fully charged batteries in the event of a charging failure. The actual load voltage may vary between 21.5V and 26V and in the event of over-voltage, series dropping diodes are switched into the equipment power feed. Battery charging regulation is achieved using incremental series (or open-circuit) regulator units. The solar arrays are mounted on aluminium frames installed on the seatainer roof.

Wayside Services:

At Menzies a main bearer 300 channel drop/insert facility facing Kalgoorlie will allow access to supergroup 3 for local exchange traffic. There is an NPTV drop from the South-North protection bearer at Menzies. At all other repeaters drop/insert access to the 0-252kHz sub-baseband facing Kalgoorlie for single channel wayside subscriber services has been provided. Twelve channels in the band 12-56kHz are equipped for wayside services as shown in **Fig. 6**. Future expansion of wayside channels will be implemented using DTL channel multiplex equipment. Special allowance was made to interface DTL shelves with the sub-baseband drop/insert equipment. All wayside services will terminate at Kalgoorlie.

Cost Estimate:

The all-up estimated cost of the system, at 1979/80 prices, was $1.56 million.

CONSTRUCTION

The entire system was installed and commissioned by Telecom staff. The following major items were supplied under collective purchase contracts:

a. Radio equipment, including supervisory system, service and wayside channel ends and order wire facility;
b. Pre-fabricated steelwork for the antenna support structures, including the Menzies tower, and guys;
c. Underground shelters;
d. Antennas, feeders and circulators;
e. Solar power plant, including seatainers, solar panels, frames, regulators;

External Plant:

The installation was carried out in four major phases:

a. Site excavation work;
b. Installation of mast foundations, guy anchors, underground shelter, and seatainer foundations;
c. Erection of structures and antennas;
d. Installation of waveguides.

During excavation, rock was encountered at most locations. A large rock drill and blasting were required, together with a back-hoe, compressor and jack-hammers. A four man team was used for this phase of operations. Following excavation, a five man team installed the foundation steelwork using specially developed jigs to maintain the high order of positioning accuracy required. Roughly 200 cubic metres of ready-mixed concrete for the foundations and any anchors was carted from Kalgoorlie to all sites including Leonora, a distance of some 240Km. Setting retarder was used in the concrete for obvious reasons.

The underground shelters were transported to site on a flat-top truck and lowered into place using a crane. Special quality sand for backfilling was carted to each site and compacted around the shelters. This operation proved to be quite difficult as great care had to be taken to ensure that the corrosion proof coating was not mechanically damaged. Fumes from the engine driven compactor exhausts also proved to be a problem in the confined spaces.

A six man team erected the guyed masts and the tower, and raised the antennas into position. It was found convenient to assemble the bottom sections of the guyed masts accurately on the ground prior to erection, then lift them into position. The upper mast sections were installed using a jury rig. Following erection, the mast guys were tensioned with the aid of two theodolities to ensure structural verticality. The final phase was the installation of waveguides, a task which also called for a high degree of positioning accuracy to ensure that the elliptical guides were correctly run along the gantries and bent into the shelters without excessive twisting. Prior to construction it was thought that waveguide installation would be a routine task; however, despite a conscientious effort by the Radio Lines crew, it was discovered that considerably more on-site engineering supervision and guidance should have been provided. This is a point which should not be overlooked by construction engineers engaged on future projects.

The power plant seatainers were delivered to Kalgoorlie by the manufacturer with the solar panels, frames and regulators stored inside. It was found expedient to empty the seatainers and transport them to site during the external plant installation phases, when a crane was available to lift them into position. The waveguides were then run through the seatainers and into the underground shelters.

Internal Plant:

Because of the relatively small scale of the project, and the three repeaters being the only essentially identical installations, no underground shelter pre-wiring was carried out. This was not seen as a disadvantage as little wiring was necessary and valuable in-field installation practice was gained. The radio equipment was delivered on-site in the original packing and installed without pre-testing, which proved to be quite satisfactory. Equipment was lowered into the underground shelters prior to the installation of the power seatainers.

Two 2-3 man installation teams carried out the equipment installation and testing. Per hop group delay equalisation was carried out using plug-in IF modules, a function which would have been made considerably easier had a full range of modules for each site been provided. Differential absolute delay equalisation between the main and protection bearers was carried out over the Kalgoorlie to Leonora switching section as well as to the 300 channel drop/insert point at Menzies. The combined feeder/antenna return-loss was adjusted using the swept frequency method. It would have been preferable to test the antenna and feeder return-losses separately; however, facilities were not available for this to be carried out at the appropriate times. Dent tuning of the waveguide with a clamp was found to be effective in improving peak return-loss without degrading the overall rms return-loss.

A number of equipment problems were encountered which slowed the rate of installation. Poor frequency response, crosstalk and instability in the sub-baseband channels was traced to hybrid and DTL interface panels which have been replaced. Baseband spurious signals were caused by interference from the supervisory equipment bay. Extensive earth strapping to individual PCB cards was necessary to reduce interference to an acceptable level.

Power Plant:

The solar panels, frames, regulators, rectifiers and batteries were transported to site and installed in the seatainers and transportable shelters. The solar power installations were commissioned using a "live" solar input and a variable voltage regulated power supply to simulate the batteries. In this way the operation of the incremental series regulator was checked and the battery monitor and alarm levels and diode dropper switch-in voltage set.

Actual System Cost:

The final installed cost of the system at 1979/80 prices was $1.2 million, significantly lower than the original estimate. A total of 22,500 man hours were used to complete the radio relay system, including the provision of diversity equipment as discussed in the next section.

FADING PROBLEMS

During installation in May 1980 deep fading on the Packard to Menzies main and protection bearers was reported. Urgent action was undertaken to install temporary diversity antennas, and obtain chart recordings of the main and diversity path received signal levels in both directions. The antennas were loaned by the Research

Department. Recorders were also set up on both bearers in at least one direction of the other four paths to assess the extent of the fading problem. The system commissioning and cut-over was deferred pending further investigation of the fading problem.

It was assumed that reflections on the Menzies to Packard path were due to Lake Ballard, (see **Fig. 9**), which contained a considerable volume of water following heavy rains. Based on this assumption the temporary diversity antennas were placed 13m below the main antennas. In order to measure the diversity signal at Menzies, the main bearer receiver facing Goongarrie was cross-connected to the temporary antenna.

The recordings quickly verified that two-ray interference was indeed causing the fading and that with the antenna spacing chosen the diversity signal showed excellent anti-correlation with the main signal. Urgent action was undertaken in June to provision diversity antennas and feeders for the Menzies-Packard path and arrange for spare NEC diversity equipment to be obtained from the Alice Springs-Tennant Creek system for the main bearer.

When recordings of the main bearer signal from the main and diversity antennas at Packard became available, two significant points were evident:

a. Fading on the main bearer signal from the main antenna was not as severe as in the Packard to Menzies direction (it was later established that this observation also applied to the standby bearer). This occurred over a period of some 40 days when simultaneous recordings were obtained from each direction of transmission.

b. With 13m antenna spacing, the diversity signal was not showing good anti-correlation with the main bearer signal fading events.

It was also observed that the diversity signals at Menzies and Packard did not exhibit the same degree of fading as the main antenna signals. These observations suggested that the fading was strongly frequency dependant and/or the path reflection model incorrect.

Further investigation verified both of these points. Using reflection analysis programs developed by the WA Radiocom Design Group, it was shown with the aid of path profile and signal level versus k factor plots that:

a. With two-ray fading, the degree of fade depth was strongly frequency dependant, accounting for the difference of fading distributions between each direction of transmission over the Menzies-Packard path;

b. The Packard main antenna height is not optimum, causing the Packard to Menzies main and standby signals to experience prolonged two-ray fading nulls for normal daytime k values;

c. Reflections from Lake Ballard or atmospheric layers above the Lake could not cause the observed signal levels and fading distributions. Only multiple reflections from scrub covered terrain to the North of Lake Ballard, previously considered to be unable to support such reflections, could cause the measured fading.

Considerable effort was put into confirming the above findings. It was found that the optimum diversity spacing at Packard was not 13m as previously determined, but 7.5m. The temporary antenna was relocated at the higher level early in August. The chart recordings showed a significant improvement in diversity performance as predicted, which provided further confirmation of the scrub covered terrain reflection model (Ref. 3).

During late August to early September 1980, permanent antennas, feeders and diversity equipment were installed on the Menzies to Packard path. Following this chart recordings were resumed. Due to guy-wire restrictions the Packard diversity antenna was mounted 8m below the main antenna rather than 7.5m. Recordings showed that this spacing, and 13m spacing at Menzies gave the expected diversity improvement. The number and duration of simultaneous fades was very much smaller than the total number of fades experienced on the main antenna alone.

It was evident that, as could be predicted from reflection analysis, the diversity paths in both directions were experiencing less fading than the main path (between the main antennas). This improvement is enhanced by the attenuation of reflected signals caused by an obstructing ridge near Menzies. These observations suggested a receiver re-arrangement whereby the main paths operate via the diversity (lower) antennas, and the diversity receivers operate from the main (upper) antennas as shown in **Fig. 9**. The number of diversity switches were reduced by adopting this configuration.

Performance objectives for the path were easily being met. An analysis showed that diversity would provide a similar improvement on the protection bearer. Diversity was subsequently provided for the Menzies to Packard protection bearer which carries NPTV. The regular two-ray fading events were found to have little dependence on meteorological conditions, occurring during wet, windy and cool as well as dry, fine, still and warm weather. It was concluded that the scrub covered terrain produces consistent reflections.

Attention was turned to the Packard to Leonora path where similar two-ray fading had been measured at Leonora, mostly at night time. A traffic performance tester was used to measure the overall system noise performance at Kalgoorlie. With diversity on the Menzies to Packard path, the Packard to Leonora path was contributing to virtually all of the overall system fading noise.

A reflection analysis carried out on the Packard to Leonora path showed that the observed fading was due to reflections, again from scrub covered terrain similar to that on the Menzies to Packard path. No measurements were carried out on Packard to Leonora diversity paths. It was subsequently determined that the system was meeting performance objectives, and diversity on the Packard to Leonora path was not required.

Recordings of signal levels on the remaining three paths did not exhibit significant fading, performance objectives being easily met. Other fading phenomena including that caused by multipathing and possibly night time temperature inversions, as one might expect, were occasionally observed on all paths. The system was placed in service for telephony transmission in October 1980.

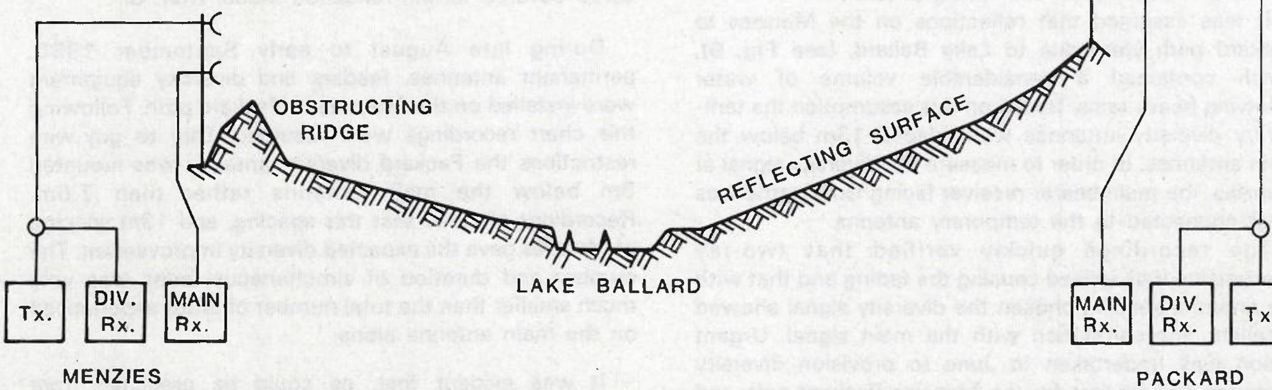


Fig. 9 — Final Space Diversity Configuration on the Menzies to Packard Path, Showing Actual Path Profile.

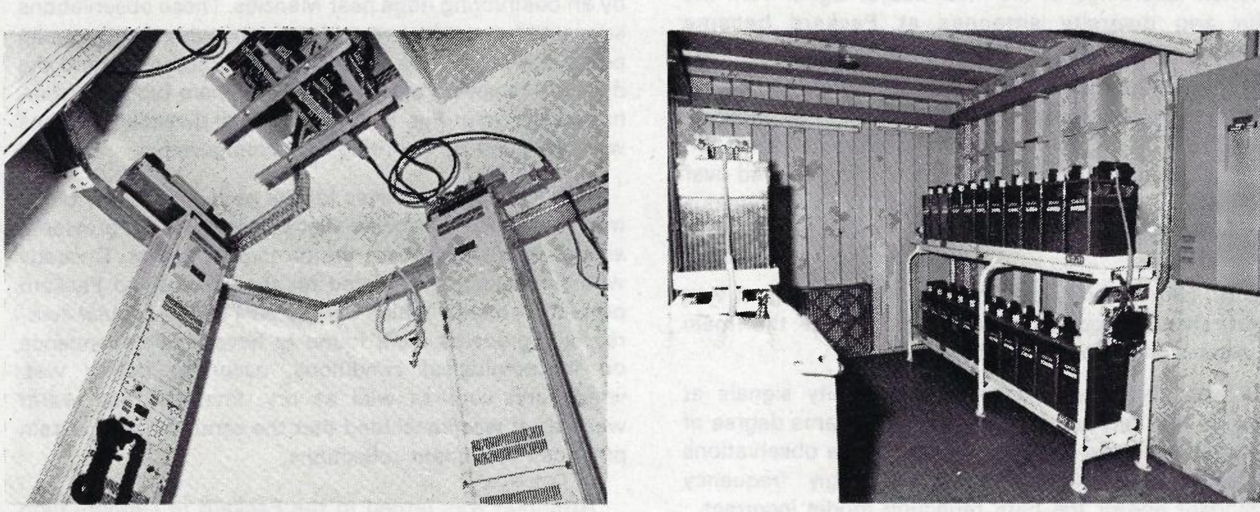


Fig. 10 — Equipment Installations.
(a) Radio Repeater Equipment in Underground Shelter.

(b) Battery Installation Inside Seatainer.

CONCLUSION

Despite the unexpected fading problems encountered, the microwave system has provided excellent performance commissioning. During the actual worst-case telephone channel noise was measured at 220 pWOp or approximately 1.0 pWOp per km, well within the objective and less than that predicted.

REFERENCES

1. Bursill H O, "Souvenir of the Posts and Telegraphs Dept. of WA, 1898". Copy held at Telecom Museum, Perth.
2. Mencel A J, "Alice Springs — Tennant Creek: A New Approach to Radio Relay Systems". Telecommunications Journal of Australia, Vol. 30, No. 2, 1980.
3. Haime A L, Patterson K, Wienecke J, "Kalgoorlie-Leonora Microwave System Correction Report Volume 1". Radio Section Publication, Telecom, Perth, May 1981.

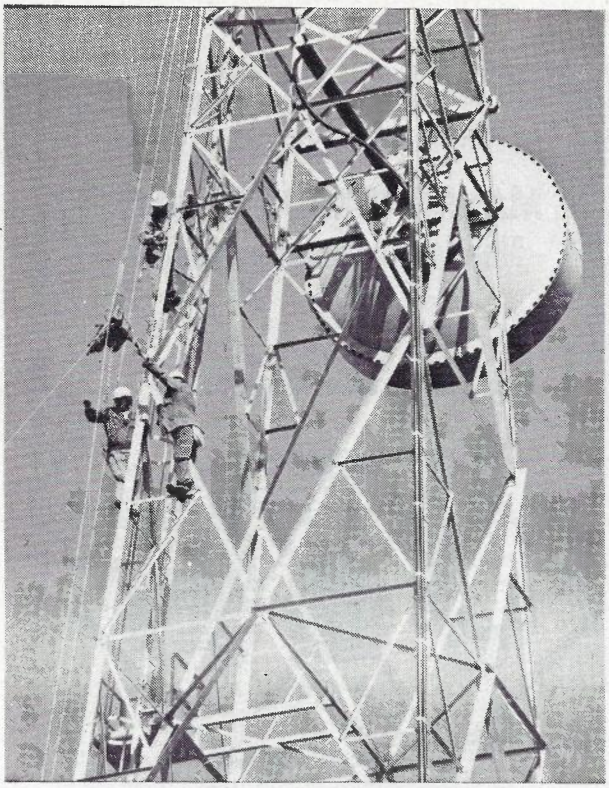


Fig. 11 — External Plant Erection, Menzies.

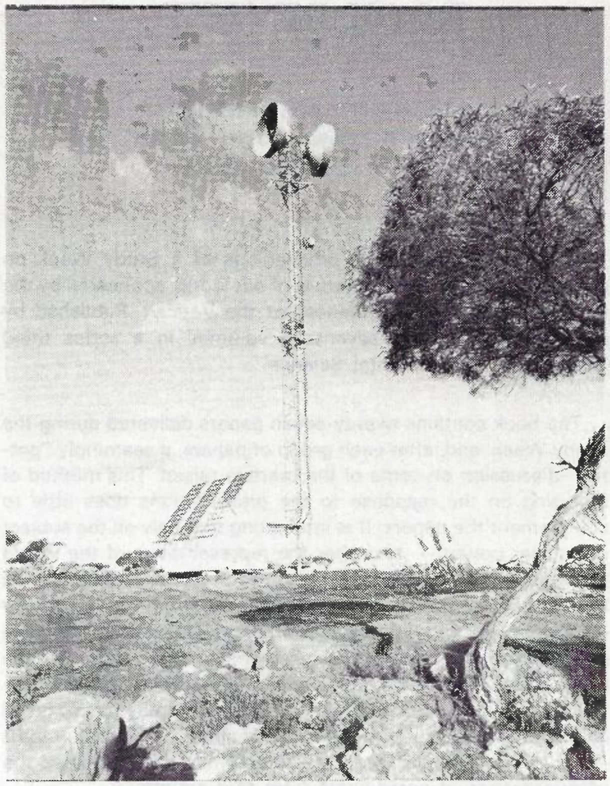


Fig. 12 — Packard Repeater.

BOOK REVIEW

MANKIND AND ENERGY:
Needs — Resources — Hopes
Edited by Andre Blanc-Lapierre

This book contains the proceedings of a Study Week on energy and its place in the future of our world, sponsored by the Pontifical Academy of Sciences at the Vatican. Published by Elsevier, it is one of seventeen volumes in a series titled "Studies in Environmental Science".

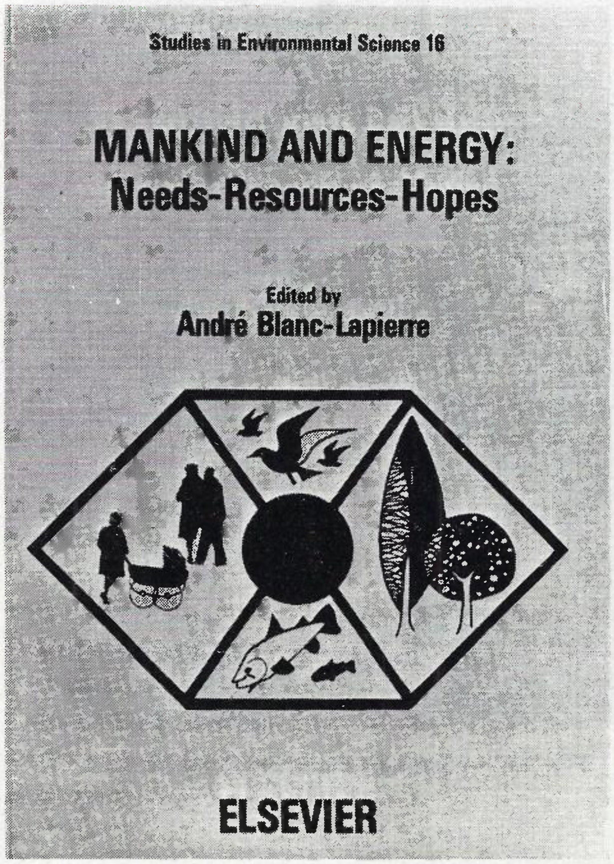
The book contains twenty-seven papers delivered during the Study Week, and, after each group of papers, a seemingly "potted" discussion on some of the matters raised. This method of reporting on the response to the presentations does little to complement the papers. It is interesting that only on the subject of nuclear power — and after the representative of the World Council of Churches had developed an argument for a moratorium on the use of nuclear energy for electricity generation — did the discussion show signs of heat. The participants, predominantly academics, did little in the discussion to add to the points raised, but did clarify some matters where translation or subject unfamiliarity may have caused confusion. The discussion reportage is spoilt — for me, at least — by being partly in French — which may have reflected the preponderance of participants from that country.

Seven participants came from South American countries, so that there is a considerable direction of attention toward the energy philosophies relevant to the so-called Third World. This direction comes halfway through the book, which starts off with well-researched and informative articles about oil, coal and nuclear sources of energy, oriented toward large power plants and Western consumption patterns. The Study Week was obviously designed in this way, to develop toward alternative energy considerations after providing a firm basis on the major fossil fuel energy sources.

However, some of the participants obviously were looking for answers to other questions. An Israeli participant said "Most discussion so far on nuclear energy and, in part oil and coal, has been in regard to the enormous needs of energy of the highly developed countries . . . I feel a certain inferiority complex and it is probably shared by some of my friends from the developing countries, because most of the discussion on nuclear energy and coal energy has been concerned with the giant nations of the world . . . But, I believe that it is one of the functions of this meeting to talk about the problems of the smaller countries."

The Study Week did develop along these lines, with increased emphasis on the non-technological aspects of energy, such as cost, environmental and health concerns, and future lifestyles, as well as some interesting papers on alternative energy technologies, including the use of "solar ponds" for storage of heat. Included is a quite remarkable paper which examines the developments in the transfer of information via "telematics" and leads through this discussion to the philosophical examination of mankind's reaction to the challenge of reduced availability of fossil fuels.

The book contains excellent reference material and several quite readable essays on the economic and socio-political ramifications of energy production. The pen of the academic is evident, but the book is quite readable, if sometimes overloaded with data. There is evidence throughout the discussion, and the



latter areas of study reported in the book, of the conflict between the subjective views of the "environmentalist" and the pragmatic dogmatism of the "technologist". This is clearest in the discussion on nuclear power and seems to reflect the same conflict as we have recently seen over the issue of the establishing dams for hydroelectric power on the Franklin River in Tasmania.

The book tries hard to tie together the technical and social considerations of the supply and consumption of energy, with the latter taking greater emphasis than is usual in such discussions.

I cannot help but agree with Pope John Paul II who in his opening address said "Energy is a universal good that Divine Providence has put at the service of man, of all men, to whatever part of the world they may belong". This view was also supported by Dr Pasztor of the World Council of Churches who said, during the debate on nuclear power — "We, at the WCC, agree very much with the view of the Roman Catholic Church that science is a part of culture. If this is true, then it is impossible to talk about science without bringing in values".

Mankind and Energy is an interesting book for those interested in the energy debate, in that it attempts to bring together the energy technology and the needs of mankind. No solutions are offered — and are probably not possible because of the disparity in value positions of the participants — but the interested reader can gather enough useful information to support presently held opinion.

Reviewed by:
Hugh P. Guthrie
National Energy Co-ordinator
TELECOM

A Technique for Locating Faults in Loaded Cables

E. C. Thrift

In Telecom Australia today, there is a need for fault locating equipment which can keep pace with the ever increasing use of loaded cables.

The test procedure described in this article utilises existing pulse echo test (PET) equipment and a cable simulator. The significance of the procedure is simplicity, speed, and accuracy under field conditions.

INTRODUCTION

Loaded cable, wherever it is used creates a particular problem for maintenance staff. How to test it? This is a recurring question which is only partially answered by current test procedures and equipment.

Much of the problem lies in the situation that is usually created when faults occur due to storm damage. The volume of faults, and hurried restoration of service, demands rapid and accurate fault location. Quite often the staff available do not have the skill or the repetitive practice to operate complex test equipment or calculate accurate results.

The result of this is often a piecemeal repair job with emphasis on service restoration rather than total fault repair. Over a period of time, there may be a gradual decline in transmission, and eventually a series of simple faults can become a major restoration project.

All of this could have been avoided if a functional test instrument and procedures had been available. Test equipment which is complex or requires ideal/critical conditions cannot be classed as functional. It must be equipment which does the job. **and** is understood by all levels of staff.

Loaded Cable Fault Location Methods

The Armidale district in New South Wales is an area where voice frequency (VF) loading has been extensively used in the rural cable network. It is also an area of severe lightning activity during the summer months.

Over a period of time, the cable system had become degraded very much in the manner just described. Because of this, the District decided to attempt restoration of the loaded cables. It was obvious that costs would be high, and all the known test procedures were reviewed to find a workable solution. The following methods were tried, and except for PET with a simulator, were found inadequate.

- Point-to-point tests by external plant staff; found to be too costly due to the labour required for such a large job.
- DC tests by technical staff; inconclusive results and no indication of fault location.
- Frequency response tests; showed that faults existed but gave no location.
- Return loss measurement; as for frequency response.
- Pulse echo tests; showed promise of results, but the methods (see Reference 1) were not fully effective due to a lack of reference data on which calculations could be based.
- Pulse echo tests with cable simulator; this method, using a loaded cable simulator, was the only one which showed any promise. It gave indication of the presence of faults **and** the fault locations by direct comparison between the cable and the cable simulator.

Table 1 gives full details and comparisons fo the various test methods evaluated.

Direct Comparison Testing

The technique of direct comparison testing is not new and takes several different forms. Broadly speaking, there are two groups into which the methods can be classified. One group identifies significant differences only, attempting to balance all normal characteristics. The other group displays ALL characteristics for interpretation.

Both groups can be accurate, but the significant difference technique requires a degree of understanding to identify the different points which may be displayed. In the "one only" fault condition, the fault or difference is usually readily identified, but even in this ideal case, which is rare in loaded cable, the accuracy of results is dependent on the operator's skill and knowledge of the calculations required.

The method is prone to error due to failure to identify which differences are significant, and therefore the method is inefficient for general field use.

A display of all characteristics is far less dependent on critical factors or operator skill. Since all the line characteristics are displayed on the PET, the operator only needs to be able to recognise five basic trace characteristics as shown in **Fig. 1**: non-loaded pair, normal loaded pair, loading fault, short-circuit condition or open-circuit condition. Short or open-circuit faults can easily be confirmed by DC tests.

Comparison testing requires display of traces from both the test line and "something else". The "something else" is vital to the success of the method chosen, and is provided by the cable simulator which includes a series of controls with which the operator attempts to make (and usually succeeds in making) the two displays almost identical. The settings on the controls of the simulator are then a direct interpretation of the trace pattern.

The Cable Simulator — "Simline"

The cable simulator used in this test procedure is an extension of the device offered to the Telecom Australia Staff Suggestions Board by J. A. Strugnell of Swan Hill, Victoria. In the SIMLINE loaded cable simulator, the electrical properties of up to 40 km of 0.90 mm conductor loaded cable are duplicated. The device can by key operation simulate any length of cable from 915 m to 40 km, using steps of 1830 m. Each step is equal to one loading section. The loading coils can be independently shorted out to simulate a point where a coil should have been but, has for some reason been removed. There are also facilities for simulation of fault conditions, such as "teed" or multiple joints, short circuits, open circuits and earth faults. The simulator also includes terminating networks and end section capacitance.

Although the SIMLINE is constructed to simulate 0.90 mm conductor cable, it has been proven to function quite satisfactorily for cables of lighter or even mixed gauges.

The fault location process with the simulator and a pulse echo tester (PET) is simply a matter of identifying what type of fault exists, and duplicating that condition in the simulator. The physical location of the fault is indicated by which key or keys are operated in the simulator. This is described in detail in the fault location procedure.

Pulse Echo Testers

Pulse echo testers of the type found satisfactory operate on the principle of using a pulse, echo and time base. That is, a pulse is transmitted along a line or cable pair, and any disturbance in line constants causes an echo to be returned. This echo is received by the PET and displayed on an oscilloscope screen. The horizontal trace length is set by a fixed or reference time base. Without the simulator, fault location would be achieved by observing the time taken between the start point and the location of the abnormal echo pulse. Propagation time is an important factor. From this data, the location of the physical fault can be calculated.

In the test procedure using the cable simulator, the time base and propagation time are disregarded as they are irrelevant. No calculation is performed at any stage, other than relating loading points or fault locations to geographical locations.

There are, however, some specific facilities required in the PET, and these are:

- **Size of Display Screen**
  This test procedure results in a large and sometimes complex trace pattern. It was found that the large 10 cm screen of the North-east Electronics Corporation NEC TTS 17A and the Telephone Manufacturing Company TMC PET 100 A/B were ideal. The smaller 60 mm screens of modern instruments, such as the Cossor T216 or the Howaldtswerke Deutsche Werft HDW T08/3, gave a trace pattern which was small and difficult to interpret.
- **Dual Beam or Dual Trace**
  The most efficient interpretation is achieved by direct comparison of the traces resulting from the line and the cable simulator. Simultaneous display of the cable pair and simulator traces is essential.
- **Trace Stability**
  To interpret the trace effectively, the pattern must be stable. Any flicker or oscillation makes trace matching very difficult and creates severe eye strain, if viewed for any length of time.
- **Variable Trace Spacing**
  Final comparison often requires the superimposing of the two patterns. This is essential for accuracy. On the other hand, a continuously superimposed or mirror image trace makes initial matching difficult.
- **Line Switch Facility**
  The instrument must be capable of performing continuously alternating tests over two separate circuits (i.e., the cable and the cable simulator).
- **Pulse Frequency**
  Loaded cable at voice frequencies has a pass band from 200 Hz to 3600 Hz. It is necessary that the pulse frequency be within this range, preferably 2000 Hz. A pulse of this frequency gives a useful display pattern, and is sensitive to any critical line characteristics.
- **Pulse Voltage**
  This must be adequate for cables up to a length of 40 km to ensure a substantial return echo. A low voltage requires excessive receiver gain and generally results in trace distortion due to noise.

Suitable instruments

There are two suitable makes of pulse echo testers available within Telecom Australia. These are the NEC TTS 17A, and the TMC PET Type 100 A/B which is used widely in country areas.

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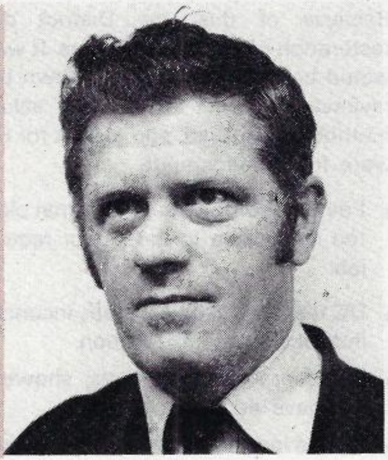

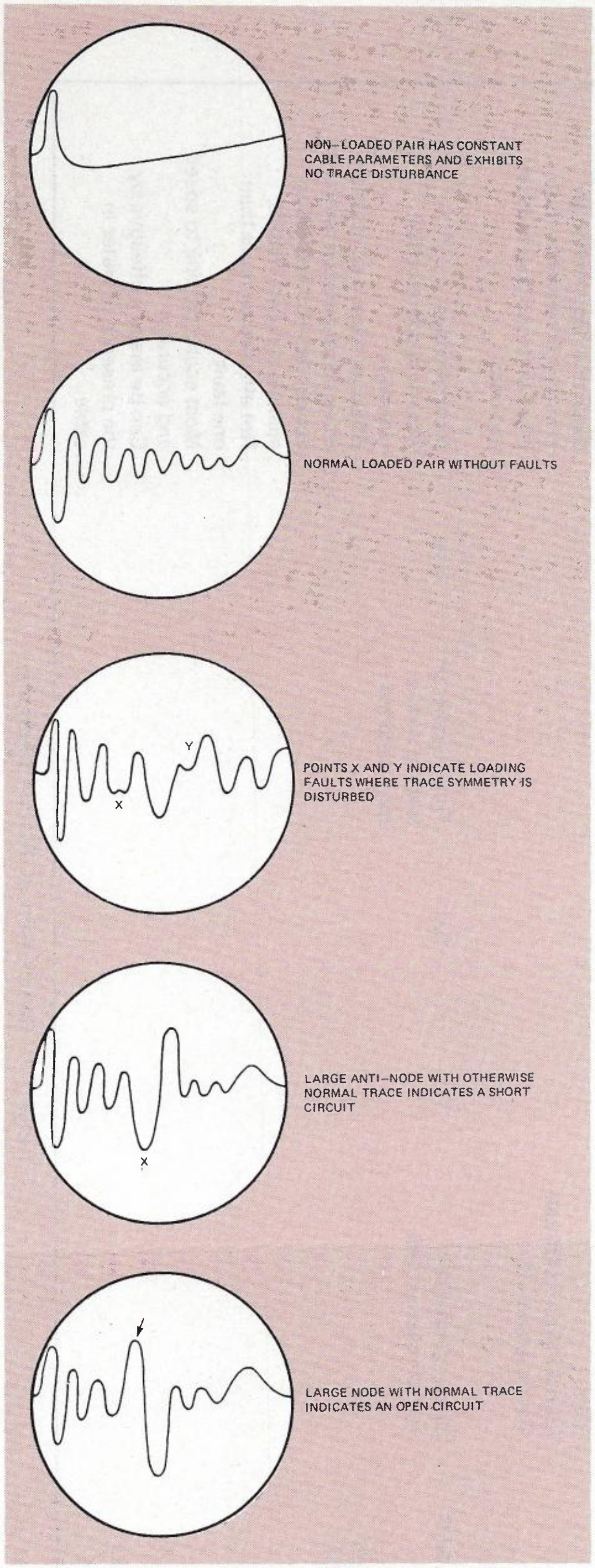

Fig. 1 — Trace patterns from a pulse echo test set showing basic trace characteristics due to faults in loaded cables.

NEC TTS 17A. This is a pulse echo tester which has been used with a "Lear Siegler" artificial line. The instrument meets all the requirements, and has been used in the Armidale District very successfully.

TMC PET 100 A/B. This instrument, though considered obsolescent in some areas, is widely used. It meets all requirements, except for the dual trace, and even this was solved by a small modification. This PET is now being used in the Armidale District, and is performing most satisfactorily.

PET 100 A/B Modification

Two techniques have been used to achieve a dual trace synchronised display on the PET 100 A/B instrument. The trace, when modified by these techniques, shows both cable pair and simulator at the same time.

The first technique connects the cable pair and simulator via a relay line switch **(shown in Fig. 2)** which is driven by the 17 Hz ring. The second technique, which was developed by the Wagga Engineering Section, New South Wales, relies on a solid-state internal modification to the PET 100 A/B. The modification **(see Fig. 3)** consists of two miniature relays and a solid-state driver circuit, and offers several advantages over the relay line switch particularly as it is built into the instrument and requires no external power source.

For each technique, switching is synchronised with the trace shift. The relay line switch uses a frequency of 17 Hz whilst the internal modification operates at 50 Hz. Both switching rates were found to be effective.

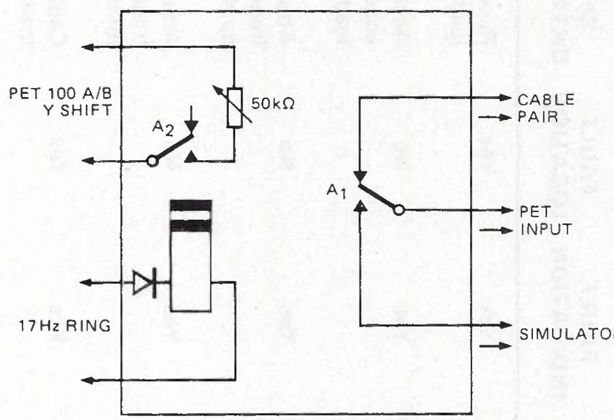

Fig. 2 — Relay line switch for use with PET 100 A/B

Test Procedure

The equipment and data required are: Suitable pulse echo tester; a cable simulator such as SIMLINE or some other suitable type, a set of cable plans showing distances, number of coils, loading range and pair distribution. The steps in the procedure are as follows:

- SET UP the PET and simulator according to **Fig. 4.** See also **Fig. 5.**
- PROGRAM the simulator to the same line length as the cable pair under test.
- ADJUST the terminating network to suit.
- ADJUST END CAPACITANCE on the simulator to match end capacitance of pair. (This adjustment results in approximately the same trace lengths).
- ADJUST SPACING CONTROL (on line switch unit) to suitable tracing spacing.
  (NOTE: Line switch unit not required in TTS 17A or PET 100 with internal modification).

TEST METHOD	DETAILS OF TEST	FAULT INDICATION	FAULT LOCATION	REFERENCE DATA REQUIRED	STAFF INVOLVED	COMMENT
Point-to-point by external staff	Physical inspection of each loading point	Yes	Yes	Records of loading points	One or more	Effective, but very slow and very costly.
DC test by technical staff	Accurate loop resist-ance versus distance	Yes	No	Accurate data, conductor size, loading etc.	Two	Ineffective due to failure to locate loading fault.
Frequency response	Frequency run from 200 Hz to 4000 Hz	Yes	No	Attenuation-frequency curves for the distance	Two	Ineffective due to failure to locate loading fault.
Return loss	Impedance-frequency response plot	Yes	No	Attenuation-frequency curves for the distance	Two	Ineffective due to failure to locate loading fault
Pulse echo test (see Dossing Reference 1)	Pulse echo versus time base. Calculate time or distance to source of echo at fault (Some instruments have distance read-off).	Yes	Yes	Cable distances, loading details	One	Effective in some instances. Requires highly skilled operator. Not practical due to time taken and dependence on accuracy of reference data. More than one fault reduces accuracy.
Pulse echo NEC TTS 17A or PET 100 A/B and SIMLINE	Direct comparison with simulated cable	Yes	Yes	Total number of loading coils or total distance	One	Most effective. Minimum operator skill required. Does not require calculation. Does not depend on reference data or detailed records to achieve accurate results. Not affected by more than one fault. Most economic due to speed and accuracy. Can be made ineffective by the presence of water in cable.

Table 1 — Comparison of Testing Methods

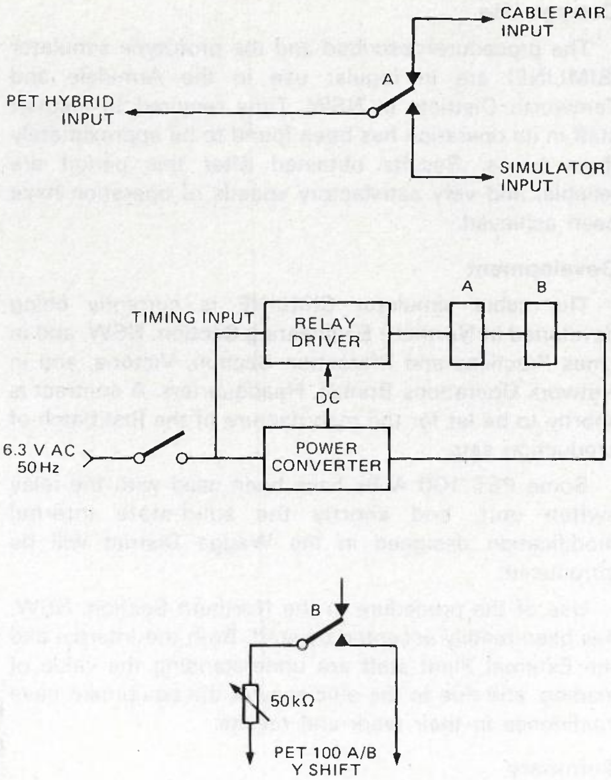

Fig. 3 — Solid-State internal modification for PET 100 A/B to achieve dual trace display.

- PROCEED to try variations of line faults in simulator until traces match.
- SUPERIMPOSE traces for final check.
- FAULTS are indicated and located by the control settings on the simulator.

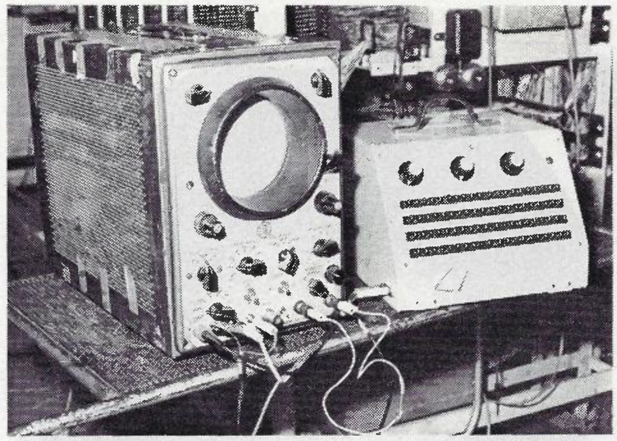

Fig. 5 — Modified TMC PET 100 A/B being used with SIMLINE cable simulator for location of faults in loaded cables.

Accuracy and Employment

Loading errors or faults are indicated at the point where they occur. Short- or open-circuit faults are pin-pointed if they are in a loading coil or in a loading section (if they are in the cable). Should such faults be within a section length, other procedures are available for fault location between loading points.

Accuracy is reduced for faults beyond about 10 loading sections. On longer cables it may be necessary to test from both ends. Water may be encountered in unfilled plastic insulated cables and this will prevent the location of faults beyond any extensive wet section.

Where one operator has been using the procedure for more than one or two days, the test rate can be as high as 50 pairs per hour. This applies only for initial or fault appreciation tests. Once work on repair commences, the progress rate depends on the efficiency and number of

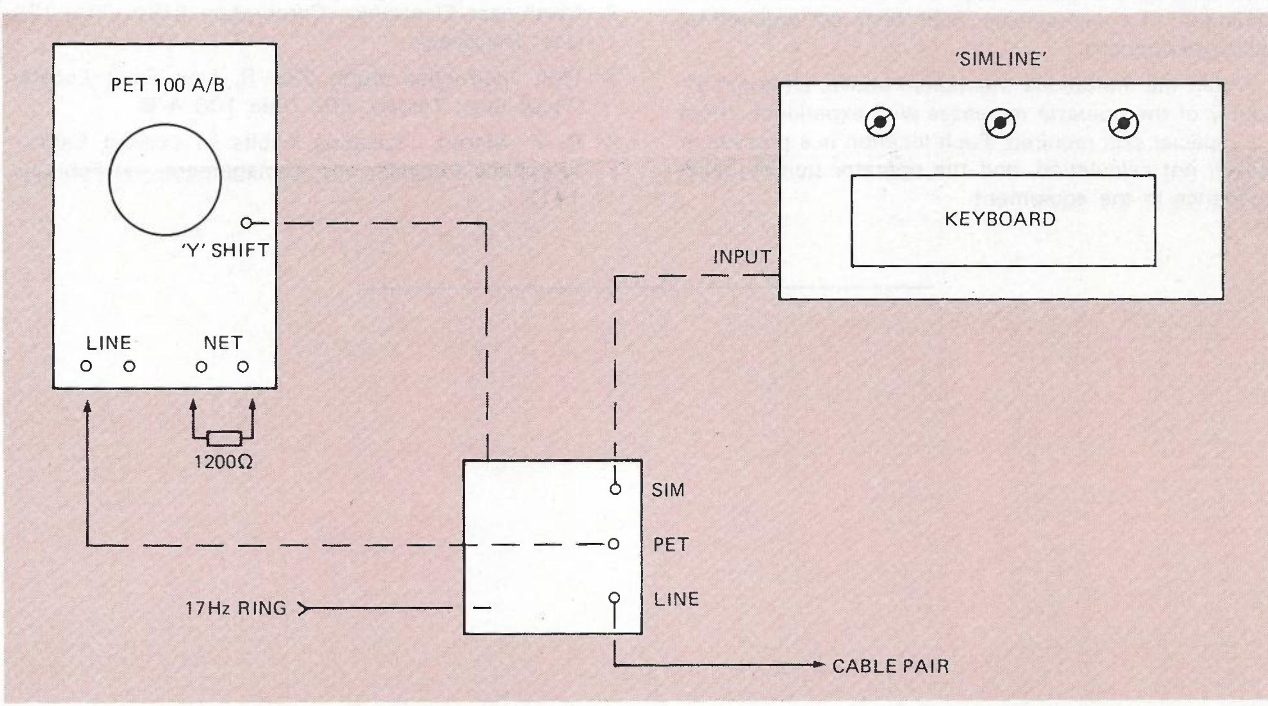

Fig. 4 — PET-SIMLINE Schematic Layout

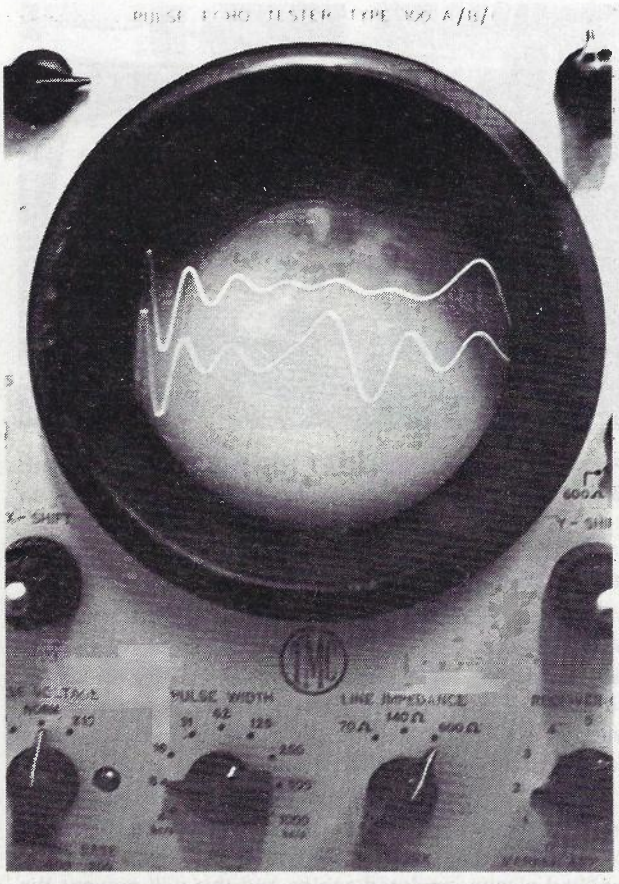

Fig. 6 — Dual Trace on modified TMC PET 100 A/B Top Trace: Normal loaded line (12 loading coils) Lower Trace: Open circuit at sixth loading coil.

cable jointers that can be made available. Two or three jointers can be directed with ease if necessary.

In addition to fault location, the procedure is ideal for performing an acceptance test on a loaded line prior to connection of a new service. Such tests are required by official instructions.

Within the limitations mentioned above, although efficiency of the operator increases with experience, there is no special skill required. Fault location is a process of display, not calculation, and the operator quickly gains confidence in the equipment.

Current Use

The procedure described and the prototype simulator (SIMLINE) are in regular use in the Armidale and Tamworth Districts in NSW. Time required to instruct staff in its operation has been found to be approximately three hours. Results obtained after this period are reliable, and very satisfactory speeds of operation have been achieved.

Development

The cable simulator SIMLINE is currently being developed in Northern Engineering Section, NSW, and in Lines Practices and Protection Section, Victoria, and in Network Operations Branch, Headquarters. A contract is shortly to be let for the manufacture of the first batch of production sets.

Some PET 100 A/Bs have been used with the relay switch unit, and shortly the solid-state internal modification designed in the Wagga District will be introduced.

Use of the procedure in the Northern Section, NSW, has been readily accepted by staff. Both the Internal and the External Plant staff are understanding the value of loading, and due to the efficiency of the equipment have confidence in their work and results.

Summary

The procedure detailed in this article utilises a simple instrument and straightforward method to achieve an effective technique to locate faults in loaded cables. It is readily accepted by staff at all levels, and has met all technical requirements.

REFERENCES

1. S. Dossing, "Pulse Echo Tests for Open Wire, Cable and Composite Lines", The Telecommunication Journal of Australia, Vol. 12, No. 5, October 1960.
2. North-east Electronics Corporation (USA) TTS 17A User Handbook.
3. TMC Instruction Book 238 R, Line Fault Locator (Pulse Echo Tester), PET Type 100 A/B.
4. D. F. Martin, "Locating Faults in Loaded Cable", Telephone Engineer and Management, 1st February 1972.

Economic Analysis — Making Investment Decisions

C.W.A. JESSOP, BSc, MESc, MIEE, CE., B.M. YEOH, BSc (Hons), C.W. PARRY, Dip PA, BEc.

Economic analysis of proposals for telecommunication projects is becoming increasingly important. This series of articles will, following a brief introduction of general principles, discuss some aspects which cause problems when evaluating telecommunication projects. The articles intend to explore areas of contention, discussing the advantages and disadvantages of various approaches, leaving the reader to decide which approach is relevant to a particular case for which an economic analysis is required.

INTRODUCTION

This is the second of three articles dealing with investment evaluation. The first article dealt with the comparison of projects which involve different cash flows over a period of time. This article identifies the nature of the costs likely to be incurred during the life of an engineering project, and how they should be treated in an economic study. Often there is a concentration on techniques while the importance of cost data, the core of the matter, is given secondary consideration.

Too often, it becomes clear with 40/20 hind-sight that costs which "should have been obvious" have been overlooked. For people intent on getting a new technical facility in and working, a momentary distraction such as an untimely incoming telephone call, or the pressure of having to prepare a case to support a rush project in a climate of funds drought could be sufficient to cause a key cost factor to be forgotten for the moment, but become clearly apparent just as the balloon goes up.

Relevant Factors

In making an investment decision, all relevant costs and benefits should be considered. Here, "relevant costs and benefits" means those directly associated with, sensitive to, or affected by the investment decision. A cost or benefit is relevant only if it occurs as an outcome of investment expenditure, or conversely, would not have occurred if that capital expenditure had not been made. The relevant project costs can be represented diagrammatically: See **Fig. 1**.

Design and site costs will be incurred before the major project costs are incurred — those involving purchase, delivery and installation of the capital equipment. From the commissioning date, operating costs will fall initially

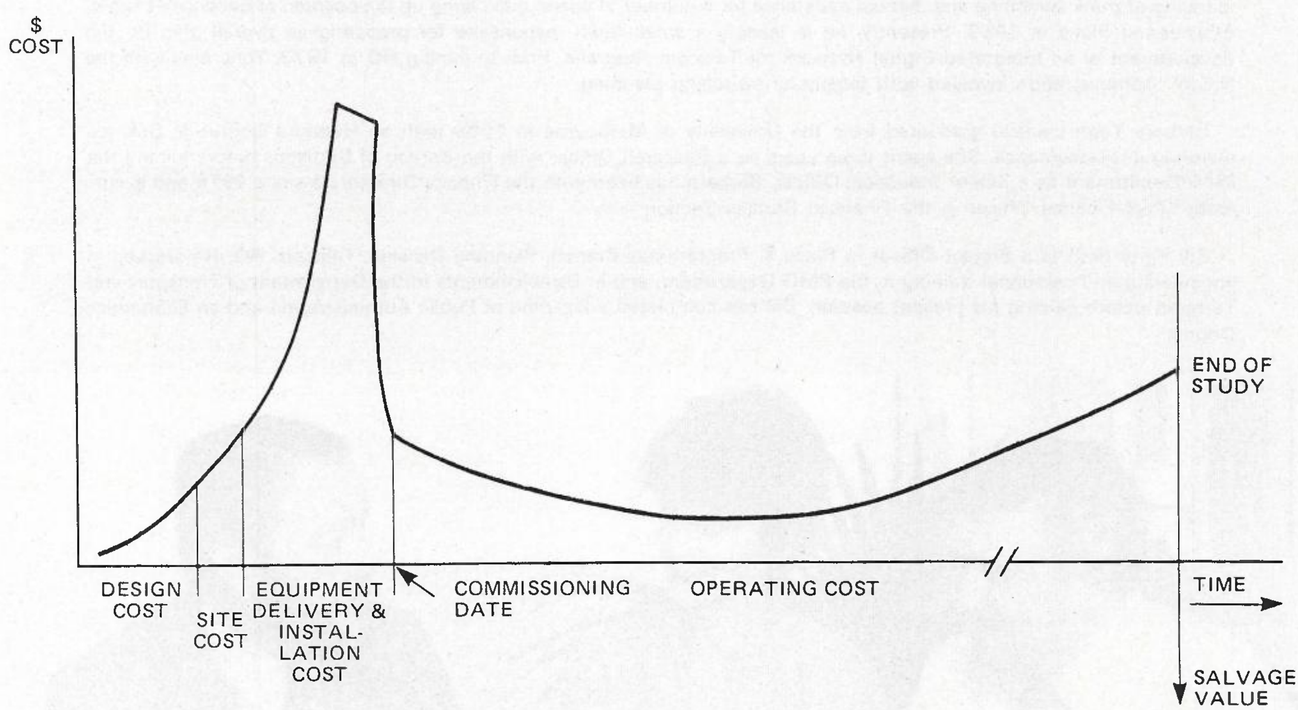

Fig. 1 — Project Costs viewed over project life

as the equipment is settled-in. As the equipment ages, operating cost can be expected to increase with time, until the end of the study period, or the retirement of the equipment, at which time the salvage value of the equipment may be relevant.

In Telecom the measurement and quantification of costs and benefits relates only to those effects which accrue to the organisation, as measured by cash outflows and cash inflows. This approach to defining relevant costs and benefits is analogous to the approach to economic evaluation adopted by private enterprise.

The wider net benefits which accrue to society as a result of telecommunications investment are not quantitatively assessed, as the Government, through its capital allocation processes, effectively values these benefits. Moreover, if these external benefits and costs were to be included in economic evaluations they would present significant conceptual and technical difficulties in terms of both definition and measurement.

Whilst all relevant costs and benefits should be considered in an economic evaluation, it is necessary to recognise that even with the exclusion of external benefits and costs, not all relevant factors can be expressed in monetary terms either before or after the investment has been made. Such factors are often referred to as intangible or notional costs or benefits.

Common Costs

For the purpose of a comparative study of exclusive alternatives, where it has been assessed that benefits are common to all alternatives, elements common to such projects may be ignored in the interest of completing the comparison simply yet effectively. Certain capital costs payable to manufacturers, contractors, or entrepreneurs for equipment items, sites, buildings, building security, fire or lightning protection, or operating costs which would occur irrespective of the alternative chosen, may be eliminated from a comparative study when common to the competing feasible alternatives. A deficiency of this method of eliminating common costs is that, while this effectively identifies the least cost alternative, it does not identify the total costs or the timing and scope of funds as they are employed in the project. Thus it makes it difficult to assess the extent of revenue or benefits required to provide a pre-determined return on capital, or to assess the profitability of such projects.

Delivery costs

Elements of delivery costs will be specific to some projects while others may be common to competing alternatives. Delivery costs from the manufacturer's store to the project site include intermediate storage and handling charges, and insurance charges if applicable. Dependent upon relative remoteness of sites, delivery costs reflect labour, overhead, and penalty charges, and the availability or otherwise of alternative or competitive transport modes.

Installation Costs

Subsequent to delivery to the site, handling costs such as unpacking, erecting in position, cabling, testing, commissioning and work supervision contribute to installation cost. Supervision is normally included in overhead costs, once such support costs are identified. However, a prototype installation may not have support costs fully identified, and specific allowance may have to be made for elements of what are normally classed as overhead costs.

Ancillary Costs

In addition to obvious capital costs, for some project

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Barbara Yeoh (centre) graduated from the University of Melbourne in 1969 with an Honours Degree in Science majoring in Mathematics. She spent three years as a Research Officer with the Bureau of Statistics before joining the PMG Department as a Senior Statistical Officer. Barbara has been with the Finance Directorate since 1976 and is currently Chief Finance Officer in the Financial Studies Section.

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alternatives there may be some substantial ancillary costs incurred. These typically include assigned maintenance aids, special tools, specific software requirements, costs of adaptive design, aesthetic treatment, environmental-effect studies, power conversion and distribution costs, provision of facilities for fuel storage and delivery, and air-conditioning equipment costs. These latter climate-control costs can be particularly dependent upon the technology adopted in fulfilling the project's specifications, and the type of building or shelter in which the equipment is housed, quite apart from ambient weather conditions.

Running Costs

Prospective running or operating costs must be taken into account in an investment evaluation. The type of technology, and the accessibility and dependability of components featured in the equipment of which the project is comprised may generate quite different running costs between alternatives. Such costs should be identified and assigned to the periods in which they are expected to be incurred, rather than assigned as equal periodic charges over the life of the project. As shown in Fig. 1, these costs typically increase as the equipment ages.

Labour Costs

Whenever possible, labour costs should not be capitalised, and it should be noted that they will differ according to the degree or type of skill required to undertake identifiable stages of a project. Further, the extent to which the technology involved is familiar to the staff engaged will affect project costs. Unfamiliar technologies may become the source of industrial disputation, in terms of appropriate organisational arrangements, demarcation problems, and appropriate remuneration. Minimisation of these latter costs will be dependent upon the efficiency of negotiations generally conducted by parties other than the project evaluators. Telecom has an industrial agreement intended to obviate such problems.

In Telecom, advice is given from time to time of current manhour rates to be used for the two types of engineering project labour used — technician and lineman rates. These rates do not differentiate amongst the various categories of staff available within those designations, but are set on a State-wide basis in relation to a standard price base. The rates assume a standard 1911 manhours availability per man-year, and include supervision and other relevant administrative overheads.

Once a project is actually completed, precise costing of a project can be made on a District basis, using manhours and wages actually involved. Precision of this order is not generally used in an economic comparison performed to assess project viability.

Sunk Costs

Sunk costs are past investments that cannot be recovered. The only portion of a sunk cost relevant to an economic study is that portion of the past cost which can be recovered as a result of disposal or de-commissioning. This recoverable cost will generally be reflected in the resale value or assessed salvage value, and credited to the outgoing project but debited to incoming proposal. The remaining portion of the past investment is regarded as sunk, and is irrelevant to the particular alternative under consideration. However, design costs incurred as part of preliminary systems design are not always a sunk cost, as they are a necessary part of any project development.

The advancement of future costs is a matter for consideration when a particular proposal makes use of spare capacity in existing plant, as spare capacity represents a sunk cost. In such cases the costs relevant to the proposal should include not only the immediate costs of making the spare capacity serviceable, but also any incremental costs involved in keeping the plant in service versus the cost of its idle status, and the cost of advancing the time when new capacity must be added because the spare plant has been used.

Opportunity Cost

Opportunity cost is an economic term which identifies the cost of an opportunity forgone through the employment of limited capital and resources in a competing alternative. The opportunity cost is represented by the return on investment forgone when capital is invested in one project to the exclusion of all other competing alternatives. Opportunity cost assessed in this way can be a measure of the minimum return required to justify investment in a particular project.

The term "opportunity cost" is sometimes applied in economic studies to reflect the use of an asset which could otherwise be leased or sold to an outside organisation. This is illustrated in the following example: a project proposal involves the dedication of an existing telephony circuit which could otherwise be available for lease to a customer. The cost of the circuit, although a sunk cost, should be charged against the project proposal at the periodic commercial rate which would normally apply to the circuit when employed as a leased line; the best feasible alternative.

Depreciation cost

Depreciation cost, sometimes called book cost, is in general not relevant to an investment decision. Depreciation is an accounting convention used to assign the capital cost of an asset proportionally over each year of its expected working life. This annual depreciation figure represents the contribution to the cost of the year's operations embodied in the use of the capital asset.

Intangible Costs

Most factors which need to be considered in an engineering economic study are capable of having their value assessed in monetary terms. A difficulty arises in those cases in which the values objectively assessed are unable to be monitored after the investment has been made, or where in some cases monetary values may or may not be capable of assessment until after the investment has been made. There are other factors associated with a project that may defy monetary evaluation, but must nonetheless be considered by management. Such factors are often referred to as intangible factors.

Intangible costs may typically include incremental travelling time and detrimental environmental factors such as noise of operation and aesthetics. However, intangible costs are generally insignificant compared with intangible benefits. The next article in this series will outline an approach which should assist in the assessment of net intangible benefits.

Salvage Values

The term salvage value, previously used in the discussion of sunk costs, is the cash inflow received from the disposal of an asset at the end of the project life. This cash inflow could be represented by a trade-in value, its scrap value, or its assessed worth to some other project within the organisation where specific re-use can be reasonably identified. Salvage values should be assessed net of any costs of removal, demolition, or de-commissioning.

Unequal plant lives

It would be convenient if all economic studies involved only the comparison of two projects with capital purchases being made in the same year, and with equal plant lines. The study period would be set equal to the economic plant life, and the comparison would be represented as shown in **Fig. 2.**

With telecommunications projects, two significant impediments to this technique appear:

- Telecommunications equipment typically has a very long life, generally greater than 30 years for telephone switching equipment. An economic study is rarely worth doing over such a protracted study period.
- Items of plant are often added during the life of the project. This means that there is no common end time for salvaged plant.

This propect raises the problem of deciding on the appropriate proportion to be charged to the project. In some cases the risks of technological obsolescence could lead to the decision to ignore the effects of the plant life beyond the study period. The likelihood of this outcome increases as the changes in large scale integration techniques impact on the price and availability of new products, and as the demand for new telecommunications products and services accelerates the need to adopt digital switching and transmission techniques in place of analogue methods. These changes tend to reduce the economic life of equipment and result in the total capital cost being charged to the project.

Where the proportional technique is decided upon, there are two basic approaches which are described in the literature:

- convert the capital cost into an equivalent annual charge over the expected economic life of the equipment; this charge being included in the project costs for each year that the particular item is used.

The annual cost can be pictured in different ways: e.g. as a hiring cost (as if the equipment had not been purchased) or as repayments on a loan which was obtained for purchasing the item.

- Determine a value for the item at the end of the study period and regard that value as a salvage value. In the simplest case this value would be the price of the equipment on the open market. A comparable case is the market value of a used car. Where this figure is available it should be used; where it is not available it must be estimated.

Of the two methods outlined above, the explicit recognition of a salvage value is to be preferred as it retains the cash flows (when money is spent) and can lead to a more realistic set of costs. The traditional approach has been to convert the capital cost into an equivalent annual charge. However, given the problems of inflation combined with the use in Telecom of a high discount rate to allow for capital rationing, the blind application of this approach can lead to unrealistic and misleading estimates of salvage values.

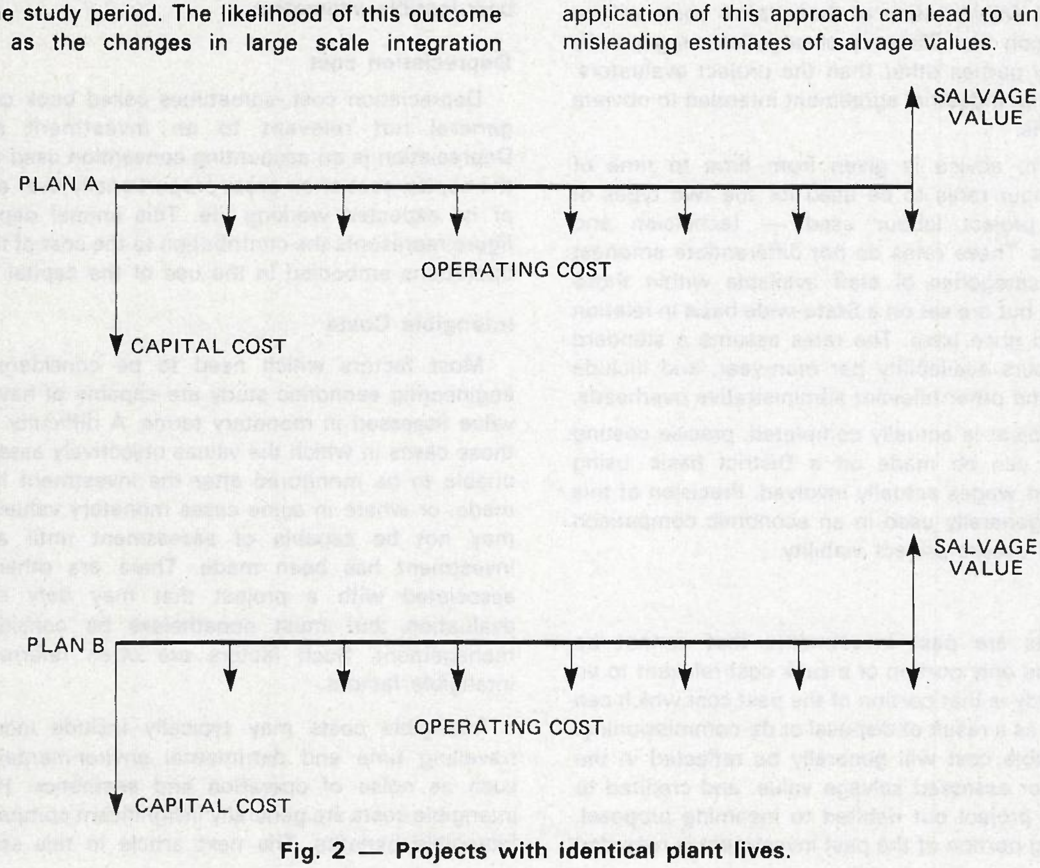


Fig. 2 — Projects with identical plant lives.

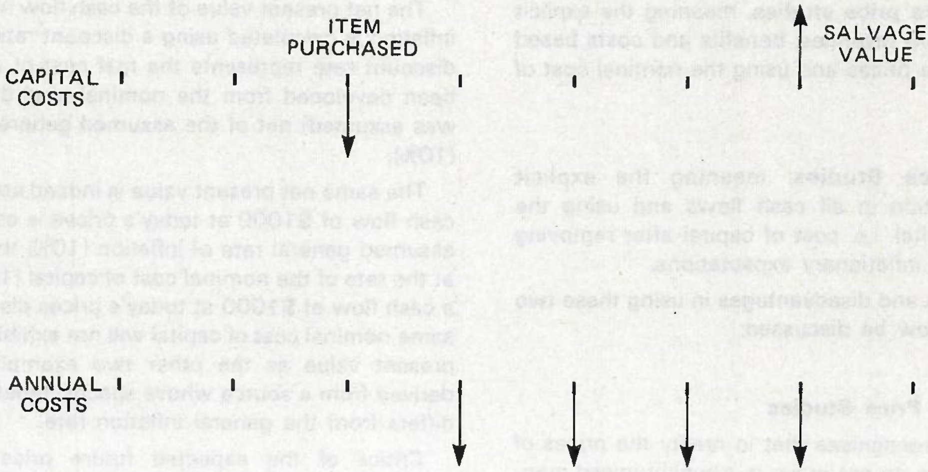


Fig. 3 — Capital cost and equivalent annual cost.

THE EVALUATION OF CAPITAL EXPENDITURES UNDER INFLATIONARY CONDITIONS

During the 1960s the general level of inflation in Australia averaged 2.5% p.a. and increased sharply to an average of 10.2% p.a. during the 1970s. A similar steep rise in consumer prices during the 1970s was also recorded in OECD countries as a whole. This situation is reflected in the general neglect of the problem of inflation in project evaluation until the 1970s.

Two types of inflationary situations can be distinguished in the context of an economic evaluation:

Synchronised inflation, meaning a situation where the movements in prices of all components of the cash flows, that is revenue, benefits and cost factors, are the same and in accordance with the general rate of inflation as measured by an appropriate index.

Non-synchronised inflation, meaning a situation where one or more of the conditions for synchronised inflation is absent.

Non-synchronised inflation is the norm and is illustrated in the comparison of movements in the Consumer Price Index (CPI) and Average Weekly Earnings (AWE) given below.

	1. Consumer Price Index %	2. Average Weekly Earnings %
1970/71	4.8	11.1
1971/72	6.8	10.0
1972/73	6.0	13.8
1973/74	12.9	16.2
1974/75	16.7	25.4
1975/76	13.0	14.4
1976/77	13.8	12.4
1977/78	9.5	9.8
1978/79	8.2	7.7
1979/80	10.2	9.4
1980/81	9.4	13.5

Sources: 1. ABS, Consumer Price Index, Cat No 6401.0
2. ABS, Average Weekly Earnings, Cat No 6302.0

The Consumer Price Index (CPI) is the generally accepted measure of overall inflation in Australia. However, movements in the CPI, both past and forecast, can conceal differential price movements relating to specific goods and services. The price level of a particular good or service may change with time for reasons other than general inflation, e.g. changes in technology or relative scarcity of the goods or services. In addition there are leads and lags in the system which also contribute to non-uniform movements in prices of goods and services.

Inflation impacts on the amount of working capital necessary to support a unit of production output as well as the cost of replacing plant and equipment. The extent to which revenue can be adjusted to compensate for factor price increases will impact on the profit margins obtained. The impact of inflation will vary between projects depending on the mix of capital, materials and labour consumed in the project, and the extent to which a compensating adjustment can be made to revenue.

DETERMINATON OF THE MINIMUM ACCEPTABLE RATE OF RETURN UNDER INFLATIONARY CONDITIONS

Inflation adds to the difficulties in estimating future cash flows. It also needs to be considered in determining the minimum acceptable rate of return for capital investments.

In a business enterprise the decision to accept or reject an investment proposal is generally measured against a weighted average cost of capital. Thus the cost of capital is influenced by the prevailing structure of interest rates. This in turn reflects the market perception of future inflationary trends. Similarly in the public sector, borrowing rates will be influenced by inflationary expectations so that the current cost of capital can be regarded as containing some allowance for prospective inflation. Hence it is not only unnecessary but also wrong to adjust the current cost of capital for future inflationary expectations.

RECOGNISING INFLATION IN ECONOMIC STUDIES

The two principal methods of recognising inflation in economic studies are:

Expected future price studies, meaning the explicit calculation of future revenues, benefits and costs based on expected future prices and using the nominal cost of capital.

Constant Price Studies, meaning the explicit exclusion of inflation in all cash flows and using the "real" cost of capital, i.e. cost of capital after removing the allowance for inflationary expectations.

The advantages and disadvantages in using these two approaches will now be discussed.

Expected Future Price Studies

This approach recognises that in reality the prices of goods and services do not move in a synchronised manner. It allows for the effect of these differentials in price movements to be reflected in the unique mix of capital, labour and materials for the investment proposal being considered.

It is sometimes argued that escalating the expected cash flows to account for inflation, then discounting those cash flows at the nominal cost of capital, are counterbalancing procedures. That is, in calculating the net present value, the discount rate effectively removes the inflation for which allowance had been made in the cash flows. Strictly, this will only be true when the inflationary component in the cost of capital equals the rate of inflation in the cash flows. The following example illustrates this point.

Assume a cash flow of $1000 p.a. at today's prices over ten years. Assume that the nominal cost of capital is 15%, the general rate of inflation is 10%, and the specific rate of inflation applicable to a particular cash flow is 12%. The cash flows under the unadjusted, 10% and 12% inflation rates are shown in columns one to three respectively, and have been rounded.

Year	1. Cash flow not adjusted for inflation rate $	2. Cash flow with general inflation rate of 10% p.a. $	3. Cash flow with specific inflation rate of 12% p.a. $
0	0	0	0
1	1000	1100	1120
2	1000	1210	1254
3	1000	1331	1405
4	1000	1464	1574
5	1000	1610	1762
6	1000	1772	1974
7	1000	1949	2211
8	1000	2144	2476
9	1000	2358	2773
10	1000	2594	3106
Discount rate	$100\left(\frac{1.15}{1.10}-1\right) = 4.5\%$	15%	15%
Net Present Value	$7895	$7895	$8672

The net present value of the cash flow not adjusted for inflation is calculated using a discount rate of 4.5%. This discount rate represents the real cost of capital, having been developed from the nominal cost of capital (15% was assumed) net of the assumed general inflation rate (10%).

The same net present value is indeed achieved when a cash flow of $1000 at today's prices is escalated at the assumed general rate of inflation (10%) then discounted at the rate of the nominal cost of capital (15%). However, a cash flow of $1000 at today's prices discounted at the same nominal cost of capital will not exhibit the same net present value as the other two examples when it is derived from a source whose specific inflation rate (12%) differs from the general inflation rate.

Critics of the expected future price approach to economic evaluation argue that reliable forecasts of the longer-term price increases in particular are difficult to obtain. Price forecasts therefore could be claimed to contribute to misleading conclusions.

Although it is recognised that longer-term forecasting can be particularly difficult, it should be remembered that forecasting errors in the longer-term are less critical than those in the short-term when discounted cash flow techniques are used. Further, equal changes in the cost of capital and price movements for all specific cash flow categories will have very little impact on the outcome of the economic evaluation as it is the difference between the rates that is critical, not the absolute level of the cost of capital or the specific price movements.

Sensitivity analysis based on various assumptions about specific price movements should be performed where there is some doubt about the price movement estimates used. In doing this however, it is essential to ensure that all inflationary assumptions for the various cash flows remain consistent with the general inflationary expectations incorporated in the cost of capital.

Constant Price Studies

The explicit exclusion of inflation in all cash flows assumes that inflation is synchronised. However, it will be readily admitted that this is not generally the case.

In addition, exclusion of inflation requires a "real" cost of capital to be used and assumes that the portion of the nominal cost of capital which represents the inflationary expectations of the market is identical to the general (forecast) level of inflation; this is not necessarily true. In fact the "real" cost of capital is generally considered impossible to determine. Government policies can also have an important influence on the relationship between costs of capital and inflation.

For some economic studies, costs such as lease payments may be fixed over the study period. Costs of this nature require adjustment in a constant price study.

Constant price studies were used prior to the 1970s, by tradition. They are even considered by some analysts as still being adequate for investment evaluation purposes, and preferred on the premise that they are computationally easier to undertake, and that they do not require specific price indicies.

Given the implications of the assumptions inherent in constant price studies, and the possibility that these implications can lead to an incorrect investment decision, arguments defending the use of constant price studies in today's environment are difficult to support. Respected forecasts of price indicies for various goods and services are nowadays generally available, as are many computational aids which make calculations of future price studies no more tedious than calculations for constant price studies.

SUMMARY

In this article, a broad outline of the costs likely to be encountered in economic appraisals of engineering projects has been given, together with a discussion of the constant versus future price level approach to estimating cash flows.

In Telecom, forecasts of the various escalation rates most likely to be used in economic studies are available, so that escalation factors, the discount rate, and Telecom's cost of capital are mutually consistent. By this means, all competing projects can be assessed on a common basis with respect to future price assumptions.

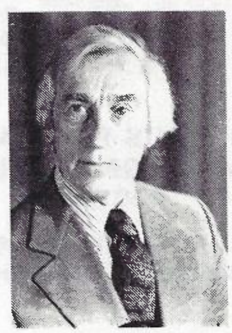
In the next article in this series a further discussion on intangible benefits and costs will be given. The article will also deal with aspects of sensitivity analysis and the assessment of risks, and will comment upon post-audit reviews.

ERRATA IN ARTICLE 1 - POINT 5 - PAGE 58

5. Internal Rate of Return Project D is ranked first, only marginally superior to A. However, the calculations for Projects A and D assume that the incremental cash flows generated could be reinvested at about 30% p.a. over the life of the project. This may not be realistic.

CHANGES TO THE BOARD OF EDITORS

RETIREMENT FROM THE BOARD OF EDITORS — LINDSAY MITTON



Lindsay Mitton has formally resigned from the Board of Editors, thus ending a long association with the Telecommunication Society; four years as Editor in Chief, during which time Lindsay enthusiastically furthered the objectives of the Society and for which the Council and the Board of Editors wish to record their appreciation. His considerable contribution has maintained the high standard of Journal material and presentation throughout his term of office.

THE APPOINTMENT OF I. B. MacKECHNIE TO THE BOARD OF EDITORS

The Board has been fortunate in that Mr I. B. MacKechnie has agreed to accept the vacant position created by Lindsay's retirement. Ian is presently Assistant Superintendent Engineer, Training, at Telecom's Headquarters and has been associated closely with the Society's activities over the last two years. In welcoming Ian, the Board wishes to thank Lindsay for his long continuous efforts in helping to produce the Journal.

Telecom's Capital Investment Policies and Practices

G.I. Cameron, B Bus(A/c), B Ec(Hons), Grad Dip A/c & Fin, AASA(Snr).

Telecom's investment policy has been developed to meet the need for rational and efficient capital project evaluation in a large, capital constrained, decentralised organisation. In an effort to balance competing demands for both social and commercial investment, a set of investment policies has evolved which best meets those needs at the present time. Investment policy is therefore a dynamic policy which must be continuously monitored to ensure it is meeting changing circumstances.

This article sets out the main policies adopted and rationales behind them, in order to ensure that there is consistent treatment of costs, benefits, inflation and other technical aspects of discounted cash flow evaluation. The continuous theme is that these are tools to assist decision making and they must be consistently applied across all projects in order to be efficient. The article also points out that the ultimate responsibility for selection of investment projects rests with decision makers who must weigh the quantifiable and non-quantifiable aspects of an investment decision.

INTRODUCTION

Telecom has adopted an investment evaluation policy and has set practices to assist its management in the matching of available funds with expenditure demands.

Under the Telecommunications Act, Telecom is required to meet from revenue all its current expenditure on costs such as wages, petrol etc. and at least 50% of its capital expenditure requirements. It therefore needs to generate profits which together with borrowings and retained earnings (i.e. depreciation), will pay for its capital expenditure.

Because telecommunications is a growth industry with high rates of technology change and demands for new and different services, there is a need for high levels of capital investment. This financial year, 1982/83, Telecom will spend some $1500m on capital works. The statistics in **Table 1** highlight the strong demand for service over the past 7 years of Telecom's existence and reflects the growing demands for capital expenditure funds.

- Telephone services in operation increased by 145%
- Local calls up by 146%
- Trunk calls up by 210%
- Telex services up 221%
- Data modems in operation increased by 615%
- Net value of fixed assets increased from $5461m to $8840m
- Annual Capital Investment increased from $747m to $1248m

Table 1 — Highlights — 1975/76 to 1981/82

Editorial Note: It is recommended that this paper be read in conjunction with the current series of papers being published on "Economic Analysis" as it provides a corporate overview to the other more tutorial texts.

If more money was available either from borrowings or revenue, then Telecom could spend more. However with restrictions on how much money can be borrowed and a desire to keep prices as low as possible, not all capital works can be undertaken, or undertaken at the size that would be liked. Investment evaluation assists in deciding which projects should be undertaken, when they should be done and how large they should be.

Telecom is obliged to make decisions which are commercially sound and generate economic benefit. It uses investment evaluation to rank projects which will maximise that benefit. (See Ref. 5).

FINANCING OPTIONS OF TELECOM

There are currently three sources of long term funds available to Telecom for financing its annual capital works programme. These are:

- Term borrowings which are available through the issue of semi-government bonds and subject to Loan Council approval.
- Internal funds consisting of trading surplus and provisions for depreciation and long service leave. In contrast to many other public authorities the minimum level of internal funding is stipulated in the Telecommunications Act. This requires Telecom to raise at least 50 per cent of its capital requirements from internal sources.
- Retained employer contributions in respect of accruing superannuation liability.

Table 2 shows the approved sources of long term funds and the estimated level of internal funds needed for financing Telecom's capital works programme this financial year.

Telecom must answer to the Government for its investment actions in the same way as any private company is responsible to its shareholders. However, the government also has macroeconomic and social responsibilities to consider when approving Telecom's

	$M	%
Borrowings on Domestic Market	204	14
Internal Funds	1173	79
Retained Provision for Superannuation	106	7
TOTAL SOURCES	1483	100

Table 2 — Sources of Funds 1982/83

borrowing levels, retained employer superannuation liability, and changes in basic tariffs.

Taken together, these factors generally place constraints on the level of funds Telecom can obtain and particularly careful consideration must be given to the timing and scope of capital expenditures in Telecom.

ECONOMICS AND THE INVESTMENT DECISION

While emphasis is given in Telecom's policy to the economic factors, these are not necessarily the only factors management considers in selecting or rejecting alternatives or projects. The type of project determines the emphasis placed on these other factors such as technical standards, resource availability, customer requirements and community social benefits which impact on proposals.

Briefly before examining some of Telecom's policy and practice it would be worthwhile appreciating the standard textbook approaches and what private firms do in this area.

Standard Approach

A standard approach to capital investment evaluation would require use of an appropriate cost of capital reflecting a company's cost of funds, that is the price it has to pay for funds, both equity and debt. All proposals for investment would be ranked on a net present value basis and a company would undertake all projects which generate a positive net present value. (See **Fig. 1**).

For example, under this method if there were 4 projects in which to invest then the present value of their future costs and benefits would be calculated. That is, each project's costs and benefits would be brought back to a single dollar value at today's prices. Then only those projects that had a positive present value, ie, A, B and C, would be undertaken.

Project A = +$12,000 PV
Project B = +$6,000 PV
Project C = +$ 0 PV
Project D = -$1,000 PV

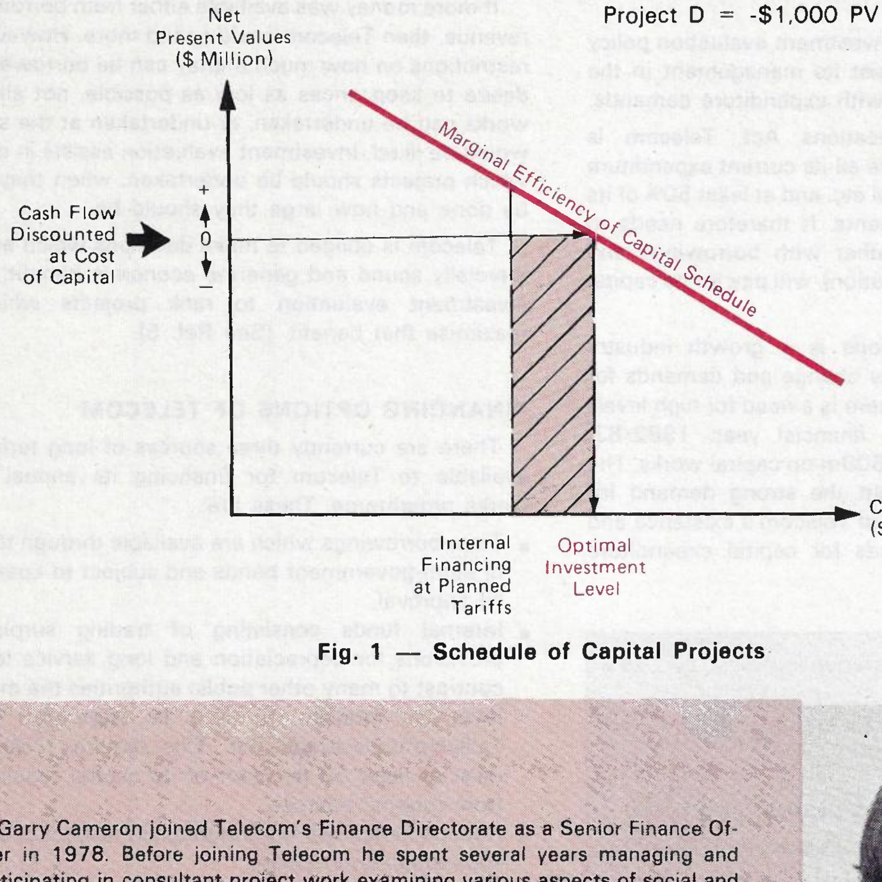


Fig. 1 — Schedule of Capital Projects

Garry Cameron joined Telecom's Finance Directorate as a Senior Finance Officer in 1978. Before joining Telecom he spent several years managing and participating in consultant project work examining various aspects of social and economic policy of the Australian Housing Industry with the Department of Environment, Housing and Community Development. He has also held various other positions in administration, budgeting and programming, supply and audit.

Mr Cameron is presently Manager, Financial Studies in the Finance Directorate, Telecom Headquarters.

In a text book approach, money would be borrowed if necessary to undertake A, B and C, as long as the discount rate used to derive the present values reflected the cost of any additional borrowings required to implement the projects.

The above method is a general outline of the discounted cash flow technique which is described in more detail in Ref. 5.

Survey of Practice

A Survey of Australian private sector practice on investment policies in 1976 indicated that of the respondents, about 60% of larger firms use discounted cash flow techniques. This compares with US survey results of 57% in 1973 and 80% in 1978.

From the US results, it is interesting to note use of the various techniques. (See glossary for explanation of terms).

In the US survey: 74% of the sample used payback
65% used rate of return (ROR)
56% used net present value (NPV)
80% used ROR or NPV or both

Telecom used at that time (and still uses) net present value, rate of return and the present value index.

The recognition of inflation in evaluations is also of interest. Telecom policy prefers the explicit recognition of inflation where it may be relevant to the decision. However, in the Australian survey only about 30% of large private sector companies were found to use non-synchronised inflation; i.e. explicitly recognise rates of inflation specific to each element of the cash flow. This is the same proportion as in the US.

TELECOM CAPITAL INVESTMENT POLICY

Telecom's policy has been framed to recognise those particular elements of its operating environment which preclude it from adopting the standard approaches, these are its size and decentralised management, the number of projects involved and its relative capital shortage.

Telecom employs approximately 89,000 people throughout Australia with capital investment decisions being made at Headquarters, seven State Head Offices and more than 80 Districts.

To be an effective tool of management, Telecom aims for its capital investment policy to impact on as many decisions as possible. This means coming to grips with the many relatively small investment decisions undertaken by local management (where the bulk of capital investment decisions would be taken) as well as the large and discrete projects which can be more readily isolated and examined by top management.

It is estimated that each year Telecom is involved with about 18,000 capital investment decisions. If they were to be examined, reviewed and ranked by a central group of analysts, it would probably require at least 380 man years of effort each year.

Another aspect to consider is Telecom's overall shortage of funds, and limited availability of other resources such as skilled staff. Telecom's financial constraints emanate from its limited access to borrowed funds via the Loan Council (which for macro-economic reasons have been limited for Telecom) and to the sensitivity of the community to large tariff increases.

Main Elements of Telecom's Investment Policy

The Discount Rate

With the above in mind, Telecom has adopted discounted cash flow techniques utilising a capital rationing discount rate (or hurdle rate) which incorporates a margin over the cost of new capital. Such a discount rate reflects both the opportunity cost of projects not undertaken due to the overall shortage of funds and Telecoms financial objectives regarding return on new investment.

Search for Alternatives

Each study should include as a first step, a thorough search for alternatives. Where feasible alternative approaches exist they should be costed and compared. In other words, staff are encouraged to think of alternative ways of achieving certain outcomes and comparing them.

Quantify Costs and Benefits

Where possible, studies should identify and quantify both costs and associated benefits. This is particularly necessary when the study considers "discretionary" investments, i.e. investments involving a clear option to invest or not invest. The aim here is to induce decision makers to look not only at the least cost solution to any investment problem but also to take account of benefits which may arise through that investment. In this context, it should be noted that all projects are to some extent discretionary, even essential work is discretionary with respect to timing, scope and size of project.

Recognise Relevant Costs and Benefits

Studies should include all relevant costs and benefits. A relevant cost (benefit) is defined as a cost (benefit) which is sensitive to, or affected by, the decision to proceed with a particular investment. Obviously, if an investment creates additional work for another area then those costs should be recognised. Similarly for benefits, as long as they relate to the specific investment action.

Account for Inflation

Telecom prefers studies to recognise future inflation. However, where the investment is a small one then a quick study that does not require the recognition of inflation, i.e. constant prices, should be sufficient. This policy obviously points to a need to balance the amount of investment analysis effort with the importance and scope of the project.

Calculate both NPV and ROR

Both the net present value and rate of return are to be calculated and used in the decision making process when costs and benefits are identified. Where the selection between alternatives is made difficult by the closeness of results, then economic ranking of alternatives should be based on the present value index.

In non-discretionary investment studies where only the costs of the various alternatives are identified and a least cost solution is required then either the net present value of those costs or their equivalent annual value may be calculated and used for decision making.

Undertake Sensitivity Analysis and Risk

Studies should incorporate sensitivity analysis to assist in the decision making process. Sensitivity analysis provides some assessment of the risks and penalties under changed assumptions, ie it provides answers to "what if . . .?"

DISCUSSION ON TELECOM'S INVESTMENT EVALUATION PRACTICES

Constant Prices versus Future Prices

Comparatively little attention has been given in academic literature to the problem of how to allow for the effects of inflation in discounted cash flow evaluations. As a result of this neglect, practice often reflects confusion. Frequently the problem is simply ignored as though no inflation were expected, presumably on the grounds that inflationary effects are counter-balancing. On the other hand some prefer an approach which attempts to escalate costs and prices on the basis of assumed rates of inflation.

For the purpose of demonstration it is useful to compare two simple situations. Firstly, where a least-cost decision is made on the basis of constant prices, (by which I mean that expected future cash flows are expressed at today's prices) and secondly, on the basis of expected future costs in a non-synchronised inflationary situation (ie where prices of components of the cash flow are expected to increase at "component specific" prices of inflation).

Reference is made to the calculations in **Tables 3 and 4** which consider the problem of selecting between two machines which produce the same output. Machine XY has a lower capital cost but requires significantly more monitoring and repair when compared with machine AB.

For simplicity, assume that both machines have an equal life of 6 years and a nil salvage value at the end of that life. As the benefits or cash inflows from the investment will be the same, a decision may be made on the basis of least-cost expressed in present values.

In the constant prices approach, machine XY is preferred as the least cost alternative. When inflation is introduced into the ongoing annual operating costs, machine AB becomes the preferred solution.

The example demonstrates the selection bias that can be incurred if inflation is not reflected in the analysis. Although the differences in NPV's in this small scale example are not large and the selection could be claimed to be indifferent, it can be appreciated that when looking at large scale projects where investments of hundreds of thousands or millions of dollars are involved, then the differences become critical.

It is sometimes claimed that non-synchronised inflation approaches are unrealistic because of the degree of risk in forecasting inflation correctly.

Telecom's approach reflects the view that it is not significant to the selection result if the numeric forecast is incorrect as long as the relative price movements

MACHINE XY

Year	Capital Cost	Labour	Material	Net Cash Flow
0	10,000	—	—	10,000
1		2,000	500	2,500
2		2,000	500	2,500
3		2,000	500	2,500
4		2,000	500	2,500
5		2,000	500	2,500
6		2,000	500	2,500

Present Value of all Costs at 15% Discount Rate = $19,461

MACHINE AB

Year	Capital Cost	Labour	Material	Net Cash Flow
0	17,000	—	—	17,000
1		200	100	300
2		200	100	300
3		200	100	300
4		1,000	300	1,300
5		1,000	300	1,300
6		1,000	300	1,300

Present Value of all Costs at 15% Discount Rate = $19,636

NOTE: 15% is the discount rate reflecting a constant prices cost of capital (ie inflationary expectations excluded) plus capital rationing.

Table 3 — Least Cost Calculations — at Constant Prices

MACHINE XY

Year	Capital cost	Labour	Material	Net Cash Flow
0	10,000	—	—	10,000
1		2,300	540	2,840
2		2,645	583	3,228
3		3,041	630	3,671
4		3,498	680	4,178
5		4,023	735	4,758
6		4,626	793	5,419

Present Value of all costs at 28% Discount Rate = $20,112

MACHINE AB

Year	Capital Cost	Labour	Material	Net Cash Flow
0	17,000	—	—	17,000
1		230	108	338
2		264	116	380
3		304	126	430
4		1,749	408	2,157
5		2,011	441	2,452
6		2,313	476	2,789

Present Value of all costs at 28% Discount Rate = $19,852

NOTE: 28% is the discount rate reflecting expected future prices (ie inflationary expectations included) plus capital rationing.

Inflationary expectations assumed for this example
— labour 15% pa
— material 8% pa

Table 4 — Least Cost Calculations — at Expected Future Prices

between components in an analysis are reasonably accurate. A constant prices approach implicitly assumes that all costs will be affected by inflation to the same degree; reality proves them not to be so. Therefore it is better in some respects to take an educated guess and come to grips with reality than to do nothing. In this context, Telecom provides forecasts of inflation factors to be used in investment evaluation and these are updated annually in the booklet "Guidelines for Investment Evaluation" issued by the Finance Directorate.

Sensitivity and Risk Analysis

There is a need to consider another element in the overall decision-making process, and this is the consequence of being wrong. Since investment analysis in expected future prices is dealing with forecasts and projections it is certain that there will be some degree of error and the consequence of error has to be assessed. The risks associated with being wrong are often not quantified and they certainly are not symmetrical. In other words, if the project performs better than expected there is little risk to the organisation compared to it performing badly. Therefore, analysis of the consequences of being wrong is needed in order to identify the key risk variables for monitoring, while the project is being implemented.

Relevant Costs and Benefits

Telecom's investment evaluation policy required that studies should include all relevant costs and benefits. A cost or benefit is considered relevant only if it occurs due to the investment expenditure , or conversely, would not have occurred if that capital expenditure had not been made.

In Telecom the measurement and quantification of costs and benefits relates only to those effects which accrue to the organisation, as measured by cash outflows and cash inflows. This approach to defining relevant costs and benefits has been commented upon by some as being too harsh. However, it needs to be remembered that the policy has been developed to meet Telecom's needs at a particular stage of its history and should be compared to a private enterprise approach rather than a public sector type of analysis.

The wider net benefits which accrue to society as a result of telecommunications investment are not quantitatively assessed by Telecom, as the Government through its capital allocation processes effectively values these benefits. Moreover if these external or society benefits and costs were to be included in economic evaluations they present significant conceptual and technical difficulties in terms of both definition and measurement.

Whilst all relevant costs and benefits should be considered in an economic evaluation it is necessary to recognise that even with the exclusion of society benefits and costs, not all relevant factors can be expressed in monetary terms either before or after the investment has been made. Such factors are often referred to as intangibles or notional costs and benefits.

Tangible benefits typically relate to labour savings which are able to be realised and reflected in actual monetary savings. For example, staff become involved with other projects or types of work activity and can be charged out elsewhere, or costs such as overtime and excess travelling etc. are reduced. Telecom has established guidelines to assist in identifying achievable labour savings and some of the main elements are as follows:

A labour saving is said to be achievable if it can be shown that a time saving may lead either to:

- a reduction in staff on a particular task; or
- a deferment of staff growth; or
- allow additional or substitute activities to be undertaken. In this case the new activities would have to be essential in that they would normally have received resources in Telecom's Manpower Plan.

Intangible or Notional Benefits

Notional savings are those for which it is not possible to indicate whether or how the savings may be realised in practice.

As an illustration of this, the proposed relocation of a depot may result in a reduction in congestion time (vehicle travelling time) of 10 minutes per day per employee, which when extrapolated to the total number of staff affected per annum, will create a significant labour saving. However, it may not be possible to monitor or quantify in monetary terms how the time saved by each employee is utilised. Unless an actual reduction in staff or increase in productivity occurs which can be reflected in increased efficiency such as more faults cleared etc., then the reduction in congestion costs should be considered an intangible benefit.

However, this is not to say that the reduction in congestion costs is not relevant. Although the policy defines that intangible benefits are not part of the 'hard nosed' economic evaluation, they can influence a decision. If for example it was considered that a reduction in vehicle congestion would improve morale and reduce existing safety hazards then these non-quantifiable factors would be communicated to management, together with the results of the economic study.

Other examples of intangible benefits include enhancement of various standards, e.g. improved customer satisfaction, increased job satisfaction, increased accuracy. These types of intangible benefits typically relate to the qualitative aspects of operations, particularly in the customer interface areas and are to be taken into account in addition to the results of an economic evaluation of an investment.

Post-Implementation Reviews

Whilst discounted cash flow techniques are used to evaluate capital expenditure decisions in Telecom, project evaluation does not necessarily end there. To supplement management control and monitoring during implementation, post-implementation of a capital expenditure will be required in the future to complete the information and decision-making cycle in project evaluation.

The prime objective of a post-implementation review is to evaluate the success or otherwise of an investment decision, although other objectives might include:

- the identification and analysis of any problems encountered during the development, implementation and early life of a project and the subsequent recommendations for corrective action in order for the full potential of a project to be realised; (such an objective is particularly beneficial where staged development and implementation of a project is being undertaken).
- to obtain information which will benefit the investment evaluation and planning of future capital expenditures;
- to evaluate management's abilities to formulate investment decisions through to their final implementation and control.

Such objectives aim not to criticise or emphasise what might have been done differently in the past but to indicate how things might be better done in the future. Additionally, they could assist in highlighting changes in organisational structure which will assist in the achievement of goals set by the organisation.

The selection of appropriate objectives would be dependent on the type of capital expenditure being undertaken. Considerations would generally include the strategic importance of the project to the organisation, and the likelihood of similar projects being undertaken in the future.

Although Telecom's existing policy recommends post-implementation reviews for large or strategic projects this should not inhibit the conduct of reviews across a broader range of smaller capital expenditures.

SUMMARY

Capital investment decision making involves many tangible and intangible factors, therefore the purpose of an economic evaluation is to summarise the tangible factors into a digestible and understandable form. The objective in establishing policy guidelines and instructions is to provide managers with tools that will assist them in making capital expenditure decisions within the capital budget requirements.

The problem of capital rationing is a complex one. A decentralised management structure and a mixture of discretionary and non-discretionary communication services add to the problem of capital expenditure decision making within Telecom.

Changes in the relative costs of various elements of labour, capital and materials reflected in different rates of relative inflation also influence future investment decisions. Telecom prefers to recognise the impact of inflation on different mixes of labour and materials in projects by undertaking its economic evaluations in expected future prices.

Finally, capital investment evaluation is seen as extending beyond the initial valuation and selection of projects based on discounted cash flow methods and the recognition on non-economic factors. The introduction of post-implementation reviews is seen to be an important and integral part of project evaluation. Not only can they provide useful information for the planning of future capital investments but they can also identify deficiencies or limitations in the current investment evaluation policies.

REFERENCES

1. Finance Directorate, Telecom Australia "Guidelines for Investment Evaluation" Issue 4, August 1981.
2. Personnel Department, Telecom Australia "Labour Savings in Investment Evaluation — Guidelines" July 1980.
3. Gena Fawns, "The Use of Investment Evaluation Techniques by Australian Industry", unpublished thesis, Melbourne University, 1976.
4. Rosenblatt M.J. and Tucker J.V., "Capital Expenditure Decision Making: Some Tools and Trends" Interfaces, Vol. 9, No. 2, February 1979.
5. Jessop, C.W.A., Yeoh, B.M., and Parry, C.W., "Economic Analysis — Principles and Problems", Telecom Journal of Australia, Vol. 33, No. 1, 1982.

GLOSSARY OF TERMS

Cost of Capital

The cost of capital is defined as the cost of new capital to Telecom, that is, the current average rate of interest payable on new borrowings by Telecom together with the costs associated with raising capital from the public and operating a stock registry.

Payback Period

It is the ratio of the initial capital investment over the annual cash inflows. The annual cash inflows are accumulated until they equal the initial capital investment, the resulting number of periods of net cash inflow required to recover the investment is the payback period. The major shortcomings of the measure are its failure to take account of the time value of money and to consider the relevance of cash flows after the payback period.

Discount Rate

A discount rate is an interest rate used to convert a series of cash flows to their present values. Not only can it reflect the cost of funds but also elements of risk and capital rationing.

Present Value

The present value of an investment is the amount of money which if invested today at a given interest rate would yield a particular future value over a given period of time.

Alternately, it is the value today of a future benefit or cost discounted at the appropriate interest rate.

Net Present Value

The net present value is the difference between the summation of the present values of the benefits occurring from an investment and the summation of present values of the costs incurred over the life of the project or investment.

If the net present value is equal to or greater than zero a proposal would be acceptable if it has been discounted at the required rate of return. In comparing between alternatives, the one with the highest positive or least negative net present value would be selected.

Equivalent Annual Value

A method for comparing unequal life projects by converting cash flows to equal annual amounts by use of discounting techniques.

Return on Investment (Internal Rate of Return)

The internal rate is the rate at which capital earns while it is invested in the project. It is the discount rate which equates the present value of expected cash outflows with the present value of expected cash inflows.

Rate of Return

Rate of return is a measure of profitability of an investment. It is often used as a measure of the acceptability or otherwise of a project.

Present Value Index

A ratio of the present value of cash outflows to the present value of cash inflows.

New Products

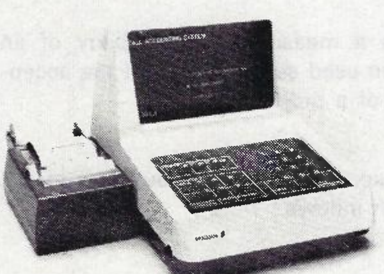
This listing is compiled from paid advertising and does not represent a recommendation by the Society. If you desire to have your product listed, contact the Advertising Manager.

AN "UNBUNDLED" PABX

A new highly flexible PABX telephone exchange designed for a wide range of small to medium business applications has been released to the Australian market by Ericsson Information systems.

Ericsson has re-designed its low-end ASB 30 system and "unbundled" the product to include a call accounting software option. The "unbundled" system provides low coast/high performance benefits previously only available to large organisations.

The Ericsson ASB 30 computer processor controlled PABX is a fully integrated system featuring an easy-to-use operator's console coupled to a wide selection of software options to meet varying small business requirements.



A significant advancement with the "unbundled" ASB 30 system is the facility for a customer to select a software and hardware package to suit the precise telecommunications needs of the business.

The new ASB 30 retains its successful hardware operational capacities of up to eight exchange lines and from four to 32 extensions. In addition, the system now offers a "call accounting" option which enables users to accurately monitor extension phone charges, a particularly useful application in the motel/hotel industry.

Built into a console not much larger than a telephone, the call accounting system connects to the ASB 30 central processor to extract details of each extension's external calls. Through a small integrated printer, the operator can determine information such as number called, time and date, plus the total cost whether it be a local, STD or an ISD charge.

The system is entirely automatic requiring no operator supervision unless a print-out is needed. This is supplied in a variety of formats to meet the specific customer application.

The Ericsson "call accounting" option was developed in Australia and is manufactured locally using the latest integrated circuitry and microprocessor engineering. The system is also available for larger Ericsson ASB PABX-s.

The ASB 30 system is now available with 23 standard extension facilities, 25 operator facilities and 10 optional extension facilities.

Among the extension options are such time saving facilities as "last number re-dial" which enables a user to instantly place a number into the system's memory for dialling at a later time by using a single digit code; and a "call back on a busy exchange line" facility to enable an extension to gain access to an external line as soon as one becomes free.

The ASB 30 offers for the first time on a small PABX, the type of cost-efficient features required to meet the demands of modern businesses.

A unique design feature of the ASB 30 system is its console — compact, unobtrusive and ergonimically effective.

Operator efficiency and the flexibility of the system for extension users capitalises on the need to streamline office systems and maximise profitability.

CONTACT: Laurie Gasper, Ericsson Information Systems, 202 Bell St., Preston, 3072. Telephone (03) 480 4888.

NRMA COMMISSIONS NEW PLESSEY RADIO SYSTEMS

The NRMA has commissioned a new mobile radio system for its 350 road service patrol vans servicing the Sydney metropolitan area.

Supplied by Plessey Australia, the mobile radio system incorporates data transmission facilities and is designed to improve the service response to NRMA members' breakdown calls.

Details of calls for assistance are entered into a central computer system and instructions are radioed to the appropriate patrol vans.

Messages from patrols are directed through an interface to the main computer.

The system has six base stations in strategic locations in the metropolitan area.

The selection of the Plessey ultra-high-frequency mobile radio and associated data transmission equipment for the service, was based on requirements for reliability, local back-up and data processing techniques that readily interface with the association's main computer at the NRMA's road service headquarters at Villawood.

The system also incorporates an emergency alarm in case of an accident by the patrolman while servicing a member's vehicle.

This alarm system is designed to alert the supervisors at the operations centre, who can then send assistance.

Issued by: Plessey Australia Pty. Limited, Telecommunications Division, Meadowbank, NSW
Through: Eric White Associates, Sydney, NSW
Contact: Ian Ingleby — 231 3300.

Network Automatic Call Distribution System

J. T. WILSON, BE, Dip Eng, A.K.K. FUNG, BE, M Comm, C Eng, MIEE.

Telecom Australia's manual assistance services are to be provided with automatic support systems to improve their efficiency and customer service. This paper describes the Network Automatic Call Distribution system which will provide call queueing facilities to the new Service Assistance and Directory Assistance Services, its enhancements and its integration into Telecom Australia's switched telephone network.

MANUAL ASSISTANCE MODERNISATION

Significant modernisation of Telecom's manual assistance services is to be undertaken during the 1980s with the implementation of modern computer systems for both traffic and information handling. The implementation of new traffic handling systems to queue calls for the Directory Assistance Service (DAS), and Service Assistance (SA) has commenced and the initial program is planned for completion by 1985.

The basic strategy is to centralise the directory assistance and service assistance traffic to large centres and evenly distribute it to available operators in both metropolitan and country Manual Assistance Centres (MACs) (see **Fig. 1**) where access to appropriate computer based information systems is obtainable via visual display terminals.

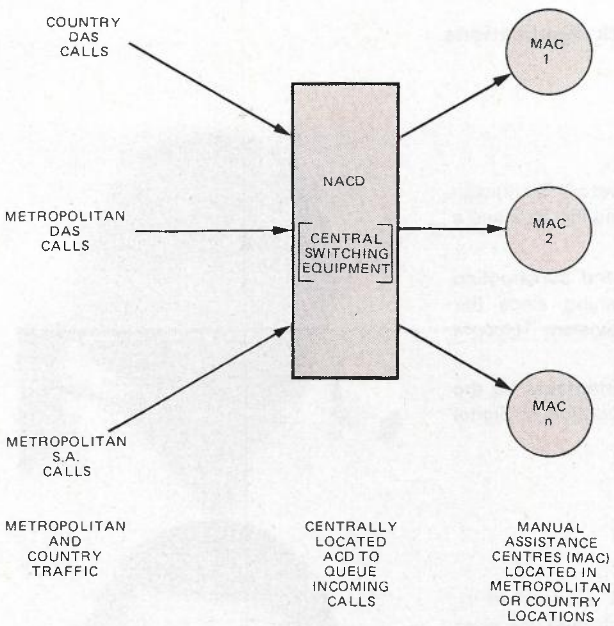


Fig. 1 — Centralised Traffic and Distributed Operator Positions.

The traffic volumes generated by traffic centralisation, in combination with the use of modern technology, will reduce capital expenditure, improve operator productivity and efficiency and contain the rapid growth of operator numbers. The new systems will also provide a means to retain operator employment opportunities in country areas, which would otherwise be lost as the rural network is automated.

AUTOMATIC CALL DISTRIBUTION (ACD) SYSTEMS

ACDs are primarily designed as customer switching systems to connect large volumes of incoming traffic to a large number of operators who are employed for the purpose of answering incoming calls. These systems are used by large organisations such as airlines, taxis, newspapers, betting agencies and service authorities such as gas, electricity, police and so forth.

When calls are received by the ACD they are automatically connected to a free operator, if one is available, otherwise the call is placed in queue until an operator becomes free. Operators can be formed into specialist groups to handle particular types of calls.

The larger ACD systems normally provide a number of incoming call queues, each of which can be assigned to a different incoming call code. A number of operator queues are also provided, each of which can be assigned to specific incoming queues. Calls from the incoming queues are generally switched in arrival sequence to the longest waiting operator in the allotted operator queue.

NETWORK APPLICATIONS FOR ACDs

ACDs are to be utilised to queue calls for the Directory Assistance Service, metropolitan Service Assistance and Phonograms, in some States, and to distribute these calls evenly to dedicated operator groups, which can be spread over a number of locations. These ACDs are to be integrated into the switched network and will be known as Network Automatic Call Distribution (NACD) systems. The service codes to be trunked to the NACD are shown on **Table 1**. The basic NACD application and interrelationships to other systems is shown in **Fig. 2**.

SERVICE	CODES
DAS	013, 0175, 0170, 0143*, 0144* (* from overseas operators)
SA	1100 (metropolitan only), 15xxx (operator enquiries)
Phonograms	015, 0174, 0177

Table 1 — Service Codes to be Trunked to the NACD.

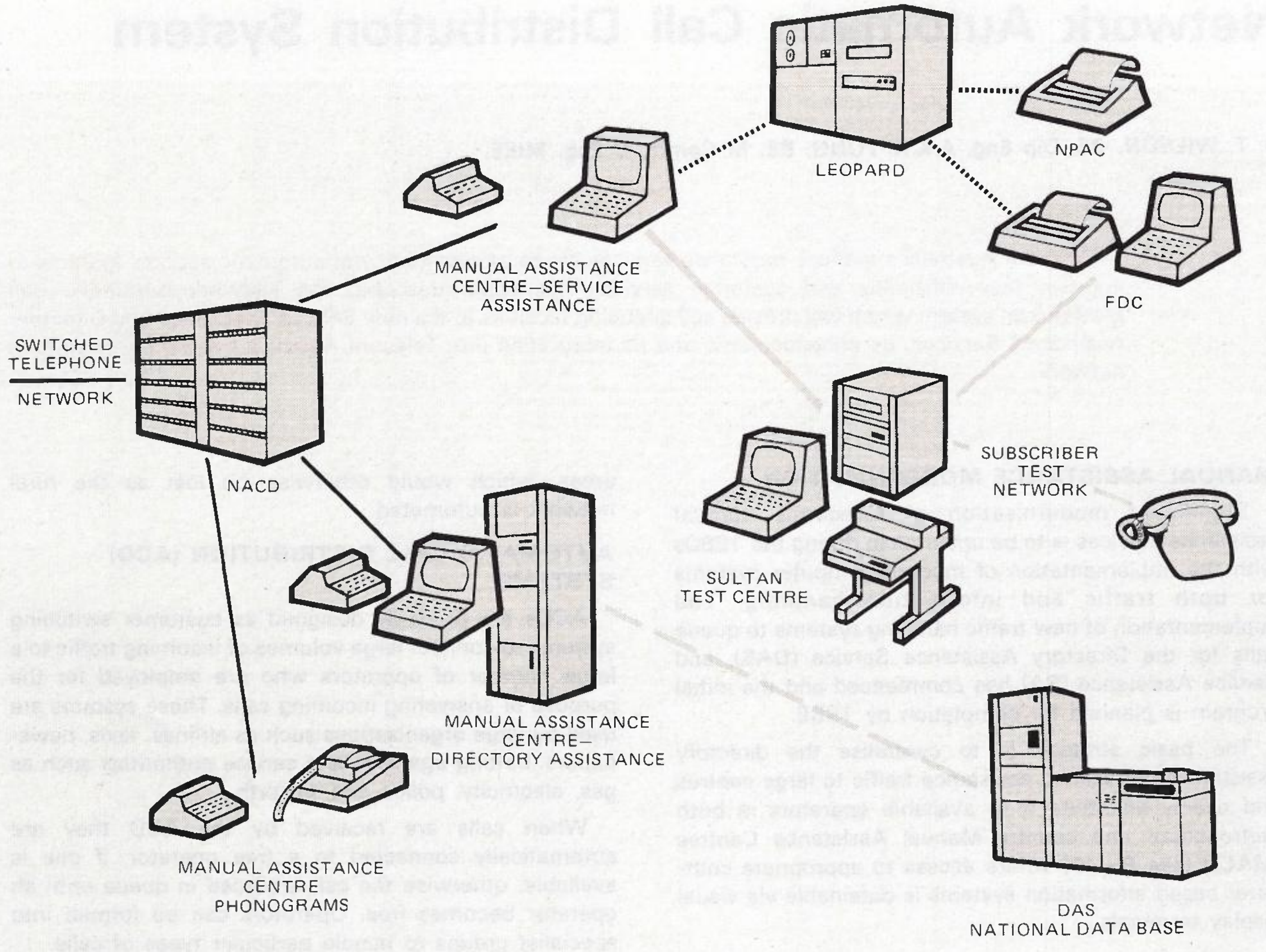


Fig. 2 — ACD Network Applications.

Julie Wilson commenced her career with Telecom as a Laboratory Technician and advanced to Engineering, obtaining a Diploma of Engineering in 1973 and a Degree of Engineering in 1974.

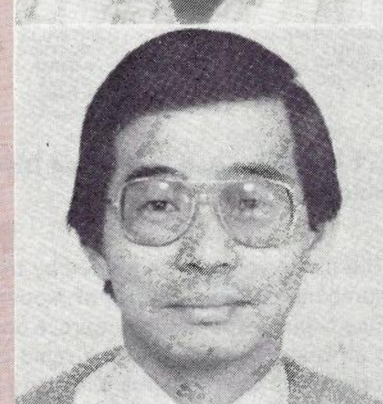
She has since gained experience in telephone switching and construction planning fields and has been responsible for NACD planning since her appointment to the position of Senior Engineer, Planning Division, Telecom Headquarters.

She is currently employed on the specification of PABX interfaces to the switched telephone network, and the investigation and specification of digital signalling systems.

Andy Fung joined the APO in 1974 as an Engineer Class 1. He worked in Services and Design and Practices Branch of the NSW administration. He was involved in the design of a microprocessor based centralised cable protection system, and was the microprocessor co-ordinator in NSW.

In 1979 he was promoted to a position of Engineer Class 3 with the Switching Design Branch, Telecom Headquarters, based at Parramatta.

He was involved in the evaluation of SPC PABX's and ACD's and since 1981 has been with the NACD project and its National Support Centre to support field installation and operation.



Service Assistance (SA)

Service assistance is currently a labour intensive service which uses manual recording and filing methods and a variety of subscriber testing networks to determine subscriber line, instrument and network faults. Certain features of this service are being automated to provide a more accurate and efficient service to the customer and to reduce operating costs (Ref. 1).

The features of this new service are:

- queueing of subscriber calls on the NACD;
- an information system called LEOPARD (Local Engineering Operations Processing Analysis and Recording of Data) to provide immediate and direct access to customer records and fault reporting facilities; and
- a new national testing network called SULTAN (Subscribers Universal Line Test Access Network) to provide SA operators with the means to verify whether a customer's line is operational or faulty.

Directory Assistance Service (DAS)

Directory assistance currently employs paper records for the retrieval of directory information. This system is labour intensive and has inherent difficulties, such as the maintenance of accurate updated records and the ability to handle a rapidly increasing volume of calls. The look-up and retrieval functions are being automated to improve customer service and reduce operating costs (Ref. 2-4; 7 and 8).

The features of this new service, known as DAS/C, are:

- queueing of customer calls on the NACD;
- a national directory assistance computer data base to replace the current paper records; and
- a national computer network with individual operator access to the data base using a visual display terminal. The computer network will be supported by a national data update centre to maintain accurate and up to date records.

THE NETWORK AUTOMATIC CALL DISTRIBUTION SYSTEM (NACD)

The ACD selected for Telecom Australia use is LM Ericsson's ASDP162 (Ref. 5).

This ACD provides a four level operating hierarchy:

1. Operators, in groups of 12, to answer incoming calls.
2. Supervisors, one per operator group; incoming calls can also be handled at these positions.
3. Control positions, for the management of a number of operator/supervisor groups; for example, in large MACs.
4. A master control position, for total system management.

The configuration of incoming trunks, incoming queues and operator assignments are dynamically flexible under the control of the master control position. System management decisions are based on performance information available at the master control position and are aimed at optimum control of staffing arrangements to suit the prevailing traffic conditions. The basic system structure is shown in **Fig. 3**.

The system has been enhanced for Telecom use and additional facilities to those described in Ref. 5 include:

- The ability to work to operator groups in MACs which can be remotely located from the central switching equipment. Normally, operators work up to a distance of 500 m from the switching equipment, but the addition of the new remote sub-system will allow complete decentralisation of operator groups. A four-wire speech connection is provided to each operator and a pair of dedicated data links is provided per group of 12 operators and one supervisor to convey the signalling information for that group (see **Fig. 4**).
- MFC indialling. The NACD will be able to analyse all incoming service codes internally through the ability to interwork with the network using multi-frequency code (mfc) information signalling. Capacity will be provided for discrimination on up to 32 codes of 3 or 4 digits which will be specified in installation data. Other codes will be rejected, with number unobtainable tone fed back to the network.
- Direct interfacing to the junction network to improve trunking and call handling arrangements. Further details are set out in a later section of this paper.
- An improved through-connect facility for SA calls. A standard facility exists which allows operators to transfer an incoming trunk to an outgoing trunk, with complete dissociation from the call on transfer. In this case the NACD will act as a transit switch. This facility is being enhanced to allow the operator to speak to either or both parties prior to dissociation from the call. A selection of outgoing routes, providing either time unlimited or time limited connections will be provided as part of the improved facility.
- A remote call barometer. The call barometer is a wall mounted display which indicates the number of calls waiting in a trunk queue or in the whole system. The current facility provides a single display at the central site only and is to be replaced by one which will provide each MAC, irrespective of its distance from the central switching equipment, with details of the calls waiting in the trunk queues handled by that MAC.
- The supervisory and management systems which collect, collate and disseminate system statistics and data to control and master control positions are to be considerably improved.

NACD SYSTEM ARCHITECTURE

The NACD is a stored program controlled automatic call distribution system with a single stage non-blocking digital switch and a two level processor hierarchy, consisting of duplicated central processors (CP) and up to five unduplicated regional processors (RP). Pulse code modulation is the technique used to encode and decode speech in the digital switch.

There is a complete redundancy in the CPs with one working as executive and the other as standby and the two communicate via a communication link. The basic processor supervision technique utilises a series of signals, which each central processor sends to the other and which each regional processor sends to the executive CP. If the executive CP fails, the standby processor will take over control of the system. If a regional processor fails, the executive central processor will itself perform the function of the failed RP.

The software of the NACD consists of 9 sub-systems which interwork with each other through program signals. The same generic program is used in all installations with only exchange data being different. The sizes of the CP and RP programs are approximately 52k and 8k words respectively. The size of exchange data for a typical installation is 3k words. All the programs are in APN 162 minicomputer assembly language.

Input and output devices in a typical NACD installation would include a 300 baud teleprinter in the equipment room for use by technical staff for maintenance, and a 2400 baud VDU for use by master controller for system performance monitoring and reconfiguration. Further teleprinters and VDUs may be added, up to a maximum of eight.

NACD SYSTEM SIZE

The system is modular in construction and can be built up in a variety of sizes and configurations. The required number of trunk circuits and operator positions is provided by fitting the appropriate number of trunk circuit magazines and operator position magazines. The system size and the ratio of operators to trunks to suit any application, can be catered for in this way.

The ratio of operators to trunks for Telecom applications will be of the order of 1:2, and system sizes will be of the order of from 100/200 (operators to trunks) up to the largest size of around 200/400.

SYSTEM DIMENSIONING (Ref. 6)

ACDs are a delay-loss system where the delay is the call waiting time in queue and the loss is the calls lost due to system and trunk congestion. Delay is introduced when the number of incoming calls exceed the available operators and calls are placed in queue. This delay is dependant on operator dimensioning which depends on:

- operator/trunk ratio;
- call holding time;
- operator post-call activity time.

A major constraint in system dimensioning is the provision of operator groups which are provided in modules of 12 operators and one supervisor. These groups are not divisible between MAC locations and therefore the total operator capacity for the system includes the unused operator positions in any partially equipped operator groups.

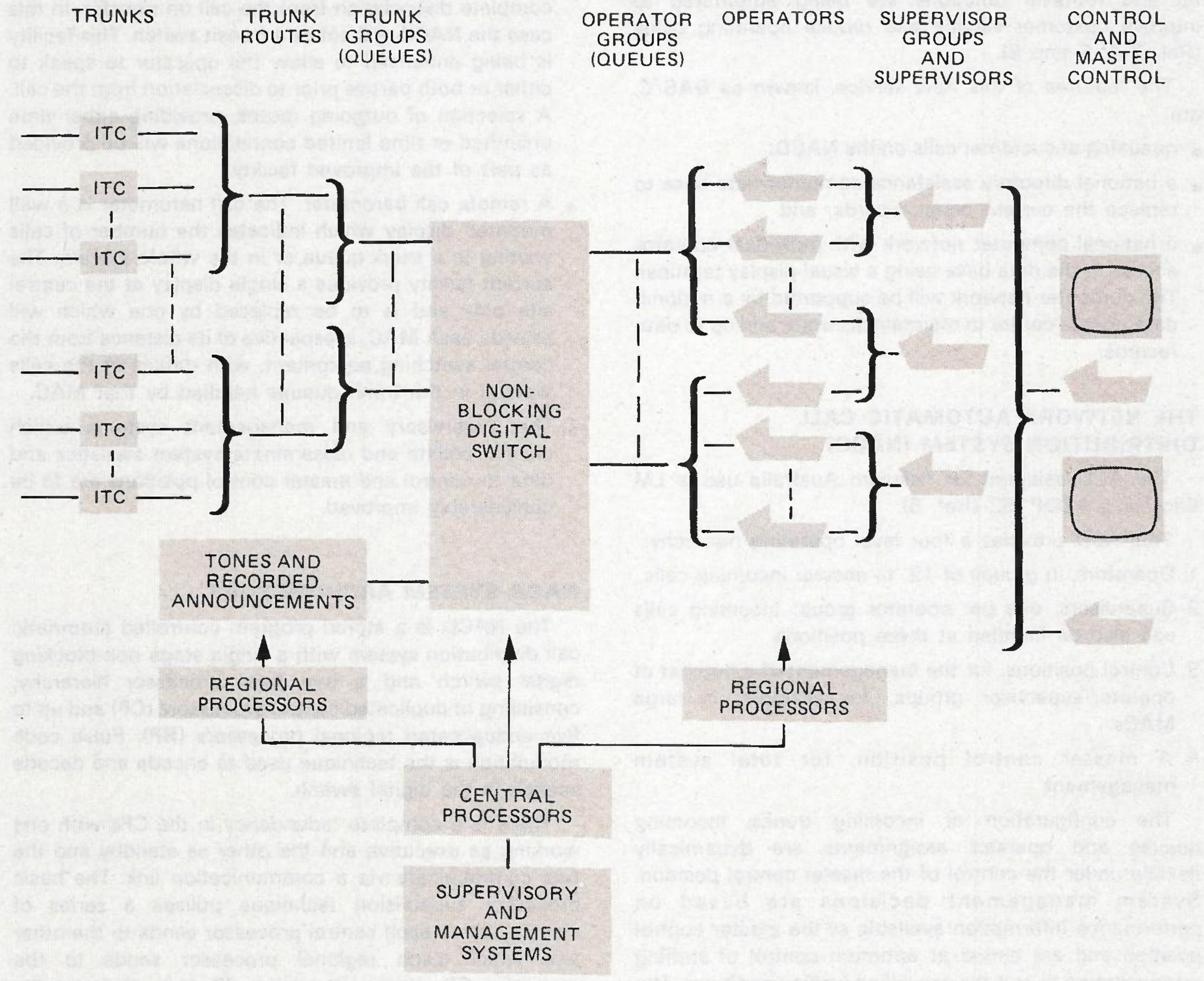


Fig. 3 — Basic NACD System Structure.

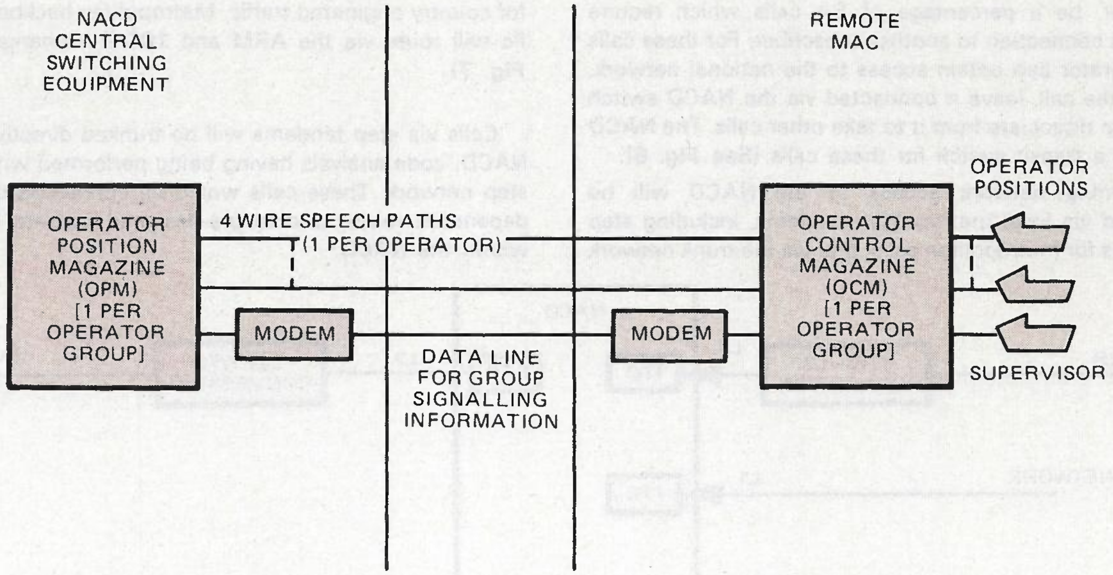


Fig. 4 — Remote Operator Working.

The delay and loss standards to be applied by Telecom for DAS and SA operator position dimensioning are:

- The probability of delay exceeding 10 seconds shall be less than or equal to 10%.
- The probability of delay exceeding 90 seconds shall be less than or equal to 0.5%.
- The overall probability of loss for NACD calls shall be 0.01%.
- The loss standard above leads to a requirement to dimension incoming (and outgoing) routes to a grade of service of 0.001.

NACD SYSTEM MANAGEMENT

The management of the NACD system is performed from the master control position (MCP). Access is provided to a variety of real time status displays and to a comprehensive set of system performance reports which provide the basis for system and staff management decisions. The MCP has access to an extensive range of dynamic system reconfiguration facilities covering, for example, the arrangement and allocation of trunks and operators.

Continuous supervision and gathering of statistics is performed by two separate systems, namely an "Operations and Maintenance Subsystem (OMS)" (see Ref. 5). and an intelligent peripheral (PDP 11/23) called the "Business Performance Analyser (BPA)", which is effectively treated by the NACD system as an input/output device.

The BPA is to be enhanced to provide improved and additional statistics. It is also planned that at a later date the control positions in large MACs will be given access to system displays off the BPA.

NETWORK TRUNKING

NACDs are to be integrated into the switched telephone network and will interface directly to the exchange signalling systems. The interconnections to be set up for the various signalling schemes are shown in **Table 2** and **Fig. 5.** This mode of operation will help to optimise the trunking arrangements and trunk utilisation.

For the majority of incoming calls, the NACD will be the terminal point — a call will be connected to an operator who will handle it to completion. There will,

SIGNALLING SYSTEM	INTERFACE
L-series, loop-disconnect (L1, L2)	— 2 wire and 4-wire incoming trunk circuit (ITC) — 4-wire outgoing trunk circuit (OTC)
T and T3 — Pulse signals	Conversion relay set
T6 — PCM	T6 loop converter
mfc information signals on indialling circuits	2-wire and 4-wire ITC
Decadic pulsing on outgoing circuits	4-wire OTC

Table 2 — NACD Interfaces.

however, be a percentage of SA calls which require through connection to another subscriber. For these calls the operator can obtain access to the national network, set up the call, leave it connected via the NACD switch and then dissociate from it to take other calls. The NACD acts as a transit switch for these calls (See **Fig. 6**).

Incoming network access to the NACD will be provided via local metropolitan tandems, including step tandems for metropolitan calls; and via the trunk network for country originated traffic. Metropolitan backbone traffic will route via the ARM and 10C-T exchanges (See **Fig. 7**).

Calls via step tandems will be trunked directly to the NACD, code analysis having being performed within the step network. These calls would be connected on code dependent routes and to pre-assigned operator groups within the NACD.

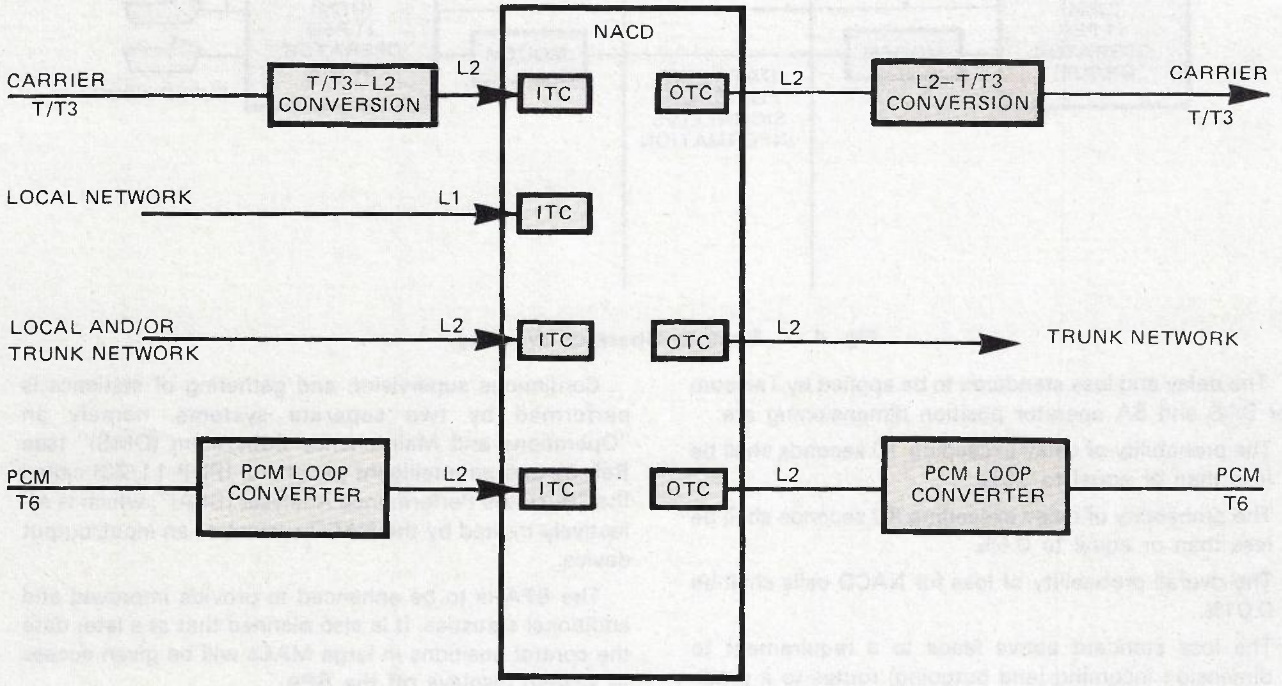


Fig. 5 — NACD Interfaces.

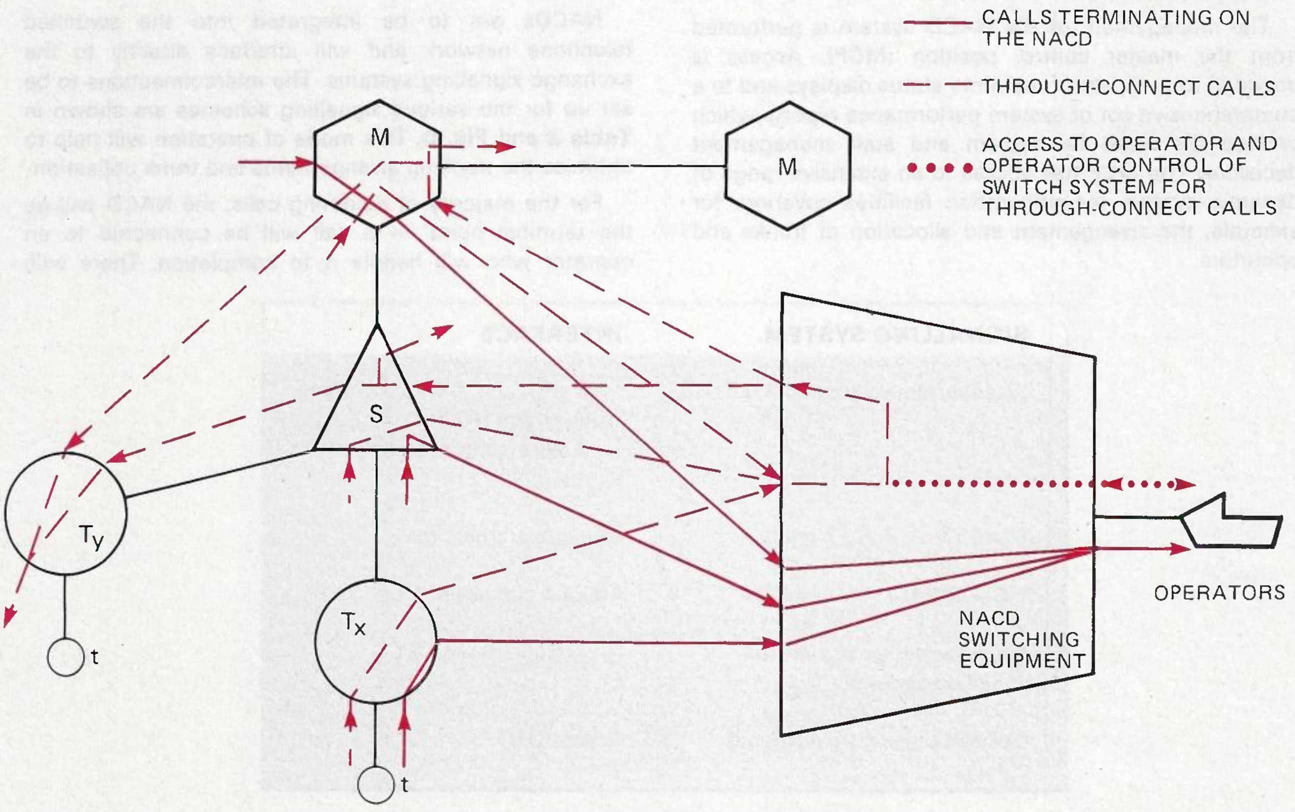


Fig. 6 — Network Integration of NACD.

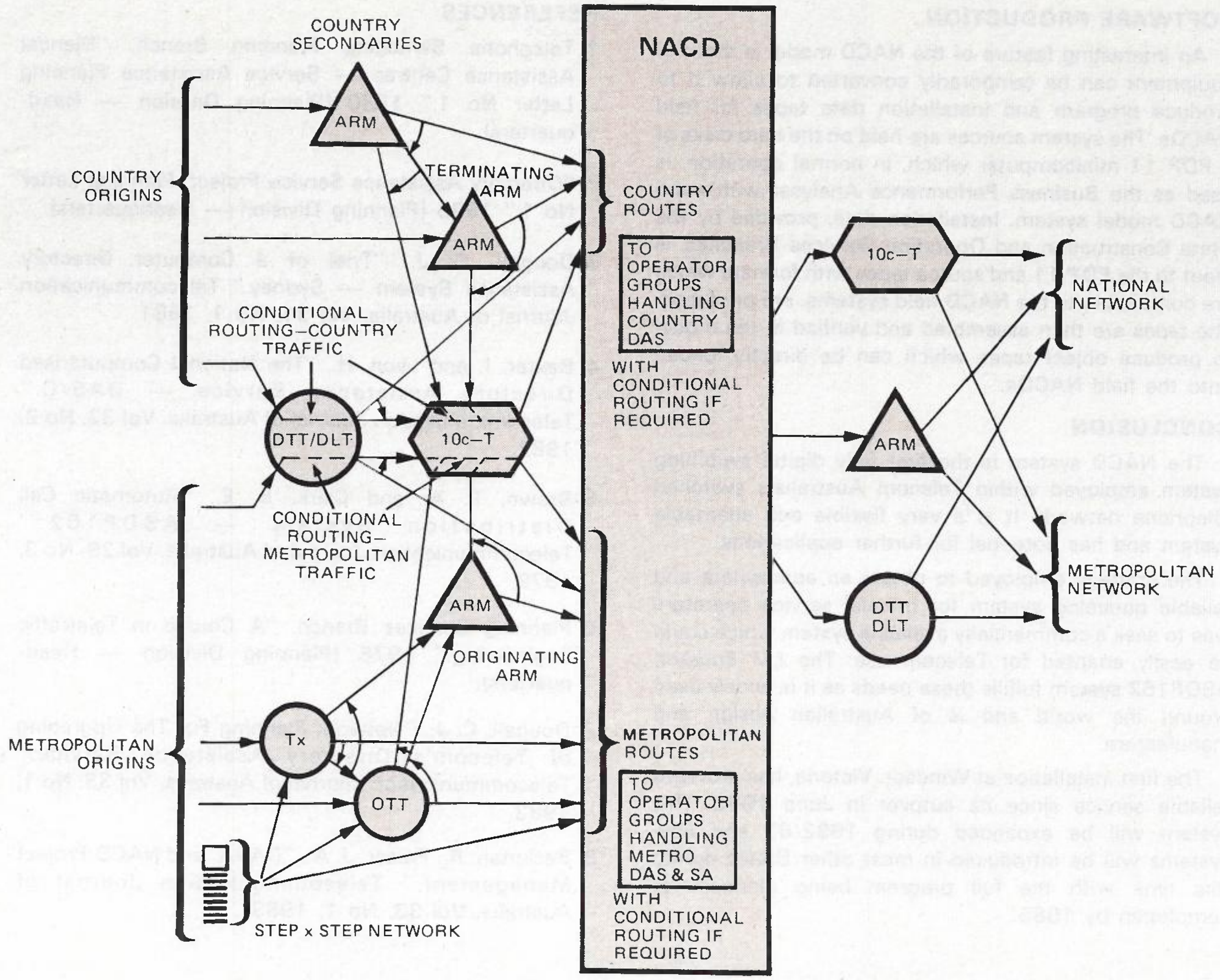


Fig. 7 — Typical Network Trunking.

Calls via metropolitan tandems and the trunk exchange network will be connected to the NACD on grade of service routes using mfc signalling. Analysis on these calls will be performed by the NACD for the valid indialling codes, and for selection of the appropriate operator group.

It is also planned that country and metropolitan DAS enquiries could be segregated and selectively connected to operator groups dedicated to handling either country or metropolitan calls. This type of call segregation would provide some improvement in operator efficiency. Conditional routing techniques can be applied in both the switched telephone network and the NACD to achieve this call separation. Conditional routing can be provided in 10C-T and AXE digital trunk tandems where the outgoing route selection can be made dependant on the incoming trunk route and the dialled code. ARMs do not provide conditional routing, therefore metropolitan DAS traffic will be trunked via an originating trunk tandem, and country DAS traffic via a terminating trunk tandem.

Similarly, the NACD can conditionally route incoming calls to specific operator groups using the same criteria — that is, incoming trunk route identification plus the indialled code.

Outgoing access to the national network, for SA through-connect calls and operator enquiry calls, will be provided via the trunk network to ensure that the network transmission requirements can be met and to provide the outgoing route discrimination functions to the national network which are not available within the NACD.

NACD SYSTEM SUPPORT

A National Support Centre (NSC) has been established in Parramatta, NSW, to support the NACD installations throughout Australia. A model NACD has been installed in this centre which also provides full software production facilities.

The functions of the NSC are to:

- support the system software by providing changes in software to correct deficiencies or implement new facilities;
- investigate faults and design defects;
- test new hardware and software items;
- produce installation tapes for each NACD based on individual system requirements as specified by each State;
- provide practical training on the system equipment for activities such as fault finding, man-machine communications, loading of tapes and so forth.

SOFTWARE PRODUCTION

An interesting feature of the NACD model is that the equipment can be temporarily converted to allow it to produce program and installation data tapes for field NACDs. The system sources are held on the hard disks of a PDP 11 minicomputer which, in normal operation, is used as the Business Performance Analyser within the NACD model system. Installation data, provided by the State Construction and Operation Services Branches, is input to the PDP 11 and source tapes with formats which are compatible to the NACD field systems, are produced. The tapes are then assembled and verified in the model to produce object tapes which can be directly loaded onto the field NACDs.

CONCLUSION

The NACD system is the first fully digital switching system employed within Telecom Australia's switched telephone network. It is a very flexible and adaptable system and has potential for further applications.

The strategy employed to obtain an appropriate and reliable queueing system for manual service operators was to seek a commercially available system which could be easily adapted for Telecom use. The LM Ericsson ASDP162 system fulfills these needs as it is widely used around the world and is of Australian design and manufacture.

The first installation at Windsor, Victoria, has provided reliable service since its cutover in June 1982. This system will be expanded during 1982/83 and new systems will be introduced in most other States during this time with the full program being planned for completion by 1985.

REFERENCES

1. Telephone Switching Planning Branch, "Manual Assistance Centres — Service Assistance Planning Letter No 1," 1980 (Planning Division — Headquarters).
2. "Directory Assistance Service Project, Planning Letter No 1," 1980 (Planning Division — Headquarters).
3. Dougall, C. J., "Trial of a Computer Directory Assistance System — Sydney." Telecommunication Journal of Australia, Vol 31, No 1, 1981.
4. Baxter, I. and Lyon, H., "The National Computerised Directory Assistance Service — DAS/C." Telecommunication Journal of Australia, Vol 32, No 2, 1982.
5. Brown, P. A. and Clark, B. E., "Automatic Call Distribution System — ASDP162." Telecommunication Journal of Australia, Vol 29, No 3, 1979.
6. Planning Services Branch, "A Course in Teletraffic Engineering," 1978 (Planning Division — Headquarters).
7. Dougall, C. J., "Network Planning For The Upgrading of Telecom's Directory Assistance Service," Telecommunication Journal of Australia, Vol 33, No 1, 1983.
8. Backman, R., Fraser, J. A., "DAS/C and NACD Project Management," Telecommunication Journal of Australia, Vol 33, No 1, 1983.

The Tarong Power Station Regional Effects and Provision of Services

B. R. LANG BE MIE (Aust) RPEQ

The commencement of building of the 1400 MW Tarong power station in a quiet rural part of South East Queensland caused massive changes to the pattern of telecommunications development in the area. The project was brought forward by 17 months causing dislocation in planning already made. This article gives a brief insight into the communication needs for a large remote project, and highlights the need to generously dimension all services and resources provided on such projects.

THE PROJECT

The Tarong Power Station is being constructed by the Queensland Electricity Generating Board (QEGB). The importance of the project to Queensland's development can be understood in terms of power usage. When Tarong's first generating unit is brought into service in May 1984, the winter peak demand in Queensland is expected to be around 3340 MW. Tarong's contribution to this demand, currently growing at 9% per annum, will ultimately be 1400 MW.

Tarong is a coal fired station. Ideally such thermal power stations are located near the fuel they need for driving boilers and turbines, and near the water required for cooling.

The Tarong power station has been located close to 287 million tonnes of coal, initially discovered in 1939 but not formally explored until 1967 by CRA Exploration Ltd. The water will come via a 96 km pipeline from the Boondooma Dam now being built on the Boyne River west of Murgon Fig. 1 shows the location of the power station, the mine, and the pipeline, in South East Queensland.

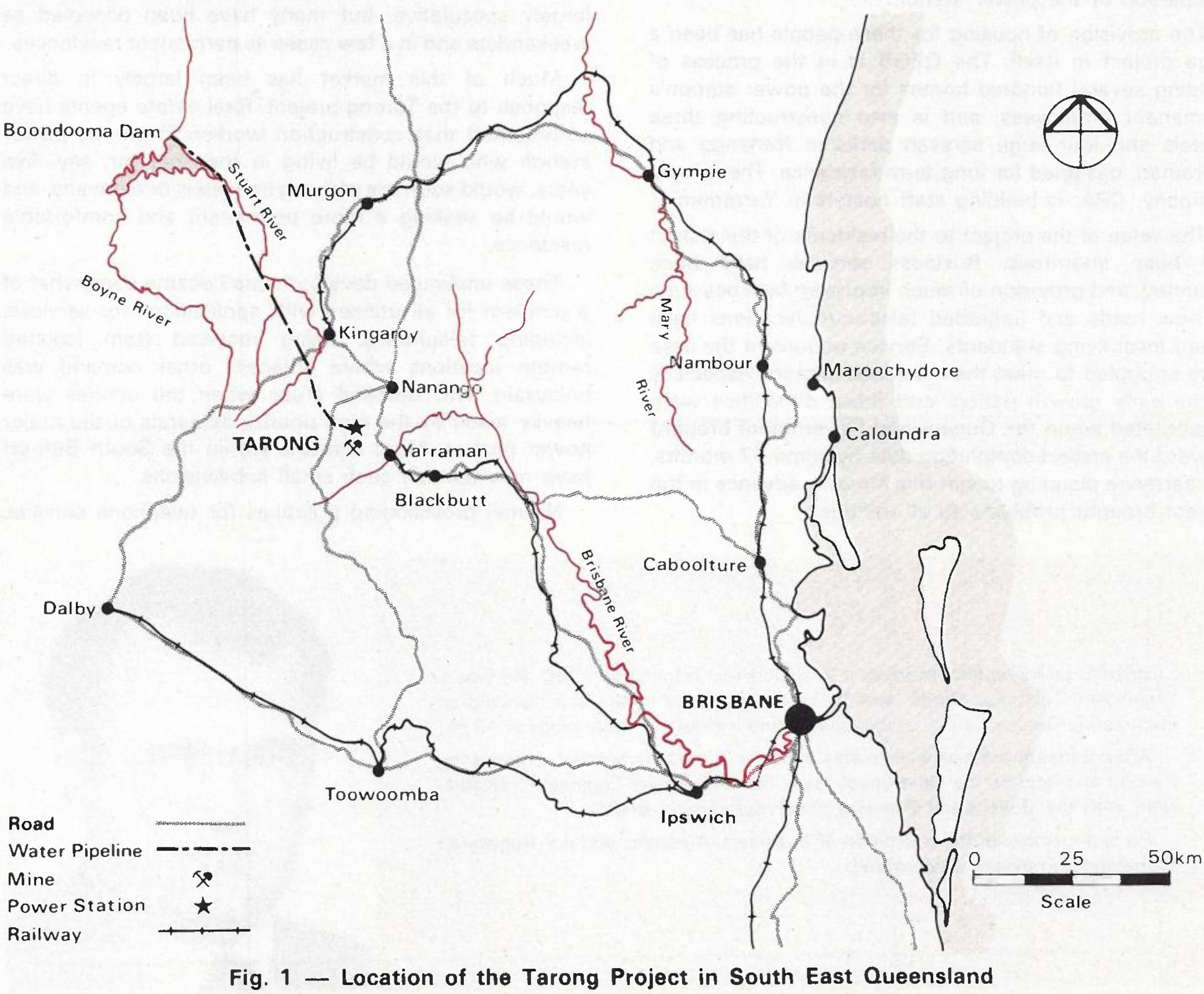


Fig. 1 — Location of the Tarong Project in South East Queensland

The Tarong power station will have four boiler/turbo-generator units, each with a capacity of 350 MW. Coal is provided via a 1800 tonnes/hour conveyor from the Pacific Coal Pty Ltd mine adjacent to the site. Pacific Coal is a subsidiary of Conzinc Riotinto of Australia Ltd (CRA). Cooling is provided by two 700 MW hyperbolic concrete natural draught towers of height 118 m and base diameter 113 m. The station chimney is 210 m high and 20 m in diameter, with an internal lift and four brick lined flues. Site water storage is provided by two dams of 3000 ML each. Ash disposal, at 48 tonnes per hour, is by water jet and pumping through a pipeline to a large ash storage dam.

DEMOGRAPHY

The power station is situated in a quiet rural area on a 1500 hectare site about 180 km by road from Brisbane, at the lower end of the South Burnett District noted for its rich grain and peanut industries. In the immediate area of the power station are agricultural, grazing and stud cattle activities. There are also some forestry industries in the area.

The surrounding towns are Nanango 17 km to the north-east, Yarraman 11 km to the south, and Kingaroy 40 km to the north. Prior to the power project the population of the towns were, Kingaroy — 5 000; Nanango — 1100; and Yarraman — 600. The creation of the power station brought an additional 4000 people to these towns, of whom about 2500 will remain after completion of the power station.

The provision of housing for these people has been a huge project in itself. The QEGB is in the process of building several hundred homes for the power station's permanent employees, and is also constructing three hostels and four large caravan parks in Nanango and Yarraman, designed for long term residence. The mining company, CRA, is building staff hostels in Yarraman.

The value of the project to the residents of the district has been enormous. Business services have been extended, and provision of much improved facilities such as new roads and upgraded telecommunications have raised local living standards. Service utilities in the area have struggled to meet the increased demand especially in the early growth period, and these difficulties were accentuated when the Queensland Government brought forward the project completion date by some 17 months. To rearrange planning to suit this massive advance in the project brought problems to all utilities.

REGIONAL EFFECT ON TELECOM

Three major factors affected Telecom's ability to meet demand in the area.

Firstly, the power project brought with it considerable growth in the surrounding area. For example, there was a massive increase in building activities, all requiring new communication facilities.

Secondly, during the power station construction period, a large rural upgrading programme was implemented to convert exchange services in the area from magneto to automatic operation. The Proston, Wondai, Nanango and Blackbutt exchange areas were upgraded at a cost of some $2M in external plant works alone.

Finally, the power station project caused new interest in real estate in the area and something of a boom developed.

There was a boom in the towns where large urban subdivisions and multi-unit developments began in areas undreamed of till now. Also, for a number of years there had been a growth in rural residential five and ten acre subdivisional activity sweeping north through the Brisbane Valley towards the South Burnett. Much of the land was capable of little production and had no power, water, sealed roads or telephones.

Nevertheless, the subdivisions sold quickly with most buyers residing in Brisbane or the large provincial city of Toowoomba. The nature of these investments has been largely speculative, but many have been occupied as weekenders and in a few cases as permanent residences.

Much of this market has been largely in direct response to the Tarong project. Real estate agents have commented that construction workers from the power station who would be living in the area for, say, five years, would soon tire of living in hostels or caravans, and would be seeking a more permanent and comfortable residence.

These unplanned developments became somewhat of a problem for all utilities with applications for services, including telephones, being received from isolated remote locations where adjacent other demand was uncertain. This demand arose when the utilities were heavily taxed by the high priority demands of the major power project. Most councils within the South Burnett have now banned such small subdivisions.

Normal provisioning practices for telephone services

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After graduation, Bruce was an area engineer in the Maryborough Engineering Section and later on the Gold Coast. He is currently Senior Engineer (Transmission) with the Queensland Planning and Programming Branch.

He is a member of the Institution of Engineers, Australia, and is a Registered Professional Engineer, Queensland.

were impossible to apply in these subdivisional areas. It has been necessary to adopt an external plant dimensioning process in the rural residential parts of the region by subjectively assessing which areas are more desirable places to live from aesthetic or practical points of view and to nominate development figures accordingly.

Summarising, the Tarong power project presented Telecom with three major projects —

- The direct requirements of the Tarong project;
- Rural automatisation;
- Rural residential subdivision activity;

The achievement and co-ordination of which have required a concerted effort.

For example, early in 1979 before the Tarong project commenced, the Telecom line depot at Nanango was staffed by three to five men. The depot had to be upgraded in supervisory level and additonal gangs brought in from Bundaberg, Maryborough and Brisbane so that the necessary external plant projects could be carried out.

Conversions from magneto to automatic in a number of areas were brought foward. Typical of these was Nanango, where external plant reticulation was by both underground and aerial cable dimensioned to suit a stable growth rural area and with insulation resistances not suitable for other than magneto working. This is a familiar situation in any rural area, and in any automatisation programme, large resources are committed to upgrading the network to largely overcome the insulation resistance problems on aged, weathered bearers.

In the case of Nanango, because of the sudden growth and some particular difficulties due to existing reticulation being by aerial cable feeding down narrow lane-ways to the rear of buildings, a complete town redesign of cables, conduits and pillar areas was undertaken.

Close oversight of all facets of construction, external and internal, was necessary to meet the cutover dates. A criticial path diagram was developed to assist in meeting the deadline.

PROVISION OF SERVICES TO THE POWER STATION AND MINE

The nature of the telecommunications services required at the power station and mine includes all that would be expected in a metropolitan area: telephone and telex services; PABX facilities; special services — tie lines, control lines, equalised programme lines; mobile telephone services off PABXs, facsimile, etc.

Telecom's approach to the provision of services was to consider the regional network planning implications from the outset. On the basis of information provided by the QEGB and CRA, plus knowledge of the demand for services at the earlier constructed Gladstone Power Station, further north on the Queensland coast, it was concluded that the demand for all services at the power station and mine would be of the order of 80 to 100 lines during the construction phase reducing to a much lower figure during the operating phase. This forecast was proven to be low, for reasons to be described later. The implications of recovering from the under-provisioning were considerable, and emphasise the benefits of being in possession of all the facts before vital decisions are made.

To meet the predicted demand and the high traffic to be carried, it was obvious that the local ARK511 exchange at South Nanango would need to be upgraded. Accordingly, a new South Nanango ARK521M exchange was installed at a point some 1.6 km closer to the power station site with junction and Voice Frequency Telegraph facilities being extended through to the minor switching centre at Kingaroy on physical bearers, and a Z12 carrier system over a new cable teeing into a 14/0.90 PIQC cable linking the major towns along the D'Aguilar Highway.

The physical link to the power station was by a new 100/0.64 hard-jacketed plastic cable extending from the old South Nanango exchange past the new exchange site through a Forestry Reserve and into the power station, augmenting a 6/0.64 plastic cable installed some years earlier. Prior to the new exchange cutover, this cable was slightly outside transmission limits, but this was a temporary measure to avoid the use of more expensive 0.90 mm gauge cable which would not be required with the new exchange.

It was intended that this cable would feed both the power station and the mine, as discussions with the mine operators indicated that the Tarong coal mine was not particularly large by modern standards and therefore would have minimal telecommunications requirements. Further, activity charts supplied by both the QEGB and CRA indicated that many of the power station contractors would be finished their contracts by the time that the mine construction was commenced, thus freeing communication plant for other uses.

Fig. 2 shows the immediate geographical area around the mine and power station **Fig. 3** shows the stage of construction of the power station late in 1982, viewed from the south east.

To extend cable to the mine from the new South Nanango exchange, it was necessary to either lay the cable through the power station, taking the shortest route, along or near the conveyor, or alternatively, circumscribe the power station around the road system via the area known as Kissing Corner. In the initial stages neither roads nor power station planning was firm enough to guarantee cable security on the power station site, but fortunately the mine was a much later development than the power station. Accordingly, the choice of a final route for the mine cable could be delayed until late 1981, two years after the power station had been commenced.

It was always intended that the mine cable would simply be an extension of the power station cable, but this did not eventuate. It became apparent in early 1982 that the new 100 pair cable servicing the power station would be inadequate for the needs of the power station, let alone the mine also. Consequently, to service the mine, a new 100/0.64 hard-jacketed jelly-filled cable tapering to 70/0.90 was installed from the South Nanango exchange through the power station site to the mine. The considerable additional costs involved in providing the additional cable, some $100,000, raises

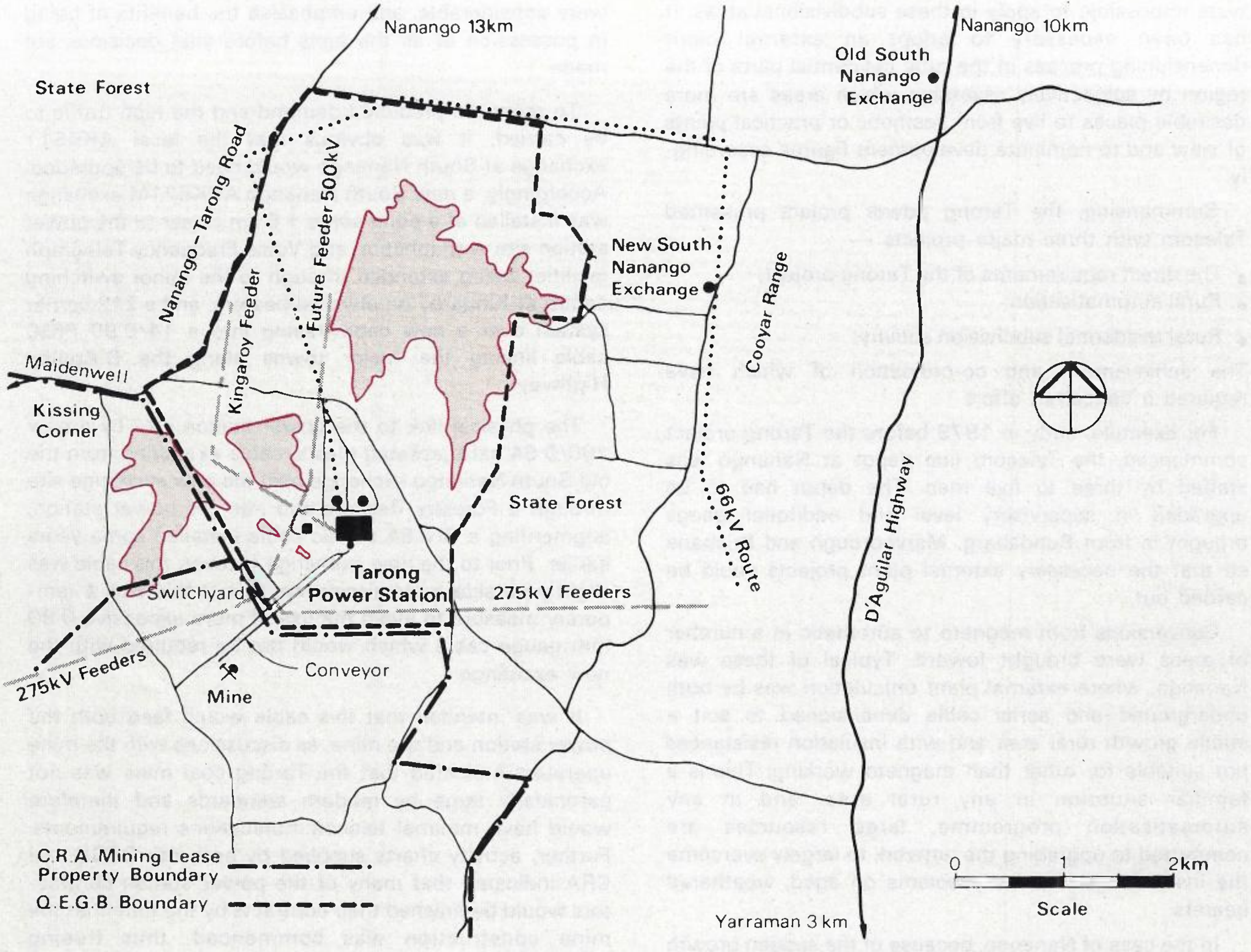

Fig. 2 — Immediate Geography — Tarong Power Station

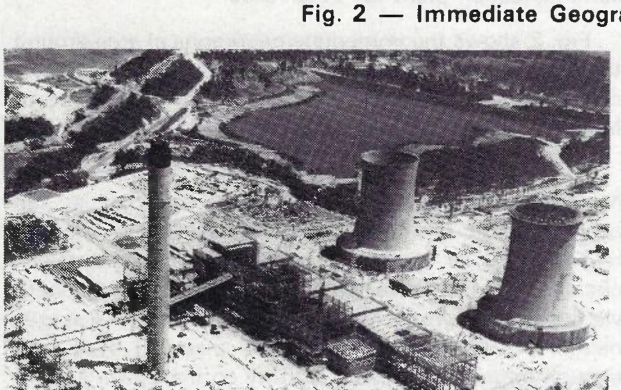

Fig. 3 — Construction as at December 1982

the question of where the original demand forecasts went wrong.

The answer lies both in an under-estimation of potential demand and also in a set of circumstances which could not have been foreseen.

The under-estimation related to the requirements of site contractors. Large projects such as this need to set aside areas of contractors, many of whom set up quite large facilities such that even some of the smaller contractors on the Tarong project required up to five lines for such purposes as multiple handsets, small business systems, tie lines, telex and facsimile. Some 50 contractors were on the power station site at the one time.

Unforeseen circumstances related to contractors were twofold. Firstly, some contractors who completed their original contracts, also won other contracts in the area, such as at the mine or on other services in the area. This extended their stay and consequently continued their demand for communication services.

Secondly, the advancement of the project schedule by 17 months threw all earlier planning into disarray.

To overcome these problems, much consideration was given to the possibility of augmenting the initial cable with either Z12 cable carrier systems or Voice Frequency Telegraph systems installed on the power station site. Both of these options were possible, but were not proceeded with for a number of reasons, the main one being that neither gave a significant cost advantage over a ploughed-in supplementary cable. Therefore it was decided to run the abovementioned exclusive cable from the exchange to the mine. For security reasons, different routes were taken for each of the two cables.

POWER CO-ORDINATION

From Fig. 2 it may be seen that in the design of these cables power co-ordination aspects needed to be considered. The power station has many high voltage power lines, and is sited on high resistivity soil. Dual problems can arise in cable design because of these factors.

The first of these relates to the possibility of hazardous voltages being induced into the telephone cable from lengthy adjacent high voltage lines at times when fault conditions exist on the power lines.

Fortunately, with the grade of power system protection employed on the lines in the vicinity of Tarong, and a cable route design that avoided lengthy paths parallel to these power lines, calculations indicated that no special precautions would be necessary because of the potential problem of high induced voltages.

The second problem that can arise is that of the extension of a remote earth into the potential gradient area of the power station, such as by the metal moisture barrier sheath of a jelly-filled cable. A description of this aspect of power co-ordination investigation follows. However, in terms of the design of the cables passing through the potential gradient area of the power station, steps were taken to ensure that only plastic cables without a metal moisture barrier were installed on sections of the routes passing through the potential gradient area.

PROTECTION OF SERVICES IN A POWER STATION

In supplying telephone services to a power station, or a substation for that matter, special measures must be taken to protect the telephone user and the instrument from the ground potential rise during times of power station faults.

Fig. 4(a) shows a telephone service, in the confines of a power station, electrically connected via low resistance telephone wires to a remote low resistance earth at the telephone exchange. When a fault develops in the power station, such as a high voltage power line falling to earth, circuit breakers normally act to cut power from the downed line. However, this is not instantaneous, and during the momentary switching delay the earth in the region of the fault is raised to the full potential of the power line. The remote exchange earth is extended into the power station via the telephone line. Thus a very high potential will exist between the surrounds of the telephone, including the user, and the electrical parts of the telephone, endangering both the user and the instrument from insulation breakdown through the telephone.

There are two ways of protecting against this eventuality. The first involves the use of an isolating transformer and signalling relay set for each line. This is a fairly expensive arrangement, especially for multiple lines, and the alternative method of neutralising transformers is more commonly used **Fig. 4(b)** shows the details.

The neutralising transformer has a single primary winding and several sets of secondary windings. One end of the primary winding is connected to the power station earth mat and the other end is connected, via an insulated conductor separate from the communications cable, to a remote earth electrode outside the gradient area of the power station. When, due to a power system fault, a rise of potential of the station earth mat occurs, a current will flow via the primary winding of the transformer to the remote earth, inducing a potential in the secondary windings of the transformer. These secondary windings are arranged so that the induced potential will be about the same value as the raised potential of the station earth mat. As a result, at the telephone a safe potential difference will exist between the user and the telephone.

To facilitate the use of these neutralising transformers, site cabling was arranged so that all incoming pairs terminated on a centrally located distribution frame adjacent to which were connected, via isolating links, the neutralising transformers. Distribution to various points of the site was provided by cables in conduit radiating away from this distribution frame. Much of the distribution cable followed the same path as the incoming cable from the exchange. Whilst this would appear inefficient in terms of cost and transmission, it was necessary for protection purposes and in fact, was preferred by the QEGB who recognised the security enhancement offered by isolating the main arterial cable into the power station from the regular incursions into it that would be expected if a separate parallel distribution cable was not available.

EQUIPMENT DETAILS

Equipment provision on the power station site was an initial 90 line ARD571 PABX which has since been replaced by a 12A2 NEAX PABX. At the mine, a contractor-installed Philips D1203 PABX was installed.

In addition, the QEGB has its own network incorporating an ASB900 PAX connected via power line carrier over 275 kV bearers and a radio link via the Bunya Mountains. Two Z12 systems exist on site for distribution of control data around the site.

Some 14 telex machines have been installed and more are expected. There are also many miscellaneous special services, data links and tie lines.

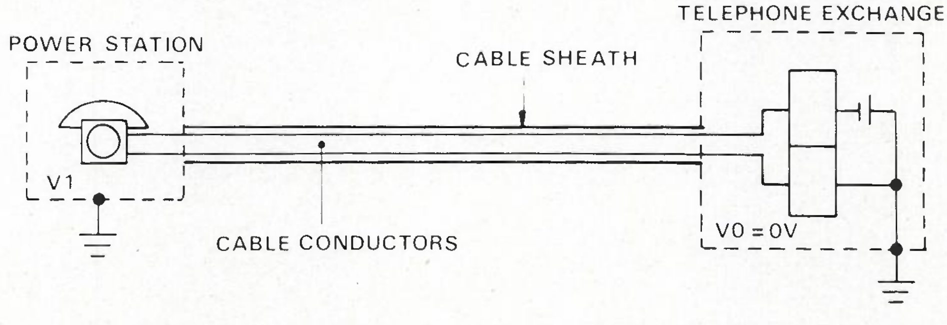

Fig. 4a — Exchange Line Connected to Power Station

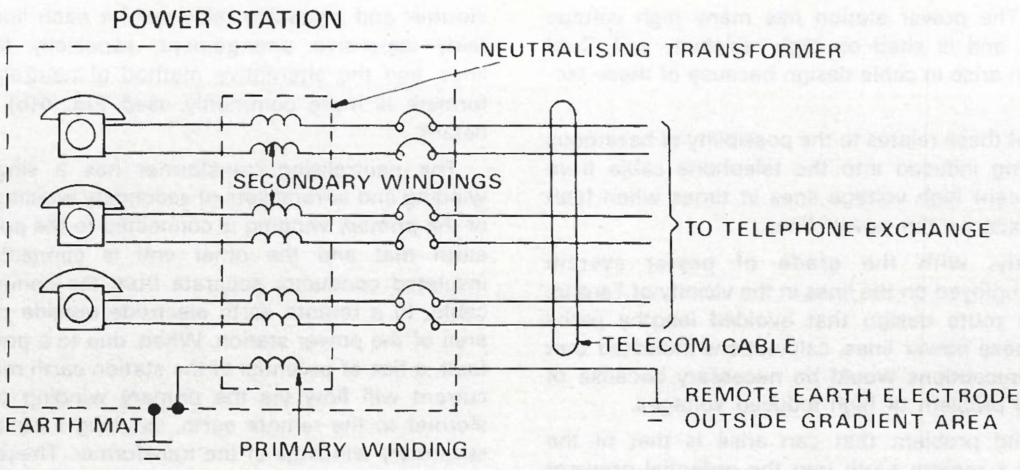

Fig. 4b — Protective Neutralising Transformer

SOME INTERESTING PROBLEMS

Some interesting problems have arisen in the provision of communications to the project.

The most obvious difficulty is that of providing physical plant on a site which must be considered as a three dimensional space full of pipes, cables, ever-shifting ground levels and roads. It is a place where a mountain can be shifted within a week. Even with the best help and guidance from planners, constructors, contractors and surveyors, the haphazard nature of the early construction phase caused by the project advancement of 17 months, made any chance of secure and integral physical construction most unlikely.

Inefficient use of junction facilities arose in the following way. At the request of the QEGB, indialling facilities were provided to the Tarong power station PABX. This facility could only be provided via 10 incoming circuits from Kingaroy ARF exchange since indialling could not be provided by the ARK local exchange. Consequently, when any of the 50 contractors on site, or those at the mine, make a local call to the QEGB, also on site, the call is trunked from the South Nanango exchange to Kingaroy, thus using junctions bothways on a local call. One interesting feature of the power station is that the power station and the switchyard lie on different earth mats. Any PABX extensions provided in the switchyard would require special protection for the same reasons described above for power station services. However, to connect switchyard PABX extensions, the QEGB is providing channels of a Z12 carrier system over a protected bearer, and this will provide safe conditions.

ADMINISTRATION

This project, proceeding at the rate of $1m. a day, required special co-ordination, and Telecom was involved in regular project control meetings with QEGB, CRA and others.

LEARNING FROM THE PROJECT

It is clear that the ramifications of satisfying the telecommunications needs of a major project like the Tarong Power Station go far beyond the bounds of the project site.

A whole new demography is born into a region, and new telephone customer patterns emerge. Future projects of this size in remote locations must be expected to also radically affect the surrounding telecommunications environment. This should not be overlooked in the future.

The major lesson from on site at the power station project concerns generous dimensioning of plant for the provision of communication services on such projects.

The Telecommunication Journal of Australia

ABSTRACTS: Vol. 33, No. 2

ARMY COMMUNICATIONS LOOKING AHEAD; Colonel P. G. Skelton, Telecom Journal of Aust., Vol. 33, No. 2, 1983, page 83.

This article describes the need for communications for command control of the Army. It summarises the various levels and types of communications provided and describes the elements which exist to provide these communications. The article looks forward indicating the type of communications and equipment which can be expected in the future.

INVESTIGATION OF PREMATURE DEPLETION OF STABILISERS FROM SOLID POLYETHYLENE INSULATION; B. L. Board, H. J. Ruddell, Telecom Journal of Aust., Vol. 33, No. 2, 1983, page 91.

Early failure of solid polyethylene insulation jointed in above ground closures is a serious field problem in Australia in cables made between 1965-74. Analysis has confirmed thermal oxidation as the cause, resulting from inadequate initial stabilisation and rapid depletion of antioxidant in service. No failures have been reported in more recent insulation incorporating the current primary antioxidant/metal deactivator systems, as used in many other countries. However, these systems are also depleted prematurely, and current polymers are unlikely to provide the expected life. Several factors cause this depletion of stabilisers, including rapid migration to the polymer surface due to insolubility at all service and polymer storage temperatures, substantial extrusion losses, elevated service temperatures and reaction with colourants. The use of a secondary antioxidant appears beneficial, and triple component stablisation systems, with components chosen for their excellent solubility and oxidative stability, are being evaluated.

TRANSMISSION PERFORMANCE TESTER; J. D. Delinicolas, Telecom Journal of Aust., Vol. 33, No. 2, 1983, page 105.

The Transmission Performance Tester is used to monitor the performance of the Broadband Transmission Network for continuity, level variations and noise.

This article gives a general description of the system and the performance data it produces.

AN INTRODUCTION TO THE CCITT RECOMMENDATION X.25; J. L. Snare, Telecom Journal of Aust., Vol. 33, No. 2, 1983, page 113.

This tutorial paper gives an introduction to the CCITT X.25 protocol for interworking between packet mode terminals and public packet switching data networks. A top-down approach is taken, with a description of the intended purpose of each of the three X.25 layers, followed by a discussion of typical protocol procedures that are used to support these functions.

REMOTE AREA (SATELLITE) TELEVISION IN QUEENSLAND; V. L. Cavallucci, Telecom Journal of Aust., Vo. 33, No. 2, 1983, page 125.

Those of us who have had a choice of television programmes for many years may find it difficult to appreciate how those without television in remote areas feel about their isolation. The unique problems and dispersal of communities in this country has required pioneering efforts to extend the National Television Service coverage. The problem has always been the very high cost of relaying the programme, as most of Australia outside the urban areas is sparsely settled with numerous small communities. Otherwise each could be easily served with a low power transmitter, at reasonable cost.

This article outlines how services have been established at an "affordable" cost at many isolated localities in Queensland. The system utilises an existing satellite for the Australia-wide relay of television programmes.

THE KALGOORLIE TO LEONORA MICROWAVE RADIO-RELAY SYSTEM; A. Haime, Telecom Journal of Aust., Vol. 33, No. 2, 1983, page 135.

The expanding requirement for communication services resulting from the discovery and exploitation of mineral deposits has made it necessary for Telecom Australia to extend its broadband network into remote and hostile areas. This paper presents an overview of the planning, design and construction of Western Australia's first major solar powered microwave link between Kalgoorlie and Leonora. An examination is also made of fading caused by strong specular reflections from an unexpected source, namely flat scrub-covered terrain.

A TECHNIQUE FOR LOCATING FAULTS IN LOADED CABLES; E. C. Thrift, Telecom Journal of Aust., Vol. 33, No. 2, 1983, page 147.

In Telecom Australia today there is a need for fault locating equipment which can keep pace with the ever increasing use of loaded cables.

The test procedure described in this article utilises existing pulse echo test (PET) equipment and a cable simulator. The significance of the procedure is simplicity, speed and accuracy under field conditions.

Telecom Journal of Australia — Article II of III ECONOMIC ANALYSIS — MAKING INVESTMENT DECISIONS; C. W. A. Jessop, B.M. Yeoh, C. W. Parry, Telecom Journal of Aust., Vol. 33, No. 2, 1983 page 153.

Economic analysis of proposals for telecommunication projects is becoming increasingly important. This series of articles will, following a brief introduction of general principles, discuss some aspects which cause problems when evaluating telecommunication projects. The articles intend to explore areas of contention, discussing the advantages and disadvantages of various approaches, leaving the reader to decide which approach is relevant to a particular case for which an economic analysis is required.

TELECOM'S CAPITAL INVESTMENT POLICIES AND PRACTICES; G. I. Cameron, Telecom Journal of Aust., Vol. 33, No. 2, 1983, page 161.

Telecom's investment policy has been developed to meet the need for rational and efficient capital project evaluation in a large, capital constrained, decentralised organisation. In an effort to balance competing demands for both social and commercial investment, a set of investment policies has evolved which best meets those needs at the present time. Investment policy is therefore a dynamic policy which must be continuously monitored to ensure it is meeting changing circumstances.

This article sets out the main policies adopted and rationales behind them, in order to ensure that there is consistent treatment of costs, benefits, inflation and other technical aspects of discounted cash flow evaluation. The continuous theme is that these are tools to assist decision making and they must be consistently applied across all projects in order to be efficient. The article also points out that the ultimate responsibility of selection of investment projects rests with decision makers who must weigh the quantifiable and non-quantifiable aspects of an investment decision.

NETWORK AUTOMATIC CALL DISTRIBUTION SYSTEM; J. T. Wilson, A. K. K. Fung, Telecom Journal of Aust., Vol. 33, No. 2, 1983, page 169.

Telecom Australia's manual assistance services are to be provided with automatic support systems to improve their efficiency and customer service. This paper describes the Network Automatic Call Distribution system which will provide call queueing facilities to the new Service Assistance and Directory Assistance Services, its enhancements and its integration into Telecom Australia's switched telephone network.

THE TARONG POWER STATION REGIONAL EFFECTS AND PROVISION OF SERVICES; B. R. Lang, Telecom Journal of Aust., Vol. 33, No. 2, 1983, page 177.

The commencement of building of the 1400 MW Tarong power station in a quiet rural part of South East Queensland caused massive changes to the pattern of telecommunications development in the area. The project was brought forward by 17 months, causing dislocation in planning already made.

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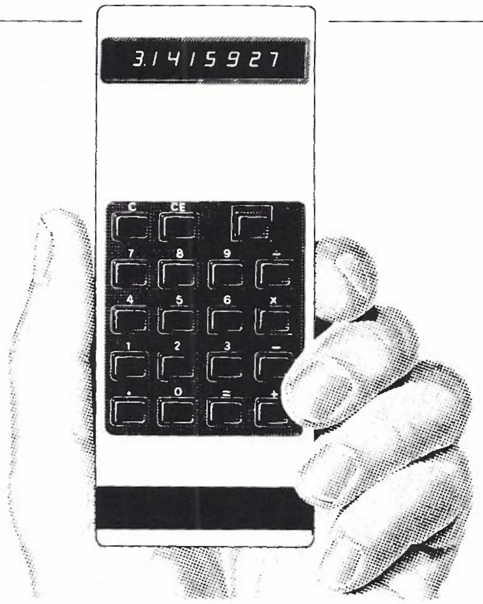

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And that's why communications has joined computing and information-handling as the third great technology in the integrated, automated office.

STAND-ALONE EQUIPMENT DOES PRECISELY THAT.

Word-processor, computer, copier, printer – each of them is like your pocket calculator: on its own, it raises office productivity substantially. And then it stops. More productivity means another word-processor, another personal computer, and so on. If each is used to even 80% of its capacity, the whole is substantially less than the sum of its parts!

The alternative? Well, it's not a return to the vast central computer. The best approach is a communications link between several pieces of equipment. You can put the processing power where you like, and the specific functions where you need them.

An Ericsson system is designed to do just this. It uses the same communications principles in the office network as an Ericsson public telecommunications network.

And those principles are currently the most successful in the world.

AXE: THE WORLD'S MOST SUCCESSFUL MODERN TELECOMMUNICATIONS SYSTEM.

The Ericsson AXE is technologically quite advanced.

It's digital; and has been accepted by more public telecommunications authorities around the world than any other system.

Perhaps this is why Australia chose the AXE system for upgrading its telecommunications network.

It's this AXE experience which Ericsson is now bringing to bear on office automation.

What we've learnt in public networks is now available to you through our range of PABX equipment, radio paging, Alfaskop terminal systems, Series 16 business computers and a host of other high technology products for commerce and industry.

HIS COMPUTER, THEIR WORD-PROCESSOR AND ERICSSON COMMUNICATIONS DON'T ADD UP TO A NETWORK.

It's not, of course, a matter of finding a few stand-alones and simply using AXE to link them.

At Ericsson, we begin by defining the whole system – what capability the network needs to have and what functions it must perform.

The system is broken down into sub-systems, and each sub-system assigned a group of functions. Then we take each function individually and define the equipment to perform it.

The outcome is an integrated information-handling network. It links telephones, computers and terminals each designed to work in the network. And it links smoothly with the public telephone, telex, teletex, and data networks.

PLANNING SHOULD START TODAY.

A complete integrated system requires analysis and planning.

Now is the time to start.

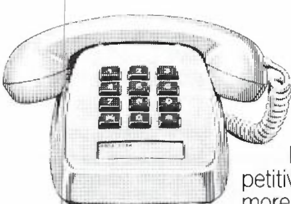
Now is the time to ask Ericsson what we can plan for you.

ERICSSON

61 Riggall St.,
Broadmeadows, Vic. 3047.
(03)309 2244.

VIC.: (03)480 4888
N.S.W.: (02)438 3999
QLD.: (07)262 6222
S.A.: (08)212 3161
W.A.: (09)277 5544
TAS.: (003)31 3727
P. N.G.: (0014675)25 6566

To improve your business efficiency get Telecom working for you.

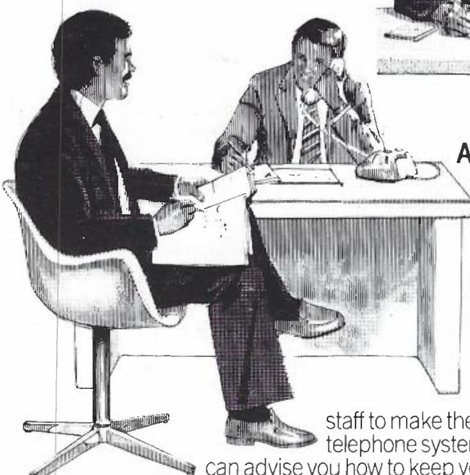


Can you imagine doing business without a telephone?

Your basic telephone is essential, but in today's competitive markets you need more than a telephone on your desk to survive. Telecom is more than a one-product organisation. With years of experience in telecommunications, Telecom have a service or system designed to meet almost every business need.

INFORMATION

A phone call or visit to a Telecom Business Office can put you in touch with the many products and services Telecom has to offer. You can find out about small business systems, investigate the cost-effectiveness of Telex, ISD and INWATS, even be put on the right track to permitted private suppliers of equipment like answering machines or facsimile machines. Your nearest Telecom Business Office is a good place to start improving your business efficiency.



ADVISORY SERVICES

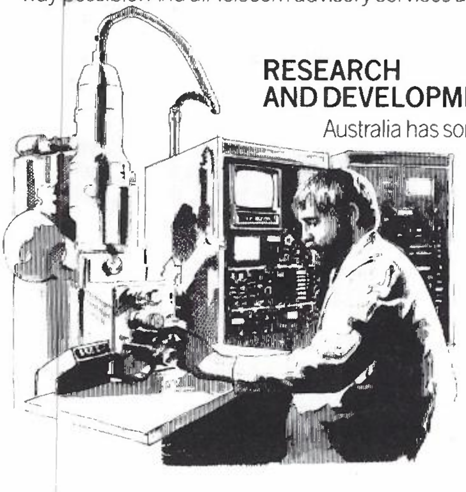
Telecom's advisory service to businessmen is more than just training telex and switchboard operators. They will visit your office to advise you which telephone system is most suited to your business, or help arrange training sessions for your staff to make the best use of your current telephone system. Telecom consultants can advise you how to keep your computers talking to each other across the country in the most efficient and cost-effective way possible. And all Telecom advisory services are free!

TECHNICAL EXPERTISE

As a businessman you appreciate how important it is to keep the lines of communication open. Telecom maintains a force of engineering linesmen and telecommunication experts around the country to keep business in touch with business–twenty-four hours a day, seven days a week.

GET TELECOM WORKING FOR YOU

The Telecom Business Office listed in the front of your telephone directory can solve most of your problems. Or, we'll arrange for one of our specialists to evaluate your specific needs.



RESEARCH AND DEVELOPMENT

Australia has some of the best telecommunications the world can provide. Telecom's research and development programmes are aimed at assessing new services, improving the quality of existing services and containing or reducing the cost of these. Current projects involve the use of optical fibres, micro-electronics, solar powered transmissions, and holography using laser light.

Telecom Australia
Working for you

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