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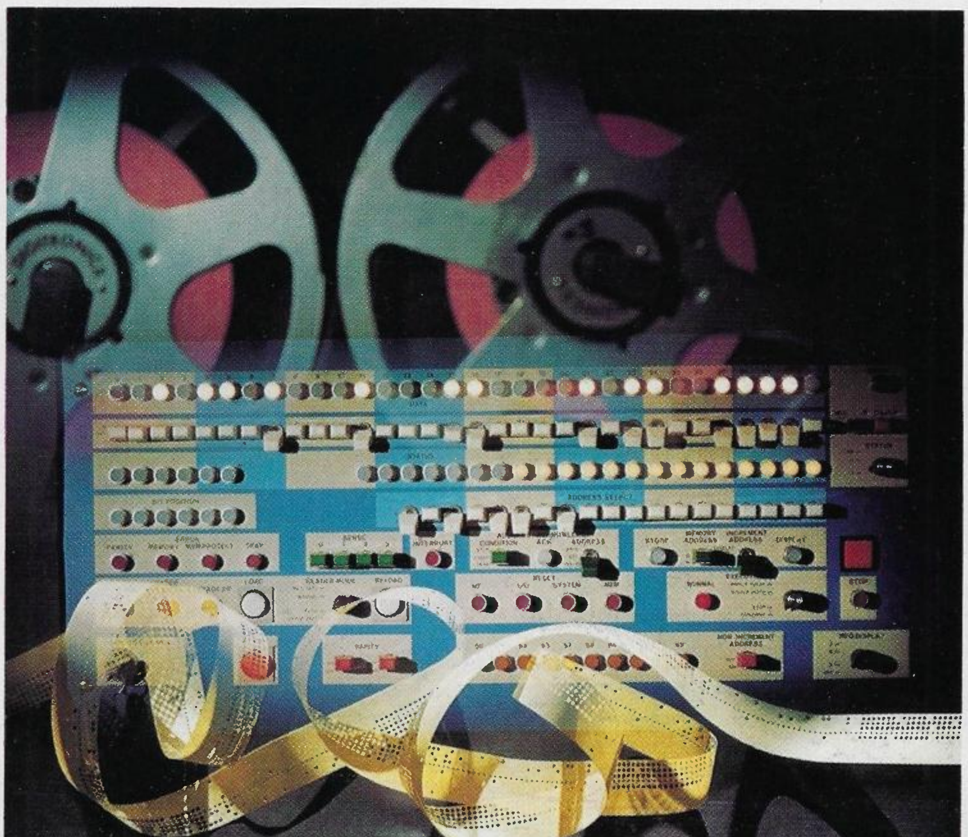

IN THIS ISSUE

25/1

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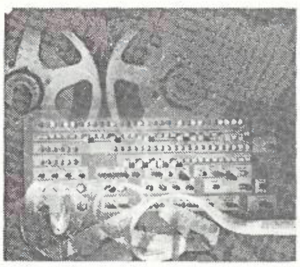
CONTENTS



COVER
PROCESSOR CONTROL
PANEL — SPC EXCHANGE

The Telecommunication Journal of Australia

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Official Opening of the Pitt 10C Exchange

The new Pitt stored program controlled trunk exchange was opened by the Postmaster-General, Senator Reg Bishop, at a dinner in Sydney on 2nd December, 1974.

Guests, who included leaders of commerce and industry, were welcomed by the Director-General, Mr. E. F. Lane, and the response on their behalf was given by the President, Bell Telephone Manufacturing Co., Antwerp, Mr. F. Pepermans.

All speakers referred to the size, complexity and importance of the exchange, and to the co-operation between suppliers and the APO which had been a feature of the project.

During the opening, the Postmaster-General handed the keys of the exchange to the Director, NSW, Mr. F. L. C. Taylor, and made a call via Pitt to the Administrator, Northern Territory, Mr. J. Nelson, to inaugurate the STD service to Darwin.

The APO Director, Public Relations, Mr. B. Luscombe, was the guide for a video tape walk through Pitt, and at the conclusion of the dinner, the APO film "Decisions", which was produced to mark the occasion, was screened for the first time.

All in all, the function was fitting recognition of a major telecommunications achievement. Many of the guests later wrote to the Director-General expressing their appreciation of the way in which the function was conducted.

The Postmaster-General Opens the STD Service to Darwin.

Pitt 10C Stored Program Controlled Trunk Exchange

R. J. HOLT, B.E., A.S.T.C., G. PAGE-HANIFY, B.E., B.Econ., M.I.E. Aust. and W. R. DEDRICK, B.Sc., M.I.E. Aust.

The Pitt (Sydney) 10C stored program controlled STD trunk exchange was put into service in September, 1974. The exchange is briefly described and experience during installation, acceptance and early service is outlined.

INTRODUCTION

A study in 1967 showed that to meet the anticipated trunk telephone traffic in Sydney after 1973, a new 8,000 line capacity crossbar trunk exchange would be required every two to three years, and that a larger capacity (50,000 lines) trunk exchange would be the most effective way to handle the traffic.

A world wide schedule for the supply and installation of a large trunk exchange in the Pitt (Sydney) Communications Building was issued by the APO in 1968, and in 1969, STC's tender for Metaconta 10C stored program controlled equipment was accepted. In 1970, 10C equipment was approved by the APO as an alternative standard to crossbar equipment for:

- Switching of STD calls;
- Manual operator assistance for national and international trunk calls;
- Reminder and appointment calls;
- Automatic centralised interception for subscribers.

Other contracts were placed with STC in 1971 for the supply and installation of 10C trunk exchanges at Lonsdale (Melbourne) and Waymouth (Adelaide), and in 1974 for the supply of equipment for Bendigo (Victoria).

This article deals briefly with the Pitt STD exchange which was put into service in September 1974.

THE PITT STD EXCHANGE

The Pitt STD exchange is a main trunk exchange located in the Pitt Communications Building, Pitt Street, Sydney. Its initial capacity is 12,500 trunk circuit terminations and it is sharing the traffic load with Haymarket crossbar trunk exchange (16,000 terminations).

Incoming trunk circuit terminations at Pitt are allocated as follows:

• Sydney local network	2,600
• NSW trunk network	1,000
• Other States' trunk network	1,050
• International network	100
• Manual assistance centre (when installed)	800
• Maintenance and test equipment	50
• Echo suppressors	310

The exchange is expected to develop to about 50,000 terminations by which time it will be handling most of the STD traffic through Sydney, and as well, a high proportion of the trunk calls from Sydney subscribers requiring manual assistance.

BRIEF DESCRIPTION OF METACONTA 10C SYSTEM (REF. 1)

The Metaconta 10C trunk exchange is a Stored Program Controlled system using ITT 3200 processors to control a reed relay switching network.

Incoming circuits are connected to incoming junctors, which are connected as required to signalling receivers and through the voice switching network to outgoing junctors.

Peripheral equipment collects information from the incoming signals and the switching equipment. The information is processed in the central processing unit, and orders on the switching equipment are executed by markers and drivers to

- Connect incoming and outgoing circuits.
- Connect senders to the outgoing circuits.
- Where required, provide for periodic metering pulses to be returned to the calling subscriber.

Fig. 1—Test Consoles.

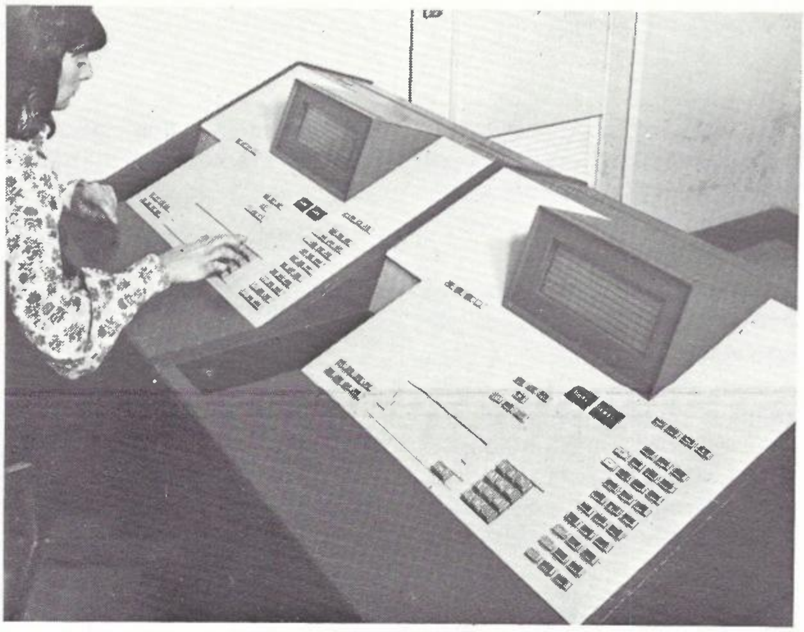


Fig. 2—Service Assessment Positions.

For reliability, peripheral equipment is duplicated, each part having access to a separate processor. Each processor has its own operating memory and translation table memory blocks are duplicated. In this way even if a major sub-system fails, service continues to be provided on the remaining parts.

The system has a wide range of inbuilt self-checking procedures, and when a failure is detected, further checks are automatically made to locate the faulty area. Automatic takeover and recovery features re-arrange the system to eliminate or bypass the fault, and a detailed printout is produced on a teletype, enabling the fault to

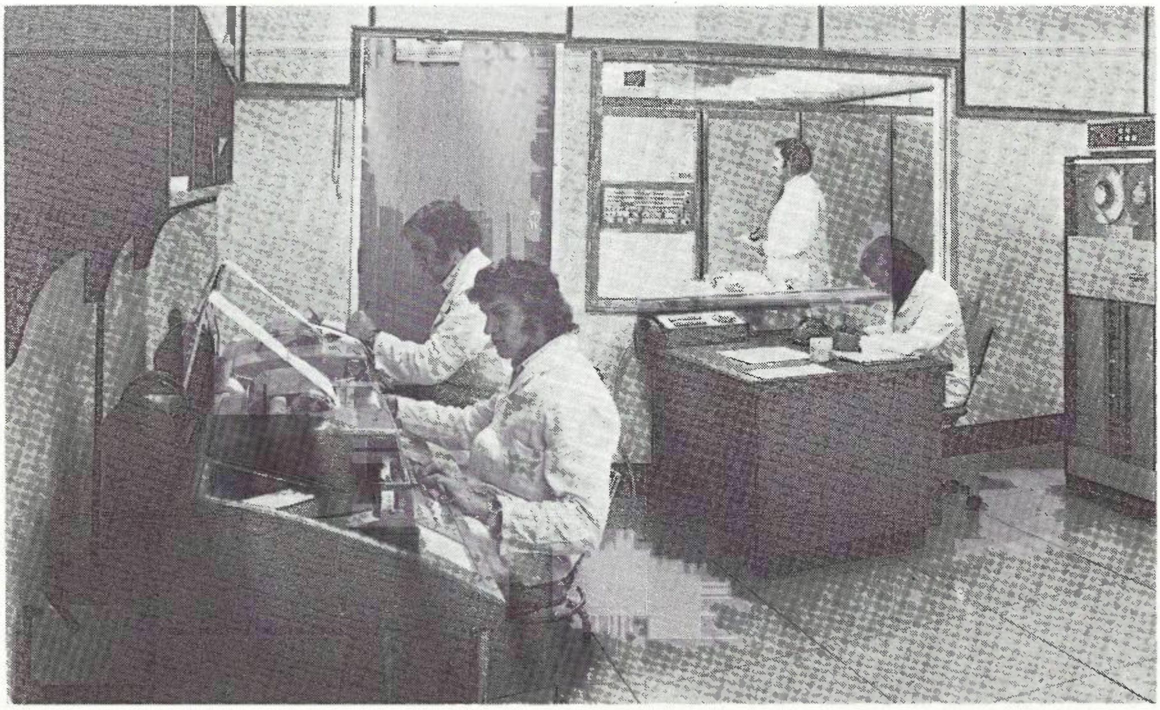


Fig. 3—

be quickly rectified by replacing a printed circuit board. If necessary, the contents of the processor memories are automatically reloaded from standby magnetic-tape units. Calls in the conversation phase are not interrupted by reloads.

Normal operating and maintenance functions of the exchange are performed using teletypes for man-machine communication.

The Australian version also includes a traffic route tester for automatic measurement of the quality of service to subscribers, an automatic transmission tester, test consoles (Fig. 1) on which tests are made on the external circuits connected to the exchange, and manually operated service assessment positions (Fig. 2).

The service assessment positions are remotely located at the Dalley exchange and incorporate some of the operating and design features of the manual operating positions currently being installed, for example, docketless operation, selfscan display and general programming techniques.

A wide range of information, including circuit and device occupancy, total traffic and revenue, and the results of tests made by the operating, maintenance and service assessment facilities, is recorded on magnetic tape and is processed by the APO ADP facilities.

Fig. 3 is a composite picture of the maintenance control room. Commencing at the left of the picture, the equipment shown is:

- Control room teletypes.
- System program tape reload magnetic tape units.
- Statistical and other information magnetic tape units.
- Alarms, traffic route tester.
- Automatic call sender.

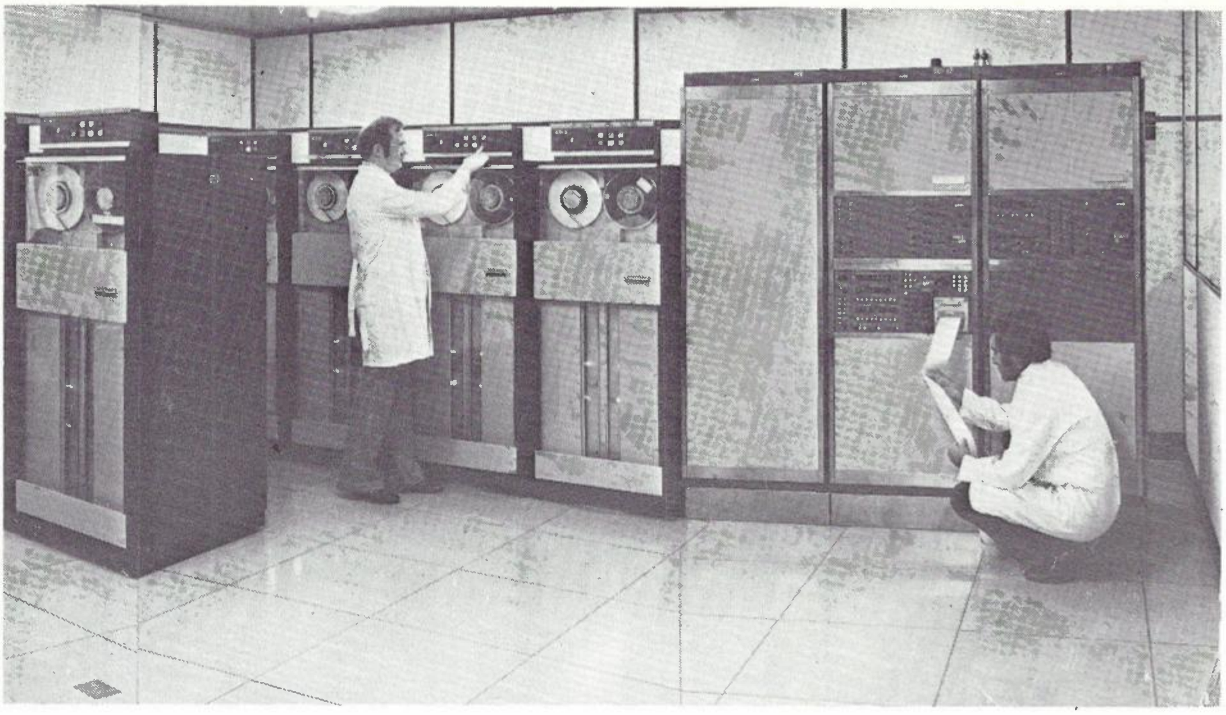
One of the central processors can be seen through the window.

DEVELOPMENT OF THE 10C SYSTEM FOR PITT

The development of the system for Pitt was undertaken by Bell Telephone Manufacturing Company (BTM), Belgium, an associate of STC. During this stage, teams from STC and APO were located at BTM for periods of between two and three years to participate in development work, and to ensure that matters requiring interpretation of APO requirements and an understanding of the detailed operation of the APO national telephone system were dealt with as they arose.

The teams included:

STC:	Engineers	14
	Technical Officers	7
APO:	Engineers	7
	Programmers	2



Maintenance Control Room.

As well, over 50 short term visits were made to Belgium by STC and APO specialists, 33 technical meetings between APO and STC were held, and APO requirements were clarified in detail in many technical documents.

INSTALLATION

The initial Pitt trunk exchange consists of 500 racks, 30,000 printed circuit boards, three million reed relay inserts, over one million wire-wrapped teminations and two central processors. It is the first of its type in Australia, and installation techniques and standards were developed and refined as the work progressed, to facilitate their use at subsequent installations.

Installation of the equipment was carried out by STC, using a combined BTM/STC installation team with APO personnel also participating to gain experience with the system.

The installation cabling involves a large-scale use of wire-wrapped terminations and the quality of these connections was continually checked, including a daily check on the wrapping guns.

The initial installation occupies most of the eighth floor of the building as well as part of the seventh floor. Fig. 4 shows some of the switching equipment on the seventh floor.

Two other floors are set aside for the manual assistance positions (about 250) which will interwork with the existing switching equipment. These positions are currently being installed.

The various aspects of installation work were documented by STC and approved by the APO.

INSTALLATION TESTING

STC/APO teams developed the principles and techniques to be used for installation testing. APO staff were closely associated with testing as it progressed, and became increasingly familiar with and confident in the exchange operation and performance. Regular APO/STC progress review meetings were held.

Installation testing was in the following stages:

- Central processor and common control.
- Switching and peripheral equipment hardware.
- Off-line testing of software.
- On-line testing of call processing software.
- On-line testing of other software packages.
- Integration of all software into an operational exchange.

While hardware testing was proceeding in each of the switching modules, operational software was being tested off-line. When hardware testing was completed the operational programs were loaded.

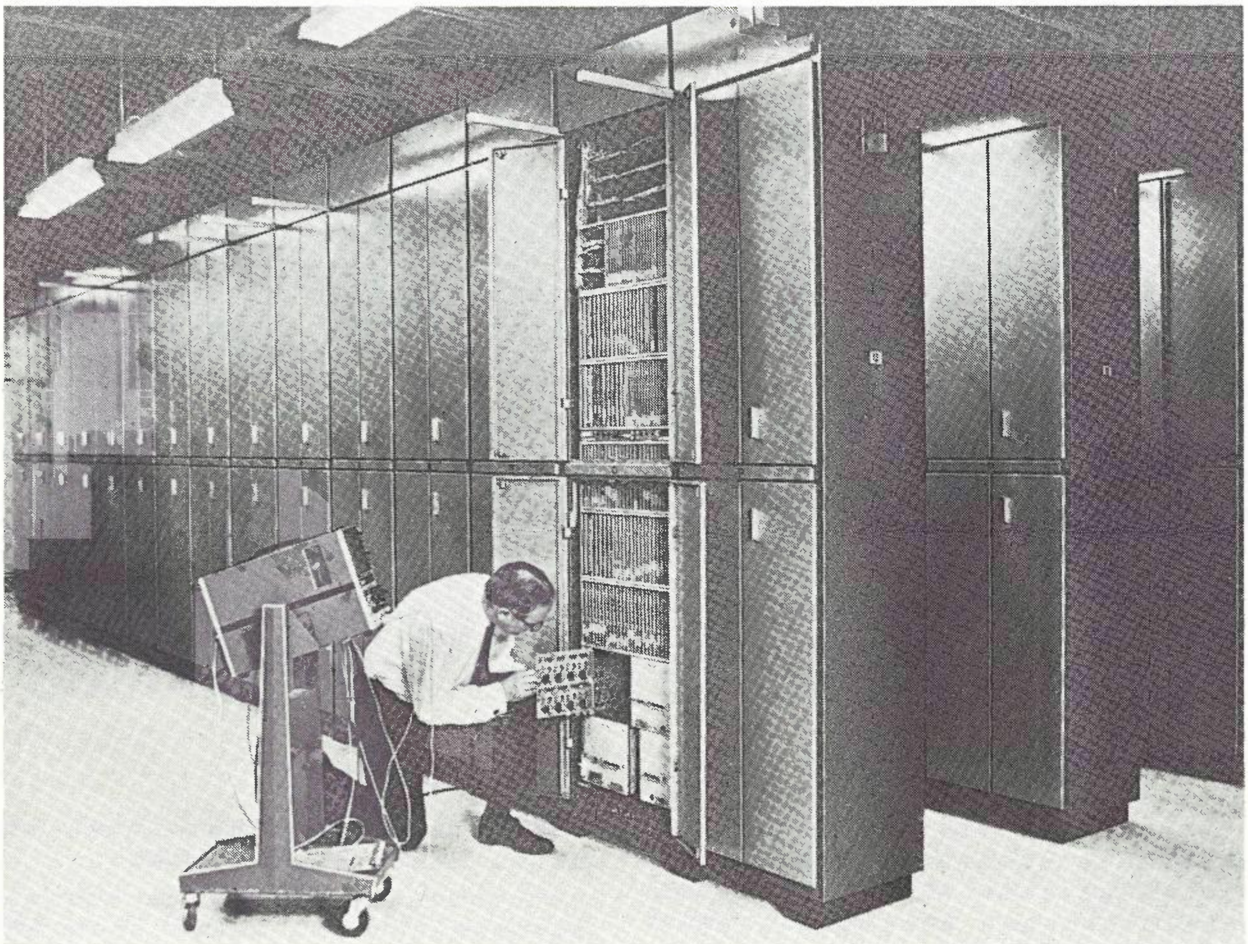


Fig. 4—Switching Equipment.

The call processing software was tested first, then a background of test traffic was established using machine test-call generators and answering equipment located at Pitt and at other exchanges throughout Australia, as well as traffic generated by APO staff. Against this traffic background, the various other software packages were tested individually and then progressively as combinations, until the exchange was proven to perform all its functions under operating conditions.

Particular care was taken with Takeover and Recovery, the important software package which detects and reports a trouble, and reconfigures the exchange so that the trouble does not affect service to the subscribers.

In addition, tests were performed by introducing faults into the equipment to check that the exchange reacted as expected, and that the faults could be traced by maintenance staff to the printed circuit board involved by using the teletype printouts, the maintenance documentation, and other information available.

In mid-June 1974, the APO and STC agreed that the criteria for handover had been met, and APO acceptance testing commenced.

ACCEPTANCE TESTING

Acceptance testing followed closely the principles of installation testing except that the APO controlled all activities. Weekly APO/STC review meetings were held.

Acceptance testing was in four main stages:

- Central processor and common control testing.
- Switching and peripheral equipment hardware testing.
- Software facilities testing.
- Testing as an operational exchange.

All hardware and individual software areas were tested and proved before operational testing commenced in week 7.

The central processor and common control equipment is vital not only to the operation of the exchange but also to much of the acceptance testing. It was tested in the first two weeks largely by using off-line testing programs.

Other common control equipment such as power supplies and alarms was tested by conventional means.

The automatic call sender, traffic route tester, test consoles and service assessment positions, were also tested early in the period, partly using test programs and partly using tightly specified manual methods.

Installation tests of software were sampled in major areas.

From Week 7 the exchange was in a pseudo-operational state. That is to say, the exchange was kept operating continuously as far as possible, all software packages were active, all equipment powered-up, substantial numbers of test calls were processed and all ancillary devices such as test consoles, automatic test equipment, teletypes, and service assessment positions were utilised.

Operation and installation staffs performed typical duties such as fault detection, magnetic tape handling, use of on-demand programs and testing of external trunk circuits. This integrated exercising, when many combinations of hardware and software were interacting dynamically, exposed the more obscure problems so they could be corrected. The faults from Week 7 onwards were mainly of this nature.

Fig. 5 shows the hardware and software faults found during each week of acceptance testing. The peak in Week 7 reflects the situation when all software packages were activated simultaneously.

The APO generated non-subscriber test traffic throughout this pseudo-operational period, to provide:

- Background traffic against which other exchange operations could be conducted to ensure that there was no adverse effect upon call handling.
- A measurable load to check the accuracy of charging, routing and destination of calls, statistics, service assessment, grade of performance, service features, etc.

When the exchange had passed all the tests using non-subscriber traffic, about 100 Erlang of selected subscriber traffic was let into the exchange in the last two weeks.

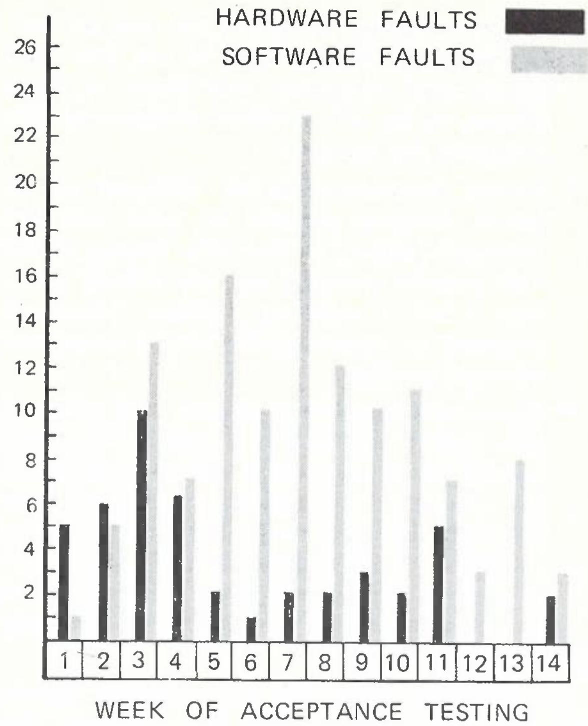


Fig. 5—Hardware and Software Faults During Acceptance Testing.

The grade of performance given to this subscriber traffic was measured by sampling 2300 calls with the service assessment facility. The grade of performance was better than that experienced by subscriber traffic elsewhere in the network.

A measure of system reliability is the weekly count of duplex (both processor) failures and reloads. See Fig. 6. Increased reliability can be seen as the acceptance testing and fault rectification process continued.

Reloads still occur from time-to-time, but with reducing frequency as the causes are identified and eliminated.

Some problems occurred when the 10C system was interacting with the APO network with moderate traffic loads. The service assessment facility gave the first indication of some of these, for example:

- A high call failure rate due to congestion on carrier routes was observed. Line signals from the APO network were misinterpreted in some cases by the 10C software, and the effect was that the relay set at the distant end was held but the outgoing junctor at Pitt was set free. Consequently the next call to use this trunk encountered congestion and failed. A modification to the call handling program quickly overcame this problem.

- Service assessment records indicated an apparent charging anomaly on some calls and apparent charging on free calls. Testing proved that incorrect charging was not actually occurring; it was a recording problem, which was corrected by amending the service assessment software package.
- The service assessment display and magnetic tape record indicated that part of the called number was being added onto the end of the full number. Investigations revealed that although the calls were not failing, partial repetition of the number actually was occurring; some distant exchanges had not carried out specified equipment design modifications.

ACHIEVEMENT

In September 1974, the APO and STC agreed that the criteria for putting the exchange into service had been met, and in some instances surpassed.

SERVICE EXPERIENCE

The exchange performance during the first few weeks in service with 950 inlets and 1960 outlets connected has been good.

Initial teething troubles have been overcome and the staff in the exchange and in support have rapidly become experienced with the technical and operational capabilities and limitations of an SPC exchange.

The number of duplex processor reloads is decreasing. (See Fig. 6).

The exchange is providing considerable information to assist network performance groups. It monitors the signalling of each call it switches to a greater extent than has previously been practicable, and provides detailed printouts of any non-standard conditions encountered. These printouts are analysed by APO staff, and when justified remedial action is taken in the exchange concerned.

DESIGN AND OPERATIONAL SUPPORT FACILITIES

STC is responsible for the design of the system and has established a design centre in Sydney. It consists of processors and peripheral equipment and its role is to provide a complete software design facility.

The APO has operational responsibility for the national telephone system and has established a model 10C trunk exchange as part of the simulated national telephone switching network at the H.Q. Telephone Switching Equipment Laboratories in Melbourne. It consists of a 2-processor CPU, peripheral equipment and a 256 termination switching network. It is linked to the Pitt exchange via a data link.

The main functions of the model exchange and its staff of Engineers, Programmers and Technical Officers are:

- Providing a 24-hour consultative service to field exchanges, especially on urgent software problems.
- Preparing system tapes and other supporting software to ensure program and data software at field exchanges is up to date.
- Verifying new hardware and software designs before they are introduced into field exchanges.

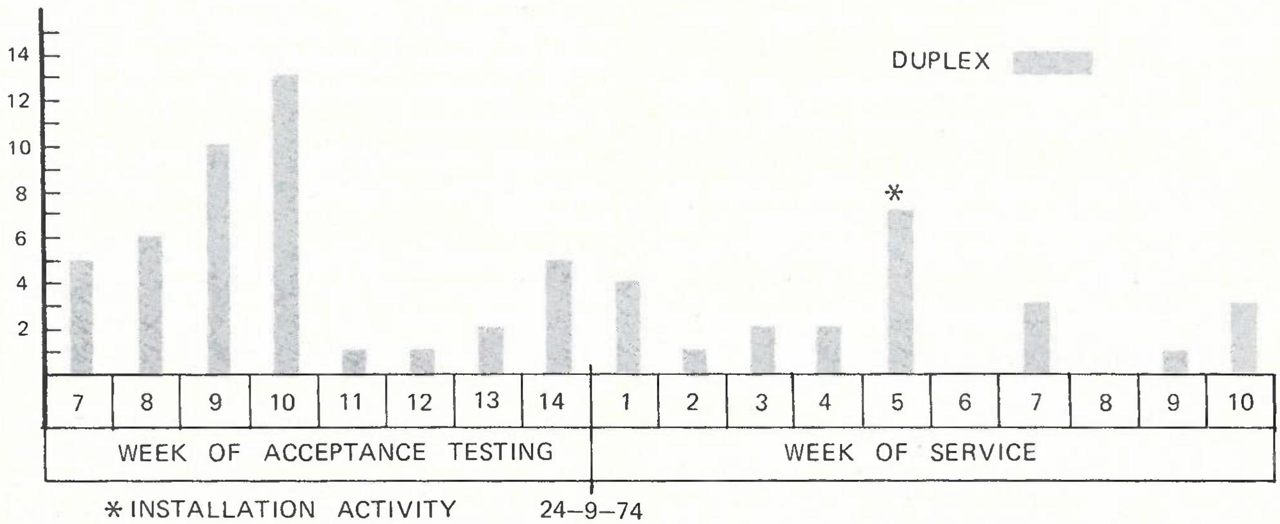


Fig. 6—Duplex Reloads During Acceptance Testing and Early Service.

MAGNETIC TAPE OUTPUTS

Statistical information relating to the operation of the STD exchange is recorded on magnetic tape which is then processed by the APO ADP facility in Melbourne. Information produced includes:

- Volume and dispersion of traffic on various routes.
- Occupancy of devices in the exchange.
- Service assessment information.
- Call and revenue statistics.

TRAINING

The first four training courses for APO staff were conducted by STC and BTM experts over a period of 15 months. They were each of six months duration and enabled key APO personnel to become familiar with the new technology.

APO instructors from HQ attended these courses and then developed courses more directly related to the range of APO staff that would be involved in later 10C trunk exchange projects.

The first APO courses have been held and are being evaluated. They are:

- Appreciation — 1 week; all categories of staff.
- Servicing and network maintenance — 3 weeks; Telecommunications Tradesmen.
- System maintenance and acceptance testing — 20 weeks; Engineers and Telecommunications Technical Officers.

CONCLUSION

This paper deals briefly with the installation, acceptance and early service performance of the Pitt STD trunk exchange which was put into service in September 1974 as a second main trunk exchange for New South Wales.

ACKNOWLEDGEMENTS

The introduction of the new technology into the existing national telephone system involves many people throughout STC, BTM, APO Headquarters, APO New South Wales and other APO State Administrations. The authors wish to record their appreciation of the competent and enthusiastic work done by all who have contributed and are contributing to the success of the project.

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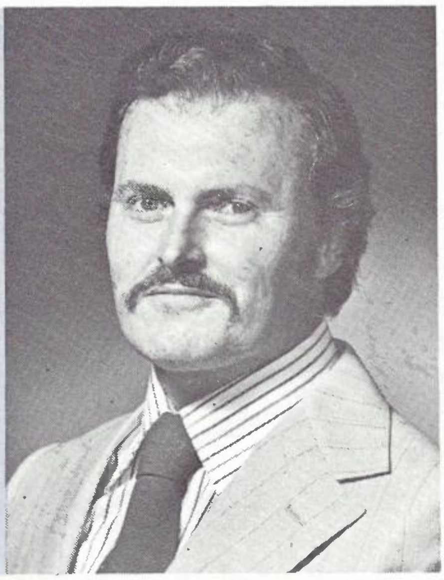
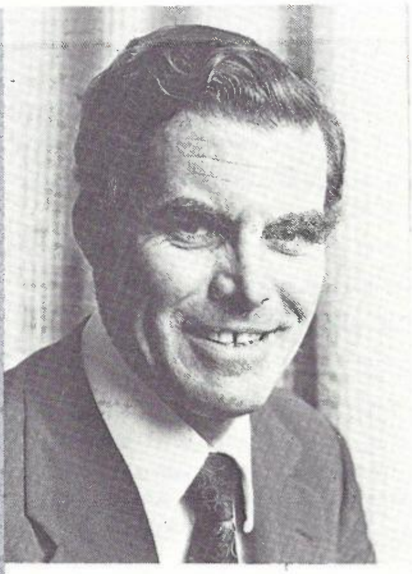
R. J. HOLT joined the APO as a Cadet Draftsman in Sydney in 1953. After advancement to Engineer in 1958, he was engaged in the installation of telephone exchanges in the metropolitan area of Sydney as an Engineer Class 2 in 1959 and as a Class 3 in 1966. In 1970, he was transferred to the newly formed electronic exchange installation section as installation project engineer in charge of the Pitt 10C Trunk Exchange Project. He was departmental Liaison Officer for the Pitt 10C exchange contract with STC during the STD portion of that contract from 1970 to 1974.

He spent a total of five months in 1970 and 1972 at the factory of the design house, BTM, Antwerp, Belgium, advising on site and installation requirements.

Mr. Holt is currently a Principal Engineer in the Switching and Facilities (Metropolitan) section of the NSW Planning Branch.



G. PAGE-HANIFY is General Manager of the Electronic Switching Division at STC Pty. Ltd., Sydney. He holds degrees in Engineering and Commerce from the University of Queensland. Prior to joining STC in 1960, he was an APO Engineer in Queensland, where he participated in the installation of the first ARF crossbar exchange in Australia at Toowoomba. He initiated the crossbar engineering group at STC in 1961, and during the mid 1960's he was engaged on the development of electronic switching systems. In 1969 he established STC's 10C Division. Since August 1974, he has been responsible for engineering, manufacture and marketing of Metaconta 10C exchanges and electronic Minimat PABXs.



W. R. DEDRICK commenced with the A.P.O. as a Clerk in 1937, and after war service with the A.I.F., he completed an Engineering cadetship and qualified as Engineer in 1950. He has worked on subscribers' installation, professional and technical training and the design of telephone switching equipment, including PABXs. Since November, 1971, he has been APO project manager for the 10C trunk exchanges being installed at Pitt (Sydney), Lonsdale (Melbourne) and Waymouth (Adelaide). He is an Editor of this Journal.

A New MIS for Exchange Construction Work

G. NOTI, B.Sc., B.E. (Hon), Ph.D., MIEEE, MIREE, M.E.Ch. Soc.

A new management information and control system suitable for construction work is presented, ARF installations work is PERT scheduled by subdivisioning it into 20 to 30 units. This results in a simple and flexible schedule which is easily adjusted to the required accuracy, can be updated efficiently and be used for effective control of resources.

It provides the technical staff with an enriched and more challenging work environment based on worker participation and resulting in better staff morale, increased productivity and target performance.

INTRODUCTION

The last few years have seen the introduction of systems approach to planning and managerial decision making. Systems analysis is a process that interrelates the systems approach and the planning process in such a manner that the solution obtained is optimal overall and is not the sum of optimal solutions to additive parts of the problem. Program Evaluation Review Technique (PERT) is one of the better known techniques of systems analysis (Ref. 1).

Most large organisations attempted to use some form of PERT to assist planning, scheduling and controlling of work. But since PERT in its basic definition is rather vague and if used from first principles rather time consuming in the implementation phase, organisations intending to use it generally simplify it and modify it for their specific application. The APO followed this trend and several handbooks were published by the Department which adopted PERT to the specific problem of Telephone Switching Equipment Installation and Testing (Refs. 2 to 6).

All of the above attempts made use of several hundred activities, varying widely in duration, from as short as 10 minutes unit time to as long as 20-100 hours (Refs. 5 and 6). Such a large number of alternatives possible could be expected to yield an unwieldy problem even if solved using a computer. Fortunately, there are very few restrictions in the order of work in an ARF installation and hence a PERT schedule describing such an installation consists largely of parallel lines and very few dependent branches. This makes the solution, although very time consuming and complicated, possible even using manual methods.

DEFICIENCIES OF PREVIOUS SYSTEMS

There are a number of weaknesses in the present PERT networks for ARF installation. Since the breakdown of the job is so detailed, there is considerable time required not only to obtain the original plan of execution but also to implement a feasible control system. Part of the problem is the reporting and updating. Because of the short unit times involved the time taken for reporting and updating can be comparable with the relevant unit time. This directly implies an inefficient operation overall.

A PERT schedule is only useful if it can be accurately followed. This implies that the installation manager has complete control of material supplies. This, however, is not the case unfortunately, and hence, due to this additional (variable) constraint combined with the very detailed nature of the schedule frequent reschedulings are necessary. The more detailed the breakdown of the work, the more susceptible it is to changes in material supplies and the more time consuming the rescheduling becomes.

From the above discussion it is clear that the PERT schedules obtained are time consuming to prepare and can lack the accuracy required of them. This in turn tends to lead to inaccurate reporting and even less reliable schedules and control system.

DESCRIPTION OF THE NEW SYSTEM

Instead of the 200 to 300 units, the work is to be subdivided into 20 to 30 logical units. These units should correspond to distinctive phases of the installation work. The PERT schedule is to be based on this. Once such large blocks are used as units for scheduling there is a certain amount of sequential dependence. The manual solution of the problem is quite easy.

Considerable attention should be paid, however, to the estimated times. This method of scheduling was first employed during the acceptance testing of the Pitt ARF Exchange. The exchange holds 20 000 lines at this stage, 6 000 lines were put in service during the first stage and the remaining 14 000 are to replace most of the old City North Exchange. The estimating and planning of an approximate strategy of implementation was carried out by the engineer and supervising technical staff, i.e. TTO2-s and STO-s. Based on these plans a PERT schedule was manually prepared, further discussed and modified. The final schedule was accepted by all technical staff as optimal from the practical point of view subject to the relevant restraints.

For instance, the acceptance testing of the GIV and 1GV stages were each broken down to 'functional' and 'outlet testing'. The testing of registers and associated equipment was broken down to 'strapping', 'testing', 'functionals', 'DS, KS and KSAN' testing. These were entries which represented much smaller unit times e.g. 'establish PBX groups', 'testing PBX groups' and 'testing of permanent meters'. It is worth noting, however, that the smallest unit time was 4 manweeks and the next smallest, 6 manweeks, i.e. long enough to occupy at least two men sufficiently long time, that they felt that they were as a group responsible for their own performance in an identifiable manner.

The final schedule is drawn up in the format of a bar chart, with the time axis labelled in terms of absolute time (i.e. days and months of the year — see Fig. 1). The bar shown is for SL stage testing (say) for the 14 subunits. The starting date is 10/3/74 and expected completion date is 1/5/74. Once the PERT bar chart is drawn, time consideration no longer enters the reporting system. The performance is reported as a percentage of the relevant subunit of work. Thus, if 7 subunits have been acceptance tested, then an 'achievement bar' is drawn as shown (dotted line). The length of that line is drawn with no regard to the time axis. Thus, if the work shown was completed on the 11/4/74 then from the time axis it can be read off, that the work is 6 days behind schedule. It is worth also noting that when the bar chart is drawn an absolute time axis is used, and allowance is made for weekends and holidays. All future considerations are in terms of actual elapse time.

ADVANTAGES OF THE SYSTEM

The greatest advantage of this system is its simplicity. It is in this regard that the difference from the previous systems is most apparent. The preparation of the schedule is relatively simple.

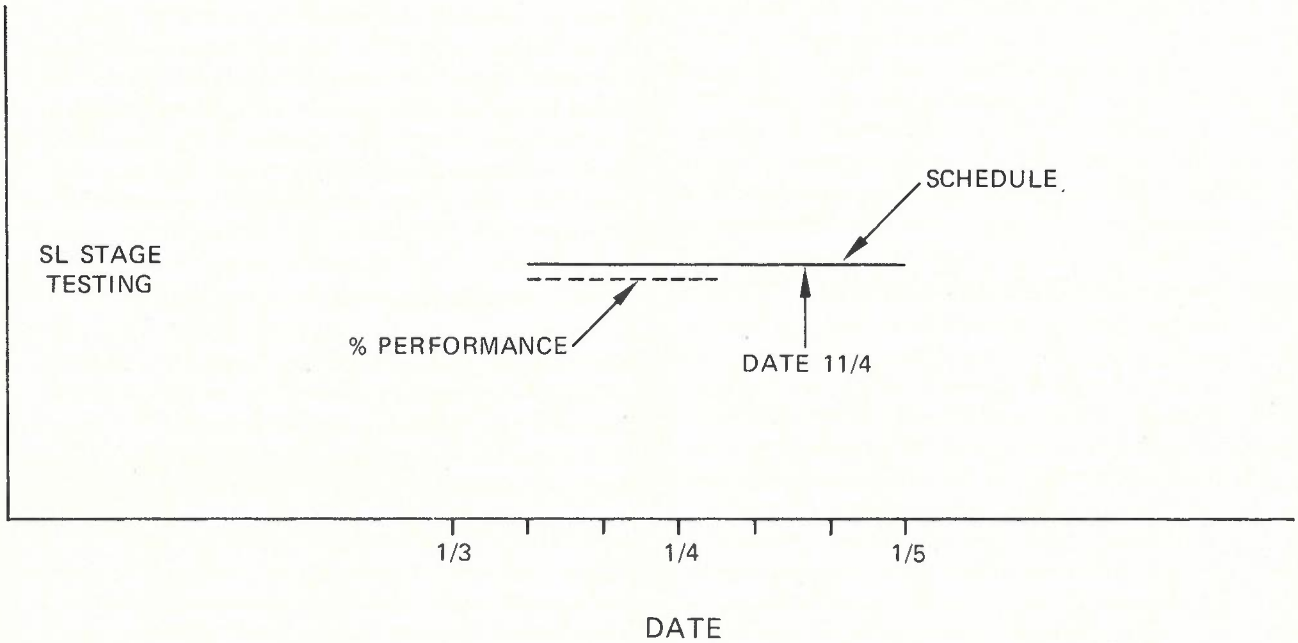


Fig. 1 — Bar Chart

Its updating consumes little time and is not only meaningful to the person reporting but also simple. During the acceptance testing of the Pitt St. Exchange the updating was carried out weekly by an engineer for the first contract and by an STO for the second contract. Three TTO-s spent about 20-30 minutes and an STO about 2-3 hours weekly on the updating.

The great success of this method is largely due to the fact that the formal structure used is quite similar, if not identical, to an efficient informal structure (Ref. 7). The units of work used are large enough to correspond to the responsibility of a TTO1. Because of its relatively large size, unexpected hold ups or difficulties can be compensated or solved by mental rescheduling *within* the unit. This is the type of information a technician is capable of processing and, in fact, forms part of his normal duties. Under the previous system, the slightest problem required a completely unnecessary rescheduling, because of the small units used. Apart from the actual time lost, the previous system has negative effects on the performance of staff; it takes away all sense of responsibility from them.

Under this system, the staff is committed to the schedule: they help to plan it, they feel responsible for its success, it is a team effort. TTO1-s and 2 discuss minor reallocation of resources within units as part of a normal day's work; verbally.

A large bar chart was put on the wall in the exchange and was updated weekly. This way everyone was involved, everyone knew how they were performing. This type of feedback is essential for success (Ref. 8). Every job is meaningful to the staff involved and they can see how it fits into the overall plan.

SECTIONAL AND BRANCH CONTROL

So far, only the use of the system at subsectional level was discussed. However, the system is just as useful at sectional and even branch level, depending on the magnitude and the importance of the particular installation. Once a schedule is prepared for each job that must be completed in the section, resource allocation is possible.

Since each schedule consists of only about 20 to 30 units, material and manhour needs are clear without being unnecessarily too restrictive. A small change in the available resources could leave the schedule unaffected. Even if rescheduling is required due to new restrictions, the extent is minimized by using the large units. Also, since the complete scheduling itself is simple, all subsequent complete reschedulings are also simple.

The output of subsectional demands can be used to reallocate resources, if it is felt that a particular job must be completed because of some restrictions, such as directory etc.

The above also holds at branch level. Allocation of material and manhours are made based on a summation of schedules. Again, if some installation has overriding importance it can be given preference at the expense of one or several other installations, and one section can be given priority over another. The schedules prepared for Pitt St. Exchange were in fact used as the basis for reallocation of manhours and testing equipment in the Construction Branch.

ACCURACY AND FLEXIBILITY

So far nothing has been said about the accuracy that can be achieved using this MIS system. In fact, the 20 to 30 units of work to be used were not listed either. This list is not omitted accidentally; it is omitted to underline the fact that it depends on the particular job and on the field staff. The ideal subdivision of work can be best understood when compared to responsibility accounting (Ref. 9). A unit of work can be one which would normally be the responsibility of a TTO1. This implies directly that the bigger the installation is, the more units should be used. This makes good sense, since the importance of a job tends to be related to its size especially when resource allocation is considered. On the other hand it is not implied that the number of units used for scheduling is equal to the number of TTO1's, but rather to the number of logical parts of the job, each of which is likely to be the responsibility of a TTO1.

The achieved accuracy of the schedule is the wanted accuracy. In the planning of the acceptance testing of the Pitt St. Exhange, staff level variation due to 'random' factors were also considered. These considerations included staff fluctuation due to taking of annual recreation leave and sick leave, resignations and recruitment. On smaller jobs one might justifiably neglect these affects as a first approximation.

In general, the discussions about completion times can be based on 'agreed times' (Ref. 6). Then only deviations from the normal difficulty need consideration and adjustment to the completion times are made. This approach is especially important for acceptance testing of contractor installation. No two installations are identical or have the same complexity, hence no two installations have identical completion times.

It it also possible that the plans for the original installation are significantly changed. This normally means additional work; a new unit of work should then be introduced in the schedule.

The new installation might have some new features, or simply features they have not encountered as yet. A brief 'training course' treating these features may well pay dividends.

FIELD STAFF PARTICIPATION

The MIS introduced and discussed was shown to be a flexible system for scheduling installation work of the APO. It would be misleading to believe that the success of this method is due to purely technical superiority. Far from it, staff participation is an essential part of the system.

The previous PERT systems aimed at increasing productivity by mechanizing every detail of the implementation phase. When every detail is programmed, all initiative is taken away from the technical staff, with consequent loss of job interest, and loss of efficiency (Ref. 10).

By making the task more meaningful, encouraging thought and initiative, and providing greater participation in the setting of goals, the new scheme paves the way for increased productivity and efficiency.

The use of larger units of work introduced units on which at least two or three people can work for 2 or 3 weeks. It introduces a group performance criteria and sets meaningful group goals in terms of achievable, functional targets.

CONCLUSION

It has been shown that the MIS presented has several advantages over the previously used PERT methods. It is simpler and less time consuming to schedule, update and implement. Its inherent flexibility and adjustable accuracy makes it competible with variable constraints of resources and results in virtually eliminating reschedulings.

The setting up of schedules in conjunction with technical staff result in goals to which the staff is committed. Large units of work constitute group goals which encourage initiative and result in a meaningful task. The net result is better staff morale, high productivity, and performance efficiency.

ACKNOWLEDGEMENTS

The author is indebted to Messrs K. Douglas and R. McCarthy for their support in the implementation of the MIS described and to Mr K. Douglas for helpful discussions of the manuscript.

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G. Noti joined the APO in 1963 as a Cadet Engineer. He graduated from the University of Sydney as Bachelor of Engineering in 1967, gaining Distinction in his final year with First Class Honours, and was appointed as Engineer Class 1 in the Training Subsection of the Support Services Branch. He was granted a Post Graduate Scholarship and completed studies which led to a Doctor of Philosophy Degree in Electrical Engineering.

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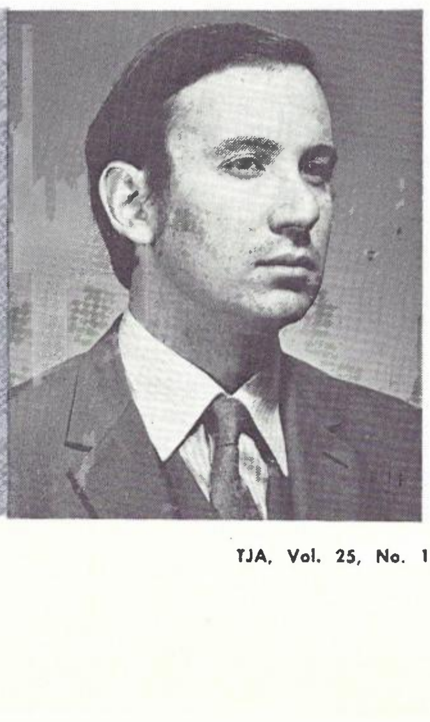

Television Transmitter Luminance Linearity Measurements

D. GOSDEN, B.E., A.M.I.R.E.E. (Aust.).

Television transmitter luminance line-time linearity measurements are carried out by a number of different techniques at present. These are classified broadly into three categories:

(a) those where a sawtooth or staircase signal is observed directly.

(b) those where a staircase is differentiated and the resulting pulses evaluated.

(c) those where another signal such as a low amplitude sinewave or a series of pulses is superimposed on the sawtooth or staircase signal. After transmission the superimposed signal is separated and evaluated.

These techniques often lead to inaccurate results (for various reasons). Where a sawtooth or staircase signal is observed directly, meticulous care is necessary to produce repeatable results, especially as the result will be affected by instrument linearity. Evaluation of the superimposed signal is much easier but if the transmitter has a level dependent amplitude/frequency response then errors will occur. The amplitudes of the pulses resulting from the differentiated staircase can also differ due to level dependent frequency responses—amplitude and/or phase.

The technique described in this paper involved measurement of a differentiated sawtooth signal. This method produces a result which is easy to measure and is not affected by level dependent frequency response errors.

INTRODUCTION

The line time linearity of a television system is an important factor in determining how faithfully the system will reproduce brightness values contained in the original picture. Ideally, except for intentional gamma correction, the transfer characteristic from the camera tube output to the receiver picture tube input should be perfectly linear. In practice, however, errors creep into the system which distort the transfer characteristic making it non-linear. The transmitter is usually the most serious offender because of the non-linear transfer characteristics of high powered vacuum tubes. The transmitter characteristic is usually improved by the use of adjustable linearity correctors. Their use requires a specification for linearity and a method of easy measurement to enable operating staff to carry out the necessary adjustment.

SPECIFICATION AND METHODS OF MEASUREMENT

There are essentially two techniques being used in Australia at present for the measurement of transmitter linearity. The method used by the Australian Post Office is based on CCIR Test Signal No. 3 for line time linearity measurements of television systems. (Ref. 1). Essentially, the method uses a saw-tooth signal on every fourth line, upon which is superimposed a low amplitude sinewave at 1 MHz (See Fig. 1). The three intermediate lines are at black to offset the average level of the signal to the maximum likely to be encountered in an average picture. (Alternatively the three intermediate lines may be at white level to offset the signal in the opposite direction). This signal is then fed into the transmitter, detected, and passed through a high or band pass filter to remove information below 1 MHz. The resulting signal is displayed on an oscilloscope, the part of interest having the appearance of Fig 2. Assuming that the low level frequency response of the transmitter up to about 1 MHz is independent of set-up level, the amplitude of the 1 MHz signal at any point along the line represents the 'incremental gain' and hence the slope of the transfer characteristic at that point. The maximum and minimum amplitudes of the envelope which represents the maximum and minimum slopes of the transfer characteristic are designated M and m respectively. The incremental gain factor is calculated as follows:

$$G = 100 - 100\frac{m}{M}$$

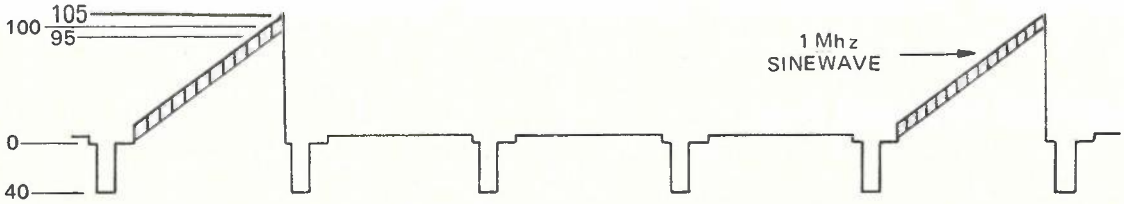

Fig. 1 — Test Signal Used by APO.

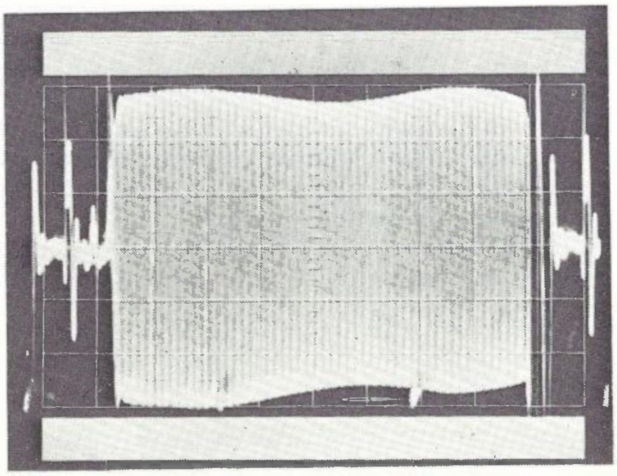

Fig. 2 — 1MHz Signal at Transmitter Output after Filtering.

An alternate method is used by the Australian Broadcasting Control Board (Ref. 2). The test signal is a standard sawtooth signal similar to that used by the Post Office but without the superimposed sinewave. Generally the sawtooth appears on every line rather than every fourth. This signal is fed through the transmitter, detected and displayed on an oscilloscope. The average slope of the transfer characteristic is then determined by passing a straight edge through the start and finish of the sawtooth. The straight edge is then set tangentially to different parts of the sawtooth to determine the maximum slope deviation from the average. The specification requires that the slope of the transfer characteristic at any point shall not deviate from the average slope by more than a predetermined amount.

A third method (Ref. 3) which is used in some other countries employs a multistep greyscale signal (5, 7 or 10 steps) with accurately controlled transitions between the steps. After passing through the equipment under test, the waveform is differentiated and displayed on an oscilloscope. Each step produces a spike whose amplitude depends on the height of the step. Any change in the slope of the transfer characteristic will change the amplitude of the step at that level so the variation in spike amplitude is a measure of transfer characteristic slope.

MEASURING DIFFICULTIES

The technique used by the ABCB measures directly the quantity which is required. That is, the deviation of the incremental slope of the transfer characteristic from the average slope. In measuring the quantity at line rate, effects of variations in the frequency response of the transmitter with set-up level are minimised. Accordingly, the measurement accurately determines the system's low frequency transfer characteristic.

Unfortunately, this method suffers from a serious disadvantage. It is extremely difficult to produce repeatable measurements. An evaluation of the non-linearity of the sawtooth in Fig. 11 by a number of different observers will bear this out.

The method used by Post Office overcomes the difficulties of measuring the slope of the sawtooth signal. By superimposing a low amplitude sinewave on the sawtooth and removing the unwanted information, the requirement for measuring a slope is converted to one of measuring an amplitude. It is important to note, however, that this technique measures the incremental gain of the system at 1 MHz. The incremental gain is not necessarily the same at other frequencies. Fig. 3 shows the sawtooth linearity for the transmitter whose incremental gain at 1MHz is shown in Fig. 2. In this case the transmitter has been adjusted for minimum variation in incremental gain at 1 MHz but because the incremental gain varies with frequency, the sawtooth is severely distorted. Hence it is apparent that the incremental

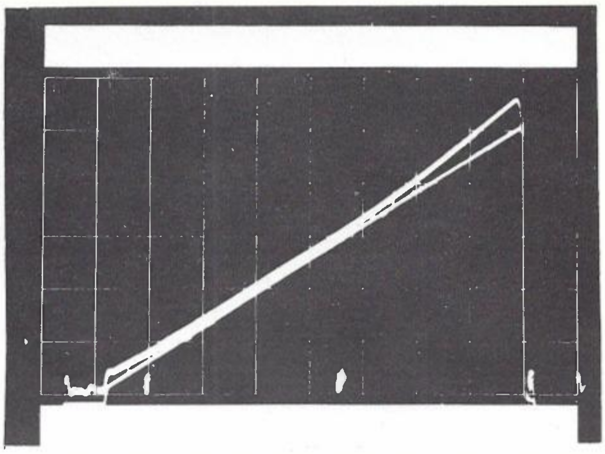

Fig. 3 — Sawtooth Signal without Superimposed Sinewave: Lower Trace — Transmitter Input, Upper Trace Transmitter Output with Linearity Correctors Adjusted to Produce Characteristic Indicated in Fig. 2.

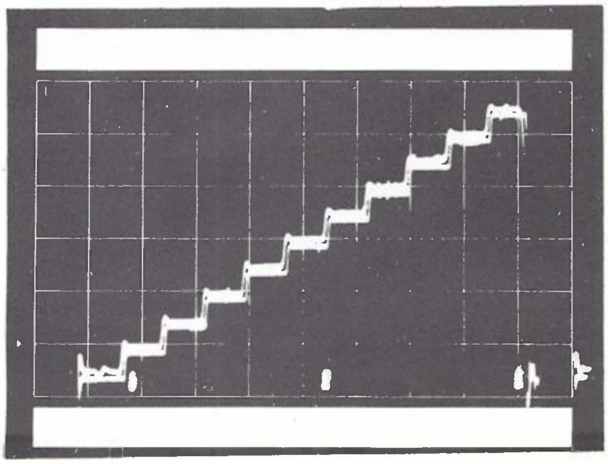

Fig. 4 — Staircase Signal: Lower Trace — Transmitter Input, Upper Trace — Transmitter Output.

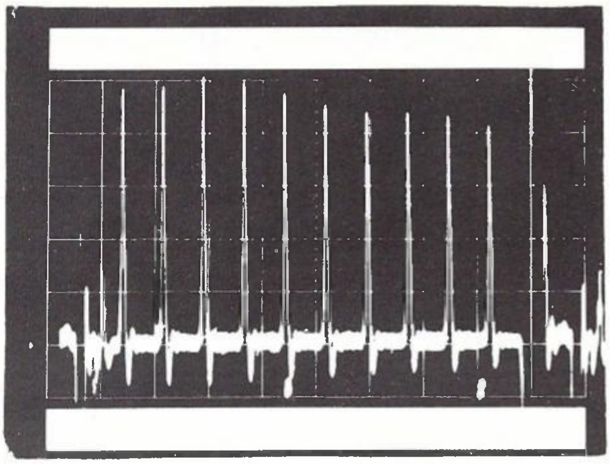

Fig. 5 — Differentiated Staircase Signal at Transmitter Output.

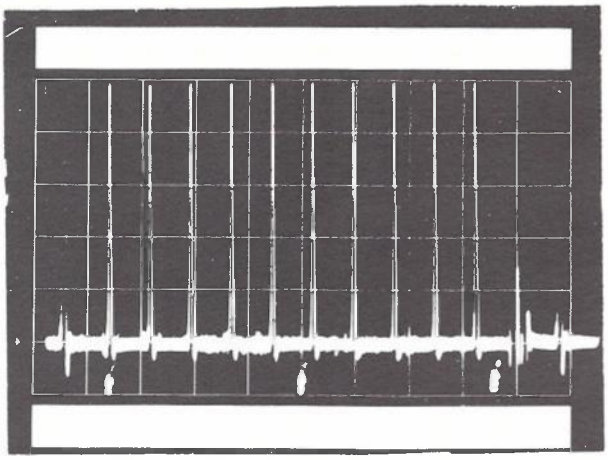

Fig. 6 — Differentiated Staircase signal at Transmitter Input.

gain at 1 MHz is not necessarily a good indicator of the incremental slope of the transmitter's line frequency transfer characteristic. This situation arises for one of two reasons, or a combination of both:

- Phase modulation of the vision carrier may be occurring in sympathy with the intended amplitude modulation. The filterplexer response in the region of the 1MHz lower sideband is generally changing quite rapidly. Hence phase modulation will be converted to amplitude modulation by slope detection. When this mechanism is operating in isolation, the incremental gain is generally constant at frequencies outside the range of approximately 0.75-1.25 MHz.
- The low level amplitude/frequency response of the transmitter may vary with carrier level. The upper and lower sidebands may or may not be similarly affected. In this case the incremental gain will vary with frequency.

The use of a lower measuring frequency such as 0.5 MHz usually results in closer agreement with the sawtooth slope, however, some errors can still occur.

The use of a differentiated staircase signal results in errors similar to those which render the sinewave measurement unsatisfactory. In this case the level dependent frequency response causes a level dependent variation in transient

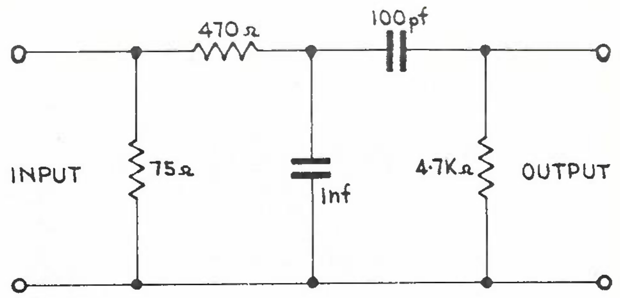

Fig. 7 — Circuit of Differentiator.

response. An examination of Fig. 4 shows that the staircase levels at the transmitter output follow very closely those of the signal generator. However Fig. 5 indicates a considerable variation in the amplitude of the differentiated steps. In fact a close examination of Fig. 4 will indicate a reduction in overshoot after the transition as the staircase progresses from black to white. Fig. 6 shows the differentiated input signal.

SAWTOOTH DIFFERENTIATOR

A method of measuring linearity has been developed which overcomes both the difficulties of measuring the slope of the sawtooth and the errors arising from the indirect methods of measurement. The test signal consists of a standard sawtooth with intermediate lines at black or white as shown in Fig. 1 but without the sinewave superimposed on the sawtooth. After passing through the transmitter and demodulator, it is differentiated and fed to an oscilloscope. The differentiator circuit (Fig. 7) consists of a 100pF capacitor and 4.7K resistor which carry out the actual differentiation. The 470 ohm resistor and 1 nF capacitor reduce the steep slopes encountered in the sync-pulses and the trailing end of the sawtooth. This is desirable to reduce high level spikes which would otherwise appear at the output of the differentiator. Some idea of the amplitude of these spikes may be appreciated by considering that the sawtooth signal takes about 50 μS to progress from black to white whereas it can return to blanking level in as little as 0.1 μS. This means that without some reduction in the high frequency component, the amplitude of the unwanted spikes may be as much as 500 times the amplitude of the wanted signal. Some oscilliscopes could be overloaded by a spike of this amplitude. Fig. 8 shows the output of the differentiator for an input consisting of sawtooth with three intermediate lines at black. The upper horizontal line represents the positive sawtooth slope while the lower represents the zero slope

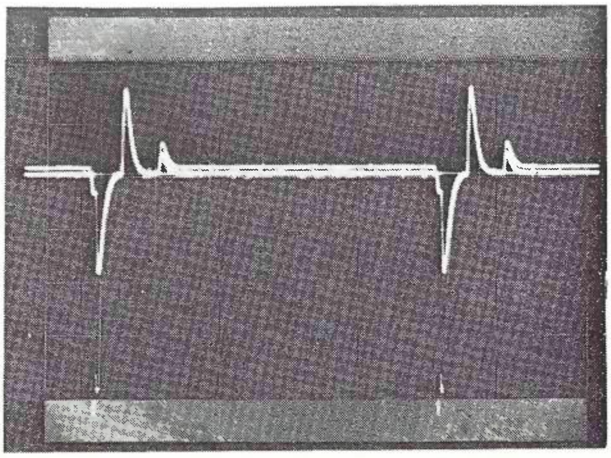

Fig. 8 — Differentiated Sawtooth Signal at Transmitter Input.

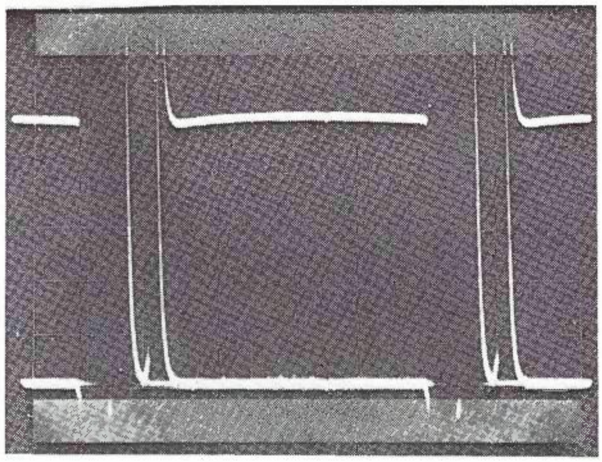

Fig. 9 — Differentiated Sawtooth Signal at Transmitter Input with Vertical Scale Expanded to Useful Level.

of the black lines. The prominent negative and positive spikes are due to the rise and fall of the syncpulses while the two smaller positive spikes are due to the set up from blanking to black and the onset of the sawtooth. The recovery of the sawtooth to blanking can be seen extending to almost the bottom of the picture. These spikes did not cause any overload problem in the particular oscilloscope used. Fig. 9 shows the section of interest expanded vertically to usable proportions. It will be noted that about the first five microseconds of the sawtooth are unusable due to the recovery after the set up. This is not considered a serious deficiency since disturbances rarely occur in this region which are not apparent when the sawtooth is observed directly. However, reduction of the recovery time could be effected

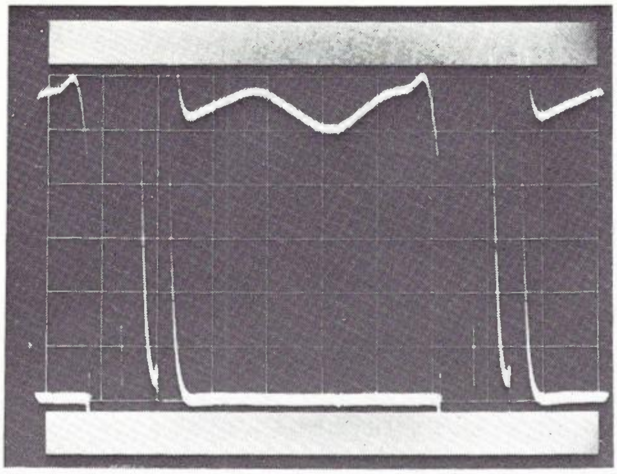

Fig. 10 — Differentiated Sawtooth Signal at Transmitter Output.

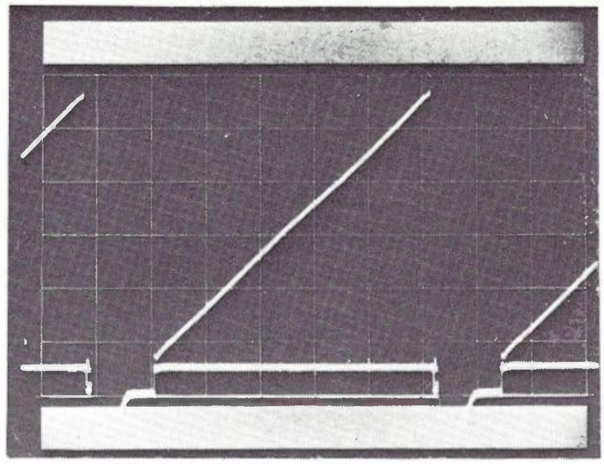

Fig. 11 — Sawtooth Signal at Transmitter Output Adjusted as for Fig. 10.

by reducing the time constants in the differentiator at the expense of higher unwanted spikes and degraded signal to noise ratio.

Fig. 10 shows the differentiated transfer characteristic of a typical transmitter. The ratio of minimum to maximum slope is about 4.5/6, giving a linearity factor of (6 — 4.5) ÷ 6 or 25%. The sensitivity of the measurement can be seen by comparing this figure with the sawtooth before differentiation (Fig. 11). Note the rapid change in slope over the last 3–4 microseconds.

It can be seen that it is fairly simple to calculate the linearity factor in terms of maximum and minimum slopes. It is not as easy to arrive at a figure in terms of the ABCB specification relating to deviation from the average slope. This requires a horizontal line to be drawn through the sawtooth slope trace (Fig. 10) at the average slope level. It is rather difficult to do this accurately by estimation, however, electrical averaging methods could produce good results.

CONCLUSION

A method of measuring transmitter linearity has been developed which will provide accurate, repeatable results without the errors caused by incremental gain measurement at specific frequencies. The technique is simple to use and does not require any unusual test signals or measuring equipment.

Improvements could be made by fitting a clipper to the differentiator to remove unwanted spikes. This would eliminate the need for the components which reduce the steep slopes and have the secondary effect of rendering the first 5 μS of the differentiated sawtooth unusable.

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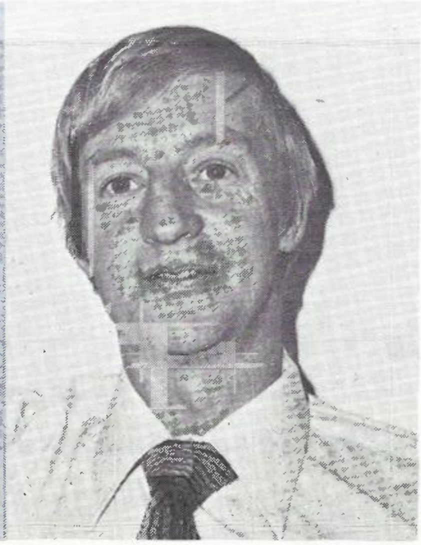
In 1969 he took up the position of Senior Engineer in charge of the installation and operation of National television transmitting stations. In 1971 he established a new group within the Radio Section to undertake the conversion of National television transmitting stations for colour operation. During 1973 he carried out research into drive systems for electric cars and prepared a thesis which was submitted to the University of New South Wales in 1974 for the Degree of Master of Engineering. In July 1974 he left the APO to take up his present position at the Tasmanian College of Advanced Education.



MFC Signalling Principles

J. P. STEENDAM, A.R.M.I.T., Grad. I.E.

This paper outlines the principles involved in compelled sequence MFC signalling. The basic requirements of a signalling system are discussed and comparison made with the manner in which these characteristics are incorporated in the MFC signalling systems in use in the APO telephone network.

INTRODUCTION

The operation of a telephone network relies upon use of information signals between telephone exchanges. Inter-exchange signalling permits telephone calls to be established, supervised, charged and subsequently to be disconnected. In this context, signalling may be regarded as the nervous system of the network.

The Australian telephone network has grown from about 1.5 million to nearly 3.5 million telephone services since crossbar switching techniques were introduced in the early 1960's. At present, nearly 2.5 million lines of local crossbar equipment have been installed in the network and all except a tiny fraction of these crossbar exchanges use MFC (Multi Frequency Code) signalling.

The forward and backward transfer of information that takes place between telephone exchanges can be considered in two categories:

- the signals required to set up the call, e.g. transfer of address digits;
- the signals required to supervise the call, e.g. seizure, answer or clear signals.

Corresponding to these requirements, the signalling functions can be divided into:

- Inter-exchange information signals (used for the establishment and routing of the telephone call);
- Inter-exchange line signals (used for the supervision of the call).

With common control switching as used in the APO crossbar network, it is useful to employ this functional segregation of line and information signals to provide for separate information and line signalling systems.

INFORMATION SIGNALLING

The inter-exchange information signalling or inter-register signalling system is principally governed by the information requirements during the initial establishment of the call. Therefore, as information signalling takes place during the initial establishment and routing of the telephone call, it is feasible to provide complex equipment using common control principles to obtain rapid transmission and processing of the information signals.

The transfer of information between switching points in a multi-link telephone connection may be performed either by link-by-link or end-to-end signalling techniques or a combination of both.

Link-by-link signalling implies that the complete B-party number is received by each switching point (except the last) and requires the regeneration of all digits at each transit exchange. Basically, link-by-link signalling tends to increase the connection time of a telephone call (longer post dialling delay), but does possess certain characteristics which can simplify some equipment design problems. Generally it is not suitable for national networks unless the number length can be easily determined at the originating exchange.

With end-to-end signalling, only sufficient information is sent to each transit switching point to permit routing to be effected. The originating register stores the B-party's number and each switching point requests only those digits it requires so that faster call connections (shorter post dialling delays) result. However, end-to-end signalling is more susceptible than link-by-link signalling to signal distortions due to the transmission path, as these distortions will be cumulative and this should be considered when selecting a signalling system.

In total, the requirements and complexities of the telephone network are such that the information signalling system must be flexible, reliable (which in part implies backward signals), and must provide for error detection, large signal capacity and high speed transfer of information.

MULTI-FREQUENCY (MF) signalling systems have been adopted by many telephone adminstrations with some variations as they meet the above requirements for information signalling, and provides the facilities which are essential for modern switched telephone networks.

TYPES OF MF SIGNALLING SYSTEMS

A number of MF signalling systems have been developed, mainly differing in the principles employed to determine signal durations. The two main systems in use are the Pulsed MF signalling system and the Compelled Sequence MF signalling system and each contains a number of variations to suit particular networks and facilities required.

Each signal in an MF signalling system is represented by a discrete combination of two out of N frequencies (usually N=5 or 6). This gives a self checking and reliable signalling scheme — a parity check ensures that two and only two frequencies are received within set tolerances — and gives up to 15 signalling combinations in each of the forward and backward directions.

PULSED MF SIGNALLING

Pulsed MF signalling employs signal pulses of fixed length. While in most cases these are not acknowledged, some modern systems do provide for acknowledgement either separately or in groups by similar pulsed signals in the opposite direction. Pulsed MF signalling is used extensively in North America, Japan and in the intercontinental network. Examples of this method have been specified by the CCITT for their R1, No. 5 and No. 5 BIS signalling systems (Ref. 1).

Pulsed MF Signalling is especially suitable for signalling via links with long propagation delays such as encountered on some international calls. The information is transferred on a link-by-link basis and if outpulsed in a continuous sequence (unacknowledged en-bloc signalling), high speed transmission of signalling is obtained.

The disadvantages of Pulsed MF signalling are the problems associated with the lack of backward signals, possible loss of signals if subject to short link interruptions and that the signalling equipment must be operated within close set tolerances for reliable pulsed signalling transmission and reception to be achieved.

COMPELLED SEQUENCE MFC SIGNALLING

Compelled MFC signalling is the world's preferred modern signalling system. It has been adopted by a large number of telephone administrations for use in national networks and by the CCITT for regional use. The CCITT signalling system R2 (Ref. 2) which is similar to the Australian system, has been adopted for the European, African, South American, Southern and South-East Asian regions.

The mode of operation for compelled sequence MFC signalling is shown in Fig. 1.

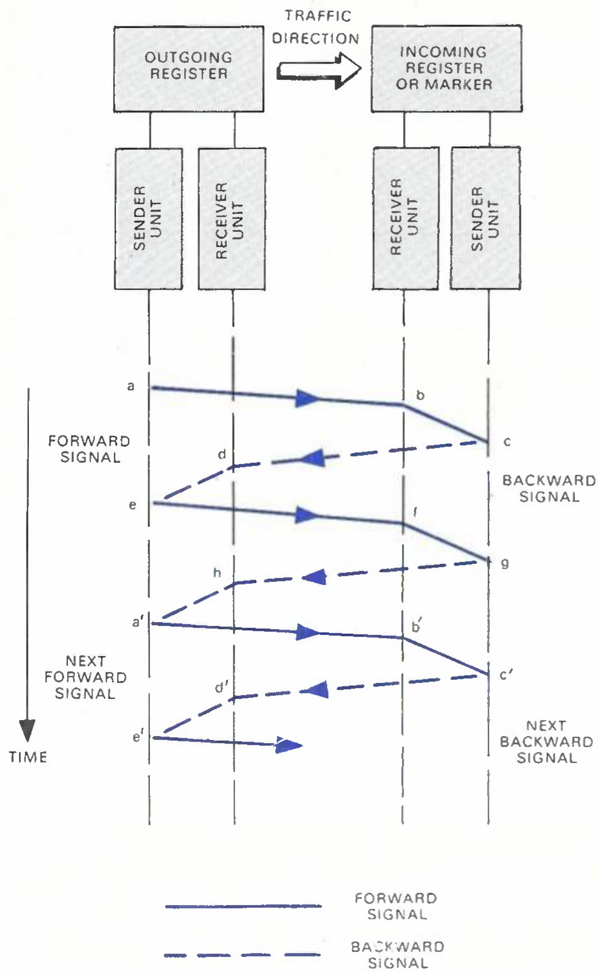
ADVANTAGES OF COMPELLED MFC SIGNALLING

In the selection of an inter-register signalling system, consideration must be given to the features required and the ability to inter-work with the telephone switching systems in use in the communication network. The desired features of a signalling system were outlined under the heading of "Information Signalling", and the Compelled MFC system more fully satisfies the requirements for the APO network than the Pulsed MFC system for the following reasons:

- The length of each signal and the intervals between signals need not be maintained within very tight tolerances, as is the case with Pulsed MFC system. This permits the senders and receivers to be capable of interpreting the pulses within prescribed limits and adapts itself automatically to the signalling speed.
- The compelled method of signalling minimises the error rate and ensures that short interruptions or short bursts of noise generally only slow down the speed of signalling.
- Originating and transit registers can be programmed to permit overlap working and to require the minimum number of digits at each switching point. This results in minimum length post dialling delays.
- Suitable for end-to-end signalling and allows the use of backward signals which greatly enhances flexibility of use.
- Suitable "shift" signal techniques can be employed to extend the number of interpretations that can be assigned to a particular signal during the various stages of the telephone connection to give a much larger signalling capacity.

FREQUENCY ALLOCATION AND SEPARATION

Compelled MFC signalling systems employ forward (numerical) and backward (controlling) signals utilising frequencies within the range of 500 to 2000 Hertz.



LEGEND

a The outgoing register starts sending a continuous forward code signal.
b The incoming device recognizes both frequencies of the forward signal.
c The incoming device starts sending a continuous backward code signal.
d The outgoing register recognizes both frequencies of the backward signal.
e The outgoing register interrupts the forward code signal.
f The incoming device recognizes that both frequencies of the forward code signal have ceased.
g The incoming device interrupts the backward code signal.
h When the outgoing register perceives that both frequencies of the backward signal have ceased, this register may (if possible and required) proceed to send the next requested forward signal.

Fig. 1 — Principle of Compelled MFC Signalling.

Worldwide experience has shown that the choice of this frequency range avoids mutual interference between the MFC signalling system and the exchange service tones below 500 Hz and possible voice Frequency Line signalling schemes above 2000 Hz. Also, it is desirable to limit the upper frequency to permit MFC signalling over loaded junction cables with low cut-off frequencies.

To permit signalling over 2-wire circuits (as well as 4-wire circuits), different frequency allocations are required for each direction of transmission. The upper range of frequencies is assigned to the forward direction and the lower range to the backward direction; each uses constant frequency spacing. For example, in the APO network, the two directions are separated by a spacing of 240 Hz and within each directional band, each frequency is separated by 120 Hz from the next. These spacings have been chosen so as to minimise the interference from both intermodulation and harmonic distortion. Each signal is formed by the selective combination of two frequencies as indicated in Fig. 2. In addition, each individual signal code can have several meanings by changing the interpretation with certain backward shift signals. In the Australian telephone network, this has resulted in 11 Groups of forward signals and 10 Series of backward signals to provide all the facilities presently required in the network (Ref. 3). There is of course much spare capacity — not all the 165 potential forward signals are used. By introducing additional signal Groups and Series, or by using some of the spare capacity presently existing, the signalling possibilities may be extended to cope with any currently foreseen demand.

SIGNAL No.	FREQUENCIES IN Hz					
FORWARD	1380	1500	1620	1740	1860	1980
BACKWARD	1140	1020	900	780	660	540
1	X	X				
2	X		X			
3		X	X			
4	X			X		
5		X		X		
6			X	X		
7	X				X	
8		X			X	
9			X		X	
10				X	X	
11	X					X
12		X				X
13			X			X
14				X		X
15					X	X

Fig. 2 — Frequency and Signal Allocation.

TIME SEQUENCE OF A COMPELLED MFC CYCLE

The duration of an MFC cycle is not determined by any timing arrangements but is controlled by signals in opposite directions; both the commencement and the termination of the signal are determined by the arrival or disappearance of a signal sent by the other end of the connection. The intervals which make up a compelled MFC cycle are determined by the necessary processes required for the transmission, reception, logical analysis and the operate or release times during the transfer of the MFC signal.

An analysis of the timing sequences of an MFC signal is shown in Appendix 1.

SIGNALLING SPEEDS AND RECOGNITION TIMES

High speed transfer of information signals is a basic requirement in modern telephone networks to minimise post dialling delays (especially on trunk and international calls), and to provide for facilities such as alternate routing or re-routing within a limited time period. Further, for optimum utilisation of common equipment, it is desirable to keep the signalling time to a minimum.

The speed of compelled MFC signalling is generally determined by two factors:

- Propagation delay in the transmission path, and
- The operate times of the various element in MFC senders and receivers.

Even with high speed transmission plant, the propogation delay of approximately 1 ms per 250 Km can significantly reduce the signalling speed when long distances are involved as the cycle time includes four times the one-way propagation delay. (See Appendix 1).

The method of digit storage in the MFC receiving equipment is another factor which determines signalling speed and in the APO crossbar network two methods are presently used:

- Crossbar switch storage (ARM exchanges).
- Relay storage (ARF and ARK-M exchanges).

Further details are given in Appendix 2 which provides an analysis of the two methods and indicates the approximate signalling speeds attainable in the APO crossbar network.

MFC SIGNALLING IN 10C TRUNK EXCHANGES

The existing MFC signalling speed in the APO network is generally limited by the comparative slowness of the logic hardware associated with electro-mechanical crossbar exchanges.

With the introduction of Stored Program Control (SPC) 10C electronic trunk exchanges in the APO network, the MFC senders and receivers are controlled by a Central Processor Unit (CPU). The CPU periodically scans the signalling of the incoming and outgoing circuits to detect any change from the previous scan. Associated with the CPU is a signalling program which controls the reception and sending of the appropriate signals as required. The faster logic equipment employed by the 10C trunk exchanges can lessen the overall duration of a complete MFC cycle by reducing the internal logic operation times. However, for interworking with the present crossbar telephone network, the signalling speed is partly governed by the MFC senders and receivers associated with the crossbar exchanges. This means that the scanning rate for the MFC devices can be optimised to obtain the best balance between real time consumption in the CPU and the signalling speed in a network with both crossbar and SPC exchanges.

Ultimately, with increasing penetration of SPC electronic exchanges into the APO telephone network, it is likely that the signalling between SPC exchanges will be performed by using Common Channel signalling over a data link.

RELIABILITY IN MFC SIGNALLING

An important requirement of modern signalling systems in realibility. The system must be sufficiently flexible to tolerate minor irregularities and short interruptions in the transmission path and to be capable (within certain tolerances) of dealing with a range of signal levels, large voltage transients and unequal amplitude of the two signal frequencies received.

The characteristics of MFC signalling systems and the design of the sending and receiving equipment are such that error detection is incorporated in the system and generally it is self-healing if a fault condition does occur in the transmission equipment.

Any short interruption in the transmission path during the transfer of MFC signals will generally only cause some delay in the overall connection. This can be verified by analysing the compelled MFC cycle shown in Appendix 1 and considering the possible timing points at which undetected faults could occur. A burst of noise or transient link interruption of particular duration can result in an undetected error only under very limited conditions. For example, an error could result if a short link interruption occurs at that point in the timing sequence where the forward signal has been stored, and although transmission of the backward signal has commenced it has not yet been recognised by the originating MFC sender. The forward signal will cease at the terminating end and this will be interpreted as a result of the cessation of the backward signal even though the forward signal is still being sent. On restoration of the transmission link, the same forward signal will be received and could be wrongly recognised as the next numerical signal.

However, the timing periods under which these misoperations could occur are very limited and with the increased reliability of both modern exchange and transmission equipment, the incidence of faults due to this cause is negligible.

REQUIREMENTS OF MFC SIGNALLING EQUIPMENT

MFC signalling takes place on a variety of 2-wire and 4-wire inter-exchange links; this imposes several conditions on the formulation of the MFC sending and receiving equipment specification.

The design of the APO network is such that the attenuation of the transmission path will affect the received level of the MFC signal depending on the number of links in the connection and the status of each link in the transmission hierarchy.

The sensitivity range of the MFC receiving equipment must therefore be sufficient to accept the various signalling levels and yet be able to reject signal imitation due to noise or intermodulation.

In consequence, the receiving sensitivity for all the signalling frequencies is regulated to a value which corresponds to the level of the incoming

TABLE 1

Parameter	Current APO Specification
Sending frequency	nominal ±2 Hz
Sending level	−8 dbmO ± 1 db (with 1 db max. difference between the two parts of a signal).
Received level accepted by receivers	−6 to −36 dbm.
Level difference tolerated by receivers	8db max. between the two parts of a signal.
Frequency variation tolerated by receivers	± 12Hz

signals. This provides active protection against signal imitation due to noise, intermodulation and double echo effects; it requires that the sending equipment must ensure that the two frequencies constituting each signal are kept within set tolerances for both deviation and level.

The maximum sending level of each signal is limited chiefly by considerations of overload in carrier circuits and has been calculated taking into account the maximum signalling energy generated by the establishment of telephone connections during the busy hour using a statistical distribution.

The requirements for sending and receiving equipment in regard to tolerances and maximum allowable deviations as specified for the APO network are shown in Table 1.

CONCLUSION

The principles of compelled sequence MFC signalling are such that by proper planning and implementation, the inherent characteristics of this type of signalling can be used to provide a large capacity information system together with reliability and a reasonable speed of transfer in the APO telephone network. As additional information signals are required, new functional blocks can be added within the existing framework to augment the present signals available.

However, with increasing requirements of the communications network and longer propagation times for STD and ISD calls especially over satellite links, inter-exchange signalling may eventually require the introduction of a new signalling scheme with much larger message carrying capacity and more rapid transfer of information.

To cope with new requirements and greatly increased traffic, computer based exchange systems are being brought into use. The natural mode of information transfer between computers is by data link; CCITT Signalling System No. 6 for international working makes use of data links for information transfer and has been specified and tested. The International Gateway exchange at Broadway in Sydney is now equipped to signal in this mode as well as with more conventional signalling systems.

Widespread interest is being shown around the world in national common channel signalling systems similar in many respects to Signalling System No. 6. New signalling systems are under constant study in the APO Research Laboratories, in conjunction with continuing planning studies to determine the future signalling facilities required in the APO telephone network.

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APPENDIX 1—ANALYSIS OF COMPELLED MFC CYCLE

The overall duration of a complete compelled MFC cycle can be defined using the following time sequences shown in Fig. 3.

Note: The intervals T_O and T_R include the time necessary for validation of the signal; i.e. the protective function of determining that two and only two frequencies have been present (or have been removed) for a certain minimum time.

If the values of $T_{int\,2}$ and $T_{int\,3}$ lie within certain limits, they do not contribute to the overall duration of the MFC cycle.

T_{S1}, T_{S2} : the time taken to start or stop the emission of a signal (pure switching on or off time, without logic operations).

From Fig. 3 it may be seen that the time T for a complete cycle is given by:

$$T = 2T_{PF} + 2T_{PR} + 2T_O + 2T_R + 2T_{S1} + 2T_{S2} + T_{int\,1}$$

Under ideal conditions, with no propagation delay, $T_{PF} = T_{PR} = O$ and this reduces to:

$$T = 2T_O + 2T_R + 2T_{S1} + 2T_{S2} + T_{int\,1}$$

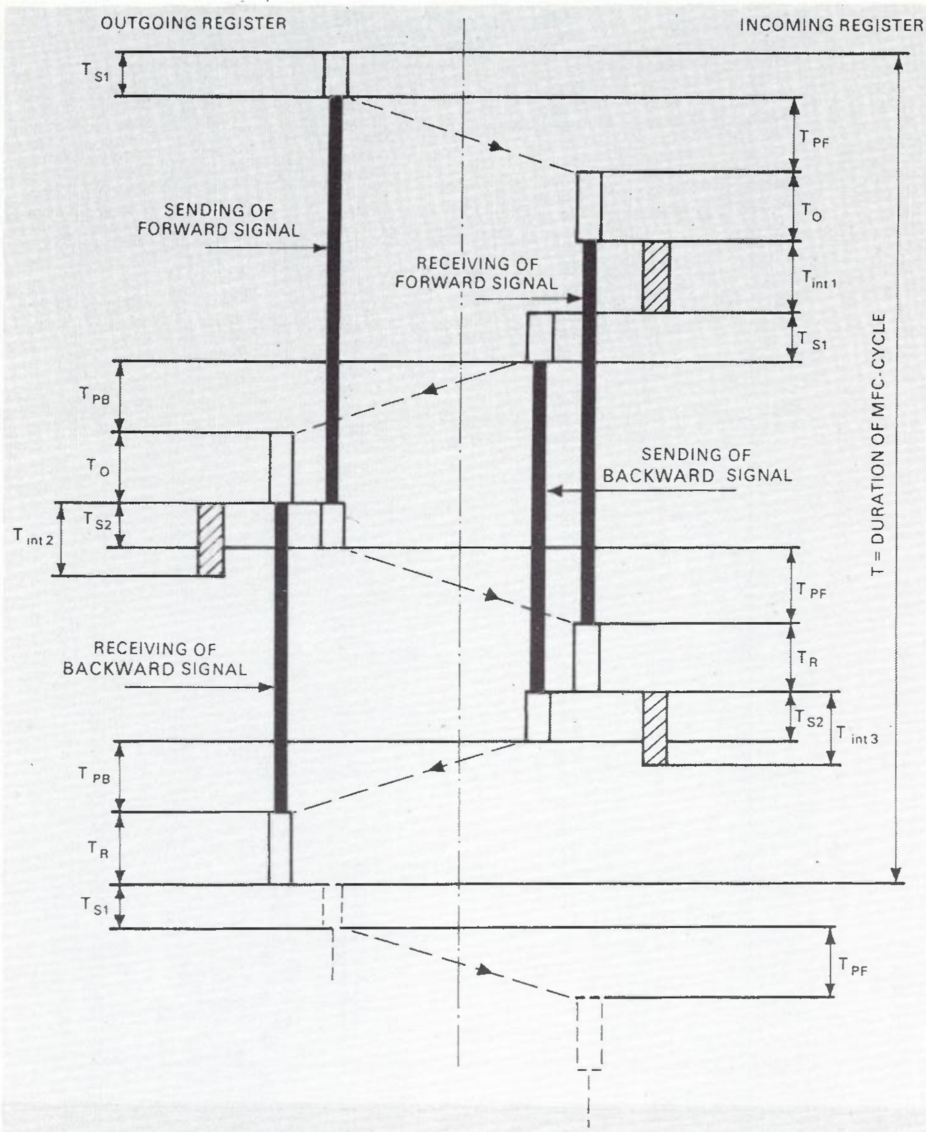
APPENDIX 2 — DIGIT STORAGE IN APO SWITCHING EQUIPMENT

Crossbar Switch Storage

The rate at which numerical forward signals can be stored on the verticals of a crossbar switch is the main factor in the speed of signalling between ARM crossbar trunk exchanges. This can be seen from Fig. 4 which shows a typical MFC cycle of a forward digit and a backward signal requesting next digit.

A guard period with minimum duration of 180 ms is required between subsequent storage on each vertical and this prolongs the $T_{int\,3}$ time interval significantly before the next forward signal can be stored.

The timing sequences shown in Fig. 4 were measured and recorded during the actual transfer of digital information between two ARM exchanges;



LEGEND

T_{PF} : The propagation time in the forward direction.

T_{PB} : The propagation time in the backward direction.

T_O : The interval between the moment at which both frequencies of a signal are applied at the input of the receiving part of the signalling equipment and the moment of recognition of the signal. This is known as the "operating time".

T_R : The interval between the moment that both frequencies of a signal are cut off from the input of the receiving part of the signalling equipment and the moment when the end of the signal is recognised. This is known as the "release time".

$T_{int\,1}$: The time an incoming MFC register needs to determine which backward signal it must send in response to a forward signal received. This time is determined by the speed at which the register logic operates.

$T_{int\,2}$: The time taken for an outgoing MFC register to determine which forward signal to send next in response to the backward signal it has received.

$T_{int\,3}$: The time taken by the incoming register to carry out any internal functions required in order to be prepared for the reception of the next digit.

Fig. 3. Timing Sequence of a Compelled MFC Cycle

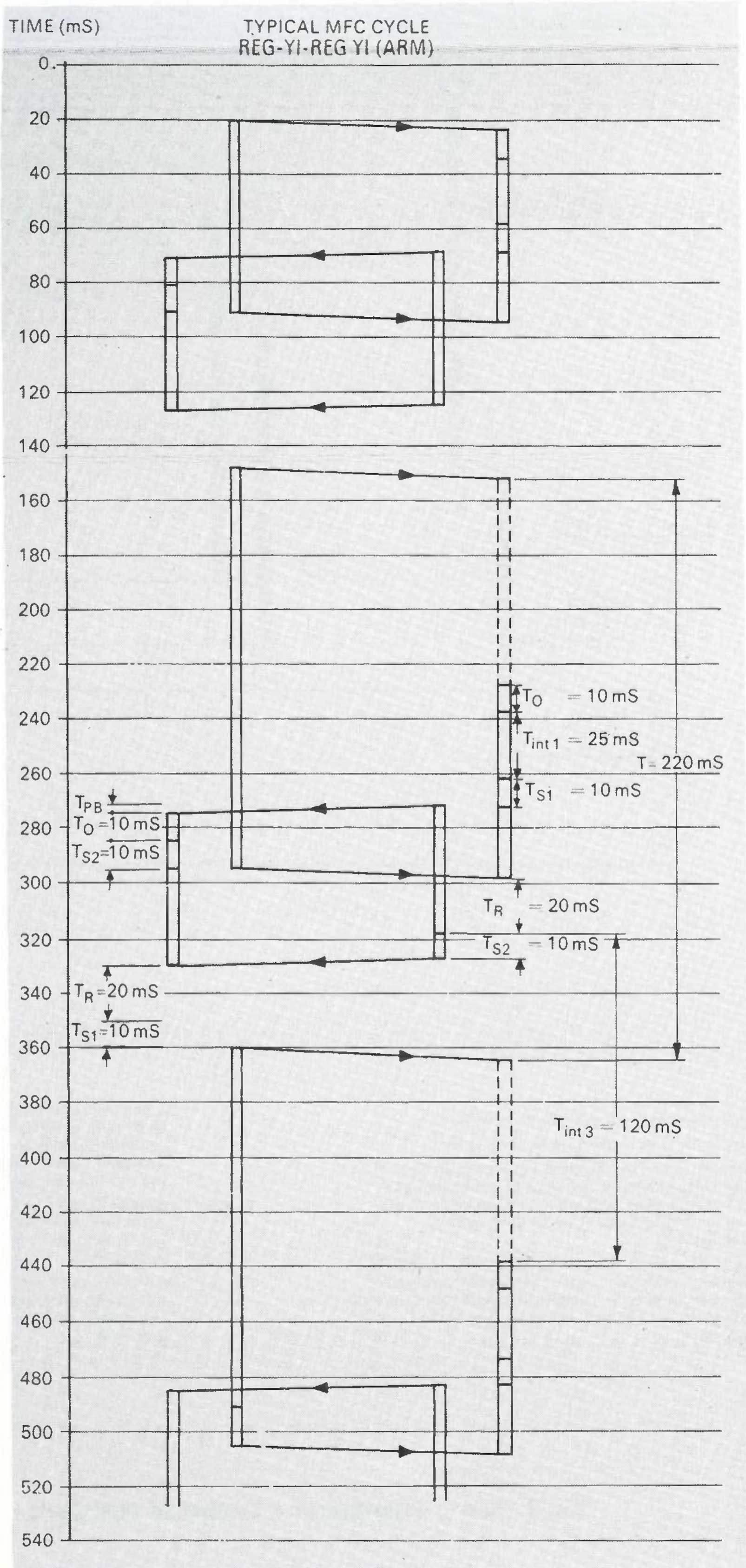


Fig. 4 — Timing Sequence using Crossbar Switch Storage.

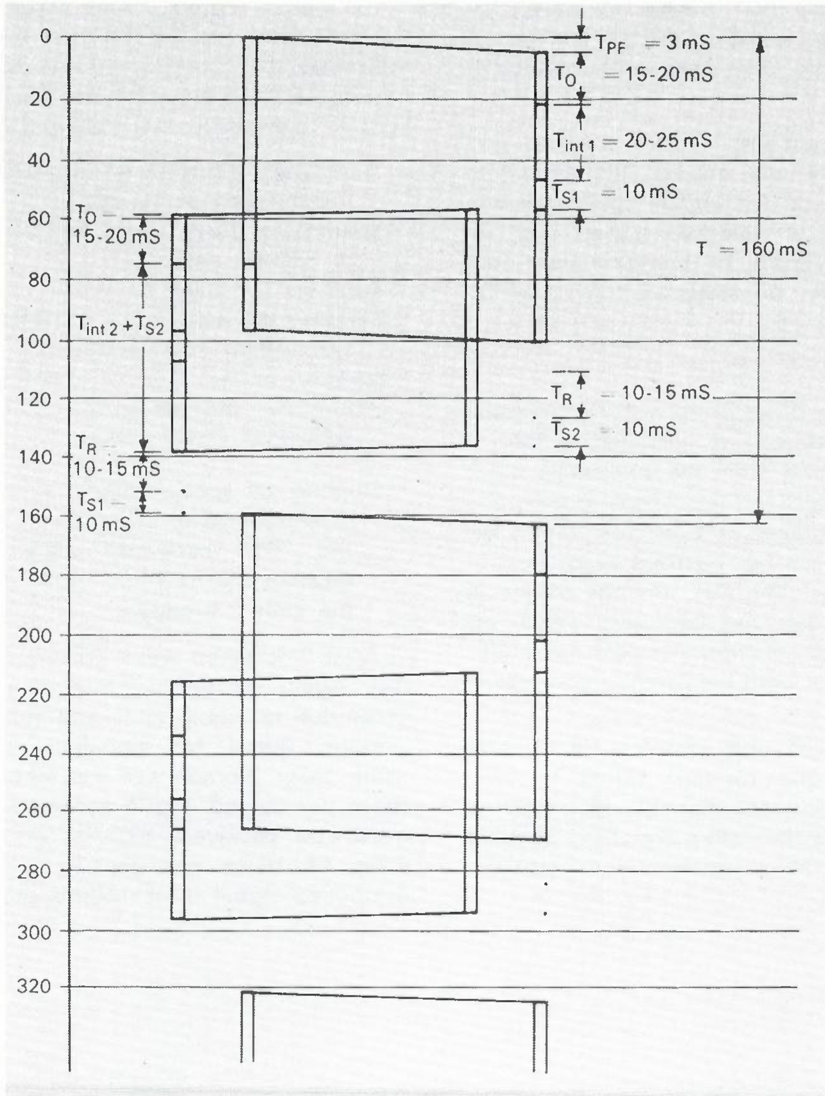


Fig. 5 — Timing Sequence using Relay Storage.

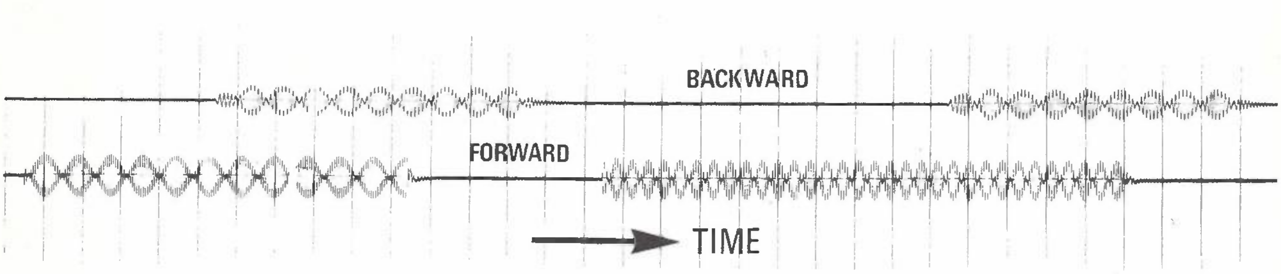


Fig. 6 — "On Line" Forward and Backward MFC Signals.

they show that the duration of one complete MFC cycle using crossbar switch vertical storage is approximately 220 ms over links with negligible propagation times.

Variations in adjustments of the sending and receiving components will change the signalling speeds and the times of the logical operations will depend on the type of revertive signals that are returned. However speeds of approximately four digits per second can be assumed for signalling between ARM exchanges.

Relay Storage

The digit reception times of forward information signals using relay storage is indicated in Fig. 5. The times were derived from measurements made in an ARF 102 Reg-ELP/H4 exchange during the establishment of a number of local calls within the same exchange and can be regarded as typical for this type of exchange. The MFC timings shown in Fig. 5 are those where the backward signal requested the next digit; minimum logical operations were thus required for both the sending and receiving equipment.

The total time T of one complete MFC cycle (commencement of one forward signal to commencement of next forward signal) was measured as 160 ms and shows the faster signalling possible with relay storage as compared with crossbar switch storage.

To analyse the total time taken from seizure of the code sender to the return of the 'B' series signal indicating the condition of the called subscriber's line for a local six digit call in an ARF102 Reg-ELP/H4 exchange, the following times refer:

Time from seizure of KS (R1 relay) to transmission of 1st digit	= 500 mS
Sending of three digits to GV-KMR at 160 mS each	= 480 mS
Time for GV stage to switch	= 100 mS
Sending of two digits SL stage CD-KMR at 160 mS each	= 320 mS
Sending of last digit of subscriber's number and return of "End of Selection" signal "3A3"	= 260 mS
Sending of special digit signal indicating class of call and return of the "B1" backward signal indicating the free line condition of the called subscriber	= 215 mS

Total time taken was 1 875 ms for this particular call. Again recognising that many variations will occur due to adjustments and switching times, the average speed for signalling between devices using relay storage can be taken as five to six digits per second. Fig. 6 shows two compelled forward and backward signals "on line". The time scale, of 10 ms per division indicates that each compelled signal is of 160 ms duration.

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In 1972 he was appointed as Engineer Class 3, Signalling and International Interworking, in the Telephone Switching and Facilities Planning Branch, in Headquarters, where he is engaged on planning and application studies to determine required facilities for the national signalling systems and for interworking with the International Gateway Exchanges.

APO Optical Fibre Investigations

The APO Research Laboratories have been investigating theoretical and experimental transmission characteristics of the liquid-filled multi-mode optical fibres developed by Commonwealth Scientific and Industrial Research Organisation (CSIRO). The theoretical work has attempted to predict the transmission performance of these fibres by using an electromagnetic wave theory approach as well as a simplified geometrical optics approach. The results from both of these models indicate that the bandwidth of a fibre, in the absence of mode mixing within the fibre, tends to a constant value after a length of several hundred metres, this length and the actual asymptotic bandwidth being functions of the fibre parameters, namely core diameter, core and cladding refractive indices, and the attenuation of the cladding. A third theoretical model developed by Gloge of the Bell Laboratories takes into account the mode mixing which could occur due to imperfections in the core and at the core-cladding interface. This model predicts that over long lengths of fibre the bandwidth will be inversely proportional to the square root of length.

Although there are differences between these models, it follows from all of them that over very long lengths (the order of kilometres) the asymptotic bandwidth is independent of the excitation condition, that is, independent of whether the source is collimated (as for a laser) or wide-angle (as for a light emitting diode). It follows also that this bandwidth will be greater for fibres having larger cladding losses, smaller diameter, or smaller refractive index differences between core and cladding. As well, the possibility exists of increasing the bandwidth by control of the degree of mode mixing through control of the geometrical perturbations of the core-cladding interface.

Measurements so far have been made on two tetrachloroethylene-filled fibres of approximately 1 km length, one having a core diameter of 90 μm and the other a diameter of 130 μm. The transmission characteristics for a length of fibre were determined from the analysis of the output pulse shape at that length due to excitation with a short optical pulse injected into the fibre from a GaAs laser diode. The output pulses were recorded for various launching and detection conditions (to simulate, for example, collimated and wide-angle sources), after which the fibre was shortened and the measurements repeated. A standard Fourier transform technique was used to obtain the frequency response from the measured input and output pulses.

For these particular core diameters, the maximum lengths measured were not sufficiently great to allow the asymptotic bandwidths to be predicted with certainty, nor to confirm which of the various theoretical models discussed above is the most satisfactory. However, the trends are quite definite. For the 90 μm diameter fibre, for example, the bandwidth for wide-angle launching reduces from 40 MHz at 100 m to about 10 MHz at 1 km, while for collimated launching the corresponding bandwidths are about 150 MHz and 15 MHz. The bandwidth would appear to become independent of launching conditions at around 2 km, at which length the bandwidth would most probably be about 8 MHz. Further measurements on longer lengths will soon be undertaken, as well as on straight lengths to isolate mode-mixing effects due to fibres being wound on drums.

The CSIRO Division of Tribophysics has recently modified its fibre pulling machine to produce fibres of more precise geometry. They have, as well, been carrying out extensive spectrographic analyses of tetrachloroethylene to determine the process of degradation in that liquid. They have demonstrated that unless there is complete removal of oxygen and water decomposition of the liquid occurs when it is exposed to light.

A further significant advance in the APO Laboratories research programme has been the development of fibre-compatible light-emitting diodes. These LED's generate in excess of 3 mW of optical power at 0.89 μm for a drive current of 400mA, and have rise times of 2-3 ns. These devices are relatively inefficient, but further work on the diode structure should allow efficiencies of up to 30% to be achieved.

International Stored Program Controlled Telephone Exchange — Sydney

P. F. ALLEN, B.E. and P. J. SINDEL; B.Sc., B.E.

In March 1974 the Overseas Telecommunications Commission (Australia) placed in service an L.M. Ericsson AKE-131 exchange, the first stored program controlled exchange in service in the Southern Hemisphere.

This article describes the exchange, the project and the first eight months of in-service experience.

INTRODUCTION

In March 1974 the Overseas Telecommunications Commission (Australia) (OTC(A)) placed in service an L. M. Ericsson AKE-131 Stored Program Controlled trunk exchange at Broadway, in Sydney.

The Broadway exchange operates in parallel with OTC(A)'s Paddington ARM international telephone exchange. (Ref. 1). The two exchanges switch international telephone traffic to and from Australia and international transit traffic.

International telephone traffic originating in Australia is offered to either Broadway or Paddington exchange, and is switched to the country of destination either directly or via international transit exchanges. An overflow route exists between the two OTC(A) exchanges to provide full access to all international circuits. International telephone traffic entering Australia is offered to either Broadway or Paddington exchange (again with overflow between the exchanges) and is switched to the major trunk exchanges throughout the Australian national network. Sydney is a major transit switching centre for international telephone traffic in the South East Asia and Pacific Ocean region.

This paper describes the Broadway exchange, the project organization and the first eight months of in-service experience.

THE BROADWAY AKE-131 TELEPHONE EXCHANGE

This section of the paper gives a broad description of the exchange characteristics and trunking, and then an appreciation of the system organization.

Exchange Characteristics

The AKE-131 exchange employs a 4-wire electromechanical switching network under the control of an SPC system. The SPC system contains the logic of the exchange and performs all the common control functions such as digit storage and analysis, route selection, line selection and the establishment of connections within the switching network. The SPC system employs microsynchronized pairs of Central Processing Units (CPUs) in 'data processing channels'. The switching network employs codebar switches and is constructed in groups of 600 inlets.

The Broadway exchange has 2400 bothway inlets and 1 data processing channel containing 2 CPUs and 1088 K bytes of memory, with provision for expansion to 9600 bothway inlets and 3 data processing channels. The ultimate capacity of the AKE-131 system is approximately 30,000 bothway inlets with 8 data processing channels.

The Broadway exchange is equipped with 4 signalling systems. The national signalling systems are the APO MFC and Loop Disconnect (L-series) systems, and the international signalling systems are the CCITT No. 5 and CCITT No. 6 systems. CCITT No. 5 employs multifrequency pulsed register signals and 2 VF tone line signals. CCITT No. 6 is a recent innovation in telephone signalling in which all register and line signals for the circuits are transmitted in digital form on a 2400 bit per second data circuit. This is a mode of signalling feasible only between SPC exchanges. (Ref. 2).

There is provision for 16 route alternatives in

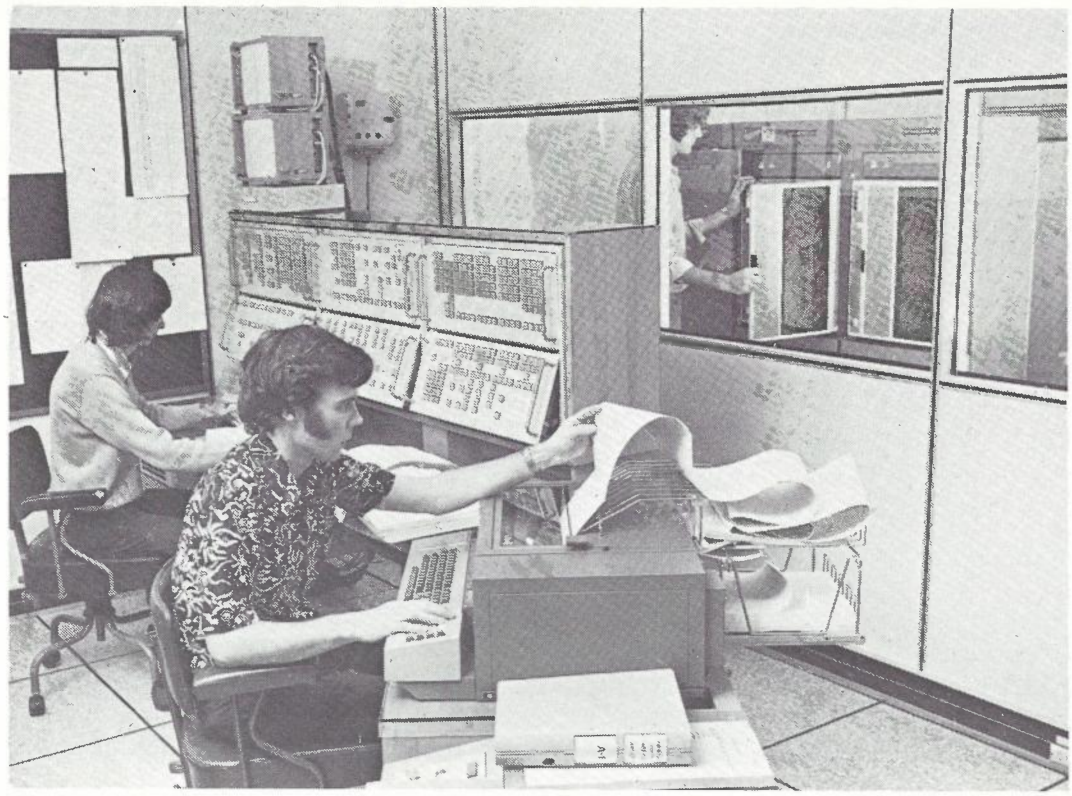


Fig. 1 — Exchange Control Room. (The input-output equipment shown is a typewriter in the foreground and the magnetic tape equipment through the window; the processor maintenance unit is in the centre.

the Broadway exchange. This large number of alternatives is made necessary by the complexity of routing in the international telephone network. (Factors contributing to the complexity are, restricted access on some circuits, the need to discriminate between Satellite, Cable and TASI (Time Assignment Speech Interpolation) bearers, combinations of bothway and oneway circuits on one route, and the use of fixed and random orders of search).

There are 2 major control areas associated with the Broadway exchange, the Exchange Control Room and the International Transmission Maintenance Centre (ITMC). In the Exchange Control Room (Fig. 1), all exchange maintenance, supervision and fault investigation is carried out, while in the ITMC, the maintenance and fault reporting on the international telephone circuits, as well as supervision of the flow of traffic through the exchange, is performed.

Trunking

The trunking of the exchange is shown in Fig. 3. The switching network is a 4-stage network with the code-bar switch (shown in Fig. 4) as the switching element. All equipment, with the exception of the code receivers and code senders (KM's and KS's), is connected to the A-stage of the switching network.

The line terminating equipment (which contains no logic) is mounted on printed circuit cards with either 128 or 224 circuits per rack. In Fig. 4 line terminating equipment may be seen. The circuit card on the left is a CCITT No. 6 termination (FDR-6) and the two circuit cards to the right form a CCITT No. 5 line termination (FDR-5).

Maintenance Facilities

The circuit tester CIT automatically tests the code receivers and code senders (by sending and receiving tones) when an excessive number of failures occur in the code equipment.

The link tester LINK-T performs routine tests on the switching network by checking the continuity of 4-stage connections established through the switching network. Whenever a fault is found details of the switching path are printed.

Fig. 2 — Maintenance Desk (M–Desk).

The maintenance console M-DESK (Fig. 2) is an important tool of the International Transmission Maintenance Centre. Each M-DESK is equipped with transmission measuring equipment, orderwire facilities and an exchange typewriter. Circuits under test are connected automatically to the M-DESK.

SYSTEM ORGANIZATION

The AKE-131 system is divided into two subsystems:

- the telephone switching subsystem (APT-131) composed of switching equipment (hardware) and the set of programs (software) which supervises and controls it
- a specialized data processing subsystem (APZ-130) composed of digital computer equipment (hardware) and software which supervises and controls it.

A block diagram of the hardware is shown in Fig. 5. The APZ subsystem stores and executes the APT software which control the APT hardware (Switching Equipment (SE)). The APZ subsystem is standard for all AKE-131 installations, while the APT subsystem is designed separately for each installation.

APT-131 Subsystem

The APT software is subdivided into modules, each for a particular telephony function and each usually associated with a particular item of Switching Equipment. The combined hardware and software for a particular function is known as a block. For example the hardware and software associated with incoming Loop Disconnect lines is known as block FIR-L.

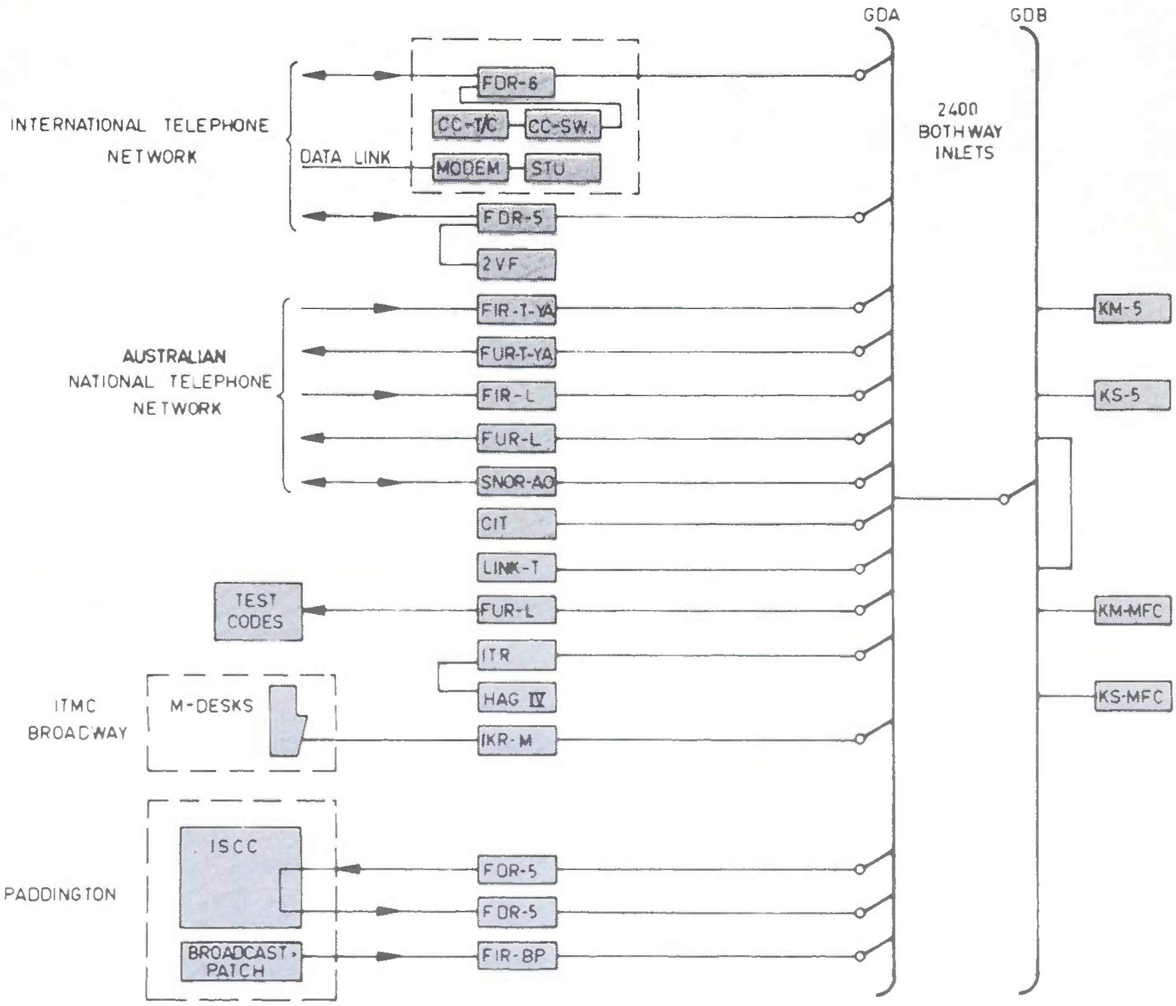
One group of APT blocks perform the basic switching functions. For example, there are separate blocks for:

- each type of line termination;
- operation of the code-bar switches.

Another group of APT blocks enable rearrangement of the exchange to be made from a typewriter. Some worthy of special mention are:

- block ANDG (Analysis Generation) which enables modification of digit analysis data;
- block EXASS (Exchange Assembly) which enables new routes to be introduced and lines to be allocated to them.

A third group of APT blocks provides traffic and



LIST OF ABBREVIATIONS

CC-T/C	CONTINUITY CHECK TONE TRANSCEIVER
CC-SW	CONTINUITY CHECK SWITCH
CIT	CIRCUIT TESTER
FDR-5	BOTHWAY LINE TERMINATION (CCITT NO. 5)
FDR-6	BOTHWAY LINE TERMINATION (CCITT NO. 6)
FIR-T-YA	INCOMING LINE TERMINATION (APO MFC)
FUR-T-YA	OUTGOING LINE TERMINATION (APO MFC)
FIR-L	INCOMING LINE TERMINATION (APO LOOP DISC.)
FUR-L	OUTGOING LINE TERMINATION (APO LOOP DISC.)
FIR BP	INCOMING LINE TERMINATION (BROADCAST PATCH)
GDA & B	'A' & 'B' STAGES OF BOTHWAY SWITCHING NETWORK
HAG IV	RECORDED VOICE ANNOUNCEMENT MACHINE
IKR-M	CONNECTS M DESK TO GD INLET
ITR	RELAY SET FOR CONNECTING A VOICE ANNOUNCEMENT
ISCC	INTERNATIONAL SERVICE CO-ORDINATION CENTRE
ITMC	INTERNATIONAL TRANSMISSION MAINTENANCE CENTRE
KM-MFC	CODE RECEIVER FOR APO MFC SIGNALS
KM-5	CODE RECEIVER FOR MULTIFREQ. CCITT NO.5 SIGS.
KS-MFC	CODE SENDER FOR APO MFC SIGNALS
KS-5	CODE SENDER FOR MULTIFREQ. CCITT NO.5 SIGS.
2VF	RECEIVER FOR 2VF TONES CCITT NO 5 LINE SIGS.
LINK-T	SWITCHING NETWORK LINK TESTER
M-DESK	MAINTENANCE DESK
MODEM	MODEM FOR CCITT NO 6 SIGNALLING
SNOR-AO	FORWARD TRANSFER OPERATOR LINE TERMINATION
STU	COMMON CHANNEL SIG. UNIT FOR CCITT NO.6 SIG.
TEST CODES	AUTO. TESTING & ANSWERING EQUIPMENT

Fig. 3 — Exchange Trunking Diagram.

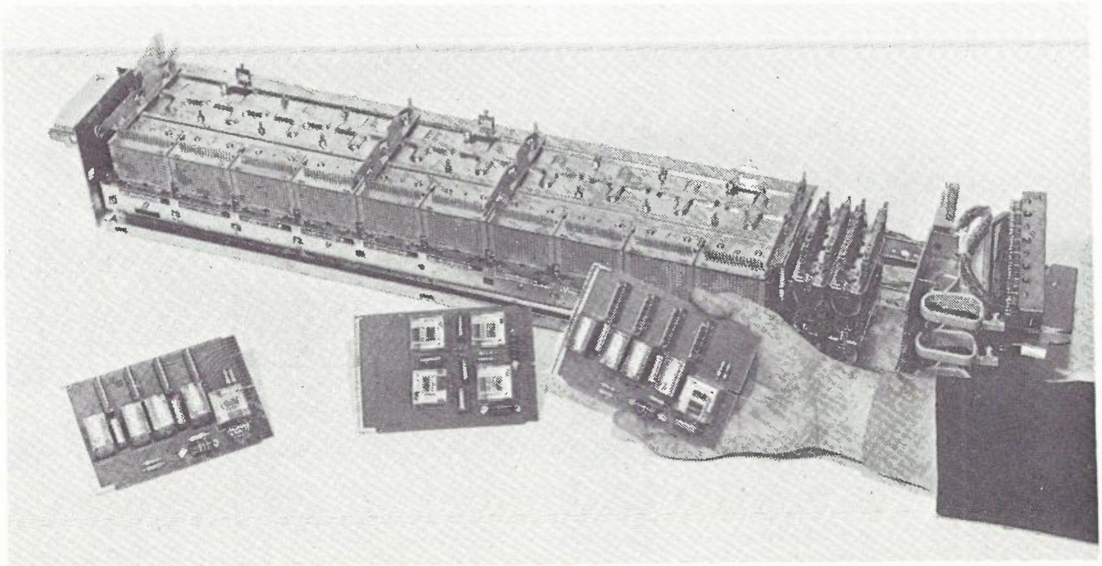


Fig. 4 — Code Bar Switch and Line Termination Circuit Cards.

signalling supervision and maintenance facilities.

For example:

- blocks BLS (Blocking Supervision) and COS (Congestion Supervision) which supervise the number of devices blocked and the level of congestion for each route.
- block SIST (Signal and State Recorder) which is able to record and print every signalling event during the course of a call.

APZ-130 Subsystem

A survey of the APZ hardware appears in Fig. 5. Three areas can be identified:

- the Data Part (DP);
- the Test and Operation equipment (TO);
- the Input/Output equipment (IO).

The Data Part is the central computer which controls all functions of the exchange. The Test and Operation equipment is an interface with which the Data Part can examine and control relays in the Switching Equipment. The Input/Output equipment permits contact between the exchange and staff by typewriters and enables the external storage of data on paper or magnetic tape.

As can be seen most units in the Data Part are provided in pairs, including the Central Processing Units (CPU). One unit of a pair is known as the 'A unit' and the other as the 'B unit.' All operations within the Data Part are performed simultaneously by the A and B units and the results are compared to check for equipment faults. Typically, comparisons are performed 5 times within a single operation occupying 3 microseconds. When a fault is detected both units are automatically checked and the faulty unit is blocked. A and B units may be interconnected quite freely.

The Supervisory Unit (SVU), which is an unduplicated unit, is normally dormant but plays a key role should a fault be detected. The Supervisory Unit records all alarms and the system status at the time of the fault and then, using wired logic, determines emergency action. The Supervisory Unit is central to the reliable operation of the Data Part. The Processor Maintenance Unit (PMU), which is also unduplicated, enables manual testing of the Data Part from panels in the control room. The PMU is shown in the centre of Fig. 1.

Memory is divided into Program Store (PS) and Data Store (DS). The Program Store contains the instructions for controlling the exchange and the Data Store contains both permanent and temporary information.

The program instructions will normally require the Central Processing Unit (CPU) to operate towards Data Store or Transfer Control (TC), via an electronic switching network, the Multiplexor. The Central Processor uses the Data Store as a repository for information. Transfer Control enables the Central Processing Unit to control the Switching Equipment and Input/Output equipment.

The basic unit of information is a word of 16 bits

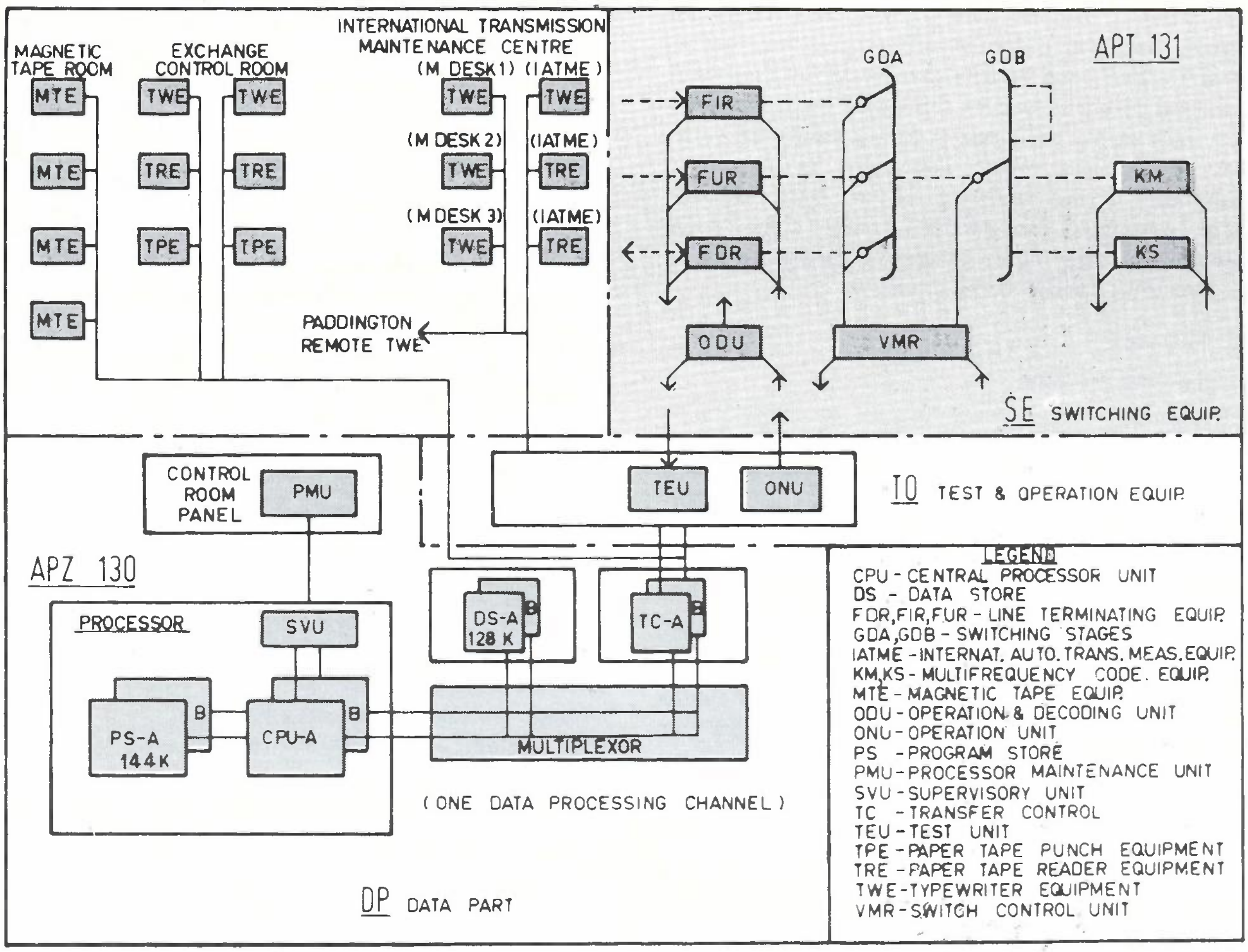


Fig. 5 — Block Diagram of Broadway Hardware.

and all timing is derived from a 5 millisecond clock interrupt signal.

The APZ software is constructed in blocks and may be divided into a number of broad areas such as:

- the Job Monitor which calls in all programs when they are scheduled;
- Loading Programs which can transfer programs stored on magnetic or paper tape into memory;
- The System Monitor, Recovery and Hardware Maintenance Programs which, in conjunction with the Supervisory Unit, respond to fault conditions within the APZ subsystem, and perform routine testing of the APZ hardware. The System Monitor is the master controller of an AKE system.

SOFTWARE CHANGES

When a major change of facilities is required it is necessary to introduce new software. A special provision exists in the AKE-131 system for introducing new software.

The Data Part of the APZ hardware may be separated into two autonomous computer systems, one system continuing normal traffic handling with the current software, while the idle system is loaded with new software. The two computer systems then change roles. Should a fault arise in the new software there is an automatic return to the old software and normal traffic handling.

POWER DISTRIBUTION AND EARTHING

The exchange is fed directly from a —48V DC power supply. Those racks which require logic voltages are equipped with DC/DC converter power supplies. The Input/Output equipment and some miscellaneous APT equipment requires no-break 220V AC power, which is provided by static DC/AC inverters.

In order to protect data from short circuit fault currents and the potential differences they cause, the entire exchange area is covered by an overhead earth grid of heavy copper cable at 1 metre spacing. Every rack in the exchange is connected to the earth grid. A problem which can arise in computer equipment is the building up of static charges which may cause malfunction of logic circuitry. To prevent this the floor of the exchange area is covered with special conductive tiles.

THE PROJECT

General Organization

The project organization aimed at achieving a high degree of participation by OTC(A) personnel. OTC(A) personnel formed part of the software design team established by L. M. Ericsson in Sydney, carried out the hardware installation and testing, played a significant role in the System Testing, and performed the Acceptance Tests.

From the outset the OTC(A) maintenance personnel were integrated into the project team.

The principal milestones of the project were established as part of the contract. They were the System Handover Date and Final Acceptance Date. System Handover occurred at the completion of the Acceptance Tests. Following the System Handover the exchange was placed into service for a period of three months of Confidence Trials.

System Acceptance occurred at the successful completion of the Confidence Trials.

Timing

The project spanned 40 months from January 1971, when the Contract was let to the Final Acceptance Date in June, 1974. The project fell into four phases.

The first phase (31 months) included a number of major activities carried on in parallel. These were equipment manufacture, software development, hardware installation and testing.

The second, third and fourth phases were:

System testing (5 months)
Acceptance testing (1 month)
Confidence trials (3 months).

Equipment Manufacture

The equipment was manufactured principally by L. M. Ericsson in Sweden while DC/DC converter power supplies were manufactured by North Electric Company of the USA and some miscellaneous hardware was manufactured by L. M. Ericsson, Australia.

Software Development

L. M. Ericsson established a design office in Sydney for the design, assembly and testing of software. This work spanned 2 years from the beginning of 1972 to the end of 1973. The major design effort was in the APT software. Of the 50K words of APT software, approximately 15K were fully developed in Sydney, while some of the remaining 30K, which had been developed in Stockholm, were modified to meet OTC(A)'s requirements. The software for the CCITT No. 6 Signalling System was developed by the Sydney design team following initial devolpmental work by L. M. Ericsson and OTC(A) in Stockholm for the CCITT FT6 Field Trials. (Ref. 3).

During the software development preliminary tests of the new designs were carried out using OTC(A)'s AKE-131 FT6 Field Trial Exchange at Paddington. (Ref. 3). Later when the Data Part of the Broadway installation became available the bulk of the switching functions in the software were tested by the software test aid STB (System Test Block). STB simulates the responses of the Switching Equipment. The assembling of the Broadway software package was performed with the L. M. Ericsson program preparation system, APS, on an IBM System/360 computer at the ICI plant in Melbourne.

Hardware Installation and Testing

Installation of the hardware was carried out by OTC(A) under the technical direction of L. M. Ericsson. The initial hardware tests were performed by OTC(A) staff and the final tests were performed by special test teams comprising both OTC(A) and L. M. Ericsson personnel.

The hardware testing was greatly assisted by test aids provided by L. M. Ericsson.

Initially parts of the system were tested separately. The Program and Data Store and the Transfer Control equipment was tested using a CPU Simulator, the Test and Operation equipment was tested with a TO Tester and the switching network was tested using an electromechanical test aid VMR-P. The initial testing of the Central Processor Units was carried out from the Processor Maintenance Unit.

The Data Part was then commissioned using software test aids OFF SU (Store Unit), OFF CPU (Central Processor Unit), OFF SVU (Supervisory Unit). At the completion of these tests the Data Part was fully operational and could be used to test the remainder of the exchange. Software test aids were again used. OFF TO was used to test the Test and Operation equipment, the functions of the switching network were tested using OFF A LINK and OFF B LINK and the ODU's were tested using OFF ODU.

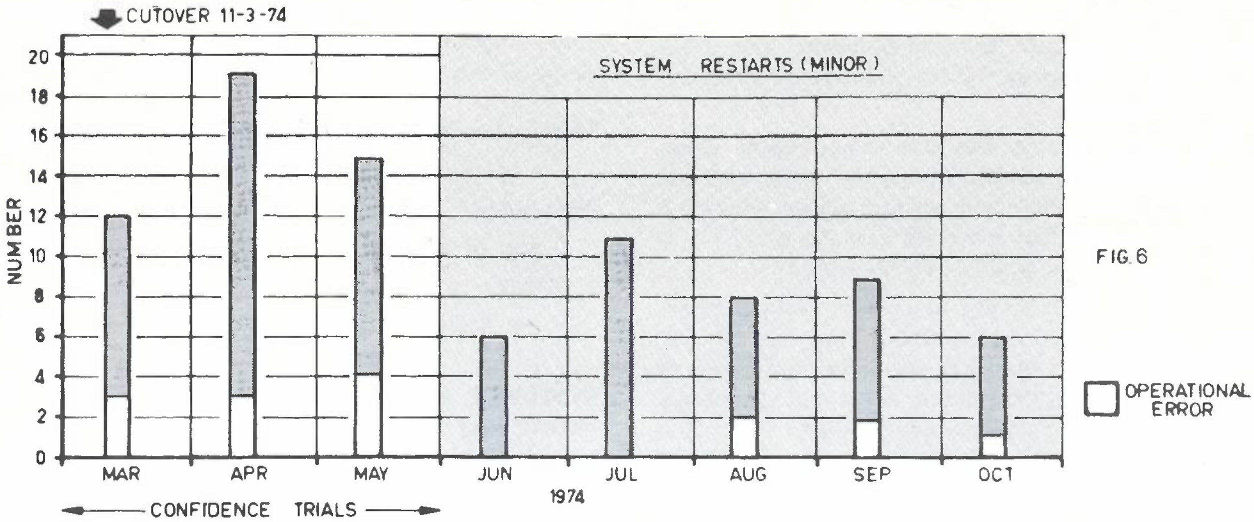


FIG.6

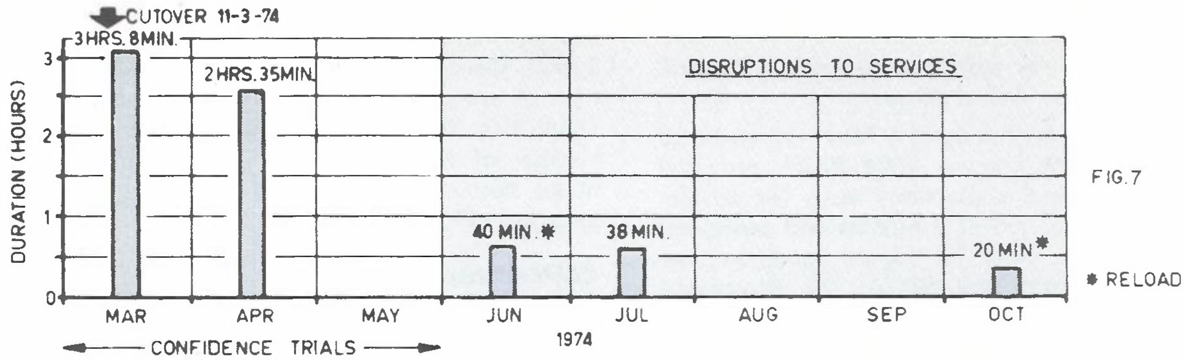


FIG.7

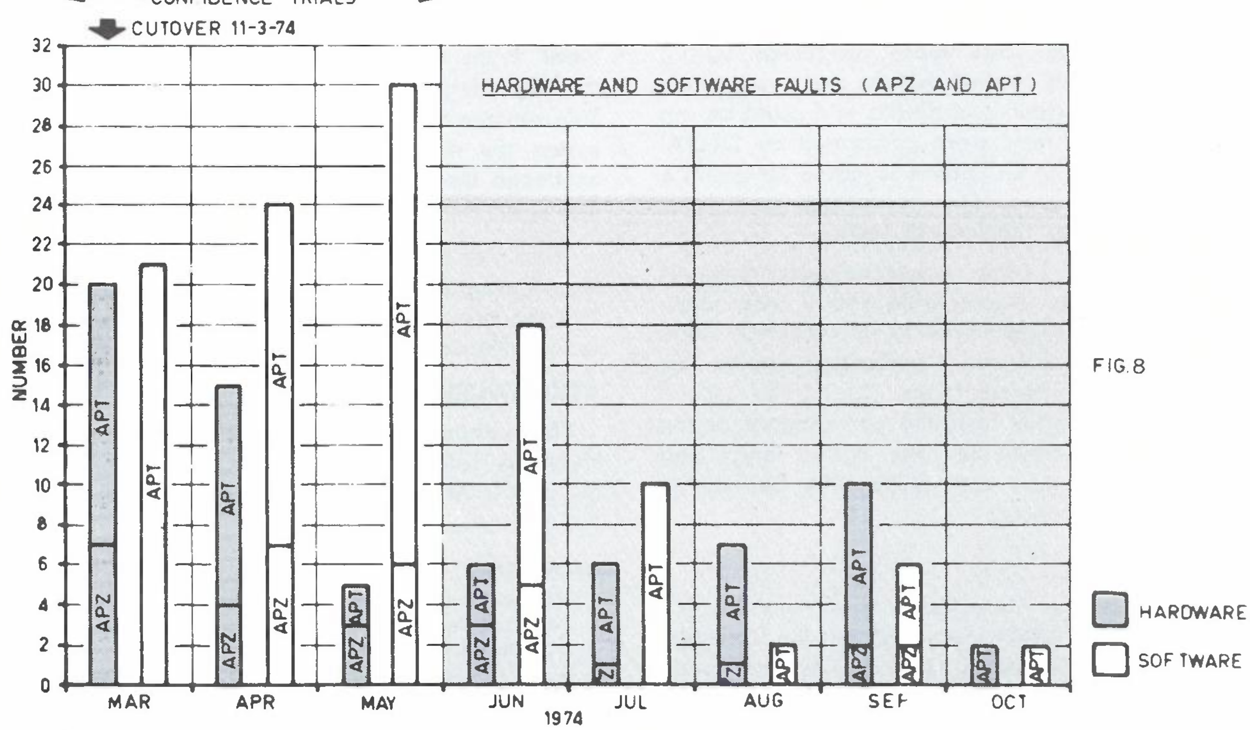


FIG.8

Figs. 6, 7 and 8 — Histograms Showing In-Service Performance.

System Testing

The System Tests were carried out by 7 test teams, 4 led by L. M. Ericsson personnel and 3 led by OTC(A) personnel, under the overall direction of L. M. Ericsson.

The System Testing was able to commence when the design and assembly of the software, and the hardware installation and testing were completed. At this stage the first complete package of APT and APZ software was loaded into memory.

During the later stages of System Testing extensive use was made of software test aid FIR-TG (Traffic Generation block) to generate high levels of test traffic. In addition three Automatic Exchange Testers and a National Network Simulator were used to measure the grade of service. Tests of the CCITT No. 6 system were carried out between the Broadway exchange and the British Post Office No. 6 Field Trial Exchange in London.

The ability of the system to detect and isolate component failures was checked.

Documentation for the System Tests was prepared principally by L. M. Ericsson while OTC(A) provided documentation for the telephony tests. The System Tests spanned a period of 5 months and concluded in January 1974, when, by mutual agreement between L. M. Ericsson and OTC(A), the Acceptance Tests were commenced.

Acceptance Testing

The Acceptance Tests were conducted during February 1974 and verified that the exchange would work under operational conditions and could be put into service. The tests were performed by OTC(A) personnel following an agreed Schedule set out in a strict 14 day program. The Acceptance Tests were not a repetition of the System Tests.

During the first 14 day period the performance of the exchange was unacceptable and it was necessary for the Acceptance Tests to be repeated. There had been 38 Restarts and 6 periods of System Disruption due to software faults. During the second period of Acceptance Tests the performance of the exchange was acceptable (one Restart only) and the System Handover took place. The Confidence Trials then commenced.

Confidence Trials

The Confidence Trials lasted three months. For Final Acceptance OTC(A) required that the Exchange switch traffic satisfactorily, that the documentation enable OTC(A) Operations personnel to operate the exchange properly, and that the in-service performance of the exchange be satisfactory.

The exchange was put into service by OTC(A) Operations Branch personnel and the performance of the exchange was gauged against criteria previously agreed between OTC(A) and L. M. Ericsson. Some of the results are shown in Table 1.

TABLE 1—PERFORMANCE DURING CONFIDENCE TRIALS

Performance Criterion	Upper Limit	Achieved
Grade of Service	0.005	0.0025
Reloads	0	0
Minor Restarts	120	46

IN-SERVICE PERFORMANCE OF THE BROADWAY EXCHANGE

Figs. 6, 7 and 8 show a graphical summary of the in-service performance of the exchange. The performance to date has been satisfactory. There has been a marked reduction in the duration of the System Disruptions since cutover, due to the correction of software faults and shorter repair times. There has also been a general decrease in the number of Minor Restarts. The present level of Minor Restarts is not causing a significant disturbance to traffic.

CONCLUSION

The success of the Broadway SPC exchange project was largely due to the AKE-131 System, and test aids, being in an advanced state of development. From a project management point of view, the high degree of involvement allowed Overseas Telecommunications Commission (Australia) to assess the development and performance of the exchange throughout the project and to develop a group of skilled staff.

In-service experience indicates that the Broadway stored program controlled exchange is reliable, and that the benefits sought by Overseas Telecommunications (Australia) will be largely realised.

ACKNOWLEDGEMENTS

The authors acknowledge the permission of the Overseas Telecommunications Commission (Australia) and L. M. Ericsson Pty. Ltd. (Australia) to publish this article.

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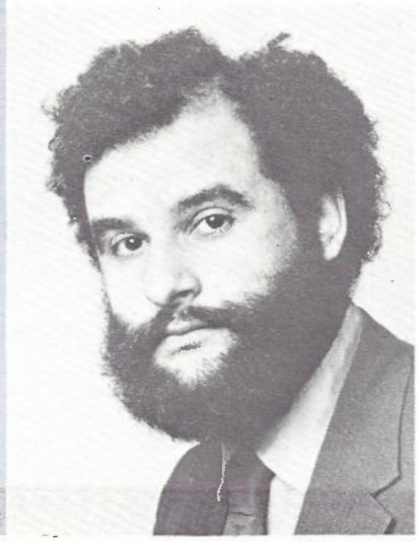
P. F. ALLEN is a Sectional Engineer in the Engineering Branch of the Overseas Telecommunications Commission (Australia). He joined the PMG Department as a Cadet Engineer in 1958 and after graduating as a Bachelor of Engineering from the University of NSW in 1963, spent 5 years as a Class 1 and Class 2 Engineer in the PMG Department. In 1968 he joined Plessey Telecommunications Pty. ltd., Sydney where he was responsible for the contract exchange installation section. In 1970 he joined the Overseas Telecommunications Commission (Australia) and was appointed project Engineer for the Broadway Exchange in 1972. In 1974 he was appointed to his present position.



P. J. SINDEL is an Engineer Grade II in the Engineering Branch of the Overseas Telecommunications Commission (Australia). He studied at the University of Sydney receiving a B.Sc. degree during 1969 in Computer Science and a B.E. degree in Electrical Engineering two years later. Since then he has been associated with a number of computer applications within OTC (A), primarily, the testing of the Broadway exchange from 1972 to 1974. Currently he is working with the OTC(A) Operations Branch developing operational and maintenance procedures for the exchange.

10 to 10 Programme Unit Model Q1

A. K. GRANT B. E. (Elect.)

The 10 to 10 Programme Unit described in this article has been designed to extend the usefulness of the portable Traffic Route Tester, Model Q1. Previous articles Ref. 1 and Ref. 2 have described the application of the devices and design aspects of the Traffic Route Tester.

This article explores some general aspects and particular design approaches used in the Programme Unit.

INTRODUCTION

The Programme Unit development followed closely in time and in design principles to the Model Q1 TRT. It is expected that ultimately a large percentage of the TRT's produced will be provided with a Programme Unit. 10A Line to 10B line programmed calling, together with print-outs of all faults will be the main advantages obtained by the addition of the Programme Unit to the TRT. Other advantages will be the ability to interwork with the Remote Call Repeater (Ref. 1) and to interrupt Observe Service TRT runs should a predetermined fault rate be exceeded.

PHYSICAL ASPECTS

The major constraint placed on the size of the unit was the need for the TRT and Programme Unit to fit side by side in a BDH rack. Another requirement was portability. These were achieved using the same size case as the TRT.

Interconnections

The Programme Unit is connected to the exchange via ten sets of exchange interface wires (the ten 'A' lines). These are wired to an 80 point plug on the front panel. Included in this plug are all wires required for operation of the Remote Call Repeater.

A second 80 point plug on the unit carries the selected A-line exchange interface wires, and B-line digital information from the Programme Unit to the TRT. This plug also carries fault information, the micrologic power supply, and various control signals from the TRT to the Programme Unit.

COMPONENTS

Logic circuits, active and passive components, relays etc. are identical to those used in the TRT, Ref. 2. Because of space limitations on the front panel it was necessary to use miniature keys, but care was taken that those chosen were sufficiently reliable. Edge connected slide-in printed circuit boards are used in the design. The choice of the plugs and sockets for connection of the Programme Unit to the TRT has been a matter of some concern. Gold contacts appear essential to ensure that logic signals are transmitted with negligible voltage drop. Also a connector which does not allow incorrect registration during insertion is essential to avoid damage to logic circuits.

Thumbwheel Switch Wiring

The connection of the ten 10-bank thumbwheel switches to the control circuitry within the case posed a design problem. Finally to avoid the need for excessive wiring to printed circuit boards the 'mother-board' principle was adopted. The 'mother-board' located directly behind the front panel holds the thumbwheel switch sockets which are soldered into the board's printed wiring. Using this principle wiring to other boards from the thumbwheel switch sockets was reduced by approximately two thirds. To reduce the insertion pressure required to place the switches into the 'mother-board' the bank commoning is made on the switches and only two of the wafers are actually inserted into sockets (Figure 1).

Servicing

All boards, except the mother board can be serviced by using a 'stand-off' board. The mother-board can be serviced in situ by removing thumb-wheel switches from the front panel to gain access. A simple removing tool is envisaged to facilitate the removal of the switches.

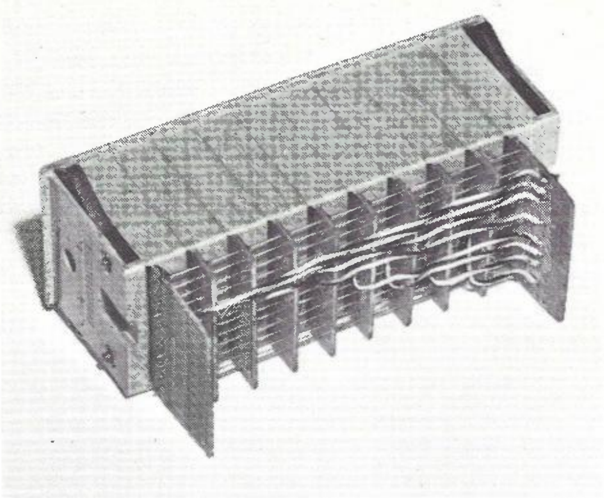


Figure 1 — Thumbwheel Switch, Rear View

B-Line Number Information

The thumbwheel switch bank is the base of 'B' number digital information from which the TRT draws when decadic impulsing during a test call. The digit read out to the TRT depends on the B line selected by the Programme Unit and the digit (e.g. first, second, etc.), requested by the TRT.

Print Sequence

The print sequence is generated at seven pulses per second when initiated by a fault signal from the TRT. During the print sequence a spacing line of zeros is printed and then the A line, B line, and fault code number information relative to the fault. The information is obtained by pulsing the respective number wheel magnets and counters allocated to them in parallel until coincidence is reached between the counters and the numerical codes indicating the A line, B line or fault code, to be printed.

DESCRIPTION OF MAJOR FUNCTIONS

The major functions are generated by TTL logic circuits notably counters, pulse generators, latches and gates. These interface electromechanical devices, (relays, printer, and thumbwheel switches), to gain access to the exchange or to transmit information to or from the user.

A and B Line Stepping Control (Figure 2)

The basis of the call programme in the Programme Unit ensures that all A-B line combinations are tested during a full call cycle. This has been achieved by incrementing the A and B line numbers simultaneously by one on the first ten calls. However, whereas the B line counter returns to one on the next count the A line counter counts to eleven. No call is attempted before the counters take the next step, (A line restores to one and B line increments to two), and the second series of ten calls is commenced. This process continues through the complete call cycle.

Line Cancelling Facilities

A lines are taken out of the programme by means of one key per A line. B lines are removed from the programme by setting the first digit of their line number to the blank position. Operation of either of these cancelling devices has the effect of maintaining the input to the counters if either of them correspond to the number of a cancelled line. The counters continue to increment until the numbers obtained correspond to an A and a B line neither of which are cancelled. The A and B line numbers in use on any call are displayed on the front panel.

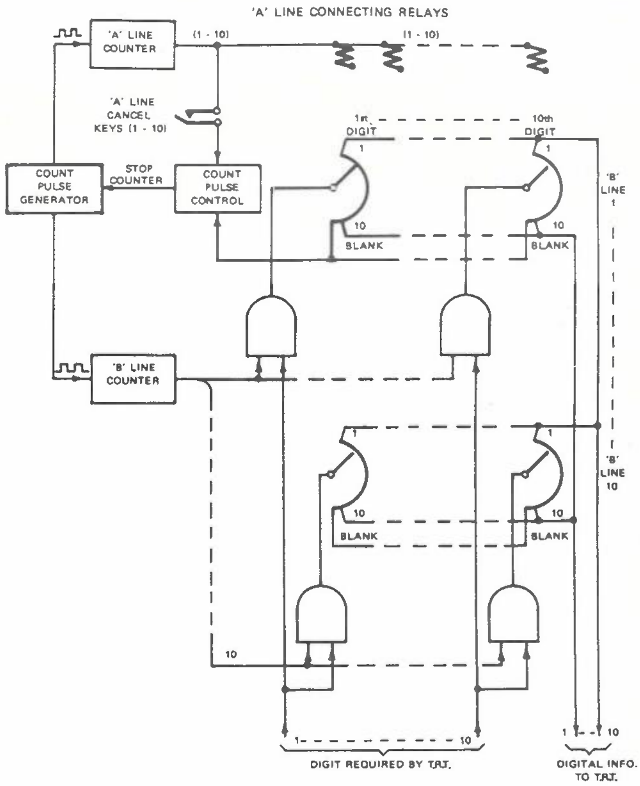


Figure 2 — A and B Line Stepping Control

Machine To User Numbering Translations

The counters used for A and B line stepping reset to zero on switch on. Because of the desirability of starting on line 1 during a call programme count O is translated to show 1 on the visual display. Similarly all other counts are incremented by one before visual display. During printing A and B line numbers reference is made to the basic A and B line counters. Therefore the same translation has to be allowed for. To achieve this it is necessary to reset the A and B line number wheel setting counters to nine prior to pulsing the counters and number wheels. It is also necessary to ensure the number wheel is pulsed at least once to avoid a print out of 0 when it should be 10, viz.:

A -line Counter	Printer Counter after reset (No pulses received)	Correct User A Line Number	Position of Print Wheel (No pulses received)
9	9	10	0

It can be seen that coincidence is reached between the two counters whereas the print wheel is incorrectly positioned. If one pulse is admitted correct coincidence will be reached in the above case only after the 10th pulse, thus giving the correct printout.

FIELD TESTING

Testing of the Programme Unit in combination with the TRT has been performed by Network Performance and Operations Branch, Central Office. Tests were conducted in all representative subscriber exchange types including SCAX's in and around the Melbourne area. These tests were satisfactory and indicated the versatility and effectiveness of the devices.

FUTURE DEVELOPMENTS

During the development of the Programme Unit two areas where cost, size and reliability improvements could be made were recognised. One was the use of bipolar random access memories to replace the thumbwheel switches. Considerable design effort would have been needed however, to overcome the fact that the memories are volatile and have no intrinisic visual display. The other was the use of solid state thermal printing. The main problem encountered here was the unavailability of detailed data regarding these devices and suitable paper feed mechanisms. It is expected that future generations of programmable TRT's will utilise these principles.

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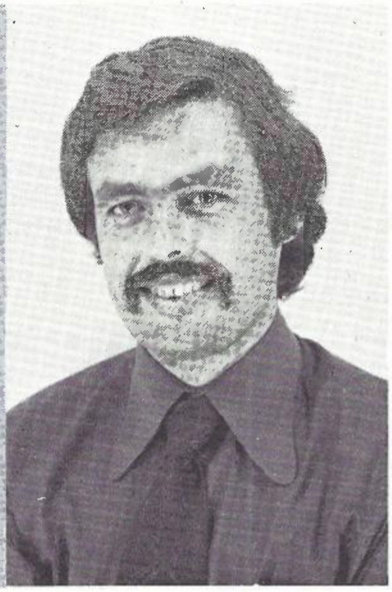
A. K. GRANT was appointed as Engineer Class 1 to the Roma Division in 1965. Since then he has served periods in Country Installation Qld, Systems Design Central Office, Design Co-ordination Qld, and Metropolitan Installations Qld. It was during his period in Design Co-ordination that he was responsible for the prototype development of the Programme Unit.



Why Is An Erlang So Called?

A.K. Erlang was born nearly one hundred years ago on 1st January, 1878, at Lomberg in Jutland. Erlang was introduced to a study of the application of probabilities to telephone problems by Dr. Johanssen, who had written two essays on the subject in 1907 and 1908. He was engaged by Dr Johanssen to work with the Copenhagen Telephone Company in 1908, as a scientific collaborator and it was this position which gave him the opportunity to develop and utilise his gifts for the rest of his life. Erlang's most important work, "Solution of Some Problems in the Theory of Probabilities of Significance in Automatic Telephone Exchanges" was published in 1917. This paper contained his formulae for congestion loss, and waiting time which are of fundamental importance to the theory of telephone traffic. Agnar Krarup Erlang died on 3rd February, 1929, only 51 years old.

Prior to 1943 the name of the unit of telephone traffic had many different variations and in 1943 it was proposed that the name of "Erlang" be introduced as the title of the unit of traffic. This proposal was adopted in Scandinavian countries in 1944, and in 1946 it was proposed to the CCIF (Le Comite Consultatif International des Telephoniques a Grande Distance) and unanimously carried. The following definition is recorded:

> "For a group of circuits (or devices), the average intensity of traffic, during a period, equals the total occupancy divided by T. The unit of traffic intensity defined above is called the "erlang."

The number of calls in progress varies from moment to moment, the actual number depending on the times of arrival and the duration of calls. The above definition implies that the average number of calls in progress simultaneously is numerically equal to the average traffic intensity in erlangs.

The product of the number of calls originating in a given period and the average holding time in this period, expressed in hours, is equal to the traffic volume in erlang hours. If a switch is engaged on one call for 60 minutes its occupancy is one, the traffic intensity is one erlang and it carries a traffic volume of one erlang-hour. Similarly, twenty 3-minute calls occupying a switch in succession would correspond to the same traffic intensity and volume.

In 1973, the number of calls maturing locally in the APO networks amounted to over 3,000,000,000 and if these averaged 3 minutes each they would amount to a traffic volume of about 150,000,000 erlang-hours. These are spread over a year, so that if on each weekday the same number of calls was carried and each busy hour had ⅛ of the daily total traffic, the traffic volume would be 72,000 erlang-hours and the average traffic intensity would be 72,000 erlangs during a busy hour. Sufficient plant must be provided to carry this traffic intensity with, on the average, not more than one call in 100 lost in the busy hour between origin and destination. The symbol for an erlang is 'E'.

Erlang's theories, and later developments by other notable people, have brought systematic rational processes into the "dimensioning" of our networks. "Dimensioning" is the procedure for deciding upon the configuration and number of switches, circuits and other devices needed to handle the traffic intensity with a satisfactory grade of service in the most economical way.

Errata – Vol. 24, No. 2, 1974

Colour Television — Some Effects on APO Plant.

On page 110 it is stated:

. . . (as T = 500μs for 1 MHz bandwidth) . . .

this should read

. . . (as T = 500ns . . .) . . .

The Bellenden Ker Television Project (Part 2)

A. B. POULSEN, B.Sc., Dip P.A., M.I.E. and P. J. REED B.E.

Part 1 of this article, in the previous issue of the Journal, outlined the background to the Bellenden Ker television transmitter and radiotelecommunications project, and described the construction of a passenger cableway to the top of the Bullenden Ker range for site access. This second part of the article describes the equipment installed in the transmitter building and the operation of this equipment by remote control. This was the major factor permitting the integration of all radio operations in the Cairns area into a functional Radio District.

TELEVISION AND RADIO EQUIPMENT

Reliability was of course the primary consideration for equipment to be installed in such an isolated location, and this was achieved in general by the selection of high quality equipment of known performance and stability, and the use of solid state design wherever possible.

The microwave radio installation carries the two television programmes, National and Commercial, from Cairns to Bellenden Ker and also some 600 bothway channels of telephony between Cairns and the Atherton Tableland. In addition to this, a number of VF channels are available between Cairns and Bellenden Ker for such purposes as remote control channels, order wires and for use with VHF base stations for "Other Services" such as Police and Ambulance. The Cairns to Bellenden Ker hop is in the 2 GHz band to minimise fading attenuation from heavy tropical rainfall, while the remainder of the link to the Tablelands is in the normal 4 GHz spectrum. Equipment installed by the Department of Transport includes a number of transmitters and receivers in the 120 MHz band for air-to-ground communications, together with associated VF channels to Cairns.

The television equipment itself is fairly conventional and comprises a "shared" installation such as has been put into operation at many other places in Australia. The sharing concept implies that as much common equipment as possible is used by both National and Commercial interests and includes items such as the building itself, test equipment, the transmitting antenna tower and in this case the transmitting antenna as well. Under such an arrangement the APO also carries out all operational and maintenance activities on the commercial transmitting equipment. The main factor distinguishing the transmitting equipment from other similar installations is that it was designed and installed to be suitable for colour transmission which, at the time of planning, was some years in the future.

A block diagram of the national television facilities for Channel 9 is shown in Fig. 10. The commercial facilities for Channel 10 are similar, except that the test equipment and similar items are not duplicated. Each channel consists of twin 5 kW vision and 500 W sound transmitters operating in parallel. These outputs are then combined in a Channel Diplexer so that a common transmitting antenna may be used. This antenna itself consists of two halves which are fed from a power splitting transformer. Parallel transmitter operation guards against programme breaks in the event of a fault in one unit, while the use of a common antenna results in considerable economies in capital expenditure for antennas and the supporting tower. The programme input equipment for the transmitters has been kept as simple as possible to minimise maintenance problems on site. The video and audio channels are duplicated; complex devices such as stabilising amplifiers are not provided but may be inserted in the programme chain at Cairns if required at any time. In addition to the normal programme, a video and audio test signal source or an emergency slide and music may be selected for transmission.

A transmitting tower near the eastern face of the building carries all antennas for the complex.

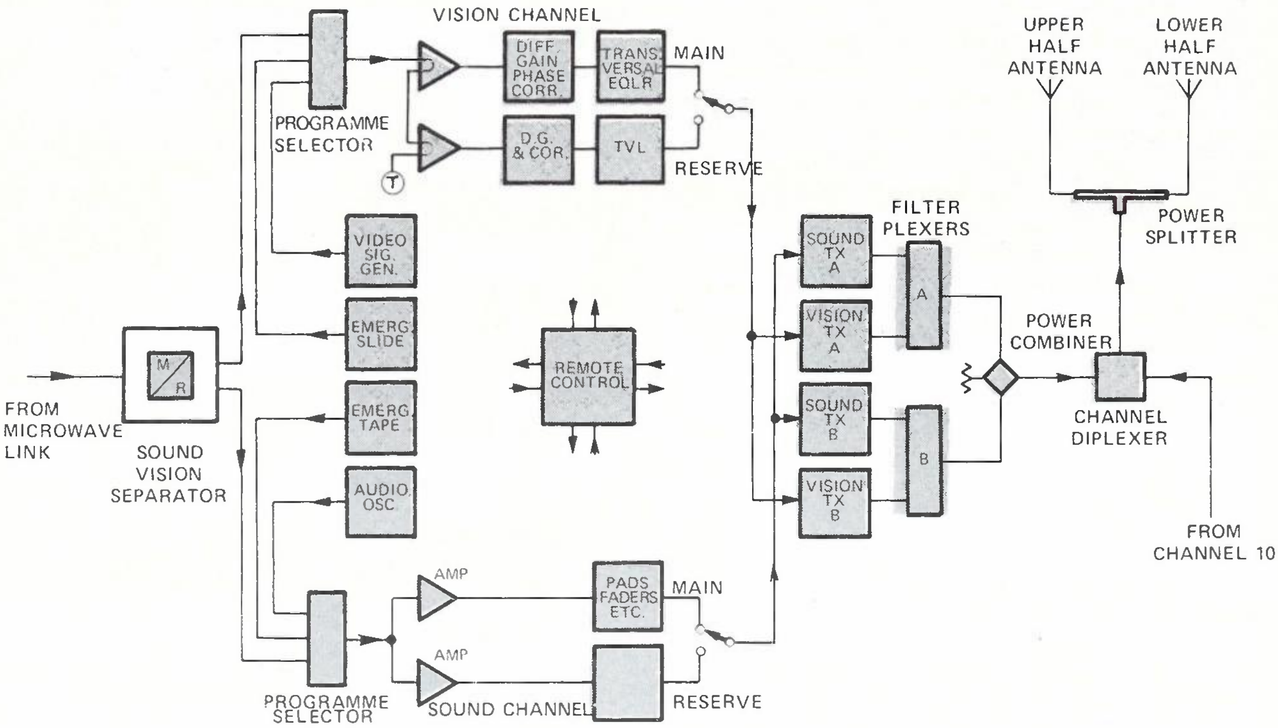


Fig. 10 — Channel 9 National Television Facilities.

This tower consists of a standard 60 m extreme duty microwave link tower modified with offset footings to suit the site and a 25 m extension to carry the two-section television transmitting antenna which consists of six bays of double-dipole panels. In addition to this, a number of 3 m parabolas for the microwaves links, and discone antennas for the air-ground communication links are mounted on this common tower, which is designed to resist winds of 225 km/hr.

All equipment in the building is supervised by a special fire protection system. This consists of smoke detectors installed in strategic areas of the transmitters and equipment rooms, backed up with thermal detectors and BCF pressure sprays. Operation of a smoke detector in a transmitter causes circuit breakers to remove all primary AC power from that transmitter and transmission of an alarm to the control centre. Should combustion continue in any cabinet a thermal detector actuates a BCF pressure spray in the cabinet. Equipment areas have smoke detectors for early warning alarms, backed up by a number of BCF bottles with thermal heads.

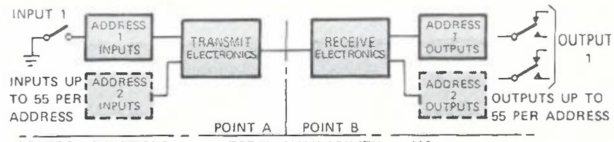
Emergency power for the building and equipment is provided by a 170 kVA diesel alternator, arranged for automatic start and load transfer should the incoming AC mains vary outside preset limits. The plant runs until normal mains have been restored and then closes down automatically in a controlled sequence. Starting and stopping of the plant may also be done by remote control if required for any reason. Sufficient fuel is stored on site in service tanks to enable the station to run for at least one week on full load during prolonged interruptions to the commercial mains supply.

REMOTE CONTROL EQUIPMENT

The whole design philosophy of the equipment installation was based on the plan to operate by remote control from Cairns. Factors which influenced this decision were mentioned previously and included the isolation of the station as well as the possibility of considerable savings in operational costs by having an integrated radio control and maintenance centre in Cairns. Another important consideration was that a concentration of skilled staff working from one centre and having the responsibility for a wide variety of radio, television and microwave equipment should lead to a more challenging range of duties and result in enhanced staff career interest and fulfilment.

The major problem to be faced was the current requirements of the Australian Broadcasting Control Board (ABCB) for remote control operation of television transmitters, which stated that a number of parameters in the transmitted signal must be both adjustable from and continuously monitored at the control centre. However a controlled field trial of a number of transmitters had convinced us that the daily setting up procedures were not only unnecessary but actually detrimental, and that the transmitters were normally capable of performing well within the required limits for periods of at least a week without any attention. Accordingly it was decided that variable controls and analog monitoring of the transmitter functions would not be provided and the approval of the ABCB was obtained for such a system on a trial basis. The advantage of such a design is that the overall system can be less complex, thus lowering the capital cost and reducing maintenance problems.

Once such a system was defined and the details of the equipment to be installed were known it was possible to specify how many bits of data were necessary for satisfactory operation between the control centre and the station. This consisted of a number of "On", "Off", "Select" and similar functions to control the transmitting equipment together with similar status indications at the control centre to monitor the equipment functions and alarms. Previous experience at another station had convinced us that the most satisfactory method of installing remote control equipment was to buy the data transmission system as a "black box" with the required number of bits and to design and install any necessary interface equipment to suit our own requirements. This concept has particular relevance where a complex system of controlled outstations is involved. The system design was for a control centre in Cairns to control and monitor the two sets of television transmitters on Bellenden Ker and the three MF broadcasting transmitters at Mossman, Gordonvale and Atherton. After careful consideration the data transmission system finally chosen was a two-address system for the TV control and a separate three-address system for the broadcast control. A block diagram of the basic system concept is shown in Fig 11, which also specifies in general terms the allocation of data bits to the various functions in each direction. An earth on any input at the data transmitter will cause a correspond-



CONTROL FUNCTIONS CONTROL CENTRE TO T.V. TRANSMITTER SITE	TOTAL AVAILABILITY	100	
	TOTAL IN USE	74	
	EG: TRANSMITTERS		36
	PROGRAMME SWITCHING		10
	METERING		24
	EMERGENCY ENGINE		4
SUPERVISORY FUNCTIONS TRANSMITTER SITE TO CONTROL CENTRE	TOTAL AVAILABILITY	110	
	TOTAL IN USE	106	
	EG: TRANSMITTER STATUS AND ALARMS		56
	PROGRAMME SWITCHING		10
	DIGITISED METERING		14
	ENGINE STATUS AND ALARMS		5
	COMMON EQUIPMENT ALARMS		8
	BUILDING ALARMS (FIRE, AIR COND., ENTRY, ETC.)		13

Fig. 11 — System Concept — Television Remote Control Equipment.

ing relay at the far end to operate two sets of changeover contact units which may be utilised in any desired fashion.

The data transmission system itself is quite complex and a simplified functional diagram is shown in Fig. 12. Input data is supplied in parallel form and each address block has 55 available inputs. The transmitter scans each input of address A in sequence and the input data is converted to a serial form of short pulses (SP) or long pulses (LP) corresponding to open circuit or earth on the inputs. This pulse train is used to phase reversal modulate a VF carrier generated in the equipment and this carrier is sent to line after suitable filtering and processing. The pulse train consists of 64 bits; the first five bits carry the address information in binary coding; the 55 data bits follow; then comes 2 bits for system alarms, a parity check bit and finally an "extra long" synchronising pulse (ELP) which updates the memory and prepares for the next pulse train. When the first pulse train is completed, a programmer steps the scanner to address B, which has another 55 inputs but is identified by a different binary coding of the 5 address bits. These inputs of the second address are similarly encoded and transmitted and the process continues, stepping around as many addresses as are provided before returning to the first. The speed of transmission is set by the clock pulse generator and may be varied from 50 to 1200 bauds depending on requirements and the availability of a suitable VF signalling channel. In the Bellenden Ker system a speed of 200 bauds was chosen. This ensures that the maximum response time from the initiating of a command in the control centre to the receipt of an acknowledgement from the transmitter is about 2.5 seconds.

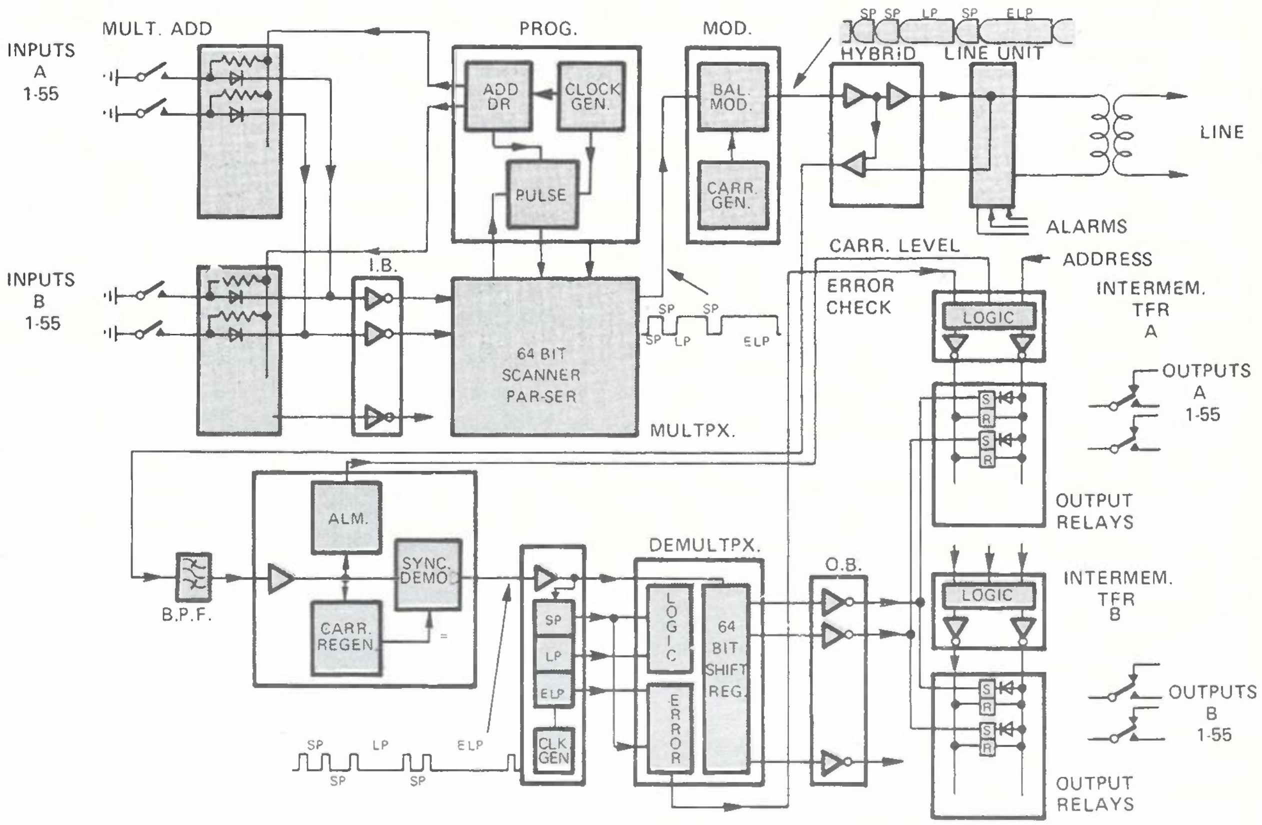


Fig. 12 — Data Transmission Equipment — Transmit and Receive Electronics.

At the receiver, the input carrier is filtered, amplified, clipped, synchronously demodulated and processed to give a pulse sequence identical to that originating in the transmitter. For each transmitter address there is a corresponding inter-memory transfer circuit and set of output relays in the receiver which form a latching permanent memory. As a pulse train is received the condition of each pulse (long or short) is stored in a temporary memory and converted from serial to parallel form again. During the last extra long synchronising pulse the contents of this temporary memory store are transferred to the permanent memory relays of the corresponding address provided a number of message checks are valid. These include—

- Input signal level
- Total number of pulses
- Correct parity
- Correct sync pulse length
- Correct address coding.

If these checks are verified the data is transferred to the appropriate permanent memory relays as determined by the address bits at the beginning of the pulse train. The numerous checks applied to each message ensure the system is very reliable even when channels with poor signal/noise ratio are used. Extensive use of integrated circuits is made and the system has been very reliable in operation.

Operation

At the control centre in Cairns control panels are provided with push-buttons for operation of all required facilities. Integral status indication lights are provided to give continuous indication of all monitored functions and alarms. As stated previously, analog monitoring of such functions as vision transmitter power is not part of the system design; instead two preset alarms for "power high" and "power low" are provided; each of these needs only 1 data bit for transmission. However, in order to assess the usefulness or otherwise of such a facility, provision was made for analog monitoring of selected quantities using an analog-to-digital converter at the transmitters and a number of bits in the data transmission system, together with a digital readout at the control centre. The experience of the maintenance staff has confirmed that the facility is of interest value only and is not necessary for satisfactory system operation and monitoring.

Apart from status and alarm monitoring on the remote control system, a precision off-air TV monitoring receiver is used for continuous check of the radiated signal, and will ultimately be used for routine testing so that visits to the site for this purpose can be reduced in frequency.

After full power operation on 100 kW ERP commenced, a detailed field survey was undertaken to determine the grade of service in all areas which the transmitters were designed to cover. Because of the many uncertain factors in signal strength predictions, it had been anticipated that certain localities could have an unsatisfactory standard of service and this was, in fact, verified by the survey. It will be necessary to establish translator stations at a number of sites, but this task will be simplified by the general availability throughout the area of a high quality primary signal source.

As a result of the implementation of an integrated control and maintenance centre (Radio District), it has been possible to reduce the total technical staff in the Cairns radio area by some 30%. At the same time, the practice of having skilled staff scattered around a number of small and generally isolated areas has been eliminated, and this, in conjunction with the diversification of duties should lead to a greater degree of career satisfaction and contentment among the technical staff. Apart from the obvious gains of reduced labour costs and better staff morale, the other advantage for management is that of having a large pool of skilled technical staff concentrated in one place, giving considerable operational flexibility.

CONCLUSION

The Bellenden Ker project was conceived as the best realisable solution to the problem of providing a television service for the Cairns area and grew in the planning to be a major radio facility. Since it became a reality, experience has shown that the aims of the project have been generally achieved and the centre which has been established will serve as a vital telecommunications facility in the area for many years to come.

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An Historical Survey of Communications Satellite Systems — Part 1

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The history of communications satellites from 1945 to the present is given. Experimental and operational satellites and satellite systems, past, present, and future are described. Some applications are discussed, and two related subjects, operating frequencies and launch vehicles, are mentioned. The significance of these topics for an Australian National Satellite System is emphasized throughout.

INTRODUCTION

The phrase "Live Via Satellite" has become familiar to television viewers, and today the majority of international telecommunications traffic is carried by satellites. Their use is also beginning to extend to national systems, both in industrially advanced countries such as Canada, the USSR, and the USA; and in developing nations such as Brazil, India, and Indonesia. The national systems are intended to supplement existing networks, to extend existing networks into areas difficult to reach with conventional terrestrial equipment, and to provide new types of service.

This article, the first of three parts, describes early satellite communications experiments; the international satellite system Intelsat; US, UK, and NATO military communications satellites; and the Russian national satellite system. The second and third parts will discuss general types of satellite system implementations, some more recent experiments, and national and regional systems for Canada, the USA, Europe, and Japan. In addition, the important allied topics of operating frequencies and satellite launch vehicles will be covered.

EARLY HISTORY

Any discussion of the history of communications satellite systems must begin with Arthur Clarke's paper, "Extra-Terrestrial Relays", which appeared in the October 1945 issue of *Wireless World*. At a time when the largest operating rocket, the German V-2, had a maximum altitude of about 150 km and a maximum horizontal range of a few hundred km, and when many reputable scientists were still maintaining that it was physically impossible to build a rocket which could go into orbit around the earth, this RAF radar officer, a writer by trade and member of the British Interplanetary Society by interest, had the combination of knowledge, foresight, and imagination to conceive what has become the standard communications satellite system. Other possibilities have been proposed, tested, and (with one exception, discussed below) discarded. Some of the features, for example inter-satellite communication links, were so far advanced that they are only now planned for implementation. It is difficult to improve the original explanations, so the features may be summarised by means of a few quotes:

- "One orbit, with a radius of 42,000 km [an altitude above the earth's surface of 36,000 km] has a period of exactly 24 hours. A body in such an orbit, if its plane coincided with that of the earth's equator, would revolve with the earth and would thus be stationary above the same spot."
- "Let us now suppose that [a satellite were] in this orbit. It could be provided with receiving and transmitting equipment and could act as a repeater to relay transmissions between any two points on the hemisphere beneath."
- "Moreover, a transmission received from any point on the hemisphere could be broadcast to the whole of the visible face of the globe."
- "A single [satellite] could only provide coverage to half the globe, and for a world service three would be required, though more could be readily utilized."
- "[Antenna dishes] about a metre across would beam almost all the power on to the earth. Larger reflectors could be used to illuminate single countries or regions."
- "A fundamental problem is the provision of electrical energy . . . Thermoelectric and photoelectric developments may make it possible to utilize the solar energy more directly."

- "The [satellite] would be in continuous sunlight except for some weeks around the equinox, when it would enter the earth's shadow for a few minutes every day . . . The total period of darkness would be about two days per year, and as the longest period of eclipse would be little more than an hour there should be no difficulty in storing enough power for an uninterrupted service."

Some alternatives to the above configuration of an active-repeater satellite in a geostationary synchronous orbit are passive reflectors of various kinds, active repeaters in relatively low orbits a few hundred to a few thousand kilometres high, active repeaters in near-synchronous circular orbits, and active repeaters in a particular 12-hour orbit which may be called pseudosynchronous. Excepting the last, these alternatives have been tried and found inferior to Arthur Clarke's system. The 12-hour orbit is presently used in the Russian domestic system and is planned for some of the satellites in the next US military system. The reasons for its use in these cases, and why it too is inferior to the geostationary orbit for most applications, are discussed below.

The world's first artificial satelite, Sputnik I, was launched in October 1957 by the USSR. Just over a year later, the US Score satellite included the first satellite repeater. It was used to relay messages between Arizona, Georgia, and Texas, and also to demonstrate broadcasting from space as it transmitted a recorded Christmas message from President Eisenhower. The US military continued its satellite communications experiments in 1960 with the Courier and West Ford projects. The former was another low-orbit repeater, this time including delayed transmission capability for communications between opposite hemispheres. The latter consisted of millions of tiny dipoles distributed in a band around the earth, to provide an efficient passive repeater at the resonant frequency of the dipoles. In the same year, the US National Aeronautics and Space Administration (NASA) initiated its communications experiments with the launch of Echo I, a large metal-coated balloon which was another form of passive reflector. Although the West Ford and Echo projects (including Echo II, launched in 1964) showed that communication using passive reflectors in space is possible, the results were not encouraging and only active repeaters are now considered for any satellite communications system.

Before leaving the passive reflectors, it is interesting to note that the communications aspect of the experiment was successful only in a negative sense, that is the concept was shown to be inferior to active repeaters. However, the changes in the orbits of these high-drag objects provided valuable data on the density of the small part of the earth's atmosphere which exists at altitudes of several hundred kilometres. In addition, the loss of gas in the Echo indicated by the "roughness" of the skin as seen by radar gave some measure of the density of micrometeorites above the atmosphere. These are excellent examples of the scientific "fallout" obtained from early satellites, foreshadowing the applications fallout which may be expected from communications satellites.

The Telstar satellite, built by the American Telephone and Telegraph Company (AT & T) and launched in July 1962, represented the first non-government satellite (since it was intended to be experimental only, it might be inaccurate to refer to it as "commercial"). Among other experiments, it provided the first transatlantic color television transmission. Later the same year, NASA's Relay spacecraft was launched. It, like Telstar, was a low-orbit active repeater. One of its experiments, the first transpacific television transmission, brought the news of President Kennedy's assassination to Japan in November 1963. A second Telstar was launched in 1963, and a second Relay in early 1964. In the meanwhile, however, after nearly 18 years, Arthur Clarke's vision had been implemented in the Syncom spacecraft.

The first *Syn*chronous-orbit *Com*munications satellite never went into operation, because of a presumed launch failure. The launch sequence for this and most other synchronous-orbit satellites is as follows. After separation from the launch vehicle, the satellite is in a highly elliptical orbit with a perigee (lowest altitude) of a few hundred kilometres and an apogee (maximum altitude) near the synchronous altitude of 36,000 km. After a few orbits in this ellipse, the orbit parameters have been well established and the orbit can be precisely circularized. Near apogee, a small additional rocket stage (called the apogee kick motor, or AKM) is fired, and the spacecraft orbit becomes circular at synchronous altitude. The satellite is then allowed to drift to its intended orbit position, at which time its station-keeping system is activated and it is put into service. In the case of Syncom I, everything went normally up to the firing of the AKM, upon which contact with the spacecraft was lost. The obvious conclusion is that the AKM firing was responsible for the loss of the spacecraft. At any rate, five months later, in July 1963, Syncom II was successfully launched, injected into synchronous orbit, and went into operation. A third Syncom, launched the following year, was also successful.

This period of time, 1963-1964, marks the end of the early history of communications satellites. A number of experimental programs had tested various alternatives, and the original concept had finally been shown to be technically feasible. The Intelsat consortium had been formed, leading to an operational satellite system for worldwide communications. In the second phase, experimentation continued but the chief characteristic was the implementation of several systems: the Intelsat network; the US, UK, and NATO military systems; and the USSR Orbita network. The third phase, in which satellites are used to provide national communications for countries such as Australia, is just beginning. With this broad outline in mind, the progress of the individual programs can be considered separately in detail.

INTELSAT

In August 1962, President Kennedy signed the Communications Satellite Act, which stated, "It is the policy of the United States to establish, in conjunction and in cooperation with other countries, as expeditiously as practicable a commercial communications satellite system, as part of an improved global communication network." Recall that Telstar had just been launched, there was still doubt that a synchronous satellite system was feasible, and the first transatlantic telephone cable had been in service just over five years. This Act established the Communications Satellite Corporation (Comsat) as the US body responsible for international satellite communications. As a result of this and of discussions which began in 1960, the International Telecommunications Satellite Consortium (Intelsat) was established in 1964. The Consortium would own, operate, and share the revenue from the satellites and control stations (together comprising the "space segment"), while each member would own and operate its own earth stations. In Australia's case, for example, the Ceduna, Moree and Carnarvon earth stations are owned and operated by OTC (A). Membership in the Consortium would be open to any country, the size of its investment and return being based on the amount of traffic generated by it. The governing body was the Interim Communications Satellite Committee (ICSC), membership in which was limited to countries (or groups of countries) with 1.5 percent or more of the total investment. Administrative and financial management was carried out by Comsat. This temporary arrangement was superseded in February 1973 with the formation of the International Telecommunication Satellite Organization. A number of structural and legal changes were made of which the most significant were the replacement of the ICSC with a Board of Governors and the gradual phasing out of Comsat as the system manager.

Needless to say, this description passes over a number of rough spots. Before the US Congress passed the Communications Satellite Act, there was a great deal of disagreement over the organization which should be responsible for communications satellites: the government, the existing common carriers, or a new corporation. Intelstat was originally established only with the proviso that a permanent arrangement would be worked out in 1969, but it took over three more years to reach agreement. The Americans felt that their great contribution to Intelsat was not being fully appreciated, the Europeans wanted to reap some of the spinoff benefits from the space system, the small countries felt inadequately represented and worried that some of the money spent in Europe for space hardware was advancing European technology at their expense, and almost everyone was unhappy at a private US company running the show. Some idealists feel that Intelsat might have provided a worldwide education and television system, or at the very least put more money into the space segment so that less expensive earth stations would be required and small countries would find it easier to join. Its defenders argue that, had Intelsat taken more time to develop the technology for such ventures, other forms of communication would have built up such a lead that there would be no satellite system at all, and as a result transoceanic communications would cost two or three times as much as they do*.

The technical history of the Intelsat system is much simpler. Its first satellite, "Early Bird", a straightforward derivative of the Syncom satellite, was launched in April 1965. There were eleven members of the Consortium, but only five earth stations (one in the US, four in Europe). The first satellite in the second series was launched in October the following year. The Intelsat IIs were slightly enlarged and modified versions of Early Bird, and a large factor in their rapid development was NASA's desire (and willingness to pay) for communications to support the Apollo program. The third series, Intelsat III, was a new, larger design. Most satellites were and are spin-stabilised, that is the whole spacecraft is set spinning so that the axis about which it spins maintains its orientation in space. This is necessary to keep the solar cell

* Very interesting discussions of these political problems may be found in Brenda Maddox's book *Beyond Babel* (an extract titled "Intelsat-Lament for a Lost Hope" appears in *New Scientist* of 1 June 1972) and in N. V. Shenoi's lecture "Satellite Communications — A Case Study" published in the *Journal of the Institution of Telecommunication Engineers*, Vol. 19, No. 3, 1973.

array, which is the prime power source, illuminated at all times, and to keep the earth in the field of view of the communications antennas. Previous satellites used antennas with cylindrical coverage so that the antenna could rotate along with the spacecraft body. The Intelsat III introduced the mechanically despun antenna, that is, the directional antenna was rotated at the same speed but in the opposite direction to the spinning spacecraft body, so that it stayed pointing at the earth. Eight of this type were launched between September 1968 and July 1970, of which three failed to achieve the proper orbit, two are unusable, and three are still used as backup for the next series.

The Intelsat IVs, five of which are now in service, are larger still. Aside from the higher available power and channel capacity, the most significant improvement is the addition of two steerable "spot beam" antennas to the despun global coverage antennas. This allows a greatly increased traffic volume for limited areas such as the eastern US or Europe. In contrast to the rather mediocre record of the previous series, there have been no launch failures, and the only performance problem has been a loss of sensitivity in some of the satellite receivers, requiring an increase in earth station transmit power.

The characteristics of the four types of satellite used so far are summarized in Table 1.

TABLE 1: CHARACTERISTICS OF INTELSAT SATELLITES

	Intelsat I	Intelsat II	Intelsat III	Intelsat IV
First launch	4/65	10/66	9/68	1/71
Mass in orbit (kg)	38	87	140	720
Solar array power (W)	45	90	160	700
Number of transponders (1)	2	1	2	12
Transponder bandwidth (MHz)	30	125	225	36
Transponder equivalent power output (W)	40	40	150	2400
Number of two-way voice circuits	240	240	1200	9000
Design life (years)	1.5(2)	3(3)	5	7

Notes:

1. A satellite transponder is the combination of receiver, frequency translator and transmitter; sometimes called a repeater.
2. Life in service was over four years; retired 8/69.
3. Life in service was over four years; last still functional when retired 8/71.

While the entire Intelsat network has been growing at a great rate, by far the major part of the traffic and of the traffic growth is in the Atlantic basin, and three of the five Intelsat IV spacecraft are used for this traffic. The long-range plans for the space segment called for an Intelsat V to be introduced when the IVs reached the end of their design life, starting in about 1978. By using higher frequency bands, techniques for using the same frequencies several times, and possibly some switching in the satellite, capacities of more than 100,000 voice circuits per spacecraft would be provided. Such a satellite is still planned, but because of the Atlantic traffic growth, an interim design, the Intelsat IVA, will be launched in 1975. By taking advantage of advances in technology and by using only spot beams, it will provide twice as many transponders and voice circuits as the Intelsat IV with hardly any increase in size, weight, or cost.

At the end of 1972, the earth segment of the network consisted of 65 earth stations in 49 countries. There is no restriction on the size of an earth station and, in fact, mobile stations with antennas of less than 5 metre diameter have been used for demonstrations and temporary coverage. However, the rate structure is based on large stations, the smaller stations being required to pay a higher rate per circuit, so that all the recent permanent stations have antennas of about 30 metre diameter.

Although the allowable percentage ownership is based on usage of the network, there is no requirement that a user be one of the members. For example, the (non-member) Peoples' Republic of China is building three stations, two near Peking and one near Shanghai.

The Intelsat agreements restrict the carrying of international traffic by domestic satellite systems of member countries. However, the international network is permitted to carry domestic traffic, and there are several examples of such use. The United States has used Intelsat for mainland-Hawaii, mainland-Virgin Islands/Puerto Rico, and contiguous states-Alaska traffic, much if not all of which will presumably be taken over by one of the US national systems being implemented. Spain leases a number of circuits for traffic with the Canary Islands, and Algeria is planning to lease a transponder for national use. In 1969-1970, the Australian Post Office leased 24 circuits for use between Sydney and Perth until inauguration of the East-West Microwave System. With these examples one might wonder why a country need consider a national system when satellite capacity is already available for leasing. Leasing capacity has the advantage that the large initial capital expense of the satellite and its launch is not required, but more than offsetting this are the higher per-annum costs of the satellite capacity and the requirement, in view of the rate structure, for large earth stations. As an example, a US-Alaska circuit via the Canadian national satellite costs one-third as much as the same circuit via Intelsat. Again, a station with a 30 metre antenna costs $5-6 million, while one with a 15 metre antenna which would provide the same performance with a national satellite would cost under $3 million.

While Intelsat circuits are expensive compared with those provided by national satellites, they are more than competitive with transoceanic cables. Moreover, the rates for their use have decreased significantly, reflecting Intelsat's increased profitability, as indicated in Table 2.

TABLE 2: INTELSAT FINANCIAL OPERATIONS

Year	Charges ($US thousands per unit * per annum)	Revenue ($US millions)	Expenses ($US millions)
1965	32	2	8
1966	20	3	12
1967	20	17	24
1968	20	29	22
1969	20	45	35
1970	20	75	31
1971	15	78	43
1972	13	90	55

* A charge unit is a voice half-circuit of standard quality, through a standard earth station.

Source: Aviation Week and Space Technology, March 19, 1973.

One operational feature of the Intelsat network merits some discussion. A great advantage of a satellite over line communications such as cables is that any station within its coverage area can communicate with any other. Up until 1971, this capability was implemented only by assigning a frequency channel to each station, with a bandwidth appropriate for the number of telephone circuits at that station. This gave long-term flexibility, since changes in traffic patterns could be efficiently accommodated by changing the assignments. In the short term, however, if a circuit were not in use by one earth station, the portion of the total system frequency band to which the circuit was assigned was not available for use by other stations and circuits. The SPADE demand-assigned system introduced in 1971-1972 greatly increases the effective capacity of the network by making a pool of circuits available to all the stations. A station placing a call is assigned a circuit from the pool; when the call is completed, the circuit is returned to the pool. The capacity is further increased by turning off the earth station transmitter during pauses in the conversation, a procedure called "voice-activated carrier". This feature more than doubles the traffic capacity of a transponder in this multiple-access mode. The demand assignment feature, depending on the traffic characteristics of the stations using it, can give up to a twelvefold increase in effective capacity. A similar system could be very attractive for servicing a number of small communities in Australia, although the SPADE system itself is probably too expensive.

WESTERN MILITARY SYSTEMS

The possible military uses of communications satellites were recognised at an early stage. However, in spite of the early start discussed above, the development of military satellites has lagged behind that of civilian systems in most areas. This is chiefly because of a difference in requirements and constraints. The most important requirement and constraint of a commercial system is economic: it must provide a specified performance at the minimum cost per circuit. The economic factor has led to the rapid development and deployment of larger, higher capacity satellites for commercial use. While economy is also desirable in a military system, there are many other factors of greater importance. Foremost is probably security, both from eavesdropping and from interference. Survivability, availability and reliability under hostile conditions are also necessary. These requirements have led the military both to higher frequencies (7-8 GHz, compared with 4-6 GHz for most non-military satellites) and to sophisticated wideband modulation techniques, at the expense of capacity.

Shortly after the Score demonstration, the US Army and Air Force began work on a communications satellite called Project Advent. In 1962 this program was cancelled, with the explanation that the satellite would be too big for available launch vehicles. After briefly considering just leasing capacity from Comsat/Intelsat, the Department of Defence approved a more modest Initial Defence Communication Satellite Program (IDCSP), which would involve the launch of 15 to 20 small satellites into low random-coverage orbits. Development of the large Titan IIIC launch vehicle allowed the orbit to be raised to synchronous altitude, but the small size and lack of provision for stationkeeping were retained in the satellite design. Each satellite would have a drift of about 20° per day, so that a large number would still be required for continuous coverage over the whole globe. Seven were launched in 1966, and 19 more over the following two years. As might be expected from a military system, nearly half of the 30 earth stations were mobile, and for the Phase II system (see below) all the stations were at least transportable.

While the IDCSP (subsequently renamed Initial Defence Satellite Communications System, or IDSCS) was being implemented, experimental progress in the area of tactical communication was made with the Lincoln Experimental Satellite (LES) and Tactical Satellite Communications (TacSat) programs. These provided direct communications to "man-pack" transceivers.

The system was upgraded in 1971 with the launch of the first two of an eventual eight DSCS-II spacecraft. These provided higher power and therefore greater capacity than the IDSCS, and also were placed in a truly synchronous orbit so that only three spacecraft would be required for global coverage. An interesting situation has developed with the first two of these. The satellite contract called for incentive fees for meeting performance goals. The contracting agency, the USAF Space and Missile Systems Organisation (SAMSO) has reduced these fees by $1.4 and $1.7 million because of operational difficulties, but ironically the one with the greater initial difficulties (and thus greater reduction in incentive fee) is now considered operational, while the other is not.

The design of the Phase III system has been slowed by the differences in the services it is to provide. Strategic communications are required between large semi-permanent installations at bases around the world. At the other extreme, tactical communications as demonstrated by LES and TacSat are also required. And in between, communications with every ship and aircraft are the goal. It is hoped that all these services can be provided by the US Navy FleetSatCom now scheduled for a 1976 launch, although the large terminals will still have the DSCS-II available. The Navy's needs for communications with ships will be met in the meanwhile with the Maritime Satellite (MarSat).

This system, being built by Comsat for the US Navy and US Maritime Administration for 1974 launch, will initially provide both military and civilian links, and upon launch of the FleetSatCom will become completely non-military. Only two MarSats are planned since it is only in the Atlantic and Pacific that significant US maritime communications are required.

Because of geometric considerations, a satellite in a geostationary orbit covers slightly less than a hemisphere of the earth. Complete global communications for terrestrial services can be provided with three satellites spaced around the world, as done in the Intelsat system. The areas left with no coverage, around the north and south poles, also have no permanent inhabitants and thus need no commercial service. The USN and USAF, however, operate ships, aircraft, and even a few bases in polar regions (the Early-Warning and Air Defense base at Thule, Greenland, for example, is well above 80°N). Polar coverage could be provided by a number of spacecraft in a low orbit at a suitable inclination to the equator. A more attractive solution to the problem is the use of a pseudosynchronous orbit such as that of the USSR's Molniya discussed below. This orbit has a perigee of a few hundred kilometres, an apogee near synchronous altitude, an inclination (the angle between the orbit plane and the earth's equator) of about 65°, and a period of 12 hours. The ground track of this orbit is fixed, and at every other apogee the satellite is visible up to 10 hours from a high-latitude earth station. The pseudosynchronous orbit has two advantages over a low-orbit random-coverage system: the satellite's apparent motion when in view is much slower so that antenna tracking requirements are less stringent; and since each satellite is in view for a considerable period of time, fewer satellites are required for continuous coverage. The USAF has launched at least two "advanced experimental communications satellites" into such an orbit.

As the closest ally of the USA, the UK participated in the IDSCS program from the first launch of a spacecraft in 1966. In 1971, the British ground network consisted of five large permanent stations, two mobiles, and two shipboard terminals. While the Americans were designing DSCS-II, the British were developing their own somewhat smaller military communications satellite, the Skynet. Two satellites were built in the US and launched in 1969 and 1970 and are now in service. An advanced version, the Skynet-2, is being built in the UK for a 1974 launch.

Two additional Skynet-1s were launched by the US for NATO in 1970 and 1971. These operate with 12 medium-size fixed earth stations in the NATO countries. A contract was recently awarded for the construction of two spacecraft to replace the NATO-1 and NATO-2 when they reach the end of their service life.

As a final note, there is mutual compatibility between these three systems (US, UK, and NATO) so that an earth terminal in one can operate with satellites of the other two if any of their satellites are in view.

THE USSR ORBITA NETWORK

Russia, like Canada and Australia, is a developed country with large undeveloped areas. Desire for communications between these areas and the more densely populated regions provided the stick, and Russia's position as a leader in space technology provided the carrot, for establishing the world's first national communications satellite system*. The Orbita network uses Molniya spacecraft in the 12-hour orbit mentioned previously to provide colour television, radio, facsimile, and some telephone service to far north, far east, Siberian and Central Asian regions of the USSR. The Mongolian People's Republic also receives television, which originates in Moscow. Altogether there are about 40 earth stations, including large ones near Moscow and Vladivostok.

The pseudosynchronous orbit was chosen for two reasons. First there was the need for far-north coverage (at least five of the stations are north of the Arctic circle). The second reason has to do with the location of the Russian launch sites, which are all north of 45°N. For a given launch vehicle and orbit altitude, the maximum payload capability is obtained with a due-east launch so that full assistance from the earth's spin is available. This results in an orbit inclination (the angle between the plane of the orbit and the plane of the earth's equator) approximately the same as the launch site latitude. For other inclinations, in particular the 0° of a geostationary orbit, a "dog-leg" manoeuvre is necessary, which reduces the possible payload size.

The first Molniya ("Lightning") spacecraft was launched two weeks after Early Bird, and there have been further launches at intervals of a few months. At the time of writing (June 1974), the most recent launch, the twenty-fifth, was in November 1973. Chiefly because of the orbit, the spacecraft design is quite different from most communications satellites. Whereas all the others till now have been barrel-shaped and spin-stabilized (some with despun antennas, however), the Molniyas are body-stabilized, that is the spacecraft does not spin. The solar cell array which provides electrical power is in the form of petals extending from the main body, rather than wrapped around the body. The two antennas are separately gimballed and steerable. The first of a larger version, Molniya-2, was launched in November 1971, and seven more have followed, but since launches of the earlier type have continued, it is not clear what the operational differences are. The physical differences are an increase from five to six solar cell petals, an increase from two to three cell arrays per petal, the addition of a TV camera for earth imagery, and a change in the type of antennas used.

As already noted, several services are provided by the system. However, the most important are apparently television and facsimile transmission, used for distribution of a single national TV program and newspaper from Moscow. At present, most of the earth stations are receive-only, but by the end of 1975 many of these are to be upgraded to provide telephone and TV transmission capability. It is also planned to continuously expand the network with the addition of both receive-only and transmit-receive stations.

The great majority of telecommunication traffic originating in eastern bloc countries is to others in that bloc. For this reason, rather than joining Intelsat, Russia has organized its own international communications satellite system, Intersputnik. The nine members are Bulgaria, Cuba, Czechoslovakia, East Germany, Hungary, Mongolia, Poland, Rumania, and the USSR. When operational, the system will use both Molniya satellites and a new spacecraft, the Statsionar. As implied by the name, this will be in a geostationary orbit over the Indian Ocean. The organizational details are similar to Intelsat: the space segment eventually will be owned by the organization, and each member will own and operate its own earth stations. Decisions are made by the organization as a whole, but since initially Russia will provide the satellites and launches, she has reserved a veto power over any decision affecting the space segment. No dates of launches, earth station construction, etc. have been given except that they are to be accomplished in the current five-year plan which ends in 1975.

* In honesty, there is some disagreement about which was the stick and which the carrot.

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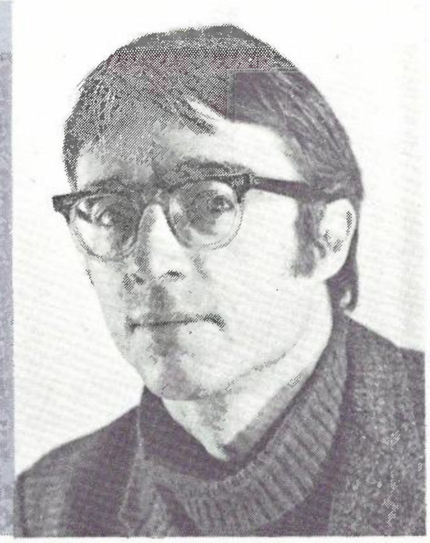


Transmission Aspects of a TV Telephone Network

R. J. DEMPSEY, B.E.

The transmission requirements of a subscriber reticulated TV telephone service are given together with possible solutions and compromises to the problems involved in the introduction of a service of this type. The discussion is mainly centred on the initial introduction of a TV telephone system into the present network.

INTRODUCTION

The Introduction of the TV telephone seems assured at some time in the future, either as a separate entity or as a facility of a more comprehensive wideband communications network. Looking at present achievements however, it is seen that even though much experimental and developmental work has been carried out, no systems have advanced from the trial stage to general acceptance by the public, nor have any world-wide standards been agreed upon. Indeed, recent thinking has questioned the original premise that the TV telephone should be provided mainly for face to face communication and suggested that more effort should be directed to providing effective transmission of graphic and textual material. To achieve the high resolution that this requires, either the bandwidth of the system has to be greatly increased or special techniques used, such as operating in a slow scan mode, where a single picture frame may take a few seconds to transmit. As the final form of the TV telephone has not yet been resolved the discussion here will centre mainly on providing face to face communications with a system bandwidth of the order of 1 MHz. Nevertheless, much of what is stated is still relevant to TV telephone systems that differ in concept.

The performance objectives and signal standards of a complete TV telephone network are determined mainly by the resultant picture quality which is acceptable to the user, the transmission requirements thus being fairly well defined. So that an orderly approach to the design of the transmission network may be made, it is necessary to adopt a transmission plan which takes into account the whole of the transmission area and the performance objectives aimed at for the network.

TRANSMISSION PLAN

A number of factors must be considered when deciding on a transmission plan, it being necessary to adopt a compromise between the cost and performance of each component of the TV Telephone system. Consideration should be given to the following areas all of which influence the transmission of the TV telephone signal: the subscriber's set, the line between subscriber and exchange, local switching and trunking and finally long haul switching and trunking. In designing an optimum system it is necessary to allocate allowable impairments to each of the parameters defining the transmission performance of the above system components such that the cost of the overall service is minimised. In particular, consideration should be given to the fact that the line joining the subscriber to the local exchange is normally used by a single customer, whereas the switching equipment and trunks are shared, in general, by a large number of subscribers.

The switching hierarchy of the TV Telephone system will probably be similar to that of the normal telephone network, with the actual network configuration depending on the relative cost of switching equipment, transmission equipment (including cables), and the number of subscribers and their distribution.

The main transmission performance parameters include random noise, crosstalk, gain, and probably most important, parameters defining frequency and phase responses such as echo rating

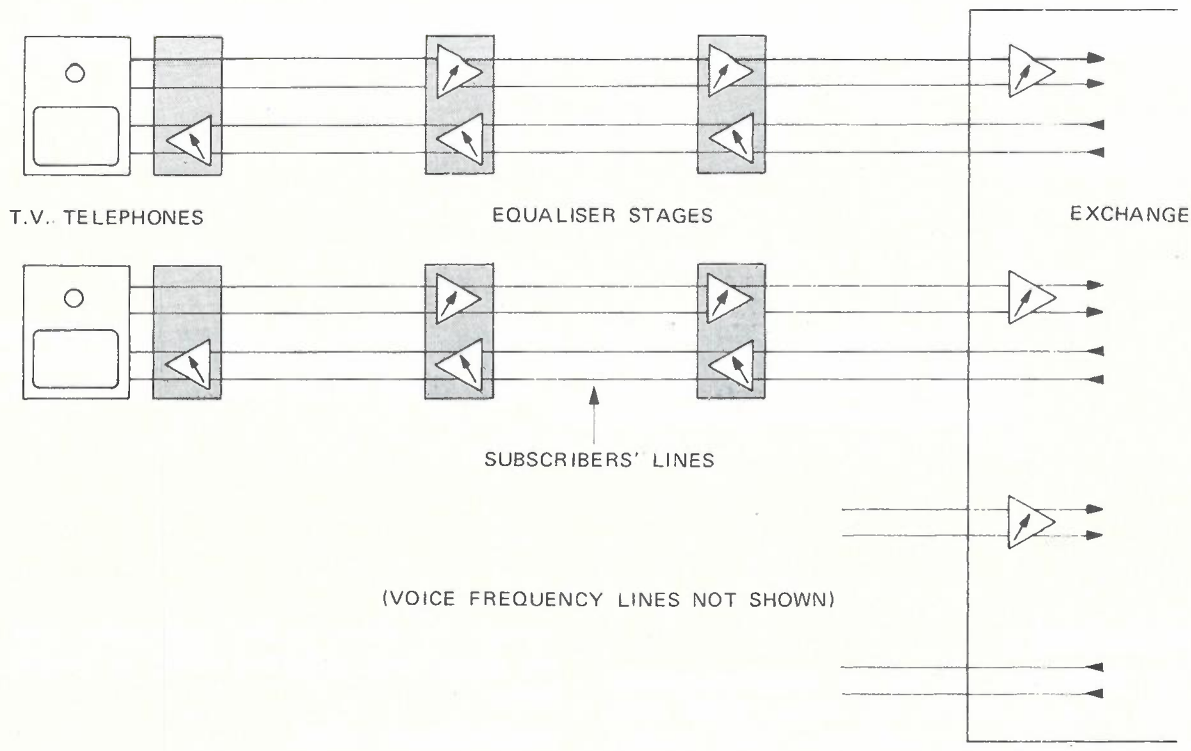


Fig. 1 — Local Area TV Telephone Transmission.

(Ref. 1). Before a transmission plan can be decided upon it is necessary to know the statistics of these parameters, such as the mean value and standard deviation (most parameters approximate a normal or log normal distribution). The parameters must then be assigned design values which are expected to be attained in a given percentage (for example in 99%) of all connections.

An understanding of the TV Telephone network can be obtained by examining its three main areas of operation. The first area depicted in Fig. 1 shows a typical local video transmission system. For the local network, in the initial stages, the most economical method of introducing the TV Telephone is to utilise the existing cable pair system provided for the telephone network. Initially, three pairs of wires would be used for each connection, two pairs being used for video (one for each direction) and the third being used for audio and signalling as in a normal telephone system. It may be possible to save one pair of wires by combining the audio and signalling with the video signals. The second area of operation involves short haul trunk routes as shown in Fig. 2, while the third area to be considered involves long haul trunk routes, for example, those between capital cities.

EQUALISATION OF CABLE PAIRS

Signal bandwidths of the order of 1 MHz (Ref. 1) have been proposed for the TV telephone, particularly in America, where extensive development work favouring this bandwidth has been carried out by the Bell Telephone Laboratories. However, a bandwidth of 4 or 5 MHz seems to be winning favour in some countries, notably, Sweden and Japan. The wider bandwidth has major advantages in making the TV telephone system compatible with conventional closed circuit TV equipment and domestic receivers and also provides high resolution for text and graphics without requiring special techniques such as slow scanning. The actual bandwidth used is a difficult compromise; the wider bandwidth producing good picture detail but presenting difficult and costly transmission problems, particularly so, in the case where balanced pair cables originally designed for carrying voice frequency signals are to be utilised.

The loss in balanced pair cable is high at video frequencies, for example the loss at 1MHz with

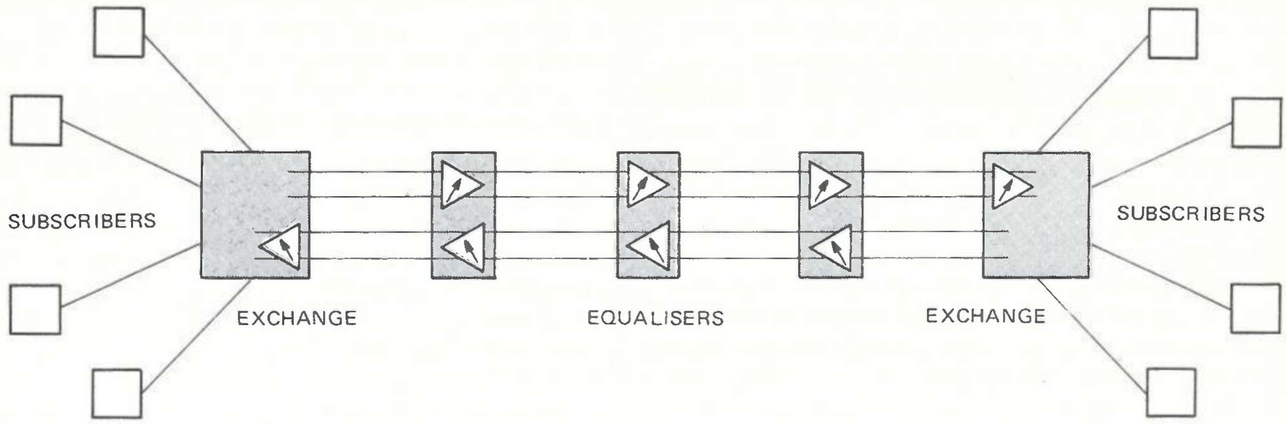


Fig. 2 — TV Telephone Transmission Over A Short Haul Trunk.

0.4 mm paper insulated unit twin cable is approximately 25 dB/km and in the case of 0.64 mm paper insulated quad local cable is approximately 18.7 dB/km. Normally the 0.4 mm cable is used between subscriber and telephone exchange and 0.64 mm cable used for junctions between exchanges. Loss versus frequency characteristics are shown in Fig. 3 for the above cable types. Clearly before these cables are acceptable for TV Telephone use equalisation is required.

As an example of the accuracy of equalisation required, the tolerance for insertion loss of one cable section used in the Picturephone System (Ref. 5) is ±0.1 dB from D.C. to 500 kHz and ±0.3 dB at 1 MHz. While it is possible to work in terms of frequency response and phase response, it is more convenient to define a new parameter which represents both. An example of a suitable parameter is that used in the echo-rating method (Ref. 2, 3). It is shown by Wheeler (Ref. 2) that the residual gain and phase of a link can be represented as a series of echoes displaced at various distances in time from the original signal, the size and position of the echoes are found from the frequency and phase response of the link, determined by the use of a suitable test set (Ref. 3) or calculated from empirical equations based on previous measurements. To obtain the true subjective effect of these echoes they are weighted according to their distance from the original signal. A second parameter, widely used for standard TV links, is the K-rating of the link (Ref. 4). As in the echo-rating method we have a parameter which gives an indication of the subjective quality of a link when used for video transmission.

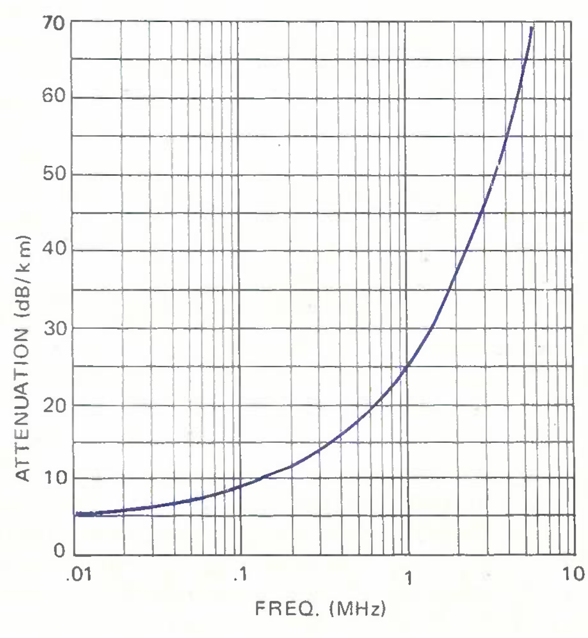


Fig. 3 — Typical Cable Attenuation versus Frequency Characteristic (0.4 mm PIUT at 20°C).

It is useful to find the limiting factors in the maximum length of cable which may be used in the one connection. In general, the length limitation is the result of the combination of two factors: firstly, phase distortion and secondly the effects of cable temperature variations (where this is not compensated for in the equalisers). Equations have been derived for echo-rating (Ref. 5) due to cable temperature variations as a function of cable length and gauge and due to phase distortion as a function of cable gauge and length. In this later case the phase distortion is related in part to the particular type of equaliser used.

The Picturephone System (Ref. 5) may be used as an example to show typical values of the maximum length of cable which may be used in a single connection. In this system each subscriber's link to the exchange and the total of all trunks are given equal transmission performance allocations for echo-rating. An additional consideration is that as temperature changes and phase distortions tend to be correlated in different parts of the network, the impairments add on a voltage rather than power basis. In the Picturephone system the maximum design length of subscriber to exchange lines for temperature deviations of 13.9°C. and the phase distortion resulting from the use of first generation repeaters is limited to 1554 metre for 26 gauge cable (equivalent to 0.4 mm paper insulated cable in Australia) and 2100 metre for 24 gauge cable (equivalent to 0.64 mm cable). It is interesting that the cable repeater spacing, unlike the maximum line length, depends not so much on equalisation problems but on the crosstalk properties of the cable. Second generation repeaters for the Picturephone System which have equalisers that compensate for cable temperature variations and have less phase distortion can increase the maximum length of subscriber lines from 1,544m to 4,570m for 26 gauge cable and from 3,050m to 30,500m for 22 gauge trunk connections.

Echo-rating really only describes the performance for frequencies of 20 kHz to 1 MHz and as a result the low frequency performance of the transmission link is best described by another parameter such as the tilt of low frequency square waveforms.

The Australian Post Office has developed a cable equaliser for baseband video transmission based on a design by Thiele (Ref. 6). This equaliser would appear to have an application to TV Telephone usage. It can be shown that if the cable is image matched and the cable loss characteristic is sufficiently consistent the equaliser needs only one adjustment for cable length. The equaliser has low phase distortion but has the disadvantage that an equaliser stage is limited to a maximum slope of 6 dB/octave.

In addition to the above equaliser, developmental work has been carried out on an automatic equaliser for TV Telephone use (Ref. 7, 8). The advantage of this equaliser lies in its ability to compensate for the major portion of variations in cable characteristics due to temperature changes, variations between links (in a switched network) and transmission imperfections such as impedance mismatches that cannot be compensated for by fixed equalisers. The main disadvantage of an equaliser of this type relates to its relatively high cost; unless this can be reduced significantly it is likely to find application only in high utilisation trunk areas.

CROSSTALK IN MULTIPAIR CABLES

Crosstalk interference is the unwanted coupling of signals between cable pairs and in analogue video baseband transmission may be broadly categorised into two main forms. The first and possibly most annoying subjectively, is the visible interference pattern. As the TV Telephone system is asynchronous these patterns appear to drift across the screen. Also, the crosstalk increases at higher frequencies as shown in Fig. 4, so that there are emphasised sharp transitions in the interfering signals, in particular, synchronisation pulses appear as vertical lines moving across the screen.

Crosstalk interference may be considered as random noise when the interference is not recognisable or produces no recognisable pattern. This second type of crosstalk may be due in part to other TV Telephone channels but also results from interference from other types of uncorrelated transmission systems sharing the same cable sheath such as voice frequency channels, carrier systems, data signals and pulse code modulation (PCM) systems.

Additionally, crosstalk should be considered in the light of instability due to coupling between equalisers. For example, spurious oscillation (or impaired transmission due to poor frequency and phase response even if oscillation is not reached) may occur around the path formed by two oppositely directed repeaters due to near-end crosstalk as described below.

The two ways in which crosstalk coupling occurs is illustrated in Fig. 5 (a) and 5 (b). Far-end crosstalk (FEXT) occurs between signals having the same direction of transmission and near-end crosstalk (NEXT) occurs between cables having opposite directions of transmission. In general the effect of NEXT may be reduced by decreasing repeater spacings or by segregating the cable pairs in separate units or even different cables if this is possible. The effect of FEXT, while independent of repeater spacing, may be likewise reduced by cable pair selection. The large variation in crosstalk (for example NEXT) between adjacent and other pairs is shown in Fig. 6 for a cable type which is applicable for trunk usage. To avoid instability due to NEXT it is necessary to have the crosstalk loss greater than the gain of the repeater. If the repeater spacing is reduced the equaliser gain may be correspondingly reduced, hence reducing the possibility of instability. Alternatively, the use of segregated cable pairs which have higher crosstalk loss will achieve the same end result.

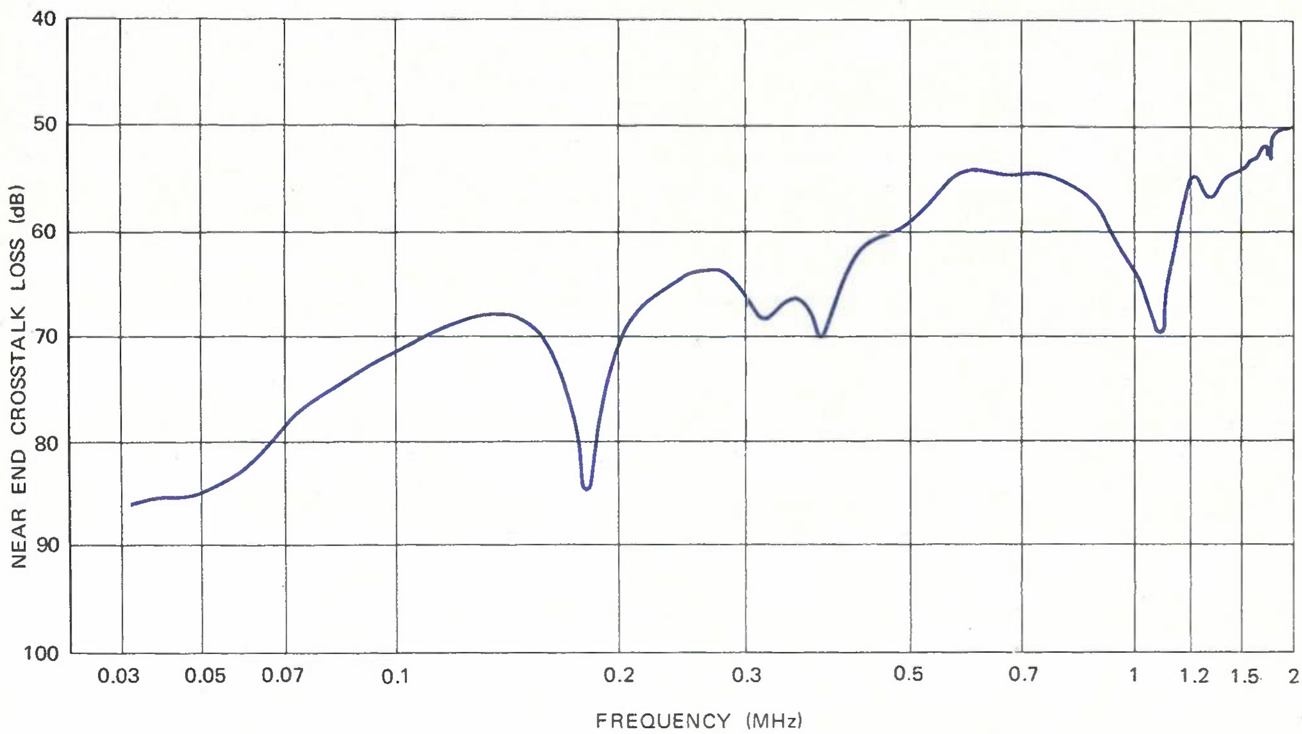


Fig. 4 — Typical Near-End Crosstalk Loss.

The analysis of the effects of crosstalk is amenable to statistical methods which are well documented (Ref. 9). As an example of the limitation of NEXT in the Picturephone network the maximum repeater spacings are limited to 1.1 km or 1.76 km for 26 gauge cable pairs depending on whether opposite directions of transmission are in the same or adjacent cable units (Ref. 5). With NEXT increasing with frequency the possibility of oscillation occuring outside the bandwidth of the signal is likely, it is therefore good system design to deliberately roll off the response of the equaliser above 1 MHz but without interfering significantly with the phase and frequency response below this frequency.

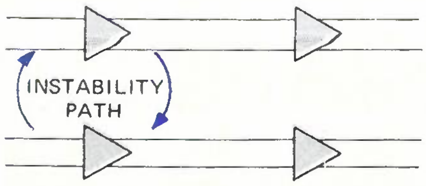
NOISE PERFORMANCE OF THE NETWORK

The noise due to crosstalk is the major contributor to noise in the network, most of that remaining is allocated to codec noise (quantising distortion) if a digital link is used in the connection. There are other sources of noise which in general have only a minor effect on the overall system performance but are nevertheless worthwhile of mention; these include noise generated in the camera tube at low ambient light levels, power line interference (50 Hz and its harmonics), interference from radio transmitters, impulse noise, and noise generated in repeater amplifiers.

Subjectively different interfering frequencies have different effects and it is necessary to take this into account when comparing the effect of interfering signals. Low frequency interference has the greatest subjective effect, however, the signal is very susceptible to high frequency interference as it reaches the input of an equaliser because the high frequency gain of the equaliser is much higher than the low frequency gain. The result of this is that in effect high frequency interference becomes predominant and to counteract this it is desirable to pre-emphasise the video signal at high frequencies. In addition, the viewer is more sensitive to moving interference patterns than stationary ones and to stationary patterns more than random patterns.

REQUIREMENT OF LINE EQUIPMENT

An important factor influencing the input design of the repeater stages is the presence of longitudinal signals on the cable, probably the most important of these being power line interference. The input stage is required to have sufficient common mode rejection to ignore these signals in favour of the desired transverse signal. With a frequency band



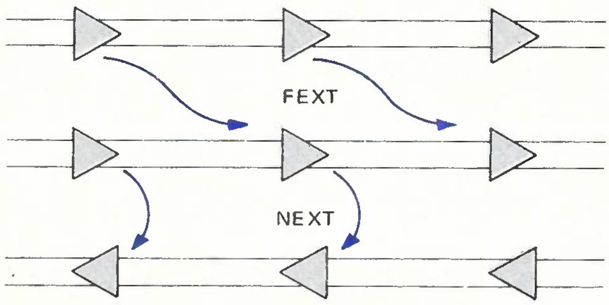


Fig. 5 (a) — A Possible Instability Path Between Repeaters.

(b) — Near End (NEXT) and Far End (FEXT) Crosstalk Paths.

extending down to a few Hz it is probably not economic to use input transformers so that care has to be taken to see when amplifier input stages are used to provide longitudinal rejection, they are not overloaded by the longitudinal signal. A second problem that may arise is that the zener diodes used in repeater powering may become reverse biased by severe longitudinal signals.

The longitudinal rejection achieved depends on the input balance of the repeater and this needs to be high enough only to reduce the effect of longitudinal signals to below the level of interfering transverse signals. The output balance of the amplifier should also be kept sufficiently high to ensure that any crosstalk is dependent mainly on the cable balance and not on the balance of the repeater output stage. Powering of repeaters should not present many difficulties; with power requirements of about two watt per repeater, line currents would be of the order of 50 mA per wire which should give powering distance of the order of 3 km for 0.4 mm cable before voltage drive limits are exceeded.

Protection against lightning strikes on the cable must be provided, the problems involved not differing greatly from those encountered in other line transmission systems. Adequate low voltage protection may be provided by conventional or varistor diodes and high voltage protection by carbon block protectors or gas discharge devices.

Cable temperature variations result in gain changes in the connection between the transmitter and receiver. These may in turn result in level variations sufficient to cause overload conditions in repeater amplifier. In practice a satisfactory overload capability margin has been found to be 6 dB (Ref. 5).

REQUIREMENTS OF PAIR CABLE FOR TV TELEPHONE

There are a number of special considerations in the transmission of TV Telephone signals over cable networks designed for telephone usage. Firstly, bridged taps provided for the convenience of connection of subscribers to the telephone network may cause serious impairments to the TV Telephone signal. The effect is worse for long taps and for many taps. The actual impairments resulting from bridged taps are given in Ref. 10 showing that in some instances the effect may be ignored. Nevertheless, it is stated that taps of 30 metres or more in length should be removed and that a cumulative total of 60 metres for all taps in a link should not be exceeded.

Loading coils are often added to cable pairs to improve the audio frequency response of the cable. Unfortunately, the amplitude and phase distortion caused by the coils to a video signal is so severe that the coils must be removed. This also applies to the build out capacitors associated with the loading coils. The loading coil positions may provide suitable mounting positions for the equalisers, providing that repeater spacings are not otherwise dictated by other considerations.

Aerial cable should be avoided in long lengths because it is subject to large temperature changes (resulting in equalisation problems) and radio frequency interference. It must in all cases be shielded. Soldered joints must be used on video pairs where low contact resistance cannot be ensured as a result of D.C. current flow used for repeater powering.

Cables having inherently low crosstalk should be chosen where possible and pair selection or segregation of pairs be considered where necessary. This particularly applies where other wideband systems share the same cable sheath. The worst situation occurs when the interfering signal

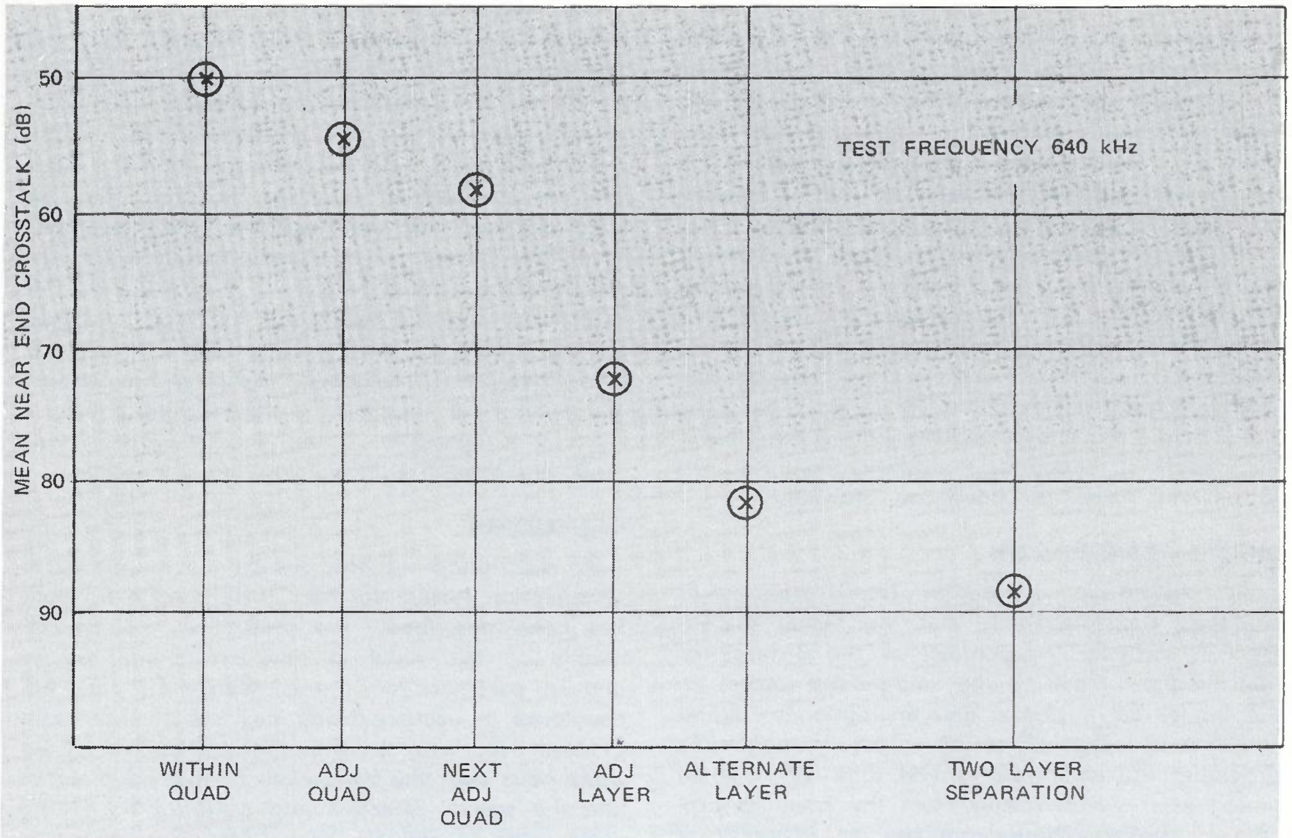


Fig. 6 — Typical Crosstalk Between Different Pairs of a Multipair Cable.

is being transmitted in the opposite direction to that of the TV Telephone.

TRANSMISSION IN THE SWITCHING AREA

By careful design of the wiring distances in the exchange, in particular between the wideband switching bays and the distribution frames the transmission losses can be equalised and thus made independent of the actual connection (Ref. 11).

Shielded cabling may be required in some areas to reduce the effect of coupling, although in multi-pair cable a more economic solution is to vary the twist lengths of all video pairs (Ref. 11). To minimise noise being induced from the switching equipment all switching control cables must be separated from video cables and suppression techniques may need to be applied to the switching equipment itself. Crossbar switches give satisfactory performance as video switches, particularly if alternate lines of the switch are grounded, thereby acting as a shield and reducing coupling between different signal paths.

TRANSMISSION OVER FREQUENCY DIVISION MULTIPLEX (FDM)

As mentioned above it will be economically advantageous in the immediate future to use analogue baseband transmission between subscribers and exchanges and over short haul trunks. However, transmission impairments, even with use of optimumly placed repeaters, limit the practical length of these links to something of the order of 20 km. For long-haul trunk routes broadband FDM analogue transmission systems may be used as for the provision of normal television links. As the cost of these systems is high it is very important to find the most economic transmission method.

Australian FDM systems generally conform to Procedure 2 of the CCITT Recommendation G211 which uses a 15 supergroup assembly occupying approximately 4 MHz and with each supergroup occupying 240 kHz. The 15 supergroup assembly is the basic building block of the 4 MHz, 8 MHz, 12 MHz and the proposed 60 MHz systems. Another CCITT preferred FDM system uses an arrangement where 5 supergroups are combined into a mastergroup of 1.2 MHz bandwidth. A bandwidth of this order would appear to give a satisfactory TV telephone performance when conventional vestigial side-band modulation methods are used (Ref. 12). Unfortunately these latter systems are not as yet used in Australia so that a solution applicable to the 15 supergroup assembly is desirable. In this case because no block of channels has a bandwidth in the vicinity of 1 MHz (unlike the situation where mastergroups are used) it is necessary to extract 5 supergroups out of the 15 supergroup assembly and provide special frequency translation equipment to transmit the video signal in the remaining 1.2 MHz slot. Alternatively, a complete 15 supergroup assembly may be used to transmit three TV Telephone channels.

DIGITAL TRANSMISSION

An advantage of digital transmission over analogue transmission is that the signal impairment is virtually independent of the distance of transmission. Most of the impairment occurs in the digital - to - analogue and analogue - to - digital conversions. The effect of errors is negligible providing the error rate is less than 10^{-7}, while timing jitter which results from the retiming process in digital regenerators has an insignificant effect in a well designed system.

Differential pulse code modulation (DPCM) is attractive for the digital transmission of TV Telephone signals rather than Pulse Code Modulation (PCM) as it is more efficient in this particular application (Ref. 13). The analogue signal is sampled at the Nyquist rate of 2 MHz (for a 1 MHz analogue bandwidth) with the amplitudes of the differences between successive samples being encoded into 3 or 4 bit binary codewords resulting in bit rates of 6 or 8 Mbit/sec. The reason that relatively few bits/sample are required is that the human eye is unable to resolve large brightness changes as accurately as smaller ones. Therefore, large differences need not be accurately coded, resulting in a lower overall bit rate.

There is a further advantage in using digital transmission in that the bit rate may be further reduced by employing additional coding making use of the statistical redundancy which exists in a television picture (Ref. 14).

In digital transmission systems digital regeneration of the signal is used to reduce transmission impairments. Digital transmission is therefore attractive on long haul trunk routes where the impairments in an analogue transmission system tend to become intolerable. It is not expected that initial installations would employ digital transmission over subscriber lines though this may become attractive at a later date. The introduction of digital TV Telephone transmission over trunk routes depends on the availability of suitable digital channels. At the present moment these are not available in Australia, however they are used overseas, the most suitable being secondary level PCM systems which usually operate at bit rates of the order of 6 to 8 Mbit/s. If suitable bit rate reductions can be achieved by more efficient coding techniques it may be possible to transmit more than one TV Telephone signal on one secondary level PCM channel. To reduce signal impairment it is desirable to introduce a limit of one A/D and one D/A conversion per connection.

CONCLUSION

A description of the means of providing a transmission system for the TV Telephone network has been described. The discussion has centred mainly on the initial introduction of the service and in particular on the problems that are encountered in using existing pair cable. The main problems are seen to lie in the equalisation of the cable pairs over the bandwidth of the video signal and the special selection and conditioning of the cable pairs to reduce the effects of impairments such as crosstalk. While many of these problems have little significance in the telephone network they become very important in the design of a TV Telephone network. Finally methods which may be used for transmission over long-haul trunk routes have been described with a brief mention of digital transmission of the TV Telephone signal.

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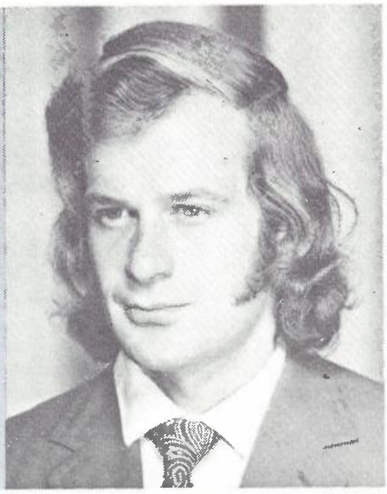


APO Model Digital Telephone Exchange in Traffic

The APO Research Laboratories have designed and constructed a model of a digital tandem exchange to switch pulse code modulated (PCM) telephone circuits without the need to demultiplex or demodulate the transmitted signals. The exchange switches digital signals in a time division mode and employs microelectronic technology throughout; control signals and telephone service tones are also generated directly as digital signals in PCM form.

This model has been developed to investigate the concept of integrated switching and transmission (IST) in the Australian telephone network. Aspects of its design have been presented in previous issues of The Journal.

The exchange is controlled by two ITT 1600 processors which execute the programs which determine and control the functions of the exchange. The model exchange consists of three functional blocks:

- Terminal equipment to terminate the PCM transmission systems. These units receive the incoming bit streams and separate the individual speech channels and control signals. They also form the bit streams for transmission in the out-going direction by combining individual channels, synchronising information and out-going control signals;
- Switching equipment which interconnects the PCM channels terminating on the exchange through a space-time-space matrix. The space switches provide interconnection between separate PCM systems and groups of systems, and the time switch provides interconnection between the different time slots in the PCM systems;
- Service equipment which receives and generates dial information, voice frequency control signals, call supervision signals and service tones.

The model exchange was installed in the Windsor telephone exchange, Victoria, on the 12th May, 1974. It had been pre-assembled in the Laboratory, and was ready for operation within a week of moving to the field trial location.

The model exchange is currently undergoing a series of tests to evaluate its performance. In particular, features such as exchange security, recovery after failure, network interworking arrangements, signalling and transmission performance, operation and routine maintenance are being examined.

A second phase of this project has already commenced. This is designed to investigate aspects of remote control of a subscribers switching stage from the two processors controlling the model tandem exchange. These investigations will produce information relevant to the design of future telephone networks.

Why Are Tandem Exchanges Provided?

Telephone exchanges grow to various sizes, most of which, at the present time, do not exceed about 10,000 lines. The largest network, in Sydney, has about 120 exchanges in a variety of sizes. Each exchange has to be able to submit calls to every other exchange in the network and in the absence of any other switching system there would need to be 120 x 119 = 14280 individual routes. These direct routes between origin and destination would be dimensioned to provide a grade of service of 0.01 for the busiest hourly traffic or one call in 100 lost due to route congestion.

For example, if all exchanges were equal and originated 300 erlangs of traffic, 250 erlangs of which was destined for other exchanges, each route would have 2.1 erlangs offered and require 7 circuits. The total number of circuits in the network would then be 99960. These would span the whole network on the 14280 routes, each of which it would be obligatory to provide.

If instead of this large number of direct routes a tandem exchange with a route to and from each of the 120 terminals were provided, the number of routes would be greatly reduced and their efficiency, with a larger volume of traffic per route, would be much improved, but each route would need to be dimensioned to provide a better grade of service than that of the direct routes to enable the same origin to destination grade of service to be achieved. A grade of service of 0.005, or one lost call in 200, would in fact be required and the number of circuits necessary to carry 250 erlangs to and from each of the terminal exchanges would be 240 x 279 = 66960 circuits.

If this traffic were suddenly raised by 10%, the GOS for the 1 tandem case would reduce to 0.02 whereas the "all direct" network would function at nearly the same grade of service. Hence, although the all-tandem network has less overall circuits of a shorter average length, it has less stability for traffic variations and uses more switching stages to handle all the traffic.

In practice a mixture of direct routes and tandems is chosen to give the least total network cost. Each of the tandem areas has its own originating and terminating tandem so that traffic can overflow in two levels. The provision or otherwise of any route is determined on an economic basis and this is such that direct routes and some tandem routes are designed efficiently at high occupancy, and one final backbone route carries the overflow residue at reasonable efficiency. Generally speaking small traffics are best handled by amalgamation in tandem groups until such time as direct circuits are economically justified.

Why Do We Have Post-Dialling Delay?

Post-Dialling Delay (PDD) is defined as the time period occurring after the telephone subscriber has completed dialling the required number until the reception of a service tone. The phenomenon of PDD is a side effect of the APO decision to change the telephone network from one based on a step-by-step (SxS) operation to one using common control (Crossbar) equipment with registers and markers. In the SxS system each digit dialled by the subscriber causes each successive switching stage to be set. Hence, the delay between dialling the last digit and the return of a service tone when the last stage is set is minimal and generally in the order of one second or less. The PDD under this condition is considered to be zero.

In the common control system of switching, all digits are dialled into and stored in a register which then uses them to set up the call in the appropriate manner. A PDD is now introduced and is the time taken by the register to switch the call through the subsequent switching stages. PDD in itself is not a problem until it becomes excessive. The subscriber may then interpret it as a 'no progress' call and hang up prior to the switching being completed. PDD will be influenced by the following factors:

- Subscriber speed of dialling.
- Routing pattern.
- Analysis required to determine the Number Length (NL) and
- Type of Terminating Equipment (TOTE).
- The starting point for forward signalling.
- Variations in telephone traffic.
- The number of SxS switching stages traversed.

The main contributing factor to PDD is the number of SxS switching stages traversed by the call in networks having a mixture of crossbar and SxS equipment. The register must regenerate decadic impulses to set the SxS stages at a similar rate as the subscriber would dial them (10 ips. plus nominal interdigital pauses) in a completely SxS call. If the call has to be switched via other common control stages, the register uses a high-speed multi-frequency code (MFC) signalling scheme (7 digits per second) and the delay experienced by the subscriber is reduced. The delay in this case is largely influenced by the prevailing traffic conditions and the routing of the call. The PDD is a minimum when a direct route is used and a maximum when the 'back-bone' route is selected. In the heavier traffic periods the 'back-bone' would be selected for a greater proportion of calls. Complex analysers are used to give the registers information derived from analysis of the dialled number to assist in establishing the call. This information consists of:

- The number of digits that must be stored before the register can start signalling forward and
- When the register can 'ready connect' on calls which are completed by decadic signalling.

This information is generally referred to as Type of Terminating Equipment (TOTE) and Number Length (NL).

On calls which are to be completed via the common control system the register is required to store all digits before commencing to signal forward. Ideally, on calls to be completed via the SxS system with decadic pulsing, the register should commence to start signalling forward as soon as possible. The code analysis can, therefore, influence the PDD, as to achieve the ideal condition on SxS switched calls all codes corresponding to these cases should be analysed to the point where the earliest starting point can be determined. However, due to limitations in the amount of code expansion available, it is sometimes necessary to use later starting points than the ideal, with a consequent increase in PDD. In most instances a compromise is necessary between the amount of analysis and the increase in the average PDD being experienced.

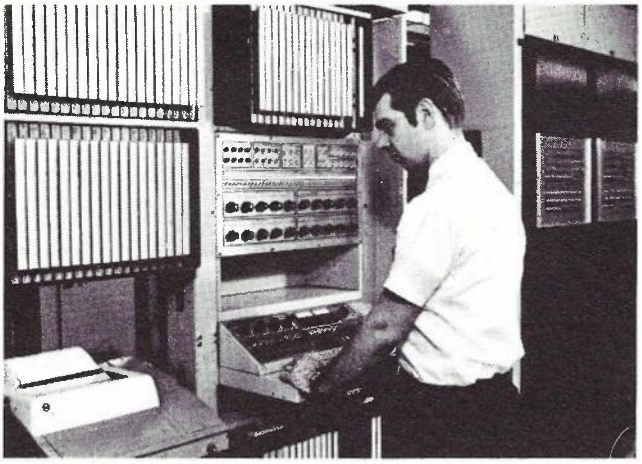
Measurements of the PDD are carried out by the Telecommunications Division during commissioning tests of new exchange equipment and during routine service sampling checks of the network. These measurements are carried out by the following means:

- Manual test calls using a telephone and stopwatch. The acceptable limits for PDD from this test are:
  - (a) 80% of test calls to have PDD of less than 8 seconds.
  - (b) The remainder of the test calls to have PDD of less than 10 seconds.
- Service assessment of live local and STD traffic. The results of these tests are recorded and analysed under the following categories:
  - (a) PDD less than 4 seconds
  - (b) PDD less than 9 seconds
  - (c) PDD greater than 9 seconds.

The results of these measurements are then forwarded to Engineering for examination and suitable action where the limits are being exceeded.

As step-by-step equipment, last purchased in 1962, represents a steadily decreasing proportion of the total switching equipment in the Australian network, PDD of excessive duration will be experienced infrequently by subscribers in general. However, on particular routes to SxS terminals from crossbar sources, PDD will remain. So, in the future, the only significant reduction in PDD would be effected by the programmes replacement of SxS equipment. Another factor which could reduce PDD in sectors of the network is the introduction of Stored Programme Controlled (SPC) exchanges in both the trunk and local networks whereby the respective processors would exchange the information signals via an extra-highspeed data link using a signalling scheme similar to the proposed CCITT No. 6 Scheme.

C-1 EAX Computer for the small



Our C-1 EAX is an electronic stored-program switching system that brings the advantages of a large exchange to meet the needs of small and medium telephone offices providing local and local tandem service.

With as few as 400 subscriber lines the C-1 EAX can provide high profitability—and it has plenty of room for growth.

Expansion can be made by installing 200 line factory-wired units without regrading or rewiring the existing system.

Expansion can continue up to 7200 lines or more.

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It also provides faster and more economical administration techniques. Day-to-day subscriber updates, such as number additions, removals, routing instructions, and class of service require only simple memory alteration.

By using these advanced computer techniques the C-1 EAX opens up revenue-producing features that have not been practical in the past.

Features such as:

Touch Calling—with mixed rotary dial and touch telephones on the same line.

Automatic Number Identification—in CAMA format.

Off-Hook Service for Hotels, Taxis—may also be assigned for normal incoming service.

Speed Calling—with a repertory of 8 frequently called numbers per subscriber that can be dialed by single-digit codes or up to 30 numbers by 2-digit codes.

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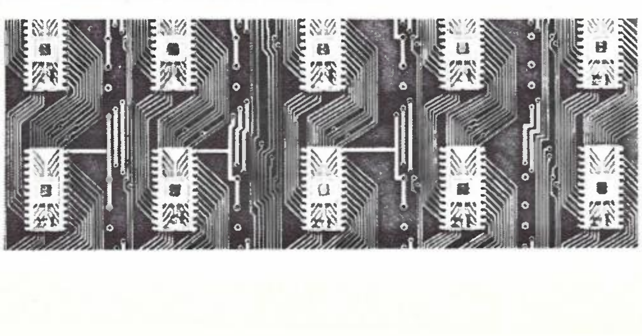
From GTE. technology exchange.

conversation indicates a call in waiting. A subscriber can place the existing call on "hold," answer the second party, and return to the first party by a simple hook-switch operation.

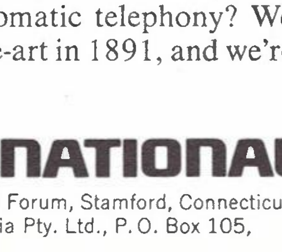
The use of MOSFET large-scale integrated circuits in the C-1 EAX common control and other state-of-the-art technology devices allow a higher capacity while reducing the actual physical size. C-1 EAX uses the time-proven GTE Automatic Electric crosspoint switch with gold contacts in the voice transmission path.

Although C-1 EAX is state-of-the-art, it's had plenty of experience. Over 82 systems (86,800 lines) have been installed since 1970. Forty more (about 60,000 lines) are in the process of installation and manufacture for locations in Canada, the United States, Mexico and other countries.

C-1 EAX is also available for mobile or portable use. In the transportable configuration, multiple modules can be provided for exchanges up to 4800 lines and trunks.



C-1 EAX is only one part of GTE's family of switching and recording machines. A family that is designed to meet the needs of every exchange capacity and application—No. 1 EAX for the large metropolitan local tandem or toll office, No 1 CAMA (Centralized Automatic Message Accounting), No. 1 XPT Tandem (4-wire toll office), and the No. 1 TSPS (computer-controlled system for operator-assisted traffic).



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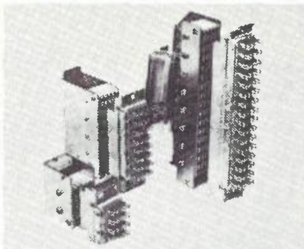
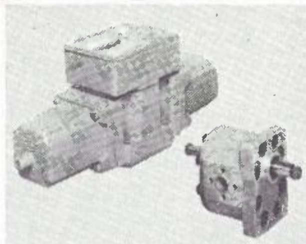
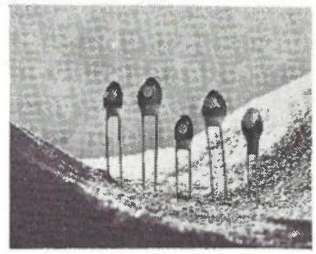


Plessey knife and fork connectors are part of the wide range of multi-circuit connectors marketed by Plessey Australia, Components Division. They are available in standard 20, 40 and 80 way sizes.

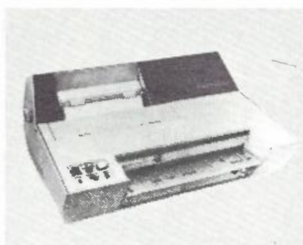


Internationally recognised "RACINE" hydraulic pumps and valves are sold and serviced throughout Australia by Plessey Australia, Telecommunications Division, Meadowbank, NSW.

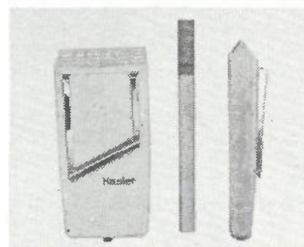


These NEC solid tantalum capacitors are designed for decoupling, by-pass, blocking and filtering applications in both professional and domestic electronic equipment. They are but one of the extensive range of professional components available from Plessey Australia, Components Division.

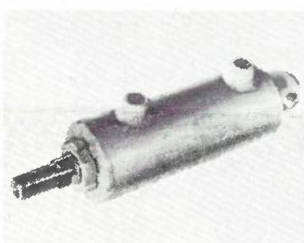
Illustrated is the MRT 40 mobile 2-way radio system with an SC 201 Decoder fitted. Developed by Plessey Australia Electronics System, Richmond, Victoria, the system employs a method of selective calling whereby each operator receives only those messages specifically directed to him.



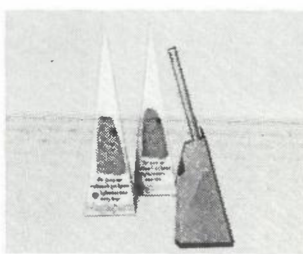
Marketed by Plessey Communication Systems, the Facsimile Remote Copier is a desk-top copier capable of transmitting and receiving over public or private telephone lines, printed, written or graphic material within minutes.



This radio paging miniature receiver uses the most advanced electronic circuitry to maximise efficiency in the location of staff. This inductive loop system is available from Plessey Communication Systems.



Designed and manufactured locally, Plessey hydraulic cylinders and presses are available for a variety of industrial and mobile applications. The cylinder illustrated is just one of the wide range available from Plessey Australia, Telecommunications Division, Meadowbank, NSW.



Marketed by Plessey Australia, Components Division the 'Magispark' is a compact electronic gas lighter providing a continuous spark suitable for use in kitchens, on boats, caravans and for outdoor stoves and gas barbecues.

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Factory capacity: 1 million sq. ft.
Employees: 4,000

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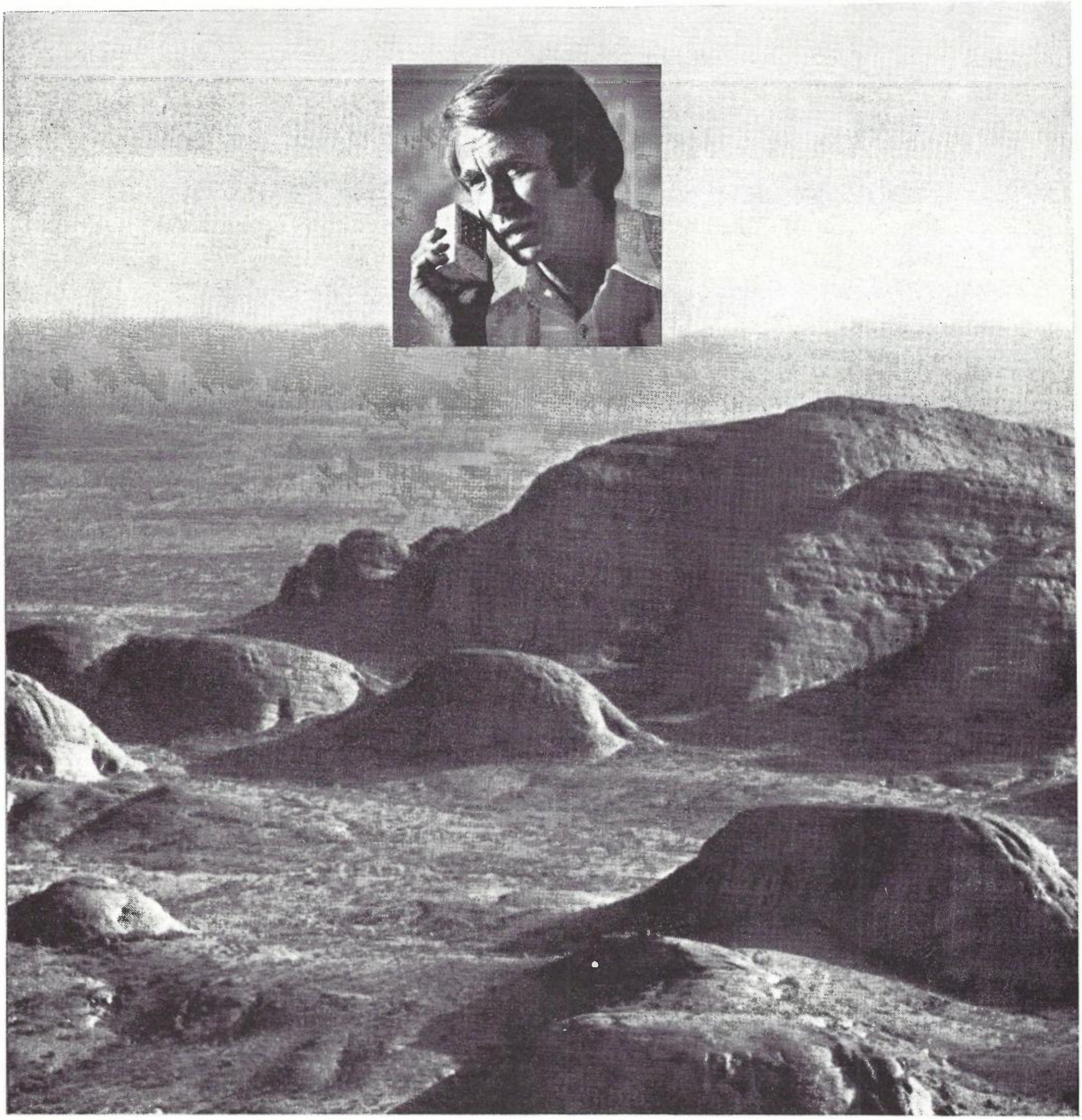

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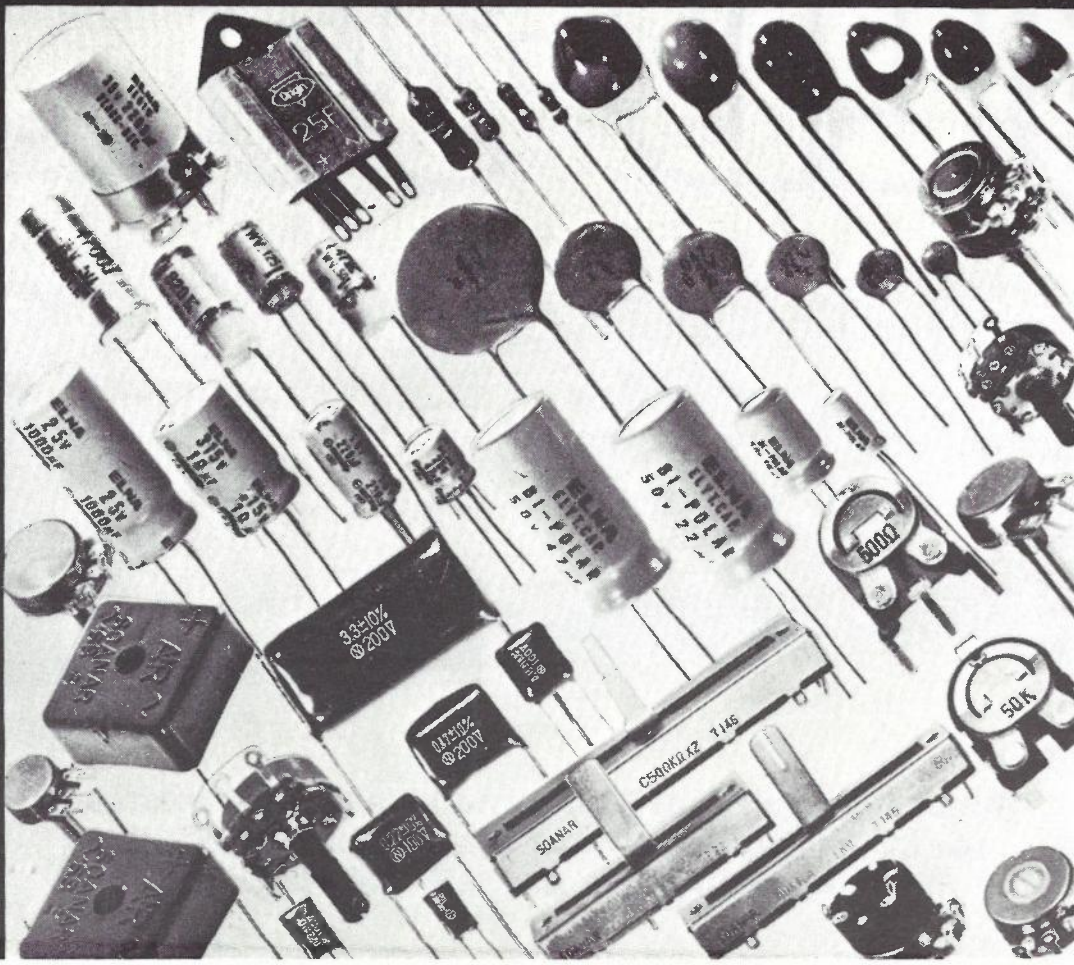

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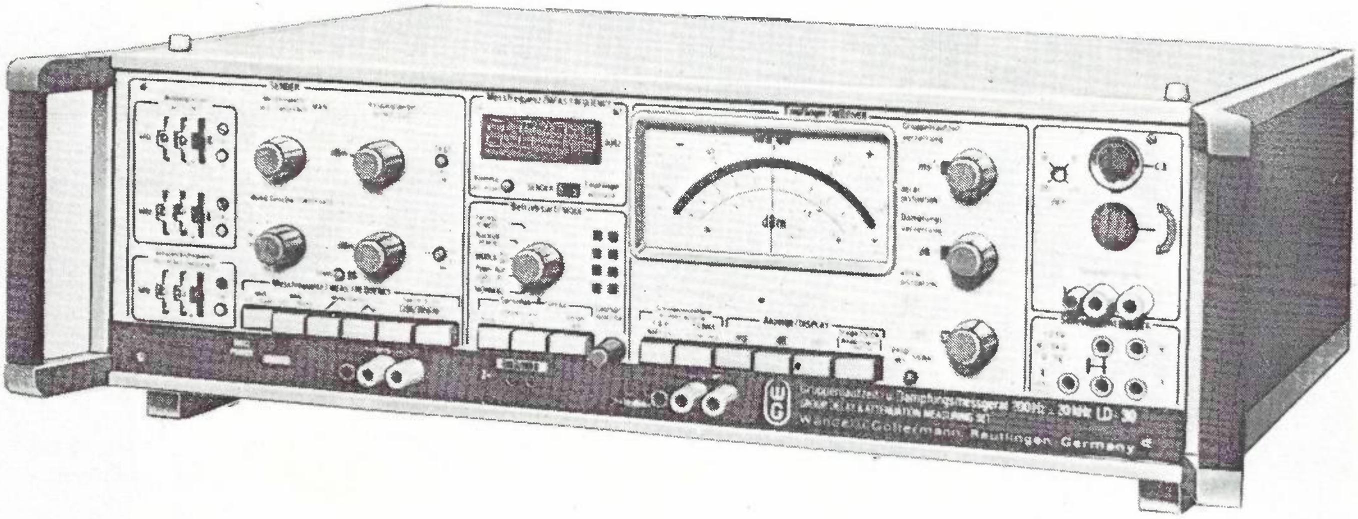

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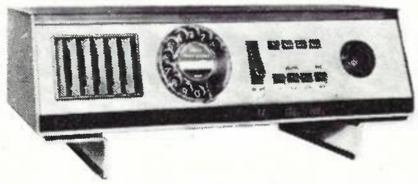

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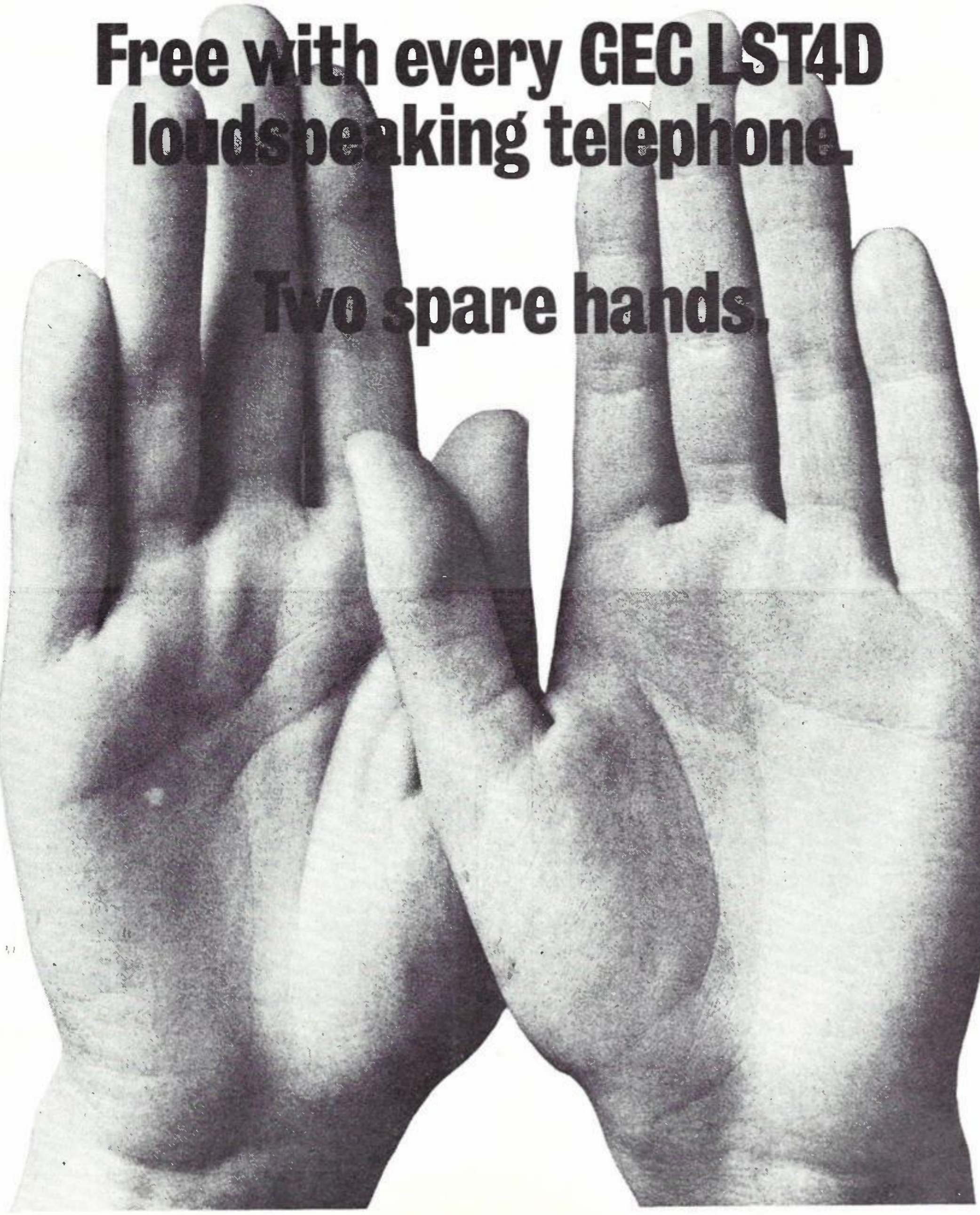

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The Telecommunications Journal of Australia

ABSTRACTS: Vol. 25, No. 1

ALLEN, P. F. and SINDEL, P. J.: 'International Stored Programme Controlled Telephone Exchange — Sydney'; Telecomm. Journal of Aust., Vol. 25, No. 1, 1975, page 34.

In March 1974 the Overseas Telecommunications Commission (Australia) placed in service an L. M. Ericsson AKE-131 exchange, the first stored programme controlled exchange in service in the Southern Hemisphere.

This article describes the exchange, the project and the first eight months of in-service experience.

BALDERSTON, M.: 'An Historical Survey of Communications Satellite Systems — Part 1'; Telecomm. Journal of Aust., Vol. 25, No. 1, 1975, page 53.

The history of communications satellites from 1945 to the present is given. Experimental and operational satellites and satellite systems, past, present, and future, are described. Some applications are discussed, and two related subjects, operating frequencies and launch vehicles, are mentioned. The significance of these topics for an Australian National Satellite System is emphasized throughout.

DEMPSEY, R. J.: 'Transmission Aspects of a TV Telephone Network'; Telecom. Journal of Aust., Vol. 25, No. 1, 1975, page 61.

The transmission requirements of a subscriber reticulated TV telephone service are given together with possible solutions and compromises to the problems involved in the introduction of a service of this type. The discussion is mainly centred on the initial introducton of a TV telephone system into the present network.

GOSDEN, D.: 'Television Transmitter Luminance Linearity Measurements'; Telecomm. Journal of Aust., Vol. 25, No. 1, 1975, Page 17.

Television transmitter luminance line-time linearity measurements are carried out by a number of different techniques at present. These are classified broadly into three categories:

(a) those where a sawtooth or staircase signal is observed directly.

(b) those where a staircase is differentiated and the resulting pulses evaluated.

(c) those where another signal such as a low amplitude sinewave or a series of pulses is superimposed on the sawtooth or staircase signal. After transmission the superimposed signal is separated and evaluated.

These techniques often lead to inaccurate results (for various reasons). Where a sawtooth or staircase signal is observed directly, meticulous care is necessary to produce repeatable results, especially as the result will be affected by instrument linearity. Evaluation of the superimposed signal is much easier but if the transmitter has a level dependent amplitude/frequency response then errors will occur. The amplitudes of the pulses resulting from the differentiated staircase can also differ due to level dependent frequency responses — amplitude and/or phase.

The technique described in this paper involved measurement of a differentiated sawtooth signal. This method produces a result which is easy to measure and is not affected by level dependent frequency response errors.

GRANT, A. K.: '10 to 10 Programme Unit Model Q 1'; Telecomm. Journal of Aust., Vol. 25, No. 1, 1975, page 44.

The 10 to 10 Programme Unit described in this article has been designed to extend the usefulness of the portable Traffic Route Tester, Model Q1. Previous articles Ref. 1 and Ref. 2 have described the application of the devices and design aspects of the Traffic Route Tester.

This article explores some general aspects and particular design approaches used in the Programme Unit.

HOLT, R. J., PAGE-HANIFY, G. and DEDRICK, W. R.: 'The 10C Stored Programme Trunk Exchange'; Telecomm. Journal of Aust., Vol. 25, No. 1, 1975, page 4.

The Pitt (Sydney) 10C stored programme controlled STD trunk exchange was put into service in September, 1974. The exchange is briefly described and experience during installation, acceptance and early service is outlined.

NOTI, G.: 'A New MIS for Exchange Construction Work'; Telecomm. Journal of Aust., Vol. 25, No. 1, 1975, page 13.

A new management information and control system suitable for construction work is presented, ARF installations work is PERT scheduled by subdivisioning it into 20 to 30 units. This results in a simple and flexible schedule whch is easily adjusted to the required accuracy, can be updated efficiently and be used for effective control of resources.

It provides the technical staff with an enriched and more challenging work environment based on worker participation and resulting in better staff morale, increased productivity and target performance.

POULSEN, A. B. and REED, P. J.: 'The Bellenden Ker Television Project — Part 2'; Telecomm. Journal of Aust., Vol. 25, No. 1, 1975, page 48.

Part 1 of this article, in the previous issue of the Journal, outlined the background to the Bellenden Ker television transmitter and radiotelecommunications project, and described the construction of a passenger cableway to the top of the Bellenden Ker range for site access. This second part of the article describes the equipment installed in the transmitter building and the operation of this equipment by remote control. This was the major factor permitting the integration of all radio operations in the Cairns area into a functional Radio District.

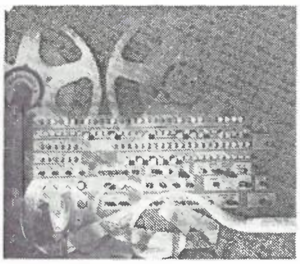
STEENDAM, J. P.: 'MFC Signalling Principles'; Telecomm. Journal of Aust., Vol. 25, No. 1, 1975, page 23.

This paper outlines the principles involved in compelled sequence MFC signalling. The basic requirements of a signalling system are discussed and comparison made with the manner in which these characteristics are incorporated in the MFC signalling systems in use in the APO telephone network.

THE TELECOMMUNICATION JOURNAL OF AUSTRALIA

VOL. 25. No. 1. 1975

CONTENTS



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