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IN THIS ISSUE

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COVER
SYMBOL OF
TELECOM AUSTRALIA

The Telecommunication Journal of Australia

The Journal is issued three times a year (February, June and October) by the Telecommunication Society of Australia. The object of the Society is to promote the diffusion of knowledge of the telecommunications, broadcasting and television services of Australia by means of lectures, discussions, publication of the Telecommunication Journal of Australia and Australian Telecommunication Research, and by any other means.

The Journal is not an official journal of the Australian Telecommunications Commission. The Commission and the Board of Editors are not responsible for statements made or opinions expressed by authors.

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Telecom Australia

G. MOOT, M.I.E. (Aust.)

EDITORIAL NOTE: One of the functions of this Journal is to record the key milestones in the growth of telecommunications in Australia. In spite of the wide publicity already given to the establishment of the Australian Telecommunications Commission no apology is needed for the present article. In addition, our many overseas readers will appreciate a resume of the main features of the new Commission and some of the reasons underlying the changes that have been made.

INTRODUCTION

On the 1st July 1975, the former Postmaster General's Department was split into two Commissions, the Australian Postal Commission and the Australian Telecommunications Commission in accordance with the recommendation of a Commission of Inquiry established early in 1973. The Australian Telecommunications Commission is known commercially as Telecom Australia. The Postmaster General's Department was retained; it now consists of a nucleus of administrative staff together with the spectrum management and Radio Regulatory and Licencing staff.

The following are some of the main features of Telecom Australia. For the most part they are the direct consequence of recommendations of the Commission of Inquiry:

- The Commission at present consists of 7 Commissioners (maximum of 7), responsible for the general oversight of the Commission's operations. Five of the members are part time and are nominated by the Minister. The Managing Director of Telecom Australia is the one full time member. One of the part time members is a representative of officers and employees of the Commission. An officer of the PMG's Department is also a member of the Commission.
- The Commission is required to report to the Minister, the Postmaster General on the results of its operations. The Minister may, after consultation with the Commission, give certain directions in writing to the Commission with respect to the performance of its functions and the exercise of its powers as may appear necessary to the Minister in the public interest. In addition, the Commission is to seek the approval of the Minister for fixing or varying the main tariffs and charges for telecommunications services.
- The Managing Director is the Chief Executive of the Commission and is responsible for its overall management. Day to day operations of the Commission are controlled by the Chief General Manager who reports to the Managing Director.
- A Planning Directorate has been established for corporate planning and long term planning of national telecommunications.
- All Engineering activities at Headquarters have been brought together under one Engineering Department.
- A revised form of organisation involving the establishment of a new Operations Department is proposed for the States with the object of providing greater responsiveness to customer needs.
- The former ADP Branch at Headquarters has been incorporated in an Information Systems Department.

THE COMMISSION'S CHARTER

The Telecommunications Act gives the Commission the responsibility to plan, establish, maintain and operate telecommunications services within Australia. The Act specifies that the Commission shall perform its functions in such a manner as will best meet the social, industrial and commercial needs of the Australian people for telecommunications services throughout Australia for all people who reasonably require those services.

The Commission is required to have regard to:—

- the desirability of improving and extending its telecommunications services in the light of developments in the field of communications;
- the need to operate its services as efficiently and economically as practicable; and
- the special needs for telecommunications

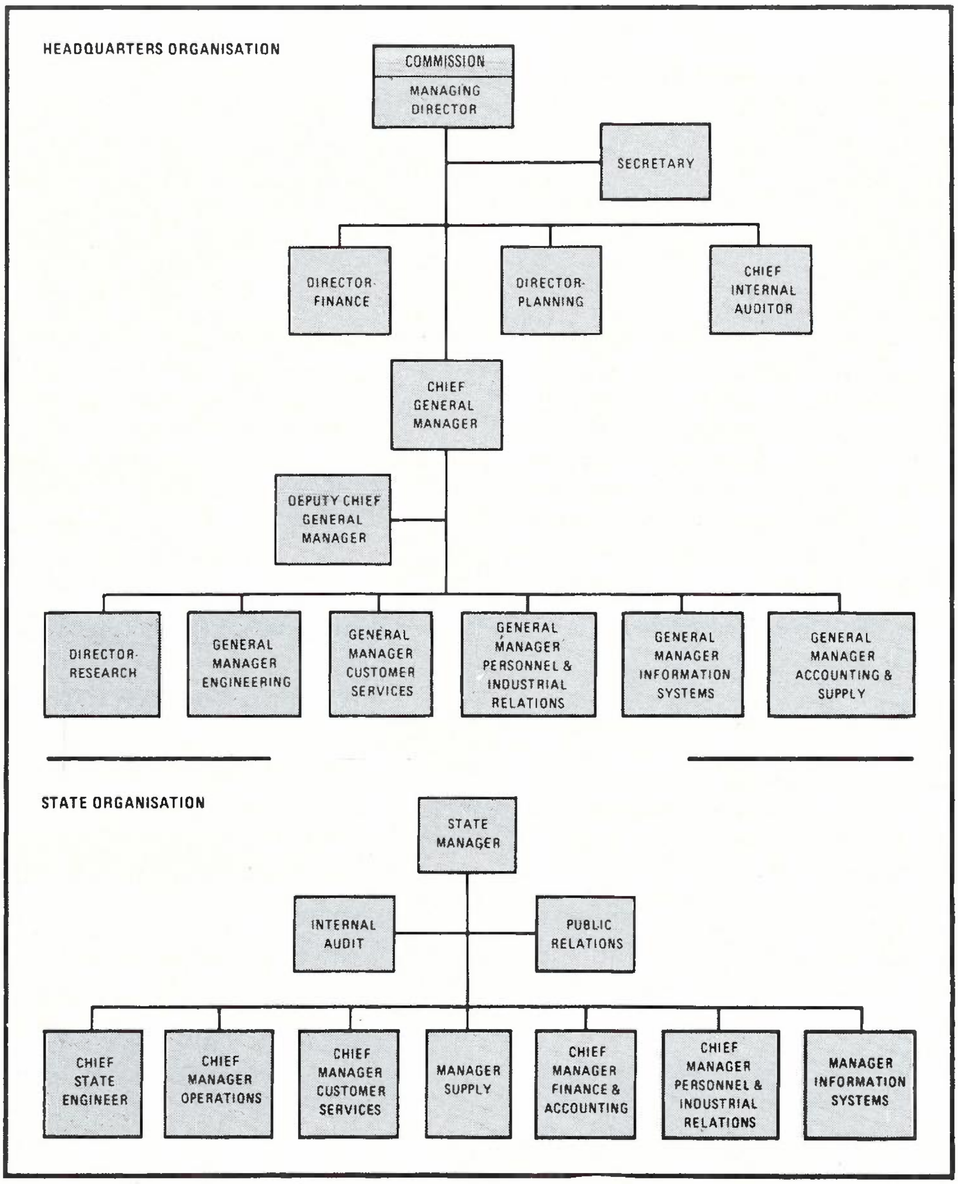


Fig. 1 — Headquarters and State Organisations, Telecom Australia

services for people who reside or carry on business outside the cities.

The Act specifies that the Commission must pursue the following financial policies:

- revenues are to cover all operating expenditures.
- at least 50% of capital expenditure is to be financed internally by the Commission, the balance being advanced from the Australian Government's Budget as borrowings.

Where the Minister does not approve variation of tariffs for basic services to the extent recommended by the Commission, it may under certain circumstances be entitled to claim from the Government as a receipt not attracting interest payments, the amount of revenue equal to the amount of revenue foregone.

Responsibilities under the Wireless Telegraphy Act and Regulations have been retained by the new PMG's Department. The Government wished to place the activities of the Overseas Telecommunications Commission under the Australian Telecommunications Commission but the Australian Parliament rejected the proposal.

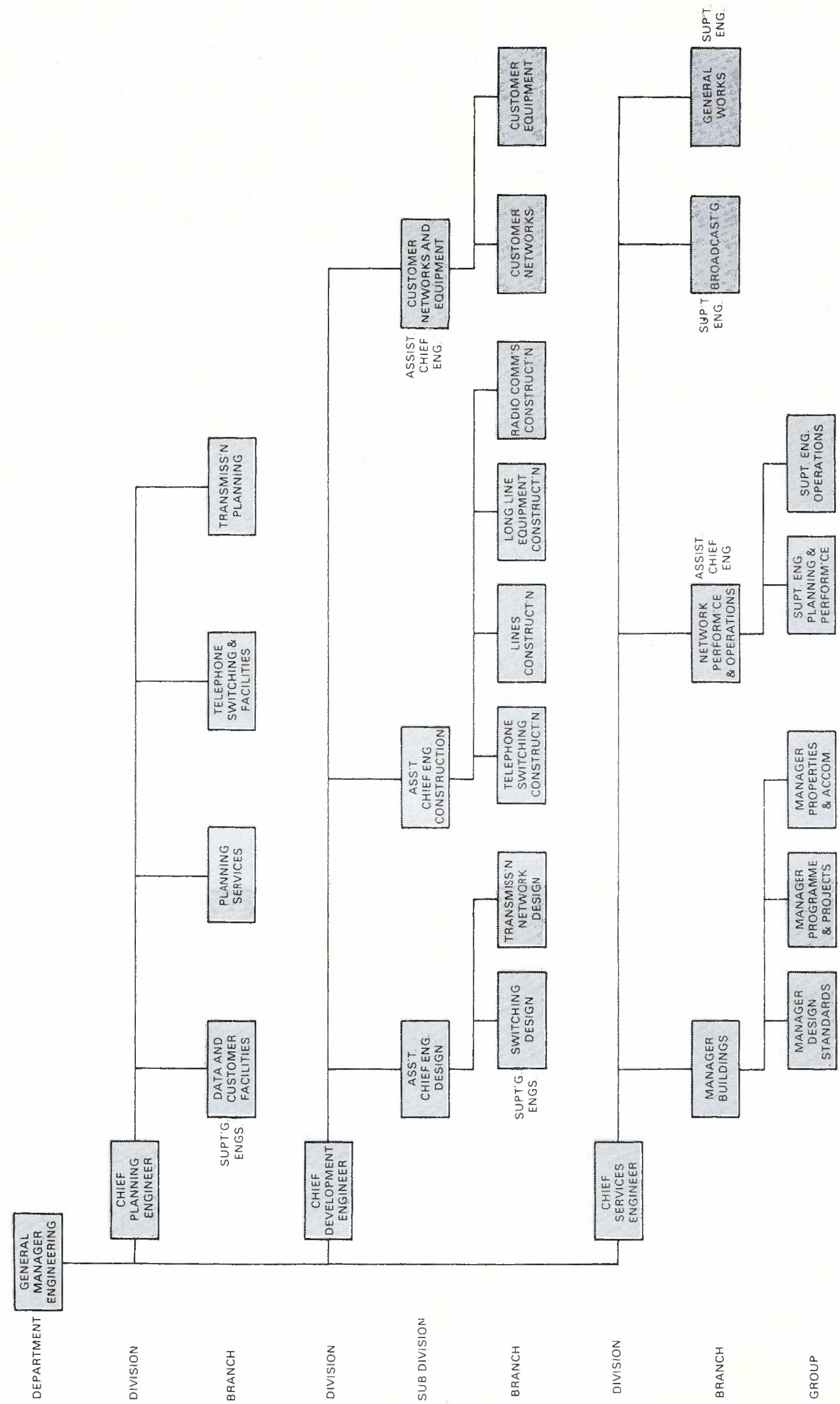


Fig. 2 — Engineering Department Organisation, Headquarters.

INDUSTRIAL RELATIONS

The Commission of Inquiry recommended that the Commission be removed from the jurisdiction of the Public Service Board and the Public Service Arbitrator, and that a special tribunal be established. The Government decided to appoint the existing Conciliation and Arbitration Commission as the arbitral authority responsible for awards on wages and salaries and conditions of service and employment.

A Consultative Council has been established having representatives from the Commission and the Staff Associations. The Council is a forum where basic policy matters affecting conditions of service and staff welfare generally can be discussed.

NEW ORGANISATION AT HEADQUARTERS

The organisation for Headquarters is shown in Fig. 1. It closely follows the recommendations of the Commission of Inquiry.

- All the Telecommunications activities report to a single head, the Chief General Manager, whereas in the previous organisation they reported to the Director-General who was head of the PMG Department.
- The State Managers report to the Deputy Chief General Manager.
- The Engineering activities now report direct to a General Manager, Engineering, compared to separate Engineering heads for:

(i) Planning and Research
(ii) Engineering Development; and
(iii) Engineering Services

in the previous organisation.

The organisation of the Engineering Department is shown in Fig. 2.

PROPOSED NEW STATE ORGANISATION

Details of the new State Operations organisation had not been finalised at the time of writing.

The main change proposed is the establishment of an Operations Department separate from the Engineering Department to undertake all that day to day activity for the provision and maintenance of subscriber services. Each State will be divided into areas, each under the control of a District Telecommunications Manager who would be responsible for:

- handling of sales orders; implementation of district sales and advertising campaigns; provision of advisory services to customers.
- the installation of standarised equipment in customer premises, including the connection to the cable network.
- the operation of telecommunications equipment by telephonists and telegraphists.
- the maintenance of the telecommunications network.
- the preparation of budgets and provision of various support services.

Essentially the district form of organisation within each State would combine in the Operations Department the day to day functions now performed in the Engineering and Customer Services Department.

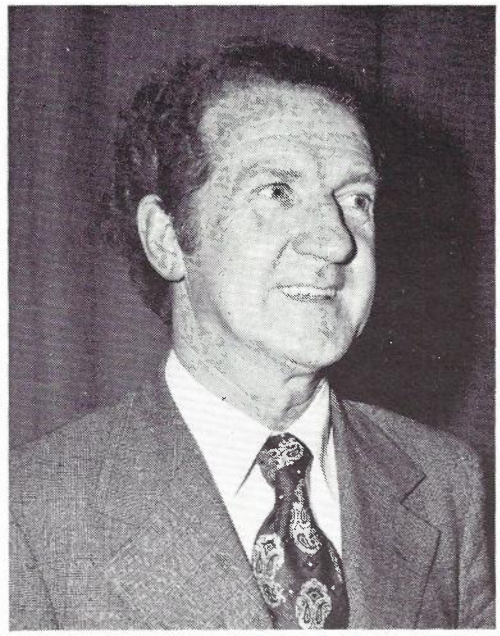
The Engineering Department will under the new organisation concentrate on the tasks of planning, designing, specifying, programming and constructing the telecommunications network, and monitoring its standards and technical performance. The Engineering Department would also provide professional support for the Operations Department as required.

The consultants in developing proposals for the Operations organisation recommended that Australia be divided into 83 District Telephone Manager areas each controlled by a District Telecommunications Manger (DTM). The numbers of districts proposed in each State was:

NSW — 30
VIC — 21
QLD — 13
SA — 9
WA — 7
TAS — 3

In NSW and Victoria because of the numbers of District Telephone Manager areas, Regional Operations Managers will be required to whom a number of DTMs would answer. Three Regional Operations Managers were recommended in NSW and two in Victoria; they in turn will report to the Operations Manager.

A Message from the Chief General Manager



Mr. W. J. B. Pollock
Chief General Manager

I welcome the opportunity to record in this journal a few personal thoughts about the vital issues which will affect the future success of Telecom Australia. The establishment of Telecom Australia has meant quite extensive changes in the structure and methods of operation of the former P.M.G's Department. Clearly these changes will not in themselves provide an immediate solution to all those problems which inevitably beset rapidly growing enterprises. They will provide an improved framework within which to pursue our objectives but the extent to which we succeed depends on the efforts of all of us.

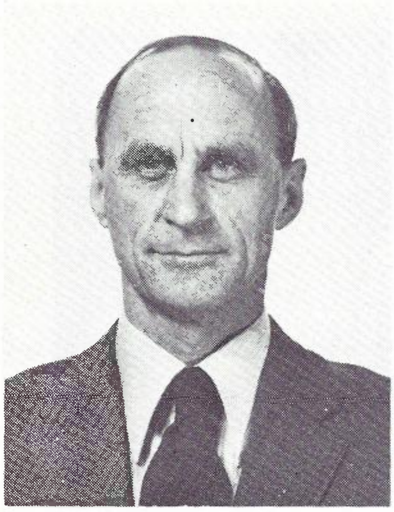
The Telecommunications Act established the Australian Telecommunications Commission "to plan, establish, maintain and operate telecommunication services within Australia." The Act requires the Commission to "perform its functions in such a manner as will best meet the social industrial and commercial needs of the Australian people for telecommunications services and . . . so far as it is in its opinion reasonably practicable to so do, make its telecommunications services available throughout Australia for all people who reasonably require those services".

The Act states that the Commission shall "operate as efficiently as possible and make available services . . . at rates and charges that are as low as practicable consistently with its duty" to secure revenue sufficient to "meet all expenditure and provision for expenditure of the Commission properly chargeable to revenue" and not less than half of its capital expenditure.

In fulfilling these responsibilities our aim is to make Telecom Australia a vigorous first class organisation providing an efficient telecommunications service with reasonable charges and courteous and individual attention to its customers.

In achieving this aim and to enable Telecom Australia to fulfill its responsibilities it will be administered in accordance with the accepted principles of business management and the effectiveness, efficiency and vitality of its operations kept constantly under review.

Headquarters Staff of Telecom. Australia



Mr. J. H. Curtis
Managing Director

Mr. J. R. Smith
Deputy Chief General Manager

Dr. R. B. Cullen
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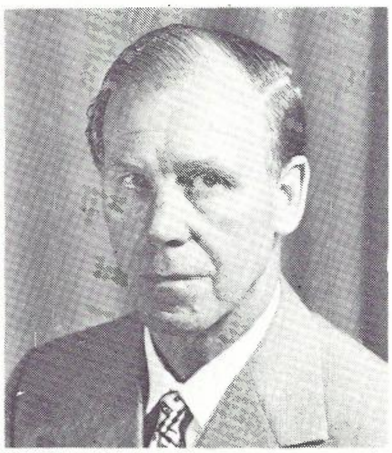
Mr. P. R. Brett
Director, Corporate Planning



Mr. S. H. Hansen
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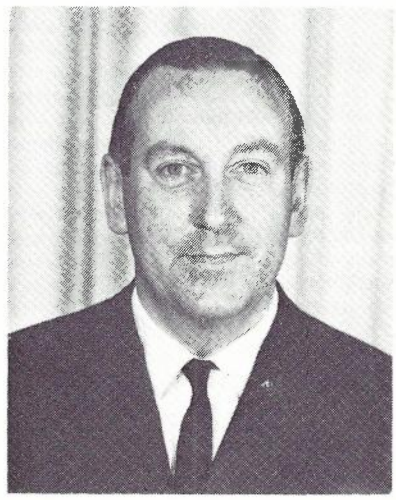
Accounting & Supply Dept.



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Customer Services Dept.

Headquarters Staff of Telecom. Australia (Ctd.)

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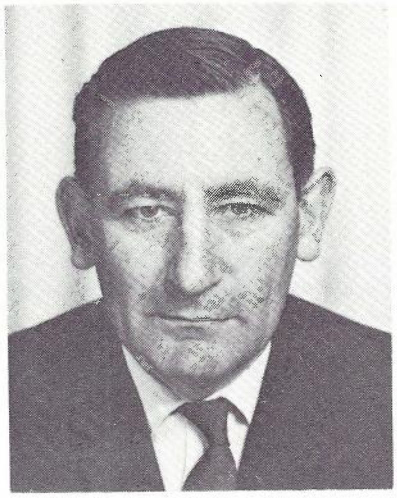
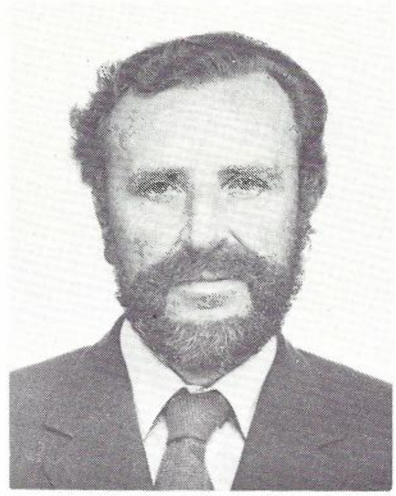
General Manager,
Engineering Dept.



Mr. E. Sanbach
Director, Research Dept.



Mr. A. Kellock
General Manager,
Information Systems Dept.

PABX's and Other Subscribers Automatic Voice Switching Systems in Australia

I. E. BULTE, ARMTC.

This article gives an overall picture of PABX and ACD equipment types available in Australia. It gives some details of equipment approval methods used in the APO and comments on equipment design trends in the past decade.

INTRODUCTION

Since the decision by the Australia Post Office (APO) in 1957 to allow the sale and installation of PABX systems by approved contractors direct to subscribers, a number of different types of equipment has been approved for sale on the Australian market. Prior to this period, step by step equipment had been supplied by contractors, but with the advent of crossbar equipment in the public exchange area in the early 1960's, the provision of crossbar PABX's with increased reliability and additional facilities followed as a logical step.

Whilst allowing the sale of PABX's direct to private subscribers, the APO continued to provide PABX services for Government organisations on a leased basis. Until approximately 1970 the major demand was for PABX equipment, but in recent years larger subscribers with special requirements due to concentrations of traffic into information or booking areas (e.g. airline bookings, and newspaper classified advertising), have generated a need for more specialised equipment to queue incoming calls and then distribute them to trained operators. This equipment is generally referred to as a Queueing System or Automatic Call Distributor (ACD).

It is the purpose of this article to provide an overall picture of equipment types currently available for new installations in Australia, to describe broadly some of the methods associated with the technical approval of systems, and to discuss the effects of developments in technology in this area.

GENERAL

The approved contractor scheme allows subscribers a choice of PABX equipment types and facilities coupled with a competitive sales situation. However, when extensions to existing installations are required this competitive element does not exist.

The APO in controlling the approved contractor scheme in conjunction with carrying out the maintenance of the approved equipment, endeavours to maintain a balance between the number of types necessary to provide a competitive selling situation and adequate facilities for subscribers, and the number of types necessary to hold maintenance costs at a reasonable level. The costs of maintaining the logistic and training facilities associated with a variety of PABX types are very real, and rise significantly with the number of types of equipment to be maintained. It is also desirable to ensure that the relatively small Australian market (approximately 65,000 extension lines of PABX equipment per year) is not fragmented to the extent that equipment manufacturers cannot retain a viable production situation with consequent cost penalties to the subscriber.

Over the years that the approved contractor scheme has operated, there have been significant developments in the types of equipment available and the capacity of the APO to specify, examine, and test equipment for approval. In the early period of the scheme, the lack of detailed knowledge of Australian requirements and the limited resources available led to the marketing of some equipment not well suited to Australian conditions. This equipment is no longer marketed.

Table 1 is a list of PABX systems currently approved for sale for new installations in Australia. Table 2 is a list of queueing systems (ACDs) approved for new installations.

APPROVAL OF EQUIPMENT

When, within APO policy, it is decided to accept equipment for approval examination, it is thoroughly examined in progressive stages. The approach taken to examining new equipment depends upon

TABLE 1.—PABX TYPES APPROVED FOR NEW INSTALLATIONS (MAY, 1975)

*Approved Contractor	System Designation	Crosspoint	Control Elements	Maximum System Capacity (Extensions)
Amalgamated Wireless Aust. Ltd. (AWA)	Hitachi AX2X	Crossbar Switch	Wire Spring Relay	560
	Hitachi AX3S	Crossbar Switch	and Wired Logic	3,200 (4,800 at low traffic)
L.M. Ericsson Pty. Ltd. (LME)	ARD 520	Crossbar Switch	Relay and Wired Logic	10
	ARD 526	Crossbar Switch	Relay and Wired Logic	16
	AKD741/4	Codebar Switch	Relay and Wired Logic	50
	ARD 571(2 Stage)	Crossbar Switch	Relay and Wired Logic	270
	ARD 571(4 Stage)	Crossbar Switch	Relay and Wired Logic	810
	ARD 591	Crossbar Switch	Relay and Wired Logic	Unlimited
Siemens Industries Ltd.	ESK 7/30	ESK Relay	Relay (Min) and Wired Logic	30
	ESK 60/400	ESK Relay	Relay (Min) and Wired Logic	400
Standard Telephones and Cables Pty. Ltd. (STC)	APX 20/70	Crossbar Switch	Relay (Min) and Wired Logic	70
	APX 50/90	Crossbar Switch	Relay and Wired Logic	90
	APX 200	Crossbar Switch	Relay and Wired Logic	200
	APX 800	Crossbar Switch	Relay and Wired Logic	800
	APX 2000	Crossbar Switch	Relay and Wired Logic	2000
	† Minipak 26	Miniswitch	Relay and Wired Logic	26
	† Minimat 90	Miniswitch	Solid State and Min Relay	90
	† Minimat 190	Miniswitch	Solid State and Min Relay	190

* In some cases systems are manufactured and/or installed under licence. Only the prime contractors responsible for system design are listed here.

† New range of equipment. Approvals not complete May 1975.

TABLE 2.—ACD SYSTEMS APPROVED FOR NEW INSTALLATIONS (MAY 1975)

Approved Contractor	System Designation	Crosspoint	Control Elements	Maximum System Capacity (Exch. Lines/Operators)
Amalgamated Wireless Australia Ltd. (AWA)	AWA Queue	Crossbar Switch	Wire Spring Relay and Wired Logic	100/70
Collins Radio Co. (Australasia) Pty. Ltd.	Collins ACD	PCM Switch	Stored Program (DEC PDP11)	600/512
L.M. Ericsson Pty. Ltd. (LME)	ARDP 931	Crossbar Switch	Relay and Wired Logic	40/40
	ARDP 951	Crossbar Switch		100/100
E. S. Rubin Manufacturing Company Pty. Ltd.	System R	Crossbar Switch	Stored Program (DEC PDP8)	60/60
Standard Telephones and Cables Pty. Ltd. (STC)	52 Line ACD	Crossbar Switch	Relay and Wired Logic	52/38

* Approval examination in progress May 1975. Possible test installation late 1975 or early 1976.

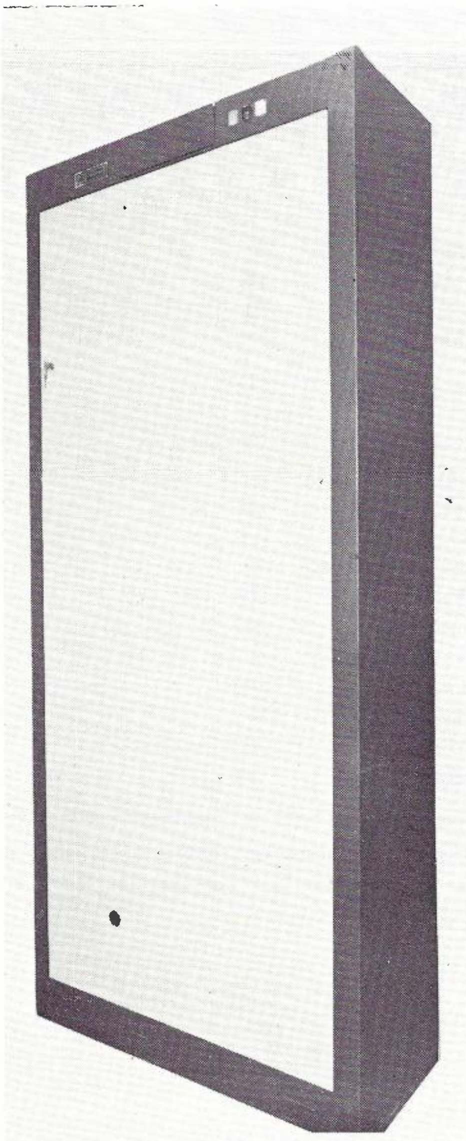


Fig. 1—STC Minimat 90 PABX with Front Cover On.

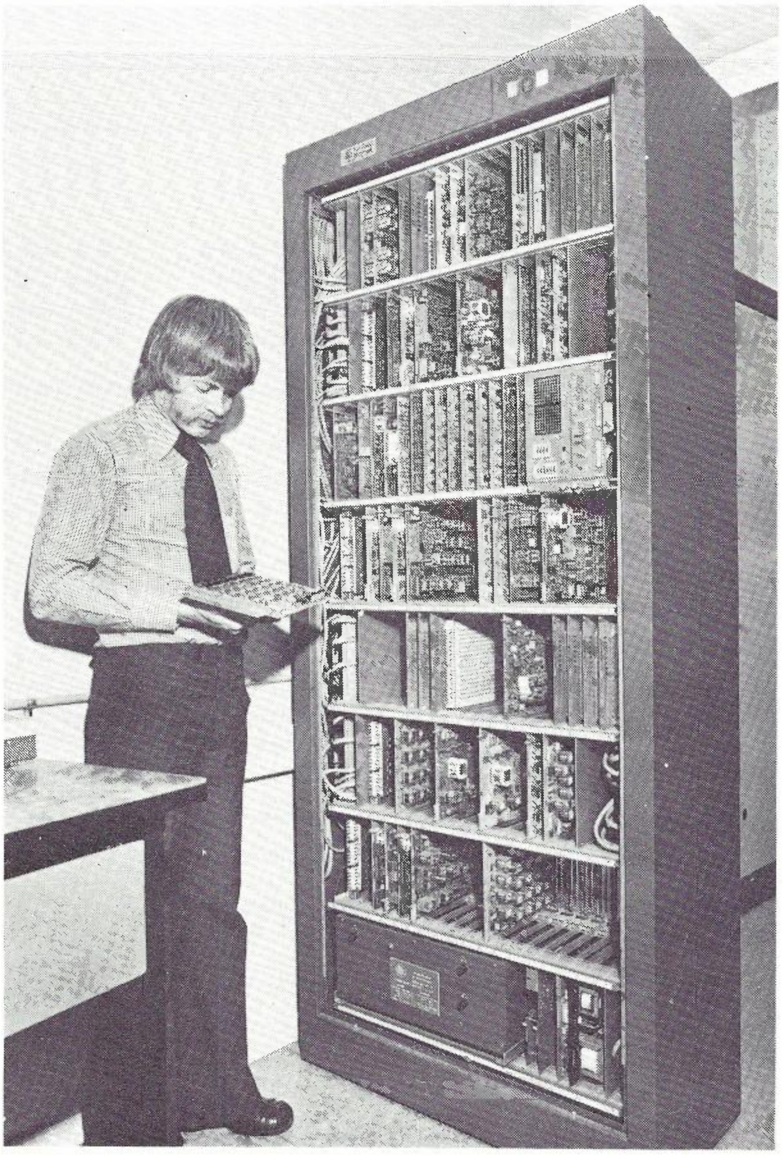


Fig. 2—STC Minimat 90 PABX with Front Cover Off. Note test set at right hand end of third shelf from top.

the historical background of the design. Where the equipment has been in service in other countries and a record of proven reliability is available, less testing of a first-principles nature is required. However, where a new design with unfamiliar components and practices is involved, then detailed check procedures must be followed; for equipment in this category, the following broad steps are generally involved in approval examination.

Examination of Documentation

Company documentation should provide a basic understanding of the system and its maintenance philosophy. The state reached in the finalisation of the design is also indicated by the completeness of the documentation.

Examination of Performance Tests

Results of tests carried out by the designers to confirm performance of the equipment against specifications are examined, (e.g., life testing of components, transmission tests). The APO may request further tests by the company, and for critical items (e.g., switching cross points) samples for testing by the APO may be requested. Theoretical predictions of traffic capacity are examined.

Fig. 3—STC Minimat 90 operators console. Note LED extension busy display top left and exchange line meters.

Installation of Equipment in APO Laboratory

If the documentation is adequate, and the examination of performance tests is progressing satisfactorily, then a working system is installed in the APO Subscribers Equipment Laboratory. The system is load tested with automatic call generators and given a thorough facility check, including the effects of using incorrect operating procedure. The construction is examined in detail and the maintainability and maintenance aids are examined closely. Then the complete system, or part of it, may be operated in environmental chambers simulating different conditions.

Test Installation

If all earlier steps are satisfactory then a test installation in Subscribers premises is authorised. Prior to carrying out the installation, arrangements for maintenance, spare parts, and staff training are completed. This test installation is jointly acceptance-tested by the State acceptance team and Central Administration approval staff. The test installation is then maintained by APO staff, who have been specially trained in the new equipment, for a period of time determined by the equipment performance.

Preliminary Approval

When the equipment has performed satisfactorily for an acceptable period, a "face value approval" is given in conjunction with an agreed marketing plan.

This approval allows sale of the equipment on a progressive basis in areas where staff can be given appropriate training prior to cutovers; responsibility for correcting any design problems remains with the contractor.

Final Approval

When equipment has been marketed for a period, and performance has been confirmed, final approval is given.

DEVELOPMENTS IN PABX TECHNOLOGY

General

The contractor scheme has provided an area in which to observe, and, to some extent test, the design philosophies of different companies. Equipment developed in Australia, France, Germany, Japan, Sweden and the United Kingdom has been approved.

PABX and ACD systems are usually derived from public exchange equipment switching philosophy, adapted by the contractor concerned, to provide the simpler switching requirements and the more sophisticated facilities of PABX and ACD working. With some exceptions the economics of the situation generally favour similar hardware being used for public exchange and PABX/ACD equipment. The following discussion gives some details of trends observed.

Connecting Elements

To date, all systems approved have used space division connecting elements of the electro-mechanical type. The tendency has been towards miniaturising and increasing the reliability of these.

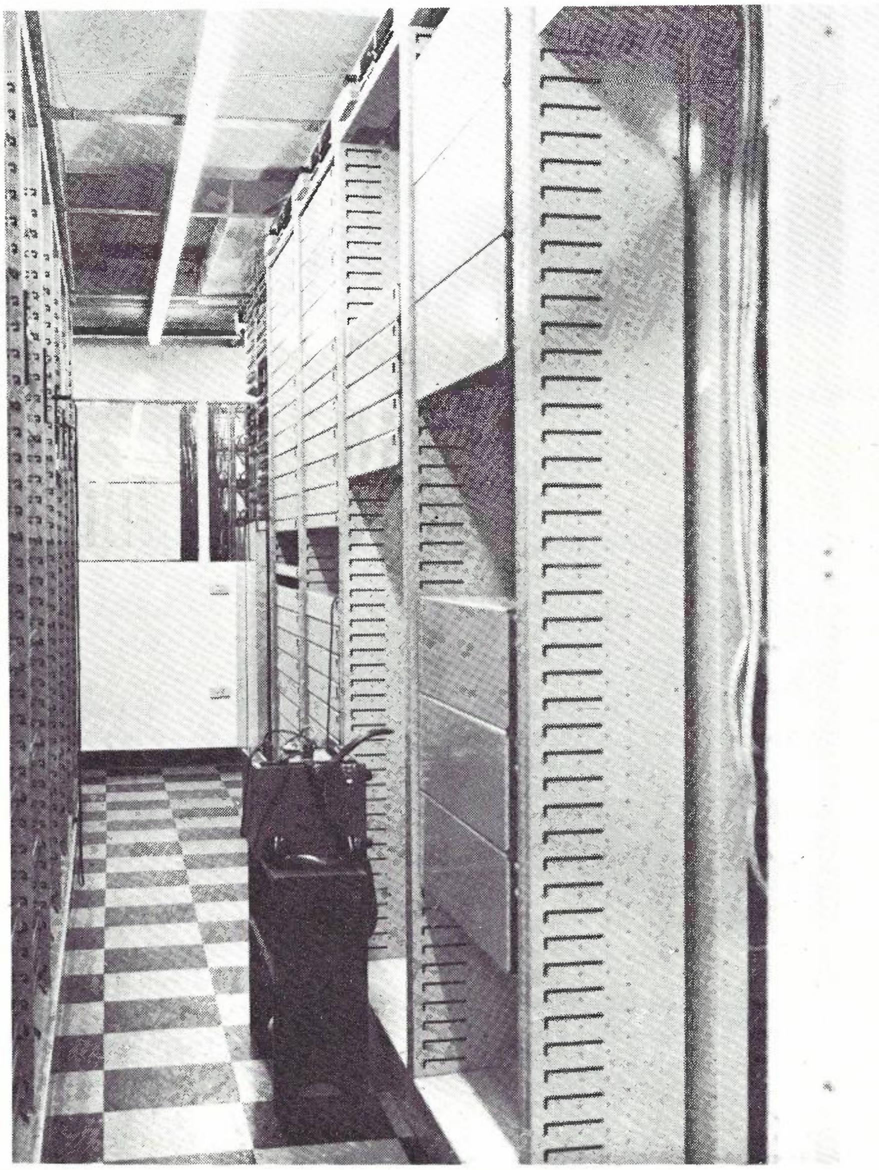


Fig. 4—LME ARDP 951 ACD Installation for Melbourne "Herald" Newspaper.

The main electromechanical elements that have been approved are:

- Electromechanical selectors — crossbar, rotary, bi-motional.
- Improved forms of crossbar switch — Code bar in LME AKD 741.
- Miniature relays — Siemens ESK.
- Miniselectors which retain the arrangement of crossbar but with greatly reduced dimensions — STC Miniswitch.

Further developments in the field of space division connecting elements include reed relays, and electronic crosspoints such as the PN PN diode. These are not currently in use in PABX's in Australia.

Time division switching developments have been followed closely, and some systems employing time division techniques are currently under investigation.

Control Elements

Over the years there has been a transition from step by step equipment with decentralised control to common control systems using registers and markers with wired logic. There has also been a gradual miniaturisation of the control circuitry and an increase in its electronic content.

Stored Program Control

A number of stored program control PABX's has been developed overseas. These are generally controlled by a small computer which is built to communication reliability standards and may be duplicated. Generally these developments are taking place in the larger size equipments, but it is expected that smaller systems will prove-in economically as techniques improve.

One stored program controlled ACD system (Rubin System R) developed in Australia has approval. This system uses a minicomputer, DEC-PDP8, and crossbar switches.

Another large stored program controlled ACD, developed by Collins Radio of USA, is currently

Fig. 5—Answering Position LME ARDP 951 (Classified advertising department, Melbourne "Herald").

Fig. 6—Rubin "System R" ACD Equipment, NRMA, Sydney.

Fig. 7—DEC PDP 8 Computer and Input Output Teletype "System R" ACD.

undergoing approval examination. This system uses twin PDP 11 computers and PCM switching.

Packaging

There has been a marked tendency in recent years to package PABX equipment in a manner aesthetically compatible with office furniture and decor. The need for structural strength in racks and cabinets has reduced as a direct result of miniaturisation and the use of solid state components. This has allowed the use of lighter materials, such as pressed metal, to form cabinets which hold shelves into which printed circuit boards are plugged. These developments permit the shaping of cabinets to give a more pleasing appearance than the rack-type construction which was necessary, for strength reasons, to carry heavy equipment.

Also as a result of miniaturisation, considerable reduction in volume of the equipment required has been achieved; it is now possible to fit the complete requirements, including power supply, for a PABX of approximately 30 extension lines into a cabinet 0.3m x 0.3m x 1m.

This reduction in space requirement allows new systems to more readily meet the lower ceiling height conditions of modern office buildings, and has also reduced problems associated with floor loadings. In some designs the high density packaging of components has resulted in the need to introduce forced cooling with the consequent introduction of a vulnerable electromechanical element. New component designs and proper attention to the need for natural convection should eliminate this requirement.

Traffic Capacity

Experience has shown that PABX's designed to

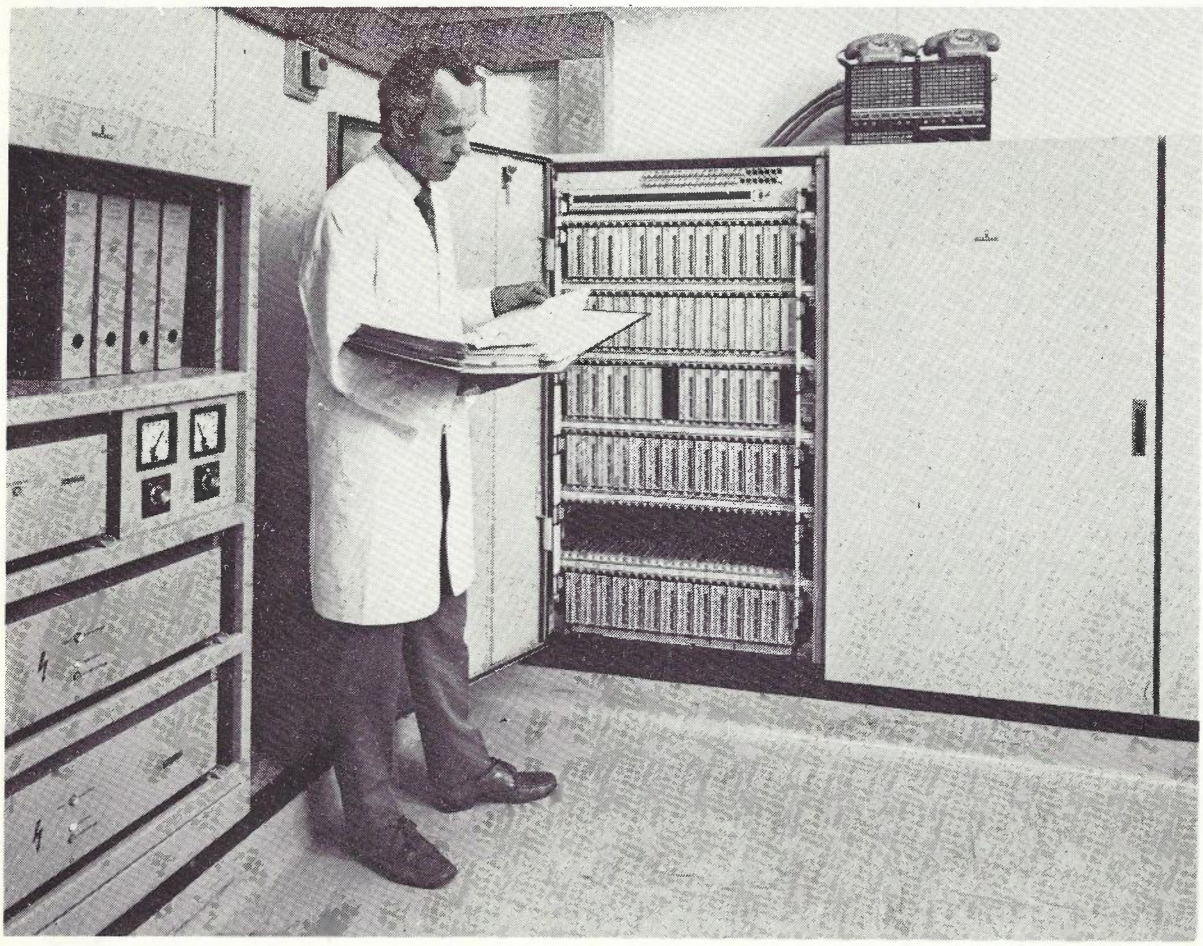


Fig. 8—Siemens ESK 60/400 PABX Robert Bosch, Clayton Victoria. Note test set rear top of cabinets. (Photograph courtesy Siemens Industries Ltd.)

meet European and Japanese traffic standards are not generally suitable for Australian requirements. In Australia, the percentage of internal traffic in a PABX is generally lower, being some 20% of the total traffic and the total erlangs per extension are higher, up to 0.2 erl/extn being a common requirement. PABX designs in which the erlang capacity per extension does not vary significantly with variation in percentage internal traffic do not encounter difficulty with this requirement, but others which may be optimised in the range of internal traffic 40% to 60% do.

Under equipping of the extension multiple, in set patterns based on traffic predictions at the time of installation, has been used as a solution to this problem. Later systems designed to meet

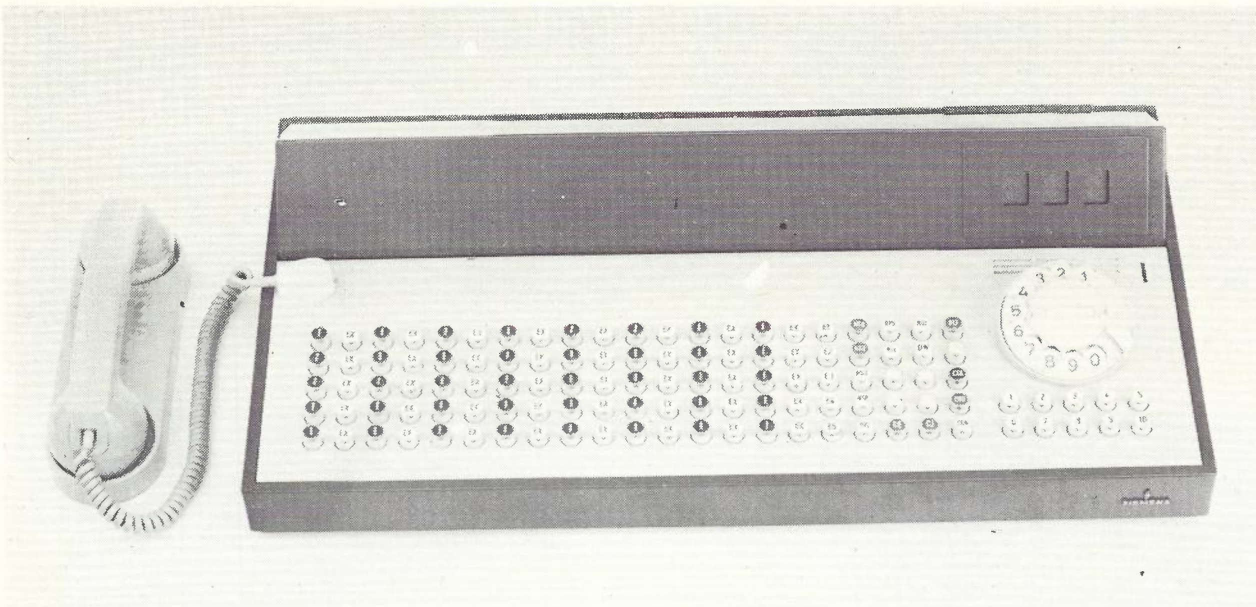


Fig. 9—Operators Console Siemens ESK 60/400 PABX. (Photograph courtesy Siemens Industries Ltd.)

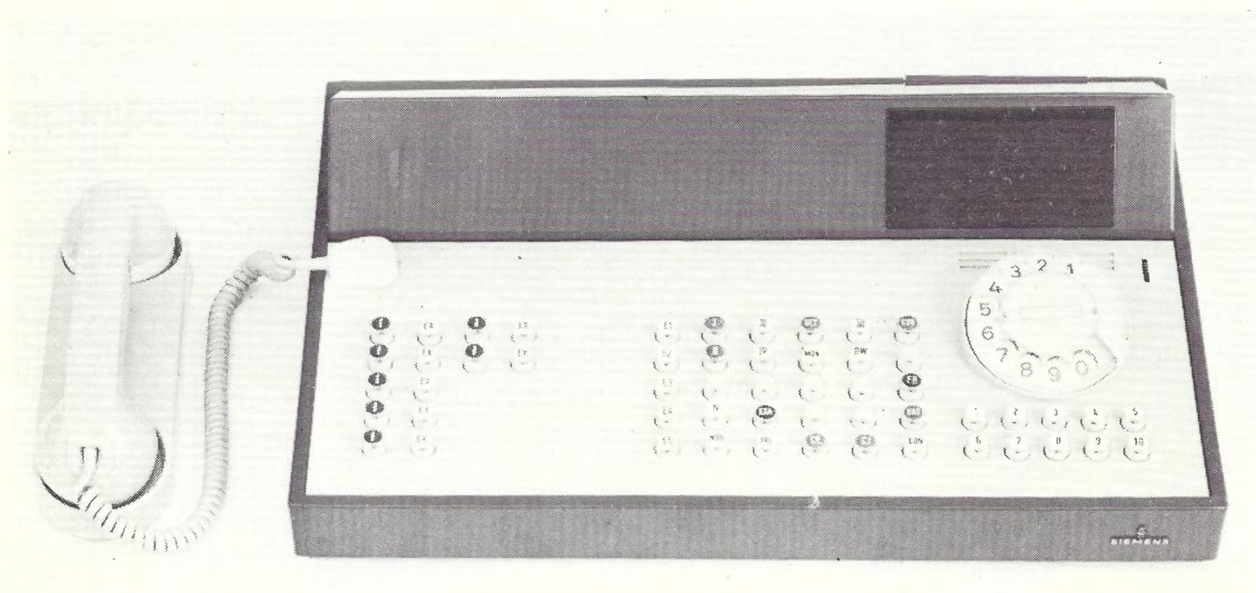


Fig. 10—Operators Console Siemens ESK 7/30 PABX. Dark space rear right is extension busy display. (Photograph courtesy Siemens Industries Ltd.)

Australian conditions rarely encounter this problem.

Maintenance and Reliability

PABX's are not generally maintained on a staffed basis and are only visited when necessary for fault clearance or at prescribed intervals for checking. High reliability and quick fault clearance times are required to minimise costs associated with despatching staff for faults.

Later designs of PABX's using printed circuit board techniques and containing integrated circuitry do not lend themselves to fault rectification on site, due to the difficulties of arranging sophisticated test equipment on site and the specialised techniques necessary for repair. In these cases, replacement of complete printed circuit boards and return of faulty boards to the appropriate factory for repair is preferable, and this method is being implemented.

A major difficulty with fault finding in this type of equipment is that it is no longer possible to tell visually the state of operation of control logic. It has therefore been found necessary, in addition to such vital signs as the presence of tones, transmission path, etc., to provide lamp indications of the progress of calls and the state of certain units of the equipment.

Operators Console

The appearance of the operator's console is important, as it is frequently on view in a reception area and must form part of the overall decor. Its appearance may even help influence the opinion of potential customers entering the premises of a firm for the first time.

The trend in console design has been away from cords and plugs, and all modern equipment is key

Fig. 11—Operators Console Hitachi AX2X PABX, Hotel Melbourne.

operated. To reduce maintenance of the console, simplicity of design and the use of reliable components is encouraged. This has led to maximum use of non-locking keys, long-life lamps (light emitting diodes are being introduced gradually as suitable types become available), and a minimum of components requiring routine maintenance.

In addition, more information about the state of a call and the category of extensions is available to operators. Visual numeric displays of busy extensions, categories of extension (e.g., trunk barred) are provided to eliminate unnecessary operations by the operator.

PABX Facilities

In a competitive sales market it is quite often the additional facility that a particular PABX can provide that makes a sale. It is also a fact that facilities much in demand are those that will save manhours in a commercial environment, reduce the tedious element in repetitive tasks, or generally speed communications. For these market reasons, PABX facilities have developed rapidly, aided by the miniaturisation of circuitry. Facilities available on PABX's develop much more rapidly than public exchange facilities, and in fact provide a practical testing ground for future public exchange facilities.

Examples of these PABX facilities are:

- *Automatic Conference Calls.* A connection which permits simultaneous transmission between three or more extensions, which is set up by one extension.
- *Automatic Call Back.* An extension, after attempting an internal call to a busy extension, has the call automatically established when the called extension becomes free.

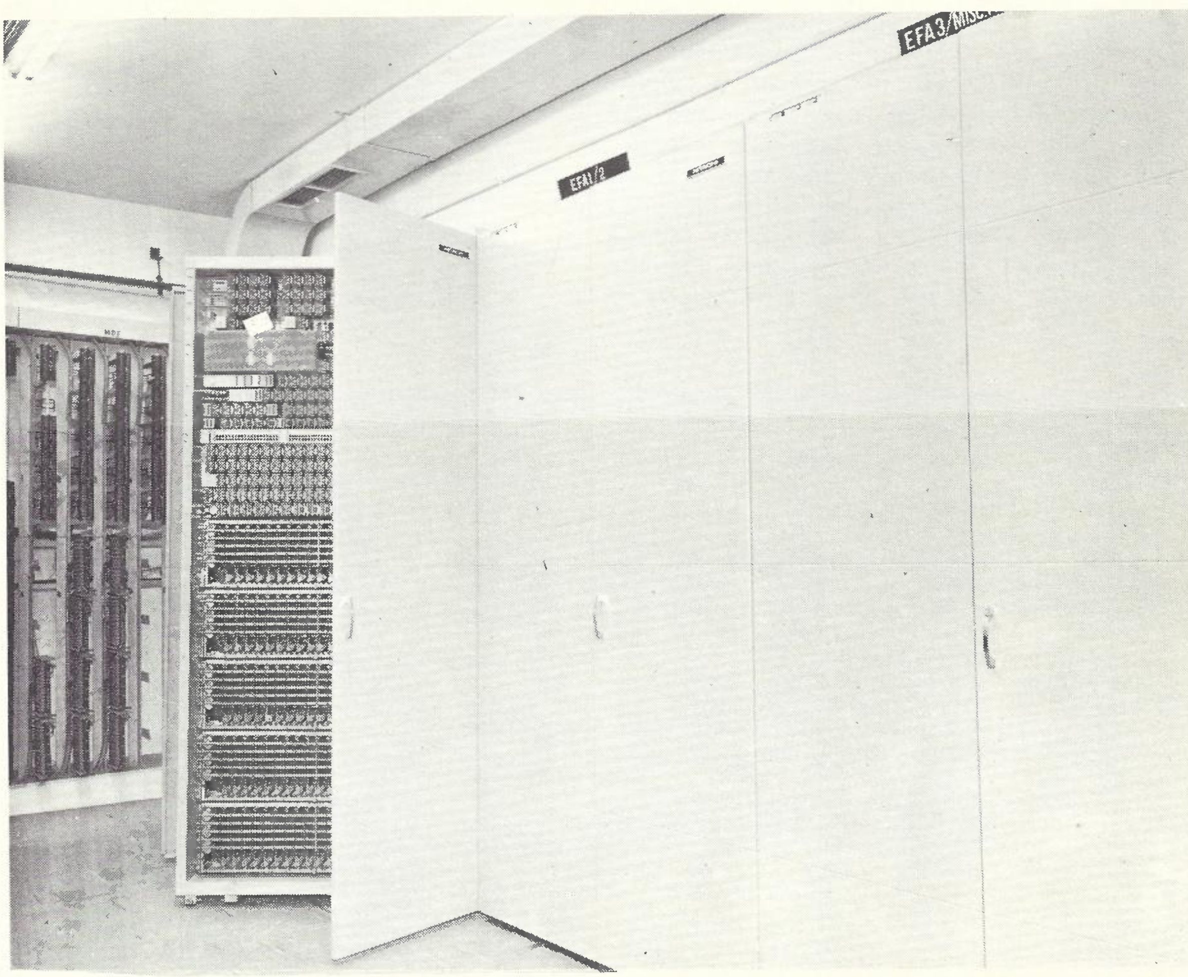


Fig. 12—AX2X Equipment, Hotel Melbourne.

- *Mobile Radio Access.* Internal calls are made to a nominated address with further signalling through the PABX to control press-to-talk half-duplex radio transmission.
- *Abbreviated Code Dialling.* Extensions gain access to internal or public exchange numbers by using special short codes.
- *Pursue Me.* Calls to an extension which is temporarily unattended are automatically diverted to another extension.

INTRODUCTION OF MORE ADVANCED DESIGNS

Now available on the world market is a number of advanced designs of PABX equipment. These include stored program controlled and solid state switched equipment. It seems inevitable that this equipment for which is claimed high reliability, increased flexibility in the provision of facilities, and simplified maintenance with fault printouts, will be introduced into Australia.

It is the opinion of the author, however, that the introduction of more advanced types of PABX equipment, and certainly the introduction of additional types of PABX equipment, should only be carried out in conjunction with the similar introduction of new generation equipment in local public telephone exchanges. The use of similar or preferably the same, philosophy, hardware and possibly software, in public and private systems can mean large savings in approval examinations, staff training and also in capital cost if the equipment is manufactured in Australia. It is also preferable the author believes that only systems already in production be considered.

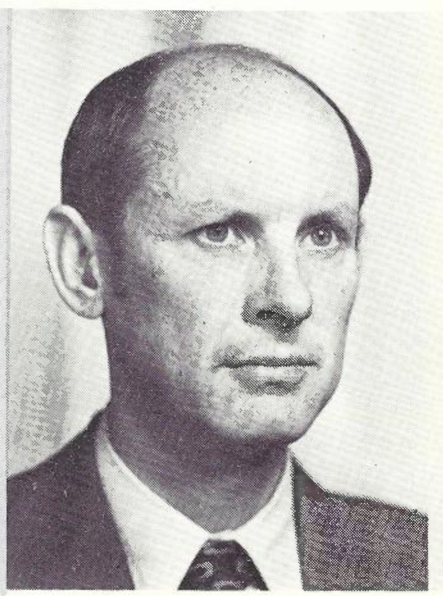
CONCLUSION

In the eighteen years since the private contractor scheme for PABX's was introduced in Australia, much has been achieved by the APO and contractors jointly in developing ranges of equipment and facilities to meet the requirements of the Australian market. This period has not been without its difficulties. Some designs have proved unsuitable for Australian application and have had to be discontinued. This history has led to the present situation where the Australian PABX market is served by four major contractors with a variety of equipment types and facilities. It is the opinion of the author that care should be taken in the introduction of the next generation of equipment to ensure that the costs of introduction and also capital and maintenance costs are minimised.

REFERENCES

1. K. V. Sharp. "A Penta Conta PABX"; Telecom. Journal of Australia, October, 1961, Vol. 13, No. 2.
2. T. Champion: "800 Line Cordless PABX"; Telecom. Journal of Australia, June, 1962, Vol. 13, No. 4.
3. A. Morton: "Conzinc PABX Melbourne"; Telecom. Journal of Australia, October, 1962, Vol. 13, No. 5.
4. A. Morton: "Subscribers' Attended 5 + 20 Line PABX"; Telecom. Journal of Australia, October, 1961, Vol. 13, No. 2.
5. A. O'Rourke: "Australian Penta Conta Crossbar PABX"; Telecom. Journal of Australia, June, 1965, Vol. 15, No. 2.

IAN BULTE joined the Postmaster General's Department in 1952 as a Technician-in-Training and after completion of a Diploma in Electrical Engineering at Royal Melbourne Technical College worked in Transmission Planning Victoria as Engineer Class 1, and Class 2. In 1961 he transferred to Substation Installation, Metropolitan Branch. After four years in Substation Installation he spent a year on temporary transfer to Sydney Metropolitan Branch working in P.A.B.X. and Exchange Installation. In 1966 he returned to Melbourne Metropolitan Branch for two years in Exchange Installation. In 1969 he joined the Headquarters Subscribers Equipment Branch where he is currently Senior Engineer Switching Systems Design.



The East-West System — Operation and Maintenance in Western Australia

A. H. FAULKNER, B.E., M.A., MIEE.

A description of maintenance experience with the East-West microwave system over the period between commissioning and the present date, including references to some problems which have occurred.

INTRODUCTION

The East-West microwave telephony and TV system, between Northam in Western Australia and Port Pirie in South Australia, has now been in service for over 4 years. This article describes experience of the West Australian Administration with the system since its acceptance for service in 1968.

A later issue of this Journal will include an article on the South Australian administration's experience with the system.

GEOGRAPHICAL CONSIDERATIONS AFFECTING MAINTENANCE

This system stretches across 2500 km of arid country and is the main communication link between the eastern states and Western Australia. The country is very sparsely populated and in one maintenance area, distances of up to 800 km have to be travelled by maintenance staff to reach unattended repeaters. The section controlled by the Western Australian administration from Northam to Eucla is approximately 1600 km in length.

Unlike in the South Australian section, where all functions including first-in maintenance, route control, and base repair, are contained within a single country section remote from the capital city, the western section commences only about 100 km from Perth, where it joins an earlier 960 channel radio system originating at Mt. Yokine, the capital city terminal. Consequently, control over the whole WA section is exercised by Mt. Yokine, and in addition the unit Base Repair Centre is located there. First-in maintenance of radio equipment, and all maintenance of the power equipment, is the responsibility of Country Branch staff at Kalgoorlie and Norseman, and second-in maintenance involving field work is carried out by staff of the Radiocommunication Service Depot in Perth.

This arrangement has the advantage that specialist staff can be called on from throughout the Radio Section, where necessary. This is particularly valuable in the case of the Base Repair Centre where operations are of a very specialised nature.

The prime source of trouble indications are pilot and noise alarms provided on the system. The alarms from remote repeater stations are signalled to the main terminals over an extensive supervisory system. Regular routine tests and customer complaints give a good indication of system performance and frequently determine when corrective action should be initiated.

REPLACEMENT UNITS

Spare units of transmitters, receivers and phase modulators, the essential bearer components, are held at Kalgoorlie and Norseman, where each have one set of all frequencies in use on their section of the route. Kalgoorlie maintains the section from Northam to one repeater past Kalgoorlie, and Norseman the remainder out to Eucla. All other spare units and all spare components are held at the Base Repair Centre and sent out as required.

Since staff do not travel with these units, it is necessary to provide transport for them. Usually this is by the Pioneer interstate coach service, which operates 5 days per week, although scheduled air services and charter aircraft are employed on occasions. The use of public transport requires that adequate protection for the units be provided. Initially transit cases of 6-ply lined with 75 mm of flexible polyurethane foam were used. These proved rather cumbersome in use, and have been replaced by fibreglass cases lined with from 25 mm to 75 mm of foam, strategically located, thus substantially reducing the weight and size of the cases. This method of transport has been found satisfactory in practice. No cases of damage and a very few doubtful cases of misalignment, in transit, have occurred.

No attempt has been made to replace units in the positions they originally came from, since this would involve a double visit and should not be necessary if specifications for the repaired and re-aligned unit are adhered to.

Complete transmitters and receivers are constructed as single units, and this has proved to be a very valuable maintenance feature.

PERFORMANCE

Measurements of basic and total noise, frequency response, spurious emissions, and pilot levels, have been made since commissioning, at approximately monthly intervals on each modulation section. These measurements have proved very valuable in detecting and rectifying faults causing performance degradation, before they accumulate to the point where complete overhaul of the system is required. In fact, the telephony bearers have never been re-aligned as a whole apart from an operation soon after commissioning directed at establishing whether 960-channel performance could be achieved. These tests showed that this could not be achieved simply by equalisation. Although some bearers gave better than 3 pw/km noise figures, others were up to twice this figure. However, the loading on the system has been increased on the end sections (Northam - Kalgoorlie and Port Pirie - Kongwirra) to 720 channels, to overcome a temporary shortage of circuits, without changing the system at all, and this has been found satisfactory, although absolute measurements of performance for this capacity cannot be made since the appropriate filters do not exist.

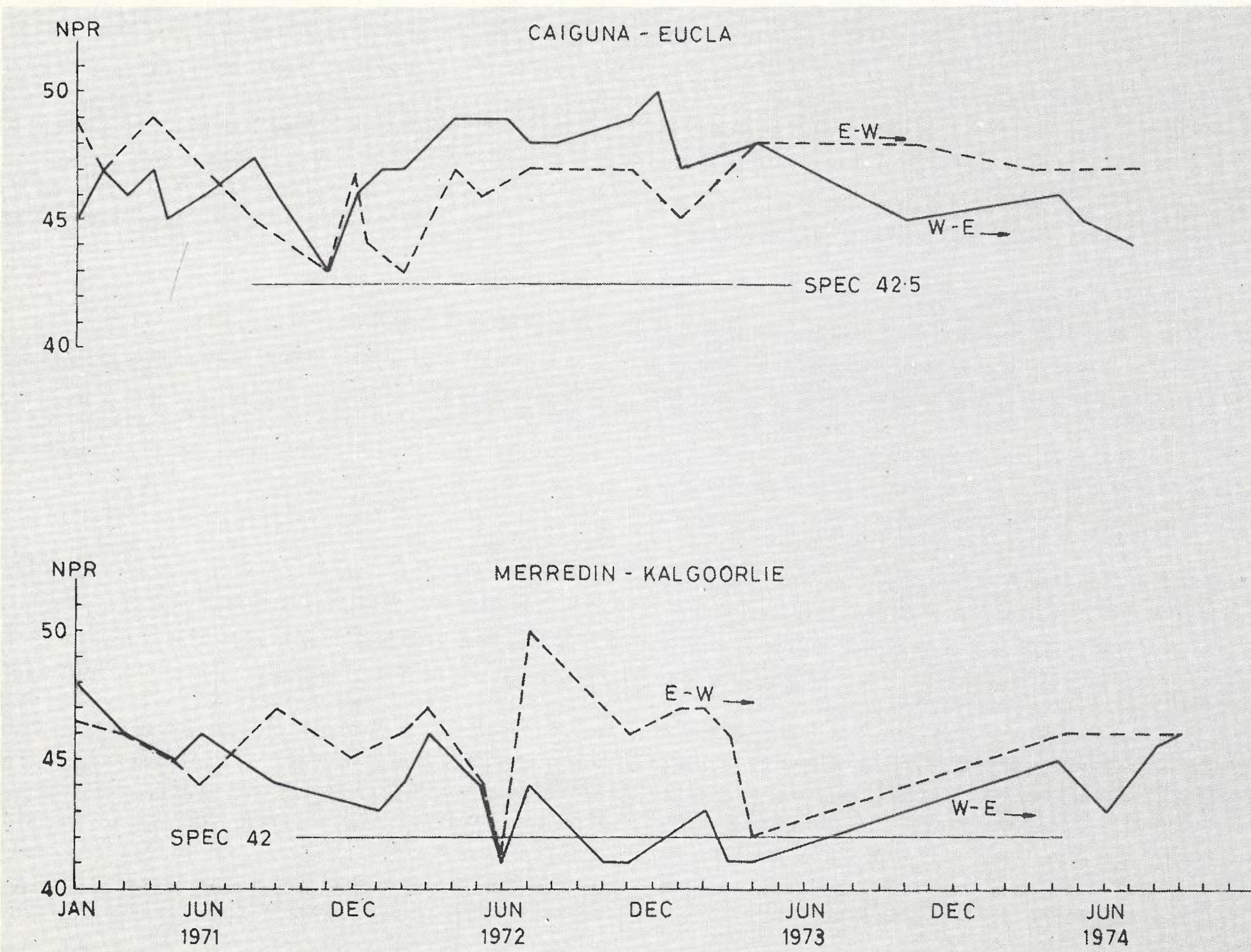


Fig. 1—White Noise Performance of Typical Bearers.

Apart from the operation described above, the telephony bearers have not been realigned, since the performance of the bearers has not deteriorated in service, and is still within the 3 pw/km maintenance objective.

It is considered that three factors have contributed to this:

- The periodic measurements described above, and consequent corrective action.
- A tight control from the outset over the alignment of units in Base Repair, to ensure that performance and inter-changeability are maintained.
- The recycling through Base Repair of some units which may have been marginal in performance when originally installed.

Fig. 1 shows the results of noise measurements over a number of typical bearers since commissioning, the figure for the worst slot being given in each month, expressed as Noise Power Ratio (NPR).

RELIABILITY

The specification for the equipment reliability of the system was for a failure rate of not more than 0.6 faults per one way repeater per year, giving a figure for WA of 92 faults per year. In the early service of the system, the fault rate was four times this figure. However, the fault incidence has fallen steadily, and has now reached a point at which the originally specified figure has been achieved. (Fig. 2).

Note that East-West 1 has twice as much equipment as East-West 2, since the common protection bearer is counted with the first-in bearer. Note also that faults in the supervisory system are excluded from this analysis.

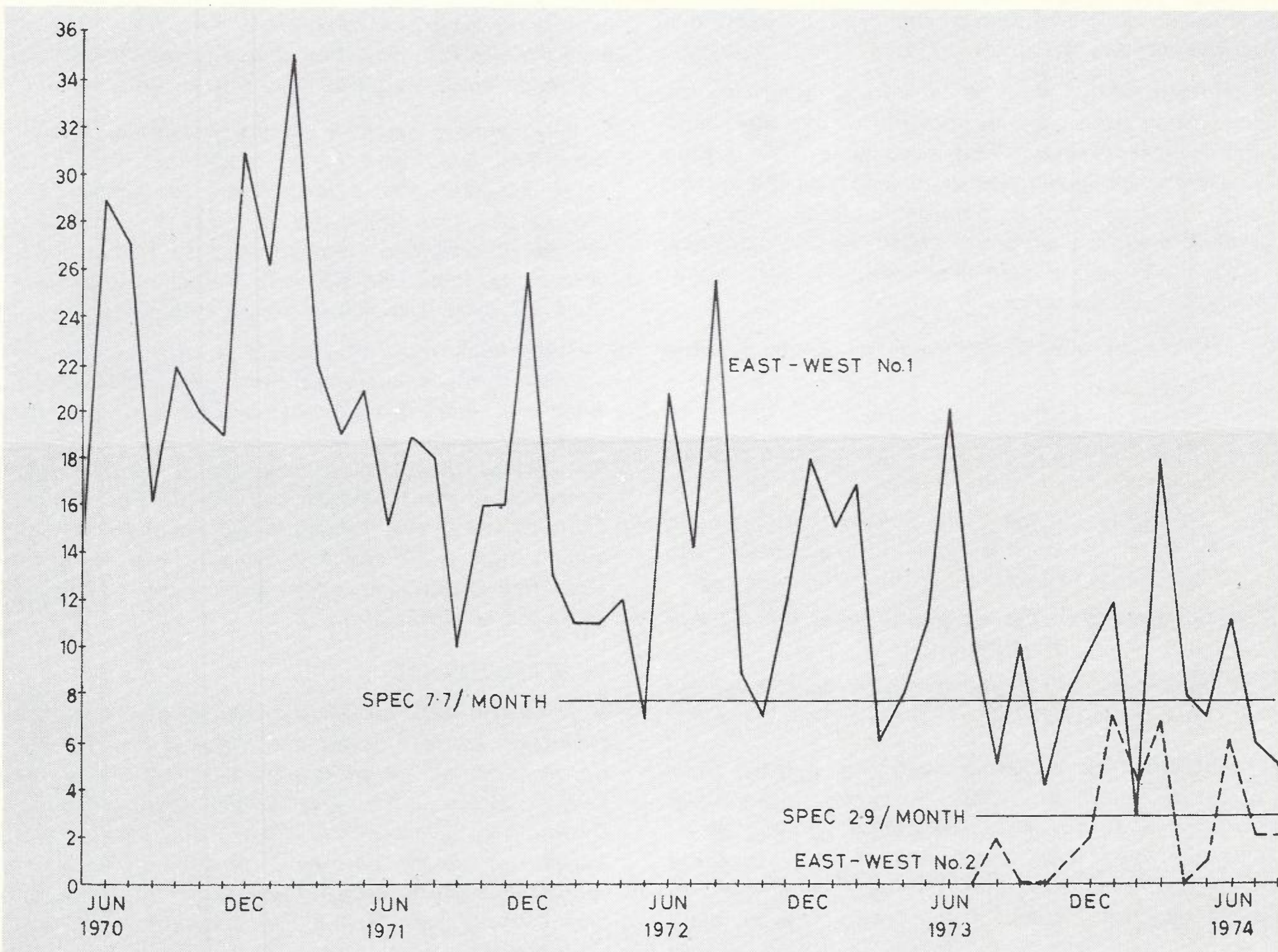


Fig. 2—Faults per Month.

TELEGRAPH PERFORMANCE

A problem which only became apparent some months after commissioning the system was the intermittent occurrence of severe mutilation of telegraph traffic. An intensive investigation by APO and contractors staff over several months finally identified the mechanism by which this was occurring, enabling the complete elimination of the problem.

The effect was found to be triggered by excessive traffic levels. Broadcast programme channels were the main offenders, levels of 20db above normal have been encountered. These were causing depression of the pilot levels in the modulator pilot receivers, which were found to be more sensitive to overload than the modulators themselves. Thus pilot fail on the modulators was being produced, causing the modulator changeover switch to operate (the system uses duplicate modulators, automatically switched). Since both modulators were fed with traffic, and pilot fail settings were the same for both, the switch chattered between one modulator and the other.

Unfortunately, due to a wiring error in the modulator input card, the polarity of one modulator input was reversed, thus causing a 180 degree phase change in the baseband output of the system each time a switch occurred. Since telegraph receivers are susceptible to phase "hits" of considerably lower order than that (Ref. 1), this would always cause an error.

The means adopted to cure this problem were as follows:

- Correction of the wiring error.
- Closer control of broadcast programme channel levels by the various studios.
- Conversion of the modulator pilot detectors to a later version, designed for colour TV use, which had less sensitivity to traffic overload.
- Staggering of the modulator pilot fail settings to give a 1 db differential.
- Reduction of deviation from 250 kHz per channel to 200 kHz.

Although the modulator switching was the main cause of telegraph mutilation, other causes were also found during the investigation, namely diversity switching and bearer switching. Diversity switching generated phase hits because of the different physical lengths of the feeders to the main and diversity antennas. Bearer switching did so because of the different electrical length of the feeders, since the differing frequencies used have different velocities of propagation in waveguide. Over a long switching section these could add up to a value giving almost 100% probability of error, whereas over the shorter sections the probability was much lower. Probability of errors is related to phase hit magnitude approximately as follows:

Below	35°	—	Nil
	45°	—	0.0004
	90°	—	0.2
Above	130°	—	1

A long switching section, e.g. Norseman-Caiguna, with 10 repeaters, has a delay difference between main and standby bearers of 250 nanoseconds. This represents a phase difference of 90° at a baseband frequency of 1 MHz, or of 180° at 2MHz, corresponding error probabilities being 0.1 and 1. For a short section such as Northam-Merredin, with 4 repeaters, the probability at 2MHz would be only 0.03 (i.e. three errors in 100 switches).

For a diversity switch, a typical delay difference would be 90ns, giving a phase hit of 81° and an error rate of 0.1. However, diversity switches would be much more frequent than bearer switches.

All diversity sections of the system have been equalised, by inserting an additional length of cable between the diversity receiver output and the switch, this being cut to such a length that the delay difference was reduced to half a nanosecond or less. A Tektronix "Vectorscope" was used for measurements of phase difference.

The equalisation of bearers is still under consideration. Much longer cable lengths are involved, since all working bearers would have to be equalised to the protection bearer, and amplification would probably be required. Also, the incidence of bearer switches has now been substantially reduced, and consequently the necessity for equalisation is in doubt. However, later systems, apart from East-West system expansions, are being equalised on installation.

TV PERFORMANCE

Extensive and increasing use is made of the protection bearers of the East-West system for the transmission of TV programmes to and from the Eastern States. This was satisfactory for monochrome TV, but with the advent of colour it was found that second harmonics of colour sub-carrier components produced pilot and noise fails, the former causing loss of the TV programme. It was consequently necessary as a temporary measure to remove the colour sub-carrier by a notch filter at the input to the system. Subsequent investigation showed that the problem was exacerbated by over-equalisation of the system, which had a slightly rising frequency response of about 1 db per section at 4.43 MHz in order to obtain a flat response in the pilot and sound sub-carrier regions. Since the effect was cumulative, this resulted in a 6 db lift overall. This was corrected by re-equalisation of the bearers, although in consequence there was some reduction in the noise performance of the pilot and sound sub-carriers.

In addition, a reduction in pre-emphasis was decided on, from 14 db to 8 db, and replacement units have been made up and installed since the system had a comfortable margin as regards chroma noise, specifications for this could still be met with the reduced pre-emphasis and transmission of colour over the East-West system is now very satisfactory.

VANDALISM

Much less trouble than was originally feared has been experienced with vandalism. Several paraboloids have had holes shot in them, fortunately without any vital part being hit. However in 1974 three stations were broken into within a week, probably by two different parties. In two cases no damage was done apart from jemmying the doors. In the third case, Boorabin, much rougher tactics were employed, a vehicle being used to force the gates and outer doors, and one of the racks being battered. Although most of the damage was confined to one supervisory alarm shelf, the rack-head fuses were also smashed, cutting power to both phase modulator transmitter drives and consequently causing over an hour's traffic loss. Although local staff were called out, and reached the station with commendable promptitude, and the police also advised, no trace of the culprits has been found.

SUPERVISION

Because of the length and importance of the East-West system, a number of additional supervisory facilities have been fitted, in addition to the normal alarm displays. A 4287 kHz continuity pilot is inserted at Mt. Yokine, looped at Eucla, and fed back to Mt. Yokane, being detected at every intermediate terminal, failure at any one being indicated by means of the supervisory system. Its level is also continuously recorded at Mt. Yokine.

In addition, two telegraph channels have been provided, one looped back at Eucla and the other at Adelaide, and reversals sent over these are also continuously recorded.

A remote control has been provided which enables the protection bearer to be looped back at Eucla, thus permitting testing of the complete occasional TV bearer. Other remote controls enable bearers to be switched to protection from Mt. Yokine.

CIRCUIT RELIABILITY

The standard for reliability of broadband circuits, as laid down in the APO Engineering Instruction Long Line Equipment, P 0497, is that interruptions to traffic should not exceed 0.12% (52 minutes) in any month for each 1000 km of route. For Northam-Eucla this gives a figure of 70 minutes per month.

Table 1 gives the traffic loss from December 1972 to December 1974 inclusive. The total traffic lost was 263 minutes from all causes, or 10½ minutes per month. This corresponds to 0.018%, approximately one seventh of the allowable loss for a system of this length.

TABLE 1—TRAFFIC LOSS FOR PERIOD DECEMBER '72 TO DECEMBER '74 (Northam-Eucla)

Cause	Number of Events	Total Duration (mins)
Equipment	5	38
Propagation	1	8
Power	4	15
Vandalism	1	112
Human Error	3	90
Total	14	263

EAST-WEST TWO

A second 600-channel telephony bearer was added to the system in 1974, (in traffic August '74) using identical equipment but installed by APO staff. However, the initial high fault incidence of the first bearer did not occur with the second, which has achieved its guarantee figure of 0.5 faults per transmitter-receiver per year, in its first year of operation.

It is considered that factors contributing to this are:

- The elimination of faulty component batches which occurred with East-West One equipment and the incorporation of modifications found desirable with East-West One.
- The testing and, where necessary, alignment of all major units of equipment before installation, including temperature cycling.

CONCLUSIONS

Although some problems were expected in the earlier period, the East-West system has now settled down, and is giving a very good service for all types of traffic. System reliability has been very good, very little traffic loss having been caused by the equipment. Almost all of the breaks which have occurred have been due to human error.

REFERENCES

1. Von Wolfgang Horak: 'Telegraph Distortions and Error Rate in Frequency Modulated Voice-Frequency Telegraph Systems owing to Sudden Phase Changes on the Transmission Path'; NTZ Communication Journal, Volume 8, 1970.
2. Faulkner, A. H.: 'Operation and Maintenance of the East-West System'; Telecomm. Journal of Aust., Vol. 21, No. 1, 1971, page 99.

A. H. FAULKNER is Class 3 Engineer, Radiocommunication Service, Perth. He graduated in Engineering at Cambridge University, England, in 1941, and was granted a Master of Arts degree in 1945. He saw five years sea service with the R.N.V.R. as Escort Group Radar Officer, after which he joined the British Post Office Research Station, Dollis Hill, as Engineer, and was engaged in the design and construction of experimental microwave television relay systems. He was the Post Office representative on the Standardisation Sub-committee on waveguides, and the Research and Development sub-committee on microwave test equipment. In 1952 he came to Australia and joined the APO Headquarters Radio Section, leaving in 1955 for private employment. In 1961 he re-joined the Department in Western Australia, and was concerned with the planning of microwave systems in that State, including the East-West system from 1963 to 1966. Since then he has been concerned with the operation and maintenance of microwave and other radio systems in Western Australia. He is a member of the Institution of Electrical Engineers.

Traffic Usage Rate Estimation for Small Country Telephone Exchanges

K. D. VAWSER, B.E., B.Sc. (Hons.), M.I.E. Aust.

This article describes a system that obtains reliable estimates of traffic usage rates for the design of small country telephone exchanges. The system also simplifies the design work involved in handling the annual volume of this work without using a disproportionate amount of design effort.

The principle used is the curve fitting of traffic usage rates obtained from traffic measurement data. The resultant curve functions generate design tables and summaries, the latter being used for design classification.

INTRODUCTION

A basic parameter in the design of telephone exchanges, or of any switching machines for telecommunications traffic, is the average traffic that each customer generates. This parameter is commonly termed a traffic usage rate.

In the case of telephone exchanges, good estimates of traffic usage rates for large automatic exchanges can be obtained from traffic measurement data. For small country automatic exchanges (exchanges with a capacity up to 200 lines) the situation is not so straightforward. There are two main problems:

- the difficulty of obtaining a good estimate of the required traffic usage rates for any one of these exchanges from a traffic study;
- the large number of exchanges of this type.

Regarding the latter, there are approximately 2,500 such exchanges in Australia, and each year a good proportion would require new design work, re-design, or design checking.

This article describes a system that successfully deals with these problems. The system has been developed by the Traffic Engineering Section in South Australia. It employs curve fitting to traffic usage rate data obtained from traffic measurements.

The resultant curves are used as average traffic usage rate functions which have been found to provide good estimates of the traffic usage rates required to carry out design work for most of the small automatic exchanges in South Australia (SA) and the Northern Territory (NT). Only 6% of these exchanges have proved to be exceptional cases for which design work still needs to be based on individual traffic study data.

The volume of design work has been dealt with by simplifying the methods employed. The use of average traffic usage rate functions enables the production of design tables, and also some of the design work is done automatically.

TRAFFIC MEASUREMENT

The first problem noted above was concerned with the difficulty of obtaining a good estimate of the traffic usage rates of a small country automatic exchange from a traffic study. In order to discuss this problem the situation for a large exchange will be compared with that in a small exchange.

Busy Hour Traffic Consistency

In a large automatic telephone exchange the time of the busy hour of each group of circuits is reasonably consistent from one working day to the next, as are also the traffic levels carried during these busy hours. This degree of consistency means that a traffic study conducted during any particular week has a high probability that it will provide good estimates of the traffic levels at that time of the year.

Small telephone exchanges, however, switch calls for small communities which means that their traffics are inherently more affected by changes in the calling times of individual customers, and by local events. Consequently, the time of the busy hour of a circuit group can vary widely from one working day to the next, and the traffic levels in these busy hours can be similarly variable. This lack of consistency means that the traffic levels measured in any particular week do not have a high probability of being representative of that time of the year.

Two types of average traffic obtained from a traffic study are the average of the daily busy hour traffics, known as the average busy hour (ABH) traffic, and the average of the daily traffics at the hour that they are consistently busiest, known as the time-consistent busy hour (TCBH) traffic (Ref. 1). For a typical large exchange circuit group the ABH traffic is 2% to 3% higher than the TCBH traffic, while for a small exchange the ABH traffic is typically 20% higher (and in some cases it can be 40% to 50% higher). This comparison indicates the greater degree of variability in small exchange traffics.

Corrections to Measured Traffic

Some corrections may be needed to the traffic levels as measured in order to obtain the expected levels of the traffic offered to circuit groups at the busy season of the year.

If an appreciable level of traffic is lost or redirected due to congestion in a circuit group then a correction is needed to the measured traffic level to obtain the traffic offered to the group. This correction factor (known as the 'offered correction') may be required for both small and large exchange traffic study data.

A seasonal correction factor is needed to estimate the traffic at the next busy season if the traffic study had to be scheduled out of season. This can be estimated in a straightforward manner for a large exchange (see below). Since small exchange traffic levels as measured by a traffic study are probably not a good estimate of the traffic at the time of year that the traffic study was conducted, the use of a seasonal correction factor is doubtful.

There is a third factor to consider with small exchanges. Despite the wide variations that can occur between busy hour traffics, the traffic fluctuations within any one busy hour are relatively smooth. This is due to the small number of traffic sources. Traffic tables based on the Engset probability distribution (Ref. 2) can be used to dimension small exchange circuit groups. An alternative approach, which is used in the system described in this paper, is to apply a conversion factor to an ABH offered traffic value to obtain an equivalent pure chance value. The full range of standard traffic tables can then be used. This conversion factor, termed an 'Engset correction', rises towards unity as exchange size increases. Above 200 working lines the Engset correction can be neglected.

Traffic Measurement Frequency

There is a considerable capital investment in switching equipment and cabling in a large exchange so that a relatively small overprovision is costly. Also, a large number of calls are switched so that a relatively small underprovision could lead to lost revenue and, more insidiously, to lost goodwill. For these reasons, regular traffic measurement of all circuit groups is justified and for large terminal exchanges the standard frequency in Australia is a traffic study every two years. Monitoring of a few key traffics at frequent intervals is also justified as it establishes the period of busy seasons and provides data for the calculation of seasonal correction factors. One system to provide this monitoring is the CENTOC system which is to be the subject of an article in this Journal.

For small exchange traffics, good estimates are possible if sufficient traffic studies can be conducted. However, the relatively small equipment investment, and the correspondingly small call revenue would not even justify traffic studies at the same frequency as that for large exchanges. (The traffic on a junction group that interconnects a small exchange to a large automatic exchange is an exception as it can be measured at the large exchange.)

With less frequent traffic studies, on traffic of greater variability, the small exchange is at a considerable disadvantage compared with a large exchange in the establishment of reliable traffic usage rates.

ANALYSIS OF TRAFFIC USAGE RATES

For large exchanges a traffic usage rate (TUR) is calculated as the traffic per connected exchange line. However, in small exchanges the proportion of party lines and PBX lines, which tend to generate higher average traffics, can vary widely. To reduce this source of variation in TURs the practice in SA has been to calculate each traffic usage rate for small exchanges as the traffic per telephone (or station).

In the ARK crossbar exchange, for example, the following TURs are useful:

- junction usage rate — combined junction traffic per station;
- local usage rate — traffic per station for traffic between subscribers on the same exchange;
- register usage rate — register traffic per station.

With the current types of traffic measuring equipment it is not an economic proposition to conduct a large number of traffic studies at each small automatic exchange in order to make a good estimate of its average TUR within a reasonable period. A possible alternative would be to pool the traffic study data for a large number of small exchanges. On the assumption that the traffics generated by most small communities follow similar patterns it would be meaningful to estimate average TURs for groups of small exchanges.

Curve Fitting

The possibility of being able to use pooled traffic data from a number of small exchanges was first investigated in SA during 1968.

Scatter plots of the traffic usage rates of small

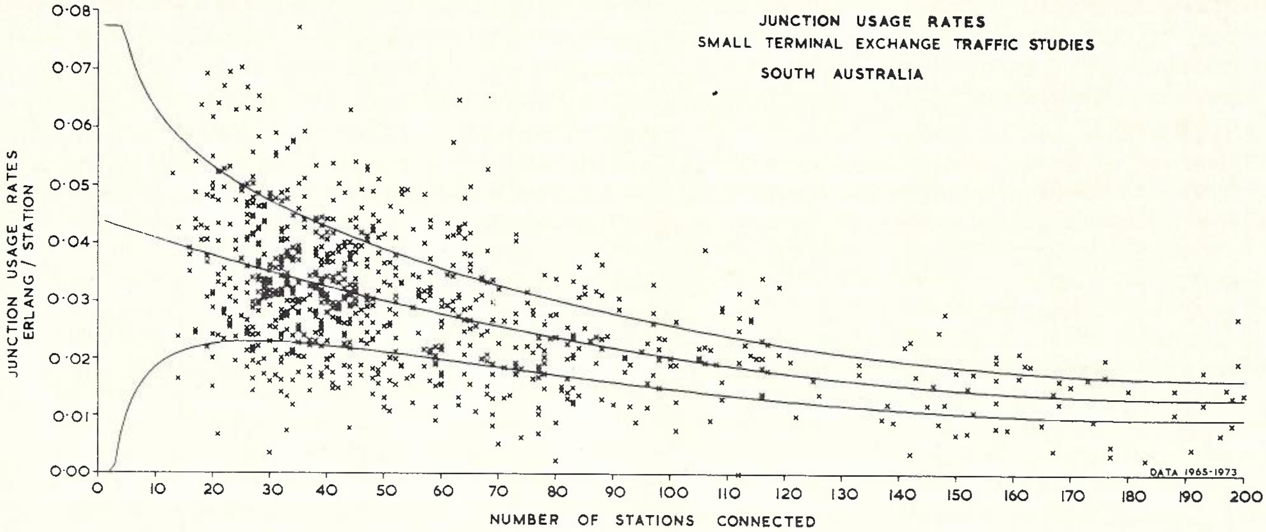


Fig. 1—Scatter Plot of Junction Usage Rates.

country automatic exchanges in SA and NT were produced to see if there was any apparent relationship between TURs and the size of exchanges. The TURs were obtained from all of the available traffic study data for these exchanges. Fig. 1 is a scatter plot of junction usage rates against stations using traffic study data obtained over the period from 1965 to 1973 (it is very similar to its initial counterpart in 1968). Each data point on the plot is obtained from a junction traffic level to which an Engset correction has been applied.

A standard approach to determine relationships from scatter plots is to obtain a least squares best fitting curve using a regression technique (Ref. 3 is one of a number of references on this technique). This type of curve is a best fit in the sense that the sum of the squares of the deviations of the points from the curve is least. A mathematical function is chosen that will give a curve most appropriate to the apparent relationship in the scatter plot.

At the time of the initial work in 1968 the computer being used by Traffic Engineering had a polynominal regression routine available. By inspection, the junction usage rates in Fig. 1 appear to fall as the number of stations increases, but not as a linear function. A quadratic function ($y = a + bx + cx^2$) could be appropriate, and this was the function chosen. (Some non-polynominal regressions could also be suitable, for instance a negative exponential of the form $y = a + b \cdot \exp(-cx)$ could be appropriate.) The central curve across the scatter plot in Fig. 1 is a best fit quadratic. This can be considered as an average junction usage rate function.

Similar scatter plots and average traffic usage rate functions were obtained for local usage rates and register usage rates.

Confidence Limits of Traffic Measurement

Any traffic measurement is subject to sampling error. For instance, in a standard study traffic levels are sampled once every three minutes during selected periods in a sample week. From statistical theory, limits can be set on either side of an average measured traffic level such that there is a designated probability that the true traffic level will fall within those limits (Ref. 4).

As an example, if a traffic study at a small exchange measured a junction traffic of four erlangs then 90% confidence limits would be 4 ± 0.6 erlangs (assuming a four minute average call hold time). This is an indication of the sampling error involved.

To judge how much of the scatter of data points in Fig. 1 could be due to measurement sampling error, each of the points on the average usage rate function was considered as if it was the result of a traffic study and 90% confidence limits were plotted above and below it. The resulting points form the upper and lower curves in Fig. 1. For instance, at 105 stations the average junction usage rate is 0.03 erlang/station, or to one decimal place this is a junction traffic of 3.2 erlangs. Considered as a traffic measurement result, the 90% confidence limits would be approximately 3.2 ± 0.5 erlangs, or 0.03 ± 0.005 erlang/station. As can be seen, sampling error can account for a good proportion of the scatter but by no means all of it. (Note that the upper and lower curves are not 90% confidence limits on the central regression curve as obviously many more than 10% of the data points lie outside the upper and lower curves.)

Two further uses can be made of the confidence limits on Fig. 1. The first is to draw the inference that with the spread of the measurement sampling error as shown there is nothing to be gained by using a more complex curve to fit the data points. Any simple function that will give a shallow curve similar to the central curve shown should be suitable. Care must be taken in extrapolation beyond a reasonable cluster of data points. A quadratic curve as shown will start to rise, which would not correspond to junction usage rates of larger exchanges. A negative exponential curve might be more suited to extrapolation. The second use of the confidence limits is in the selection of design usage rates (see below).

Referring to Fig. 1 again, when the three curves shown were initially drawn accross the junction usage rate scatter plot, the data points outside of the confidence limits were examined. The exchanges to which these points belonged fell into two categories:

- A majority of these exchanges belonged to one category in which a typical exchange had several traffic study results and most of the corresponding data points were located within the confidence limits (and they could be both above and below the average usage rate).
- In the minority category, most of the data points belonging to an exchange were consistently above the upper curve or below the lower curve.

This examination gave more confidence in the possibility of using the average usage rate function for design work.

Average Traffic Usage Rates of Regions

All of the data points were then analysed to see whether there were particular differences between regions within SA (there were insufficient data points for the NT to make a separate analysis for this region worthwhile). The data points were grouped into regions and their average traffic usage rate functions obtained. The regions chosen were the country Secondary Switching Areas of Adelaide (Country), Pt. Pirie, Mt. Gambier, and Kadina.

Fig. 2 shows these average usage rate functions plotted together, and, in addition, an average usage rate curve for the small exchanges in the Outer Metropolitan area (their data points are not included in Fig. 1). Note that the curves for the Pt. Pirie and Kadina regions are not extended beyond 130 stations as these regions have very few exchanges above this size. The curve for the Outer Metropolitan area has been included to show the higher junction usage rates which occur in exchanges with unit fee access to a capital city metropolitan area.

The average usage rate curve for all the small country automatic exchange data has been transferred from Fig. 1 and is marked as 'State (Country)' on Fig. 2. Generally most of the country curves tend to cluster around this curve; only the curve for the Mt. Gambier region is consistently different. This particular region has a higher average usage rate than the other regions.

CRAFTS SYSTEM

The analysis of traffic measurement data which has been described above is carried out by computer programs that form the CRAFTS system (the name CRAFTS is taken from Calling Rates for Terminal Exchanges). A flow chart of the system is given in Fig. 3.

There are two main programs as shown. Program CRAFTS has as its principal output a summary of traffic measurement data on terminal exchanges. To keep this summary up to date the CRAFTS program would be run several times each year. The major data analysis including the curve fitting, and the production of average traffic usage rate tables, is carried out by the program CALLRAT. This is run whenever there is sufficient new data to make it worthwhile to check average usage rate functions, which could occur at about two-yearly intervals.

Both of these programs have been developed progressively since 1968.

The CRAFTS Program

In addition to processing traffic data from small country automatic exchanges the CRAFTS program also summarises traffic data from manual terminal exchanges and the larger ARK crossbar exchanges. Traffic data from ARF crossbar and the larger step by step terminal exchanges are not processed as the output format is not suited to these types of exchanges.

During the coding of the input traffic study data, offered corrections are made in the few cases where they are required. For small exchanges the program applies an Engset correction.

An important calculation for each small exchange junction usage rate is its deviation from the average usage rate function as related to the confidence limit curves. This is required in order to select design usage rates. As can be seen from Fig. 1 the distance between the average curve and the curves for its confidence limits of measurement is not a linear function of stations, nor is it proportional to the average usage rate function. Hence expressing the deviation of a data point as a percentage of the average value does not locate it with respect to the confidence limits.

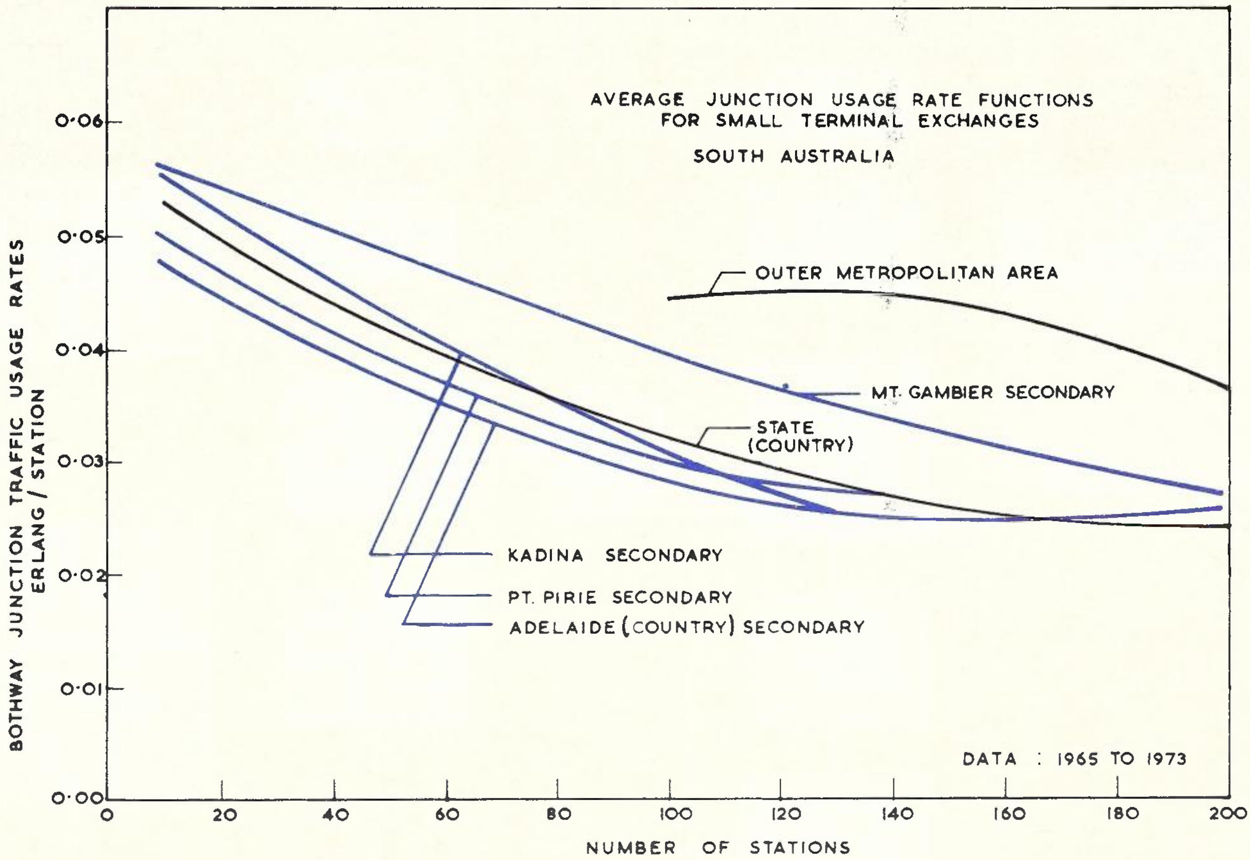


Fig. 2—Average Junction Usage Rate Curves.

The procedure which was adopted to express deviations is as follows. Each junction usage rate data point corresponds to a particular number of stations. At this number of stations the distance from the average level to each of its confidence limits is divided into ten units. The deviation of the data point is expressed in these units, taking a deviation above the average as positive, and below as negative. Thus a data point above the upper curve would have a deviation greater than +10. A data point below the average but above the lower curve would have a deviation between 0 and −10. As can be seen in Fig. 1 the size of these units varies with the number of stations (It decreases as the number of stations increases).

A traffic study data summary is the main output of CRAFTS. As this information is useful for design and operations work, a reduced copy of each computer page is prepared and then multiple copies are made and distributed to planning and operations staff. A copy of a typical page is shown in Fig. 4.

Subsidiary outputs as set out in Fig. 3 are used for data checking and for the identification of individual data points on a scatter plot.

The CALLRAT program

A number of data analysis options on traffic study data for small country automatic exchanges is available in the CALLRAT program. The data can be split into selected subsets as required.

A major output of this program is a set of tables of average traffic usage rates for the selected subsets. Multiple copies of these tables are made and distributed to staff engaged in design work.

SELECTION OF DESIGN USAGE RATES

Based on Fig. 2, it has been found that it is sufficient to use two average junction usage rates, one being the State (Country) average and the other being the average for the Mt. Gambier region.

To use the average traffic usage rate tables produced by the CRAFTS system requires the selection of design traffic usage rates for particular

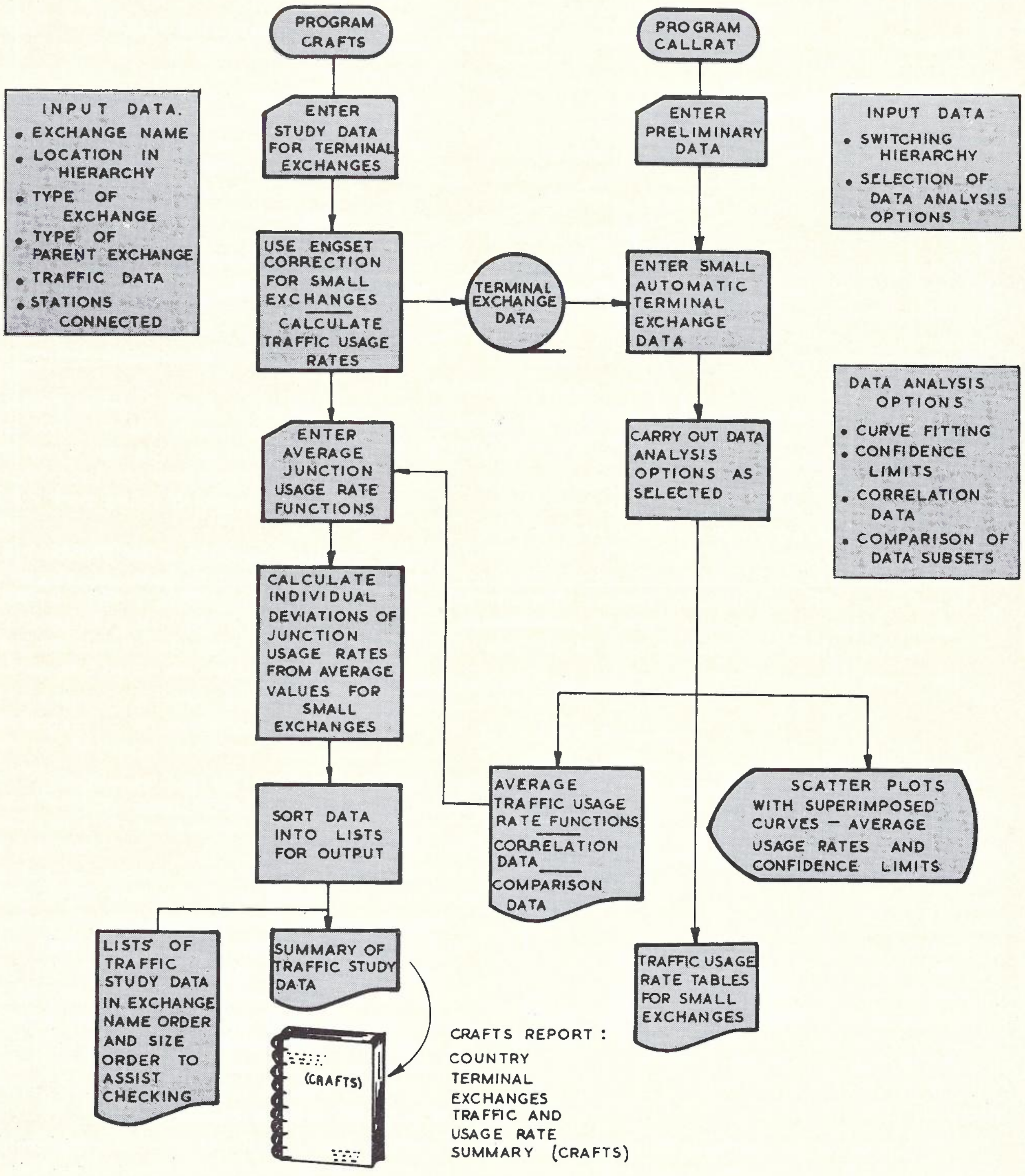


Fig. 3—Flow Chart of the CRAFTS System.

PAGE 2

EXCHANGE	TYPE	STUDY DATE	NUMBER OF STATIONS	JUNCTION MEASURED TRAFFIC	JUNCTION CORRECTED USAGE RATE	DEVIATION FROM AVERAGE OF STATE	DEVIATION FROM AVERAGE OF MTGAMBIER	LOCAL MEASURED TRAFFIC	LOCAL CORRECTED USAGE RATE
ROSEWORTHY	ARK	10/66	98	3.40	.0336	5	-10	.64	.0064
ROSEWORTHY	ARK	7/68	105	3.47	.0321	4	-12		
ROSEWORTHY	ARK	4/69	113	3.99	.0343	11	-6	.87	.0076
ROSEWORTHY	ARK	2/70	117	4.14	.0344	12	-5		
ROSEWORTHY	ARK	2/72	121	3.90	.0313	7	-10		
ROSEWORTHY	ARK	2/75	145	5.20	.0351	21	3		
SHEOAK LOG	MAN	10/66	14	.97	.0593	10	8		
SHEOAK LOG	CLS	6/67	CLOSED						
STOCKPORT	RAX	4/68	39	2.03	.0489	8	2	.70	.0170
TARLEE	RAX	4/68	91	3.80	.0404	15	-1		
TWO WELLS	RAX	3/70	150	3.05	.0200	-15	-29	1.47	.0096
WASLEYS	ARK	5/71	CONVERSION						
WASLEYS	ARK	2/72	97	2.90	.0290	-4	-18		
WASLEYS	ARK	2/75	105	3.60	.0333 *	6	-10		
WASLEYS	ARK	2/75	105	3.87	.0359	11	-5	1.43	.0133
WILLIAMSTOWN	RAX	10/66	191	4.50	.0232	-5	-12		
WILLIAMSTOWN	RAX	3/70	198	5.06	.0251	0	-5		
WILLIAMSTOWN	RAX	2/72	205	5.30	.0254				
WILLIAMSTOWN	ARK	12/74	CONVERSION						
WILLIAMSTOWN	ARK	2/75	230	6.46	.0277			1.39	.0060
WILLIAMSTOWN	ARK	2/75	230	5.90	.0253				

DATA TO APRIL 1975

GAWLER MINOR

Fig. 4—Typical Page of CRAFTS Traffic Study Data Summary.

exchanges. As junction traffic is the major traffic component in a small exchange, junction usage rates are used for this selection.

The procedure that is used classifies each small exchange into one of the following categories:

- State (Country) category;
- Mt. Gambier Secondary Area category;
- Special category.

The classification is based on the junction usage rate deviations listed in the CRAFTS traffic study data summary. An exchange for which the deviations are principally within the confidence limits of the State average (i.e. within ± 10) would be classified as being in the State (Country) category. Likewise an exchange with junction usage rates principally within the confidence limits of the Mt. Gambier average would be classified in that category. These two particular categories are sufficient as only 6% of the small exchanges in SA and NT do not fit into either and are therefore put in the special category. This method of classification does not mean that an exchange must be in the Mt. Gambier Secondary Area in order to be put in that category.

Average traffic usage rate tables have been prepared for the first two categories and are used to design exchanges in these categories. Exchanges in the special category have to be designed individually but even this is simplified by having all of the available traffic study data assembled together by CRAFTS.

The selection of the local usage rate and the register usage rate for an exchange normally follows the junction usage rate but note is taken of the local usage rates appearing in the CRAFTS traffic study summary. Allowance is made for the tendency of local usage rates to be higher in isolated exchange areas.

Design Process

For the first two categories the design process has been simplified and is to some extent automatic. Tables of equipment requirements as a function of exchange size have been prepared. In addition, forecasts of junction traffics and the corresponding circuit requirements for exchanges in these categories are automatically calculated from station forecasts using a separate computer system. This separate system, known as the CIDER system (Ref. 5), prepares a consolidated record of forecast trunk and junction circuit requirements for SA and NT which is issued annually by the Traffic Engineering Section.

In the case of the special category, individual designs are carried out as mentioned previously.

The availability of standard design usage rates is particularly helpful where there is no traffic data (a new exchange for instance), or there is very little data available.

From the amount of scatter in the data as indicated by Fig. 1 it might be considered that two standard categories could not be enough to achieve good designs. That the system works in practice is due to two factors:

- the spread of traffic measurement sampling error, particularly at low traffic levels;
- equipment requirements are step functions (for instance, it is not possible to have $2\frac{1}{2}$ junctions).

As an example of the second factor, using the standard equal marginal utility traffic table (Ref. 6) the traffic capacity of three junctions is 80% more than that of two junctions.

Logically, if there is a Mt. Gambier category, then the first category should not include data points for exchanges in the Mt. Gambier region. However, the differences in traffic usage rates involved would be small and a State (Country) average is useful in planning studies.

Previous Design System

Prior to setting up the CRAFTS system, design work was normally based on the latest traffic study data with some allowance made for previous data. The scatter diagram of Fig. 1 indicates that some exchanges would be over-provided and some under-provided as a result. Over a period of years both situations would be subsequently indicated by regular readings of the statistical meters installed in automatic exchanges. The indication of under-provision was usually reinforced by subscriber complaints.

Since the system has been in use, statistical meter readings taken over several years indicate in practically all cases that the design provision has been satisfactory. Also there has been a considerable drop in subscriber complaints concerning congestion in small exchanges.

Trends in Design Usage Rates

Another factor that has steadily increased confidence in the use of the CRAFTS system is that design usage rates have altered very little as the data base obtained from traffic studies has steadily increased year by year.

No trend in traffic usage rates for small exchanges has been established yet but this could stem from a data base which is still insufficient to detect small changes. Probably a trend may be detected when it is possible to compare two successive decades.

For the present, to allow for a possible growth in usage rates and also to act as a factor of safety, a growth rate of 1% per annum in traffic usage rates is used for traffic forecasts in SA and NT.

CONCLUSIONS

The system described in this article has proved to be worthwhile in practice. It has met its twin objectives very well:

- provide reliable traffic usage rates;
- simplify small exchange design work to cope with the large number of exchanges concerned.

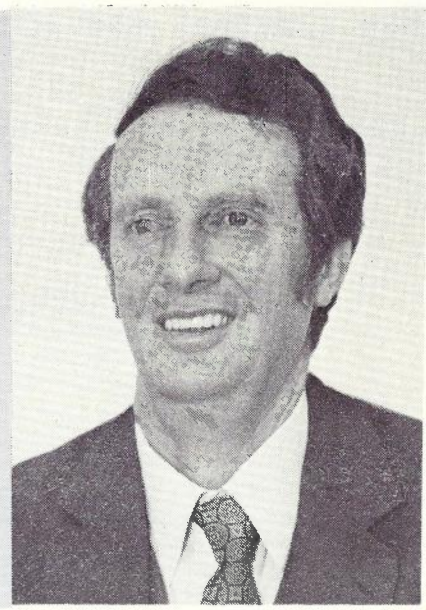
Good designs are being achieved as indicated by feedback from yearly programmes of traffic measurements, and from exchange statistical meter readings taken over an extended period.

It is intended to continue extending the data base to establish any trends in traffic usage rates. Also, when the system was initially developed there were not very many ARK exchanges over 200 line capacity in South Australia and the Northern Territory, consequently there was a dearth of traffic data. This data has since built up and an extension of the CRAFTS system of average traffic usage rates to these larger exchanges will be considered.

REFERENCES

1. Newstead, I. A.: "Review of Telephone Traffic Engineering — Part 1"; Telecom. Journal of Aust., February 1961, Vol. 12, No. 6, pp. 391-401.
2. Driskna, V. V. and Wormald, E. G.: "Engset Traffic Tables"; Telecom. Journal of Aust., June 1966, Vol. 16, No. 2, pp. 154-156.
3. Miller, I. and Freund, J. E.: "Probability and Statistics for Engineers"; Prentice-Hall, 1965.
4. A.P.O. Engineering Instruction; Planning, Traffic, D1100; "Telephone Traffic Measurements, (General Principles)".
5. Vawser, K. D.: "CIDER; A System for Providing Telephone Circuit Forecasts"; National Conference Publication, No. 74/1, May 1974, IE Aust., pp. 198-202.
6. Marrows, B: "Circuit Provision for Small Quantities of Traffic and the E.M.U. Traffic Tables"; Telecom. Journal of Aust., February 1959, Vol. 11, No. 6, pp. 208-211.

K. D. VAWSER joined the APO in 1954 as an Engineer, graduating as a Batchelor of Engineering from the University of Adelaide in that year. After experience in country work and in engineering training he joined the Traffic Engineering Subsection in 1963 shortly after its inception in South Australia. He was associated with a continual improvement in traffic measurement, dimensioning, and traffic forecasting. Appointed in charge of this Subsection in 1969 he has since been closely associated with a rapid growth of computer system development in all facets of traffic engineering work. During 1967-1968 he gained a Public Service Board Scholarship to study additional mathematics and computing science at the University of Adelaide, gaining a degree of Bachelor of Science with first class Honours in 1969. He is currently acting in the position of Supervising Engineer, Switching and Facilities Section.



Quality Control and the Plant User

N. R. BEDFORD, B.Sc. (Eng.), M.I.Q.A., A.M.B.I.M.

This article is the last of a series of three which collectively could be entitled "Quality – What it is and how to control it". The full impact of this article can only be felt if read in conjunction with the previous two articles in Volume 24 No. 3 Pages 227–238.

True Quality Control is a systematic approach to firstly specifying what quality is required (Telecom Australia does this for its own equipment) and then ensuring that the product manufactured is of the specified quality.

The process of control is analogous to physical control systems, in which feedback is an essential element of control; there are in fact a number of feedback loops, using information derived from the manufacturer's inspection, the user's inspection, and finally the plant installer or operator himself.

Because Quality Control does ensure production at minimum cost, does ensure consistency of quality, it is best for the manufacturer and certainly best for the customer.

INTRODUCTION

We are all purchasers and users of plant of one sort or another, some simple, some more complex. We expect all of these pieces of equipment to work when we buy them and to carry on working. In the same way, the Australian Telecommunications Commission (Telecom Australia) is a very big user of telecommunications equipment and previous articles in the Journal (Refs. 1, 2) have shown how both the manufacturer and Telecom Australia attempt to ensure that quality standards have been met. To help to achieve this there is a need for a flow of information from the user of the equipment back to the manufacturer to let him know how he is meeting these standards. This article describes the formal system in use in Telecom Australia.

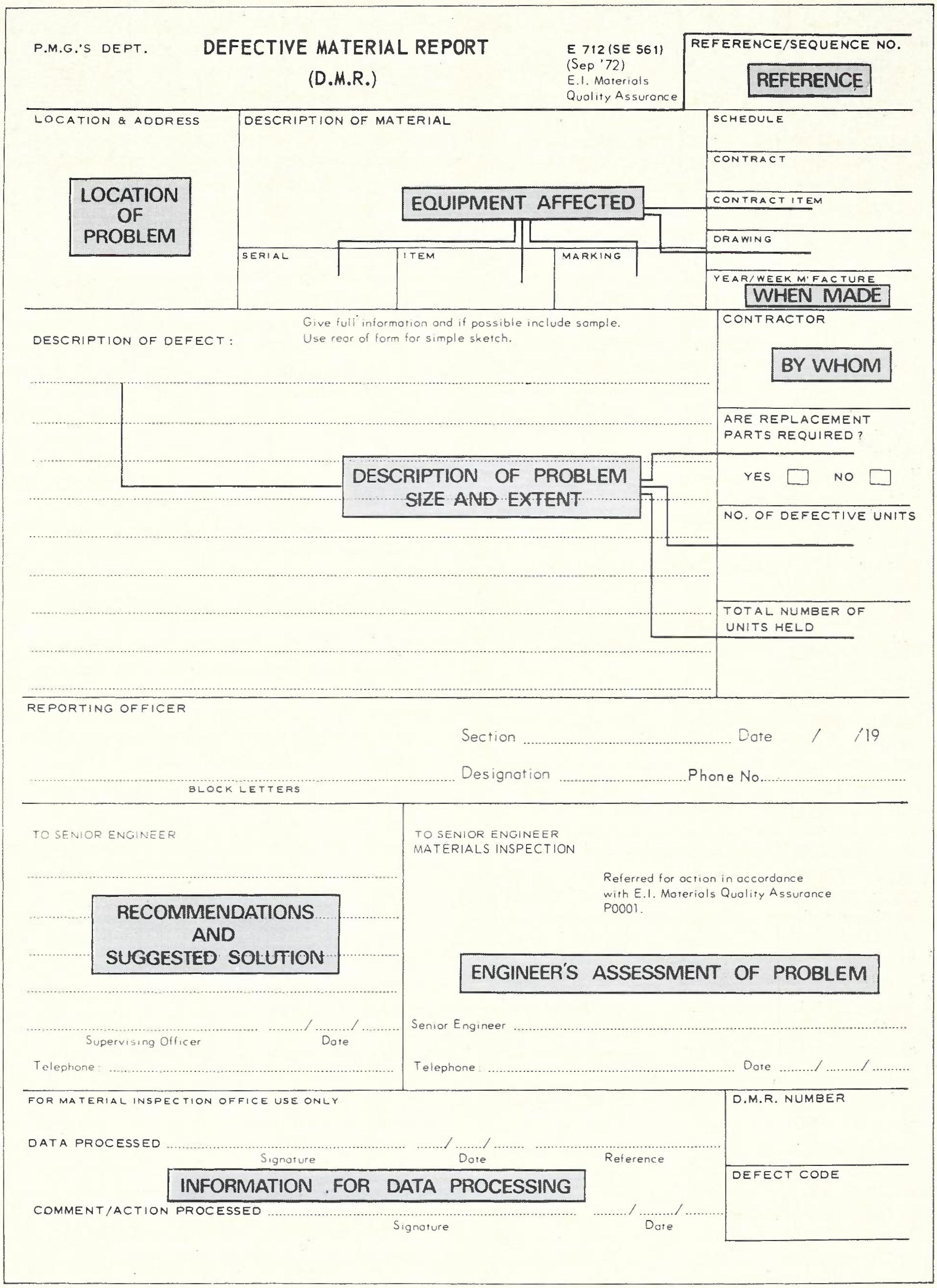
BACKGROUND

At about the time of establishing the manufacture of crossbar exchange equipment in this country and in order to get necessary information on what was then a new product, the crossbar feedback label was introduced. Later on, certain major suppliers of equipment were recognised as having satisfactory quality assurance systems, i.e., as being Telecom Australia "Approved Firms". However, a quality assurance system can only be properly effective in obtaining some corrective action if it has the information on which to operate and a necessary feature of a manufacturer's quality system is a means of handling customer complaints fed back to it. To facilitate this process of feedback, a Defective Material Report form (DMR), see Fig. 1, was introduced. This gives more detailed information back to the supplier than the earlier crossbar feedback label and is now increasingly being used to provide information to other contractors and to those supplying non exchange type equipment.

HOW DEFECTIVE MATERIAL ARISES

The basic underlying cause of most errors made in manufacture is people. Because of the complexity of manufacture, detailed drawings, documentation and instructions need to be written to control the manufacturing processes which are involved. If mistakes in manufacture are made it is often because these written documents are in some way inadequate for their purpose. Their purpose is basically to define operations which have to be performed in such a way that the fallible human element is minimised.

Unless they are very frustrated in their working situation, individuals usually prefer to do a good day's work from a quality point of view. Management also in the wider sense sees no real future in producing equipment of substandard quality since to do so continuously will place its long term existance in jeopardy. Consequently it is prepared to back up its reputation with warranty on the equipment it makes.



P.M.G.'S DEPT.

DEFECTIVE MATERIAL REPORT (D.M.R.)

E 712 (SE 561)
(Sep '72)
E.I. Materials
Quality Assurance

REFERENCE/SEQUENCE NO.

REFERENCE

LOCATION & ADDRESS

LOCATION OF PROBLEM

DESCRIPTION OF MATERIAL

EQUIPMENT AFFECTED

SERIAL | ITEM | MARKING

SCHEDULE

CONTRACT

CONTRACT ITEM

DRAWING

YEAR/WEEK M'FACTURE

WHEN MADE

DESCRIPTION OF DEFECT: Give full information and if possible include sample. Use rear of form for simple sketch.

DESCRIPTION OF PROBLEM SIZE AND EXTENT

CONTRACTOR

BY WHOM

ARE REPLACEMENT PARTS REQUIRED?

YES ☐ NO ☐

NO. OF DEFECTIVE UNITS

TOTAL NUMBER OF UNITS HELD

REPORTING OFFICER

Section .... Date / /19

BLOCK LETTERS .... Designation .... Phone No. ....

TO SENIOR ENGINEER

RECOMMENDATIONS AND SUGGESTED SOLUTION

Supervising Officer .... Date ..../..../....

Telephone ....

TO SENIOR ENGINEER MATERIALS INSPECTION

Referred for action in accordance with E.I. Materials Quality Assurance P0001.

ENGINEER'S ASSESSMENT OF PROBLEM

Senior Engineer ....

Telephone .... Date ..../..../....

FOR MATERIAL INSPECTION OFFICE USE ONLY

DATA PROCESSED .... Signature ..../..../.... Date .... Reference

INFORMATION FOR DATA PROCESSING

COMMENT/ACTION PROCESSED .... Signature ..../..../.... Date

D.M.R. NUMBER

DEFECT CODE

Fig. 1 — Defective Material Report

There is also a problem of defining the "right" quality. Telecom Australia recognises that perfection in all aspects of the equipment it purchases is not possible and this is where the concept of Acceptable Quality Level (AQL) comes in. Use of an AQL does not mean that the Commission knowingly accepts any material which is known to be defective but that there is a possibility that faults up to a certain level may exist in equipment when it is sent to the field. The overall optimum quality must strike an economic balance taking into account the cost of meeting AQL's in the factory and the problems, and therefore costs, which only arise later, from supplying sub-standard materials. Acceptable quality levels are set fairly tight so as not to seriously embarrass installation and use of the equipment, and to provide a long term safeguard for satisfactory operational service. Because human beings are fallible, mistakes can and do occur in design, in manufacture and in testing and unacceptable material can reach the field. One hundred per cent checking of quality at all stages, even if it were not prohibitively expensive, would not necessarily achieve any improvement. In general it would be performed by fallible human beings; it is generally recognised that such 100% inspection is rarely more than 85% effective.

THE NEED FOR CONTROL

How does any particular factory gain control of this situation so as to reduce the number of errors which can arise? How does the factory produce the required quality. Successful quality control in any organisation lies not so much in having good 'quality', although this is of course important, as in having good 'control'. One is unlikely to have a satisfactory quality product without having a fair measure of control over what is done and what is not done. To achieve the required quality the quality control section relies heavily on information, both from within the factory and from outside, which it processes and in turn uses to feed back and correct unwanted situations in production and elsewhere. Effective quality control is concerned to ensure that quality is built into the product and to do this it must be concerned not only with the end product but just as much with the documentation, systems and procedures that go towards controlling production.

In the chain of events leading from design, through manufacture to use of a product, quality problems can arise then or later, as a result of misunderstanding or a breakdown in communication at any stage. Most product quality problems that arise can be put down to a failure in communication of one sort or another. Whilst there has to be verbal information to inform people what jobs they are to do, the complexity of manufacturing telecommunications equipment necessitates clearly written information and instructions. Nevertheless, mistakes can still occur and to correct these some form of feedback of information is required. Verbal communication is usually an unsatisfactory method and more effective corrective action is likely to result when there is formal written communication. Such feedback about quality problems not only needs to operate between user and manufacturer, but also, separately, within the manufacturer's premises, so that errors can be rectified early on before they become problems of using equipment in the field.

Particular emphasis is placed both by factory quality control and Telecom Australia on a thorough check of prototype equipment, as at that stage design and manufacturing documentation is checked to ensure compatability before bulk production is commenced. This coupled with field testing of first off equipment will pick up many potential problems but others only appear after equipment is operated over a period. For this reason therefore the reliability aspect is also important and a particular part of the overall quality control programme is concerned with a continuing evaluation of how different products perform over a period.

THE NEED FOR DEFECTIVE MATERIAL REPORTING

Just as there is a need for internal feedback in the factory to keep processes within control and to achieve the desired quality etc., there is an even more important requirement for information back from the field. The plant user has a key role to play in reporting such problems. Defective material can affect him in a variety of ways. It affects him because items which should assemble together will not, or because incorrect items have been supplied or equipment will not function correctly. In the longer term it may be found that because adjustments are incorrect, or wrong components used, equipment will not function satisfactorily over a period.

The Defective Material Report provides the feedback link between the user and the manufacturer. It is designed to provide all the necessary data which will enable the Material Inspection section and the Contractor to jointly assess the situation and to take some corrective action. The prime purpose of collecting such information is to prevent the problem recurring. The report form is designed to show what equipment is affected and how much, what the problem is, who the contractor was and when the equipment was made.

DEFECTIVE MATERIAL INVESTIGATIONS

When defective material arises in the field an investigation takes place at two distinct levels. Firstly, there is a local investigation within the plant user section and secondly an investigation between Materials Inspection staff and the manufacturer.

Fig. 2 shows these two separate investigations as feedback loops. The first investigation into the particular field operation is necessary to determine the extent of the trouble and whether one or more items of equipment are affected. As much information about this is forwarded on the DMR so as to assist the Contractor in determining when, how and why the problem occurred. Of particular importance is the year and week of manufacture of the equipment as this enables the company to more accurately pinpoint the assignable cause of the trouble. Following the local investigation at the work site, a more detailed assessment should be made in the local section to see whether other areas are experiencing similar problems. It is most desirable at this stage that an overall picture is given as this will influence the action subsequently taken by the manufacturer and Materials Inspection in dealing with the problem.

The second stage of the investigation concerns Material Inspection and the manufacturer. On receipt, the DMR is logged into the section and the essential information concerning the type of equipment, contractor, number affected, etc., are extracted for subsequent data processing. At this stage the reported defect is given a fault identification code which makes it possible at a later stage to analyse reported defects into types. The data processing system enables a historical record of some 18 months or more of complaints to be maintained to which new ones are continuously added. As well as catering for complaints which originate in New South Wales, the system caters for complaints from other States which use equipment which was made in NSW.

Usually at this point the reporting officer in the field is contacted as his assessment of the problem in terms of its seriousness and extent is vital if a successful investigation is to be conducted. The particular work site from which the report emanated is often visited to obtain the views of the actual plant user and to confirm the extent of the problem. Visits to other similar work sites may also be made to see whether a similar problem exists and whether it is common to other suppliers as well. Samples from the site help to demonstrate the fault to the manufacturer, who may also visit the site either to get first hand experience himself or to carry out repairs after the need for these has been negotiated.

In order to get further information about an actual problem or even about suspected areas of future trouble, it may be desirable to extend the investigation over a wider area within the state. Additionally, where designs or specifications may

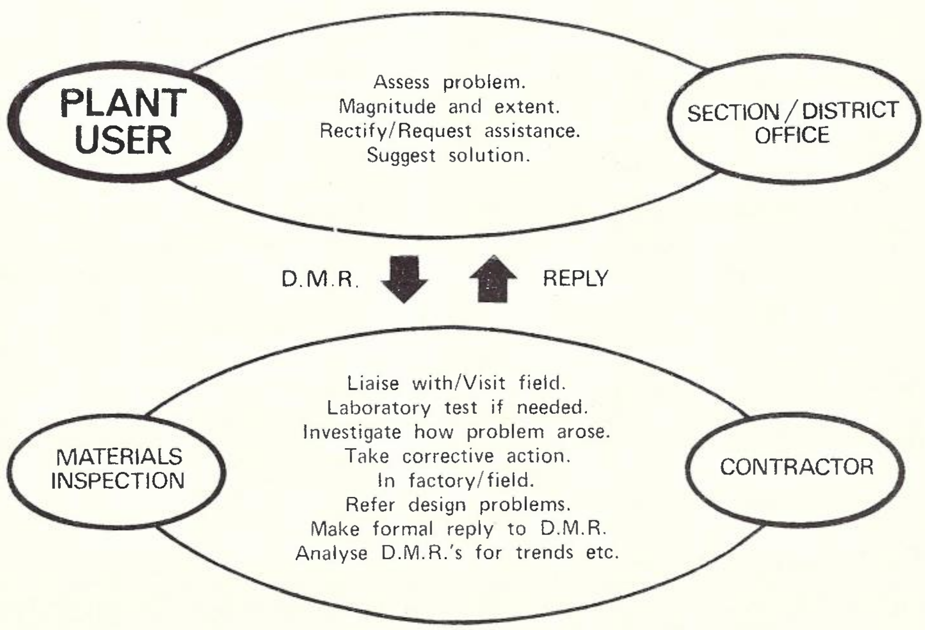


Fig. 2 — Defective Material Investigations

be involved or where manufacturers in other states may be implicated, Materials Inspection may conduct enquiries through Central Administration. A particular field problem may highlight the need to conduct laboratory tests on samples to see what happens when equipment with a known or suspected fault is operated over a period.

These discussions will confirm the exact nature of the problem as it affects the field and can then be used in the factory investigation to see why inspection and testing failed to detect the condition complained of. It is necessary here to compare the level of defects against predetermined quality levels which have been defined as being acceptable, which is why information from the field about the magnitude of the problem is so important. The senior technical officer who is in charge of Telecom Australia inspection of the particular manufacturer's product is responsible for furthering the investigation in the factory. With his own staff and in co-operation with quality assurance representatives of the company a detailed investigation is made, the prime object of which is to understand the reasons why the problem occurred. Only when this has been done successfully can some control be instituted which will overcome the problem in the future or at least reduce the likelihood of a recurrence. To assist in understanding the reason why the problem arose the Telecom Australia investigating officer has a standardised check list type of reply form which he uses in his investigation. This highlights whether or not the same problem reported has also been discovered in the factory, what action the company proposes to take, both in the short term in the field and in the long term as regards the basic underlying cause. Such investigations concerning customer complaints form part of the overall quality assurance activities within the factory, one object of which is to identify weaknesses in designs or specifications or in inspection and test methods so that these can be rectified.

Once the factory investigation is complete this information is then referred back to the Materials Inspection Office which makes a formal reply to the reporting officer and at the same time prepares further information for subsequent data processing. A formal reply to the complaint is always made thereby completing the feedback loop.

In a large number of instances, and in particular if the complaint is not too serious the plant user will take some necessary remedial action soon after discovering the initial trouble. In the interests of continuity of equipment installation or testing to meet cutover dates this is inevitably the only possible alternative. However, even though a particular piece of defective material appears to be an isolated occurrence it is important that such instances are reported via a Defective Material Report. Depending on its seriousness, an individual complaint may or may not warrant any action on the part of the supplier. From a purely statistical point of view a single complaint is not significant (except of course to the chap in the field who has to fix it). However, when such complaints are collated from all over the country and analysed as regards particular types of fault, particular periods of manufacture, etc., the problem may be seen to be much more significant and a more meaningful investigation can be made. A comparison of similar types of faults between different suppliers or an analysis of the fact that different suppliers of the same equipment experience particular types of faults can also give rise to investigations within the companies. The end objective is always to try and reduce or eliminate the problem. The deficiency, whatever its basic cause, may be capable of some quick, easy and inexpensive solution once it has been recognised as being a problem. It can only be recognised as such if DMR's from the field point it out in the first instance.

CONCLUSION

As a very large purchaser of telecommunications equipment Telecom Australia has to ensure that it is getting value for money. In this context this means the right quality at the right price. To obtain this necessary assurance a formal feedback system is required to notify contractors of quality discrepancies and to become aware of occasional design weaknesses. **The plant user has a vital role to play in providing this information.** This applies to the whole range of telecommunications equipment and to the whole range of suppliers. A detailed analysis and investigation of such information will enable better quality and reliability to be built into the product in the future. Quality built in at the outset is the most economical since prevention is better than cure. Better quality control in design and manufacture jointly achieved by Telecom Australia and contractors will benefit the plant user and in turn the community as a whole.

REFERENCES

1. Dodds, R. E.: 'Quality Control and the APO Inspector'; Telecomm. Journal of Aust., Vol. 24, No. 3, 1974, page 227.
2. Marchant, J.: 'Quality Control and the Manufacturer'; Telecomm. Journal of Aust., Vol. 24, No. 3, 1974, page 233.

N. R. BEDFORD was recruited to the APO in August, 1971 from the United Kingdom where he was previously working in the telecommunications industry. After taking his degree at Imperial College London, he joined GEC (Telecommunications) where he was later in charge of inspection in the manufacturing division. Subsequently, immediately prior to coming to Australia, he was Quality Assurance Manager of a division of Standard Telephones and Cables making crossbar exchange equipment.

He is now working as Quality Assurance Engineer in the New South Wales Material Inspection section concerned with the purchase of a wide range of telephone switching equipment. In particular he is concerned with the assessment and audit of quality control systems used by some of the major contractors.

Retirement of Director General, Mr. E. F. Lane

Concurrent with the change to Commission status as from the 1st July, 1975, the Director General of the then PMG's Department, Mr. Eber Lane retired from the service.

Mr. Lane was one of the most popular of the twelve men who held this office. He was held in high esteem both inside and outside the Post Office for his integrity, knowledge and ability to discharge the office of Director General.

He began in 1927 in Queensland as a telegraph messenger, served for six years as a telegraphist and nine years as a traffic officer before being promoted to Superintendent, Telephone Service Branch, Tasmania in 1954. Three years later he was the State Director, Post and Telegraphs. Then followed rapid promotion; Controller, Central Office (1961) Assistant Director (1961), Director Queensland (1966), Director NSW (1971) and Director-General (1972).

The Society wish Mr. and Mrs. Lane a long and happy retirement.

Retirement of Mr. R. Turnbull

Mr. Ron Turnbull, M.B.E. Dip. Elec. Eng., FIE Aust. retired recently from Telecom. Australia after 38 years of service. At the time of retirement, he was serving as the General Manager of the Engineering Department at Headquarters.

Mr. Turnbull entered the Postmaster-General's Department in 1937, and progressed through senior ranks to Superintending Engineer in 1955, Assistant Engineer in Chief in 1962 and FADG (Engineering Planning and Research) in 1973. He was also a Commissioner and Vice-Chairman of the Overseas Telecommunications Commission (Australia).

Just prior to retirement, Mr. Turnbull was Chairman of the Council of Control of the Telecommunication Society of Australia. He has had a long association with the Society, and has contributed many articles to the Journal since 1941.

The Council of Control has very real pleasure in placing on record its warm appreciation of the many services Mr. Turnbull has rendered to the Society. We wish Ron and Mrs. Turnbull a long and happy retirement.

New Chairman for Council of Control

Following the retirement of Mr R. Turnbull, Mr. P. R. Brett B.Sc., FIREE, has been appointed the new Chairman of the Council of Control of the Telecommunications Society of Australia.

Mr. Brett joined the Service as a Clerk in 1940. On graduation from Melbourne University, he was appointed Physicist Grade 1 in the Research Laboratories. In 1964 he was appointed Senior Assistant Director General, Research Branch at Headquarters, which position he occupied until his recent appointment as Director, Planning, in the Headquarters organisation of Telecom Australia. Mr. Brett has contributed a number of articles to both this journal and the Australian Telecommunications Research Journal.

The Council of Control congratulates Mr. Brett on his recent appointment, and looks forward to working with him as Chairman for the next two years.

Some Tests Proposed for Evaluating the Colour Television Performance of Microwave Radio Relay Systems

D. J. HAUW, B.E., G.DIP.IND.MGT (SWINBURNE)

This paper discusses four CCIR waveform tests and considers them to be inadequate for use in determining the acceptability of new microwave radio relay systems for purposes of commissioning into traffic service. Additionally, a test procedure is introduced to measure a new distortion not considered by the CCIR.

Editorial note: This paper was first published in the Conference Preprint Volumes to the Annual Engineering Conference of the Institution of Engineers, Australia, in February, 1975, and is reprinted here with their kind permission.

INTRODUCTION

Waveform testing has been universally accepted as the standard method for the measurement of distortion in television studio and transmitter equipment. Its use has been extended by the CCIR (Ref. 1) to cover long distance television relay performance. The preference for waveform testing over conventional sinewave methods for television system performance has been due to several advantages, which are well documented in (Ref. 2), (Ref. 9), (Ref. 10), (Ref. 11), (Ref. 12). However, these waveform tests are not necessarily suitable for evaluating the acceptability of new equipment.

Many waveform tests have been recommended by the CCIR (Ref. 1) and additional ones to cover different parameters are being considered (Ref. 3). Corresponding to these tests are allowable distortion limits which, with the interconnection of microwave radio equipment with other peripheral equipment, such as studio cameras, cable-tails and broadcast transmitters, would present a picture of acceptable subjective quality to the home viewer. The CCIR have conveniently defined a reference to which all their distortion limits will be referred. This in the Hypothetical Reference Circuit (HRC). It is composed of three video interconnection points over a distance of 2500 km. For practical systems of lesser or longer lengths, the CCIR have described methods for apportioning their HRC objectives.

In this paper, four of the tests are considered, and their inadequacies are discussed as tests to determine the acceptability of new microwave radio relay systems. The tests are return loss, non-linearities of the synchronizing signal and chrominance channel gain and chrominance-into-luminance intermodulation. One new distortion, peak white signal non-linearity, and its measurement are also introduced. There is also a need to vary the definition of the HRC for the Australian conditions. This is discussed in the paper.

RETURN LOSS

Weaver (Ref. 4) originated the proposal to use a waveform test signal to evaluate television equipment impedance, in terms of return loss. The signal was the T pulse, band-limited to the video band of 5 MHz. Subsequently, a 2T pulse was nominated.

The CCIR (Ref. 1, p. 197) recommend three signals:

(a) 2T monochrome pulse-and-bar

(b) 50 Hz square-wave

(c) T_C and $2T_C$ pulse-and-bar.

In the author's opinion, the inadequacies of the above test methods are:

(a) These waveforms have been devised to measure specific distortions other than return loss and none are designed to include the measurement of return loss. Also none satisfy all signal conditions which occur during programme transmission. It would, however, be impracticable to increase the number of test signals in order to cover all such conditions.

(b) Irregularities and transients in the displayed reflected signal are difficult to interpret correctly.

(c) Some measuring methods require a significant length of cable to introduce a delay of the reflected signal so that both the incident and the reflected signals may be displayed on the CRO. Additional distortions may be introduced here.

Sweep frequency sinewave technique would be more appropriate, if limitation is placed on the bandwidth to be measured, 30 Hz to 5.5 MHz. Or, alternatively, use may be made of the composite sweep frequency television signal. The higher accuracy and the little or no ambiguity obtained from the results from sweep frequency sinewaves make this method amenable to acceptance testing purposes. It will be noted that it is also a standard test for microwave telephony bearers, and, television broadcast transmitters.

The single figure specification for return loss in the video band should be retained, until more information is obtained on return loss effects at various video frequencies, particularly at chrominance channel frequencies.

SYNCHRONIZING SIGNAL NON-LINEARITY (COMPRESSION)

The use of the CCIR signal, consisting of a five-riser staircase followed by three intermediate lines of black or white, is considered to be a dynamic test of limited range. It is not a searching test and contemporary microwave radio equipment readily handles this condition. Instead, a more severe dynamic test is suggested. The non-linearity can be measured during "bounce" conditions in the test for long-time linear waveform distortion where it appears as a compression of the synchronizing signal amplitude.

To explain briefly the bounce phenomenon, it can be said that it occurs when signals containing changes in average picture levels pass through AC couplings, feedback or filter networks. By connecting several of these AC networks in tandem, the bounce becomes increasingly pronounced. Greater overshoots occur, thus causing extreme excursions along the equipment dynamic transfer characteristics. Non-linearities may then be imparted at these extremities.

With various AC networks to be encountered, various time constants are also present, and it is desirable in acceptance testing of new equipment to test under the most severe conditions which are likely to occur during programme transmission as has been done with television broadcast transmitters. The frequency of the test waveform should then correspond to the circuit time constant. It implies a variable frequency bounce test waveform, the frequency being in the range of 0.2 to 2 Hz. CCIR composite square wave (Ref. 1, p. 206) is suitable provided its frequency can be reduced to this range.

In addition, it is insufficient to test for bounce a system of only one or two video actions. It should also be tested for performance as part of a long chain of video sections, possibly up to an AHRC in length (refer Sec. 7). To achieve this, a "bounce pre-distorter" can be used to pre-distort the bounce waveform before application to the microwave radio system under test. The pre-distorter can be made up of RC circuits to the number of video sections to be simulated and separated by buffer amplifiers which would also restore the level of the test signal. The time constants of the simulator should be within the range to be found generally in commercial radio relay equipment, i.e. 0.5 to 5 seconds corresponding to 0.2 to 2 Hz.

PEAK WHITE SIGNAL NON-LINEARITY (COMPRESSION)

During "bounce" conditions, explained previously, equipment transfer characteristic non-linearities could also cause distortion in the white signal region. The result is a loss of picture brightness and of contrast near the white level. At other signal conditions, the non-linearities could still be present, but in smaller proportions. It follows that the test for this distortion should be performed during the bounce test, together with that for the synchronizing signal distortion.

The CCIR have not, to the author's knowledge, considered this distortion, but some consideration will probably be made in the near future.

If a burst of colour information is successively switched on and off, bounce can also occur on a microwave radio system. The non-linearities here can affect both the amplitude and phase of the subcarrier and the luminance information. However, the susceptibility of radio equipment to this sort of distortion is open to further discussion.

LINE-TIME CHROMINANCE CHANNEL GAIN NON-LINEARITY

To measure this distortion, the CCIR are considering a three-amplitude subcarrier signal, shown in Fig 1. (Ref. 3, p. 15). The graded amplitudes show how much non-linearity is present at each level. The non-linearity is defined by the CCIR as the greatest departure from proportionality between the amplitude of the chrominance subcarrier at the input and the corresponding amplitude at the output.

The CCIR signal has insufficient subcarrier "steps" to be a sensitive gauge of the non-linearity.

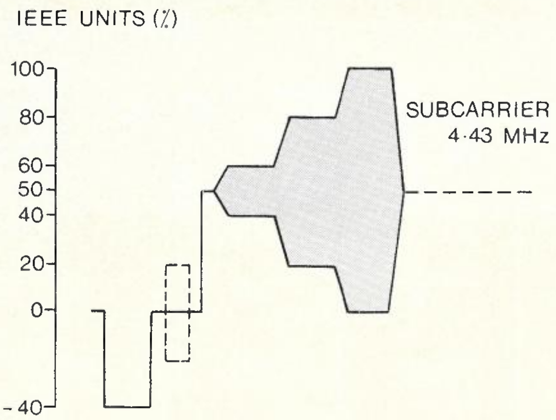


Fig. 1—CCIR Signal G2.

The non-linearity effects will be averaged over the three steps. Furthermore, the maximum subcarrier amplitude of ± 50 IEEE units (in CCIR terms, this is IRE units and corresponds to ± 0.35V) does not allow for measurements to be made under conditions of maximum signal deviation, viz. input subcarrier amplitudes up to ± 63 IEEE units. This condition can be encountered during programme transmission with fully saturated hue contents.

The suggested replacement signal is shown in Fig. 2 which will be referred to as the chrominance staircase. Note the increased steps of subcarrier amplitude to five, and the amplitude of the largest step to ± 62.5 IEEE units.

Measurement of chrominance gain non-linearity can be achieved by providing a suitable step attenuator to reduce each step to a common amplitude to allow a direct comparison of the peak-to-peak amplitude of each step. Any deviations from that common amplitude (peak-to-peak) would be a measure of the non-linearity. The reference can be the first step which is expected to suffer least distortion.

The CCIR (Ref. 3, p. 15) and IEC (Ref. 13) method of testing for the departure of each pre-set step height (i.e., peak rather than peak-to-peak) could be made invalid by luminance shifts. In this case, the subcarrier will be assymetical about the 50% IEEE unit setup level. Also, the non-linearity limit specified by IEC is unnecessarily stringent because the distortion is compared to the step height, and it is doubtful if such small occurrences could be measured. Furthermore, a pre-determined absolute step value has no meaningful significance as a constant attenuation on all steps is not considered a non-linearity, merely a lack of gain.

CHROMINANCE-INTO-LUMINANCE INTERMODULATION

The CCIR (Ref. 3, p. 16) are also considering the use of Signal G2 for measurement of chrominance-into-luminance intermodulation. The distortion is observed as a variation of the pedestal amplitude from its 50% IEEE unit set up level Fig. 3 (a). It is this maximum variation in relation to 100% IEEE units which gives a measure of the distortion.

The author suggests that the chrominance staircase is also appropriate here and the increased steps offer better gradings on the presence of intermodulation with each subscarrier amplitude, Fig. 3 (b).

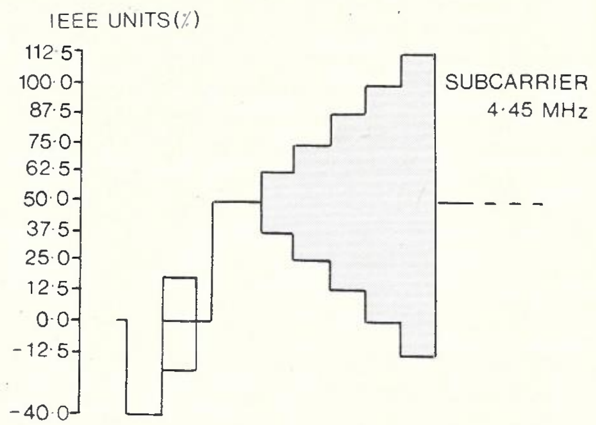


Fig. 2 Chrominance Staircase

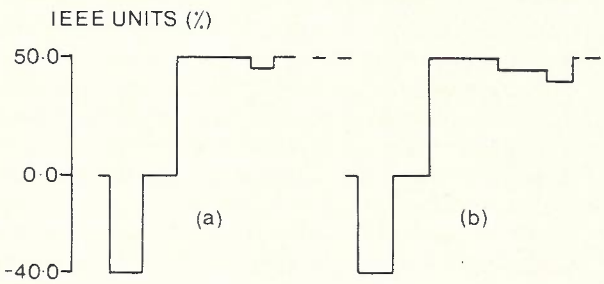


Fig. 3 Chrom-into-Lum Intermodulation Shown by
(a) CCIR Signal G2 and
(b) Chrominance Staircase.

TABLE 1—MODIFICATION FACTORS FOR LAWS OF ADDITION OF AHRC AND HRC DISTORTIONS

Australia $\left(\frac{n}{9}\right)^{1/h}$				CCIR $\left(\frac{n}{3}\right)^{1/h}$			
n	h			n	h		
	1	$^3/_2$	2		1	$^3/_2$	2
1	0.11	0.23	0.33				
2	0.22	0.36	0.47				
3	0.33	0.48	0.57	1	0.33	0.48	0.58
4	0.44	0.58	0.66				
5	0.55	0.68	0.74				
6	0.66	0.76	0.81	2	0.67	0.76	0.82
7	0.77	0.84	0.88				
8	0.88	0.92	0.94				
9*	1.00	1.00	1.00	3*	1.00	1.00	1.00
10	1.11	1.07	1.06				
11	1.22	1.14	1.10				
12	1.33	1.21	1.15	4	1.33	1.21	1.15
13	1.44	1.28	1.20				
14	1.55	1.34	1.26				
15	1.66	1.40	1.29	5	1.67	1.41	1.29

* Note: AHRC and HRC length, video sections, n = 9 and 3 respectively.

THE AUSTRALIAN HYPOTHETICAL REFERENCE CIRCUIT (AHRC)

The CCIR Hypothetical Reference Circuit, abbreviated to HRC, is a long distance reference over 2500 km. It has been defined to consist of three video sections. Maximum distortion limits have been referred to the HRC and methods set down for calculation of sectional requirements. These are described in CCIR Recommendation 451-1 (Ref. 1, p. 193).

In Australia, most television programmes are transmitted on assigned bearers sharing a common protection bearer with telephony bearers. Of necessity, the latter are demodulated where traffic drops and inserts are required and, in general, baseband switching is used. At switching points, all bearers are demodulated. Therefore the number of sections making up the television and telephony HRC's would generally be identical for the Australian conditions. As there are nine telephony baseband sections in the circuit (Ref. 6), a variation to the CCIR television HRC would be appropriate. The author suggests nine video sections to make up the Australian Hypothetical Reference Circuit (AHRC).

The AHRC is to embrace only FM microwave radio relays so that it can be used as the reference during acceptance tests of new systems. No other peripheral equipment, e.g. cable-tails and coaxial cables, would be considered. This is because an acceptance test is a test of the manufacturers' equipment performance guarantees as well as the users' system objective compliance, and it is very unlikely that one manufacturer would guarantee an overall performance of a communication system which includes other manufacturers' equipment. In this regard, and in the number of video interconnection points, the AHRC differs from the National Reference Video Connection (NRVC) of the APO (Ref. 7, p. 3).

In apportioning the HRC distortion limits to circuits of different lengths (i.e. video sections), the CCIR have produced a table of Laws of Addition (Ref. 1) for the different distortions. This is shown on the right-hand side of Table 1. The allowable HRC distortions are multiplied by the relevant modification factor to obtain the distortion limits corresponding to the system length under consideration.

The left-hand side to Table 1 shows the revised modification factors for the AHRC. The AHRC consists of nine video sections, n = 9, and, at this point, it is equivalent to the HRC n = 3. The three-for-one ratio is retained, i.e. n = 1 in the HRC will be n = 3 in the AHRC, but the modification factors are the same. Therefore, more stringent limits must be applied to distortions over one video section in the AHRC as compared with that in the HRC.

TABLE 2—PROPOSED OBJECTIVES FOR ACCEPTANCE TESTING

Distortion	No. of Video Sections						
	Proposed				CCIR (Ref. 1)		
	1	3	6	AHRC (9)	1	2	HRC (3)
1. Non-linear							
a) Synchronizing signal (%)	2.3	4.8	7.6	10	4.8	7.6	10
+3dB (%)	4.6	9.6	15.2	20	9.6	15.2	20
b) Peak White Signal (%)	4.6	9.6	15.2	20	—	—	—
+3dB (%)	9.2	19.2	30.4	40	—	—	—
c) Line time LUM (%)	2.8	5.8	9.2	12	5.8	9.2	12
+3dB (%)	5.6	11.6	18.4	24	11.6	18.4	24
d) Line time CHROM gain (%)	2.3	4.8	7.6	10	—	—	—
+3dB (%)	4.6	9.6	15.2	20	—	—	—
e) Line time CHROM phase (deg)	1.4	2.9	4.6	6	—	—	—
+3dB (deg)	2.8	5.8	9.2	12	—	—	—
f) Differential main (%)	1.8	3.8	6.1	8	3.8	6.0	8
+3dB (%)	3.6	7.6	12.2	16	7.2	12.0	16
g)' Differential phase (deg)	0.9	1.9	3.0	4	1.9	3.0	4
+3dB (deg)	1.8	3.8	6.0	8	3.8	6.0	8
h) CHROM-INTO-LUM intermodulation (%)	0.9	1.9	3.0	4	—	—	—
+3dB	1.8	3.8	6.0	8	—	—	—
2. CHROM-TO-LUM inequality							
a) Gain (%)	3.3	5.7	8.1	10	5.8	8.2	10
b) Delay (nS)	33	57	81	100	58	82	100

PROPOSED ACCEPTANCE TEST SPECIFICATIONS ON WAVEFORM DISTORTION

A survey carried out over the acceptance test results of existing systems seems to indicate the CCIR HRC objectives will generally be met for systems assuming AHRC configuration. The results were obtained from the following tests:

(a) Luminance-into-chrominance intermodulation (differential gain and phase).

(b) Line-time luminance channel non-linearity.

(c) Synchronizing signal non-linearity (compression) under bounce conditions.

(d) Peak white signal non-linearity (compression) under bounce conditions.

(e) Chrominance-to-luminance inequalities in gain and phase.

In the absence of contradictory results, it is suggested that the CCIR HRC objectives would be appropriate objectives for the AHRC. The difference will only be on the account of the number of video sections. Table 2 shows the two reference circuit objectives, and their respective sectional objectives.

Finally, it is appreciated that the CCIR objectives are for operational (or maintenance) testing. However, at this stage, it appears reasonable to assume that the degradation of radio equipment with age will not significantly affect the waveform distortion performance. Consequently these objectives could be used in radio relay acceptance testing.

CONCLUSION

The discussion in this paper has been centred upon four CCIR tests which are considered to be inadequate for the distortions to be measured. Alternative methods have been suggested to improve the sensitivity of the test methods. A new test has been introduced; this is the peak white signal non-linearity. And the test method has also been suggested.

In Australia, a variation has been found to be appropriate in the definition of the reference circuit. The AHRC should have nine video sections. However, CCIR HRC objectives have been thought to be achievable and, as such, should be adopted for the AHRC.

APO TESTS AND SPECIFICATIONS

The opinions expressed and suggestions offered in this paper are those of the author. These may be at variance with the official APO tests and specification. For more details of the latter, the reader is referred to (Ref. 7), (Ref. 8), (Ref. 14) and (Ref. 15).

REFERENCES

1. CCIR XIIth Plenary Assembly, New Delhi, 1970, Vol. V Pt. 2, Recommendations 421 and 451, pp 173-213.
2. THIELE, A. N.: "Methods of Waveform-Pulse and Bar-Testing"; Proc. IREE Aust., December 1966, p. 339.
3. CCIR Study Group Documents "Transmission Performance of Television Circuits Designed for Use in International Connections"; Doc. CM TT/104-E, Draft Revision of Report 486, 15 July, 1972.
4. WEAVER, L. E.: "Television Measurement Techniques"; (Peregrinus Ltd., ed 1971) p. 249.
5. HATIFIELD, G. E.: "Television Testing with High Chrominance Amplitude Signals"; Proc. IREE Aust., October 1971, p. 378.
6. CCIR XIIth Plenary Assembly, New Delhi, 1970, Vol. IV Pt. 1, Recommendation 392, p. 37.
7. "Television Relay Facilities Operational Performance Objectives". APO Engineering Instruction, Planning, Transmission and Line Systems 0 8010, Issue 2, 1973.
8. APO Radio Communications Branch Schedule C.8040 "Television Performance Specification"; Appendix 3, Table 3, Sheets 1-7, 1974.
9. PUCKLE, O. S.: "The Transient Aspect of Wideband Amplifiers"; Wireless Engineer, 1935, No. 12 p. 251.
10. BEDFORD, A. V., and FREDENDALL, G. L.: "Transient Response of Multistage Video-Frequency Amplifiers"; Proc. IRE, April 1939, Vol. 27, p. 277.
11. LEWIS, N. W.: "Waveform Responses of Television Links"; Proc IEE, 1954, Paper No. 1688, p. 258.
12. MACDIARMID, I F., and PHILLIPS, B.: "A Pulse-And-Bar-Waveform Generator for Testing Television Links"; Proc. IEE, Sept., 1958, Paper No. 2687R, p. 440.
13. IEC. "Methods of Measurement for Radio Transmitters". Doc. 12C9 2nd Draft, May 1972. Pt. 5 Sec. 6.
14 APO Specification 871. "Television Transmitter and Translator Equipment". Issue 5, January 1972, Sec. 6 and Appendix 1.
15. ABCB. "Draft Standards for the Technical Equipment and Operation of Television Stations". 22 March, 1974, Sec. 7, Appendix A, p. 36 etc.

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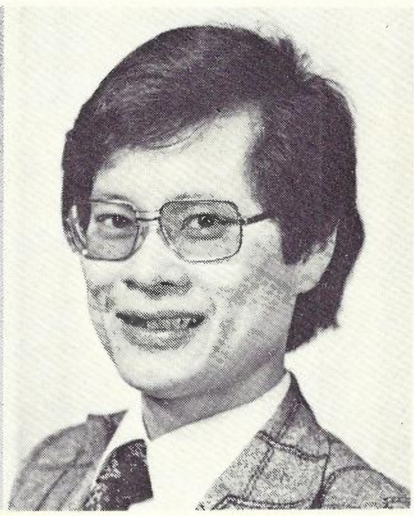


Liquid-cored Optical Fibres for Communication Systems

G. P. KIDD, B.E., B.Sc.

The development of the liquid-filled optical fibre in 1971 created new interest in fibre communication and although there have been significant advances in fibres of different materials and structure, the liquid-cored fibre still offers some advantages over these. The transmission properties of tetrachloroethylene-filled fibres developed by the CSIRO Division of Tribophysics and investigated in the APO Research Laboratories are given, as well as a description of a specially developed light-emitting diode compatible in geometry and electrical characteristics with these fibres. Possible trunk, junction and broadband subscribers systems using optical fibres are discussed.

Editorial Note: This paper was presented to the 1975 Conference of the Institution of Engineers, Australia, and their approval to republish it is gratefully acknowledged.

INTRODUCTION

The development of the laser in the early 1960's stimulated thoughts of vast rates of information transfer resulting from the potentially large modulation bandwidth of these sources, but for a number of practical reasons it was soon realised that these rates could not easily be attained. One major reason was that propagation through the atmosphere was rather uncertain at optical frequencies. It was then proposed in 1966 that this uncertainty could be removed if the light was guided along a transparent medium, namely an optical fibre. Glassy materials were the obvious choice for use as fibres, and it was considered at the time that sufficiently low loss glasses could be readily obtained given adequate purification. However, by 1971 very little progress had been made towards developing fibres having losses less than 20 dB/km, the figure often quoted as being the limit at which fibres would become viable for systems applications.

It was late in 1971 that the CSIRO Division of Tribophysics in Melbourne, at about the same time as the Bell Telephone Laboratories, announced the development of a new type of fibre in which the core of the fibre used a low loss fluid (tetrachloroethylene) instead of the more usual solid glass core. Losses for these fibres were found to be less than 20 dB/km over substantial regions of the infra-red spectrum.

The development of these liquid-filled fibres acted as a renewed stimulus for investigators everywhere, so that in these intervening years there has been considerable work carried out on fibres and associated devices. During this period there have been dramatic reductions in fibre loss, with minimum losses of about 1 dB/km being reported for solid-cored fibres using doped silica (SiO_2) as the core material. With refined purification techniques the losses in liquid-cored fibres have also been reduced to give minimum losses of about 5 dB/km. Advances in fibres using low-temperature glasses (the silicates) have been slower, but losses in the region of 20 dB/km are now being realised with these.

As well as improvements in materials, there have been advances in fibre structures. One of the most important of these is a multi-mode fibre in which the refractive index of the core is parabolically graded across the core diameter, from a low value at the cladding boundary to a higher value at the core centre. Such a graded-index fibre operates by focusing the rays periodically along its length, and so tends to minimise pulse dispersion. The bandwidth of these fibres can be considerably greater than for stepped-index multimode fibres, and under appropriate launching conditions can approach the bandwidth of single-mode fibres. Their advantages are that the core diameter can be considerably greater than for single-mode fibres thereby easing the tolerances on coupling, while allowing a greater power to be coupled into the fibre.

All major telecommunications authorities and companies are now devoting considerable research effort towards realising practical fibre systems. In Australia, the Australian Telecommunications Commission in conjunction with CSIRO have been studying the transmission characteristics of liquid-cored fibres and developing associated devices such as light-emitting diodes (LEDs) with a view to specifying the parameters for possible systems. Likewise, Amalgamated Wireless (Australasia) have been developing liquid-filled fibre systems for commercial application under contract to CSIRO.

FIBRE PRINCIPLES

Consider the fibre structure of Fig. 1 in which the core has a diameter $d = 2a$ and a refractive index n_1. The cladding material surrounding the core has an arbitrary diameter and a refractive index n_2, where $n_2 < n_1$. The external medium has a refractive index n which is generally less than n_1.

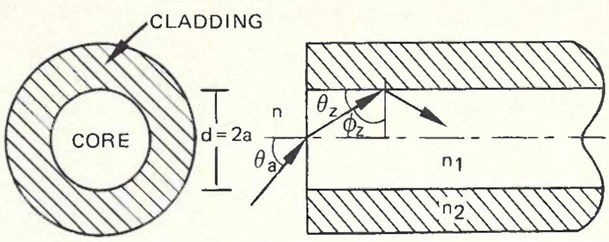


Fig. 1—Optical Fibre Geometry

Snell's law of refraction states that the relationship between incident and refracted angles at the interface between two dielectric materials is

$$n_1 \sin \phi_1 = n_2 \sin \phi_2 , \quad (1)$$

since ϕ_c, ϕ_{ca}

where ϕ is measured from the normal to the interface.

If $n_1 > n_2$ then there is a critical angle ϕ_c above which rays incident on the interface are totally reflected, where

$$\phi_c = \sin^{-1} \frac{n_2}{n_1} \quad (2)$$

Let the angle of incidence be defined as

$$\theta_z = \frac{\pi}{2} - \phi_z \quad (3)$$

Then rays impinging on the core-cladding interface of a fibre will be totally internally reflected when $\theta_z < \theta_c$. These are the so-called trapped rays. All other rays will be refracted into the cladding and their energy will ultimately be radiated off. However, some of these rays (the leaky rays) which have angles of incidence near θ_c have been shown to propagate for long distances and may contribute significantly to the total energy carried by the fibre (Refs. 1, 2, 3).

The angle of incidence θ_{ca} at the fibre face which corresponds to the critical angle of incidence within the fibre is given by

$$n \sin \theta_{ca} = n_1 \sin \theta_c ,$$

or

$$n\theta_{ca} = n_1\theta_c \quad (4)$$

since θ_c, $\theta_{ca} << 1$ so that $\sin \theta \simeq \theta$.

Thus rays incident on the fibre face at angles less than θ_{ca} will be trapped within the fibre. It is useful to characterise a particular fibre by this cone of acceptance in which $\theta_a < \theta_{ca}$. The measure used is the numerical aperture (NA) which is defined as

$$NA = \left[n_1^2 - n_2^2 \right]^{1/2}$$

$$\simeq n\theta_{ca} \quad (5)$$

From this it can be seen that the larger the difference in refractive index between core and cladding, the greater will be the numerical aperture, and therefore the greater the amount of light collected by the fibre.

Another important characteristic of a fibre is its degree of overmoding. The measure used to specify this is the dimensionless frequency coefficient defined as

$$V = \left[\frac{2\pi a \, n_1}{\lambda} \right] \theta_c$$

$$= \frac{2\pi a}{\lambda} \left[n_1^2 - n_2^2 \right]^{1/2} \quad (6)$$

It can be shown that if $V < 2.405$, only one electromagnetic mode (the dominant HE_{11} mode) can propagate in the fibre, and the fibre is therefore called a "single-mode" fibre. Typically the core diameter for single mode operation needs to be less than $10 \mu m$.

For $V > 2.405$, other electromagnetic modes can propagate, the number of propagating modes being approximately equal to $V^2/2$ for large V. Such fibre is designated "multi-mode". For a typical multi-mode fibre of core diameter 100 μm at a wavelength of 1 μm the value of V is of the order of 100.

It can be shown that the propagation of a particular electromagnetic mode along an optical fibre corresponds to a family of rays having a characteristic angle of incidence within the fibre, with this

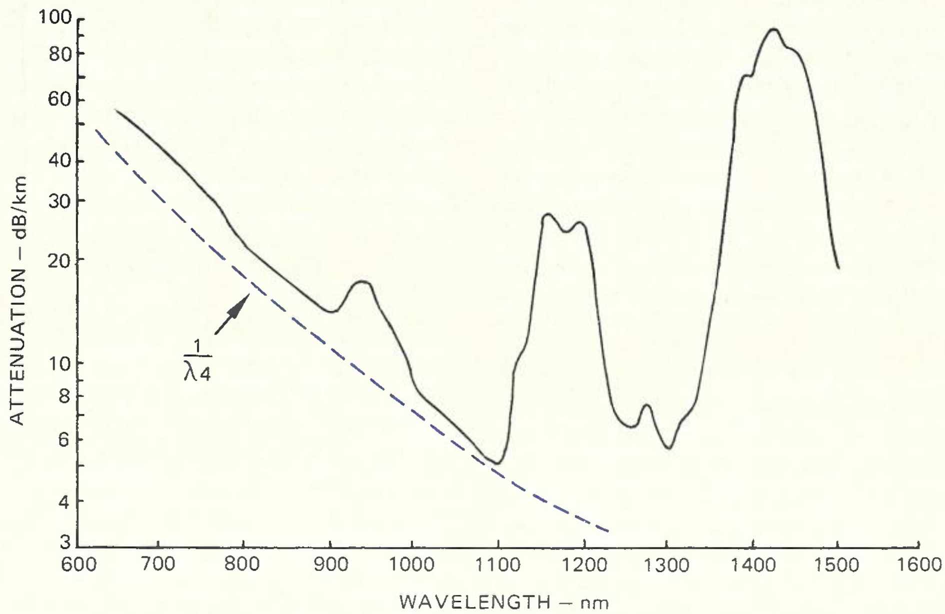


Fig. 2—Tetrachloroethylene-Filled Fibre Attenuation

characteristic angle bearing a direct relationship to the propagation velocity of that mode. Furthermore, the modes in a multi-mode fibre have uniformly decreasing velocity with increasing order, so that higher-order modes correspond to higher characteristic angles of incidence. In the limit the critical angle of incidence θ_c defines the highest order mode that can propagate within the fibre.

TRANSMISSION CHARACTERISTICS

The important transmission characteristics of a fibre are the attenuation and the bandwidth (or equivalently the pulse dispersion). Knowing these and the characteristics of devices, an overall specification for a particular system can be derived.

The transmission properties of a fibre are a function of a number of parameters including the materials used, refractive index difference between core and cladding, diameter, length of fibre, material purity and manufacturing imperfections, as well as of excitation conditions. The following discussion will describe the characteristics of the liquid-filled fibres developed by CSIRO and investigated in the ATC Research Laboratories; an extensive review of other types of fibre is given in Ref. 4.

Attenuation

The two principal phenomena contributing towards the loss in fibres are the inherent Rayleigh scattering due to the molecular structure of the core material and absorption losses due to the presence of impurities. Rayleigh scattering is inversely proportional to the fourth power of the wavelength, while impurities give rise to absorption peaks at particular wavelengths corresponding to specific impurity material.

A typical attenuation curve for a tetrachloroethylene-filled fibre is shown in Fig. 2. Very little information exists in the absolute scattering coefficient to be expected in liquids at these wavelengths, so an arbitrary $1/\lambda^4$ curve is plotted in the figure. It is seen that in the wavelength region 600-800 nm the agreement with the measured values is quite good. Other fluids (e.g. hexachlorobutadiene) have exhibited even closer agreement.

For wavelengths further into the infra-red (i.e. beyond 800 nm) the dominant losses are due to absorption. For example, the peaks at 950 nm and 1150 nm are due to the presence of water, while other peaks can be associated with specific impurities (e.g. trichloroethylene) or their overtones. Identification of these contaminants has been achieved by infra-red spectroscopy, so that considerable progress has been made in purifying the core liquids by eliminating or reducing the contaminant materials.

Other mechanisms may operate to increase fibre loss. If, for example, the cladding has significant loss (and this is usually the case), it can be shown from

Fresnel's laws that a ray will not be totally reflected but will suffer some loss at each reflection. However, in practice, this contribution to total loss is quite small in comparison to the loss experienced by the ray in the core, as has been confirmed experimentally using fibres having cladding materials of different loss. Another possible cause of additional loss is the quality of the core-cladding interface: irregularities at this boundary result in scattering of rays, some of which will be at angles greater than the critical angle of incidence, and will therefore be radiated out of the fibre. For liquid-cored fibres the interface is nearly perfect (as a result of the method of manufacture) so that, again, the effect is not significant.

Pulse Dispersion and Bandwidth

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

In non-ideal fibres, other factors operate to modify these effects. Firstly, if the cladding material is lossy then the higher angle rays which are reflected more often will suffer greater attenuation than the lower angle rays. Since these higher angle rays contribute to the tail of the dispersed pulse, it follows that increasing the cladding loss will reduce their influence and the overall pulse dispersion will be decreased. On the other hand, as the fibre diameter is increased, the number of reflections for a ray at a particular angle will be reduced. It is to be expected therefore that the reduction in dispersion due to a given cladding loss will be more significant for smaller diameter fibres.

The second modifying influence on pulse dispersion is the presence of discontinuities or irregularities at the core-cladding interface and imperfections in the core. Rays of a given angle impinging on these tend to be scattered into rays at other angles, so that after some distance a distribution of rays exists in the fibre. If the length is sufficiently great this distribution tends to an equilibrium condition independent of the launching conditions (Ref. 5).

A number of theoretical models have been developed to describe the transmission characteristics of multi-mode fibres (Refs. 5, 6, 7), but that of Rosman (Ref. 7) conforms at least as well with measured results as more complex models and will be discussed here to give insight into fibre behaviour. This model ignores the effects of mode mixing. However, as noted above, that is a reasonable assumption for well-made liquid-cored fibres. By assuming that the major effect on dispersion is that due to cladding loss, Rosman has shown that beyond some length (the "equilibrium" length) the bandwidth tends to a constant value given by

$$f_c = \frac{4\,v\,k\,n_1\,n_2}{\pi d (NA)^3} \qquad (7)$$

where f_c is the 3db bandwidth, k is the imaginary part of the cladding refractive index which is a measure of its loss, and v is the propagation velocity.

From this it follows that beyond this equilibrium length (of the order of a few hundred metres) the baseband bandwidth of a fibre can be increased by increasing the cladding loss, by reducing the diameter, or by decreasing the refractive index difference between core and cladding.

The method used in the ATC Research Laboratories for investigating pulse dispersion has been to launch a fast pulse (approximately 1 ns rise- and fall-time) of optical energy into a fibre using a GaAs laser diode, and to measure the input and the output pulse shapes for various lengths of fibre. By performing a Fourier transform on these the frequency domain transfer function can be obtained and subsequently the baseband bandwidth corresponding to that length of fibre. By appropriate use of lenses a range of launching conditions can be simulated from collimated through to uniform wide angle excitation.

A typical pulse response for a 90 μm tetrachloroethylene-filled fibre is given in Fig. 3, and bandwidth results for that fibre over a range of lengths up to 1 km with two different launching conditions are given in Fig. 4 (Ref. 8). From this figure the trend towards a common asymptote with increasing length is clearly evident, although the longest length measured was still too short to indicate precisely the asymptotic bandwidth. The difference between using collimated and wide-angle launching is also apparent. The asymptotic bandwidth derived from Equation 7 assuming an effective cladding loss appropriate to this fibre is also shown on this figure.

DEVICES

Sources

From the attenuation curve (Fig. 2) it is seen that the wavelength region over which the loss is less than about 20 dB/km extends from 800 nm to 1100 nm. Within this region the best developed sources

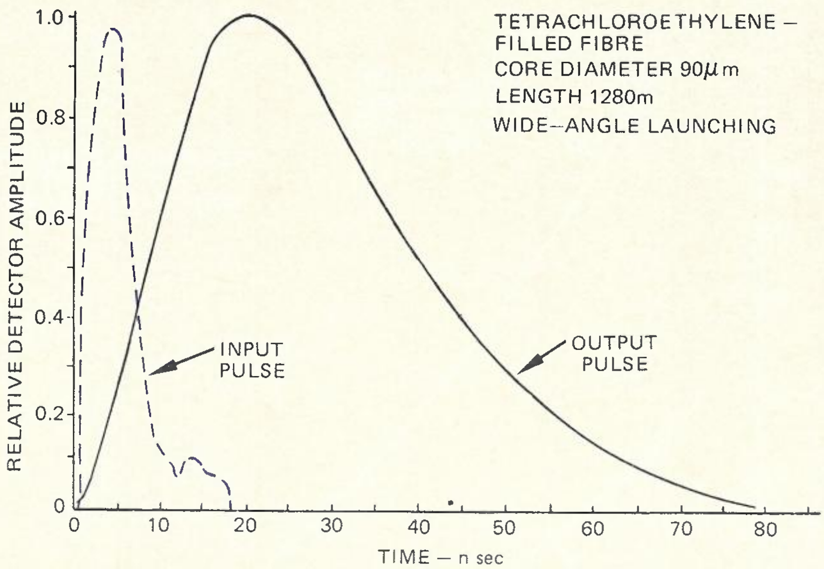


Fig. 3—Fibre Pulse Response

are gallium-arsenide (GaAs) semiconductor laser and light-emitting diodes, giving outputs at wavelengths around 900 nm, and Neodymium doped lasers (e.g. Nd:YAG) operating at 1060 nm. The GaAs devices have the advantage that they can be internally modulated at quite high rates by controlling the injection current through the diode junction. As well, by suitable doping with GaAs (for example, with aluminium), the operating wavelength can be altered over a wide range in the near infra-red region. Although they are more difficult to modulate, Nd:YAG lasers have the advantage that they operate at a wavelength near the minimum attenuation of liquid-cored fibres, which with their high power outputs, could make them attractive for long distance systems.

However, for multi-mode fibres having bandwidths of a few tens of megahertz the obvious choice at this stage is the light-emitting diode (LED). Subsequently, as GaAs laser technology improves, these devices will probably supplant light-emitting diodes, particularly as they have better electro-optic efficiencies, a greater degree of collimation and smaller spectral spreading.

The ATC Research Laboratories have developed a plane diffused-junction GaAs LED (Ref.11) which, although relatively inefficient, provides a source having a high radiance and sufficiently fast response time for use with multi-mode systems. The structure of the diode is such that the electroluminescent region is located a few microns below an etched well into which a fibre can be accurately located, so allowing maximum coupling efficiency between diode and fibre. The output power of this diode is linear with bias current up to currents of 600 mA corresponding to output powers of about 4 mW at a wavelength of 900 nm. Of this power, about 18% is coupled into the tetrathloroethylene-filled fibre (Ref. 9).

Detectors

The most suitable photodetectors with spectral responses covering the region of interest (800 nm to 1100 nm) are silicon photo-diodes having either a p-i-n junction or operating in the avalanche mode. The latter has a variable internal multiplication factor depending on the bias voltage, and particularly for large bandwidths or high bit rates gives an improved signal-to-noise ratio. High impedance amplifiers have been designed (Ref. 10) to allow low signal-to-noise ratios at the receiver using these Si detectors.

SYSTEMS

It is seen from Fig. 4 that the bandwidth of liquid-core multi-mode fibres is of the order of tens of megahertz over relatively short lengths reducing to about 10 MHz over lengths of 1 km and longer. Coupled with the small size of the fibres, which should allow a large number to be made up into cables of reasonable dimensions, these bandwidths allow the specification of a number of alternative communications systems having different capacities and degrees of transmission flexibility.

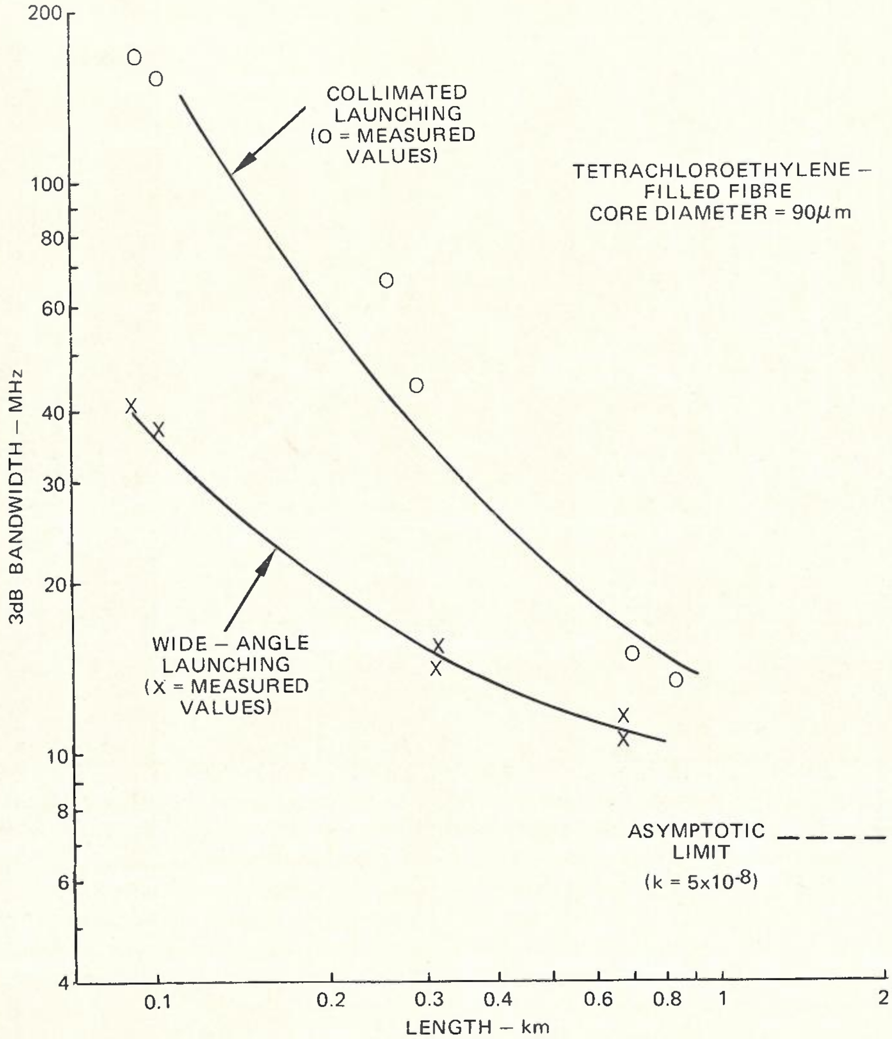


Fig. 4—Fibre Bandwidth

Possible systems being considered by the ATC for application in the longer term include those for long-distance high-capacity trunk routes using digital transmission and signal regeneration along the route; those for short-haul and junction routes using lower bit rate (e.g. PCM) digital transmission; and those for broadband local distribution using either analogue or digital transmission.

Trunk systems will require low loss, high-capacity fibres most probably of the graded-index type, although single-mode or multi-mode stepped-index fibres might also be considered. The development of suitable fibres is still progressing, as is work on compatible sources having the required power outputs, efficiencies and reliability, so that the final form of such a system is by no means certain. In Australia, trunk systems having very large total capacities of the order offered by optical fibres will not be needed for some time, probably not before about 1985.

There is a trend towards using pulse code modulation (PCM) digital transmission at rates of 8 Mb/s or 35 Mb/s over junction and other short-haul routes. These rates are well within the limits imposed by multi-mode fibres and light-emitting diodes. Such fibre systems could therefore offer advantages over conventional cables, particularly in terms of the information transfer per unit cross-section of cable which is of increasing importance as underground duct space becomes more restricted.

The third possible application of optical fibres, namely in a broadband subscribers distribution network, is the most unusual and probably the most interesting. The concept of the "wired city" is currently being seriously considered by many telecommunications authorities including the Australian Telecommunications Commission. Such a system could offer a wide range of facilities including one-way and two-way broadband channels for entertainment and educational television and video telephony, as well as data channels for services such as facsimile, remote meter reading and computer interaction. With decreasing world resources and increasing costs this type of facility offers considerable advantages in the first instance to the business community and subsequently to private subscribers.

Over distances of 1 km or more multi-mode fibres have bandwidths of approximately 10 MHz or, with proper pulse equalisation, a bit rate in excess of 100 Mb/s. Both of these capacities are compatible with the transmission of at least one television channel either in analogue or digital form. With larger capacity fibres such as the graded-index type a number of broadband channels could be transmitted simultaneously on one fibre. However, for a subscribers network the main criteria are cheapness, simplicity and flexibility, so that on these grounds a multi-mode fibre system using LEDs and a number of fibres per subscriber seems to have advantages over a higher-capacity fibre system which would require more powerful and larger bandwidth sources, and which would also have the added complexity of channel multiplexing.

Although at this stage the exact nature of the services that could or would be offered is not known, they would tend to fall into the following categories:

- one-way broadband channels
- two-way broadband channels
- two-way telephony channels
- two-way data channels.

In the simplest case one pair of fibres could be used from a central "concentrator" to a subscriber who would be provided with a "selection" channel along which control data could be sent to switch the required channel at the concentrator. Obviously, more than one pair of fibres would be installed for reliability, and so the exact configuration of channels and fibres could be more optimally arranged than in this simple example. Thus, the low rate data and telephony channels could be simply multiplexed onto the optical carrier at a frequency above the broadband information (i.e. between about 6 MHz and 10 MHz).

Two methods of distribution can be envisaged: loop or radial. In both, the channel information for a subscribers' area would be transmitted from a central "exchange" to a particular "concentrator", from whence it would be selectively distributed to the subscribers. With loop distribution the subscribers would be serially distributed along the bearer, while with radial distribution they would each have exclusive bearers. The first approach would probably necessitate the use of repeaters along the distribution path, and as well does not seem to possess the transmission flexibility of the second method.

CONCLUSION

I have, in this paper, emphasised the characteristics of one very promising optical fibre, namely the liquid-filled one developed by CSIRO, and have given possible applications for it in telecommunications networks. However, it is only one of a large number of possible fibre types into which considerable world-wide research effort is being directed at this time. There is no doubt that optical fibres will be used extensively in telecommunications systems, although there is neither certainty as to which ones will be used for particular applications nor when such systems will become practical. Over these next couple of years, though, optical fibres will move out of the research phase into development, and a telecommunications revolution will have begun.

REFERENCES

1. SNYDER, A. W., and MITCHELL, D. J.: 'Leaky Rays on Circular Optical Fibers'; J. Opt. Soc. of Amer., Vol. 64, No. 5, May 1974, pp. 599-607.
2. SNYDER, A. W., MITCHELL, D. J., and PASK, C.: 'Failure of Geometric Optics for Analysis of Circular Optical Fibers'; J. Opt. Soc. of Amer., Vol. 64, No. 5, May 1974, pp. 608-614.
3. DAVIES, W. S.: 'Significance of Leaky Rays in Liquid-filled Optical Fibres'; Elec. Letters, Vol. 10, No. 21, 17 October 1974, pp. 426-427.
4. MILLER, S. E., MARCATILI, E. A. J., and LI, T.: 'Research Towards Optical-Fibre Transmission Systems'; Proc. IEEE, Vol. 61, No. 12, Dec. 1973, pp. 1703-1751.
5. GLOGE, D.: 'Impulse Response of Clad Optical Multi-Mode Fibres'; Bell Syst. Tech. J., Vol. 52, No. 6, Jul-Aug. 1973, pp. 801-816.
6. DAVIES, W. S.: 'Dispersion in Large Ideal Optical Fibres with Plane-Wave Excitation'; Aust. Telecomm. Res. J., Vol. 8, No. 1, 1974, pp. 18-24.
7. ROSMAN, G.: 'Transmission Experiments in Large Ideal Optical Fibres'; Proc. IREE (Aust.), 4th National Radio and Electronics Convention, Melbourne, August 1973, pp. 80-81.
8. DAVIES, W. S. and KIDD, G. P.: 'Bandwidth Results for Liquid-Core Optical Fibres'; Elec. Letters, Vol. 10, No. 19, 19 September 1974, pp. 406-408.
9. COLVIN, J. P.: 'Coupling (launching) Efficiency for a Light-Emitting Diode, Optical Fibre Termination'; Opto-Electronics, Vol. 6, 1974, pp. 387-392.
10. PERSONICK, S. D.: 'Receiver Design for Digital Fibre Optic Communication Systems'; Bell Syst. Tech. J., Vol. 52, No. 6, Jul-Aug., 1973, pp. 843-886.
11. TEEDE, N. F.: 'The Optimisation of Doping Levels in Electro-luminescent Diodes'; Proc. Iree (Aust.), 4th National Radio and Electronics Convention, Melbourne, August, 1973.

GRAEME KIDD obtained his Engineering degree at the University of Queensland in 1961 and his science degree at Melbourne in 1965. He joined the APO Research Laboratories in 1962. In 1968 he became Divisional Engineer of the Transmission Lines Division which subsequently became the present Guided Media Section. He has been concerned with the characteristics of high-capacity circular waveguide, and was seconded to the BPO Research Department in 1970-71 to study developments in this area. Since 1972 his main interest has been with optical fibres.

Some Switching, Signalling and Synchronisation Techniques in Satellite Communication Systems

A. EVEN–CHAIM, B.Sc.

Techniques have been developed for satellite communication systems which aim to increase the traffic carried by the system. Demand assignment systems and digital speech interpolation are described, and techniques for hybridization of data channels with telephony considered.

The treatment embraces the interfacing, concentration and multiplexing of terrestrial circuits prior to modulation.

INTRODUCTION

One of the many areas of concern in a telecommunication system is the efficiency of the telephone and data traffic flow in the transmission medium. Newly developed techniques are continually examined and as soon as they become practical and offer economic advantage, the telecommunication network is upgraded with new installations that generally improve or optimise the overall efficiency. In particular, cases occur of lightly loaded links via satellite where full-time preassigned (PA)* point to point circuits are not justified. In these cases higher efficiency may be achieved by adding an extra switching stage at the satellite link ends; the satellite channels then form a pool and each channel can be time shared and switched on demand. This switching technique is called a Demand Assignment System (DAS).

Within the Intelsat network three major DAS developments are of interest:

- FDMA/DA — (Frequency-Division Multiple-Access Demand-Assignment) commercially named SPADE, a system already used by several administrations.
- TDMA/DA (Time Division, etc.), a system which is not yet in commercial use although several field trials have been carried out (MATE, MAT 1, etc.).
- DSI (Digital Speech Interpolation), a system in a development stage.

Fig. 1 shows the traffic load per channel for the various TDMA channel assignment methods (Ref. 1). The maximum load per channel in the SPADE system is 1 erlang. Fig. 2 shows a basic block diagram of a DAS (Ref. 2). On demand a satellite circuit is virtually instantaneously assigned between two earth stations. On release the circuit is again available, or free to be switched between any other terminal pair.

This switching facility, assignment on demand, places special requirements on the signalling scheme. A number of new techniques and methods of signalling have been considered, developed, tested and used within the satellite system, i.e. between the ground stations.

This article is a summary of some switching and signalling techniques used in satellite systems, taken from recent literature.

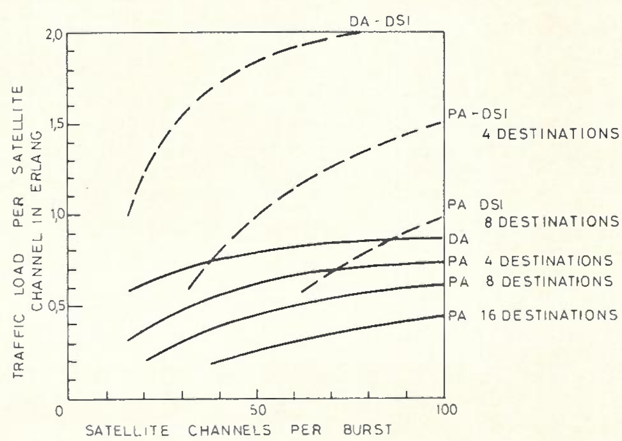


Fig. 1—Traffic Capacity of a TDMA Terminal. The DSI Curves are for 40% average speech activities.

*A glossary of abbreviations defined and used frequently in this paper is given in the Appendix.

FDMA — SPADE

General

The SPADE (Single channel per carrier, PCM multiple Access, Demand assignment Equipment) system contains a switching unit enabling a random selection of a free circuit out of the available circuits

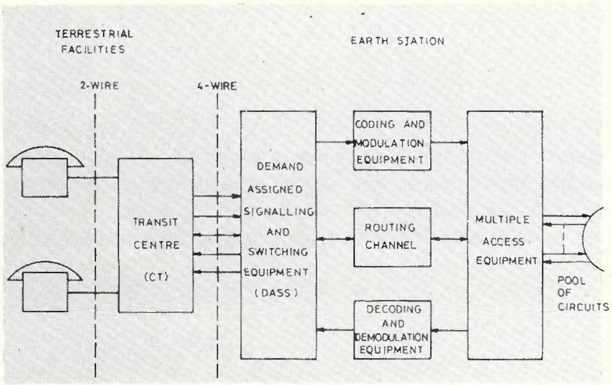


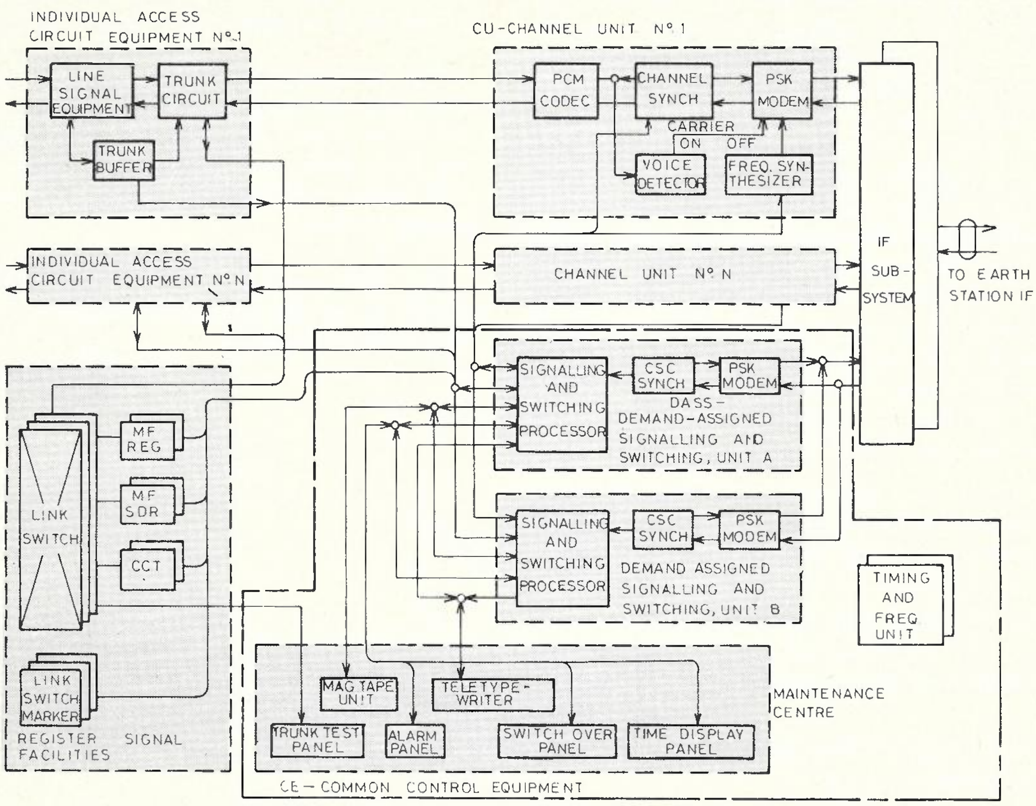
Fig. 2—Basic Function in DAS.

pool. Circuits are not permanently associated with any terminal unless otherwise mutually agreed by the operating administrations.

There is no master control station. Each participant makes use of its own Demand Assignment Switching and Signalling Unit (DASS) to select, by its own independent logic, a "free" channel. This independency is quite feasible, because each terminal continually updates the channel status in its own memory with the data provided through the Common Signalling Channel (CSC), received by all terminals. However, one terminal must act as a reference time station to provide the necessary synchronisation. Each station in turn may act as such.

Fig. 3 (Ref. 3) shows a diagram of a part of a SPADE terminal, which comprises, among others, the following main blocks:

- Terrestrial Interface Unit (TIU), comprised of the Individual Access Circuit Equipment
- Full Duplex Channel Unit (CU)
- Common Control Equipment (CE)



CCT—Continuity Check Transceiver
MF—Multi Frequency
REG—Register
SDR—Sender

Fig. 3—Spade Terminal Block Diagram.

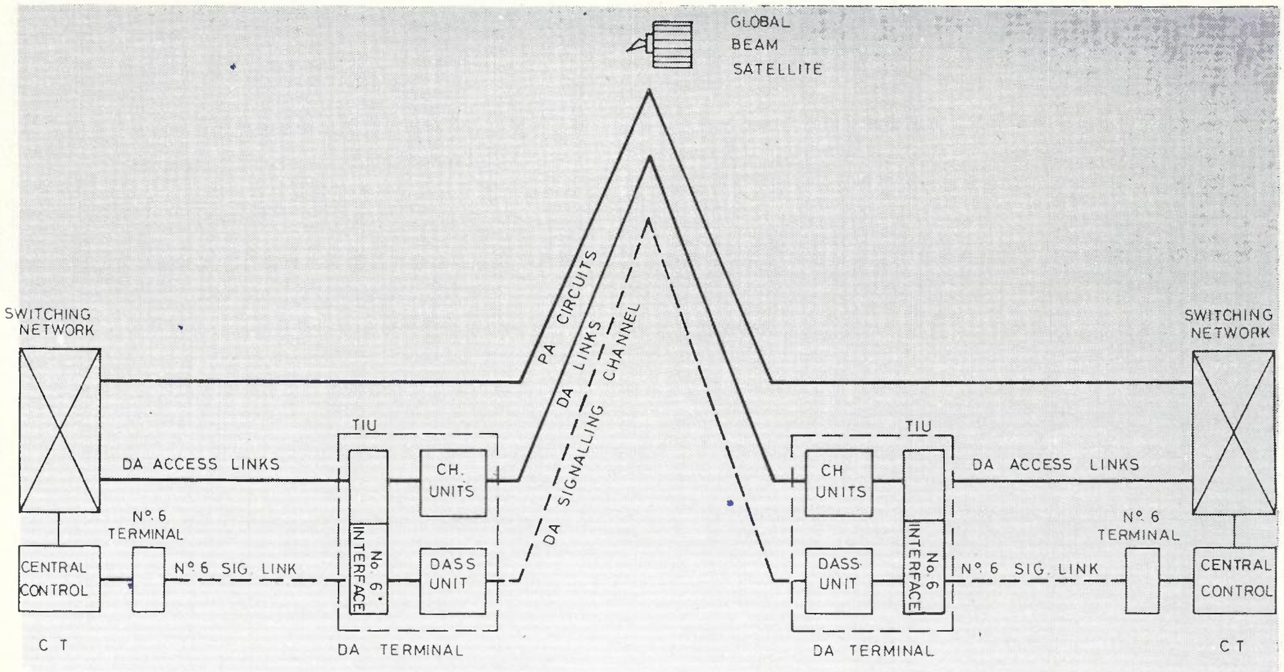


Fig. 4—The Combination of Terrestrial No. 6 Signalling System and the DA Signalling System Serving both DA and PA Circuits.

Terrestrial Interface Unit

The TIU general specifications enable it to operate with any type of an international telephone exchange or transit centre (abbreviated as CT). Two basic types of signalling links between the CT and the SPADE terminal are accounted for:

- Individual channel signalling, for example, CCITT No. 4
- Common channel signalling, that is, CCITT No. 6.

Fig. 4 shows a system layout for a No. 6 signalling link (Ref. 4).

Channel Unit

The full duplex CU for each circuit contains the following sub-units:

- PCM coder-decoder (Codec)
- Digital voice detector
- Transmit and receive synchroniser
- Channel frequency synthesiser
- 4-phase PSK modem.

While the PCM coder converts the analogue input signal to a digital format, a digital voice detector determines whether the actual voice information is present at the input. (The voice detector is bypassed when the circuit is allocated to non-telephony applications.)

As a voice is detected, and the channel (carrier) assigned by the DASS is gated on, the transmit synchroniser is triggered adding the bits required to aid in carrier and bit timing recovery at the receiving end.

Generally the synchroniser functions are:

- To generate a preamble word at the beginning of each voice burst and every 3.5 ms to combine a synchronising ("unique") sequence with the encoded voice data at the output of the PCM encoder.
- To derive frame synchronisation from the received data, and to forward the recovered data and associated timing signal to the PCM decoder.

The channel carrier frequency pair (a 4 wire circuit) for the modem is supplied by the multichannel frequency synthesiser which acts as a frequency division switch, controlled by the DASS.

The Common Equipment

This part comprises the following sub-systems:

- DASS
- Timing and Frequencies Unit (TFU)
- Maintenance Centre (MC)
- IF Stage

The DASS unit at each SPADE terminal is composed of two fully redundant Switching and Signalling Processors (SSP), Common Signalling Channel Synchronisers (CSCS), and PSK (Phase Shift Keying) modems (Fig. 3). The SSP takes care of the call initiation, registering, supervision and termination for all the circuits to and from the CT and the other terminals.

A call originated by the CT is firstly processed and the appropriate destination is determined. An idle circuit is selected and an initial addressed message is sent by the SSP through the Common Signalling Channel. This message is received by all the SPADE terminals. It indicates that a particular satellite circuit is now becoming busy, being selected by the originating terminal. The particular terminal addressed by that message answers and the two SSPs, one at each end of the selected satellite circuit, continue the inter-unit signalling sequence until the call is established. The signalling information exchange will continue as required and when the call terminates, a message via the CSC (Common Signalling Channel) tells all terminals that the circuit is returned to the pool.

The SSP also conducts operational maintenance checks (in conjunction with the MC), to ensure proper operation.

SPADE Signalling

In the 1972 CCITT Plenary Assembly, Recommendation Q. 48 was accepted (Ref. 5). The Recommendation covers, when applicable, fully variable and variable destination type of DA systems.

Selected points from the Recommendation are:

- The signalling system shall have the capacity to carry all the telephony signals currently provided by CCITT signalling systems and in addition, provide reserve capacity.
- It shall be an integrated signalling system used for both setting up the DAS speech circuits, and transfer of the (signalling) information flow for telephony.
- The message structure should be such that one message will contain all the information necessary for one event. Each signal unit should contain both information and check bits.

Fig. 5 shows the CSC signalling structure (Ref. 6).

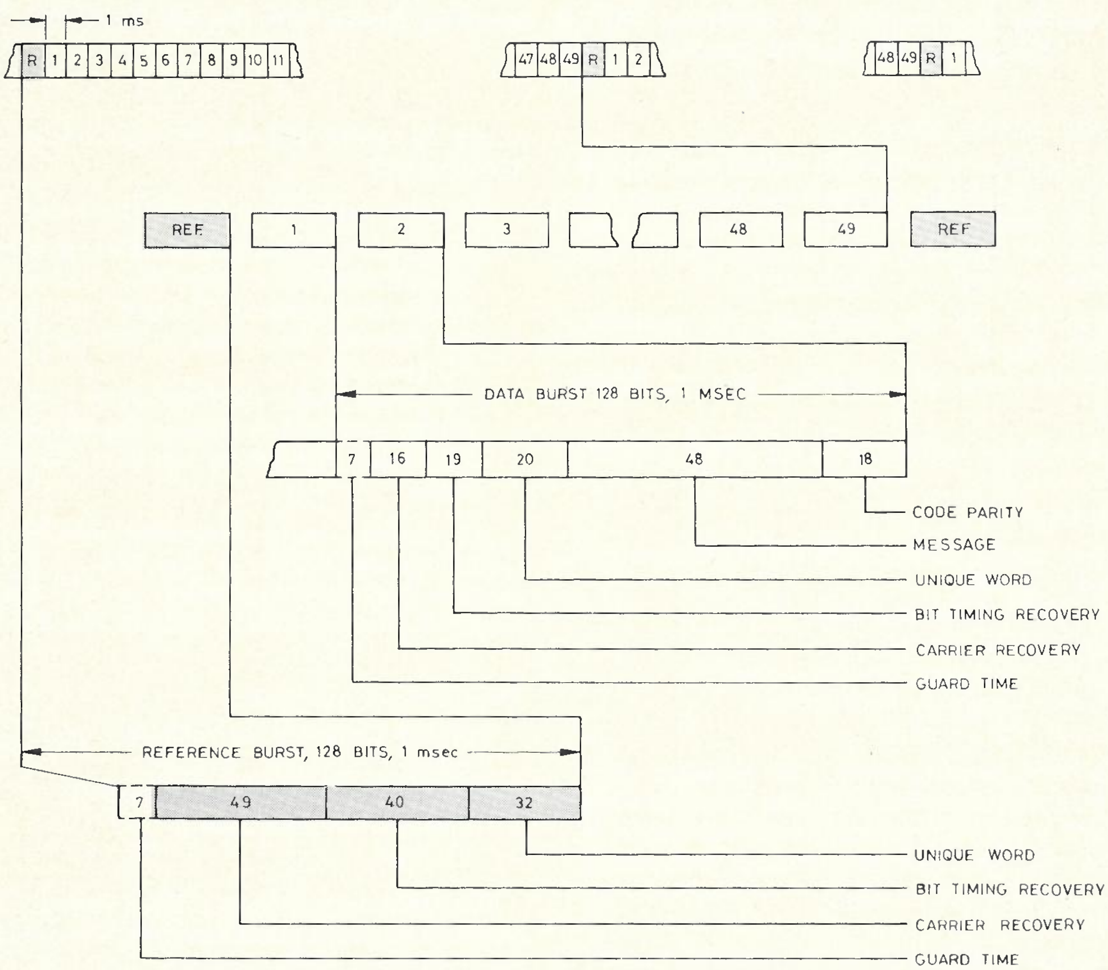


Fig. 5—CSC Signalling Structure.

Each terminal is allotted 1 ms every 50 ms to inject its signalling burst, including guard time, etc. A failure in any CSC equipment does not affect the other terminals, nor the common signalling channel performance.

Fig. 6 is an illustration of the various signal codes in the CSC message format (Ref. 6). Use is made of only 10 out of 16 identity codes, the six unused codes being available for future expansion. All the message codes less than 1000 (binary notation) are used only for system synchronisation, status and maintenance support. The last 8 identity (ID) codes are allotted for call initiation, addressing and releasing. An illustration of a message and time sequence is shown in Fig. 7 (Ref. 7).

A message priority scheme has been adopted as follows:

(i) An idle and synchronisation signal (to be sent at least once per 16 consecutive signal bursts).
(ii) A request for re-transmission.
(iii) An answer signal.
(iv) All other call signals.
(v) Circuit status.
(vi) Service circuit signals.

In addition, other priority rules must be accepted, for example:

- A message re-transmission will take precedence over other messages in the queue in the same priority category.
- Messages may be inserted between any sequence of consecutive messages, subject to the above priorities.
- A satellite circuit status message not transmitted during the last 10 seconds should have priority immediately after priority (i) above.

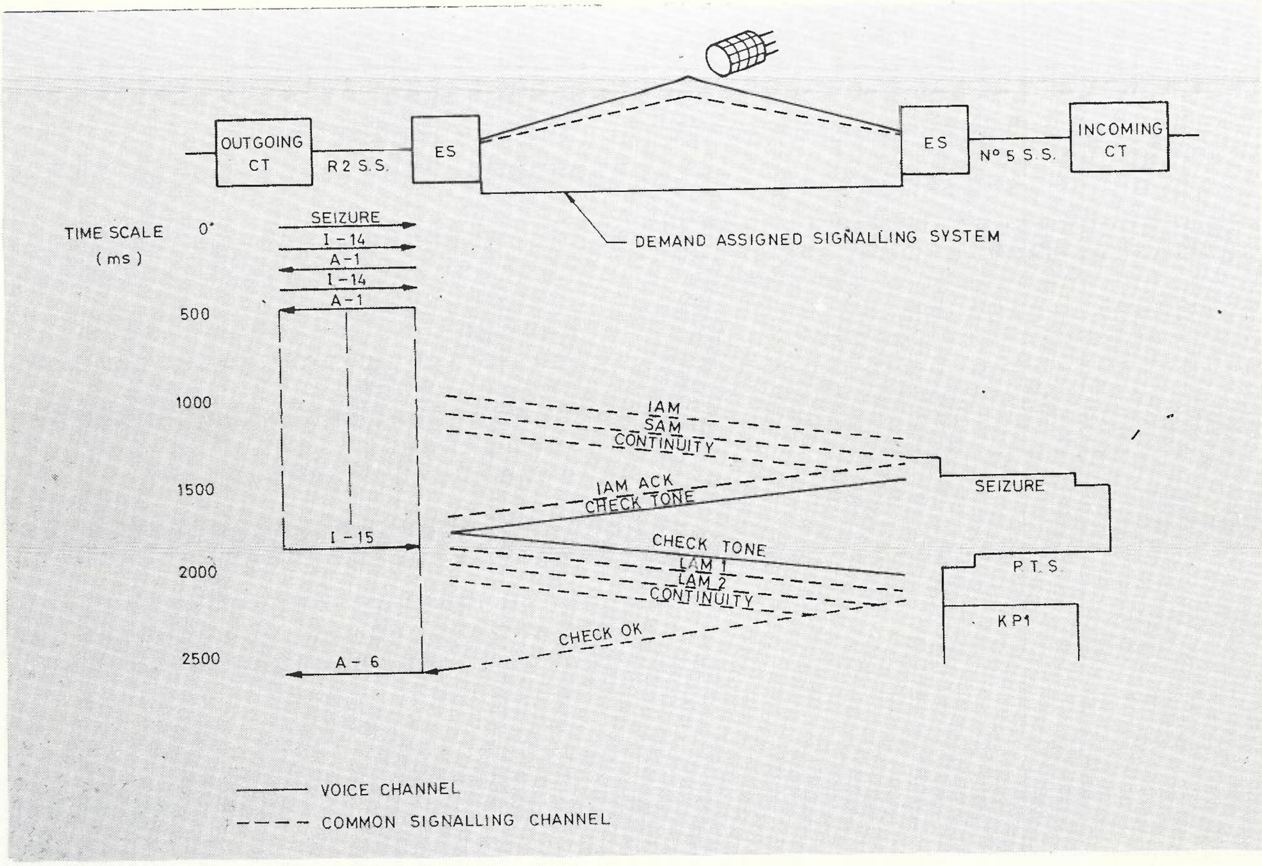
All the priorities and the rules applied are programmed and handled by the SSP.

As the signalling information is of a multi-destination mode, the CCITT No. 6 signalling scheme as a whole cannot be adopted. Each signal unit

	ID CODE (bits 1–4)	LABEL (bits 5–10)	LABEL (bits 11–16)	INFORMATION 17–20	21–24	25–28	29–32	33–36	37–40	41–44	45–48
SPARE	0 0 0 0	ADDRESSED DEMAND ASSIGNED TERMINAL	ADDRESSED ACCESS CIRCUIT NUMBER								
SPARE	0 0 0 1										
ERROR CONTROL	0 0 1 0			SPARE				MESSAGE NUMBER		FUNCTION CODES	
ENGR SERVICE CIRCUIT	0 0 1 1			TTY CHARACTER		TTY CHARACTER		TTY CHARACTER		TTY CHARACTER	
SPARE	0 1 0 0										
SPARE	0 1 0 1										
ACCESS CIRCUIT STATUS	0 1 1 0			SPARE				ACCESS CIRCUIT NUMBER		FUNCTION CODES	
SATELLITTE CIRCUIT STATUS	0 1 1 1			STATUS	SAT CIRCUIT A			STATUS	SAT CIRCIUT B		
SPARE	1 0 0 0										
ISU OF SAM	1 0 0 1			HEADING	DIGIT A	DIGIT B	DIGIT C	DIGIT D	DIGIT E	DIGIT F	DIGIT G
TSU OF SAM	1 0 1 0										
LSU OF SAM	1 0 1 1										
SPARE	1 1 0 0										
SUPERVISORY	1 1 0 1			HEADING	SPARE	SATELLITE CIRCUIT NUMBER		TRANSMITTING TERMINAL ACCESS CIRCUIT NUMBER		ROUTING AND FUNCTION CODES	
RELEASE GUARD	1 1 1 0										
IAM	1 1 1 1										

NOTES:- IAM INITIAL ADDRESS MESSAGE
SAM SUBSEQUENT ADDRESS MESSAGE
ISU INITIAL SIGNALLING UNIT
TSU TERMINATING SIGNALLING UNIT
LSU LONE SIGNALLING UNIT
TTY TELETYPEWRITER

Fig. 6—CSC Message Formats.



LAM—Lone Address Message.
I-14, I-15, A-1, A-6—Forward and Backward Signals in the R-2 System.
ES—Earth Station.
P.T.S.—Proceed to Send.
KP1—Register Signal in the No. 5 System.

Fig. 7—Simplified Time Sequence Chart. CCITT R-2 and No. 5 Signalling System Interfaces.

(message) must contain two addresses, one for the terminal destination and one for the circuit access requested. Six bits are needed for the address (to 49 destinations) and 6 bits provide access to 64 circuits, the maximum channel allotment per terminal. Use is made of the remaining 32 bits for backward and forward information. The 32 bit format generally follows the No. 6 scheme.

The CSC TDM is quite effective in reducing the chance of dual or multi-seizure of circuits. But although channels are assigned on a basis of first requests first served, it may happen that due to the various delays between the terminals, another terminal selects the circuit already requested but not yet marked busy. In this case the second terminal must get an answer to restart the call initiation sequence.

SPADE Synchronisation

Various delays caused by the terminal equipment and the transmission media are accumulated along the path due to:

- Propagation time — 274 ms one way (for 5° elevation).
- Message queueing — related to the frame length, traffic, etc. It is approximately 25 ms or about half a frame length.
- Emission time — for 128 bits/burst — 1 ms.
- Processing time — access, receive and store time, etc., estimated between 0.2 ms to 1 ms.

Two synchronisation procedures are necessary for the SPADE system operation. One is needed to synchronise the PCM voice signal on each channel carrier frequency, and the other is to synchronise the CSC TDM bursts. Each channel unit contains a transmit and receive synchroniser. In continuous operation when the voice detector is triggered "on", (voice is being continually detected), a synchronising ("unique") word of 2 x 16 bits is inserted into the channel bit stream for every 224 bits of voice information. Together the total of 56 kb/s voice information and 8 kb/s of preamble data form a 64 kb/s channel.

At the beginning of a burst when the voice detector turns on, a preamble word of 120 bits plus the 2 x 16 bits unique word is injected ahead of the data. Detection of the unique word is used during a continuous transmission to provide digital frame synchronisation.

The receive synchroniser requires detection of two consecutive unique words at the beginning of each burst, in order to lock into a closed aperture mode. After synchronisation it continues to look for a unique word every 224 bits, in reference to the original recovered frame timing. When a unique word is absent the synchroniser keeps on looking, still providing sync signal, until it observes five unique word detections missing successively. The synchroniser then drops out of lock and starts again in the open-aperture mode to look for a unique word.

The CSC synchronisation (CSCS) data is contained in the signalling and the reference burst formats (Fig. 5). The synchronisation signal bits, plus the unique word, are generated within the CSCS transmitter.

The signalling burst fixed for each terminal is timed in accordance with the reference burst. All terminals are able to transmit the reference burst, but only one pre-designated terminal is authorised to transmit the reference burst at a time. The burst reference is used by the other terminals to accurately place their TDM terminal burst and avoid overlapping with the preceding and following bursts.

In case of a reference burst transmission failure, another pre-assigned terminal takes on the duty. A failure detection is activated when two consecutive reference bursts are missed. The alternate reference terminal automatically switches on to "Reference Burst Mode" and transmits the proper message to all the other terminals. If the fault in the first terminal is only within the reference burst generation unit, the terminal automatically switches over to a "Local Terminal Mode" and continues its normal operation.

SPADE Switching

In the current SPADE system, a call offered at one of its incoming trunks (from the CT) may be individually switched to any of its outgoing trunks, up to 60 accesses per terminal. For 48 terminal destinations the maximum available number of switched links is (60 x 48) = 2880. Compared with the 800 channels physically available, the improvement in efficiency produced by the additional switching stage is substantial.

A switching action takes place in the CU where the synthesiser is being instructed by the SSP to make use of a particular channel. The channel assigned is selected at random by the SSP from the pool of idle channels. (This arrangement adds to reduce the chance of multi-seisure.) A stored program controlled terminal allows each administration to select or delete any option it might require, as long as it does not interfere with operation of other administrations.

TDMA SYSTEMS

A TDMA system feature is that each terminal transmits a carrier burst in its assigned time slot only. All the individual bursts of all the participating terminals are combined into one PCM frame. This arrangement may be regarded as an expanded application of the SPADE signalling channel. A time slot burst may comprise one circuit or several, depending on the assignment mode and traffic demands.

A guard time between adjacent bursts is essential to separate the individual bursts and to prevent overlapping caused by clock frequency deviations, propagation time variations, etc. The guard time is a part of the allocated time slot and thus the system useful capacity is reduced in proportion to the number of terminals. Fig. 8 shows TDMA frame and burst formats (Refs. 8, 9 and 13). It is expected that in future systems time slots may be allocated arbitrarily with a flexible burst length. The 125X microsec frame period, with X = 6, is the latest development. This figure was chosen in accordance with the CCITT PCM standard. Fig. 9 depicts a general block diagram of the TDMA terminal (Ref. 8). Various circuit group combinations might arrive from the CT. Each individual circuit or group might make use of one of the existing signalling schemes. The SSP Control Unit processes the information and instructs the Multiplexer accordingly. On establishing a satellite circuit, a part of the terminal time slot is allocated by the SSP. The MUX arranges the incoming traffic circuits in their allocated time slots ready to be further mixed with the preamble. Each circuit group has its own Terrestrial Interface Module (TIM).

There is not yet a finally accepted CCITT recommendation for a TDMA/DA system. Different approaches for the assignment mode level and the signalling scheme are being considered (for example, Ref. 11). Most likely the next TDMA phase will adopt a VDMA (Variable Destination Multiple Access) mode with pre-assigned time slots. Applications of TDMA systems are discussed in Refs. 10 and 12.

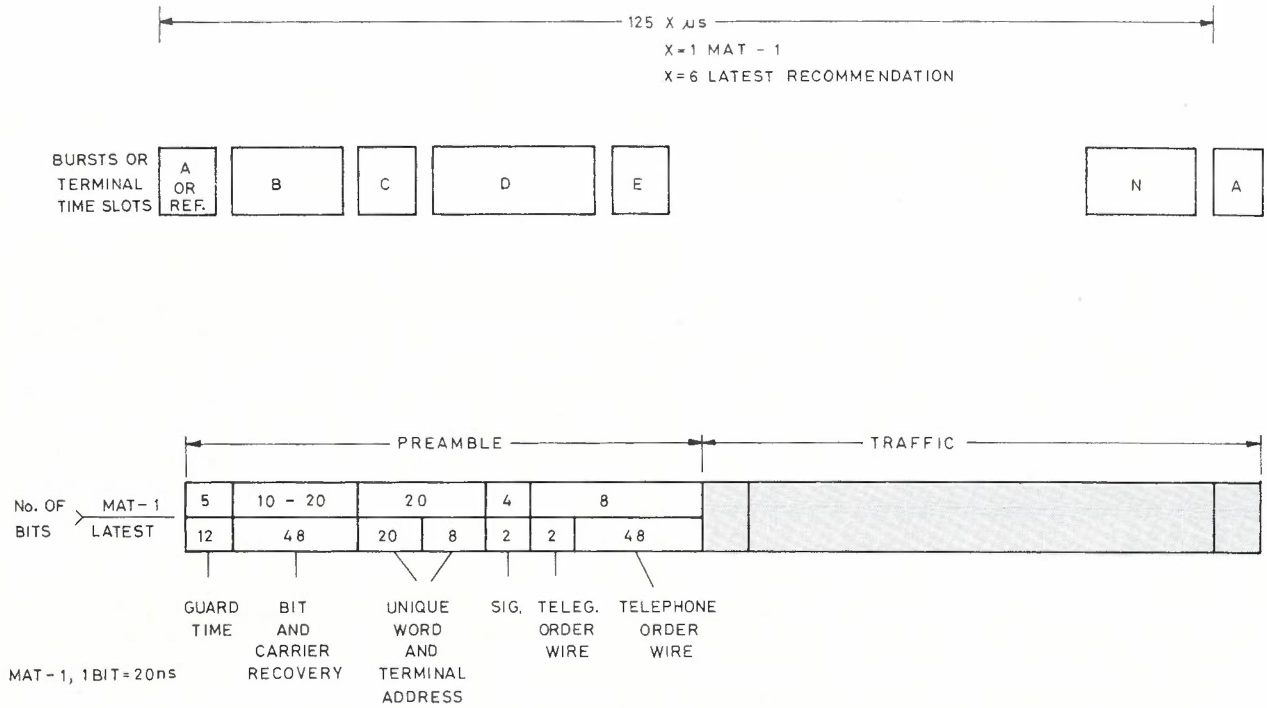


Fig. 8—TDMA Frame and Burst Format.

TDMA Synchronisation and Signalling

For TDMA systems in general, one terminal has to act as a reference station, so that frame and burst synchronisations are related to a starting time reference. Use of one reference burst per frame without traffic is recommended. (Similar to SPADE CSC synchronisation.)

The preamble of each burst (Fig. 8) contains both signalling and synchronisation information. However, the number of bits in the format should be minimised leaving maximum capacity for voice circuits. Three TDMA/DA signalling techniques, or rather channel allocation modes which optimise the number of the signalling bits are:

- The lowest numbered idle time slot is always next to be selected. Only one channel address is transmitted within the burst (the highest numbered busy one). The number of channels per burst and burst position might be re-allocated frequently.
- Slack time arrangement, in which parts of the frame are permanently allocated among the terminals, leaving unassigned gaps for partial flexibility. This technique is basically that of a preassigned system with the additional feature of variable burst length.

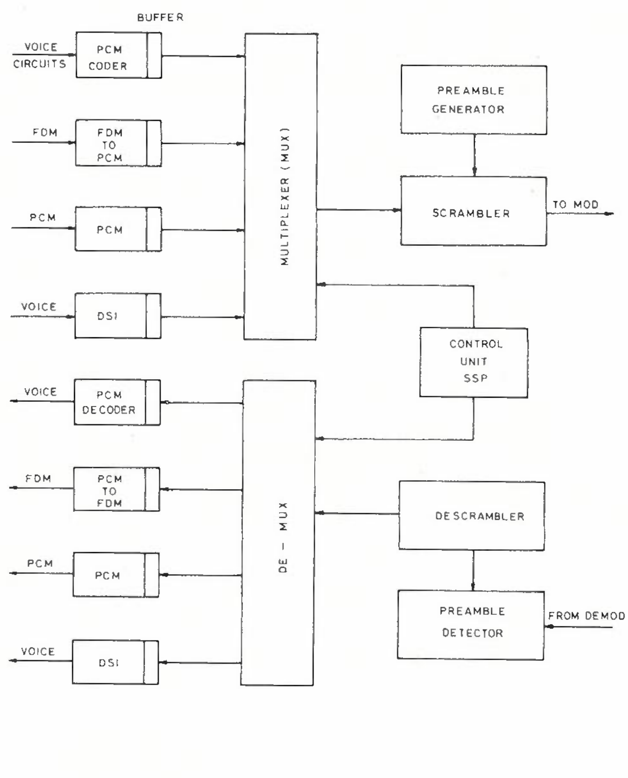


Fig. 9—TDMA Terminal, Simplified Block Diagram.

* Each terminal broadcasts, on request by the reference terminal, the number of busy channels and readjusts its burst position according to the information processed by the SSP.

In the MAT-1 DA system Fig. 8 (Ref. 13), use was made of the four signalling bits per burst (per frame) to convey part of the signalling message unit. For example, route selecting information was multiplexed in eight frames. The 32 bit word (called CARD, Channel Allocation and Routing Data) thus obtained actually included effective signalling information of 21 bits. Error detection 10 bits, and one dummy bit, yield the total of 32. Use was made of the 20 bit unique word and terminal address for the CARD multiframe synchronisation. The first 20 bit word in the 8 frame sequence was transmitted in a binary complement code, while the other seven words maintain the regular binary form.

The long preamble word (plus the guard time) reduces the TDMA/DA system capacity. Later developments limit the number of signalling bits per preamble and rely on the signalling information within the traffic format. This arrangement is more suitable where a group of channels (for example, a full PCM system) is switched simultaneously.

TDMA Switching

The terrestrial interface unit is designed to cater for several types of terrestrial circuits:

* Analogue circuits switched to a PCM codec, with expandable capacity, one channel at a time.
* A digital speech interpolation system expandable, for example, up to 60 input channels interpolated into 30 time slots.
* A 2.048 Mbit/s digital link.
* FDM groups.

The switch crosspoint at the terminal access to the satellite link is a time division controlled gate. The voice circuits to be switched through are sampled, encoded and multiplexed in a sub-frame within the terminal transmitted burst.

Many future terrestrial circuits to the earth station are expected to be in a PCM format only. This will enable the whole terminal switching or concentrating to be performed by a TDM switch.

DIGITAL SPEECH INTERPOLATION

Further demands to increase the efficiency and reduce the channel cost have revived the use of time assignment speech interpolation techniques such as TASI (Ref. 17). Because the TDM technique is closely related to speech interpolation, it is expected that DSI would smoothly integrate with TDMA systems.

The speech interpolation technique is based on the fact that it is not usual for both parties to a conversation to speak simultaneously. Also there are within a conversation, long pauses for thinking, etc. The result is that at least one direction of a telephone circuit is inactive at any given time in a normal conversation. In the case of a four-wire circuit with separate send and receive channels, the non-active channel can be further exploited when temporarily idle. The only obvious problem is that the non-active channels are unpredictable, and the channel status changes in a very sporadic and random manner. Fig. 1 has shown that on the assumption of 40 % circuit activity the traffic carried over a bundle of channels might be increased more than two-fold with an appropriate switching and signalling technique.

DSI Switching

Additional units required for a DSI terminal are mainly:

* Speech detection.
* Channel and circuit control.

The DSI control unit must be continually updated with the terrestrial channel "tri-state" status (active, non-active but still busy, and idle). Once a connection to a destination terminal has been established, the originating terminal should also store and re-transmit the far-end terrestrial circuit address each time a DSI switching takes place.

The speech quality of a DSI system is degraded in comparison to a normal time division system. This is due to the clipping caused by the fixed delay in switching of active channels, and the variable clipping introduced as the system is overloaded.

One particular approach (Ref. 14) — Variable Adaptive Length of Time Slots, VALTS — suggests the introduction of flexible time slot length, for example, 5 — 8 bit per sample depending on the traffic demands. This means that in certain conditions one frame might hold different size time slots. In practice usually only two sizes, for example 7 and 6 bits per voice sample, would be used. Such variations call for establishing a priority law, and other pre-arrangements controlled by the originating terminal. In this system approach, clipping is eliminated and traded for signal-to-noise performance. However, traffic capacity is increased by more than 50 % (at 5 - 8 bits per sample).

Traffic-wise, the DSI system is recommended for point to multi-point (variable destination) applications and large bundles of trunks.

DSI Signalling

Fig. 10 shows a DSI system signalling format (Ref. 11). The preamble, similar to that of the TDMA system, carries all the signalling information plus the synchronisation bits. Three frames are required for a complete message with all relevant addresses. Error detection is a vital feature and the use of a two out of three majority scheme is suggested.

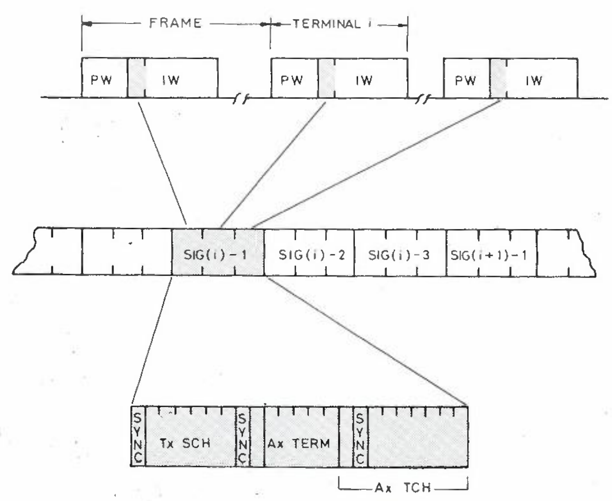
Each message unit should contain the addresses of the destination terminal, the channel allocated and the far end switched terrestrial circuit. The last address may be replaced with channel signalling information, for example, seize forward.

There is an additional signalling load on a DSI link (as compared with the systems described earlier) due to the need to retransmit signalling information each time a channel activity changes, the repetition of messages for error detection purposes, and the longer message unit.

TELEGRAPH AND DATA

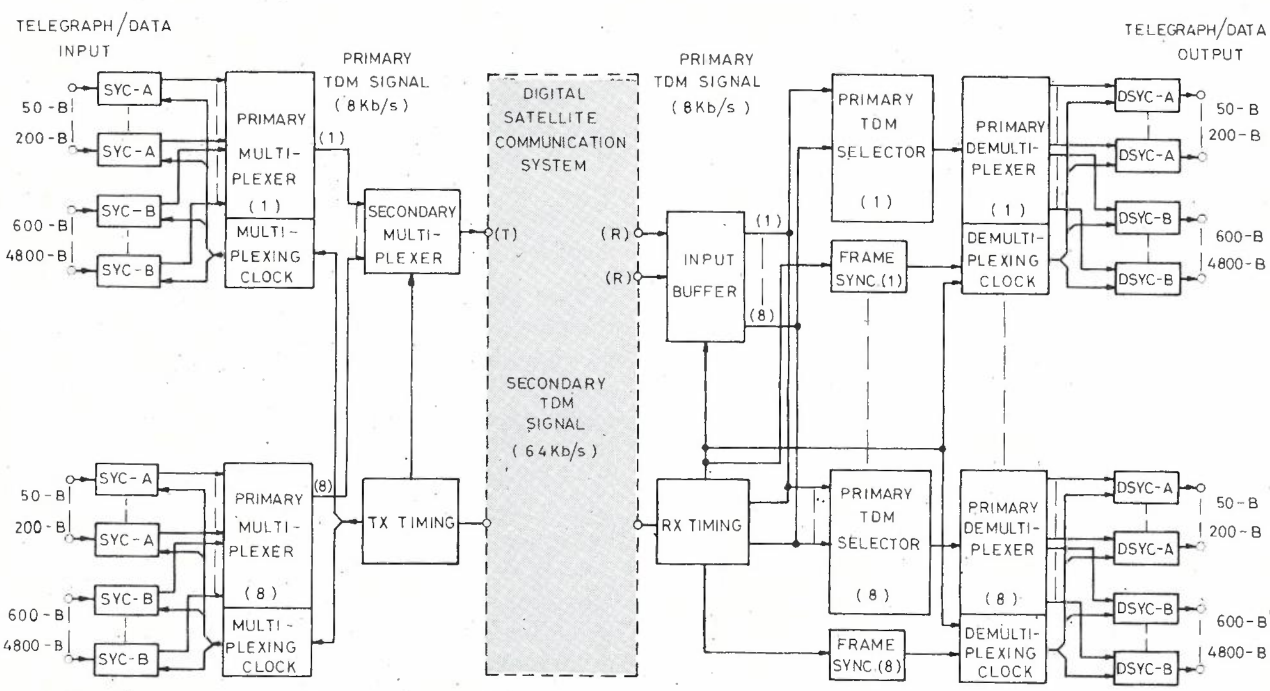
In providing telegraph and data equipment it is necessary to cater for sub-systems operating over a wide range of data rates, from 50 baud upward.

Generally, the full capacity of one or more telephone circuits will be assigned to the data services,



PW—Preamble Word.
IW—Information Word.
TX SCH—Transmit Satellite Channel.
AX TERM—Addressed Terminal.
AX TCH—Addressed Terrestrial Channel.
SIG (i)—The i-th signalling message unit.
SIGG(i)—1 = SIG(i)—2 = SIG(i)—3. Each signalling unit is transmitted three times consecutively.

Fig. 10—Format of DSI Assignment Signal.



SYC = Synchroniser, DSYC = Desynchroniser.

Fig. 11—Block Diagram of the Experimental Data TDM Equipment, Large Capacity User.

and the data channels will be multiplexed and integrated within the satellite link.

Two system applications looked at are:
- Large user with 50 — 4800 baud peripherals
- Small user with light traffic

Fig. 11 is a block diagram of a multi-data large user terminal (Ref. 15). In this system, the first multiplexing stage has an output of 8 kbit/s, formatted into frames of 42 ms length of 336 bits each. Two bits (samples) at intervals of 21 ms are enough to convey the information carried by a 50 baud telegraph circuit. Thus a 50 baud circuit occupies two bits in a frame at intervals of 168 bits. A 200 baud circuit occupies 8 bits of the frame at intervals of 42 bits, etc. Eight stages of primary multiplexing are multiplexed again to form a 64 kbit/s channel.

Fig. 12 shows the frame format of a different telegraph TDMA system (Ref. 16). A transmission rate of 128 kbit/s was chosen, which can easily be multiplexed over two channels in the SPADE system. It can also be switched through any TDMA system.

A frame of 293 ms length comprises 60 data bursts plus one reference burst. Each terminal is assigned to transmit at least one data burst of 4.806 ms. 4.3 ms of the burst or 552 bits, are allocated for the data circuits and 65 bits are assigned to the preamble. The 552 bits are divided into 184 time slots.

The data transmission shown in the figure is performed in the character mode. A 50 or 75 baud character in CCITT Alphabet No. 2 requires 5 bits and together with 1 signalling bit, each character occupies two time slots. Two 50 baud characters are transmitted consecutively and thus the burst capacity is 41 telegraph or data channels. The other data speed channels are similarly arranged. A 75 baud channel occupies six consecutive time slots and carries three consecutive characters. A 110 baud channel occupies nine time slots, also with three characters, but each one now requires 8 bits in accordance with International Alphabet No. 5. At the highest speed the burst capacity is only 20 channels.

A guard time of 5 bits is provided between the bursts and accurate synchronisation is essential.

CONCLUSIONS

Demand assignment systems seem to be very attractive, offer some traffic improvement and might

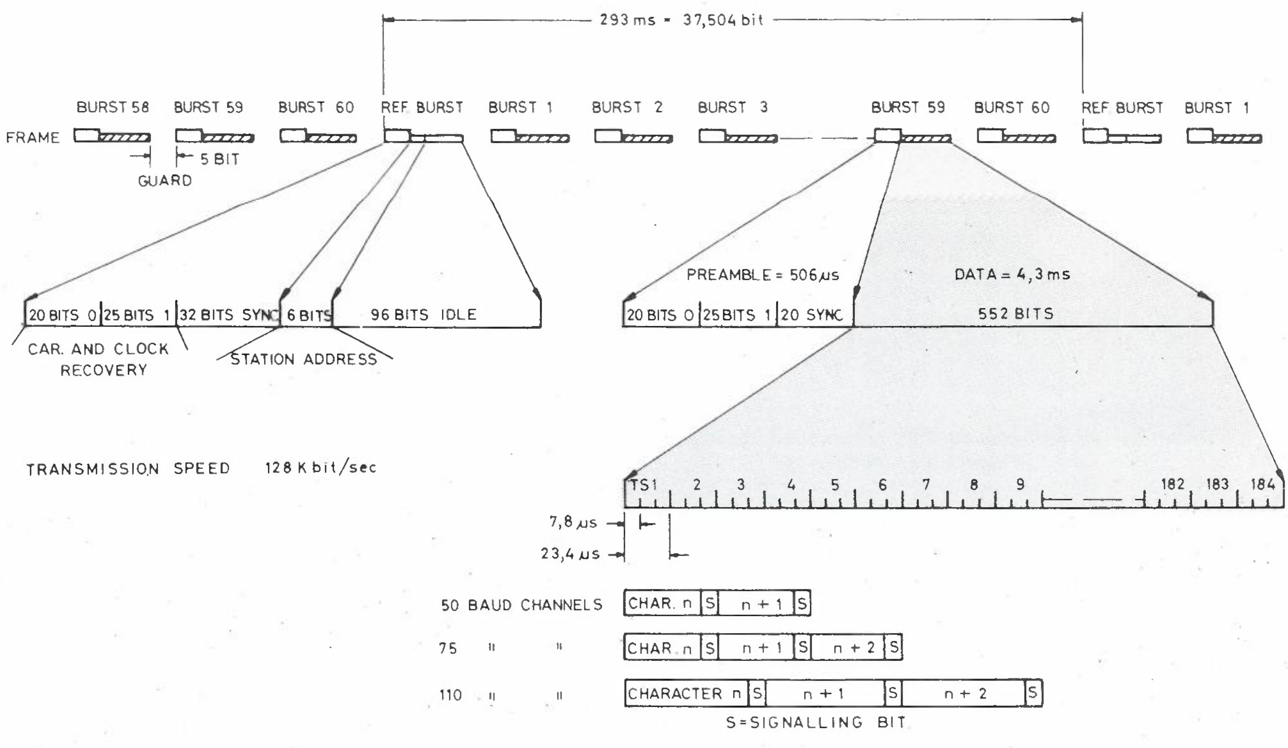


Fig. 12—Frame and Burst Format, Data TDMA System, Small Capacity User.

be implemented with time division and digital techniques when technical and economic difficulties are overcome.

A number of applications at present are chiefly practical for space communications systems. It is possible, however, like many other techniques developed for space projects, that parts and methods used in satellite Demand Assignment systems will find terrestrial applications.

REFERENCES

1. Hashimoto, M. et al: "An Application of the Digital Speech Interpolation Technique to a PCM-TDMA Demand Assignment System'; Colloque International L'Espace et la Communication, Paris, 29 March - 2 April, 1971, pp 676-685.
2. CCITT Com. XI, No. 29-E, 'Demand Assignment — A Method for Direct Access in Satellite Communication Systems'; January, 1970.
3. CCITT Com. XI, No. 27-E, 'Descripion of SPADE'; January, 1970.
4. CCITT Com. XI, No. 26-E, 'Interworking of Signalling System Nos. 5 and 6 with Communications Satellite systems', January, 1970.
5. CCITT Green Book, Vol. VI-1 Rec. Q.48; December, 1972.
6. CCITT Com. XI No. 28-E, 'Signalling and Switching in the SPADE DAS'; January, 1970.
7. Intelsat contribution, Addendum No. 5 to ICSC No. 39 — 31E, Interim Communication Satellite Committee.
8. Withers, D. J. and Jeffries, A. K.: 'A Time Division Multiple Access System for Intelsat'; AIAA Communication Satellite Systems, 4th Conference, 1972. Paper No. 72 — 538.
9. CCITT Com. XI, No. 50-E 'Time Division Multiple Access Satellite Systems', January, 1971.
10. Bachman, E.: 'Application of Digital Techniques in Satellite Communications', Radio Research Board Symposium, Satellite Communications for Australia, Melbourne, 1974.
11. CCITT Com. XI No. 85-E: 'Considerations Concerning the Interworking of the CCITT Signalling Systems and Demand Assignment Satellite Signalling Systems'; September, 1971.
12. Schmidt, W. G.: 'The Application of TDMA to the Intelsat IV Satellite Series'. Comsat Technical Review, Vol. 3, No. 2, Fall 1973, pp. 257-275.
13. Schmidt, W. G., et al.: Mat-1 Intelstat's Experimental 700 Channel TDMA/DA Systems', International Conference on Digital Satellite Communication, Intelsat/IEE, Nov. 1969, IEE Proceeding No. 59, pp. 428-440.
14. Poreti, I et. al.: 'Speech Interpolation Systems and Their Applications in TDM/TDMA Systems', Coloque International-Telecommunication Numeriques per Satellites, Paris 1972, pp. 348-357.
15. Maruyama, T. and Sasaki, H.: 'A Time-Division Multiplexing System for Telegraph and Date with Multiple-Access Capability', ibid. pp. 374-383.
16. Bernasconi, G. and Petrini, R.: 'TDM/TDMA Telegraph Multiplex Equipment', ibid, pp. 366-371.
17. Bullington, K. and Fraser, J. M.: 'Engineering Aspects of TASI' BSTJ Vol. 38, No. 2, March 1959, pp. 353-364.

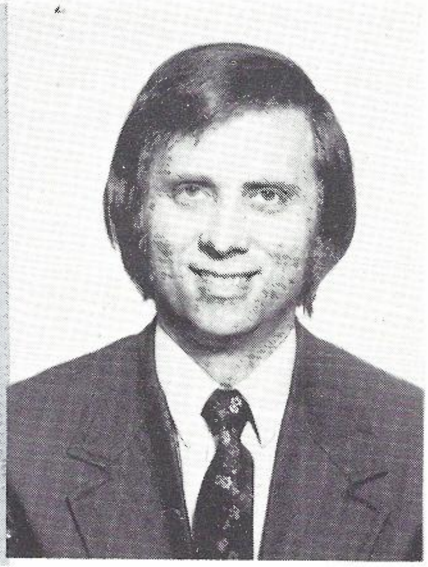
APPENDIX

GLOSSARY OF ABBREVIATIONS

CCITT — The International Telegraph and Telephone Consultative Committee.
CSC — Common Signalling Channel.
CSCS — CSC Synchroniser.
CT — Transit Centre.
CU — Channel Unit.
DA — Demand Assignment.
DAS — DA System.
DASS — DA Switching and Signalling.
DSI — Digital Speech Interpolation.
FDMA — Frequency Division Multiple Access.
PA—Pre-Assignment.
PCM — Pulse Code Modulation.
SPADE — Single Carrier per Channel, PCM, Multiple Access, Demand Assignment Equipment.
SSP — Switching and Signalling Processor.
TDM—Time Division Multiplex.
TDMA — Time Division Multiple Access.
TIU — Terrestrial Interface Unit.

A. EVEN–CHAIM received the B.Sc (Electronics) from the Technion, Israel Institute of Technology, in 1962. In 1966, after several years of engineering practice in private industry, he joined the Israeli Ministry of Telecommunications, Central Office, where he was active in systems and network planning. In 1967 he was awarded a four-month ITU fellowship to study the subject of "Earth Stations for Satellite Communications" including consultations with administrations and manufacturers in Europe.

Since 1970 he has been with the Australian Post Office, Research Laboratories, Switching and Signalling Branch, studying the various technical and economic aspects involved with the IST (Integrated Switching and Transmission) network applications.



An Historical Survey of Communications Satellite Systems — Part 3

M. BALDERSTON, B.S.E.E., M.S.E.E., M.I.E.E.E., M.A.C.M.

The first two parts of this Survey covered the past history and most of the present status of communications satellites. In this the concluding part, the present and future of US domestic, European regional, and Japanese domestic systems are discussed, and mention is made of several other systems planned or under consideration. Two topics of great importance for communications satellite systems, the choice of operating frequencies and the available rockets for launching the satellites, are also discussed. In both cases, however, an extensive treatment was not attempted since this would be beyond the scope of this paper.

The concluding section examines current trends in satellite system technology and applications, and assesses the significance of these trends and current trends of communications systems in general.

U.S. DOMESTIC SYSTEMS

In September 1965 the American Broadcasting Company applied to the US Federal Communications Commission (FCC) for permission to build, launch, and use a domestic TV distribution satellite. This application re-opened all the questions which had been raised in the Comsat debates three years earlier, and introduced some new ones. For example:

- Should any private company be granted operating rights in a domestic satellite system?
- Should a TV network be permitted to carry its own signals and thus go into competition with or take traffic away from the common carriers, chiefly AT & T?
- Would not a satellite system offer an excellent chance to establish a government TV network, or at least a national educational TV system?

The ABC application was shortly followed by others. One was from the Ford Foundation, a non-profit organization which proposed a system whose profits would be used to support educational television. Another was from Comsat, which proposed that it be permitted to establish and temporarily operate a pilot domestic system. The rationale behind this proposal was that it would allow an early start on a domestic system and the decision on the ultimate ownership and operation of the system could be made more deliberately. It was felt that this in fact if not in theory would give Comsat or whatever organization initially operated the system a great advantage, and so President Johnson appointed a commission to study the whole question. The FCC therefore suspended all action until the commission made its report. The report was submitted in December 1968, recommending approval of Comsat's proposal. The FCC re- opened the satellite hearings, and was about to approve the pilot program. However, a new Administration had taken office, and it requested that approval be delayed until President Nixon's staff could study the matter and submit new recommendations. In January 1970 the White House Office of Telecommunications Policy (OTP) officially urged the FCC to approve *any* "financially and technically qualified" application, in other words, an "open entry" policy rather than the single pilot program recommended by the previous Administration. Accordingly, the FCC invited domestic satellite proposals from all interested parties.

By June 1972, eight proposals plus comments and counterclaims from 22 other organizations had been received. The characteristics of the eight systems are summarized in Table 3. A wide variety of services were to be offered in addition to telephone trunks. For example, RCA proposed to offer:

- Receive-only and transmit/receive stations for commercial TV.
- Small to medium stations to serve as CATV heads.
- Two transponders reserved for educational TV.
- Two transponders and an eventual 250 small stations for TV in remote sections of Alaska.
- One transponder reserved for closed-circuit TV.
- Stereo audio channels piggyback with TV for National Public Radio.
- A secure voice transmission service for the US government.

TABLE 3—SUMMARY OF U.S. DOMESTIC SATELLITE PROPOSALS AT JUNE 1972

	Western Union	Hughes/ GT & E	AT & T/ Comsat	Comsat	Fairchild	Western Telecom.	RCA	MCI/ Lockheed
Spacecraft								
Type	A	A	B	B	C	D	E	F
Number active	2	2	2	2	1	2	2	1
In-orbit spare	1	—	1	1	1	—	1	1
***Earth Stations**								
Receive only	6(10 m)	7(11 m)	—	1(13 m)	—	2(9 m)	—	—
Xmit/Rcv	7(14 m)	6(30 m)	5(30 m)	4(30 m)	6(30 m)	4 (18 m)	2(30 m) 1(18 m) 10(11 m)	20(10 m)
System Cost ($US Million)	95	110+	98+	248	211	68	198	229

Spacecraft Types:
A. Modified HS-333 (Anik)
B. Modified Intelsat IV
C. Modified ATS-F
D. Similar to HS-333 but with extendable "skirt" solar array.
E. Not decided at time of proposal.
F. Large 3-axis stabilized with unfurlable oriented solar panels.

***Entry gives number proposed with antenna diameter in parenthesis.**

At that time the FCC handed down an interim decision, which basically allowed open entry but which severely restricted AT & T and Comsat: AT & T was prohibited from providing any private services, in particular cable TV; and Comsat was to choose between either providing the space segment for AT & T (but no one else) or establishing their own complete system which would make them a common carrier. After hearing appeals and more counterclaims, the FCC modified this slightly, and then began considering individual applications. The situation at the end of 1974 can best be described by treating each of the proposals listed in Tabie 3 separately.

Western Union Telegraph Company

Western Union received permission to proceed at their own risk before FCC approval was granted. In August 1972 a $US 21 million order was placed with Hughes Aircraft for three near-duplicates of the Canadian Anik, the only change being an adjustment of the antenna pattern to cover the US rather than Canada. The reason for proceeding without approval was to avoid a shutdown and subsequent restarting of assembly lines of some spacecraft subcontractors, which would have greatly increased the cost of the three satellites. The first of these satellites, named Westar, was launched in April 1974, and Westar-2 was launched in October. The system is now in operation using five of the originally proposed seven large earth stations, and in addition satellite capacity is being leased to others (see below).

(Hughes Aircraft Co.) National Satellite Service Inc./ GTE Satellite Corp.

Approval was given for the Hughes subsidiary to launch up to three satellites, lease capacity to the General Telephone and Electronics subsidiary (a smaller rival of AT & T for local telephone services), and use spare capacity to develop service to local cable TV systems. However, after suits and countersuits between AT & T and GTE, an agreement was reached whereby GTE would share satellite capacity with AT & T (see below) thus avoiding some duplication of facilities and sources. Left without its main customer, the Hughes subsidiary suspended its plans and is apparently awaiting further developments.

AT & T/Comsat

This system was also approved. AT & T is building four earth stations, and Comsat has contracted with Hughes Aircraft for four satellites for $US 65.9 million. The satellites will be modifications of the Intelsat IV-A. As noted above, use of the satellites will be divided between AT & T and GTE, the latter with three earth stations. Operation in late 1975 or early 1976 is planned. The services will be strictly long-haul trunk traffic, in the case of AT & T as backup for their terrestrial network, and in the case of GTE providing a long-haul capacity without the large expense of a terrestrial network.

Comsat, MCI, and Lockheed

In a move to avoid the necessity of choosing between serving AT & T (and being cut out of non-telephone applications) and acting as a common carrier (but losing AT & T's business), Comsat joined with two other domestic satellite applicants who had previously submitted a joint proposal. The result, CML Satellite Corp., would allow Comsat to serve AT & T and still partake of the non-telephone services through the new company. This plan was approved, but in the meanwhile MCI and Lockheed both withdrew because of financial considerations. Since Comsat was restricted to minority interest by the terms of the approval, another partner was sought. The new partner turned out to be International Business Machines (IBM). The FCC has not approved the new partnership at the time of this writing, and CML's technical proposals are still in a preliminary stage.

Fairchild Industries

Fairchild's original proposal featured satellites with several advanced features: 120 transponders, multiple spot beams, use of 7 and 12 GHz frequencies in addition to 4 and 6 GHz, and attitude control system and structure based on ATS-F. Faced with the difficulty of getting enough traffic to fill even one such satellite, the company dropped its original application. In conjunction with Western Union International, it formed a new company, the American Satellite Corporation (ASC). After several changes of plans, ASC leased two transponders on the Westar I satellite and began service using three earth stations plus some terrestrial facilities in mid-1974. The company expects to have its own satellite eventually, perhaps as early as 1977.

Western Telecommunications Inc.

WTCI requested that the FCC defer action on its original proposal, and has not made any further application.

RCA Global Communications Inc.

Although Western Union was the first company with its own spacecraft, RCA Globcom was the first of the domestic satellite applicants to begin service. RCA's only change to its original proposal was to lease capacity from Telesat on the Anik Satellite for an early phase of operation. This was approved by the FCC, but what allowed RCA to begin service was FCC approval in early December 1973 for the sale of an Intelsat earth station at Bartlett, Alaska, to RCA Alascom. This station had previously been carrying telephone traffic between the contiguous states and Alaska with capacity leased from Intelsat. On December 20 the transfer took place, on December 21 the antenna was redirected to Anik 2, and on January 8, 1974, commercial service began, In the meantime, RCA had contracted for an uprated version of the Delta booster and for three 24-transponder body-stabilized satellities, for launch in late 1975.

In summary, at the end of 1974 three US domestic satellite systems were in operation (Western Union, ASC, and RCA). Two more were proceeding to the start of operations (AT & T and GTE), while another (CML) was trying to get FCC approval.

The decision by the Nixon Administration to make the domestic satellite field a competitive private enterprise endeavour, and provide no government support, puts a great deal of economic pressure on any applicant. Because of the large initial investment in satellites and launch vehicles, any satellite system must be loaded very quickly if it is to be economic. In the U.S. the only sure source of large volumes of traffic is AT & T. It was the prospect of no traffic from AT & T which caused Fairchild to drop the 120-transponder satellite, and MCI-Lockheed to drop their 48-transponder design. The attitude of AT & T towards satellites is thus of some interest.

It will be remembered that it was AT & T which built the first communications satellite, Telstar. In 1966, a proposal for a satellite system was prepared. It involved two phases; first a number of spin-stabilized satellites using the 4/6 GHz bands were to be launched starting in 1968. These were to carry both telephone traffic and TV signals for cable TV inputs. As the satellites reached the end of their life, they would be gradually replaced with much larger spacecraft operating at both 4/6 GHz and 18/30 GHz. The receive-only TV earth stations would remain throughout the period considered in the proposal (1990) and would continue to use the 4/6 GHz bands. The telephony earth stations of the initial phase, also 4/6 GHz, would be replaced with diversity pairs* of 18/30 GHz stations as the traffic increased in the second phase of the system. In spite of their present activity, using 4/6 GHz capacity provided by Comsat, AT & T still feels the earlier plan is valid. The earlier system will add some flexibility and backup to the existing Bell System telephone network although AT & T feels that the cost will be greater than terrestrial facilities providing the same capability. Only the advanced technology and sevenfold bandwidth increase of the 18/30 GHz system offers the promise of a lower per-circuit cost for a satellite system compared with terrestrial facilities.

In view of AT & T's attitude, it is not surprising that most of the hopes of the US domestic systems for profitability are based on cable TV and other broadband services. However, the restriction to

*As discussed below, a major problem with frequencies above 10 GHz is signal attenuation by rain. Most cells of heavy rain are limited in extent, so that, when it is pouring at one location, at another only a few kilometres away it may be only drizzling or not raining at all. The use of pairs of stations separated by 10 or 20 km, and switching traffic between them as required, is one way to overcome the effects of rain attenuation on the system.

private enterprise effectively eliminates any chance for national educational TV or any other public service, at present.

THE EUROPEAN REGIONAL SYSTEM

In 1964, ten countries founded the European Space Research Organization (ESRO) to exploit space technology for scientific investigations. The terms of reference were later broadened to include applications. In 1974 ESRO combined with the remnants of the European Launcher Development Organization to become the European Space Agency (ESA). To give focus to the efforts of ESRO and ESA, one of the major applications programs is the development by 1980 of a regional communications satellite system.

Europe already has an extensive terrestrial telecommunications network, and most European countries also have Intelsat earth stations. The desire to develop expertise and technology in communications systems and satellites rather than any real inherent need is thus the main reason for this satellite system. This explains the slow pace of the program and also many of the technical features.

Several *a priori* assumptions were made about the system constraints and the nature of the services to be offered. The choice of operating frequencies, 11/14 GHz, resulted from the extensive use of 4/6 GHz by terrestrial services, the fact that 4/6 GHz technology was well in hand and thus offered little chance for advancing the state of the art, and the feeling on the other hand that 18/30 GHz would probably be too advanced. Satellite telephone channel capacity was derived from 1980-1990 traffic forecasts, the assumption that satellite circuits would be economic between centres more than 800 km apart, and the assumption that the satellite system would carry a third to a half of such traffic. The only other service would be television distribution for the European Broadcasting Union, requiring a maximum of two colour TV channels.

The earth station network will consist of telephony stations near Hamburg, Milan, and Barcelona; TV stations in the Canary Islands and near Rabat, Algiers, Tunis, Tripoli, Tel Aviv, Beirut, and Nicosia; and combined stations near 21 other cities, mostly capitals. Each station will have one or two 18 metre antennas, cryogenically cooled receivers and 2 kW transmitters. The number of antennas will depend on the eventual number of spacecraft and on the traffic distribution.

The satellite configuration is not yet certain. One possibility is a large satellite, about the size of Intelsat IV and using an Atlas-Centaur or Ariane launch vehicle. In order to achieve the desired capacity, frequency re-use by polarization discrimination would be required. This alternative would mean that any earth station would require only one antenna. The second alternative is a spacecraft about half the size of the first, allowing use of a Delta-class booster. Frequency re-use would be by orbital spacing of two satellites, and therefore at least some of the earth stations would require two antennas. However, in spite of the fact that more launches would be required, this alternative would cost less for the space segment than the first, and it has the additional advantage of allowing a "soft start". Only one of these smaller spacecraft would be needed at first, and the additional earth station antennas (which might be required at only some of the stations, with a suitable distribution of the traffic) would only be required when the traffic had increased enough to require a second satellite.

The final stage of the study and development program leading to an operational system will be the launching, in early 1977, of an Orbital Test Satellite (OTS). OTS will be built by a consortium led by Hawker Siddeley Dynamics. This three-axis-stabilized spacecraft will have a final in-orbit mass of about 360 kg, and will provide two transponders operating in the 11/14 GHz bands. Both transponders will receive via a 7.5° x 4.2° "Eurobeam". One transponder, with a bandwidth of 40 MHz, will transmit through the Eurobeam. The second will have a bandwidth of 120 MHz and will transmit through a 2.5° x 2.5° spot beam. Provision will be made to reorient the spot beam with respect to the Eurobeam over a ±3° range. Two of the goals for the OTS are experimental validation of the system design concepts, in particular the margin for rain attenuation, and pre-operational experience with a regional system. The design life is three years, at the end of which time the operational system should have been implemented.

THE JAPANESE DOMESTIC SATELLITE SYSTEM

One aspect of Japan's postwar economic growth has been a great increase in telecommunications requirements, both internal and international. Japan is now the third-largest user of Intelsat (after the US and UK) and has one of the world's densest concentrations of terrestrial communication facilities. The reasons for considering a domestic satellite system (or, more properly, systems, since it appears separate systems will be provided for different services) are of some interest.

Japan lies on the Pacific "Ring of Fire" and is subject to frequent earthquakes. Typhoons are another constant natural hazard. Satellite facilities could provide alternate routing for links passing through affected areas, and could also be used to provide emergency communications to the affected areas until terrestrial links were restored. This quick reaction capability would also be of use for short-term high demand traffic such as was experienced during Expo-70. The growth of internal traffic is already putting a strain on the available frequency spectrum, and in fact it appears that terrestrial facilities alone will not be able to handle the projected 1985 traffic. A further consideration is the increasing traffic between the main islands and outlying ones such as Okinawa.

One system under consideration is a television broadcast service. The satellite would transmit colour TV to augmented receivers such as those used in the ATS-6 demonstrations, except that the downlink will be at 12 GHz, allowing the receivers to be used in urban areas. The system would provide relief for terrestrial facilities through the use of a single transmitter (the satellite) and augmented community receivers, and it could also be used for a similar service for nearby countries such as the Philippines, Korea, etc. A development contract for an experimental broadcast satellite, approximately 330 kg and providing two active and one standby transponders, has been awarded to the team of Toshiba in Japan and General Electric in the US.

A similar development contract for an experimental telecommunications satellite was awarded to Mitsubishi and Philco-Ford. This spacecraft will also be about 330 kg, but unlike the three-axis stabilized broadcast satellite, it will be spin-stabilized. It will provide two transponders operating at 4/6 GHz and four at 18/30 GHz. All will provide much lower output power than the broadcast satellite.

The greatest problem with the use of the higher frequencies is signal attenuation by rainfall. The usual methods of accommodating this problem are to add a design margin to system characteristics (for example, make the earth station antennas 50% larger than necessary for clear-sky operation), to use station diversity, or both. The Japanese system will use the different transponders to provide frequency diversity: the main islands will normally use the 18/30 GHz transponders, but in case of heavy rainfall will switch to the 4/6 GHz transponders. The latter will normally be used to provide coverage to outer islands where interference with the terrestrial network at 4/6 GHz is much less likely. Both experimental satellites are scheduled for launch in early 1977.

OTHER DOMESTIC AND REGIONAL SYSTEMS

In response to ever-growing communications needs throughout the world, and as the usefulness and reliability of satellite systems are demonstrated, more and more countries are considering implementing domestic or regional satellite systems. Some of these are as follows.

Algeria has contracted to lease an entire transponder from Intelsat for domestic use. The large earth station near Algiers will link the domestic system with the Intelsat network, and will also transmit domestic television. Thirteen smaller earth stations (12 metre antennas) located throughout the country will receive TV and provide two-way telephone and telegraph service. A system capacity of one TV and 130 voice channels is expected to be operational in 1975.

Brazil was to have used ATS-G for educational television. With the cancelling of that satellite, alternatives are under consideration. One is to lease Intelsat capacity, and approval has been given for this by Intelsat. In the longer run, a national satellite seems fairly certain.

The Federal Republic of Germany has been studying the use of a broadcast satellite to provide 3 to 5 TV channels. By using the newly allocated frequency bands above 10 GHz, this would avoid problems with terrestrial relays and frequency assignments.

India will use ATS-6 for a year to demonstrate the use of satellites for educational TV. Eventually a domestic satellite system is likely.

Indonesia is now building a domestic system. The satellite will probably be similar to Anik and Westar, and at least 25 earth stations, each with 10 metre antennas, are to be operational during 1975. It is possible that Indonesia will also lease Intelsat capacity until its own satellite is launched.

Iran's domestic system is now in an advanced planning stage, although as of this writing no hardware contracts have been let.

The League of Arab States finance, education, and telecommunications ministers have agreed on the establishment of a regional satellite system, and three proposals for a complete system contract are under consideration.

Malaysia is also planning to lease capacity from Intelsat, but may switch to the Indonesian satellite when it is launched.

Norway's concern is communications with oil rigs in the North Sea. It is planned to lease capacity from Intelsat, and provide each rig with a 10 metre antenna.

The Philippines are studying the use of Intelsat or Indonesian satellite capacity.

Saudi Arabia, under a rush order contract, built two small earth stations to provide television coverage of the 1974 pilgrimage to Mecca to other Moslem countries, via Intelsat. These are to be replaced by large (30 metre antenna) stations in 1975, and the small terminals will then be moved to other locations for internal communications, using Intelsat at first and later the Arab League satellite.

OPERATING FREQUENCIES

Early satellite communications experiments were made at a variety of frequencies. Telstar established the standard for operational systems, using the 4 and 6 GHz frequencies then in use with some terrestrial microwave systems. The lower frequency was used for the space-to-earth "downlink", the higher for the "uplink", and it has become common practice to refer to the pair of bands: 4/6 GHz (although sometimes the order downlink/uplink is reversed, and reference is then 6/4 GHz).

The International Telecommunications Union (ITU) held an Extraordinary Administrative Radio Conference in Geneva in 1963, which allocated frequency bands below 10 GHz to be shared between satellite and terrestrial systems, and also formulated procedures for coordination to minimize mutual interference. The trend towards the use of frequencies above 10 GHz by both types of systems, and the desire to have some bands set aside for the exclusive use of satellites, led to the World Administrative Radio Conference for Space Telecommunications (WARC-ST) by the ITU in 1971. The WARC-ST formulated frequency allocations up to 275 GHz, to cover projected needs for the next ten to twenty years. Operating restrictions(specifically on radiated power levels) for the various services were also agreed upon, as were refinements of the co-ordination procedures set up in 1963.

Up to now only the 4/6 GHz and 7.5/8 GHz bands, for commercial and military use, respectively, have seen any significant use in satellites outside of Russia. In the Orbita network, the Molniya I satellites used frequencies between 800 and 1000 MHz, but the Molniya II now being introduced uses the 4/6 GHz bands. The 18/30 GHz bands are likely for a Japanese system and possible for a second or third phase US system. ESA is the only group planning to use 11/14 GHz for the fixed-satellite service although Intelsat, the CML Satellite Corporation and others have these bands under consideration. The 12 GHz broadcast band is being considered by several organizations: the Canadian/NASA Communications Technology Satellite (CTS), the Japanese broadcast satellite, and Germany. The frequencies around 2.5 GHz are the subject of some of the ATS-6 experiments, and have been suggested in satellite proposals to several developing countries. The restricted bandwidth and the heavy use of these frequencies for terrestrial services in the advanced countries (US, Japan, Europe, Canada) limits their usefulness in such cases. However, technology is well advanced so there would be no trouble implementing a 2.5 GHz system in an undeveloped country or one in which there are few terrestrial users in this band.

LAUNCH VEHICLES

No discussion of satellite systems would be complete without some mention of the launch vehicles ("rockets", "boosters", etc.) which make them possible. And in fact, the history of rockets goes back further than even the concept of satellites. The Chinese used gunpowder to propel the first skyrocket sometime before the 12th century. This would be classified as a solid-propellant rocket, and versions using more advanced fuels are still in use today, both as complete launch vehicles and for augmentation of liquid-propellant boosters as "strap-ons".

It has been known for some time that other propellants besides gunpowder could be used for rockets, and that several liquid fuels would give greater combustion efficiency, but it was not until 1926 that the first liquid-fuelled rocket was flown, by Dr. Robert H. Goddard. Goddard's work was hindered by unenthusiastic support by the US government. The German government, in contrast, recognized the military potentials of rocket engines and sponsored development work which led to the V-2 rocket. It was the success of the V-2 more than any other single factor which led to the development of guided and ballistic missiles and to the launching of artificial satellites by Russia, the US, and other countries.

At the end of World War II, the Russians captured most of the factories and equipment used for the V-2. However, most of the engineers involved with its development chose to surrender to the Americans instead. Factories and equipment were shipped east, engineers were shipped west, and the US and USSR both ended up with missiles which at first were merely refinements of the V-2 design.

In the case of both countries, the launch vehicles for most satellites were originally developed as missiles. The only exception was the American Vanguard which perhaps significantly had only three successful launches in ten attempts. The well-publicized failures in the Vanguard program have created a permanent public impression of launch vehicle unreliability, which is certainly not borne out by, for example, the Delta launcher's 94 successes in 104 attempts, or by the record of the Saturn boosters which have had *no* vehicle failures.

The boosters available today and in the near future range in size from the all-solid US Scout and Japanese Lambda and Mu with payload capacities of a few hundred kilograms to low orbit, through intermediate vehicles such as the US Atlas-Centaur and the European Ariane now under development which can carry about 1.5 tonnes to geosynchronous altitude, to the Saturn 5 which can take about 50 tonnes to the moon. To limit the discussion, only launch vehicles which might conceivably be used for an Australian communications satellite will be described.

Delta

This booster is called "NASA's workhorse". Up to the end of 1974 there had been only ten failures in 104 launches. The first payload, in 1960, was the Echo, which had a mass of just over 60 kg. The capacity of this early version was only about 100 kg to a low orbit. Over the years the vehicle has been continuously improved: in 1963 the capacity was 100 kg to synchronous altitude, by 1966 over 300 kg, and by 1968 over 500 kg. There are several versions now available offering capacity up to 700 kg in synchronous transfer orbit. A version being developed primarily for the RCA domestic satellite will increase this to nearly a tonne. It should be noted that these payloads are *not* the final spacecraft mass. The kick motor which inserts the spacecraft into stationary orbit is considered part of the payload, so the in-orbit mass of the satellite is about half that given. Except for very high-capacity satellites such as the Intelsat IV, -IV-A, and -V, and AT & T's domestic satellite, most studies have shown the Delta to be the most cost-effective launch vehicle of those available.

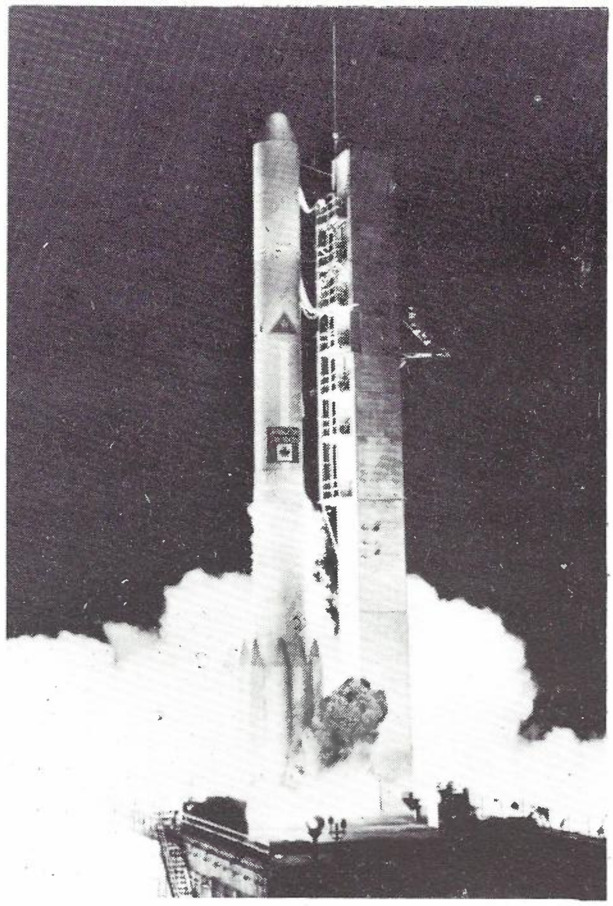


Fig. 6—Delta Number 92, 10 November 1972, put the Canadian Domestic Satellite Anik-1 into Orbit.

Atlas-Centaur

The Atlas was the first US intercontinental ballistic missile (ICBM). When "better" ICBM's became available, the Atlas was used as a satellite launch vehicle. The Centaur upper stage involved several advances over all previous rockets: It used liquid hydrogen for fuel, and it was both throttleable (that is, its thrust level could be varied) and restartable. Three years of flight testing used only dummy payloads. Then, starting in 1966, it was used to launch the Surveyor series of unmanned lunar landers. The first use for a communications satellite was the unsuccessful launch of ATS-4 in 1968. Overall there have been five failures in over 30 launches, but two of the failures were in the test program. Unlike the Delta, the initial payload capacity of nearly 1.5 tonne to synchronous altitude has not increased greatly. The Atlas-Centaur is currently used for the Intelsat IV. Future payloads will include the Intelsat IV-A and the AT & T domestic satellite.

The Japanese "N" Vehicle

Under a 1969 agreement with the US, Mitsubishi has been licensed to manufacture a version of the Thor first stage of the Delta. The National Space Development Agency has also obtained permission to build the Delta second stage, and plans to add a third stage of Japanese design to make up the "N" rocket.

The first flight is planned for 1975 or 1976. Payload capacity will be about 250 kg to synchronous altitude. The large difference between the capacity of the "N" and the Delta on which it is based is because the earlier version of the Thor which will be used is restricted to three strap-ons, while the version used in recent Deltas can use up to nine.

The European "Ariane"

Several European countries have developed small launch vehicles, but for moderate and large size synchronous orbit spacecraft they have to depend on the US Delta and Atlas-Centaur. This has caused no problem in the past but the US refuses to guarantee launch opportunities. Such refusal could become significant in case the European satellite would be a commercial competitor to a US system (the planned maritime communications satellite is regarded as such.) Thus, the reluctance to throw away the expertise gained with the unsuccessful Europa 3 booster, and the desire for regional capability has led ESA to make development of the Ariane one of its major projects. Payload capacity is to be 700 to 800 kg in geostationary orbit, or about the same as the Atlas-Centaur. First launch is scheduled for early 1979.

One further booster must be mentioned although it is unlikely it will be used for any communications satellite for some time. This is the Space Shuttle being developed by NASA. Until now all launch vehicles have been used only once; usually the boosters disintegrate or burn up in the earth's atmosphere after separation from the payload. When NASA was planning a manned space station it was obvious that this wasteful process could not continue, and the concept of a re-usable booster was introduced. When the space station was shelved, the re-usuable booster, now called the Shuttle, was retained since its benefits could apply to any satellite.

However, the Shuttle has a serious problem when used to launch communications satellites. Since it was intended to service a manned station, it can only carry its 30 tonne payload to a low altitude (about 200 km). Satellites destined for a higher orbit would require a Space Tug. This would provide the same sort of capability as the Shuttle, but instead of transfer from earth to low orbit, the transfer would be from the low Shuttle orbit to the desired one. For communications satellites, this would mean carrying the satellite from the Shuttle to synchronous altitude, injecting it into geostationary orbit, perhaps retrieving an old satellite, and then returning to the Shuttle. Present plans are for a interim expendable Tug which would consist of an upper stage or stages from an existing booster, such as Centaur or the Agena. The Shuttle is to become operational about 1980 (test flights will begin in 1978). The US Air Force hopes to have an expendable Tug by about the same time, but it will be at least 1983 before a reusable Tug is available.

PRESENT TRENDS

It is possible to discern several trends in the history of communications satellites presented here. Organizations with large traffic requirements are studying spacecraft with advanced features such as body stabilization, frequency re-use techniques, operation at frequencies above 10 GHz, etc. On the other hand the availability of a few basic spacecraft designs (e.g. Anik, Intelsat IV) has allowed smaller countries and organizations to consider establishing satellite systems at relatively low cost. For those willing to pay for satellite development, advances in spacecraft technology and in launch vehicle capacity permit a great increase in satellite capacity: compare the 12-transponder Anik designed in 1970 with the RCA 24-transponder domestic satellite of 1973. The political problems of satellite broadcasting have lessened with the increasing ability to limit coverage to a single country or part of a country, and designs for broadcast satellites are being considered in Canada, Japan, Germany, and elsewhere. Less developed countries such as Brazil, Iran, Indonesia, India, and some Arab states are now considering communications satellite systems. Some specific trends are listed below.

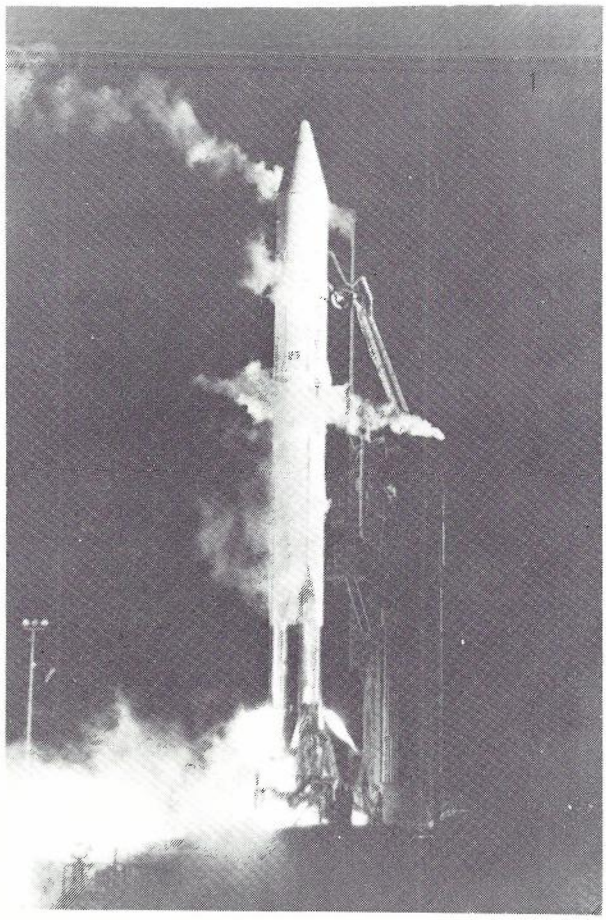


Fig. 7—Intelsat-IV (F2) was Launched by Atlas-Centaur Number 25 on 26 January 1971.

Launch Vehicles

Further increases in payload capacity of the US Delta, Atlas-Centaur, and Titan boosters are possible but the Space Shuttle could render them obsolete. The Shuttle will require a Space Tug, however, and will not be generally available until after 1980 in any case. Other launchers (Russian, European, and Japanese) may also become readily available.

Operating Frequencies

The move to higher frequencies is regarded as inevitable as greater demands are made on the RF spectrum. However, even in advanced countries such as the US, the move will not come as fast as earlier anticipated. The well-tried 4/6 GHz bands will continue to be used for the foreseeable future.

Satellite Capacity

Using present-day state-of-the-art technology, a Delta-launched satellite could be built which would carry up to 150,000 telephone channels. Whether a system using such a satellite would be more cost-effective than a much cheaper satellite system (such as the Canadian one, with a capacity of about 9000 channels per satellite) using existing well-proven hardware is open to question, especially for organizations with relatively low traffic requirements.

Satellite Stabilization

As with operating frequency, the move from spin to body stabilization is not proceeding as quickly as many authorities predicted. An increasing percentage of communications satellites will be body stabilized but the spinners will continue to be built, especially for smaller users.

Applications

In the past, communications satellites have been used largely for telephone trunk and television relay services between major centres. As the required earth station size decreases, services to smaller centres are becoming practical. In the limit this means telephony and TV for individual subscribers. Present satellite systems are being devoted increasingly to services such as cable TV, private line data, and conference TV. Several less developed countries and areas (Brazil, India, US areas, Pacific Basin) are considering using satellites for educational services. Other types of systems not usually considered as telecommunications are being implemented: maritime communications, aeronautical communications and navigation, meteorological and environmental data collection and distribution, and so forth.

The proliferation of satellite systems is only one aspect of the almost revolutionary changes occurring in the communications field in general. There is a mutual feedback effect, as the new services provide traffic for the satellite systems, and the satellite systems make easier the implementation of services which in many cases are difficult to incorporate into existing terrestrial networks. Three developments of particular interest for an Australian National Satellite System are as follows:

- *Digital Data.* Without going into its desirability, the intrusion of digital computers into more areas of people's lives seems certain. Communications between computers will make up an increasing percentage of any telecommunications network. At the same time, the use of digital techniques can make better use of facilities for telephony and TV: the huge telephone circuit capacity of a Delta-launched spacecraft mentioned above is largely the result of digital techniques, and Comsat's DITEC digital TV has been discussed. The wide bandwidth and low power of satellite systems as compared with terrestrial facilities are eminently suitable for digital signals.

- *Graphic and Printed Data.* Facsimile ("Fax") has been in wide use for some time for transmitting things like newspaper masters and weather maps. Several electronic versions are being implemented which use either a slightly modified TV receiver or a "black box" supplement to a standard TV set rather than the complex electro-mechanical Fax set. In all cases the receiver can still be used for ordinary TV. RCA's "Videovoice" uses a black box, and a standard voice circuit for transmission.

  The BBC's "Ceefax" transmits the written material in synchronization and blanking gaps of a standard TV signal; the program can be watched while several "pages" are transmitted, and then the pages can be selected at random and displayed on the TV screen. Similar systems are under development by the British Independent Broadcasting Authority, the US MITRE Corp., the Swedish Telecommunication Administration, and others. Rather mundane applications are usually proposed: a man at breakfast, after watching the early news on TV, punches a button and has displayed the previous day's stock exchange report, then his wife punches another button to see a list of sale items at the local supermarket. A more exciting and worthwhile application for Australia would be the possible improvement to the service of the School of the Air. Instructional TV in the form of lectures is fairly simple, but the combined requirement for two-way interactive communications and very low cost make a full video School of the Air a practical impossibility. However, an Outback station or mining camp which was already equipped to receive TV from a satellite could add a graphic and printed data facility very cheaply.

- *The Wired City.* This term is used to indicate a complete integrated range of audio and video telecommunication services, such as entertainment sound and TV, data services, and graphic displays, all interactive. The man and wife at breakfast mentioned above, if they were in a Wired City, would be able to call the stockbroker (by Picturephone) and discuss their portfolio, place an order at the supermarket, request a book from the library which could either be read from the display or be reproduced by a home copying machine, contact a large computer for help with the family budget, etc., etc., all from their terminal at home. Although several pilot Wired City systems exist today, their extensive use is probably quite a distance in the future. Their application to small, well-integrated new town designs, such as Shay Gap in the Pilbara, however, would be quite practical with a satellite system, and use in developing cities such as Albury-Wodonga should not be ruled out. Such applications are being studied by the National Telecommunications Plan (NTP) group within Telecomm. Australia.

CONCLUSION

We have followed the development of communications satellite systems from the original proposal almost 30 years ago, through early experiments; an Intelsat system which has consistently exceeded all growth estimates; a rather secretive Russian system; the Canadian system which will serve as an example to many other national systems as well as establishing one possible standard spacecraft design; a number of often-delayed American systems; a few other planned systems; to some future possibilities. It is evident that the increasing use of satellites to contribute to national and international communications is a certainty, and for countries such as Australia the only question is one of timing.

At the time of writing, M. BALDERSTON was Engineer Class 3 in the APO Research Laboratories, where he was conducting studies into Satellite Communication Systems. He has since returned to the USA.

See Vol. 25 No. 1, page 60.

The Detection of Smoke in Air-Conditioned and Ventilated Buildings

D. R. PACKHAM, L. GIBSON and M. LINTON

This paper introduces a new concept of 'early warning fire detection' for protecting air-conditioned or mechanically ventilated buildings by the use of ultra sensitive smoke detectors in return-air ducts. Some experiments have been done with a detector that can measure down to 0.01% m^{-1} smoke obscuration in such ducts. A first-approximation theory is proposed that should permit fire protection engineers to design appropriate installations, once smoke production rates of those materials most likely to be involved in a fire have been established, and the appropriate ignition time to 'alarm' assessed. A new approach to alarm levels is also presented, whereby a series of three alarms is used to deal with 'suspected' fires, 'incipient' fires, or 'active' fires. Some information is given about the normal smoke levels of three buildings (all telephone exchanges), smoke production rates of various materials, and the size of some incipient fires. A detector device being developed by the Commonwealth Scientific and Industrial Research Organization (Australia) and Australian Post Office is briefly described.

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INTRODUCTION

It has long been recognized by those interested in fire protection that existing means of early fire-warning by ionization detectors have severe limitations. Experience in a large number of telecommunication installations has shown that the efficiency of such detection systems is largely dependent on a number of factors which can limit the discovery of incipient fires. In fact, some fires have produced considerable visible smoke without being detected at all by an early warning alarm system.

This delay in smoke detection may also equal or exceed the escape-time available to occupants of high-rise buildings, or permit the development of a fire to the point where considerable damage is done — damage which could have been avoided if more effective means of detection had been available. Some factors that affect the operating efficiency of an early warning system are:

- The effect of forced ventilation, which sometimes prevents smoke reaching ceiling-mounted detectors;
- Complete or partial shielding of detectors by ceiling beams, equipment racks or overhead cabling; and
- The necessity to desensitize detector heads, in order to avoid false alarms arising from normal work situations, such as smoking.

It is clearly necessary to devise new and superior techniques for fire detection and control measures — the emphasis being on providing means of detecting the earliest traces of smoke from overheated equipment or from incipient fires.

One feature common to both types of building mentioned above is that each has, as part of the building services, a forced-air ventilation system or an air-conditioning system, with various supply and return-air ducts from each floor. These enter a common duct or plenum chamber, usually in the air-plant room. Modern air plants provide approximately four to 14 air changes per hour.

The desirability of sampling the air for smoke in the return-air stream has been recognized in the past, but no detection system has proved reliable enough to be of practical application; indeed, dire warnings have been issued to anyone unwise enough to attempt this attractive but difficult task — see Ref. 1.

THE THEORY OF SMOKE DETECTION

The theory proposed below is to be taken as a first step towards careful engineering of fire-detection by use of early warning detectors. The two main assumptions which we adopted were in substantial agreement with our observations. They may, however, be improved by other workers who have the facilities to conduct the necessary experiments, and the time to develop more precise expressions for the build-up of smoke in a building experiencing the first stages of a fire. The two assumptions mentioned above are that (1) a fire burns at a constant rate with a steady smoke output, and (2) the air in the building is well mixed and the smoke concentration is uniform throughout.

Preliminary Remarks

For any particular building, and its known type of occupancy, most experienced fire engineers should have some idea of the materials or contents which might first become involved in a fire. We ourselves have conducted some experiments that suggest there are four broad classes of incipient fires (see Table 1).

- Flaming cellulose which produces very little smoke — about 0.2 per cent of its weight;
- Smouldering cellulose materials which produce about 3.5 per cent of their weight as smoke;
- Flaming plastics which produce, at 2.7 per cent by weight, about as much smoke as smouldering cellulose; and finally,
- Overheating of electrical equipment and components which produce much larger quantities of smoke, i.e. ~ 28 per cent of the insulation weight.

No experiments were included with flammable liquids, and some separate attention should be given to these dangerous materials.

With this information in mind, we ask that the fire engineer (on the basis of his experience) sets his detector system to provide an appropriate alarm time: that is, the time that may elapse between a fire starting and a warning appearing. If this time is made short, then a large number of detectors is required — or a higher frequency of false-alarms must occur as a consequence of setting very low smoke detection levels. For any given alarm time, the extent to which the fire will have developed for each characteristic material can be calculated; and it can then be assessed whether or not detection of the fire at this stage would be acceptable. The arguments of Burry (Ref. 2) are relevant in helping to determine the correct stage at which a fire must be detected.

TABLE 1: SMOKE PRODUCTION PROPERTIES OF FOUR TYPES OF SMALL FIRES

	κ mean	Standard deviation	(g J^{-1})
1. Smouldering combustion and radiative ignition. Experiments 1-9 on cellulose materials	0.035	0.024	2.05×10^{-6}
2. Flaming cellulosic materials. Experiments 10, 11, 12	0.0021	0.0005	1.23×10^{-7}
3. Flaming plastics. Experiments 13, 14, 15	0.027	0.008	9×10^{-7}
4. Electrical overheating. Experiments 16, 17	0.28	0.11	2.3×10^{-5}

Theory

If the simplifying assumptions are made that the air in a ventilated room is completely mixed, and that a fire — burning at a steady rate with a constant smoke production rate — has started at a location remote from the return-air duct, then the classical differential equation for a well stirred chemical reactor can be applied, that is

$$\frac{d\sigma}{dt} = S - \frac{A}{V}\sigma = S - Ac$$

where the volume of the room or building is V (m^3) with an air flow rate of A ($m^3\ sec^{-1}$) into (and out of) the room. If the mass of smoke in the room is σ (g), then its concentration c is $\frac{\sigma}{V}$ (gm^{-3}).

If the fire is burning with a rate of weight loss of m (g sec^{-1}) and a smoke conversion factor of k, then the smoke production rate S (g sec^{-1}) is given by $S = mk$.

The equation can be solved to produce a solution for t in terms of the smoke concentration c, but fire detectors are calibrated in % obscuration per metre (ϕ % m^{-1}) which we have found for some smokes to be related to c by $c \simeq 0.0024\phi$.

In practice, the room is not fully stirred, so a correction must be added to give an estimate of the transport time from the fire to the detector in the return air duct. The correction is equal to $\psi \frac{V}{A}$ where ψ is a characteristic for any building and has, for instance, been found to be 0.6 for a large empty room. If H (Jg^{-1}) is the heat yield per gram of fuel, we can measure our fire size in watts Q and say that a fire big enough to give a smoke level of ϕ (% m^{-1}) after time t (sec) is given by

$$Q = \frac{0.0024\phi A}{K} \qquad \frac{1}{1 - e^{-At/V} + \psi}$$

where $\kappa = \frac{H}{k}$

TABLE 2: SMOKE GENERATION IN EXPERIMENTS SIMULATING INCIPIENT FIRES

Experiment No.	Fire characteristics and fuel type	Rate of Weight loss m (g sec^{-1})	Approximate Calorific Value H (J g^{-1})	Size of Fire Q (W)
1	Soft particle board 5.5 cm above a 1000 watt radiator bar	0.038	$17x10^3$	650
2	Soft particle board 8 cm above a 1000 watt radiator bar	0.029	$17x10^3$	490
3	Soft particle board 9 cm above a 1000 watt radiator bar	0.014	$17x10^3$	240
4	Hard composition board 5.5 cm above a 1000 watt radiator bar	0.068	$17x10^3$	1200
5	Plywood 5.5 cm above a 1000 watt radiator bar	0.068	$17x10^3$	1200
6	1000 watt radiator turned upside-down on wool carpet	0.064	$21x10^3$	1300
7	1000 watt radiator turned upside-down on nylon carpet	0.024	$33x10^3$	800
8	1000 watt radiator turned upside-down on acrylan carpet	0.028	$36x10^3$	1000
9	1000 watt radiator turned upside-down on vinyl floor tile	0.019	$12x10^3$	220
10	Waste bin ½ filled with paper, ignited with a match	0.38	$17x10^3$	6500
11	Waste bin ½ filled with cotton rags, ignited with a match	0.23	$17x10^3$	3900
12	Waste bin ½ filled with wood wool, ignited with a match	0.94	$17x10^3$	16000
13	Waste bin ½ filled with PVC wire insulation, ignited with a match	0.17	$12x10^3$	2000
14	Waste bin ½ filled with Polystyrene foam, ignited with a match	0.28	$42x10^3$	1200
15	Waste bin ½ filled with Polyurethane foam, ignited with a match	0.012	$19x10^3$	230
16	Relay coil overheated electrically	0.018	$12x10^3$	200
17	PVC covered wire overheated electrically	0.0003	$12x10^3$	3

Values of κ are given in Table 1. For comparison, the size of some typical fires is given in Table 2.

SETTING ALARM LEVELS

At this stage it should be pointed out that the concept of on/off alarms (i.e., fire/no fire conditions) is an insensitive and crude way of carrying out fire-detection. Several levels of alarm are much to be preferred; for example, an 'alert' level (called a yellow level) whereby the attention of a supervisor is drawn to a smoke concentration in a building that is unusual and bears further watching, but requires no action. If there is an increase in smoke concentration above the 'alert' level, then an 'action' level is reached (called an orange level) which requires investigation by, say, a technician, night watchman or building supervisor. Finally, an 'alarm' level (red level) may be reached, where there can be no doubt that a fire condition exists which requires appropriate action such as fire brigade turnout evacuation and so on. Such a three-level warning system will enable small fires to be detected early and acted upon without unnecessary 'call-out' of fire brigades.

Further restrictions may be placed on the alarm levels by requiring that yellow and orange levels be exceeded for a certain time before they are indicated. These time delays should allow sudden local increases in smoke concentration to be ignored while not causing significant delay in the detection of a slowly developing fire. Experiments suggest that the appropriate alarm should show only if a 'yellow' smoke concentration persists for 60 seconds, or an 'orange' level for 30 seconds, but a 'red' level needs no time delay at all.

Very sensitive detection of smoke inside a building requires compensation for high ambient smoke levels that originate from *outside* the building. For example, a yellow level of 0.03% m^{-1} obscuration corresponds to a visual range of 13 km and visual ranges less than this are quite frequent for cities. However, if the outside smoke level is continuously measured and the reading used to compensate the smoke level found inside, then the sensitivity of the method is improved at least ten times.

In an actual experiment, a very sensitive smoke detector was installed in three different rooms in a telephone exchange and the difference in obscuration between outside and return air was measured over periods of up to a week. The results were analysed by obtaining the mean increase in smoke for each room and the standard deviation, from which can be calculated the fraction of the time over which ϕ can be expected to exceed any selected value. The values found are given in Table 3A. Table 3B gives *suggested* levels for alarm, with expected false-alarm rates. Here, the important feature is the much lower level of smoke when the building is not occupied — hence the possibility of setting very sensitive detection levels at these times.

Figs. 1 and 2 show the smoke concentrations inside a large ventilated room resulting from various fires, and it can be seen that very sensitive detection is vital for slowly developing fires. For, in the case of Fig. 2 detection at 0.03% m^{-1} occurs after 11 minutes, but if the level had been set at 0.05% m^{-1}, 25 minutes would have elapsed before the alarm showed: then after another two minutes

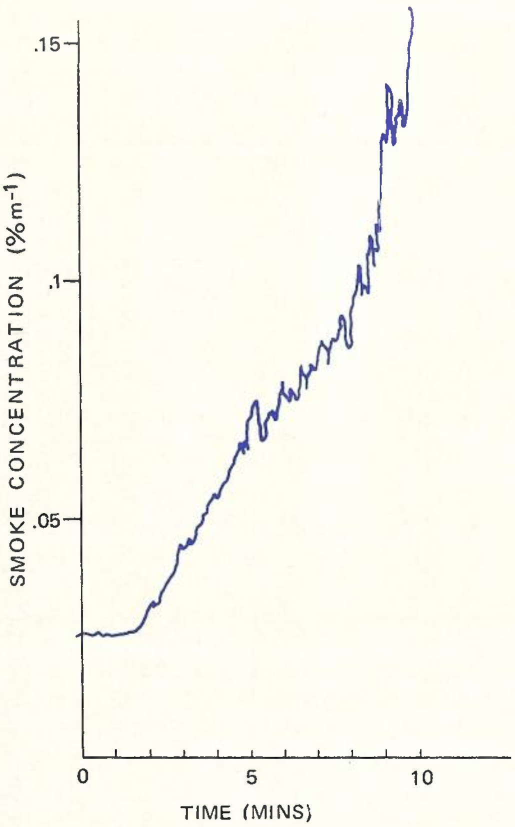


Fig. 1—Paper Ignited by Match in Waste Bin.

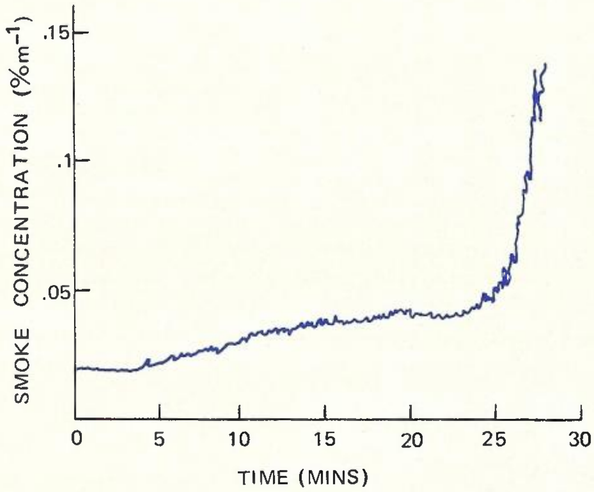


Fig. 2—Soft Particle Board 9 cm above 1kVA Radiator

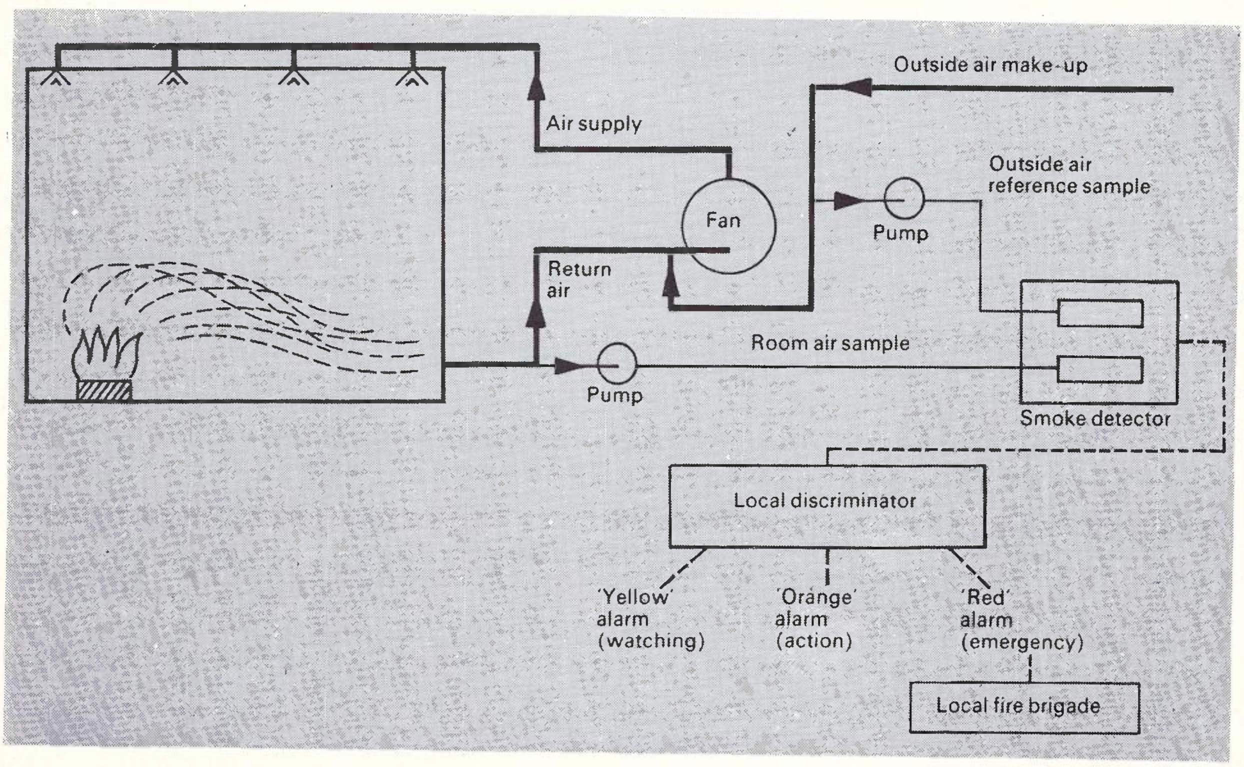


Fig. 3—Typical Sensitive Smoke Detection Installation.

TABLE 3A: NORMAL BACKGROUND OBSCURATION ϕ (%m^{-1}) WITH RESPECT TO OUTSIDE AIR

Location		Obscuration (% m^{-1}) Average Φ	Standard Deviation Φ
Telephone exchange with minor installations in progress	Day	— 0.0012	0.0086
	Night	— 0.0018*	0.0008
Telephone exchange with major installations in progress	Day	— 0.0011*	0.0112
	Night	— 0.0048*	0.0022
Computer with filtered air supply	Day	— 0.0065*	0.0014
	Night	— 0.0054*	0.0011

* Filtered air supply keeps air inside the exchange cleaner than outside air.

TABLE 3B

Recommended alarm levels at 90% limits — i.e., 90% certain that exceeding these limits is not a false alarm. Yellow is mean ambient smoke level plus 4.3 standard deviations; Orange is mean level plus 4.8 standard deviations; Red is mean level plus 5.6 standard deviations.

Location		Obscuration (%m^{-1}) ϕ Yellow	Orange	Red
Telephone exchange with minor installation in progress	Days Occupied (Day)	0.048	0.053	0.061
	Unoccupied (Night)	0.005	0.007	0.009
Telephone exchange with major installation in progress	Occupied (Day)	0.067	0.074	0.088
	Unoccupied (Night)	0.005	0.006	0.007
Computer installation with filtered air supply	Occupied (Day)	0.010	0.012	0.014
	Unoccupied (Night)	—	—	000
Estimated time between false alarms (due to random variation) with, for example, a 5 second time delay at each level		6.7 days	2.4 months	14.8 years

the fire accelerates very rapidly. During this last stage of rapidly accelerating fire the assumptions made in the theory presented above no longer apply, even approximately; however, at least two if not all of the warning levels will always need to be set lower than this last stage.

THE CSIRO/APO SMOKE DETECTOR — 'VESDA'

The Australian Post Office and The Commonwealth Scientific and Industrial Research Organisation have developed a prototype of an appropriate detector. The detector is especially suitable for high value electronic installations such as telephone exchanges and computers, but may also prove suitable for high rise buildings and hospitals. The detector incorporates three novel design concepts:

- Detection of smoke in return-air ducts by the use of a very sensitive light scattering detector;
- Compensation for outside smoke levels to enable very small smoke releases to be detected without false alarms from external smokes and
- Interpretation of the output of the detector and the activation of three alarm levels depending on the quantity and persistence of smoke in the building. The alarm levels are set on the basis of a statistical analysis of the normal distribution of smoke found in the buildings. The three levels of alarm allow either 'alert' (yellow), 'action' (orange) or 'emergency' (red) procedures to be instituted in turn.

The system is based on the detection, by a photomultiplier tube, of light scattered by smoke particles when illuminated by a powerful lamp (flashing xenon). An air sample is pumped through the detector and a reference sample from the outside air is compared with the return-air sample. If a high smoke reading is maintained for a suitable time, (0-60 seconds) then one of three alarms is activated by a discriminator or in the case of larger installations, by a small, inexpensive computer. A typical simple installation is shown in Fig. 3. Commercial development of 'VESDA' is being undertaken.

CONCLUSIONS:

With the advent of very sensitive smoke detectors and an increasing knowledge of the production and behaviour of smoke from incipient fires, the way is now clear for the application of true fire-engineering principles. In combination, the experience of the fire engineer, the expertise of the air-conditioning engineer and the sophistication of the computer man should allow effective fire-protection, especially in those places where life is at great risk — high-rise buildings, hospitals, ships at sea, and aircraft in flight. The Australian Post Office is currently carrying out field trials with 'VESDA' which could lead to the general use of this detector in telephone exchange installations. It is to be hoped that other organizations concerned with fire safety will give serious consideration to this new approach.

REFERENCES

1. Johnson, J. E.: 'Engineering Early Warning Fire Detection', Fire Technology, 5, 5-15, 1969.
2. Burry, P. E.: 'General Requirements for Fire Detection Systems with Particular Reference to the Reduction in Fire Losses', Symposium No. 6, Automatic Fire Detection, H.M.S.O. (London), 1972.

D. R. PACKHAM is a Senior Research Scientist in the Metallurgical Chemistry Section of the CSIRO Division of Mineral Chemistry, Melbourne. Before transferring to that Division in 1975 he was in the Fire Section of the Division of Chemical Technology, Melbourne, where he worked for twelve years on bushfires, aerial prescribe burning, the chemistry and physics of smoke, and the detection of smoke in buildings.

L. GIBSON is Fire Protection Officer for the APO in Victoria and has worked on the detection of smoke in buildings and the chemistry of smoke for the last five years.

M. LINTON is an Experimental Officer in the High Pressure Section of the CSIRO Division of Applied Organic Chemistry, Melbourne, having also worked on bushfire problems and the theory of smoke detection in ventilated buildings.

Communications Relies on the Soldered Connection

A. L. ROYSTON, Adcola Products.

EDITORIAL NOTE

Soldered connections are still used extensively throughout telecommunication networks and will continue to be used for some years to come. This short article will be of interest to field supervisors and staff required to make soldered connections as part of their everyday work.

Mr. Royston has been involved in the development of high-reliability soldering techniques and equipment for over 20 years. Much of this has been actively associated with the telecommunication field.

INTRODUCTION

A decade ago, when communications satellites were in their adolescence, equipment malfunction was a significant problem. It is now a matter of record that one of the major causes was simply bad soldering.

Today, communications equipment has acquired an outstanding reputation for reliability. Considering the billions of soldered connections involved, this achievement is all the more noteworthy.

Two factors have contributed to this: techniques and equipment.

TECHNIQUES

During the few seconds it takes to make a soldered connection, an incredible number of things can go wrong.

Either or both of the joint components can be dirty — and in the soldering sense, 'dirty' can mean a heavily oxidised surface, or a light, almost invisible tarnish. Solder will only bond to clean metal.

The correct solder alloy of tin and lead should be used. The joint components must not rely on the solder to achieve mechanical strength, and they must not move whilst the solder is solidifying.

The flux is mandatory for good soldering: but the flux must be non-corrosive. Possibly the most frequent fault in technique is that of applying the solder to the hot tip of the soldering tool, and letting molten solder and flux flow on to the joint. This will almost guarantee a 'cold' joint and eventual, if not immediate, failure. The only correct method is to apply the tip of the tool to the joint itself, and melt the solder by applying it to the heated joint components.

Another popular misconception is that of temperature. The misguided amateur still tends to operate on the principle of 'the hotter the better'. This is even more dangerous today than in the past, for excessive temperature will delaminate circuit board tracks and pads, melt insulation, destroy fluxing action, and ruin heat-sensitive components. With the predominance of complex integrated circuits in use today, this can be an expensive exercise.

Most manufacturers of communications equipment find it pays to have their assemblers, and even their service personnel, trained in the correct soldering techniques and the use of modern soldering tools.

EQUIPMENT

There is now a bewildering range of soldering equipment available, from hand soldering tools to fully automated wave soldering machines.

The hand-held soldering tool, of course, is still the backbone of the industry, but it has come a long way since the first bulky 'blunderbus' was constructed.

The three basic types of soldering tool are (a) continuous heat (b) quick heat and (c) controlled temperature.

The control of the temperature of the soldering tool used on modern electronic circuits — particularly printed circuits — is vital. Below 240°C (460°F) cold solder joints will result — above 420°C (800°F) poor fluxing and changes in chemical composition of the solder lead to unreliable soldering. Ideal soldering is performed within a narrow band of temperature which is impossible for the operator to monitor. Therefore, any quick-heating soldering tool must have inbuilt temperature regulation if it is to be used safely on modern electronic equipment.

Heat Requirement

Just as there are many different terminations, so there are many different heat requirements: but in this sense 'heat' does not mean 'temperature'.

The thermal *capacity* required to solder a .025" transistor lead to a printed circuit pad is only a fraction of that needed to solder a sequence of .060 leads to multiple terminal posts — but in each example the *temperature* requirements are the same.

For a given termination mass, a higher temperature is required for desoldering than for soldering, to quickly penetrate the oxide which is present. This applies particularly when using the popular desoldering braid, which also acts as a heat sink.

Controlled Temperature

By far the best soldering tools, of course, are those with controlled temperatures. These are available today with either remote temperature control, or with electronic sensing and solid state switching circuitry contained entirely within remarkably slim handles. Temperatures can be selected between about 200°C and 400°C, and will hold the selected figure to within a very few degrees.

One type still being produced uses a mechanical switch operated by a magnet and spring assembly within the barrel. Temperature is determined by the Curie point of an alloy attached to each tip, which loses its magnetic characteristics at a predetermined temperature and releases the mechanical switch. The desired temperature is achieved by fitting the appropriate special tip.

With the electronic unit, any tip (selected for its size and profile) accommodates all temperatures, which are selected by adjusting a small screwdriver slot in the handle. These are available for operation directly from AC mains.

Dual Temperature

Whilst the controlled temperature tool is undoubtedly the most sophisticated, an extremely useful dual temperature tool is also available. This idles on half-wave power at the proper soldering temperature, instantly ready for use.

However, when a long sequence of connections, or heavy chassis joints, are to be made, light pressure on a sensitive button doubles the thermal capacity by converting it to full wave power. Thus the major shortcoming of the conventional 'continuous heat' tool is eliminated, without incurring the potential hazards of the 'quick heat' type.

The telecommunications industry, to its credit, is sensitive to the quality of its soldering. As equipment and componentry become more sophisticated, the need for controlled accuracy will be further accentuated.

Both the techniques and the equipment will be equal to the task.

New Design VFT Auto Patch Relay Set

G. BARFOOT, B.E.

This article describes work being carried out to design a new Automatic Patching Relay Set for Voice Frequency Telegraph systems. Comparisons are made with the existing design in order to explain the philosophies of the new design.

INTRODUCTION

Voice Frequency Telegraph (VFT) systems in the Australian Telecommunications Network are provided with automatic patching facilities to maintain high performance and reliability objectives. Various methods are used to monitor the transmission of the VFT system and in the event of a failure on the normal transmission path, the automatic patching equipment restores the system to a standby bearer.

Present automatic patching equipment provides only for four wire circuits, but the large scale use of out-of-band signalling has given rise to the need for a six wire patching set. This requirement has given an opportunity to re-appraise existing automatic patching equipment to provide a more compact design with faster patching properties and added facilities.

Initial development of a new VFT Auto Patch Relay Set has been carried out in the Central Office Administration and several prototypes have been assembled. This article takes a brief look at the current design and explains the philosophies behind the new design.

CURRENT RELAY SET CHARACTERISTICS

The VFT Relay Set in current use throughout the Australian Telecommunications Commission (ATC) Network was originally designed in the early 1960's. It uses four 3000 type relays with a quantity of passive components mounted on a standard relay base. The design uses a diode network to monitor the condition of nine of the VFT channels (nine input Nand gate) and thus provide patching on failure of the bearer. The mod. and demod. paths are patched separately with a 150 ms delay between them. Failure to restore the VFT system on the standby bearer results in a repatch to the original bearer after a further 150 ms. If the system cannot be restored there, 'hunting' continues with a period of 300 ms until one of the bearers is restored. Fig. 1 shows a simplified block diagram of the operation of the old device.

The typical patch time for this device (i.e., the time taken to restore the VFT system) is about 185 ms. Of this, the largest component is the 150 ms inherent in patching the mod. and demod. paths separately. The remaining component is made up of transmission delays, and delays required to de-

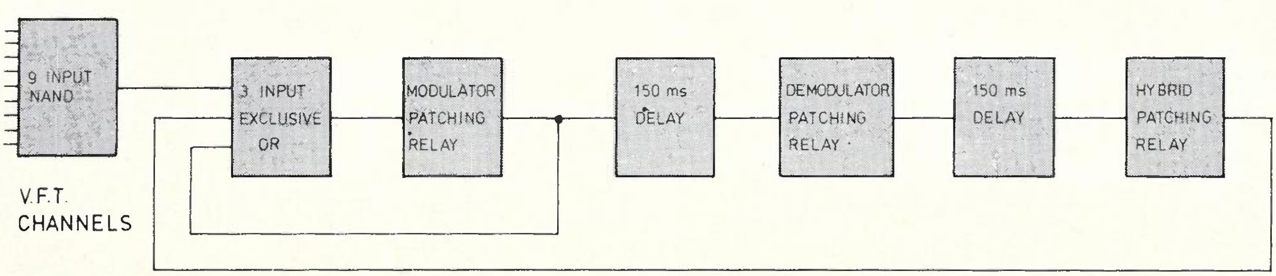


Fig. 1 — Simplified Block Diagram of VFT Auto Patch Relay Set (CN 994).

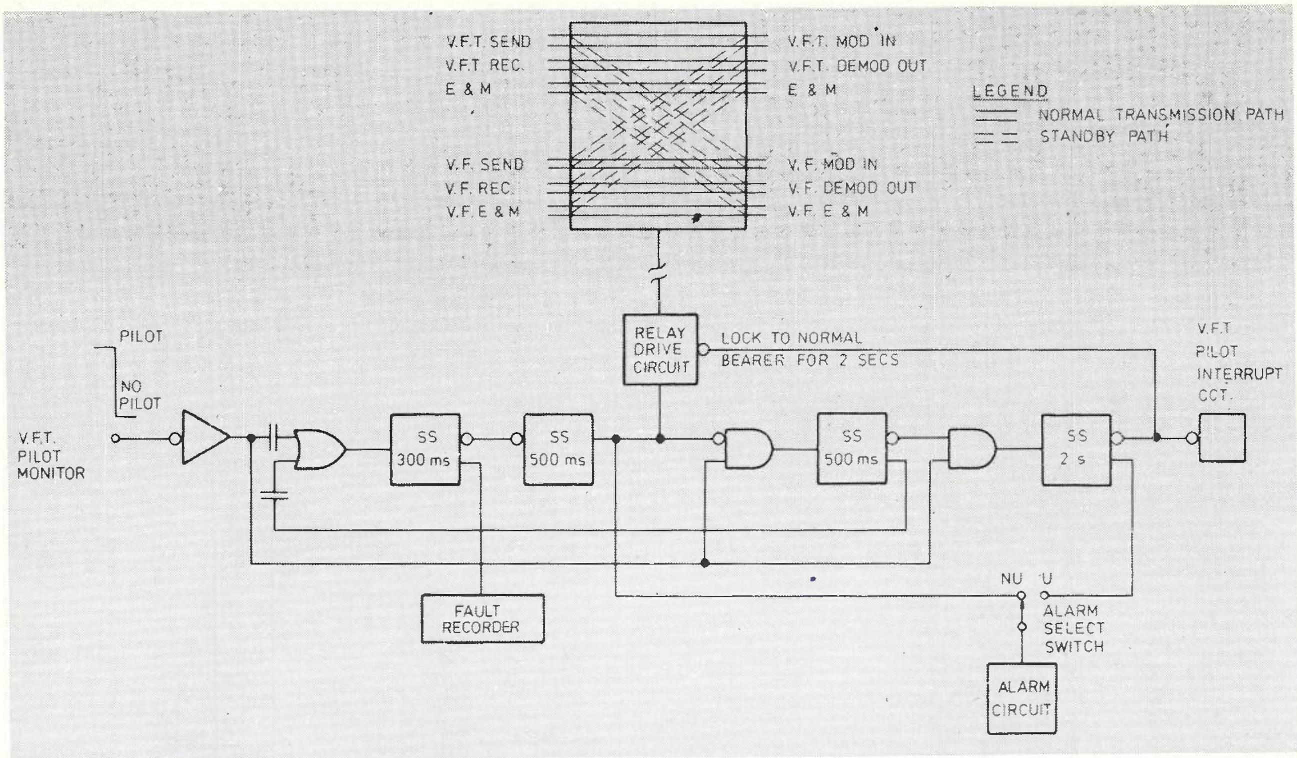


Fig. 2 — Basic Logic Diagram for New VFT Auto Patch Relay Set.

tect a 10 dB drop in level of the 300 Hz VFT pilot at each end of the system.

The major drawbacks then, with the existing design, are that it is only a four wire patching set and that it is unnecessarily slow. Of a less serious nature is the physical size of the device.

NEW DESIGN CHARACTERISTICS

A solution to the problem of a new six wire set could have taken several forms. Two basic methods exist for restoring the VFT system when the standby bearer is used for telephony:

- To do a complete six wire transfer (i.e., speech and signalling leads.)
- To patch only the VFT system and to back-busy the telephony circuit.

With either of these methods it is possible to monitor the normal bearer and return the VFT system to this bearer when it has restored. This gives four different methods of solving the problem. The one chosen for the new design was to completely transfer the two six wire circuits and not monitor the normal bearer.

The reasons for this choice are twofold. Firstly, the monitoring of the normal bearer was discounted because it immediately causes two patching operations for every failure. This would effectively double the data traffic error rate. A further disadvantage in doing this is the unnecessary patching that occurs if the normal bearer becomes particularly noisy or prone to drops in level. Secondly, to back-busy the telephony circuit and not monitor the normal bearer means the loss of the telephony circuit for approximately 50% of the time, assuming equal probabilities of the VFT system remaining on either bearer for a given period of time.

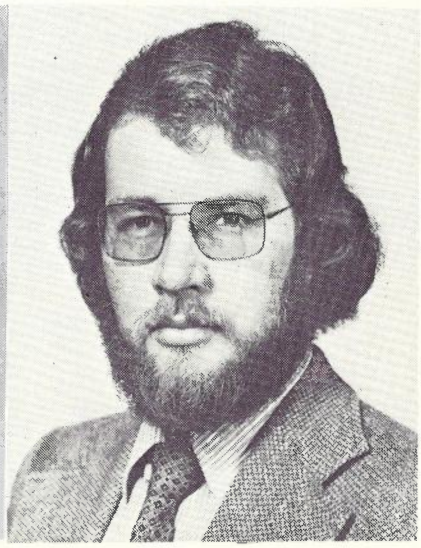
Having made this choice, it was then necessary to decide on the operating characteristics of the new device. Fig. 2 shows the basic logic diagram. In order to patch the mod. and demod. paths together, thus reducing the patch time by 150 ms, it was necessary that the device should not hunt, a condition detrimental to the network. The logical operation was to have the VFT system remain on the normal bearer after giving each bearer a chance to restore the system. This would only occur when both bearers are failed. It was decided that 500 ms is the maximum likely time that the system could take to patch and this is the time that each bearer is given before an urgent alarm is raised. A non-urgent alarm facility may also be used to indicate when the VFT system has patched but is working on the standby bearer.

The new design includes facilities which were available on the old design such as remote control and monitoring, manual patching and fault recording. The physical size has been reduced through the use of solid state components and miniature relays incorporated in a printed circuit plug-in module. The units are designed to mount in a VF amplifier panel (Serial/Item 238/100) accommodating four per panel. The sets will operate directly from -48 volts dc and dissipate approximately three watts each.

PROGRESS TO DATE

The prototype units which have already been assembled are currently undergoing field trials in the Victorian Administration. Results of these trails will be used to make any necessary modifications before proceeding with standard contractual manufacture.

G. BARFOOT graduated from Monash University in 1971 with a Bachelor of Engineering Degree (Electrical). In 1972 he joined the Postmaster-General's Department and has spent the last three years in the Long Line Equipment Branch, Central Office.



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THE OVERSEAS TELECOMMUNICATIONS COMMISSION (AUSTRALIA).

Third International Conference on Digital Satellite Communications Kyoto, Japan — November 11-13, 1975

SCOPE:

To consider contributions relating to the design, operation and economics of digital satellite communications systems and associated techniques to promote their efficiency and reliability.

BACKGROUND:

Following two successful conferences held in London (1969) and Paris (1972) the Third International Conference on Digital Satellite Communications is to be held in Japan at the Kyoto International Conference Hall on the 11th to 13th November, 1975. It is sponsored by the International Telecommunications Satellite Organisation (INTELSAT), The Institute of Electronics and Communication Engineers of Japan (IECE) and the Institute of Television Engineers of Japan (ITE).
Australia is actively supporting the conference through the Overseas Telecommunications Commission (Australia) and is represented on the Technical Program Committee.
The following are some of the topics to be considered at the Conference:
Time Division Multiple Access Systems for regional and domestic services, transmission analysis and measurements, design of high speed modems, integration of digital satellite links with terrestrial networks, digital picture transmission, echo cancellation techniques.

FURTHER INFORMATION:

Australian participants will be most welcome at the Conference (the official language will be English), and further information on the Conference, including application forms, is available from E. Bachmann or G. Berzins, OTC (A), Sydney, Telephone 230-5000.

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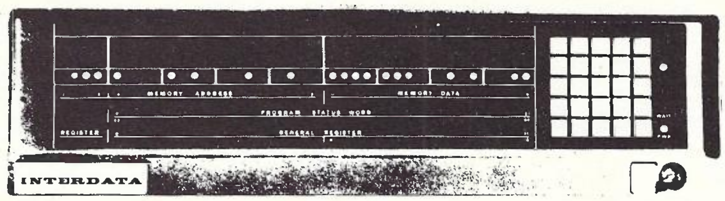

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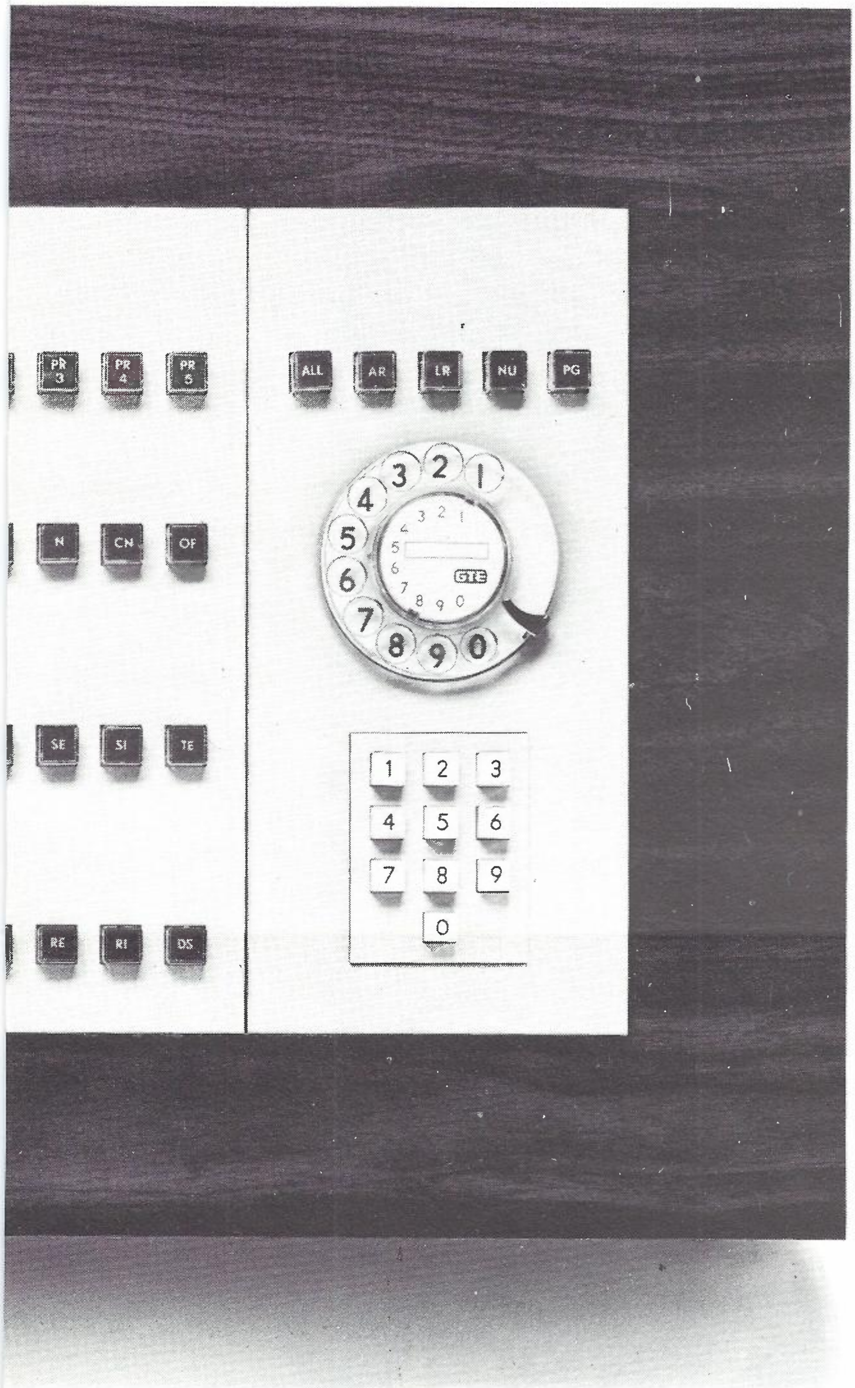

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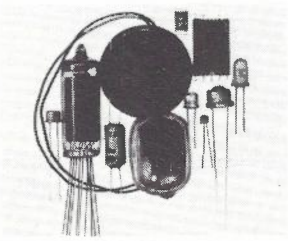
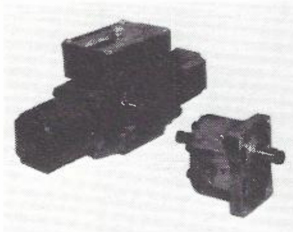


Photo diodes, light emitting diodes, solid state numerical and alpha numerical displays. These are but a few of the extensive range of devices available from Plessey Australia, Components Division for various applications, such as indicators and displays, portable calculators, cameras and electronic wrist-watches.



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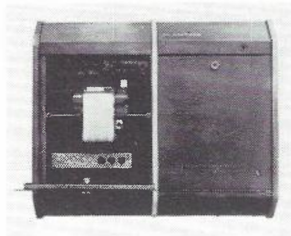
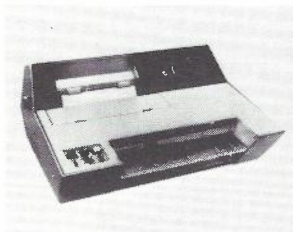
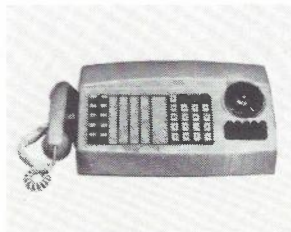


The latest addition to the Plessey Communication Systems range is the revolutionary, employee key-control PLANTIME flexible working hours system. It eliminates conventional time cards, numerical counters and provides up-to-the-minute print-outs.

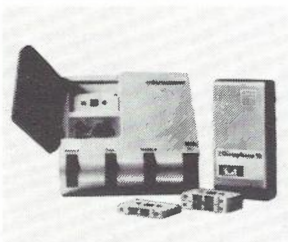
Illustrated is the MTR 40 mobile 2-way radio system with an SC 201 Decoder fitted. Developed by Plessey Australia Electronics System, Victoria, the system employs a method of selective calling whereby each operator receives only those messages specifically directed to him.



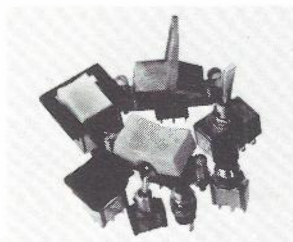
Marketed by Plessey Communication Systems, the Facsimile Remote Copier is a desk-top copier capable of transmitting and receiving over public or private telephone lines, printed, written or graphic material within minutes.



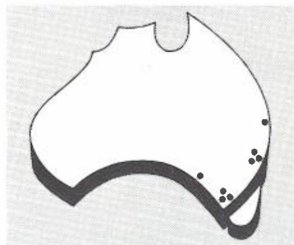
PABX—manufactured by Plessey Australia, Telecommunications Division, this private automatic branch exchange system employs crossbar switching and componentry similar to that used by the Australian Telecommunications Commission in the national telephone network.



Part of the extensive range of communications equipment available from Plessey Communication Systems is this versatile D10 & 11 dictaphone system.



Miniature, sub-miniature, micro-miniature or standard C & K switches are available from Plessey Australia, Components Division. The range embraces the widest possible variety of toggle, rocker, illuminated rocker, paddle handle, and push button switches to meet every requirement.



Number of plants: 6
Factory capacity: 1 million sq. ft.
Employees: 3,000

Plessey.

HOLT APP 72

To a telephone exchange

Our "Easydial" phone doesn't put out tone signals like other pushbutton phones. It puts out pulses like a regular dial phone. Every telephone exchange accepts pulses and will put you through to your number.

That means "Easydial" will work where the equipment needed for pushbutton phones hasn't been installed yet.

And that means—with "Easydial"—you can have the convenience of touch calling even if it's not available in your area.

ABSTRACTS: Vol. 25, No. 3 (Continued).

PACKHAM, D. R., GIBSON, L. and LINTON, M.: 'The Detection of Smoke in Air-Conditioned and Ventilated Buildings'; Telecomm. Journal of Aust., Vol. 25, No. 3, page 261.

This paper introduces a new concept of 'early warning fire detection' for protecting air-conditioned or mechanically ventilated buildings by the use of ultra sensitive smoke detectors in return-air ducts. Some experiments have been done with a detector that can measure down to 0.01% m^{-1} smoke obscuration in such ducts. A first-approximation theory is proposed that should permit fire protection engineers to design appropriate installations, once smoke production rates of those materials most likely to be involved in a fire have been established, and the appropriate ignition time to 'alarm' assessed. A new approach to alarm levels is also presented, whereby a series of three alarms is used to deal with 'suspected' fires, 'incipient' fires, or 'active' fires. Some information is given about the normal smoke levels of three buildings (all telephone exchanges), smoke production rates of various materials, and the size of some incipient fires. A detector device being developed by the Commonwealth Scientific and Industrial Research Organization (Australia) and Australian Post Office is briefly described.

VAWSER, K. D.: 'Traffic Usage Rate Estimation for Small Country Exchanges'; Telecomm. Journal of Aust., Vol. 25, No. 3, page 209.

This article describes a system that obtains reliable estimates of traffic usage rates for the design of small country telephone exchanges. The system also simplifies the design work involved in handling the annual volume of this work without using a disproportionate amount of design effort.

The principle used is the curve fitting of traffic usage rates obtained from traffic measurement data. The resultant curve functions generate design tables and summaries, the latter being used for design classification.

The Telecommunications Journal of Australia

ABSTRACTS: Vol. 25, No. 3.

BALDERSTON, M.: 'An Historical Survey of Communications Satellite Systems (Part 3)'; Telecomm. Journal of Aust., Vol. 25, No. 3, page 251.

In this concluding part of the article, the present and future of U.S. domestic, European regional and Japanese domestic systems are discussed, together with several other systems planned or under consideration. The choice of operating frequencies and available launching vehicles are also discussed. Finally the trends in satellite system technology are examined and assessed in the light of current trends in communication services.

BARFOOT, G.: New Design VFT Auto Patch Relay Set'; Telecomm. Journal of Aust., Vol. 25, No. 3, page 270.

This article describes work being carried out to design a new Automatic Patching Relay Set for Voice Frequency Telegraph systems. Comparisons are made with the existing design in order to explain the philosophies of the new design.

BEDFORD, N.R.: 'Quality Control and the Plant User'; Telecomm. Journal of Aust., Vol. 25, No. 3, page 218.

This article is the last of a series of three which collectively could be entitled "Quality — What it is and how to control it". The full impact of this article can only be felt if read in conjunction with the previous two articles in Volume 24 No. 3 Pages 227-238.

True Quality Control is a systematic approach to firstly specifying what quality is required (the APO does this for its own equipment) and then ensuring that the product manufactured is of the specified quality. The process of control is analogous to physical control systems, in which feedback is an essential element of control; there are in fact a number of feedback loops, using information derived from the manufacturer's inspection, the user's inspection, and finally the plant installer or operator himself. Because Quality Control does ensure production at minimum cost, does ensure consistency of quality, it is best for the manufacturer and certainly best for the customer.

BULTE, I. E.: PABX's and Other Subscribers Automatic Voice Switching Systems in Australia'; Telecomm. Journal of Aust., Vol. 25, No. 3, page 190.

This article gives an overall picture of PABX and ACD equipment types available in Australia. It gives some details of equipment approval methods used in the APO and comments on equipment design trends in the past decade.

EVEN-CHAIM, A.: 'Some Switching, Signalling and Synchronization Techniques in Satellite Communication Systems'; Telecomm. Journal of Aust., Vol. 25, No. 3, 1975, page 239.

Techniques have been developed for satellite communication systems which aim to increase the traffic carried by the system. Switching stages at the satellite link ends that engage the satellite channel only for the "busy" period, add significant improvement. Idle channels are held in a pool, being assigned to a terminal pair on demand only. Three such demand assignment systems techniques for telephony are briefly described: frequency-division multiple-access demand assignment, time-division multiple-access demand assignment, and digital speech interpolation. Two techniques for hybridization of data channels with telephony are outlined.

FAULKNER, A. H.: 'The East-West System — Operation and Maintenance in Western Australia'; Telecomm. Journal of Aust., Vol. 25, No. 3, page 203.

This article gives a description of maintenance experience in Western Australia with the East-West microwave system over the period between commissioning and the present date, including references to some problems which have occurred.

HAUW, D. J.: 'Some Tests for Evaluating the Colour Television Performance of Mico Wave Relay Systems'; Telecomm. Journal of Aust., Vol. 25, No. 3, page 225.

This paper discusses four CCIR waveform tests and considers them to be inadequate for use in determining the acceptability of new microwave radio relay systems for purposes of commissioning into traffic service. Additionally, a test procedure is introduced to measure a new distortion not considered by the CCIR.

KIDD, G. P.: 'Liquid-Cored Optical Fibres for Communication Systems'; Telecomm. Journal of Aust., Vol. 25, No. 3, page 231.

The development of the liquid-filled optical fibre in 1971 created new interest in fibre communication and although there have been significant advances in fibres of different materials and structure, the liquid-cored fibre still offers some advantages over these. The transmission properties of tetrachloroethylene-filled fibres developed by the CSIRO Division of Tribophysics and investigated in the APO Research Laboratories are given, as well as a description of a specially developed light-emitting diode compatible in geometry and electrical characteristics with these fibres. Possible trunk, junction and broadband subscribers systems using optical fibres are discussed.

MOOT, G.: 'Telecom. Australia'; Telecomm. Journal of Aust., Vol. 25, No. 3, page 183.

One of the functions of this Journal is to record the key milestones in the growth of telecommunications in Australia. In spite of the wide publicity already given to the establishment of the Australian Telecommunications Commission, no apology is needed for the present article. In addition, our many overseas readers will appreciate a resume of the main features of the new Commission and some of the reasons underlying the changes that have been made.

(Continued on page 290)

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OF AUSTRALIA

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