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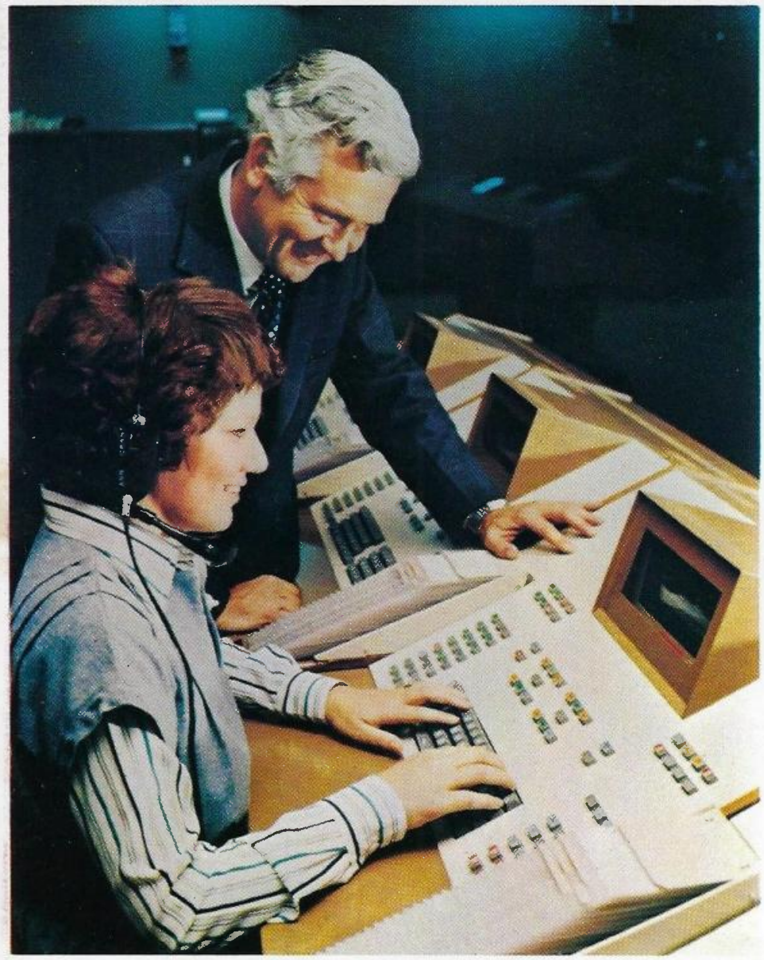

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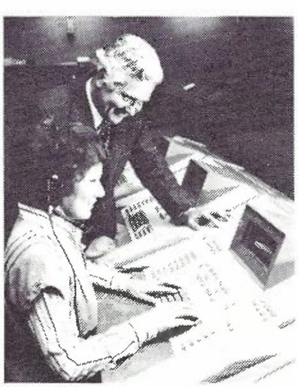

COVER
WAYMOUTH 10C
MANUAL ASSISTANCE
POSITIONS

The Telecommunication Journal of Australia

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

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OVERSEAS APPLICATIONS

The General Secretary, Telecommunication Society of Australia,
Box 4050, G.P.O., Melbourne, Victoria, Australia, 3001.

Waymouth 10C Trunk Exchange — Operational Experience

R.H. WESSON, B.E. (HONS)

The Waymouth 10C Trunk Exchange in Adelaide was commissioned in August 1976.

It was the third Stored Program Controlled Trunk Exchange to be installed in Australia, but the first to provide specialised manual assistance facilities.

This article deals with the operating experience in the first twenty one months after commissioning.

INTRODUCTION

The Waymouth 10C Trunk Exchange is a stored program controlled exchange designed by Bell Telephone Manufacturing of Belgium and installed in Australia by Standard Telephones and Cables Pty. Ltd. The exchange was the third of its type to be installed in Australia but the first to provide the specialised manual assistance facilities with subscriber trunk dialling (STD) and international subscriber dialling (ISD). The other exchanges are Pitt in Sydney, and Lonsdale in Melbourne, which were commissioned in 1974 and 1975 respectively.

Readers are directed to a previous article by K W ALLISON and R H WESSON, Vol. 27, No 2, for the testing and commissioning of this trunk exchange.

FACILITIES PROVIDED

When the Waymouth exchange was commissioned in August 1976 it provided the international manual assistance centre for South Australia, the Appointment and Reminder Service (ANR) for the Adelaide Telephone District, the main originating trunk switching exchange in Adelaide for STD traffic and a co-main for terminating trunk traffic.

The principal dimensions of the exchange were:

- Switchblock capacity installed — 4096 inlets — 4096 outlets;
- Switchblock terminations in use — 2200 inlets — 2000 outlets.
- Manual assistance positions for:

International	15
ANR and Interception Service Centre	17
Training	3
Service assessment	3

The ANR service was automated principally because of the busy callout requirement at a time of day when operators were difficult to obtain. There are two busy periods, the first between 10 p.m. and 1 a.m. when most calls are booked for the following morning and again between 4 a.m. and 8 a.m. when the majority of callout are made. **Fig. 1** shows a typical weekday callout pattern.

In September 1976, international subscriber dialling (ISD) was provided for Adelaide subscribers to various overseas countries. Progressively, this service has been extended to country subscribers and to an increased number of overseas destinations.

Fig. 2 shows the growth in the effective calls switched for international and ANR traffic since commissioning. The demand for international calls has been strong with the growth for ISD and manually switched calls being similar. This pattern of growth is expected to change when automatic message accounting is introduced in 1979, the growth for automatic being far greater than for manual. The effect of Christmas on demand for these calls is clearly indicated. The actual number of calls on Christmas day is four times more than on a typical weekday.

The demand for ANR service is also substantial with a peak during the winter months as might be expected.

In February 1978, 13 additional manual assistance positions were commissioned for national manual working from four dedicated metropolitan exchanges. By this time the switchblock terminations in use were 2500 inlets and 1900 outlets. Another 48 positions are currently being installed and these will cater for national working for the Adelaide Telephone District and also a large part of the country network adjacent to Adelaide.

A very comprehensive testing program was carried out before commissioning. This was oriented towards testing of individual software packages. A long term comprehensive test with all facilities and heavy traffic is almost impossible to achieve with test calls. Load dependent factors have become apparent during the early operational experience at Waymouth.

OPERATIONAL EXPERIENCE

Software Reliability

The planning of the maintenance strategy for the 10C exchanges in Australia assumed that the majority of the technical staff effort would be directed towards maintenance of equipment in the switchroom. Faults in this area would be detected by a wide range of inbuilt self checking procedures that would cause the faulty hardware to be placed 'out-of-service' whenever possible with an appropriate coded output message to teleprinter. By the use of diagnostic guides these messages were expected to enable the fault to be quickly located and then corrected by replacing a printed circuit board (PCB).

This approach presupposes that the exchange operational software is free of error ('bugs') and that all hardware malfunctions would be detected by the software and appropriate corrective action taken. The need for error-free software was recognised very early in the testing phase and influenced the design of the acceptance tests. It was inevitable that the most commonly used software, such as for basic call handling, would be 'debugged' first as this software is being used continually, but that software for the less frequently used programs, such as for the less common manual assistance call types and some 'on-demand' programs would take much longer.

For almost the first year after commissioning, the exchange operated in an environment of more than one fault at a time in the software and common control where it was extremely difficult to isolate the real cause of problems. Software faults corrupted the operational exchange data. Moreover, certain hardware failures had not been considered when the software was designed. During this period many software corrections were added to the programs. Tests that had been successfully performed before commissioning could not necessarily be assumed to be valid.

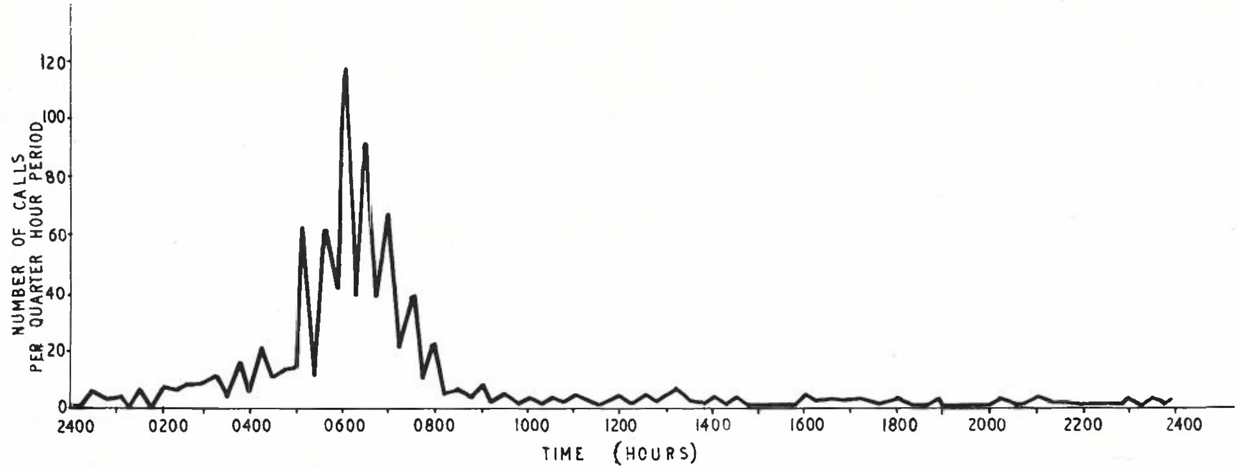

Fig. 1 — Appointment and Reminder Calls - Typical Weekday Call Profile for Auto Callouts.

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He joined the Commission in 1956 as a Technician-in-Training. After advancement to Engineer in 1965, he was engaged in the installation of telephone switching and long line equipment in country centres in South Australia. In 1969 he transferred to the Planning Branch and was involved in planning of the South Australian trunk network and in particular the Waymouth 10C Exchange.

In 1972 he transferred to Telephone Switching Equipment Branch in Headquarters and was engaged in the specification of the testing requirements for 10C Trunk Exchange with particular emphasis on Manual Assistance. From August 1972 until March 1974 he participated in the preparation of this testing at BTM, Antwerp, Belgium.

After contract completion of the Waymouth 10C Exchange in 1976 he returned to the South Australia administration to assume operational responsibility for Waymouth 10C exchange.

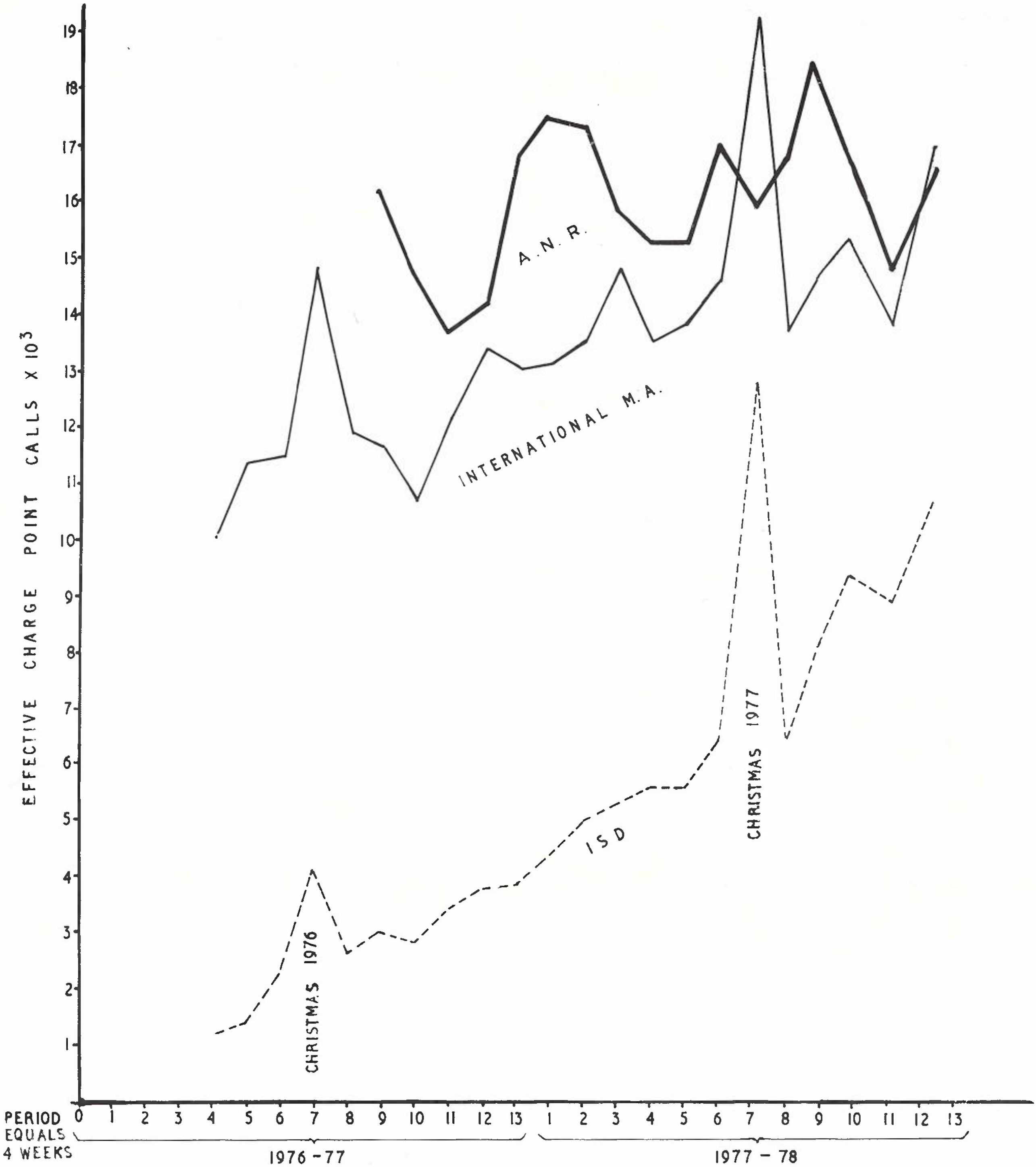

Fig. 2 — Effective Charge Point Calls for International and ANR.

The number of software faults encountered was much greater than expected. Interaction problems particularly under load conditions were numerous. There were also problems in the software package that treats hardware failure to minimise its effect on the subscriber. This package is one of those less frequently used and, therefore, takes much time to debug. But at the same time correct operation is essential if the exchange is to be kept 'on-line'. The most difficult problems to solve concerned certain malfunctions which are observed at a time well after the event that caused them.

It has been observed that the manual assistance centre provides a very good indication of the 'health' of the exchange. This is because the centre is staffed by experienced operators who know what to expect, and because manual assistance calls use most of the facilities in the exchange at some time during connection. The first effects of deterioration of the exchange are often observed on the manual assistance positions before indications are given on the teleprinter in the maintenance control room.

The main cause of data corruptions was found to be due to errors in the software although earlier it was thought that the common control hardware was a major contributing factor.

Data corruption resulted in the exchange performance being degraded in three ways:

- Loss of certain software devices — but the exchange still functions. This situation is detected by the unavailability of equipment for the manual assistance centre or from observations of an hourly interrogation tape that is run manually to check certain 'internals' of the exchange.
- Loss of facilities and the exchange performance is degraded. For example, the manual assistance operators are unable to accept calls from subscribers. Faults of this type could affect some STD traffic.
- Loss of all facilities and it is necessary for the system software to be reloaded.

It was originally thought that system degradation would eventually result in the exchange being forced to 'reload' the system software automatically and that this action would clear the corruption. This however, was not always the case and action has had to be initiated by the technical staff to force reloads of the software and to take other measures to ensure that the exchange would switch traffic after such a reload. With experience, it has been possible to clear some problems by causing particular parts of the exchange data file to be 'reinitialised' and so minimise the impact in call switching by avoiding a potential total failure.

During a total 'reload' of the software the exchange does not provide information or line signalling on trunk circuits, and as these reloads take a minimum of 100 seconds, the exchange is therefore unavailable ('off-line') for this period. **Fig. 3** gives details of the number of such failures, both provoked and unprovoked since commissioning, where 'provoked' failures are either a deliberate action to take the exchange off-line by normal means or result from human error. An 'unprovoked' failure is where the failure occurred at a time of no external activity or at the time of usage of a standard facility. **Fig. 4** gives details of the system unavailability times on account of these reloads. The Telecom short term, settling-in period, outage time target has been set at twelve minutes per four weekly period. Difficulty is being experienced in achieving this at the present time with the existing operational software program. The relatively long outage times are largely a result of the present recovery discipline of reloading the entire operational program after a system failure. However, improvements have recently been introduced into Waymouth which significantly reduce the time taken to 'restart' the system and so decrease the outage time per incident by a significant factor.

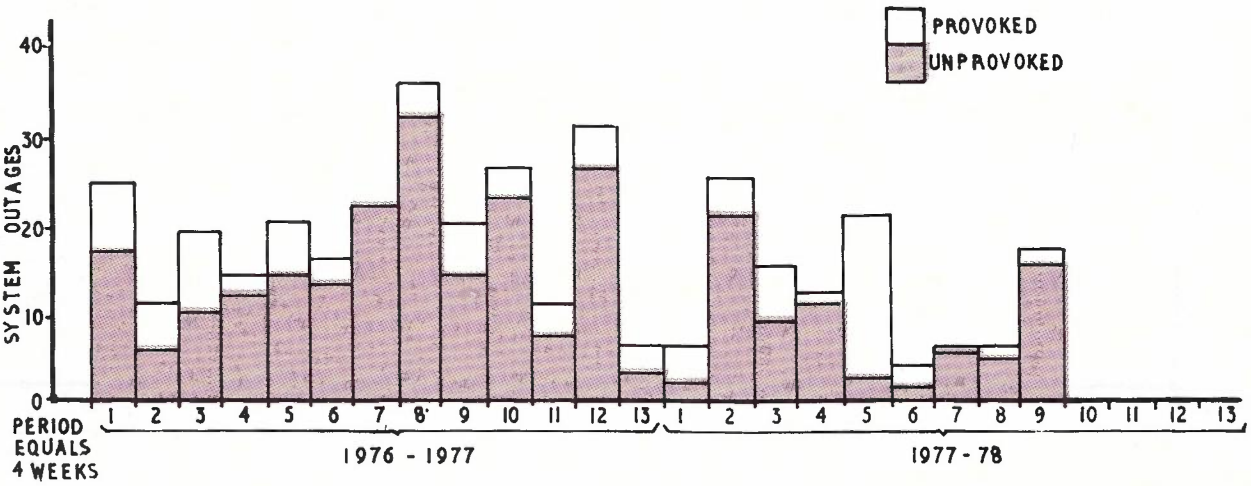

Fig. 3 — Number of Exchange Outages per 4 Weekly Period.

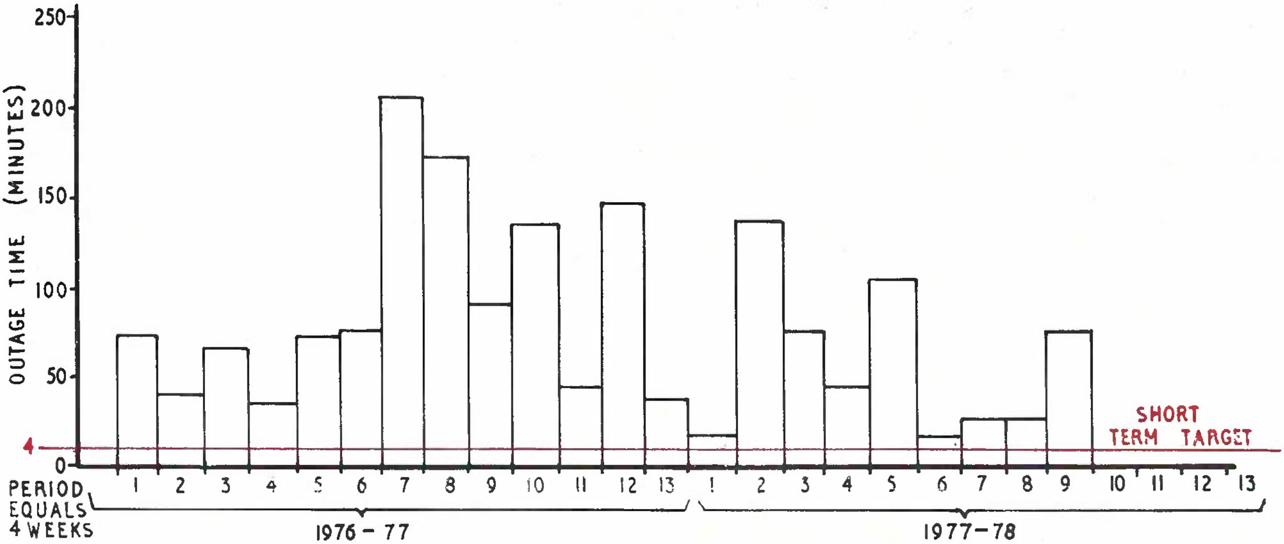

Fig. 4 — Exchange Outage Time per 4 Weekly Period.

In the 49th week after commissioning, the exchange for the first time ran for a week without any failure that affected subscribers, and shortly afterwards, there was a period of 21 days when there were no un-provoked outages of the exchange. Once this stage had been reached it became possible to isolate and correct faults of all types far more quickly.

Hardware Reliability

The mean time between failures as indicated by the number of 'hard' faults found and corrected by the normal maintenance procedure of PCB replacement has been generally satisfactory for most items of hardware. The original expectation that faults could be cleared by the PCB replacement technique has been largely fulfilled in the switchroom. However, some common control equipment faults have been intermittent and time consuming in correction. The result is that more than one such fault existed at certain times. The basic assumption for the maintenance approach derived from the system design was one fault only at one time.

Maintainability

Generally, maintainability has been good where the hardware failure has been allowed for in the software. However there have been several instances where more than one fault has occurred at a time and where a hardware failure has not been allowed for in the software. These problems demand a high level of technical skill.

Switching Performance

In general terms, switching performance for STD and ISD calls, as measured by Service Assessement and Traffic Route Testers has been within Telecom targets.

The manual assistance system experienced unsatisfactory levels of performance and disturbances under the early heavy load conditions at the first Christmas and Easter after commissioning. Since that time, corrective action has been taken to remedy the problems and the performance for an exchange the size of Waymouth is now satisfactory even during such peak periods. The manual assistance system does require much more maintenance effort than initially anticipated as the operators discern defects or malfunctions quickly and report them. The design of the manual assistance system is very complex to satisfy the wide range of facilities in use so software faults take a long time to isolate.

SOFTWARE MANAGEMENT

National Support Centre (NSC)

While BTM/STC are responsible for the design of the 10C exchange, Telecom has operational responsibility for the national telephone system and has established a 'model' 10C trunk exchange in Melbourne operated and staffed by Switching Design Branch, Engineering HQ as part of the National Support Centre. This exchange has equivalent common control equipment to the operational exchange and a 256 termination switching network. From the viewpoint of an operating exchange, the main functions of the NSC is:

- The testing of software program changes before their introduction into the operational exchanges. In a few cases, the model is unable to simulate all conditions encountered in an operational exchange.
- Preparation of system software requirements.
- Investigation of fault reports from the operational exchange. This has proven to be a greater task than first envisaged, as the number of system disturbances observed in the exchange has exceeded the initial expectations particularly for manual assistance. This

situation is being overcome by close liaison between the specialists in the 'model' and the skilled experienced staff at Waymouth. Joint investigations by BTM/STC with Telecom have significantly reduced the problem areas.

Loading New Software

New software is supplied by the National Support Centre to satisfy four requirements.

Firstly, there is the need for test programs to be run via an off-line CPU for some pieces of common control equipment.

Secondly, there is the need for on-demand test programs that are used daily for normal operational reasons. These programs are on paper tape and should rarely need updating, but do require periodic replacement due to wear and tear. A set procedure has been developed to check new copies in a quiet traffic period and this can take several hours.

Thirdly, there is the need for 'number/name' translation table updates. This table contains information for the manual assistance centre such as charging, routing and place names. It has entries for over 6000 destinations in Australia and overseas, and changes are required due to network growth. It is possible to update the table on site by use of an on-demand program, although there is a limit to the number of such changes. New versions of the tables are therefore supplied every two months.

Fourthly, and most importantly, there is the need for new versions of the exchange system tape which contains the operational program and exchange based data for such items as charging and routing. Four copies of this software are received on site with documentation indicating the changes from that previously supplied and also recommendations as to how it should be loaded. It is essential to load this software in a quiet traffic period early in the week so that its performance can be assessed whilst the exchange is staffed. The time chosen for Waymouth is 1 a.m. and comprehensive checks are performed for known variations to the software and spot checks for other areas are carried out in accordance with a pre-arranged plan. This can take up to three hours, by which time the testing team must be satisfied that the ANR call-out period which begins to get busy by 4.00 a.m. can be handled correctly. On these occasions one member of the staff remains on duty during the first night to monitor the exchange. A verbal cassette recording is made detailing actions during important parts of the loading, and this has proved invaluable the following morning in assisting the local and NSC staffs to locate the cause of any problems at times of failures. It is important to know the steps taken before a problem develops as well as the end result.

In the first 21 months of operation, 37 different system tapes have been loaded of which 28 were successful and nine failed. The exchange down time was some 75 minutes for the successful loads and 200 minutes for the failures, the additional time being due to staff obtaining vital data to assist in the later rectification of software faults with all the details being cassette recorded. **Fig. 5** shows the spread of these loadings relative to time.

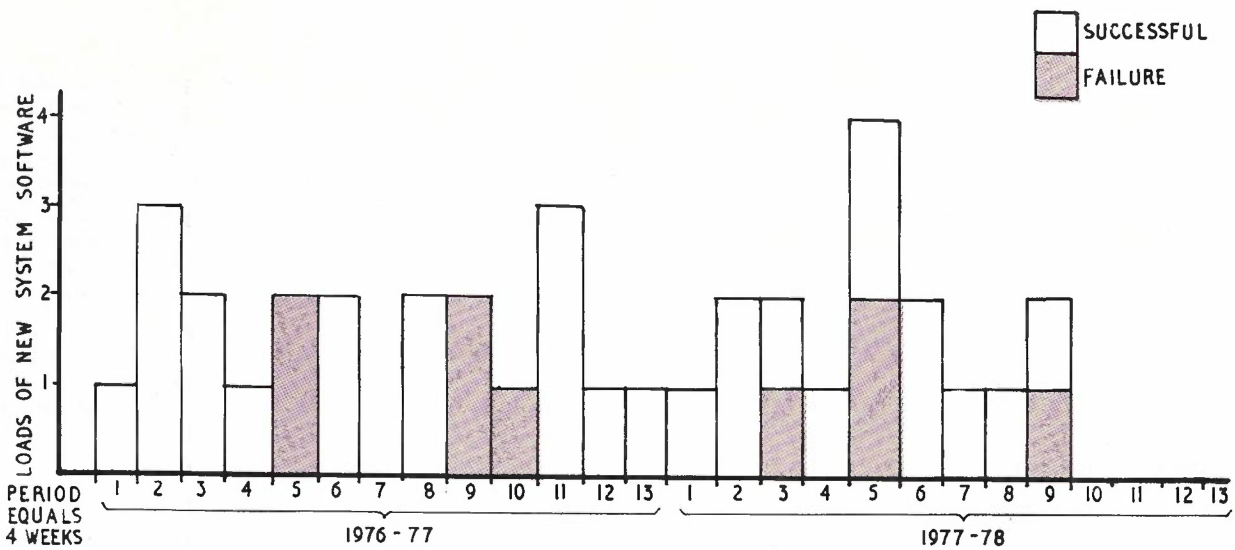

Fig. 5 — Number of New System Software Loads per 4 Weekly Period.

Magnetic Tape Outputs

Information relating to the operation of the exchange is recorded on magnetic tape which is then processed by the Telecom ADP facility in Melbourne. Information recorded covers:

- All details of calls handled by operators in the manual assistance centre;
- Statistical information on the number of calls offered to the queues and the handling of these calls by the operators;
- Service assessment;
- STD and ISD call and revenue statistics;
- Volume and dispersion of traffic on various routes.

For security, this information is recorded on two independent sets of magnetic tape units, both tapes being exchanged each week-day with a security procedure being used to transport the information to the ADP Centre. Just after these tapes are changed, certain files on the disc memories are dumped to magnetic tape and are retained in the exchange. This information would be used in recovering the data stored on the disc memories in the event of a major failure where all or part of the disc information is lost.

Once a week, a magnetic tape is made of the permanent ANR bookings that are stored on disc. Eventually, this could be used to perform certain audit functions on this information external to the 10C. At present, it provides additional security in event of disc information being lost.

OPERATIONAL SUPPORT SYSTEMS

It has been found necessary to provide operational support in three areas.

Firstly, for the Appointment and Reminder Service because the intermittent failure rate has been higher than anticipated. As mentioned previously, the period for high automatic callout is early in the morning when the exchange is not staffed. Thus failures at these times are serious. Typical problems have been failure to access the disc memory where the call-out information is stored or loss of the complete exchange due to problems not necessarily associated with the ANR service. It must be appreciated that this service is different from the other services provided by the exchange, in that failure of the ANR service is not apparent to the subscriber who booked the call several hours or days previously. Failure to the other services is more obvious to operators or subscribers at the time of a failure and immediate, appropriate action can be taken.

After the first major failure of the service in January 1977 it was found necessary to hold paper dockets of all bookings made as well as the normal booking procedure. This has been necessary because facilities do not exist to access the disc store to obtain a readout of the stored information. In the event of total or partial failure these dockets were then used to give the required service by making manual calls via the local network. Dockets also give a means of identifying and cancelling those calls that were stored in the exchange memory but were not placed due to the failure. This is essential as these calls would be made one week later as the storage is presently based on a weekly cycle, Monday being classified as 'day 1', Tuesday 'day 2' etc.

The obvious disadvantage of the back-up docket system is the time taken to write the dockets and their associated processing. A system is currently under development where the information stored in the 10C memory for the bookings is also automatically stored in an on-line microprocessor that can be accessed by the operations staff at times of failure to the service. Once this is operational the dockets can be dispensed with.

The second need for support is for telephone network security. Total exchange failures are detected in one of two ways; either by the operational software system in which case the incoming physical trunks are 'back busied' just before the exchange goes off-line and the system software is reloaded, or by an automatic supervisor in which case the incoming trunks are not back busied. The automatic supervisor is a hardware device external to the common control equipment that makes seizures into the exchange every 80 seconds to check that the exchange is operational. If the exchange is not then a reload of the system software is forced.

The initial experience was that many failures were caused by operation of the automatic supervisor and once the system software was reloaded the exchange would sometimes still not perform correctly until manual interventions were made. This type of failure has occurred in unstaffed periods resulting in the exchange being off-line until exchange staff could attend, which has been typically 40 minutes.

To minimise the effects of these shortcomings, appropriate hardware has been developed which detects that the exchange is off-line and causes a control signal to be sent to all exchanges that trunk to the 10C from within South Australia.

These exchanges have had their trunking amended such that reception of this signal causes traffic that is normally trunked to the 10C to be re-routed to a recorded voice announcement (RVA). It is also possible to change the wording of the RVA by a manual operation from a point within the main Adelaide manual assistance centre if it is considered the 10C will not be switching traffic within a reasonable period. Subscribers are then advised that access to an emergency set of switchboards is possible by use of a certain code that is used only for emergencies.

The third requirement for support is in the sorting and analysis of fault and status reports which are an output to teleprinter during the day. These mainly detail faults which are encountered while switching approximately 200,000 daily call attempts. At the present time, about 5,000 such reports are produced each weekday and at least half of these are associated with difficulties outside the exchange. It is obvious, therefore, that the 10C exchange can assist in providing information for identifying general network faults.

As it is virtually impossible to analyse these reports in real time, a procedure has been developed where a punched paper tape is made for one day a week simultaneously with the teleprinter recording. This is batch processed the following day in an off-line system which sorts and lists the fault reports. This approach has two major benefits. Firstly, faulty hardware can be more readily identified, and secondly a list is prepared which details the totals of each report type for the day. These can then be tabulated on a weekly basis and used by the exchange management in directing the activities of the maintenance staff in fault finding.

ADMINISTRATION

For the first seven months of operation the exchange was staffed continuously to ensure that the exchange performance would be satisfactory at all times. Manual interventions were required at various times to ensure that all the facilities offered were actually being provided. An hourly interrogation of certain software devices is manually performed and this has provided a most useful source of performance indication.

It is normal practice for a new exchange to be closely monitored over the busy traffic period, and for Waymouth this is from 4.00 a.m. for a 21 hour period to 1.00 a.m. the following day. This prolonged traffic profile is due to the variety of facilities provided, which commences with automatic ANR calls in the early morning, followed by STD throughout the day, then international manual assistance peaks in the late evening together with bookings for ANR calls for the following day.

In February 1977, the staffing roster was changed so that the exchange was then staffed from 7.00 a.m. to 11.00 p.m. each weekday, 7.00 a.m. to 3.00 p.m. on Saturday and 3.00 p.m. to 11.00 p.m. on Sundays. This arrangement allows for maximum cover of the busy traffic periods except for the automatic callout of ANR calls early in the morning. In addition to this, it has been found necessary to roster one staff member on stand-by duty for all hours that the exchange is not staffed so as to guarantee that specialised staff are always available. During these hours, the exchange alarms are extended to the Adelaide Trunk Switching Terminal which is staffed continuously.

Twelve technical shift positions and one clerical assistant position have been provided for normal exchange duties. The staff is arranged into three functional groups as follows:

- To handle the common control and magnetic tape equipment;
- To attend to exchange faults in the switchroom and manual assistance area;
- To handle external faults in the switched network and commissioning of new circuits.

In addition to this technical staff, two professional engineers are associated with the exchange full-time, and are located adjacent to the exchange. There has not been any additional staff for projects, all such work being undertaken by the engineers with the assistance of senior technical staff in the exchange. This arrangement has proved most productive as it has been possible for this small group of people to work together as a team in solving the many complex faults in consultation with the National Support Centre.

Weekly meetings also are held in the exchange among all shift leaders and more senior staff for a complete interchange of ideas on faults so that co-ordinated investigations can be effectively mounted.

Waymouth has been fortunate in that the staff turnover has been extremely low but, due to network growth there is still a requirement to train additional staff. This is being achieved by attendance at the training courses in Melbourne and by on-the-job training. It has been found that at least a year is required before new staff are fully competent.

Use of this new technology of software control has enabled a change to take place in the control of network growth in the trunk exchange. There have always been two areas of work involved in the exchange for growth; the design of the required changes and their implementation. Because of the substanial manpower involved to achieve strapping changes in the crossbar equipment, this work has previously been undertaken by the Construction Branch, but in the 10C exchange these changes can usually be implemented very simply by teleprinter commands. In Waymouth, all software translation table changes for network growth are controlled by the operations staff as is the associated documentation and actual additional trunk or junction circuit commissioning. It follows that exchange staff are fully aware at all times of network changes and their implications.

All records of changes to translation tables are recorded on punched paper tape when they are being addressed to the exchange memory so that they can be re-entered in the event of certain types of exchange failure. The information stored on this tape plus alterations required in the future are sent to the National Support Centre for inclusion in the next version of the operational software tape. Update tapes for data are supplied to the exchange every six weeks, and once they are loaded the punched tape of recent changes is no longer required. This is a cyclic process with the "recent change tape" growing in size between system tapes and decreasing on a successful loading of the new version of the operational software.

CONCLUSION

The initial experiences in Waymouth have demonstrated the operational savings that are achievable when a manual assistance centre is controlled by a stored program controlled trunk exchange. But the marriage of a manual assistance centre with a main trunk exchange that also caters for STD, ISD and ANR has proved to be a most complex task. The initial difficulties are being overcome and progress is being made toward improving the system availability so that in the near future the real gains from stored program controlled exchanges can be achieved.

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Radio Relay System Path Survey Techniques
Part 1 — Why a Survey is Conducted

N.L. WAIN, A.R.M.I.T.

The major portion of trunk traffic in the national network is carried on broadband radio-relay systems designed to meet performance standards based on CCIR Recommendations.

The design of these systems is conducted within the State Administration Radio Sections in accordance with guidelines set by HQ Radiocommunications Branch and may be sub-divided into three successive studies consisting of a feasibility study, a path engineering and survey study, and a transmission engineering study.

The most demanding of these functions in engineering time and effort is the path engineering phase which culminates in the preparation of a report giving exact details of path and route parameters for the final transmission design study.

This article gives an outline of the survey aspects associated with the path engineering study and is divided into two parts — the first deals with the reasons for surveying the system route and the second looks at the techniques used by the surveyors to obtain the survey information and prepare the necessary drawings.

INTRODUCTION

The reliability of a communication system is dependent on the quality of the communication equipment, the continuity of the power supply and the stability of the transmission medium.

The evolving improvements in equipment technology have reduced the significance of the plant factors in the overall reliability of radiocommunications systems. However, the transmission medium remains almost as unpredictable as ever, being controlled by the nature of the intervening terrain and the random fluctuations of the atmosphere, which, even in this enlightened age can be difficult to predict.

The majority of the radiocommunications systems operated by Telecom are fixed point-to-point services, using frequencies within the spectrum 80 MHz to 8000 MHz. Most of these systems rely on the spacewave mode of propagation and require an unobstructed path between transmitter and receiver and for this reason are sometimes referred to as line-of-sight systems.

In order to predict the likely performance characteristics of a proposed system as accurately as possible the designer must have detailed information concerning the topography of the paths forming the route. To obtain this information field survey procedures are undertaken.

The survey may simply be a map study followed by on-site field strength measurement in the case of single channel subscriber systems or could involve a more sophisticated ground survey or photogrametric exercise for long-haul broadband radio-relay systems.

To appreciate more fully the dependence of radiocommunications systems on the route survey information, an outline of basic radio propagation theory and its relationship to topography and climate will be discussed prior to elaborating on the techniques employed to survey the route.

PROPAGATION ASPECTS

The quality of an analogue communications system is measured in terms of the ratio of the wanted signal to the unwanted noise (S/N) inherent in the system. In a radiocommunications system the noise in a traffic channel is the sum of contributions from three main sources namely:-

- Thermal noise; comprising the basic noise of the radio and demodulating equipment which is fixed by equipment design and the receiver thermal noise which is a variable component dependent on the transmission path loss.

- Intermodulation noise; which is associated with the traffic loading of the system and the linearity of the radio equipment, antenna system matching and the delay properties of the transmission path.
- Interference noise; consisting of unwanted signals from other systems, industrial scientific and medical apparatus (ISM) and other man-made sources.

As will be appreciated, the transmission path plays a significant role in the noise budget of a radio system, particularly as the magnitude of its contribution is variable with time, depending on prevailing atmospheric conditions in association with the frequency of transmission and geometry of the path and can therefore be difficult to predict.

Radiocommunications services operated by Telecom utilize frequency assignments in the Very High Frequency (VHF, 30-300 MHz) the Ultra High Frequency (UHF, 300-3000 MHz) and the Super High Frequency (SHF, 3-30 GHz) bands. In this part of the radio frequency spectrum the transmission between stations is predominantly via the space wave, which, in its simplest form may be considered as being composed of a direct ray linking the two stations together with indirect rays reflected or refracted from the surrounding environment. **Figure 1** depicts a longitudinal cross-section through the radio path showing the space wave components and the topographical features along the path. Such diagrams are called path profiles and are extensively used in the design of radio-relay systems to assess the exact tower and antenna heights for clearance over the intervening terrain.

The space wave is transmitted through the lower part of the atmosphere, called the troposphere, where most of the effects of weather occur. On a given path the vector sum of the direct and indirect waves at the input to the receiver determines the strength of the resultant signal. Random variations in the structure of the troposphere cause the amplitude and phase relationships of direct and indirect waves between two points to alter and the resultant received signal level varies with time. These variations are termed fading.

As with any transmission system, the signal suffers attenuation in its passage between transmitter and receiver and the loss is proportional to the square of the product of the direct path length and frequency of the transmission which are constant for a given path. The reference to which all signal variations are compared is known as the free-space level (FS) and is that signal level that would be received if the path was located in space remote from the earth and its effects.

Fading experienced on line-of-sight paths is typically no greater than -5 dB_{FS} for large periods of time but may occasionally exceed -40dB_{FS} for very short periods introducing a corresponding degradation in S/N. **Figure 2** shows a record of received signal with respect to time for a typical radio path.

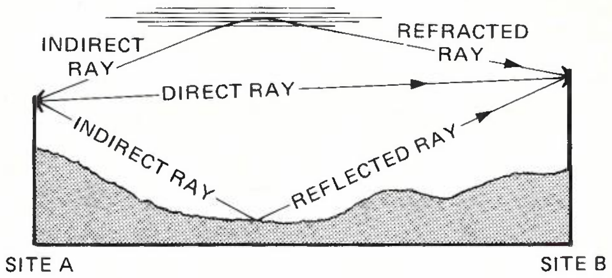
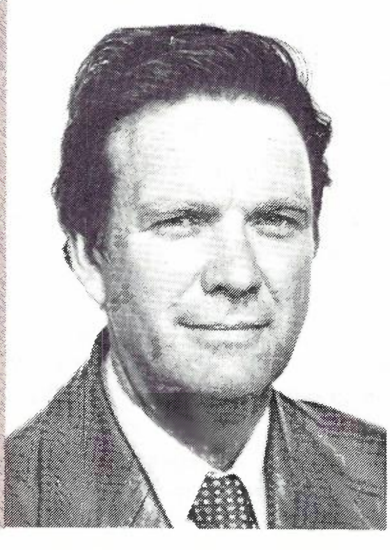


Fig. 1 — Path Profile Showing space Wave Components.

NEIL WAIN joined the PMG in 1951 as a Technician-in-Training and after qualifying as a radio Technician in 1956 was posted to the Research Laboratories, Propagation Division, where he was involved in the installation, maintenance and analysis of propagation measurements on many of the radio paths which form part of today's national trunk network.

He was admitted to the Institution of Engineers, Australia, in 1970 following part-time studies and joined the Radio Section, Headquarters, as an Engineer Class 1, dealing with the design of broadband radio-relay systems.

He is now an Engineer Class 3, in Radiocommunications Construction Branch responsible for the development of standard practices and guidelines for the design of radiocommunications systems.



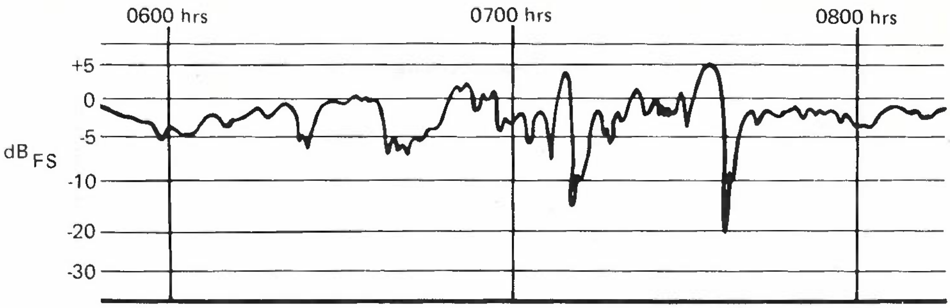


Fig. 2 — Fading Characteristics of a Typical Line-of-Sight Path

The troposphere is far from being a homogeneous medium and space wave transmissions are affected by refraction which varies with the temperature, water vapour content and pressure of the troposphere.

The radio refractive index of air is the ratio of the speed of radio waves in vacuuo to their speed in air and is close to unity (1.0003). The refractive index of the troposphere usually decreases with height causing the upper portion of a propagated wave front to travel slightly faster than the lower portion resulting in a progressive downward tilt of the wave front. The trajectory of the wave front can be represented diagramatically by a ray-line normal to the wave front, joining the two antennas (**Fig. 3**). The ray line has a radius slightly larger than that of the earth when propagated through a well mixed atmosphere.

As the atmospheric conditions change with time so the refractivity changes altering the degree of bending of the ray in the vertical plane. When downward bending is more severe than usual super-refractive conditions exist and when the bending is less than normal sub-refractive conditions prevail.

The need to correlate the tropospheric conditions and the refraction of radio waves in the design of radiocommunication systems leads to the modified earth's radius concept. This assumes the path taken by the ray is a straight line and the earth's radius is modified by a factor 'k' to restore the relative clearance of the ray over the terrain for a given refractive index gradient.

When the troposphere is well mixed, sometimes referred to as the standard condition, the value of $k = 4/3$. Subrefraction occurs when k is less than 4/3 and super-refraction occurs when k is greater than 4/3.

In Australia, radio paths for SHF systems are designed to accommodate a range of k from 0.8 to infinity. When k is equal to infinity the modified earth radius is infinite and the path has a flat datum as shown in **Fig. 4.** When considering the modified earth radius concept in conjunction with ray clarance studies the earth is said to bulge when k is less than 1 and flatten when k is greater than 1. The earth bulge at any point on a path may be determined

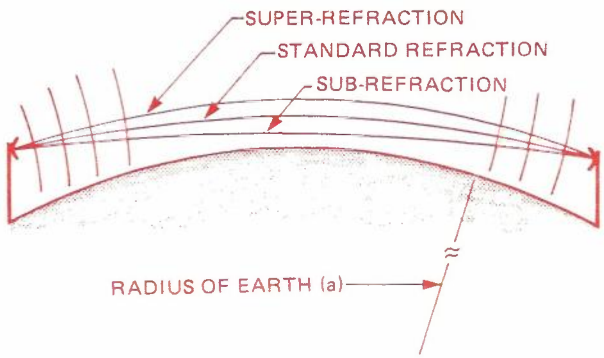


Fig. 3 — Ray-line Concept for Principal Refractive Conditions.

from the expression: $Eb = 0.0785 \ (d_1 \ d_2/k)$ metres where d_1 and d_2 are distances to the point under consideration from near and far ends of the path in km.

It can be shown using Huygens' Principle (Reference 1) that the energy received under free space conditions is the resultant of an infinite number of coherent waves arriving at the receiver via different paths. All paths which are within one half wavelength ($\lambda/2$) of the direct path will add vectorially to contribute energy in that zone. All paths between $\lambda/2$ and λ longer than the direct path will combine to subtract energy from the previous zone and so on through path differences of $n\lambda/2$ creating adjacent zones in space of opposite phase to one-another. These zones form ellipsoids of revolution around the direct path and are called Fresnel zones after their discoverer, A.J. Fresnel, the eminent 19th century researcher of optical phenomena. The central zone is called the first Fresnel zone and the successive outer zones are the second, third and so on to the nth zone. A section perpendicular to the direct ray would show the zones as concentric circles and since each zone has the same cross-sectional area the contributions from adjacent zones will tend to cancel, however, contributions from higher order zones become progressively smaller due to the additional path length and obliquity factor. The resul-

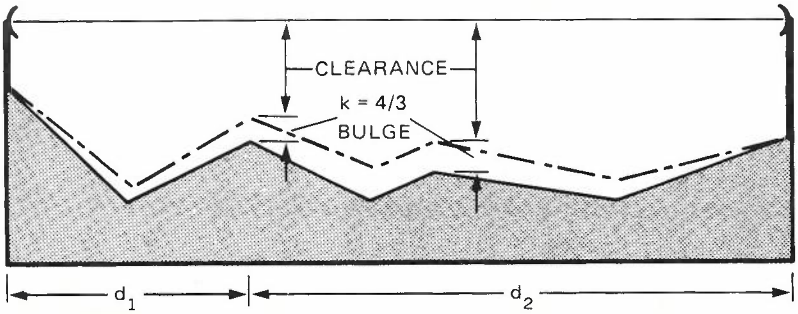


Fig. 4a — Profile Drawn on Flat Datum and Adjusted for Earth Bulge at k=4/3.

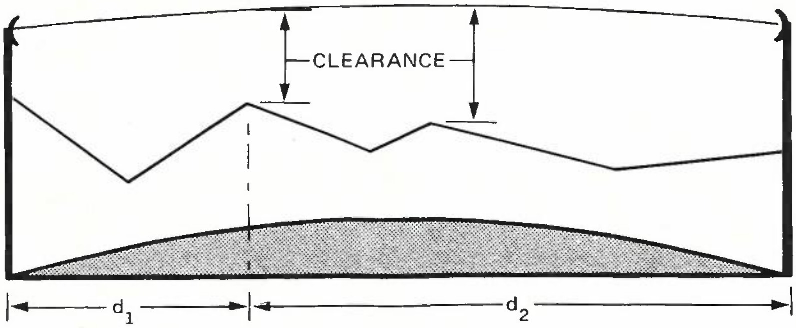


Fig. 4b — Actual Profile with Standard Refraction at k=4/3.

tant field at the receiver in free space is approximately half of that from the first Fresnel zone alone and corresponds to the free space level. The Fresnel Zone concept is shown diagramatically in **Fig. 5**.

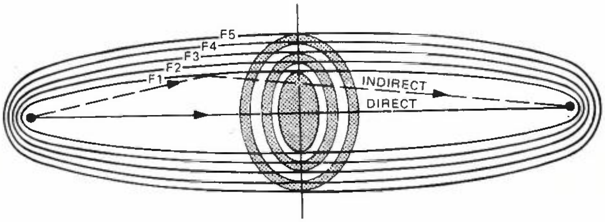


Fig. 5 — Fresnel Zone Concept.

The clearance of the ray over the intervening terrain is measured in terms of Fresnel zones. The radius of a Fresnel zone at any point along a path may be determined from the following equation:

$Fn = 548 \, (d_1 \, d_2 \, n/fd)^{1/2}$ metres

where d is path length in km

d_1 and d_2 are distances to reference point from each end of the path in km.

f = frequency in MHz

n = Fresnel zone number (integer)

In a practical line-of-sight system the earth partially obstructs the higher order Fresnel zones, modifying the free space field accordingly. However on a path of average roughness the effect is usually insignificant until the first Fresnel zone is penetrated by an obstruction. As the obstruction penetrates the lower order fresnel zones the received signal passes through successive maxima and minima corresponding to the obstruction of odd and even zones respectively until the first Fresnel zone is reached. Further obstruction beyond this point results in the signal falling from a value just above free space level to several dB below free space depending on the degree of obstruction and the nature of the obstructing surface.

The signal level obtained from such a path obeys the laws of diffraction and a sharp transverse ridge across the path exhibits less loss than a rounded hill or plain. A graph showing received signal with respect to clearance is given in Fig. 6a.

It will be seen in **Fig. 6a** that a free space signal may be received if 0.6 of the first fresnel zone is clear of obstruction and the clearance criteria employed for Telecom broadband radio-relay system design is based on this fact. It will also be recognised that clearance is a function of refractive index expressed in terms of k.

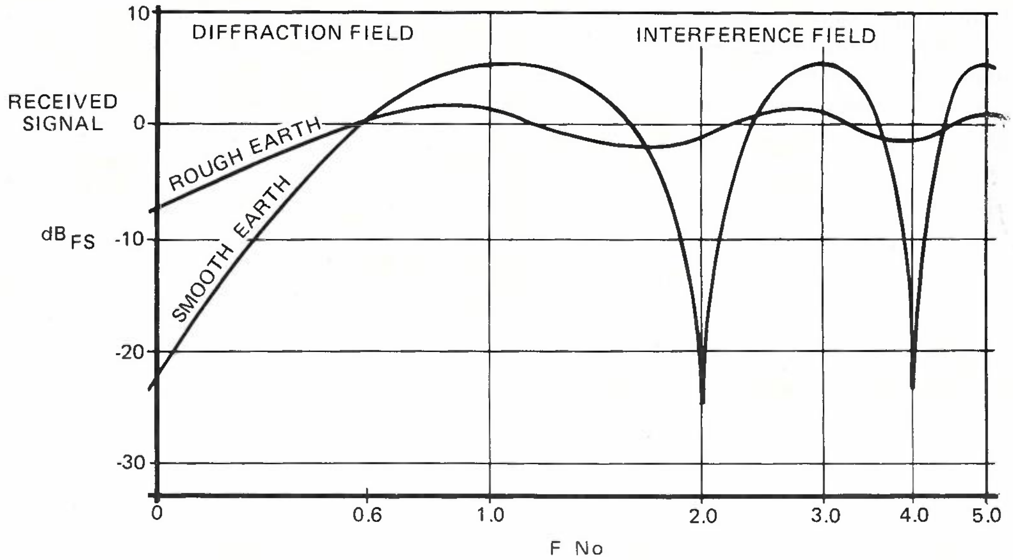


Fig. 6a — **Received Signal with Respect to Fresnel Zone Clearance.**

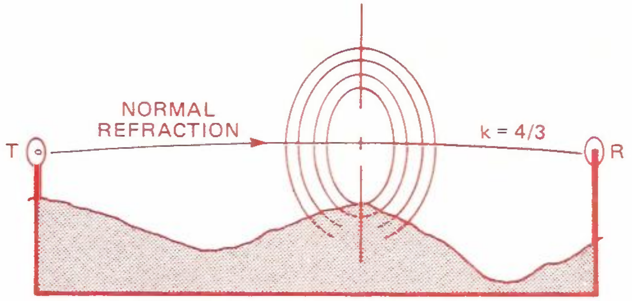


Fig. 6b — **Path with First Fresnel Zone Clearance at k=4/3.**

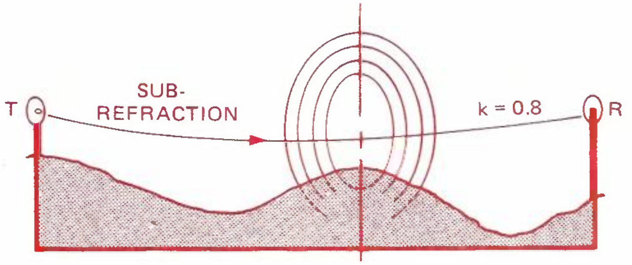


Fig. 6c — **Path with 0.6 Fresnel Zone Clearance at k=0.8.**

Telecom clearance criteria for broadband systems specifies that a path must have 0.6 of the first Fresnel radius clearance ($0.6F_1$) at k = 0.8. In certain areas, however, a higher incidence of subrefraction prevails and a more strict clearance criterion is applied viz. $0.6F_1$ at k = 0.6 requiring higher towers or shorter path lengths.

A path traversing flat plains or large tracts of water may have a high incidence of fading due to the phase relationship of the direct and indirect rays reflected from the path forming a vertical interference field pattern of maxima and minima at the receiving site. When a signal is reflected from such a surface it inherits a phase change of about 180 degrees (π radians) depending on the polarization of the signal, the angle of incidence of the ray and the dielectric properties of the surface. Considering this fact a fringe field maximum occurs when the path difference between direct and indirect rays is n λ /2, where n is an odd integer. Conversely minima occur where n is an even integer.

As refractive conditions change the relative path lengths change, altering the phase relationship of hhe two rays and effectively cause the fringe field to move in the vertical direction. The passage of successive maxima and minima past a fixed receiving antenna produces fading. This field pattern is sometimes referred to as the height gain pattern and is shown diagramatically in **Fig. 7**.

This brief resume of space wave transmission theory emphasises the dependence of transmission performance on ray line clearance and nature of the path topography.

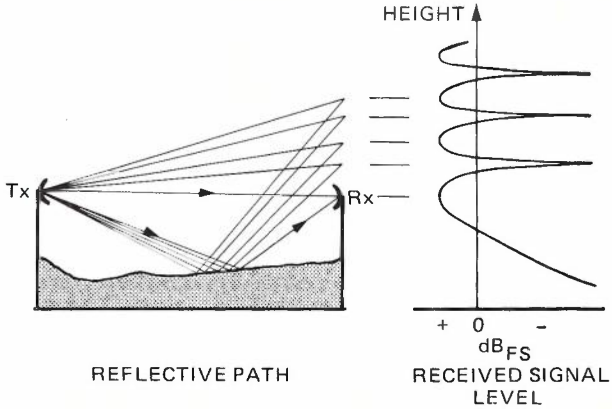


Fig. 7 — Vertical Fringe Field Pattern Due to Reflection.

PRELIMINARY STUDIES

Survey information is required to construct accurate path profiles for the assessment of tower and antenna heights to meet clearance criteria and help predict the fading characteristics of the paths.

The system designer also requires site information such as contours and soil conditions for each station, details of near-end obstructions such as trees and buildings and perhaps a transverse profile where a sloping ridge crosses a path.

Other factors to be considered in the selection of a path or route include:-

- The availability of commercial power and satisfactory all weather road access to the sites, both of which are very expensive to provide and significantly affect overall cost of the final system.
- Restrictions on tower and access construction imposed by the respective authorities in the vicinity of airports, national parks, catchment areas etc.
- Locations of potential interference sources such as satellite earth station facilities, radars, navigational aids and other terrestrial systems in the area.
- The correct orientation of each path so as to avoid overshoot interference into other paths within the system and into the geostationary satellite orbit.

Before the route survey is commenced the system designer must confirm the planning requirements for the proposed system to establish traffic drop and insert points, potential capacity of the system, future spurs and wayside channel requirements. This information will dictate the general orientation of the route. The designer then gathers topographical maps of the area and prepares a mosaic for selection of tentative sites. Having selected a route conforming to the prerequisites mentioned, a field visit is made to identify the sites and assess their potential for establishment as a radio-relay station. Generally the designer, in the course of his map study, will select several alternative routes as insurance against incorrect map information and so allow himself a degree of flexibility in the field.

The field visit would involve a small party comprising the design engineer, surveyor/draftsman and assistants. It may be necessary to check some paths using a surveyors barometer, magnetic compass and heliograph to confirm optical clearance and azimuth figures. In many cases a light aircraft is used to fly over the tentative route at low altitudes, enabling the rapid estimate of path orientation and terrain heights using the cockpit instruments.

The aircraft is also useful for checking access tracks and the extent of reflective areas.

The field visit also provides an opportunity to meet local Postal and Telecom staff who in many cases can provide useful information on the future development in the area, abnormal weather phenomena, flood levels, access guidance and introductions to local property owners. Following the field visit the information obtained is used to optimise the path engineering phase of the system design and for the preparation of a surveyors brief giving details of the work required to be done by the surveying authority.

CONCLUSION

It has been shown how the performance of a radio relay system can be affected by the topography of the constituent radio paths and the weather characteristics in the vicinity of the route.

In order to optimise the system design for economy and performance it is necessary to have accurate details of route alignment, path profiles and repeater site contours for which a detailed survey is required.

The survey techniques employed to provide this information are the subject of Part 2 of this article to be published at a later date.

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1. 'Propagation', Appendix to Section B.IV.3 of the Handbook Economic and Technical Aspects of the Choice of Transmission Systems, ITU, 1971.
2. APO Specification 1214, Issue 1, The Selection and Survey of a Radio-Relay Route.

Development of a Processor Monitoring Instrument for SPC Exchanges: Facilities and Application Areas

P. H. GERRAND, B.E., M. Eng. Sc., M.I.E. Aust. and J. L. PARK, B.E., M. Eng. Sc., M.I.E.E.E.

The Processor Monitoring Instrument (PMI) has been designed to monitor the activity of any processor employed in any Stored Program Controlled system in the Australian network, without requiring any changes in the normal operation of the system being monitored. More specifically, the PMI simultaneously displays and measures up to fourteen indicators of the processing load, including the Effective Processor Occupancy, a concept which is explained in this paper. It can be used efficiently to produce measurements for studies of processor capacity, and for more general traffic engineering studies.

A first PMI has been designed and built by Telecom Australia for application to the Metaconta 10C trunk exchanges in the Australian network. A second PMI is currently being built for application to real-time control projects in Telecom Australia's Research Laboratories.

This article describes the facilities of the PMI and its potential range of applications to system testing, operation and traffic engineering.

INTRODUCTION

Telecom Australia has already committed itself to the purchase and installation of several families of SPC (Stored Program Controlled) systems for diverse applications in the Australian telecommunications network. Many of these SPC systems have a considerable in-built capability to generate their own performance statistics, but at the cost of using valuable processing time for generating these statistics rather than handling more subscriber-generated traffic. And it often happens that the statistics of greatest interest to network planners and operations staff are those produced under peak traffic conditions, when processing time is at a premium.

It was with these considerations amongst others in mind that Telecom decided two years ago to investigate the most meaningful indicators of processor occupancy in an SPC system and, in the absence of suitable commercially available equipment, to develop a test item which would enable practical measurement of these indicators. A significant part of the project specification was that

"This test item will be used on model exchange equipment and if suitable will be used in field exchange installations where significant traffic volumes are being processed. The test items should not therefore interfere in any way with the normal exchange operation."

Telecom's Research Department began its investigations in February 1977, and in September 1977 reached agreement with the requesting Branch (Switching Design, Headquarters) on a specification for the required test/measurement equipment, later to be called the Processor Monitoring Instrument (PMI). An early prototype without the powerful information formatting and output sub-system was delivered in August 1978 to permit urgent measurements of processing times, but the first complete PMI was delivered to Switching Design Branch on 16 February 1979, following exhaustive system testing in the Research Department's Switching Processors Laboratory in Clayton, Victoria. This PMI now resides in Telecom's 10C National Support Centre (10C Model Exchange) in Melbourne.

This paper describes the facilities of the PMI and its potential range of applications, which include system testing, traffic measurement and processor capacity estimation. A later paper in the journal **Australian Telecommunication Research** will describe the detailed design of the PMI, and the considerations that led to its final design.

CONCEPT OF EFFECTIVE PROCESSOR OCCUPANCY

Typically the programs executed by an SPC processor are assigned different priorities, with the highest priority program being executed when triggered by hardware interrupts, and the lower priority programs being activated by software 'scheduler' or 'monitor' programs. **Fig. 1** shows schematically the varying composition of the total processing time occupancy of a processor having four broad levels of program priority, when sampled at frequent intervals (e.g. every 10 seconds).

Some SPC central processors generate statistics on processor occupancy by purely software means: this is usually done by incrementing a "free time counter" while executing a programming loop in the lowest priority software program e.g. at the end of Level 4 programs in Fig. 1. By subtracting the "free time count" from a measure of the total processing time, the processor can output at regular intervals a measure of its total occupancy, shown by the dashed line in **Fig. 1**. However purely software means cannot be used to measure the processing time spent in individual programs or priority levels within the total occupancy, unless the SPC system includes provision of suitable software-addressable hardware real-time clocks or counters.

In the course of our studies of processor capacity, we have found it necessary to recommend the measurement of Effective Processing Occupancy (EPO) in preference to total occupancy, for purposes of estimating the processing capacity of an exchange. EPO is defined as follows.

The processing time spent by any processor can be considered to be spent on two different kinds of activity: background processing and effective processing.

Background processing includes not only free time or idle time but also those jobs or tasks which can be deferred indefinitely without affecting the system's ability to handle its primary real-time workload.

Effective processing accounts for the remainder of the processing time: it consists of all the higher priority processing, down to the lowest priority program which cannot be indefinitely deferred without affecting the system's ability to handle its primary workload. **EPO** is

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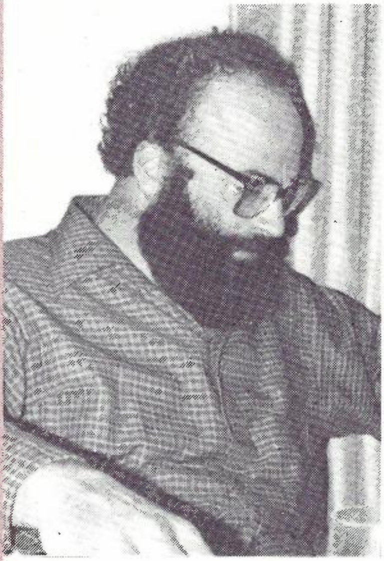
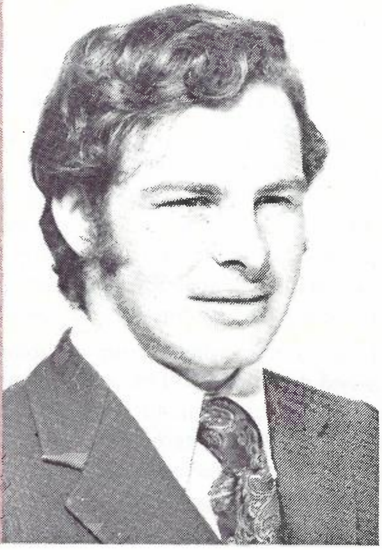
He is currently Chairman of the CCITT's Sub-Group XI/3-4 (Specification and Description Languages for SPC telephone switching systems), Editor of the Professional Officers Association's journal The Commonwealth Professional, and an Editor of Australian Telecommunication Research.



JAMES PARK received the Bachelor of Engineering and Master of Engineering Science degrees from Monash University in 1972 and 1974. The higher degree was awarded for research work on the analysis and modelling of phase-locked-loops.

From 1974 to 1976 he was a member of the Transmission Systems Branch in Telecom Australia's Research Department and studied Pulse Code Modulation systems. This work involved the design and analysis of regenerators for operation at up to 140 Mb/s and the investigation of impulsive noise effects on Primary level PCM systems.

In 1976 Mr Park joined the Switching and Signalling Branch where he first worked in the Devices and Techniques Section studying telecommunications-oriented integrated circuits and producing design guides for digital integrated circuits. From 1977 to the present he has been studying processor capacity, in the Signalling and Control Section. In this work he has been primarily concerned with the production of the Processor Monitoring Instrument and the production of Call State Transition Diagrams to describe call behaviour in SPC exchanges.



thus the proportion of time spent by a processor on effective processing alone, as illustrated in Fig. 1.

It will be seen that the concept of EPO, while being sufficiently general to apply to most real-time computer control situations, requires careful qualitative judgement as to which tasks or jobs can be 'indefinitely deferred' or not. Often this can be resolved by deciding upon a suitable time period (T) which is at least one order of magnitude greater than the slowest permitted response time of the system: then, if a program can be delayed by more than T without adversely affecting the system's primary workload, it will be defined to form part of background processing. In the case of the Australian 10C trunk exchanges, where the longest permitted response time is of the order of 15 seconds in responding to a Multi-Frequency Coded digit, it is convenient to define T = 3 minutes, since this coincides with the fundamental sampling period of the software-generated statistics; if a program can be deferred more than three minutes without affecting called handling performance or system reliability, its deferral will not be detected during the sampling period anyway, so it can safely be considered as background processing.

It may be noted that, in the special case where all processing is considered to be effective processing, then EPO coincides with total occupancy; so the PMI, which has been designed to monitor EPO, can also be used to provide an independent check on the software-generated statistics of total occupancy.

PMI SYSTEM DESCRIPTION

Functional Description

The PMI's design specification precluded making any changes to the object processor's software. The strategy chosen was for the instrument to access the object processor's memory address bus, so that it can sense at which instants the particular memory addresses corresponding to significant events occur. More complex concepts such as EPO can be monitored by logical processing of information collected on the occurrence of several significant events.

In addition to monitoring the memory address bus, a number of separate hardware locations can be monitored by the PMI. The total monitoring process, which is performed synchronously with the object processor's internal clock, is called 'signal sensing'.

The addresses activated by the object processor are compared by the PMI with up to 32 preset addresses, using a bank of bit-comparators. When one of these addresses is detected the particular bit comparator outputs a pulse. This process is called simply 'address comparison'.

Various combinations of output pulses can be used to operate counters or to start and stop timers. The user can select these combinations and wire them up on a logic patchboard located in the rear of the instrument. Most standard logic functions can be used. Typical examples of the use of the logic patchboard are:

- using any one of a set number of addresses to operate a counter
- starting a timer with one address and stopping it with another
- using one address to enable some other measurement process to proceed.

The PMI contains 14 counter/timer devices, 13 of which can be individually set by the user to be either a counter or a timer. The other is permanently set to be a timer and is used in combination with several of the preset addresses to measure the Effective Processor Occupancy.

A microprocessor is used to read the output values from the counter/timer devices, to convert EPO processing time to a percentage, to scale and format the output

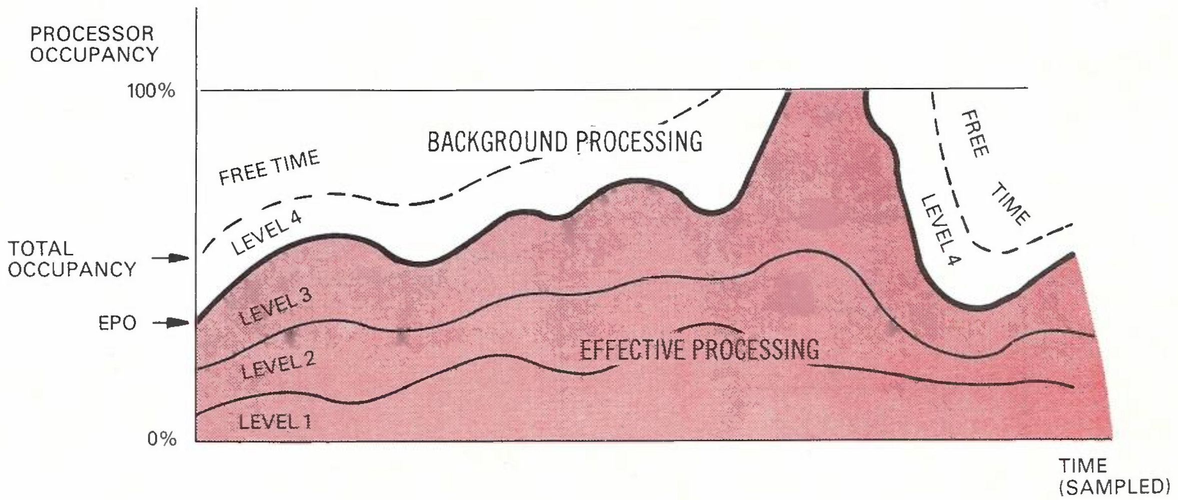


Fig. 1 — Concept of Effective Processor Occupancy (EPO), illustrated for an operating system having four broad levels of priority, of which only Level 4 work can be indefinitely deferred without affecting the system's traffic-handling performance.

information into numerical and bar-chart form, and to output this information at appropriate times. Output is via either a visual display unit at the front of the PMI or an external miniature line printer (or magnetic recording medium), or both.

A functional block diagram of the instrument is shown in **Fig. 2.** The 'Signal Sensing' block contains input probes and buffers, probe selector circuitry and latches for storing address information during each processor clock cycle. The 'Address Comparison' block contains the 32 bit comparator units and associated switches for setting the preset addresses. The 'Signal Processing and Event Counter/Timer' block consists of the logic patchboard and 14 counter/timer devices. The 'Information Formatting and Output' block is microprocessor driven and contains the visual display unit and the interface to the external data-logging facilities. The 'Instrument Control' block enables the user to manipulate the operation of the last-mentioned 3 blocks.

Physical Description

The PMI is housed in a cubic steel box of 50 cm edge; it weighs about 30 kg. is normally mounted on a trolley, and can be lifted by one strong person. The PMI consumes 200 watts from a standard 230 volt 50 Hz mains power supply.

A great deal of design effort went into ensuring that the PMI can be used for any of the SPC systems to be installed in the Australian network, without the need for any software or hardware modification of the SPC system to be monitored, and without any undesirable electromagnetic interference with the system being monitored.

A detailed description of the internal design of the PMI will be provided in a future issue of the journal **Australian Telecommunication Research.**

FACILITIES

The Processor Monitoring Instrument has been designed to give the user a versatile range of facilities. The user's controls can be seen from **Figs. 3 and 4,** showing the front and back panels of the instrument.

The facilities are as follows:

Signal Access either by a plug-in card placed inside the object processor mainframe or by using normal logic analyser

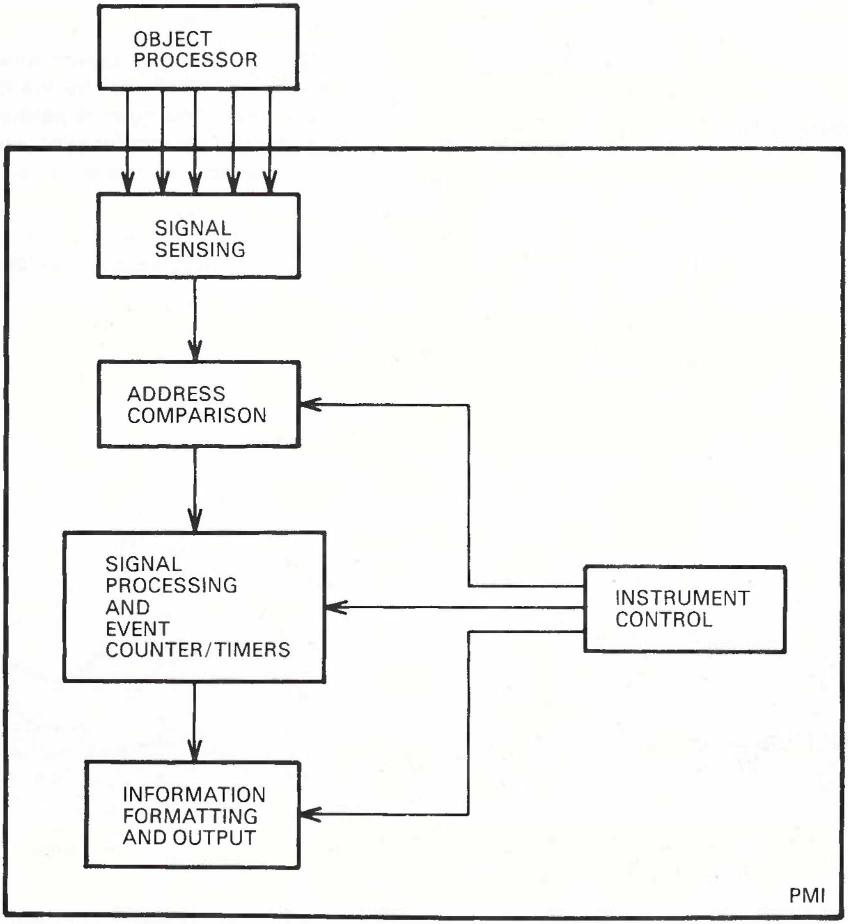


Fig. 2 — System Functional Block Diagram.

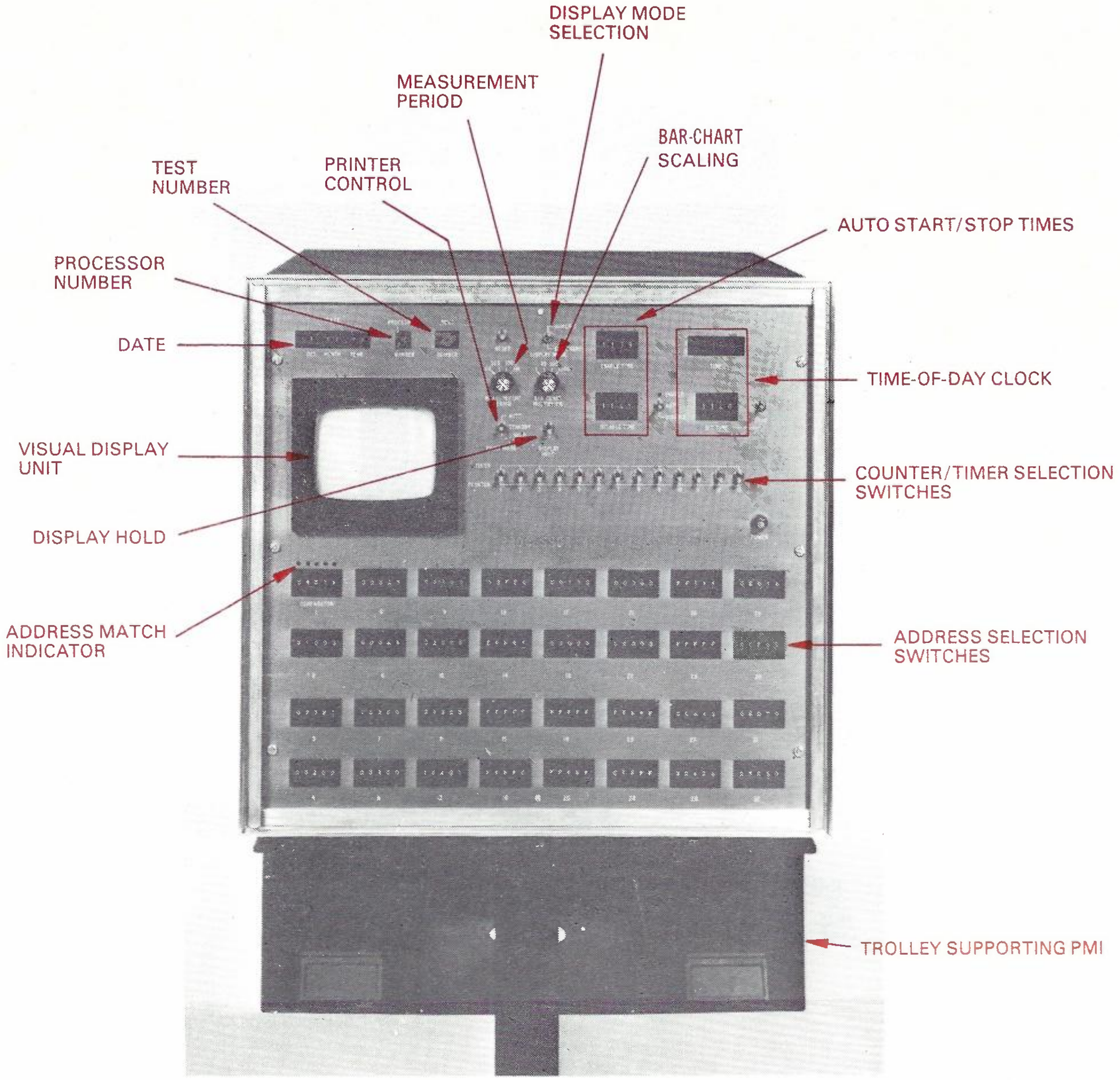


Fig. 3 — PMI Front Panel.

probes. (The PMI's signal sensing sub-system employs optical couplers for electrical isolation of the instrument from the object processor when a plug-in card is used.)

16 dual address comparators (ie. 32 comparators in total) which allow either particular addresses (x = A) or ranges of addresses (A < x < B) to be detected.

An **'address match indicator'** on one comparator which shows the user when the input address matches the preset address for that comparator.

A **logic patchboard** to give versatility in the definition of the event to be counted or timed. The patchboard includes both a wire-wrap area (for more permanently required logic connections) and a 'plug-up' area (for more temporary logic connections).

13 counter/timer devices which can be individually set to either count (up to 99999) or time (from 1 μs to 3 minutes).

A measurement period of 10 seconds, 50 seconds, 100 seconds or 3 minutes over which the inputs to a counter or input active time to a timer are accumulated.

A synchronizing signal at the start of each measurement period to enable **'single shot' times** as well as **cumulative time** to be measured.

Automatic start and stop of the instrument provided by means of a "time of day" clock.

Two display modes, either **numerical** showing the results for the previous 3 measurement periods (for all 14 counter/timers) or **bar chart** showing the current measurement

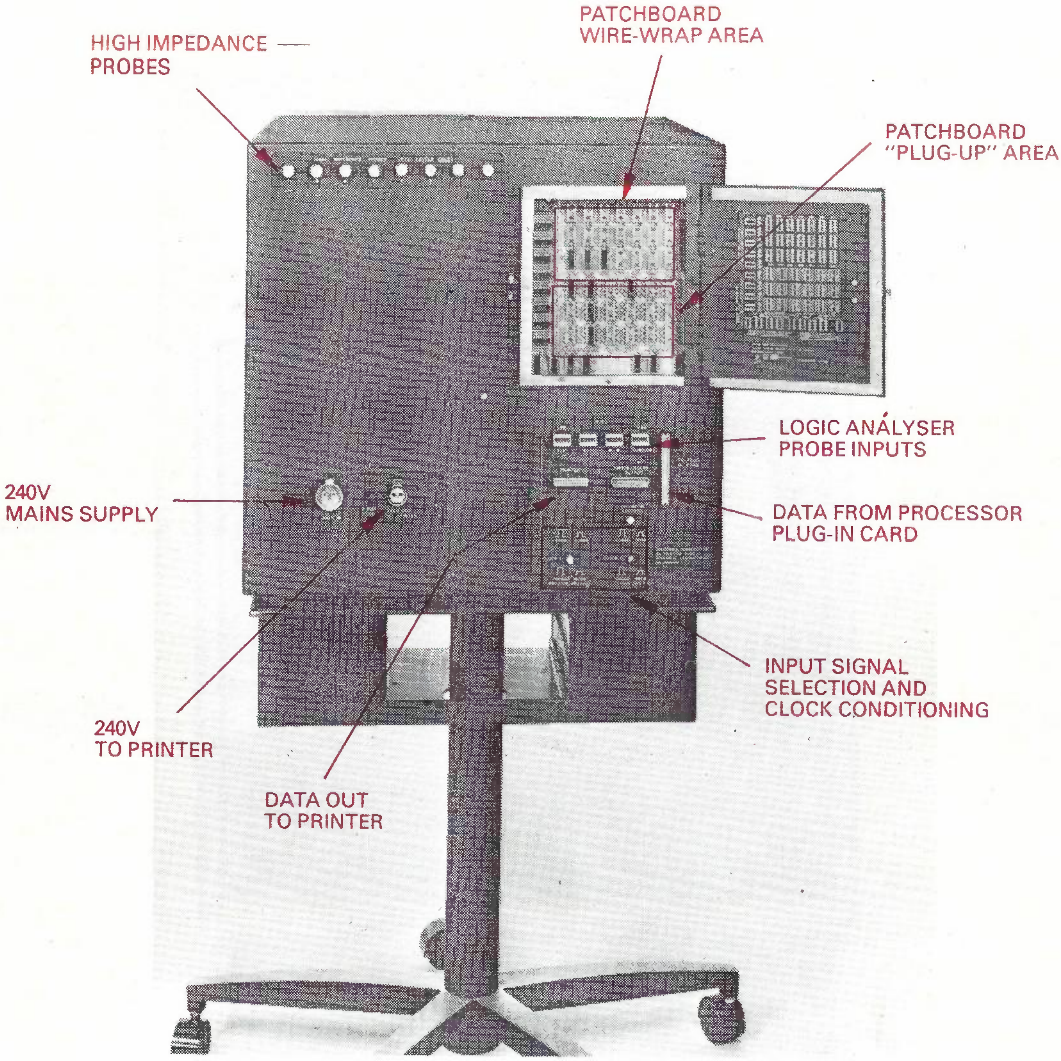


Fig. 4 — PMI Back Panel.

period (for EPO and the first six counter/timers above). The two display modes are shown in **Figs. 5 and 6.** The bar chart mode provides an easy to read comparison of counters or timers for monitoring purposes, while the accurate numerical mode can be used for either monitoring or data logging purposes.

An informative **display heading** giving the date, time of day, processor number, test number, measurement period and the mode for each counter/timer device.

A **display hold** facility which 'freezes' the current display while allowing the internal operation of the PMI to continue.

A **hardcopy** print-out, either as a single copy or automatically every third measurement period (as required by the user). It can be seen from Fig. 5 that in the numerical display mode, the PMI displays the results for the three previous measurement periods; hence in the automatic print-out mode, no measurement results need be lost.

Comprehensive **self-test** facilities.

The **accuracy** of the PMI is basically limited by the accuracy of its crystal-controlled 1 μs clock, which is rated as better than 1 in 10^4. This implies that errors in the PMI's measurement of processing time are less than $\pm$ 0.01% or $\pm$ 1 μs, whichever is the larger. Therefore any processing time measurements greater than 10 ms can be considered accurate to four significant decimal figures, and measurements less than 10 ms can be considered accurate to within $\pm$ 1 μs. Numerical information for timing and counting is stored to 9 significant decimal figures within the PMI, and displayed to 4 significant decimal figures in the case of processing times and EPO, and 5 significant decimal figures in the case of counts (which do not require the use of a decimal point).

The fact that the PMI's information processing and formatting facilities are entirely controlled by software programs stored in PROM chips means that if more

27DEC 1978, PROCESSOR 3TEST 25

T=16:20:10,			T-3M	T-6M
	EPO	52.35%	49.12%	61.54%
1	COUNT	64323	>99999	82351
2	TIME	147.6 S	123.4 S	123.4 S
3	TIME	24.89 S	87.63 S	66.78 S
4	TIME	8341.mS	8342.mS	8876.mS
5	TIME	236.1mS	237.2mS	331.6mS
6	TIME	88.62mS	89.61mS	72.34mS
7	TIME	9214.μS	9137.μS	8763.μS
8	COUNT	124	138	99
9	TIME	820.μS	811.μS	799.μS
10	TIME	77.μS	76.μS	69.μS
11	TIME	8.μS	7.μS	9.μS
12	COUNT	8672	8592	9000
13	COUNT	10	12	13

(Note: The reason for choosing time ranges such as 1000. — 9999. ms rather than 1.000 — 9.999 s is for compatibility with the bar chart display mode. With the minimum bar graph multiplication of XI, a range of 10 — 100 gives better resolution than 1 — 10 when displayed as a bar chart.)

Fig. 5 — Numerical Display Mode

sophisticated or specialised information processing facilities are required, this can be achieved relatively cheaply by writing new program modules and then exchanging the PROM chips without the need to withdraw the PMI from service. The PMI has measured its own microprocessor's EPO to be less than 20%, so there is plenty of spare processing capacity for performing additional work.

Comparison with Other Test/Measurement Equipment

The PMI's facilities differ from those of commercially available test/measurement equipment such as logic analysers in its ability to monitor EPO, to simultaneously monitor several indicators of processing load, and to provide an immediate visual display while data-logging. However the PMI does not have the logic analyser's ability to capture several consecutive memory addresses (or data words) and store these when triggered by a key address or data word. The currently available logic analysers have much more general-purpose facilities for use in software debugging, but they do not provide the particular monitoring facilities required of the PMI.

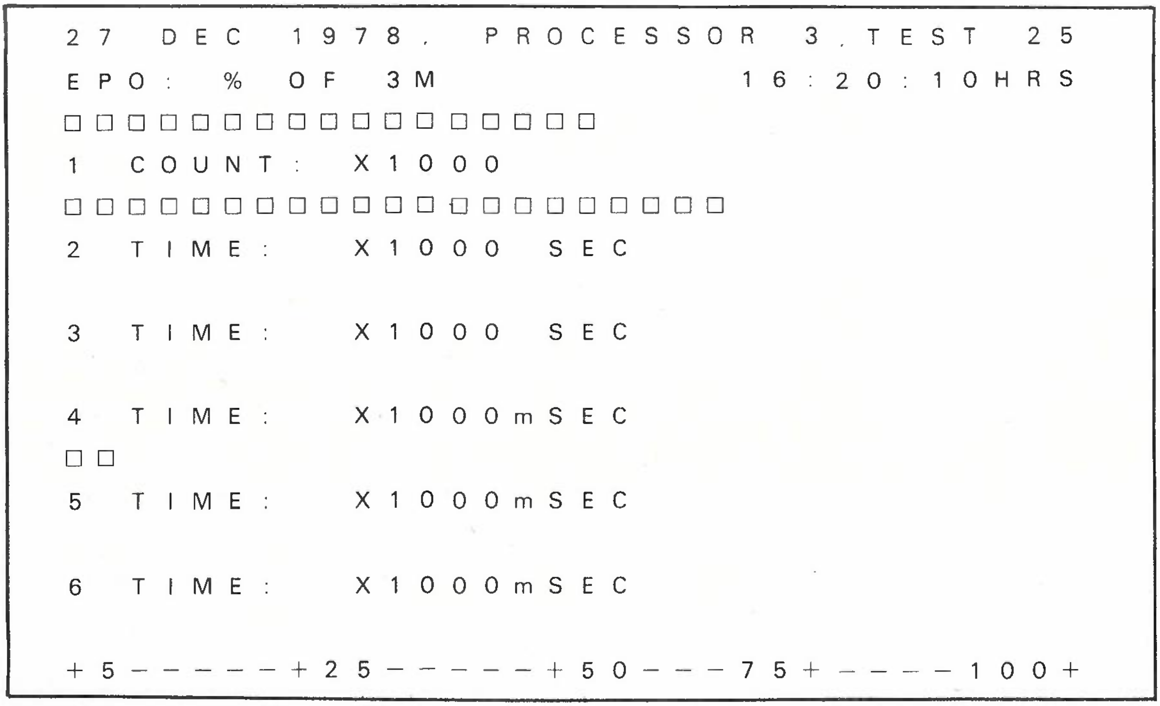
RANGE OF APPLICATIONS

Table 1 summarises the potential use of the PMI's monitoring and data-logging facilities in different areas of applications, in general terms. It may be useful to describe some of the PMI's potential applications in terms of some concrete examples.

An example of the verification of software-generated statistics could be the verification of the proportion of lost calls, i.e. the system's Grade of Service; another example could be verifying the apparent total occupancy of each central processor.

An example of the detection of a system imbalance could be the use of the PMI to measure the relative proportions of time which a processor accesses different areas of memory, using the $A < x < B$ triggering capability of the PMI's dual address comparators. The PMI could also be used to measure the proportions of time a processor spends in servicing teletype input, DMA interrupts, and in supervising the multimetering charging of long distance calls.

Virtually all traffic engineering techniques for estimating the processor capacity of an SPC system require accurate information on the amount of processing time spent on a large number of different individual tasks. The PMI is able to perform these measurements in batches of thirteen at a time, with a data-logging capability. Processor capacity studies also require reliable information on the composition of the traffic handled by the processor during busy hour conditions. The PMI is able to measure the incidence of up to thirteen different categories of calls at a time, without in any way adding to the processing load of the object processor.



The horizontal bars are read against the scale at the bottom of the display. There are 32 divisions in the horizontal scale, each division representing a range of 3 units, giving a total range from 4 to 100. The + signs in the bottom scale indicate the points corresponding approximately 5, 25, 50, 75 and 100.

EPO is graphed directly as a percentage. In this example it reads approximately 53%. Counts or times must be multiplied by the indicated scaling factor which is set by the user. Counter number 1 reads approximately 65000 and timer number 4 reads approximately 8.5 second.

Fig. 6 : Bar Chart Display Mode

MONITORING FACILITIES
Simultaneous numerical display of 14 indicators
Simultaneous bar-chart display of 7 indicators
Numerical display of results for 3 consecutive sampling periods
Automatic prescaling of display information

DATA-LOGGING FACILITIES
'Single shot' measurements of processing times
Cumulative measurements of processing times
Cumulative measurements of event occurrence
Simultaneous data-logging while display-monitoring
Use of miniature line printer or magnetic recording medium
Automatically starts and stops measurements at preset times
Numerical data measured accurately to 4 significant figures

SYSTEM TESTING AND OPERATION
Verification of software-generated statistics
Detection of system imbalances and bottlenecks
Fault detection
Design improvement

TRAFFIC ENGINEERING
Estimation of processor capacity
Measurement of traffic composition
Characterisation of traffic behaviour
Study of processor overload behaviour

Table 1 — PMI Facilities for Various Applications

CONCLUSIONS

The Processor Monitoring Instrument is a versatile instrument within a specialised range of applications. Its combination of monitoring and data-logging facilities, summarised in **Table 1**, make it a suitable vehicle for a wide range of investigative studies by system designers, network planners and operations staff in enhancing the reliability and the traffic capacity of SPC switching systems installed in the Australian telecommunication network. We believe it satisfies the toughest requirement of its design specification, which was that it should be capable of monitoring the processor performance of any of the SPC systems likely to be installed in the Australian network in the forseeable future, without interfering with the normal operation of these systems.

The first PMI resides in Telecom Australia's 10C National Support Centre in Melbourne, from where it can be flown interstate when needed to monitor the performance of the large Metaconta 10C Trunk Exchanges. A second, duplicate PMI is currently being built in Telecom's Research Laboratories for use in the Research Department's own projects, including laboratory modelling of the CCITT No. 7 signalling system.

In Brief

EARLY START FOR OUTBACK TV

The Government has allocated $8.8 million to be spent over the next two years to lay the groundwork for an outback television system, using Intelsat, in certain areas.

The Minister for Post and Telecommunications, Mr Staley, announced on January 30 that television would be brought to 76 remote population centres. The service to 49 of the centres will be provided via OTC facilities at Moree, NSW, and Carnarvon, WA. The remaining 27 centres will be served by terrestrial means. The signals will be received by small ground stations to be set up at each outback centre included in the plan.

The new system will replace an earlier plan to bring television to additional remote centres via repeater stations.

Initial costs will be significantly higher for a satellites system, but long-term running costs will be lower.

The schedule calls for 56 sites to be completed by the end of 1980/81, with 20 more to be installed by the end of 1981/82.

The decision by the Federal Government was reached following recent successful tests using a large 30 metre diameter OTC transmitting antenna and a small five metre diameter receiving antenna leased by the ABC from Plessey Australia.

The television receive-only ground station was supplied by the Telecommunications Division of Plessey Australia as a total system. It includes a five metre diameter antenna, a low noise amplifier and a video receiver.

The earth station was manufactured by Scientific Atlanta in the USA. Scientific Atlanta manufactures and supples total package earth stations and is a leader in satellite ground station technology.

Tests to determine the technical feasibility of the new system were conducted jointly by engineers of the Australian Broadcasting Commission, Overseas Telecommunications Commission, Postal and Telecommunications Department and Telecom Australia. They were held at the OTC Earth Station at Moree in New South Wales.

The small satellite earth station which was recently used to test the feasibility of providing the television to remote areas of Australia using the Pacific Intelsat satellite. The station was leased from Plessey Australia for the test.

Digital Storage — A Review of Current Technologies

C. J. SCOTT, B.App.Sc., Grad. A.I.P.

Fast storage and retrieval of digital information is an essential feature in the operation of new and improved telecommunications equipment. Digital storage technology has developed over the last decade to become one of the most rapidly changing areas in the field of electronics. Continuing rapid improvements in the density, speed and price of digital storage devices confront the designer of telecommunications equipment with an everchanging wide range of storage options. A thorough understanding of the various technology options available assures reliable, efficient and cost effective memory implementation.

INTRODUCTION

During the last decade, dramatic advances have been made in the area of digital storage technology resulting in new dimensions for the performance, cost and reliability of digital equipment. Increasingly the impact of developments in storage technology is being seen in the design of new and improved telecommunications equipment, an essential function of which is the storing and transferring of digital information.

Few sections of the electronics industry have experienced such rapid development as that associated with memory devices. The circuit designer is confronted with a constantly changing range of memory products and capabilities, from which must be selected those devices which will yield a reliable, efficient and cost effective design. This paper provides a comprehensive review of current storage technology options and outlines the major features contributing to their continued development. Information describing the better known magnetic devices such as disk, drum and core is widely available and will not be presented in this article. Attention will be directed to storage technologies which have emerged or matured in the last decade.

MEMORY CATEGORIES

Evaluation of the relative merits of the various digital storage technologies is commonly based on three major considerations:

- Packaging density, the number of storage cells provided by each device.
- Memory speed in terms of access time. Access time refers to the time delay between the application of a specified input pulse during a read cycle and the availability of valid data signals at an output. The greater the memory speed, the shorter the access time.
- Cost per bit of information stored. A bit is a binary digit — the smallest unit of information.

In an actual design situation other factors such as power consumption and the ease with which stored data may be changed can also be important selection parameters.

The existence of many different memory categories has resulted in considerable confusion, this has been further added to by inaccurate and misleading terminology. In particular the widespread use of acronyms, often inconsistently applied, is a major source of user confusion. **Table 1** provides a brief glossary of some of the more common acronyms associated with current memory technologies.

One difference between various memory types is the manner in which stored data is accessed or retrieved. Memory devices described as 'random access' have their storage cells arranged in a matrix of columns and rows. Any cell may be used, in any order, to store or retrieve information and the access time is the same for all locations. This is in contrast to 'serial access' memories in which the data is stored sequentially in a column structure. The time delay to access any particular bit of information in a serial access memory is dependent on its position in the column with respect to the point at which data is sensed. Magnetic tape and disk storage, together with shift register devices, are common examples of serial access memory.

The ease with which stored data may be altered represents another approach to defining different memory categories. Two major distinctions operate in this area, and these are usually described by the designations read/write and read-only memory. A read/write memory allows information to be written (stored) or read (retrieved) from any storage location in the memory. In contrast, the read-only memory has data entered permanently, or semi-permanently, after which it may only be used to retrieve the fixed data pattern.

One further memory classification of importance is by the technology used to implement the device. Two common subdivisions of memory technology are 'magnetic' and 'semiconductor', although other subdivisions are possible. Semiconductor memories employ many of the same manufacturing processes and variations as those used for other digital logic circuits.

Bit	Smallest unit of information, contraction of 'binary digit'
CAM	Content Addressable Memory
CCD	Charge Coupled Device
Chip	Area of silicon on which the monolithic integrated circuit is formed
ECL	Emitter Coupled Logic
FPLA	Field Programmable Logic Array
K	Symbol representing the number 1024
LSI	Large Scale Integration
MOS	Metal-Oxide-Semiconductor
nMOS	n-channel Metal-Oxide-Semiconductor
PLA	Programmable Logic Array
pMOS	p-channel Metal-Oxide-Semiconductor
PROM	Programmable Read Only Memory
RAM	Read/Write Random Access Memory
ROM	Random Access Read Only Memory
TTL	Transistor-Transistor Logic

NOTE: While 'k' is the accepted symbol representing the number 1000, in memory technology 'K' has the meaning defined above.

Table 1 — Common Acronyms Describing Various Features of Digital Storage Technology.

CAROL J. SCOTT was born in Ballarat Victoria and studied at the Ballarat Institute of Advanced Education where she obtained the degree of Bachelor of Applied Science (Multi-disciplinary, Physics) in 1973. In 1974, she joined the Research Laboratories of Telecom Australia and is currently a member of the Devices and Techniques Section, Switching and Signalling Branch. While working in the Research Laboratories, she has been concerned with the evaluation of new devices and technologies for use in switching equipment.

SEMICONDUCTOR RANDOM ACCESS MEMORIES

Rapid progress in semiconductor memory technology over the last decade has largely displaced magnetic core storage as the most widely used form of random access memory. In general semiconductor memory is faster, consumes less power and costs less per bit than equivalent magnetic core storage.

Early semiconductor RAMs consisted of a matrix of storage cells only, all addressing, timing and control circuitry was made up of conventional integrated circuits mounted externally. As integrated circuit technology developed, the timing, control and decoding functions were fabricated on the same integrated circuit chip as the storage matrix.

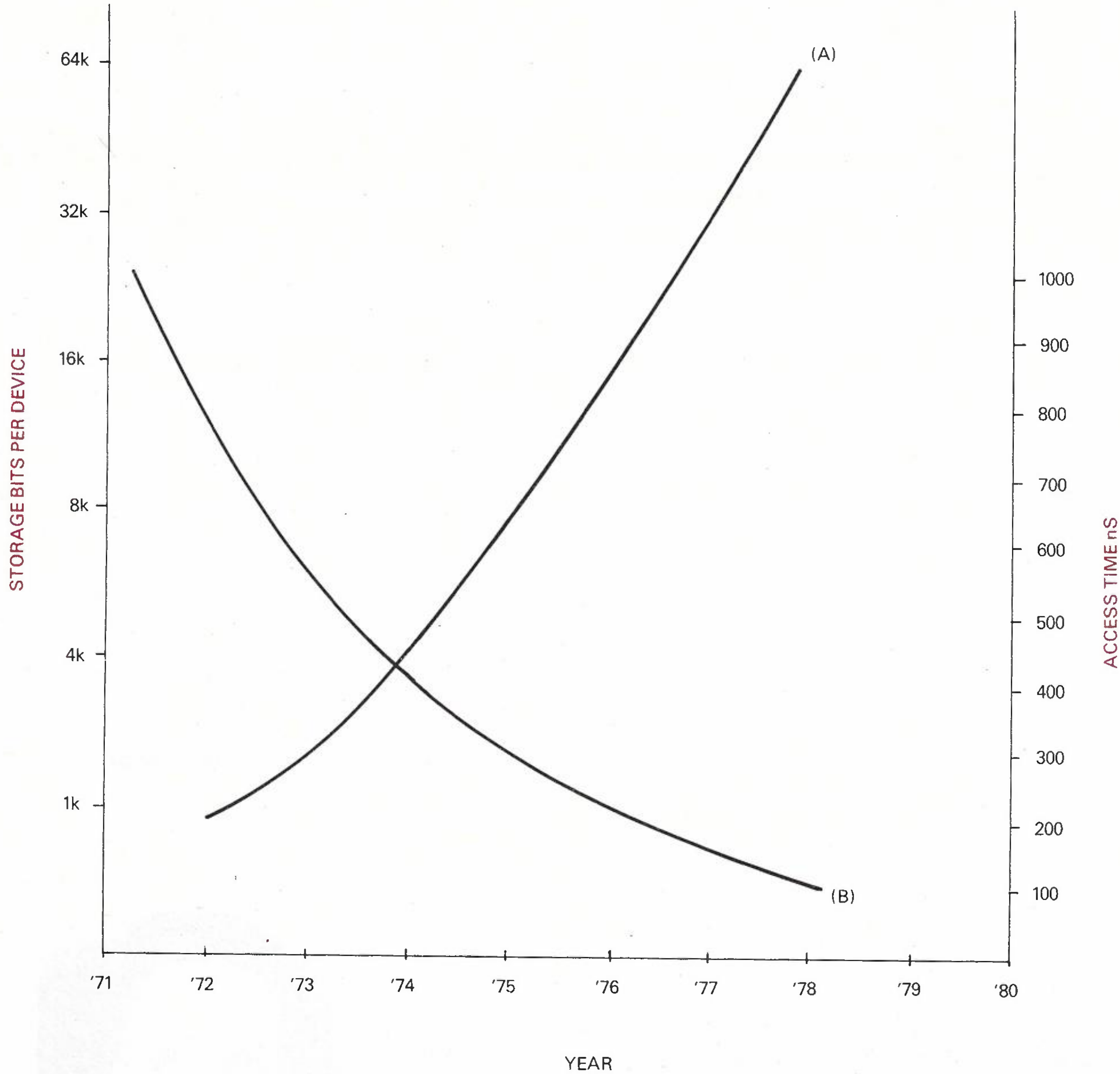


Fig. 1 — General Trends in the Development of Dynamic MOS RAM Devices.

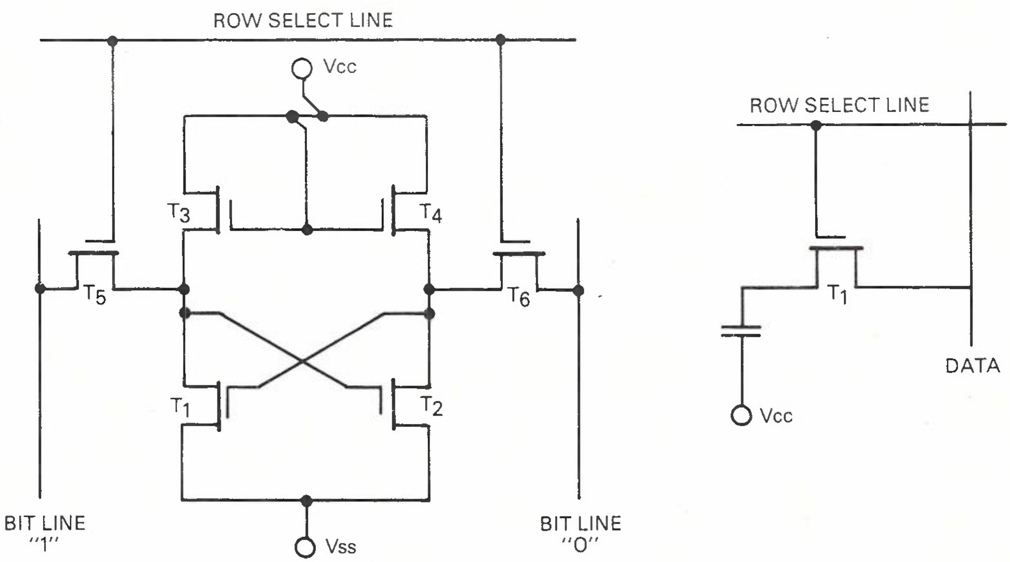
Fig. 1 describes the rapid increase in storage density of semiconductor memory devices over the last decade. Developments in semiconductor memory technology have produced a fourfold improvement in packaging density and speed every two years. As the capacity of semiconductor devices has increased so have the interconnect requirements per device package. As an example consider a dynamic memory device of capacity 4096 words, each word being one bit long. Typically such a device will require 12 address lines, 1 data input line, 1 data output line, 3 power supply lines and several other connections for control signals. The first 4096 bit RAMs required either 18 or 22 pin packages and there was little initial agreement between manufacturers as to what functions were assigned to which pin locations. More recently, large capacity RAMs are supplied in 16 pin packages and this reduction in package size is achieved by multiplexing the address bus onto half the number of pins usually required. The use of smaller packages has many advantages including the more efficient use of circuit board area and increased system reliability due to a reduction in the number of connections.

Accompanying the increase in storage density has been a corresponding decrease in device access time and cost per bit of storage. This comment applies to all semiconductor memory families. The storage cells of semiconductor RAM devices are described as being either static or dynamic in structure. The static semiconductor memory cell is based on a transistor flip-flop. A bistable circuit, the flip-flop is designed so that when one transistor conducts the other remains off. A static cell must be powered continuously to sustain the flip-flops. Bipolar semiconductor RAM devices usually consist of Transistor-Transistor Logic (TTL) or Emitter Coupled Logic (ECL) static storage cells which are capable of achieving access times ranging from eighty nanoseconds down to around three nanoseconds. Dynamic memory cells store the information as the charge on a capacitor. The capacitively stored charge leaks away with time and hence requires periodic refresh of the cells to ensure information is not lost.

As shown in **Fig. 2**, a static cell memory can be formed by cross coupling two transistors to form a flip-flop, but the total cell requirement is usually four or more transistors and the number of cells available on a single integrated circuit chip is thus reduced.

Dynamic RAM cells can be implemented using only one transistor, allowing dynamic devices to achieve greater storage densities than are possible for static devices. Generally dynamic devices cost less than comparable static devices. Cost savings at the component level for dynamic devices are offset by the need to provide external refresh circuitry and three power supplies, typically ±5V and +12V. A static device requires only one +5V power supply.

One disadvantage of semiconductor RAMs, of whatever type, is the volatility of the information stored within them. When power is removed from a RAM device, the stored information is lost. It is possible to



(A) A SIX TRANSISTOR STATIC RAM CELL

(B) SINGLE TRANSISTOR DYNAMIC RAM CELL

Fig. 2 — RAM Cell Design.

achieve a form of non-volatility by providing a low-power or standby mode of operation such that the memory is powered by batteries when the main system power supply fails. Standby power supplies add to the system cost and complexity and for this reason, data which is to be changed infrequently is more conveniently stored in read-only memory. All semiconductor ROM storage is inherently non-volatile, the stored information is retained unchanged when the device is not powered.

Speed-power trade-offs exist for memories just as they do for integrated circuit logic families. The fastest memories are bipolar ECL and Schottky TTL devices and these provide fast access times at the cost of relatively high device power consumption. Metal-oxide-semiconductor (MOS) memories have access times that overlap those of bipolar devices and typically range between 70 ns and 2 μs. The power consumption of MOS memories is generally lower than that of comparable bipolar devices. Early MOS memories were developed using p-channel MOS technology, however more recently emphasis has been directed toward n-channel technology which offers increased speed and packaging density.

Fig. 3: shows how the various semiconductor RAM technologies presently available may be segmented according to device speed and storage capacity. Each of the technologies represented can perform outside the indicated range, the performance characteristics are typical only.

Bipolar RAMs are generally used in applications requiring high speed read/write facilities such as would be

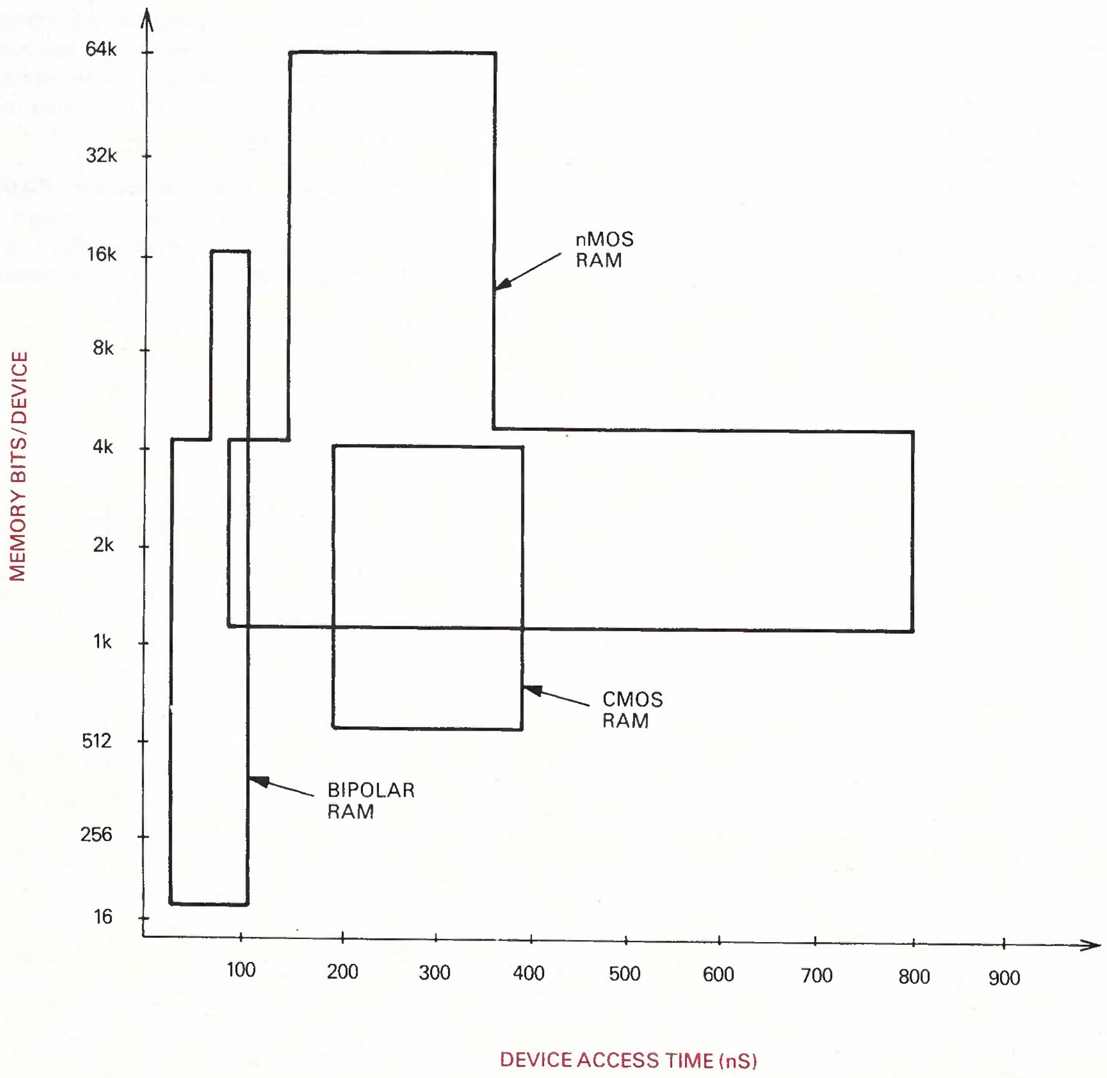


Fig. 3 — RAM Performance Spectrum, Segmented by Technology

the case for buffering between a fast processor and medium speed main memory. The storage cells of bipolar RAMs are always static in structure since this technology is not well suited to fabricating dynamic cells.

MOS RAMs are available in both static and dynamic varieties and typically offer a lower power consumption than their bipolar counterparts.

Dynamic RAMs are used as a cost effective solution for main memory applications, and are used in the construction of systems of capacities between 4K word and about 2M word, where the bits/word can range from eight to above sixty.

SEMICONDUCTOR READ ONLY MEMORIES

The semiconductor read-only memory is a logical choice where random accessed information is to be stored without alteration. Two general forms of semiconductor ROM are available,

(1) Mask programmed ROM
(2) Field programmable ROM

The term ROM generally applies to the mask programmed form which is programmed by the manufacturer during a final fabrication step. This form of memory has its contents permanently fixed in an unalterable form. Mask programmed ROMs are most economical if large quantities of memories storing the same fixed pattern are required. Apart from the development of custom circuits, mask programmed ROMs are also used to implement standard functions including code conversion and character generation. A variety of bipolar and MOS technologies may be used to fabricate mask programmed ROMs. Bipolar ROMs are available with speeds of from 25 to 40ns and with capacities of up to 16,384 bits/device. Work on 32K and 64K density bipolar ROMs is in progress in a number of companies in Europe and the United States. Japanese manufacturers can also be expected to contribute significantly to future developments. High density MOS ROMs of 32K and 64K bits are available from a number of sources and find widespread application as control program stores.

Field programmable ROM, generally referred to as PROM, are programmed by the user after the device fabrication and packaging are complete. Some PROM technologies allow the stored data to be altered or completely erased under certain special conditions, others provide unalterable storage only.

The majority of bipolar PROMs use Schottky TTL technology to achieve access times of 30 to 90ns. In these devices data is stored by introducing permanent changes in the storage cell or its interconnections. The most common programming techniques involve blowing fusible metal links or altering the characteristics of a transistor junction using closely controlled electrical conditions. Once programmed, bipolar PROMs cannot have their contents altered i.e. programming of a cell is an irreversible process, and changes to the stored information require programming a new device. The need to provide a write, or programming, facility on a PROM chip reduces the amount of chip space available for the storage matrix and hence state-of-the-art PROM devices are of lower storage density than their mask programmed counterparts. Currently the largest bipolar PROM devices have a capacity of 8K bits, organised as 1024 words by 8 bits and 2048 words by 4 bits. In the near future 16K bit bipolar PROMs will be available in 2048 word by 8 bit and 4096 word by 4 bit organisations.

Alterable PROMs are suited to prototype circuit applications or any situation where it is anticipated that some infrequent changes may be required of the pattern in the read-only store. MOS PROMs form the largest group of alterable PROMs, and have gained wide acceptance and application. One form of widely available MOS PROM allows the data stored within it to be removed by exposing the memory chip to UV light via a quartz window in the device package. Using this method it is not possible to selectively erase a specific location, and the contents of the whole device must be removed. Other forms of MOS PROM allow data to be erased by applying a specific energy pulse to the device substrate and this approach offers the possibility of a more selective erase operation. Both of the MOS PROM technologies described store data as electronic charges trapped in different circuit structures. Alterable bipolar PROMs are not possible due to the difficulty of implementing trapped charge techniques in bipolar technology.

MOS PROMs are typically five to ten times slower than comparable bipolar devices and until recently required multiple power supplies. The development of MOS PROMs which operate from single 5 volt power supplies has improved the flexibility of these devices. Currently MOS PROMs of capacities up to 16K bits/device are available from a number of manufacturers and 32K bit devices, organised as 4096 words by 8 bits, have been announced. Device designers and manufacturers are confident that MOS PROMs of capacity 64K bits can be made available within 12 months, with corresponding reductions in price and power dissipation per bit. Designing with ROMs and PROMs is far simpler than for read/write memory because read/write control lines and refresh circuits are not required.

SEQUENTIALLY ACCESSED MEMORIES.

Sequentially, or serially, accessed memories have their data bits arranged in columns and each bit has an output delay determined by its position in the store with reference to the sensing location. Typically data is moved serially toward the output where the binary state of each bit is sensed and made available consecutively for further processing or manipulation.

Most circuit designers are aware of some of the best known examples of serially accessed memories including paper tape, magnetic tape and magnetic disk stores. These media provide permanent non-volatile storage and non-destructive read out of data. They have the disadvantages of slow access times and poor reliability of the mechanism which moves the media.

A variety of electronic devices, often referred to as shift registers, can also effectively perform the serial access storage function. These devices are often used to provide temporary storage of data and are commonly of small capacity and relatively high speed. The design and implementation of semiconductor shift registers is relatively straight-forward, and since the individual bits are written and read serially there need be only one input port, one output port and a control signal designated 'shift'. Accessing stored data is a simple procedure, data entered through the input port is shifted until it appears at the output. Like semiconductor RAMs shift register cells may be either static or dynamic in structure and they provide a volatile storage medium. Common applications for semiconductor shift registers include small buffer memories, temporary storage for peripherals and terminals, and as delay line elements.

More recently two other technologies for serially accessed storage have been demonstrated to be commercially viable, these are charge coupled device (CCD) memories and magnetic bubble memories. A charge coupled memory is essentially a shift register formed by a string of closely spaced MOS capacitors which represent stored data as the presence or absence of electrical charge. CCD and MOS fabrication techniques are very similar and it is possible to incorporate logic on the chip to provide circuit control functions. The fundamental difference between CCD memory and other MOS memory techniques is that the stored charge remains in the integrated circuit substrate and is not held in conventional gate structures. Since data storage in CCD structures is dependent on volatile charge packets it is necessary to provide for periodic charge regeneration and this can limit the flexibility of this technology for some applications.

Many manufacturers are offering CCD memory products with various storage organisations and performance characteristics. The lack of standardisation between manufacturers seriously limits the acceptance of CCD devices. Available CCD memories have storage capacities up to a maximum of 64K bits serial and is expected that during the next twelve months devices of capacity 256K and 1 Mbit per device will become available. Charge coupled device memories do offer a significant speed advantage over some competing technologies such as tape and drum storage. Some commercial systems have been manufactured using CCD memories to replace conventional disk storage, however this practice is not widespread.

Magnetic bubble technology is another promising technology for digital storage in telecommunications equipment. Magnetic bubble memories store information as small cylindrical magnetic domains, or 'bubbles', in a thin ferro-magnetic film. Bubbles can be created and destroyed, moved reversibly in two dimensions and mutually repulsed to perform logic functions.

Although CCDs have a speed advantage over bubble stores, magnetic bubble memories are non-volatile. The commercial availability of bubble memories is limited to two manufacturers, both of which provide evaluation kits for their products. Military contracts and research by major telecommunications and computer equipment manufacturers has resulted in the development of a wide range of experimental bubble memory devices and these are intended as replacements for magnetic disk, drum and tape memories.

Years from now	3-5	5-10	10➡
Bubble Diameter	2-3 μm	1 μm	1 μm
Speed, Data Rate	0.1-1 MHz	0.1-5 MHz	0.1-10 MHz
Bits/Device	128K➡ 256K	256K➡ 1M	256➡10M

Table 2 — A selection of Projected Bubble Memory Parameters.

Experimentally, storage densities of up to 1 Mbits per chip have been achieved for bubble memory devices, however most devices currently being considered for system application have densities in the range 64K to 128K bits per chip. Magnetic bubble memories represent a totally new frontier in integrated circuit technology, and as with CCD memory, standardisation between devices and manufacturers is very poor at this stage in their development. **Table 2** summarises some projected trends in bubble memory development.

CONCLUSION

The number and diversity of memory types available is increasing steadily and the equipment designer is faced with a bewildering range of product options. Overlapping performance from different technologies, different cell structures, different packaging arrangements, speed, cost and power dissipation must all be evaluated in the selection of a particular digital storage device.

High density storage devices are of considerable importance since they conserve system space and contribute to an overall simplification of system design. The efficient packaging of high density devices reduces the number of device interconnections and so adds to system reliability. Because the digital storage market is subject to very rapid change, it becomes difficult to guarantee the availability of a particular device over the entire cycle of equipment design, manufacture and maintenance. It requires an awareness and understanding of device development trends to avoid selection of components which will cease manufacture or become grossly uneconomic within the life of the equipment using them.

Telecom Australia Preparation for WARC-79

V. A. CARUANA, MIE Aust. and E. R. CRAIG, B SC, MIEE

Some 1500 delegates representing over 150 nations will meet in Geneva, Switzerland on 24th September 1979 for the 10-week World Administrative Radio Conference (WARC-79). The Conference will be a major influence on radiocommunication development and on the use of the radio frequency spectrum for the next twenty years or so. Australia's preparation for this Conference commenced early in 1976 and Telecom, as the largest single user of spectrum in Australia, is heavily involved in the preparatory work.

THE WORLD ADMINISTRATIVE RADIO CONFERENCE.

A 10-week international conference on the management and utilisation of the radio frequency spectrum is to be held in Geneva during September to December 1979. The Conference is called the World Administrative Radio Conference (WARC-79) and the impact it will have on the future of radiocommunications will be of major importance. It is sometimes referred to as WARC (General), 1979.

This paper provides some background information on the international and national organisations which control the use of the radio frequency spectrum, and the preparatory work for the forthcoming Conference at present proceeding in Australia with specific references to Telecom's involvement.

RADIO FREQUENCY SPECTRUM ORGANISATIONS

ITU

WARC-79 is being run by the International Telecommunication Union (ITU). This Union has a history which goes back for more than a century but since the end of World War II it has been a specialised agency of the United Nations. It is responsible for the allocation of radio frequency spectrum to various services. The Union has a membership of more than 150 countries of which Australia is one. Its objects are essentially directed towards encouraging compatibility between the telecommunication networks of all member countries so that international services may be developed freely. In this endeavour it has been remarkably successful despite the absence of any effective legal sanctions against violating the agreements that are reached. In fact, the Recommendations, Regulations etc. arrived at in the ITU have sufficient power of moral persuasion to be universally observed. Details of the objectives, method of operation structure etc., of the ITU are contained in the International Telecommunication Convention (Malaga - Torremolinos, 1973). Some of its more specific objectives are reproduced in Appendix I, which is an extract from Article 4 of the Convention. The ITU's organisational structure is shown in **Fig 1.**

In the present context, the particular ITU Agreements of interest are known as the International Radio Regulations. These are prepared by Administrative Radio Conferences using proposals made by members of the Union. The output of such conferences appears as "Final Acts" which are then incorporated as amendments to the Regulations. Administrative Radio Conferences to deal with particular services have been held every few years. In the last 10 years for instance, these have included ones on Space Radiocommunication, on Maritime Services, on some Broadcasting Services and so on. However, at infrequent intervals there is a need to cover the whole complex of services to consider the relative balance between them and to take account of developments. That is the reason for holding the WARC (General) in 1979. The opportunity is also being taken in 1979 to revise the form of the Radio Regulations because it is now unwieldy and difficult to use.

The last general WARC was in 1959. There have been many developments in the intervening 20 years, so this year's conference is undoubtedly necessary. However, these general revisions are complex tasks; they are not embarked on lightly. In fact the last conference went on for about five months and for this coming one, which is to last 10 weeks, the expectation is that there will be 1500 delegates present. For this reason it seems generally agreed that there will not be another conference for another 20 years. Thus WARC 79 will be a strong influence and constraint on radiocommunication services for the remainder of this century. Therein is one measure of its importance.

CCIR

The International Radio Consultative Committee

(CCIR) is one of the permanent organs of the ITU. Its duties are to study technical and operating questions relating specifically to radiocommunication and to issue recommendations on them. One of the major responsibilities coming within the scope of these duties is to prepare technical bases to be used as input to Administrative Radio Conferences.

The CCIR is organised into 11 Study Groups and in addition there are two joint Study Groups for which CCIR and the International Telegraph and Telephone Consultative Committee (CCITT) are jointly responsible. In Australia, the work of the CCIR is paralleled through National Study Groups (NSG) for those subjects in which there is an identified national interest. A listing of the CCIR Study Groups and the National Study Groups which at present exist is given in **Table 1.**

Special Meetings of the CCIR are normally planned prior to the occurrence of a WARC for the preparation of a Report which will be used by that WARC. The Report contains the best up-to-date technical information available and plays an important role in the decisions of the WARC. In this connection, remember that a WARC is an Administrative Conference, so the technical factors are not the only ones which apply. For this reason the atmosphere at a WARC tends to be influenced by political considerations.

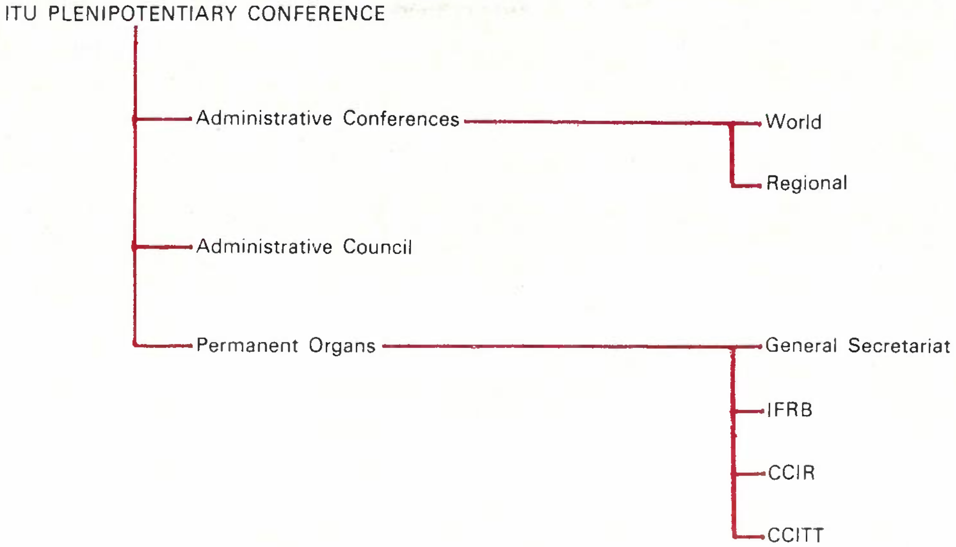
For the purpose of allocation of frequencies, the ITU divides the world into three Regions as shown in **Fig. 2.** Australia is located in Region 3 which essentially covers the Asian and Pacific areas. In many cases, the frequency allocations agreed internationally tend to be regional rather than universal to reflect the needs of each Region where these differ.

Australian Organisations

In Australia, the Postal & Telecommunications Department has the functional responsibility for national coordination of all Radio matters related to ITU activities. P&T is also responsible of course for the national allocation of frequencies to the various services. Australia as a Sovereign State is at liberty to depart from the Radio Regulations, but as a matter of policy, frequency allocations are made nationally to be consistent, as far as pos-

ALDO CARUANA joined the Australian Post Office in June 1955 as a Technician in the Central Telegraph Office, Melbourne. In January 1961 he was appointed Engineer Class 1 in the Headquarters Radio Section and worked on the design and development of equipment for broadcasting stations and the design of broadband and small capacity radio-relay systems. In January 1974, he became Engineering Section Manager of the Spectrum and Design Section responsible for the preparation of guidelines on system design and spectrum matters. Since 1971 he has been deeply involved with the work of the CCIR and has attended 6 meetings in Geneva including the 1977 World Administrative Radio Conference (Broadcasting-Satellite). More recently he was a member of the Australian delegation to the SPM. He is currently acting Staff Engineer, Radiocommunications Construction Branch.

ERIC CRAIG joined the Australian Post Office in 1949 as an Engineer and from 1950 to 1955 was with the South Australian Administration as a Radio Engineer. In June 1955, he was promoted to Divisional Engineer (Class 3) in the Research Laboratories, Headquarters, working in the Radio Section. From 1961 to 1964 he was on loan to the British Post Office for the Satellite projects 'Telstar' and 'Relay' and on his return to Australia in 1964 was promoted to Sectional Engineer (Class 4) in charge of the Transmission Media sub-section. At engineering restructure in 1972, he was appointed Head of the Satellites Section in Research in the Advanced Techniques Branch. At present he is the Branch Head. He is the Chairman of Study Group 4 of CCIR which is responsible for study of and making recommendations for the Fixed-Satellite service.



Notes:
1. The Plenipotentiary Conference is the supreme organ of the ITU. It meets at intervals of nominally 5 years.
2. Administrative Conferences have the responsibility for reviewing and revising the Telegraph Regulations, the Telephone Regulations and the Radio Regulations. They are convened as required.
3. The Administrative Council is responsible for co-ordinating the work of the ITU and for implementing the decisions of the Plenipotentiary Conference. It meets annually.
4. The General Secretariat is responsible to the Administrative Council with regard to all administrative and financial aspects.
5. The IFRB is responsible for the orderly recording of frequency assignments and the positions assigned to geostationary satellites.
6. The CCIR and CCITT are responsible for the study of technical and operating questions.

Fig. 1 — ITU Structure

sible, with guidelines agreed in the international forum.

Within Telecom, policy guidance on use of the RF Spectrum is provided by the Headquarters Steering Committee on Radio Regulatory and ITU matters. This Committee has recognised that participation in ITU activities is of benefit to Telecom for various reasons which include;

- Protection of Telecom's interest as a user of RF Spectrum
- Use of common standards for equipment design allowing ready inter-connection of systems using equipment from different manufacturers.
- Being able to influence the Agreements reached in the ITU forum in a way which may take account of special conditions affecting Australia in general and Telecom in particular.
- Interaction between Telecom Personnel and their opposite numbers in communication authorities of other countries.

Other Organisations

There are other international Committees whose field of interest cover electromagnetic interference (EMI) and electromagnetic compatibility (EMC), the latter being defined as the ability of equipment and systems to function as designed without degradation or malfunction in their intended operational environments. One of these with which Telecom is closely associated is the International Special Committee on Radio Interference (CISPR) which operates under the framework of the International Electrotechnical Commission (IEC). National co-ordination on CISPR (and IEC) matters is effected through the Standards Association of Australia (SAA).

AIMS OF WARC — 79

Article 33 of the ITU Convention says in Part 2 "In using frequency bands for space radio services, Members shall bear in mind that radio frequencies and the geostationary satellite orbit are limited natural resources, that they must be used efficiently and economically so that countries or groups of countries may have equitable access to both in conformity with the provisions of the Radio Regulations according to their needs and the technical facilities at their disposal."

In pursuance of this Article, WARC-79 is to be held in Geneva over a 10-week period commencing on 24th September 1979. The Agenda of the Conference was established by Resolution No. 801 of the ITU Administrative Council and the text of this Resolution is reproduced in Appendix II. It will be noted that the main items to be covered are:

CIR and NSG	Title	Chairman	
		CCIR	NSG
1	Spectrum Utilisation and Monitoring	Mr J. Dixon (USA)	Mr P.D. Barnes (P&T)
2	Space Research and Radioastronomy	Dr J.P. Hagen (USA)	Dr B. Robinson (CSIRO)
3	Fixed Service at Frequencies below about 30 MHz	Mr T. De Haas (USA)	
4	Fixed Service Using Communication Satellites including sharing with the Fixed Service (SG9)	Mr E.R. Craig (Australia)	Mr E.R. Craig (Telecom)
5	Propagation in non-Ionised Media	Dr J.A. Saxton (USA)	
6	Ionospheric propagation	Mr L. Barclay (UK)	Mr C.G. McCue (Science)
7	Standard Frequency and Time-Signal Services	Prof G. Becker (FR of Germany)	
8	Mobile Services	Mr W.H. Bell- (UK) chambers	Mr P.D. Barnes (P&T)
9	Fixed Service Using Radio-Relay systems including Sharing with the Fixed-Satellite Service (SG4)	Mr J. Verree (France)	Dr L. Mackechnie (Telecom)
10	Sound Broadcasting Service	Mr C. Terzani (Italy)	Mr C. Wilhelm (ABC)
11	Television Broadcasting Service	Prof M. Krivosheev (USSR)	Mr C. Wilhelm (ABC)
CMV	Joint CCIR/CCITT Study Group Vocabulary	Mr M. Thue (France)	
CMTT	Joint CCIR/CCITT Study Group on Transmission of Sound and Television over Long Distances.	Prof Y Angel (France)	Mr M. Rhein-berger (Telecom)

Notes : 1. There are no NSGs paralleling the work of Study Groups 3, 5, 7 and CMV.

2. Joint CCIR/CCITT Study Groups CMV and CMTT are administered by the CCIR.

3. NSG 8 is sub-divided into three sub-groups covering Aeronautical (Chairman : Mr R. Davies, Department of Transport), Maritime (Chairman : Mr P. Chapman, OTC) and Land (Chairman : Mr A. Caruana, Telecom)

Table 1 — CCIR and NSG Organisation

- Revision of allocations for all services
- Revision of co-ordination provisions where more than one service is affected.
- Reviewing the activities of the International Frequency Regulation Board (IFRB).
- Revising the form of the Radio Regulations.
- Providing guidelines for future optimum use of the frequency spectrum.
- Other miscellaneous matters.

One of the main tasks of the Conference will be to attempt to increase the effective size of the frequency spectrum and orbit resources. These of course are not material resources and their value lies in the use to which they are put. Therefore, the greater the use that can be made of them, the greater will be their value as a resource. If, for example, two services can use the same frequency or two satellites can share the same part of the orbit, then in both these cases, the effective size of the

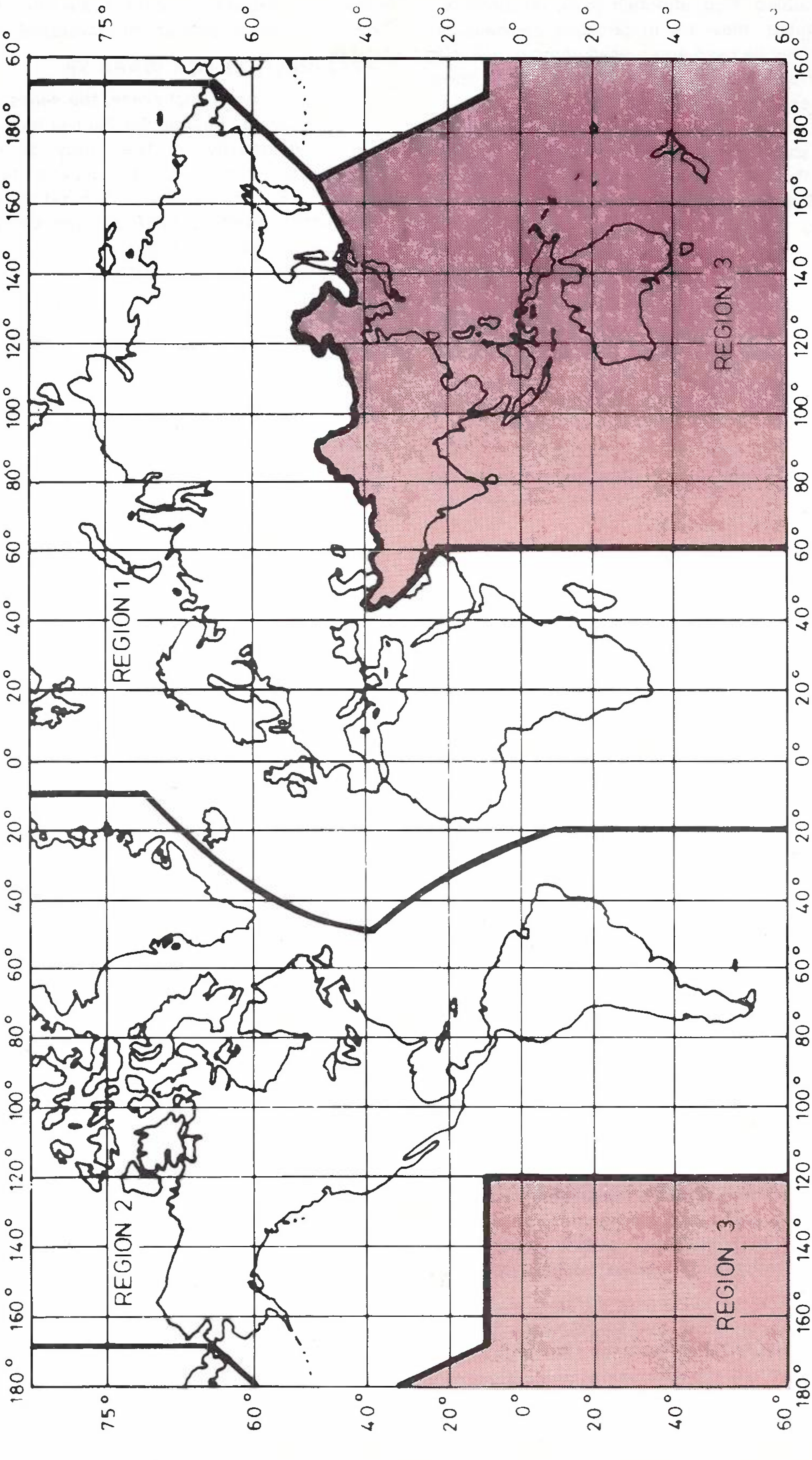


Fig. 2 — ITU Regions

resource is doubled. Also, although these resources are apparently limited, they are in principle inexhaustible because they may be used and reused without "wearing them out". However, this does mean that a more sophisticated engineering of all radio systems is required and indeed in some respects, we are talking about a real revolution in some systems planning concepts. One illustration of this is how allocations were derived for Space Radiocommunications Systems.

In the early 1960's the Fixed service, (i.e. Terrestrial Relay Systems) were already an important transmission means carrying hundreds and even thousands of circuits in many national networks. Experimental communication satellites were just starting to be built and it was obvious even then that if satellite systems were to develop, they would require bandwidth on the same scale as that allocated to the fixed service. In addition, it was also realised that each satellite could cause radio frequency interference over enormous areas perhaps up to 1/3 of the visible area of the earth. How were they to be provided with allocations at suitable frequencies where the table was already apparently full?

The answer, in principle, was very simple. The two services — Fixed service and Satellites — would have to share frequency spectrum. But a consequence of this called for this revolution in system planning. We had to design interference into our systems. Prior to this, we did our best to keep interference out and indeed it was looked on as "harmful". Now, to make sharing a reality, it had to be accepted as a means of increasing spectrum utilisation.

This sharing solution, which was incorporated in the Radio Regulations in 1963 and further developed in 1971 laid down sharing criteria and co-ordination procedures to allow space and terrestrial services to use the same frequency bands in the same geographical areas. For example, satellites have upper power limits in terms of the power flux density allowed to be produced at the surface of the earth. Similarly, there are limits set for radio relay transmitters and antennas and the requirement that, as far as possible, radio relay antennas should not point towards the geostationary satellite orbit. The object of these various limitations was (and is) to restrict the interference received by either service to be no more than an agreed amount. This has proved to be entirely practical, and indeed successful sharing on a large scale between the two services has been a fact of life for the last decade at least.

In a similar way, the use of the geostationary satellite orbit is subject to co-ordination procedures to ensure that separate satellite systems may co-exist without exceeding limits of interference agreed internationally.

WARC-79 is expected to increase the amount of sharing in the frequency spectrum and to streamline and extend the co-ordination procedures to take account of developments over the last few years. In addition, the form of co-ordination procedures and regulation of this geostationary satellite orbit will come under critical review to take into account views and needs of the underdeveloped as well as the developed countries.

PREPARATION FOR WARC-79

On the international scene, the series of CCIR Study Group Meetings held during the last four years has concentrated heavily on the study of technical and operational matters directly relevant to the work of WARC-79. The series culminated in a Special Preparatory Meeting (SPM) of Study Groups held over a 4-week period during September/October 1978. This was attended by around 700 delegates which included an Australian delegation. Its purpose was "to prepare a Report providing technical bases for the WARC-79 and for the use of Administrations in preparing their proposals to that Conference". The Report was duly prepared and it has 463 closely printed 'A4' size pages. It was intended to be — and indeed to a fair degree is — a concise summary of the technical subjects treated! The SPM Report is one of the Conference's documents and is expected to form the technical basis of WARC-79 decisions. In addition, Seminars were held in each of the ITU Regions in early 1979. The venues for these two-week Seminars were — Nairobi (Region 1), Panama (Region 2), and Sydney (Region3). Their main purpose was to discuss the impact of the SPM Report and to allow for regional discussions on critical issues.

So far as Australia's national preparations for WARC 79 are concerned, they started about 3 years ago. A Steering Committee was formed in early 1976 and this is known as the Australian Preparatory Group or APG. It is chaired by Mr. E.J. Wilkinson of the P&T Department and includes in its membership a wide representation from Government, Industry and users of radio services. Subsidiary to the main APG, a series of specialised Committees were set up to cover particular services. There are eight of these. They are numbered in accordance with the organisational arrangements shown in **Table 2.**

The functions of this APG organisation are broadly to;

- Originate and develop proposals for Australia to submit to WARC-79
- Study the proposals of other countries which become available
- Contribute to the national brief for the Australian delegation to WARC-79.

The first major output of these APG Committees was put together as the first Australian Draft Proposals. Essentially this first Draft was intended to encourage interaction between the various service interests so circulation was restricted to the APG organisation. The next round — the second Draft — was a more highly developed document and although it contained many proposals that were by no means unanimously agreed, it was circulated widely both here and overseas in the middle of 1978 so that public comment could be obtained. The proposals already sent to the ITU and those in course of preparation have the benefit of the feedback obtained from this publication.

AUSTRALIAN PREPARATORY GROUP
Chairman: Mr E.J. Wilkinson, P & T

Committee No APG	Services	Convener	Organisation
1	Aeronautical	Mr R. Davies	Dept of Transport
2	Amateur	Dr Wardlaw	Wireless Institute of Australia
3	Broadcasting	Mr C.W. Pike	P & T
4	Fixed, Mobile, Standard Frequency and Special	Mr J. D. Williamson	P & T
5	Maritime	Mr P. Chapman	OTC
6	Space (including Radio Astronomy)	Mr E.R. Craig	Telecom
7	Radio Determination	Mr J. J. Foggon	Dept of Defence
8	Frequency Table Co-ordination	Mr P.D. Barnes	P & T

Table 2 — APG (WARC-79) Committee Structure

The Australian delegation to WARC-79 is expected to comprise some 25 members including 5 officers from Telecom.

TELECOM KEY ISSUES

Some of the key issues which are of primary concern to Telecom's future radiocommunications services include:

- the HF bands where there is a heavy demand by other services (broadcasting, maritime-mobile, amateur, etc) for additional exclusive RF spectrum which can only be acquired by a reduction in the RF spectrum available to the fixed service. This has an impact on some remote area subscriber networks which on present indications can only be met economically with HF systems. Telecom policies for the future provision of services to some 2500 customers in remote areas are also likely to be affected.
- competing needs by the broadcasting, fixed and mobile services for the UHF spectrum between 470 MHz and 960 MHz with Telecom interests in the 400 MHz region (PAMTS and Telecom mobiles) and in the 900 MHz region (small capacity).
- the effect of additional RF spectrum allocations proposed for the fixed-satellite service for shared use with the fixed service. The area of concern is in the 6.7 GHz region which is one of the 3 main bands used for the interstate and intrastate trunk radio network and the only microwave band which at present is not subject to sharing with space services.
- future needs for spectrum above about 20 GHz for fixed services.

PROTECTION OF NATIONAL INTERESTS

The RF spectrum and the geostationary satellite orbit are unique national and international resources that, although available in limited quantities, are inexhaustible. They can be used and reused indefinitely. Unlike other resources, to not use RF spectrum and the orbit is tantamount to wasting them. On this matter, WARC-79 is impossible to ignore as it will have a significant impact on the whole of the radiocommunication industry.

Australia's unique features such as its vastness, its uneven population distribution, its natural geographical boundaries are all factors that need to be taken into account. Our particular interests must be defended in a forum where the interests of various nations will tend to conflict and where a satisfactory solution is usually achieved through compromise.

The preparations over the last three years have led to a set of proposals and a national brief for the Australian delegation to WARC-79 that are designed to ensure that our national interests are adequately presented and argued.

APPENDIX 1 — PURPOSES OF THE INTERNATIONAL TELECOMMUNICATION UNION

(Extract from Article 4 of International Telecommunication Convention Malaga-Torremolinos, 1973)

1. The purposes of the Union are:

a. to maintain and extend international co-operation for the improvement and rational use of telecommunications of all kinds;

b. to promote the development of technical facilities and their most efficient operation with a view to improving the efficiency of telecommunications services, increasing their usefulness and making them, so far as possible, generally available to the public;

c. to harmonize the actions of nations in the attainment of those ends;

2. To this end, the Union shall in particular:

a. effect allocation of the radio frequency spectrum and registration of radio frequency assignments in order to avoid harmful interference between radio stations of different countries;

b. co-ordinate efforts to eliminate harmful interference between radio stations of different countries and to improve the use made of the radio frequency spectrum;

c. co-ordinate efforts with a view to harmonizing the development of telecommunications facilities, notably those using space techniques, with a view to full advantage being taken of their possibilities;

d. foster collaboration among its Members with a view to the establishment of rates at levels as low as possible consistent with an efficient service and taking into account the necessity for maintaining independent financial administration of telecommunication on a sound basis;

e. foster the creation, development and improvement of telecommunication equipment and networks in developing countries by every means at its disposal, especially its participation in the appropriate programmes of the United Nations;

f. promote the adoption of measures for ensuring the safety of life through the co-operation of telecommunication services;

g. undertake studies, make regulations, adopt resolutions, formulate recommendations and opinions, and collect and publish information concerning telecommunication matters.

APPENDIX 2 WARC-79 AGENDA

(Resolution No 801 of the ITU Administrative Council)

1. To review and, where necessary, revise the provisions of the Radio Regulations relating to terminology, the allocation of frequency bands and the directly associated regulations;
2. To review and, where necessary, revise the provisions applicable to the co-ordination, notification and recording of frequency assignments except those Articles relating to a single service.
3. To review and, where necessary, revise the other Articles applicable to more than one service and provisions applicable to miscellaneous stations and services;
4. To make any necessary consequential editorial amendments to other provisions of the Radio Regulations and the Additional Radio Regulations resulting from the action taken under agenda items 1,2 and 3.
5. To review the report on the activity of the IFRB and revise, where necessary, the provisions relating to its methods of work and internal regulations.
6. To study the technical aspects for the use of radiocommunications for marking, identifying, locating and communicating with the means of medical transport protected under the 1949 Geneva Conventions and any additional instruments of these Conventions.
7. To take account of Resolution No. Sat-10 of the World Broadcasting Satellite Administrative Radio Conference, Geneva, 1977, on the possible Re-arrangement of the Radio Regulations and Additional Radio Regulations, to make such consequential changes as may be necessary to harmonize the Radio Regulations as well as the Additional Radio Regulations and to undertake any further necessary refinement and deletion of superfluous or redundant provisions.
8. To consider the proposals based on the CCITT studies carried out in accordance with Resolutions Nos. Mar 2-22 and 23 and to take appropriate decisions.
9. To consider the resolutions and the recommendations adopted by administrative radio conferences, to take such action as may be considered necessary and to adopt such new resolutions and recommendations as may be necessary.
10. To propose to the Administrative Council and to the next Plenipotentiary Conference a programme for convening future administrative radio conferences to deal with specific services.
11. To provide, for the benefit of future administrative radio conferences, such guidelines as may be found necessary for optimum use of the frequency spectrum.

Life Membership Awards

DAVID WATSON has been awarded Life Membership of the South Australian Division of the Society for his work as South Australian Representative on the Council of Control. David has represented South Australia on the Council since its inception.

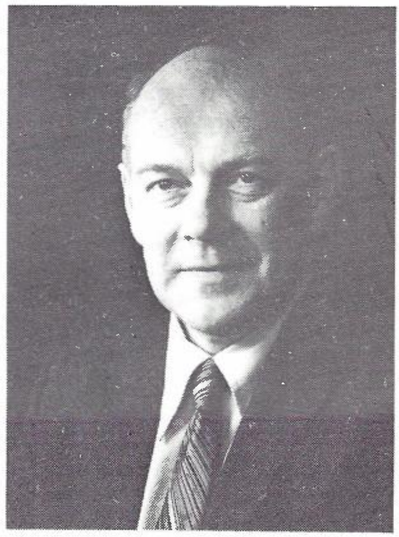
During his service he has assisted the State in obtaining the services of lecturers, advised on suitable lecture material and represented to Council matters of concern to the State Division.

David has on a number of occasions on behalf of Council examined the Constitution and recommended changes where necessary. His long service has given perspective in these matters and his knowledge is valued by Council.

ROGER SHINKFIELD has been awarded Life Membership of the South Australian Division of the Society for his work as a Committeeman, Convenor of the Lecture Sub-Committee and for his years as an Editorial Representative — a position he still occupies.

Roger first joined the Committee in 1965 and as Covenor of the Lecture Sub-Committee formulated the guidelines which still form the basis for lecture programmes in South Australia.

As Editorial Representative, Roger has set a high standard of articles of topical interest and historical significance. His assistance to authors with advice on information sources, style and content have been appreciated whilst his efforts to maintain a steady supply of articles to the Board of Editors have been appreciated by the Editors.



Conversion of the National MF Sound Broadcasting Service to a New Band Plan

A. J. EDWARDS, F.R.M.I.T., M.I.G.R.E.E. (Aust)

The national network of Medium Frequency (MF) sound broadcasting stations in Australia was converted to operation on the basis of radio frequency channels spaced by 9 kHz on 23 November, 1978. The background to this change is described, along with the effect on a diverse network of stations and some of the practical aspects involved.

INTRODUCTION

The International Telecommunication Union (ITU) convened conferences in 1974 and 1975 that led to an international agreement to adopt a plan for the future use of the LF and MF broadcasting bands in Regions 1 and 3. Australia, as a member country in Region 3 (Asia and the Pacific), was a signatory to the 1975 Agreement approved by 98 of the 99 participating ITU member countries.

The Agreement and associated Plan came into force on 23 November 1978. They will remain in operation for 11 years, whereupon a review will be conducted by the ITU. The key aspects of the Agreement are the stringent administrative procedures to be adhered to in the establishment of new stations and the adoption of an MF band plan based upon rf carriers separated by 9 kHz. Prior to this date the carrier spacing was 10 kHz in Region 3 and a mixture of 10, 9 and 8 kHz in Region 1 (Europe, Africa and part of Asia).

The administrative procedures defined by the Agreement are designed to allow usage of the bands in an orderly and co-ordinated manner aimed at minimising mutual interference. Unfortunately, these procedures will result in some delays in arranging for new services to be established or in modifying existing services, largely due to the need for multilateral negotiations with overseas administrations and the ITU.

The new 9 kHz band plan increases by 12 the number of MF channels available for use in Australia.

This paper describes the implications of adopting a new band plan for the existing network of national MF transmitters in Australia and the implementation of the changes on 23 November, 1978.

GENERAL DETAILS OF EXISTING NETWORK AND CHANGES REQUIRED

To provide an overview of the extent of the frequency changing exercise to achieve conformity with the 9 kHz plan, the following statistics are of interest (Refer to **Table 1**):

- The national network of stations consists of 90 services.
- Frequency changes were required for 78 services, with 12 services remaining on channel allocations which are identical to specified 9 kHz channels.
- Of the 78 services to be changed, 53 operate without the attendance of staff (7 of these are part attended).
- The 78 services to be changed are located at 71 sites.
- The network contains a multiplicity of installation types in terms of transmitter power, transmitter configuration (main and standby, combined or parallel transmitters, main transmitters with a shared standby for cosited services), antenna types ("short" height, antifading, directional). Operating frequencies are distributed throughout the MF band (531-1602 kHz). The network has developed over a long period of time and there is little standardisation of equipment types in any one locality. **Tables 2 and 3** give some detail of categories of installation type, without showing the diversity of equipment brand names existing.
- **Table 4** shows the magnitude of frequency shifts required to bring the national network into line with the new Plan. For the facilities in the (a) grouping, the shift was in the range 1-5 kHz, whilst for the (b) grouping the range was 12-160 kHz. The (a) group installations did not present significant difficulties in shifting frequency.

ADOPTION OF 9KHZ BAND PLAN

In order to minimise interference between services operating in the countries covered by the new Plan, the official changeover was scheduled for a specific time. This was to be 0001 hours GMT, or 1000 hours Australian EST, on 23 November 1978. However a regional conference in 1977, with representation from Australia, Indonesia, New Zealand, Papua New Guinea and Fiji, agreed that the changeover, should be com-

State Territory	Stations Requiring Change		Stations Unchanged	Totals
	Total	Unattended		
NSW	20	14	2	22
VIC.	6	3	1	7
QLD.	16	8	4	20
SA	10	7	—	10
WA	16	14	2	18
TAS.	5	2	1	6
ACT	1	1	1	2
NT	4	4	1	5
TOTAL	78	53	12	90

Table 1 — Details of National Stations Affected by New Band Plan

Transmitter Power, KW	Percentage of stations
50	14
10	30
4	1
2	19
1, or Less	36

Table 2 — Percentage of Stations to be Changed Vs Transmitter Power.

Percentage	
Main + Standby Transmitter	Parallel or Combined Transmitter
60	40

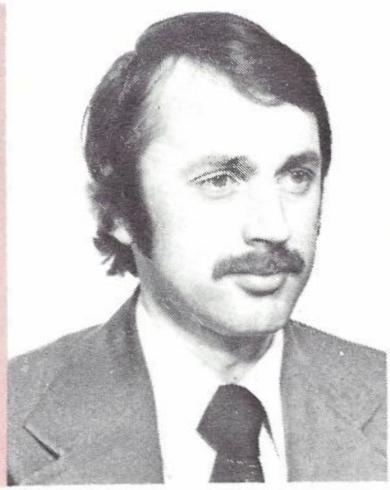
Table 3 — Percentage of Stations With Standby Plant

Percentage of Stations	
(a) Shift Less Than 9 kHz	(b) Shift Greater Than 9 kHz
74	26

Table 4 — Magnitude of Frequency Shifts

ARTHUR J. EDWARDS joined the PMG's Department in 1966 as an Engineer Class 1, in the Radio Section, Headquarters. From 1966 to 1974, he was involved in the engineering planning, design and the selection of equipment for radio telephone systems for subscriber and trunk telephone services. This work encompassed frequency bands from HF to UHF.

In May 1974 he transferred to the Broadcasting Branch, Headquarters, where he has been largely involved with the provision of new national sound broadcasting services in the MF and VHF bands. He is presently Engineering Section Manager, Sound Broadcasting Construction Section.



pleted during the daylight hours of 23 November, 1978; i.e. before long distance skywave transmission modes created serious interference difficulties. This modification to the original ITU target recognised that it would not be feasible for all installations to change frequency simultaneously. The interference generated during the daylight hours of 23 November, 1978 was to be tolerated by all operators.

TIMING ADOPTED FOR THE NATIONAL NETWORK

Transmission times are in the vicinity of 0500 hours to 0000 hours, local time.

Thus, it was decided to perform the frequency changes during the break in transmission in the early morning of 23 November, 1978, to:

- Allow staff a reasonable period of time to make the necessary adjustments with the equipment "off the air".
- Minimise breaks in transmission and disturbance to important programs scheduled by the programming authority, the Australian Broadcasting Commission.

The objective, then, became to commence transmission throughout the network on the morning of the 23 November 1978, on the new 9 kHz frequencies. The quality of transmissions would remain high, except in a few cases where the field strength throughout the service area would be reduced due to a smaller transmitter power being temporarily available immediately after the frequency change. This temporary situation would be quickly corrected.

TECHNICAL ASPECTS OF FREQUENCY CHANGING

In broad terms, changing the frequency of a station involves retuning the transmitters, the antenna coupling unit (ACU) which matches the transmission line (coaxial cable or openwire line) to the antenna, and the antenna itself. Fixed tuned rebroadcast, and monitoring receivers also require retuning.

The audio bandwidth of the broadcast system chain was to remain 10 kHz.

As the frequency shift of most installations was small (Table 4), the existing range of adjustment of the transmitter, ACU and antenna was generally sufficient to accommodate the variation, although some component changes were necessary.

The major circuit or component changes were involved with the carrier frequency generating portion of the transmitter — the exciter oscillator (quartz crystal controlled).

Prior to the changeover date, the following basic crystal units were employed at all but four sites:

- AWA 7 pin type R3535 which contained a crystal oven and an airgap pressure mounted crystal cut to the fundamental frequency.
- Philips 5 pin type SP220, which is similar to the AWA R3535.
- D style crystals housed in a variety of crystal ovens and operating at 2 to 4 times the required frequency.

The exceptions were two stations using glass vacuum ovenless crystals and two stations using Sulzer 5A Laboratory Frequency Standards. The necessary specialised crystals were supplied in these four cases, as direct replacements.

The possibility of regrinding crystals, or alternatively purchasing new crystals of the same type for the AWA and Philips units was examined. These approaches were not considered desirable for the following reasons:

- the ageing rate for reground crystals would be unpredictable, possibly involving a high level of attention by maintenance staff. This would be unacceptable for unattended stations.
- there is a high failure rate (up to 40 pc) where regrinding is attempted.
- there is an extremely limited number of people in Australian industry with the necessary skills to successfully attempt this task.
- Airgap pressure mounted crystals capable of handling 15mW or higher are no longer available. 5 mW crystals above 950 kHz are obtainable and satisfactory for use in transistor or low power vacuum tube oscillators. The majority of oscillators with the AWA or Philips crystal units use power tubes such as 807's and 6V6's and would excite the 5 mW crystals beyond the rating. However 78% of these high power oscillators are below a frequency of 950 kHz.

It was decided, therefore, to use a commercially available package oscillator where AWA and Philips crystal units were to be changed. The unit selected uses a D style crystal operating at several times the desired rf carrier frequency, and includes a transistor oscillator with frequency divider and power supply. This circuitry operates without an oven and the output level and frequency are adjustable. The units are pin compatible with the mounting arrangements for the AWA and Philips crystal units. The only transmitter circuit modification required was the removal of the transmitter oscillator feedback capacitor where parasitic oscillation was experienced.

A summary of the technical characteristics of the package oscillator is as follows:

- Frequency stability — over the temperature range -10°C to +60°C better than ±5 ppm — over 12 months, better than ±2 ppm.
- Frequency adjustable by ±20Hz
- RF output level adjustable 1 to 20V RMS
- Power supply — 12V, AC, 250 mA
- Circuitry contained in metal can 101 mm x 51 mm diam.

SPECIAL INSTALLATIONS

Installations that could be regarded as exceptional were:

- the two "synchronised" services in Queensland, 4QO and 4QB which were shifted in frequency by 55 kHz. 4QB operates from a directional antenna. Apart from the comparatively large frequency shift for the directional antenna (see comments below), special difficulty arises in shifting the operating frequency of the transmitter exciter at each site. The services are not strictly synchronised, but achieve psuedo-synchronisation by employing independent exciter oscillators of high stability (better than 1×10^{-7} per day is adequate, although 4QO and 4QB are considerably better than this). It was necessary to install the specialised replacement crystals in the particular oscillators and check the ageing and temperature stability to achieve the matching of performance necessary for "synchronised" operation.

- installations employing directional antennas. The antenna system is optimised for a particular frequency to provide a satisfactory service plus defined protection to co-channel services (perhaps overseas) at particular azimuth angles. At the design frequency, the two mast systems in the national network have a specific (electrical) height, (electrical) spacing between masts, and a particular ratio and phase relationship for the rf currents feeding the masts. The above parameters are inter-related to achieve the required performance. With few exceptions, fortunately, the frequency shifts were small (in the range 1-4 kHz) and major redesign or rebuilding of antenna systems was avoided. Of the 12 directional systems presently operating in the network, 11 were required to be retuned to 9 kHz channels.

STAFF RESOURCES

The availability of skilled broadcasting staff in remote areas is limited.

As there are a large number of unstaffed stations (**Table 1**), particularly in the larger States, it was decided early in the planning for the changeover to:

- conduct trial frequency changes at all stations and note the alterations needed to achieve satisfactory operation. These trials were generally performed by skilled broadcasting staff in the company of local first-in maintenance staff. The equipment was then retuned to the original operating frequency.
- use first-in maintenance staff to perform the actual changeover at many stations in the early hours of 23 November 1978. The small number of skilled radio staff were deployed at the more critical installations.

RESULT OF THE CHANGEOVER

The objective of commencing transmission on the 23 November 1978, throughout the network on 9 kHz channel allocations was achieved.

The 9 kHz allocations arranged for Australia by the broadcast spectrum planning authority, the Postal and Telecommunications Department, appear in practice to have achieved a low level of interference between services. There is little evidence of significant difficulties in this regard, although problems can take some time to become apparent.

CONCLUSION

With careful planning and only a small number of staff the frequency changes which had to be made at a given time to a large network of stations dispersed throughout Australia, largely in remote areas, were carried out successfully.

This project was planned in part, and co-ordinated, at Headquarters, but tribute is paid to the State administrations for the detailed preparations leading to the successful implementation of the changeover.

Any future changes, such as may be contemplated at the expiry of the 11 year operating period of the present Plan, should be considered only after a detailed study of the composition of the network, and the technical aspects involved.

ACKNOWLEDGEMENT

The particular contribution of Mr W. Edwards, Senior Technical Officer, Headquarters Broadcasting Branch, to the success of this project is acknowledged.

INTRODUCTION OF AN INWARD WIDE AREA TELEPHONE SERVICE.

Telecom Australia proposes to introduce, later this year, a new Automatic Reverse Charging System for Australia with customer selected options, to be known as Austwide and Statewide Inward Wide Area Telephone Service. The service will enable participating customers to receive telephone calls originating within specified service areas, typically at trunk call distance, but with the originating callers being charged local call fees only irrespective of the origin of their calls.

This service is expected to encourage a greater utilisation of the Australian trunk network and make more efficient use of the available trunk equipment than would other alternatives of providing a similar service such as private lines or lines connected to distant exchanges. Customers taking up the new service are expected to benefit from the new marketing initiatives that are available, the ability to re-organise and concentrate their operations and from the larger service area from which they are available at a local call fee. It is also expected that the general community will obtain significant benefits through the availability of cheaper trunk distance communications and improved access to community services.

Accessibility by telephone is an important aspect in today's world, and business organisations may be more inclined to decentralise to country locations if they are able to use STD to call them. By allowing easier access from a dispersed area to a given point, this new service has the potential to encourage decentralisation.

The inward wide area telephone service to be introduced into the Australian networks at this time will have the following features:

For Callers

- A 9 digit number will be dialled commencing with a special access code 008. The use of this special access code will simplify routing and charging analysis required in the network. The 9 digit number will also maintain national numbering compatibility.
- The cost of all calls to INWATS customers will be a local call fee only.

For Customers of the Service

- A customer may be located anywhere in Australia.
- Two basic services will be offered: Statewide (inward calling from an area approximating the State boundary) or an Austwide (Australian Wide) service. In each case the customers will have the option of either accepting or excluding calls from their own state capital city metropolitan network. Tasmanian customers will have the further option of identifying the Victorian and Tasmanian areas as a single Statewide Service Area or Tasmania only as a separate Tasmanian Statewide Service.
- The fees for the calls to the service paid by the customers will be based on the time of the day and the service option required.

Book Review

HANDBOOK OF FILTER DESIGN

Rudolf Saal and Walter Entenmann; AEG — Telefunken 1979

If your copy of "Saals' Tables" is worn out you will be delighted to learn that the familiar Catalogue of Lowpass Filters is now available in a new edition. It has over six times the information content of the original but a new type face has accomplished this without increased mass. There is now a detailed explanation of the tables, in English as well as German, and over 25 worked examples for guidance. These show how to design lowpass, highpass, bandpass and bandstop filters; bandpass filters with the minimum number of coils; branching filters and lowpass and bandpass broadband impedance matching circuits; There are also sections on the design of RC active (cascade second order and gyrator types) and digital filters, both cascade and wave.

The three main extensions to the original tables of Elliptic filters are:

- poles and zeros, as well as element values, are tabulated,
- the highest degree tabulated is now 15 instead of 9
- both singly terminated and doubly terminated filter component values are given

For the price, 220DM or over $100 Australian, I would expect a more robust binding. However, for those whose livelihood is filter design it should soon repay its cost in saved computation. For the occasional user, a library reference copy may be good value.

Reviewed by R.L. Gray, Research Department, Telecom Australia.

GaAs + FET = Improved Microwave Systems

JAMES V. DiLORENZO and WOLFGANG O. SCHLOSSER.

Newly developed low-noise and high-power gallium arsenide field effect transistors are beginning to improve reliability and performance of microwave transmission systems.

A device invented 27 years ago is now helping to revolutionize microwave technology. Combining the idea of the field effect transistor, invented at Bell Laboratories in 1951, with gallium arsenide material has yielded a device remarkably well-suited for high-frequency operation. The gallium arsenide field effect transistor (GaAs FET) has outstanding noise, gain, and power characteristics, and is the first transistor which can operate at microwave frequencies up to forty gigahertz. The GaAs FET far outperforms traditional silicon bipolar transistors and silicon field effect transistors in the microwave frequency range.

This versatile transistor can be used as an amplifier, an oscillator, a mixer, a modulator, or a high-speed logic element. After only a few years of development, GaAs FETs are being used in new low-noise and high-power amplifiers which are expected to boost the transmission capability of the TD-2 long-distance microwave radio system. In the future, GaAs FETs will undoubtedly help improve other microwave systems throughout the Bell System.

Gallium arsenide has been used as a semi-conductor material for LEDs (light-emitting diodes) and various other diodes. But until recently, several problems precluded wide use of GaAs in transistors. Because gallium arsenide is a compound composed of two elements, its properties are much more complex than those of the single element silicon, the most widely used semiconductor material. Furthermore, gallium arsenide is more brittle and less tolerant of temperature changes than silicon, so the technologies developed for silicon semiconductor fabrication cannot be directly applied to GaAs.

However, gallium arsenide has three important advantages over silicon. First, the electrical resistance of GaAs is approximately one-seventh that of silicon. This property is a key to high-frequency performance. Second, electrons can travel about five times faster in gallium arsenide than in silicon. This makes the material more efficient for amplification and enhances switching speed. And third, gallium arsenide can easily be doped with elements such as chromium and iron to render it semi-insulating. This property, which silicon does not have, allows the fabrication of almost totally non-conducting substrates. Such substrates play an important role in overall high frequency performance and facilitate fabrication of monolithic integrated circuits.

The FET design allows simpler and faster operation than does the conventional bipolar transistor configuration. Although the FET concept predates that of the bipolar transistor, it was not until 1952 that Bell Laboratories developed the first practical field effect transistors. In the 1960s advances in semiconductor technology made possible FETs well-suited for use in integrated circuits (see Anatomy of IGFETs, RECORD September 1968). But for high-frequency purposes their performance was inferior to that of bipolar transistors. Only in the last few years were materials, fabrication techniques, and packaging concepts developed that allow FET performance to far surpass that of conventional transistors for high-frequency applications.

At Bell Laboratories two distinct types of GaAs FETs have been developed: one which optimizes low noise, and one which optimizes high power. Both have the same basic configuration, an active channel of electron-rich material with source and drain electrodes near the ends and a gate electrode in the middle. The flow of electric current from source to drain is controlled by the application of bias, or voltage, at the gate (see **Fig. 1**). But the performance requirements for the two types are quite different. Input signals for the low-noise device are measured in units of a hundredth of a milliwatt (1/100,000 watt), while those for the high-power device are measured in watts (see **Fig. 2**).

Low noise, high power

The primary considerations in designing a low-noise device are that a small change in gate voltage should produce a very large effect at the drain, and that the amplified output signal should accurately reproduce the

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Basic GaAs FET Operation

The FET can be viewed as a variable resistor. The GaAs FET developed at Bell Laboratories is a channel of N-type material with two electrodes, the source and drain, near the ends and a gate electrode in the middle. The relatively thin active channel and electrodes are situated on a thicker buffer layer and substrate. The channel region under the gate is highly conductive when dense with electrons, but becomes non-conductive when the electrons are depleted. Voltage changes at the gate change the electron density under it. Since a small gate voltage can control a large drain voltage, the device amplifies.

The three figures illustrate the direct current operation of the GaAs FET; under operating conditions, alternating voltage causes the depth of the depletion region to oscillate rapidly. Since the gate has a built-in bias of 0.8V, a depletion region exists even when no external bias is applied. As positive bias is applied at the gate (A), this built-in potential is overcome and the depletion region shrinks, allowing maximum current to flow in the channel. With no external bias at the gate (B), the amount of current flowing between source and drain is moderate—neither minimum nor maximum. As negative bias is applied to the gate (C), the depletion region grows, blocking the flow of current. Sufficient negative bias causes current to be pinched off.

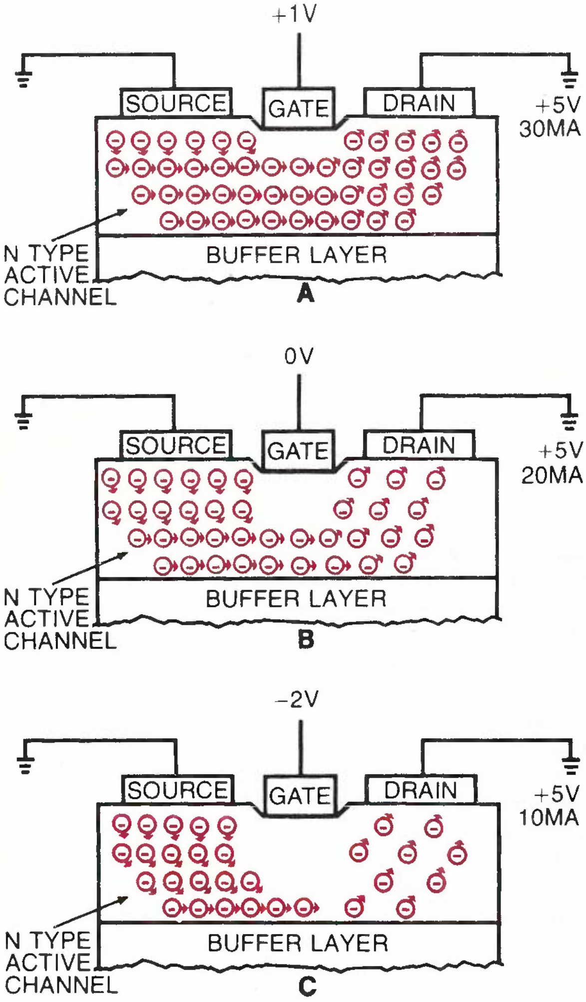


Fig. 1

input signal. There are three major sources of inaccuracies, or noise. First, resistance occurs both at the metal gate electrode and in the active channel between source and gate. Careful control of the shape of the gate electrode and the quality of material used for the active channel helps minimize this resistance. Second, scattering occurs as the electrons pass through the strong electric field under the gate. Since scattering is related to gate length, the gate is made as short as possible. Third, chemical and crystalline defects at the interface between the active layer and semi-insulating substrate necessitate the use of a high-quality, high-resistance buffer layer to isolate the active channel from the substrate.

The high-power GaAs FET must be able to sustain high current and voltage. Therefore it is designed to maximize the amount of current and voltage that can be applied between source and drain without overheating. It is also designed to maximize the amount of voltage that can be applied at the gate before avalanche (breakdown of resistance) occurs. To meet these design goals, both the material quality of the epitaxial layers and the quality of the metal contacts to the GaAs must be rigorously controlled.

The development of adequate materials and fabrication processes for the GaAs FET required several innovations. These included the development of an epitaxial growth technology able to produce extremely thin layers, and advances in high resolution photolithography and lift-off processes in order to form very small surface features.

Conventional silicon semiconductor materials are fabricated using diffusion techniques. But GaAs FETs require a fabrication technology based exclusively on epitaxial growth, a process which allows the formation of thin films on the surface of crystals. These films have the same crystallographic properties as the substrate. GaAs FETs are composed of a series of epitaxial layers, some of which are later removed to form mesas and troughs. The layers themselves must be very thin, pure, and uniformly deposited, and must have very smooth surfaces. The level of doping (introducing negatively-charged impurities) must be changed rapidly and without inter-

High-Frequency GaAs FET Operation

The GaAs FET can amplify at extremely high frequencies. Transistors generate and control streams of electric charge carriers. Amplification occurs when the power derived from the stream exceeds the power expended in controlling it. There are two types of charge carriers: electrons, which carry a negative charge, and holes (deficiencies of electrons), which carry a positive charge. Semiconductor materials are classified as N-type or P-type depending on whether negative or positive carriers are in the majority.

In silicon semiconductors, electrons and holes move at roughly the same speed, and both N- and P-type materials are used. But in gallium arsenide, electrons move much faster than holes, so GaAs FETs use only N-type material. In addition, GaAs FETs have no P-N junction barriers, which in traditional bipolar transistors tend to limit speed. Thus the GaAs FET can operate at microwave frequencies up to 40 gigahertz.

Two types of GaAs FET, one for low noise and one for high power, have been developed at Bell Laboratories. In the low noise device the main consideration is that the amplified output signal accurately reproduces the input signal. The gate voltage, and therefore the depth of the depletion region (below, red broken line) oscillates over a relatively small range. By contrast, the high power GaAs FET operates almost like a switch, rapidly varying the gate voltage and depletion region depth from maximum to minimum. Although the two types of GaAs FET differ in function, their basic configuration is the same.

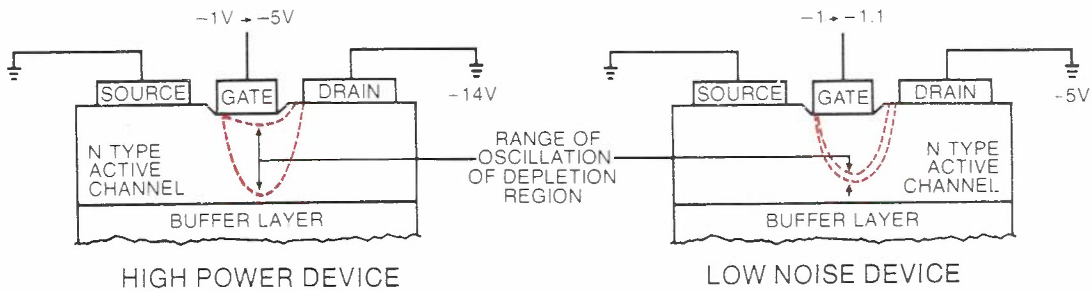


Fig. 2

rupting the growth of the various layers. Since these requirements are difficult to meet simultaneously, much work has gone into refining and perfecting the epitaxial growth systems.

Each layer has a specific role. The relatively thick chromium-doped substrate insulates the device electrically, gives it mechanical strength, and provides a base on which the various layers can be grown. The very lightly doped buffer layer, which is 3 to 5 microns (thousandths of a millimeter) thick, isolates the active layer on top from the interface below. This interface is crystallographically imperfect and chemically impure, and would obstruct the flow of electrons. On top of the buffer is the N-type active layer, 0.2 to 0.5 microns thick, which forms the channel for electron flow. Finally, a highly doped 0.2-micron-thick N + layer is grown for good contact with the source and drain electrodes.

After the wafer is formed, surface features are defined and metal electrodes attached. Mesas are created in the epitaxial material by masking parts and chemically etching away the rest, and by using a newly developed ion milling technique. Next, metal is alloyed to the N+ layer to form the source and drain electrodes. The gate electrode is placed in a trough, directly in contact with the N-type active layer. Finally, a different metal coating is built up on the source and drain contacts to decrease resistance and improve reliability.

New lift-off process

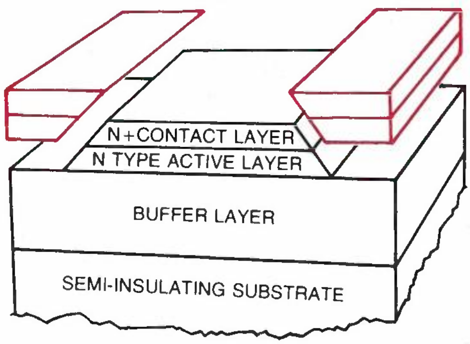
One of the major problems encountered in GaAs FET fabrication was spacing these very fine metal features close together. In the low-noise device, for example, an aluminium gate less than a micron in length is placed in a 3-micron space between the source and drain. Such fine lines could not be chemically etched from deposited metal, so a new lift-off process was developed. This process involves depositing photoresist, a light-sensitive organic polymer, on the wafer's surface. An area approximately the shape of the desired feature is then opened in the photoresist by means of focused light, and metal is applied to the wafer's entire surface. When the photoresist is dissolved, the metal on top of it is removed, or "lifted off," leaving behind the metal feature (see **Fig. 3**).

The Making of a GaAs FET

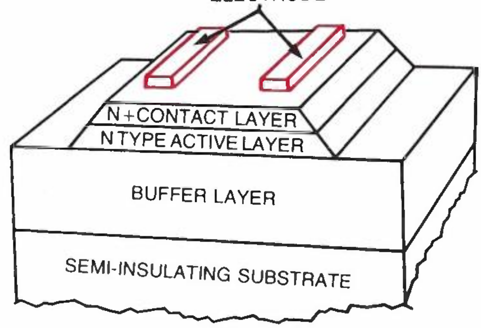
The fabrication of a GaAs FET begins with a wafer structure composed of three epitaxial layers, grown in sequence to insure purity and crystal perfection between layers. On a chromium-doped semi-insulating substrate are grown a very lightly doped buffer layer, a moderately doped N-type active layer, and a highly doped N+ contact layer. Portions of the N and N+ layers are removed to form a mesa which will become the active channel of the device (A). This mesa is formed by a newly developed ion milling technique, in which focused beams of ions dislodge atoms of the wafer material. Ion milling allows precise control of the shape of the mesa wall.

The extremely small source and drain electrodes are formed on the N+ contact layer (B) by means of a newly developed lift-off procedure (shown at right). A layer of photoresist, a light-sensitive organic polymer, is deposited onto the wafer's surface (a). Light focused through a mask opens areas in the photoresist approximately the shape of the desired features (b). A gold-germanium mixture is then evaporated onto the wafer's surface, forming a high-quality contact with the N+ layer in the areas previously opened (c). When the photoresist and excess metal are chemically removed, the desired electrodes are left behind (d).

Next, the N+ layer is selectively removed, and an aluminum gate is patterned directly on the N-type active channel between source and drain by means of a second lift-off procedure (C). The final step is the deposition and patterning, by means of ion milling, of a titanium-platinum-gold composite to facilitate contact between the electrodes and the wire leads which will be added later (D).



A



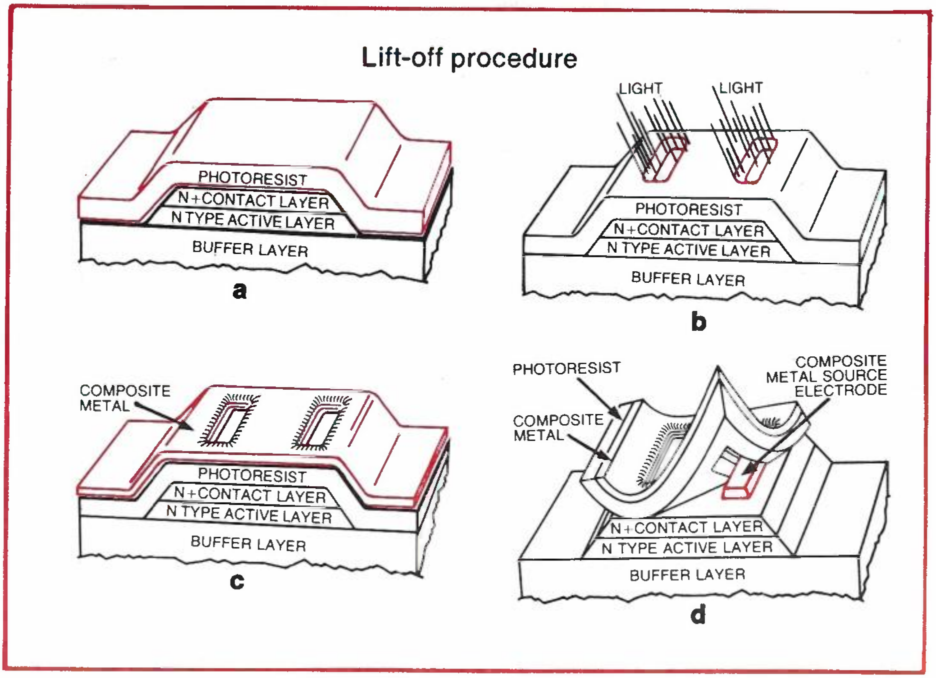
B

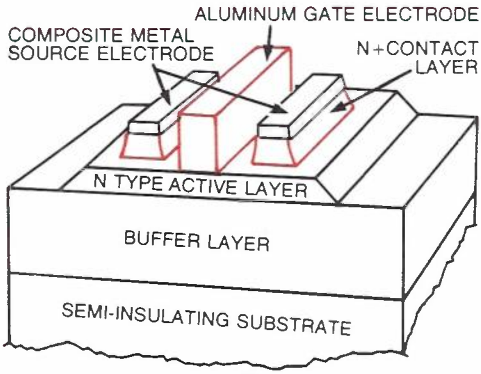
Fig. 3

A series of tests involving about 3,000 units, operating under various environmental conditions for 1.5 million device-hours, indicates the operating life of the low-noise GaAs FET should be well over 20 years. This would make it as reliable as silicon devices of similar size. The main failure mechanisms, corrosion and chemical degradation of the metal electrodes, are reduced by hermetic sealing and proper design of the metal interfaces. The high-power GaAs FET is still being tested for reliability, but preliminary indications are that its operating life will be comparable to that of silicon bipolar power transistors.

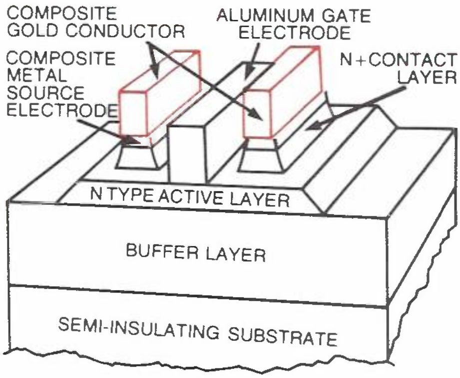
The low-noise GaAs FET has been in production at Western Electric since December 1976, and is now being used in the Bell System. It was crucial to the development of the new 652A low-noise pre-amplifier. This amplifier permits the circuit-loading capacity of the TD-2 long distance microwave radio system to be increased from 1,200 to 1,500 voice circuits per channel without the need to increase power. It serves five channels simultaneously and requires no major changes in the system.

Manufacture of the high-power device is scheduled to begin at Western Electric's Reading Works in the fourth quarter of this year. Currently, power amplifiers for TD-2 systems use three vacuum tubes, one of which must be replaced after less than one year of operation. Introducing the specially designed high-power GaAs FETs in the new 660A power amplifier is expected to substantially improve reliability and lower maintenance costs. After successful field trials, the 2-watt 660A is now scheduled to go into full-scale production. In the near future, a 5-watt version of the 660A, using improved GaAs FETs, will allow an additional increase of TD-2 channel capacity to 1800 voice circuits per channel without sacrificing system reliability.





C



D

For conventional microwave applications, the GaAs FET is expected to displace all other active solid-state devices operating at frequencies of 4 to about 25 gigahertz. GaAs FETs will soon begin replacing some bipolar transistors, Gunn and IMPATT diodes, tunnel diodes, and parametric amplifiers.

For applications in low-noise microwave amplifiers, GaAs FETs have advantages besides high gain and low noise. They also have a longer lifetime and allow simpler circuitry than do comparable devices. For power amplifiers, the GaAs FET is more powerful and efficient than other solid-state devices, and its linearity (accuracy with which output signal reproduces input signal) is superior. Compared to vacuum tubes, of course, it is much smaller and can operate at lower voltages.

In addition, the GaAs FET can serve as an oscillator, modulator, or logic element with switching speeds possibly as fast as 10 pico-seconds. Such speeds — five to ten times faster than those possible with conventional devices — suggest that the GaAs FET may be used as a building block for integrated circuits operating at data rates of many billions of bits per second. At present, however, gallium arsenide substrates are not as large as silicon substrates. This means that GaAs integrated circuits would cost three to four times more than comparable silicon integrated circuits.

At present about 70 percent of all long-distance traffic is transmitted by means of microwaves. So it is clear that the immediate impact of GaAs FETs will be strongest on microwave transmission systems. Already low-noise and high-power GaAs FETs are helping to upgrade microwave systems, and these improvements are being realized at extremely low cost. In addition to enhancing the capabilites of present equipment, GaAs FETs can be expected to reduce the size, weight, and cost of future high-frequency electronic equipment.

In Brief

AUSTRALIAN INVITED TO TENDER ON EGYPTIAN AND SRI LANKA TELECOMMUNICATIONS PROJECTS

Member companies of the Australian Telecommunications Development Association have been invited to tender on two large international telecommunications projects.

The Executive Director of ATDA, Mr T. E. Hodgkinson, said one project was in Sri Lanka and was valued at about $30 million.

To be funded by the International Development Association, the Sri Lanka project was intended to improve telecommunications facilities in that country by providing the replacement of worn and outdated manual exchange equipment, additional telephone lines and the installation of public call offices in rural areas.

Tenders have also been called for the installation of a modern telecommunications system which will enable direct dialling to major towns in Northern, Central, North Western and Sabaragamurwa provinces of Sri Lanka.

In Egypt, said Mr Hodgkinson, tenders have been called by the Egyptian Telecommunications Authority, for the supply, delivery and installation of a 421 km complete coaxial cable project from Alexandria to Port Said.

This will require a multiplex line coaxial cable, all associated trunk testing boards, hybrids, all necessary installation and testing equipment and routine maintenance, and auxiliary spare parts for five years.

The cable itself is to be of lead alloy sheath, polythene protected, with steel tape armour where cable has to be buried and with appropriate anti-corrosion protection where river crossings are involved.

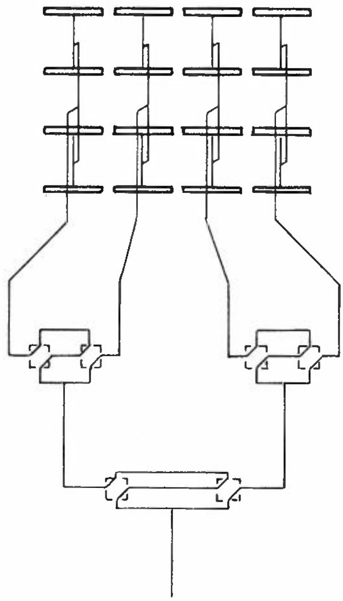
Erratum — Vol. 29, No. 1

FROM CYCLONE "TRACY" TO RADIO AUSTRALIA, CARNARVON.

As an example of how the best laid plans of editors can go awry, an illustration in Giff Hatfield's article on Radio Australia in Volume 29, No. 1, appeared upside down.

Figure 4 — Antenna Schematic Configuration, on p. 17, should have been more logically presented with the antenna elements at the top as shown here.

We apologise for any confusion this may have caused.



Financial Aid for Telecommunications Projects in Developing Countries

M. J. PRIEST, B.Sc.(Hons.), M.Eng.Sc., M.I.R.E.E. and S. A. CHAPMAN, B.Econ.

Over the last decade large sums of money in direct aid or in 'soft' loans from the World Bank have been provided for Telecommunications Projects in under-developed countries. This article examines the international distribution of telephones and their relationship to population and G.D.P. per head of population. The activities of the World Bank in Telecommunications are reviewed and Australia's involvement in these projects is discussed. Comments are made on some of the practical difficulties encountered in their implementation.

INTRODUCTION

The expansion of Telecommunications facilities plays an important part in the effective administration required for economic growth in underdeveloped nations. This article demonstrates the correlation between telephone density and gross national product per inhabitant and describes the investment activities of the organisations constituting the 'World Bank' in Telecommunications projects for the Third World.

The involvement of Australian Telecommunications personnel in these projects is discussed.

WHY TELECOMMUNICATIONS AID?

Without efficient Telecommunications facilities government and commercial activity cannot function effectively. In those parts of an underdeveloped economy without access to communications economic growth is severely limited. The expansion of Telecommunications facilities encourages economic development in two main ways:-

- By reducing the cost of overcoming the distance between markets (Face-to-face trading is a high cost method of marketing), markets are linked and enlarged. The expansion of markets reduces costs further, increasing real income and stimulating demand.
- By improving the efficiency of both business and government administration for low cost in a way (telephone) that does not require the receiver to be literate.

The number of telephones per 100 inhabitants ranges from 70 in the U.S.A. to 0.1 in Burma. In developing countries telephone expansion has generally lagged behind development in other areas, but recently there has been a trend towards faster growth. This is partly due to the expansion of loans from the World Bank for Telecommunications purposes. Aid for economic development is now on more co-ordinated basis, and the 'utilisation factor' which links the number of telephones to a value of $U.S.100,000 of gross national product has been extensively applied in international financing studies in Asia. (Ref. 1).

INTERNATIONAL PERSPECTIVE

In 1976 there were an estimated 380 million telephones in the world. The distribution of telephones is shown in **Table 1**.

A number of telephone density statistics are now used by aid authorities as indicators of economic activity. The now well-established relationship between telephone density and gross national product (G.N.P. or G.D.P.) per head of population is demonstrated in **Table 2.**

THE WORLD BANK

This is a group of three institutions; The International Bank for Reconstruction and Development (I.B.R.D.), the International Development Association (I.D.A.) and the International Finance Corporation (I.F.C.). The aim of these institutions is to channel resources from the developed world to the developing countries.

The Bank's Loans are directed towards developing countries which are at a more advanced stage of economic development than most of the 'Third World'. This is because the Bank's charter states "that it must lend only for productive purposes, that it must pay due regard to the prospects of repayment, that each loan must be made to a Government or must be guaranteed by the Government, and its decisions to lend must be based only on economic considerations." Bank loans generally have a grace period of five years and are repayable over 20 years or less. The interest rate is calculated in accordance with a formula related to its cost of borrowing.

Because Bank loans impose too great a cost on the balance of payments of the poorer developing countries,

Region	Number of Telephones (Millions)	% of World Population	% of Total Telephones	Telephones/100 Population
Africa	4.6	10%	1.2%	1.1
Nth. America	166.9	6%	44%	47.1
Sth. America	9.2	8%	2.4%	4.1
Asia	57.4	57%	15%	2.6
Europe	118.2	12%	31%	24.6
Oceania	7.1	0.5%	1.8%	35.1
U.S.S.R.	16.9	6%	4.4%	6.6
World	379.5	100%	100%	Aver. 9.6/100

Table 1: Distribution of Population, Telephones

the I.D.A. was established in 1960 to provide loans for the same purposes as the bank. I.D.A. loans are concentrated on those countries with an annual G.D.P. per capita of less than $U.S.520 (1975). More than 50 countries are at present eligible for I.D.A. assistance. The terms of I.D.A. loans, which are made to governments only, are:- 10 years grace periods, 50 year repayment period and no interest. But an annual service charge of 0.75% is made on the disbursed portion of each loan.

The I.F.C., established in 1956, aims to assist the developing countries by promoting growth in the private sector and helping to mobilise domestic and foreign capital for this purpose.

Recent trends in Bank lending for Telecommunications projects are shown in **Table 3.**

World Bank 'soft' loans to developing countries include conditions to assist in securing their investment and to promote self-assistance schemes. This requires Governments to engage Telecommunications and management consultants to administer the project and, in some cases, to set the administrative authority on a sound commercial basis.

By 1976 total World Bank financing of Telecommunications projects had reached a cumulative total of $U.S.1,034M. The total Bank loans of $609M were distributed as shown in **Table 4.**

In addition I.D.A. credits of $425M had been made, giving a cumulative total of $1,034M.

Country	G.D.P./HEAD $U.S.	Telephones/100
Algeria	709	1.4
Ethiopia	97	0.3
Sth. Africa	1340	7.8
Canada	6995	57.2
U.S.A.	7086	69.5
U.K.	4090	37.9
Chile	690	4.5
Iraq	1634	1.7
Israel	3608	23.1
Indonesia	125 (1973)	0.2
Japan	4132	40.5
France	6360	26.2
Sweden	8459	66.1
AUSTRALIA	6364	39.0
Fiji	998	5.0
Papua, N.G.	557 (1973)	1.3
India	137	0.3
Burma	101	0.1

Table 2: Examples of G.D.P./Head and Telephone Density

EXAMPLES OF RECENT PROJECTS

Burma — I.D.A. $U.S.21M. The investment provides for an extension of Rangoon's telephone network and upgrading of the trunk lines between the capital and provincial centres. Rangoon's network will be extended from 17,000 lines to 25,000; 12 additional terminal exchanges will be added to the network and a backbone microwave network will be installed. In addition, an earth station will provide improved international telephone and telex capability via the Intelsat IV Indian Ocean Satellite.

These improvements represent a most significant step forward for Burma's telecommunications facilities and will go some way towards reducing Burma's international isolation. Exchange contracts have been let to Japan's Nippon Electric and L. M. Ericsson (Sweden). Golden Star Cable (Korea) and Ericssons are providing underground cable and the microwave contract was awarded to Fujitsu (Japan).

1974			1975			1976			1977			1978		
Bank	IDA	Total	Bank	IDA	Total	Bank	IDA	Total	Bank	IDA	Total	Bank	IDA	Total
66.5	41.4	107.9	96.0	103.0	199.0	59.0	5.2	64.2	140.0	-	140.0	153.6	67.5	221.1

Table 3: Total World Bank Aid for Telecommunications $U.S. Millions

E. Africa	W. Africa	Middle East N. Africa	S. America	S.E. Asia Pacific	Asia
$88M	$47M	$136M	$221M	$94M	$23M

Table 4: Distribution of Bank Loans for Telecommunications

MICHAEL PRIEST was educated in the U.K. where he graduated with an Honours Degree in electrical/electronic engineering in 1969. Industrial training as part of a sandwich course was undertaken with G.E.C./A.E.I. (Telecommunications) Ltd. He completed a post graduate apprenticeship and was subsequently employed by the company as a telecommunications systems commissioning engineer. In 1970 he joined the Australian Post Office as Engineer 1 in the Sydney Metropolitan Branch. From 1971 to 1975 he was Engineer class 2 in Transmission and Lines Planning (Metropolitan). Following part-time studies at the University of NSW during 1971/72 he graduated Master of Engineering Science. Since 1975 he has been employed by the NSW Department of Technical and Further Education in the Division of Electronics and Communications. Part-time study for the Graduate Diploma in Technical Education was completed in 1977. He has recently undertaken consultancy work on overseas aid projects involving planning of telecommunications networks in the light of local economic factors.

STEPHANIE CHAPMAN attended school in Katoomba NSW and graduated B. Econ. from Sydney University in 1965. She was subsequently employed as credit manager in a large retail store and as a tutor at the University of Tasmania. Since 1975 she has been a teacher of economics with the Department of Technical and Further Education, NSW. In 1977 she completed a Graduate Diploma in Technical Education at Sydney Teachers College. Mrs. Chapman has an active interest in the economies of developing nations and has recently contributed to several projects in telecommunications economics.

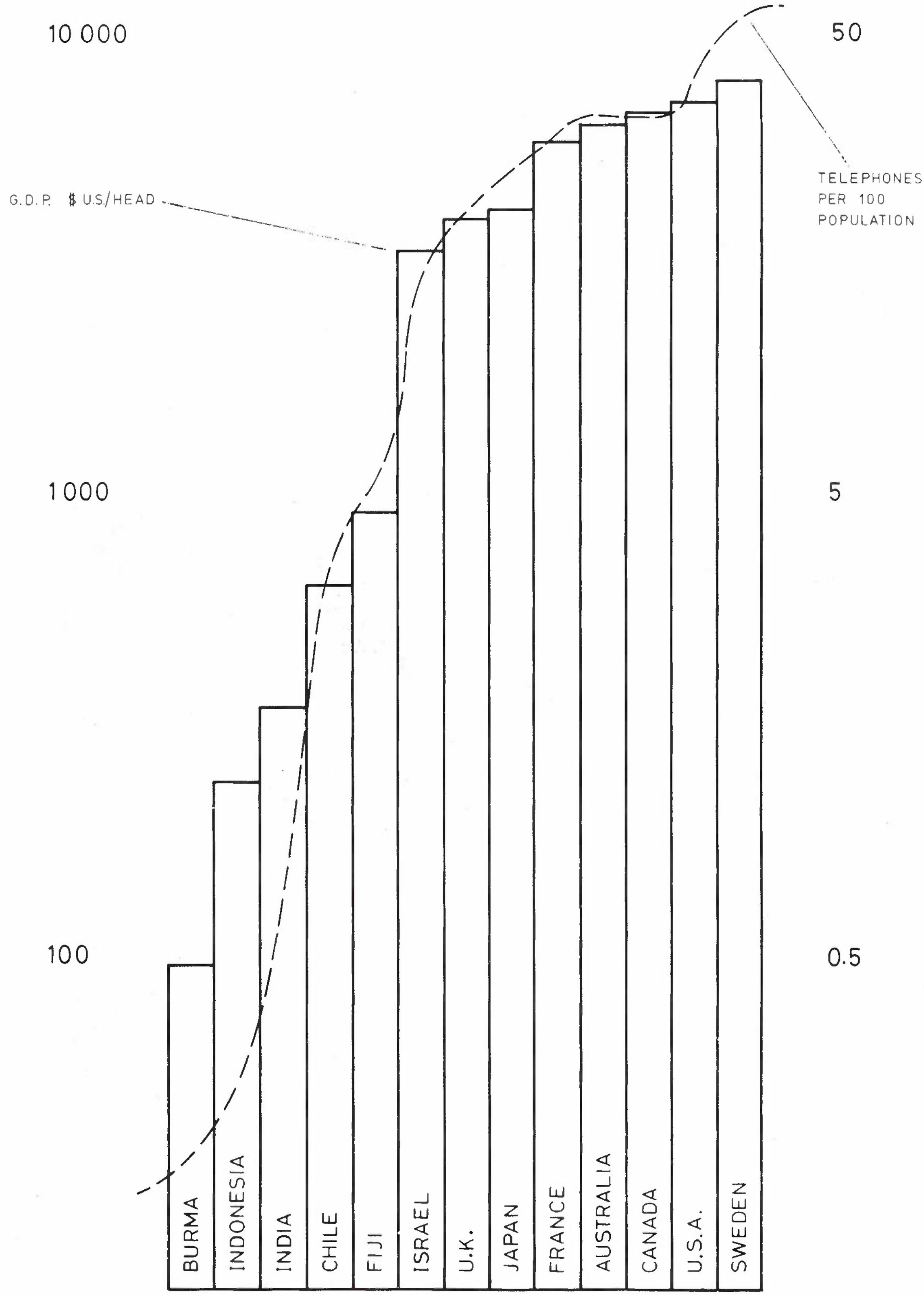


Fig.1: Correlation Between G.D.P./Head and Telephone Density

The funding of this project by the World Bank is of some further interest considering the pro-Peking alliance of the ruling Burma Socialist Programme Party.

Zambia: Exchange equipment will be installed in 60 towns, including 32 that at present have no telephone facilities. The capital, Lusaka, will be linked by microwave radio with main provincial centres. Total cost — $78M.

Other major projects in progress during 1978 include:-

Egypt **—** $30M of Bank loan in projects costing $178M (rehabilitation and development of the Egyptian network is also aided by large loans from Saudi Arabia).

Ghana **—** $23M

Guatamala **—** $26M

Columbia **—** $15M

The World Bank and the I.D.A. have played a significant part in the development of the Papua New Guinea Telecommunications Network. Following a national investment survey, a loan of $U.S.7M specifically for Telecommunications was made in 1967.

AUSTRALIAN INVOLVEMENT IN TELECOMMUNICATIONS AID

This generally consists of the provision of professional Engineering expertise and project management, often including the establishment of training facilities for local staff. Some manufacturing of specialist equipment has been involved in recent radio and broadcasting projects. The geographical extent of Australian Aid is largely restricted to the S. E. Asia and Pacific regions, particular projects are determined by the Department of Foreign Affairs with regards to strategic implications within the region. This usually is instigated by a request for aid from the country concerned, or via the I.D.A. (World Bank).

Australia's overseas aid is administered by the Australian Development Assistance Bureau (A.D.A.B.). Telecom Australia is at present associated with A.D.A.B. on two projects. The Australian Telecommunications Mission in Indonesia (A.T.M.) is involved in the planning of the national telephone network and Telecom is providing engineering staff and equipment. The team is responsible for installing, testing and commissioning trunk and local exchanges in Sumatra, and also supervises aspects of the World Bank financed Trans-Sumatra Microwave System. (See Ref. 6). The total estimated cost will be $14.5M.

The Regional Telecommunications Training Centre in Suva is a joint South Pacific Bureau for Economic Cooperation (S.P.E.C.), International Telecommunications Union (I.T.U.) and the Fijian Government project. It is an ongoing programme to train communications technicians for the South Pacific. Australia provides technician teaching staff and equipment.

During 1977/78 nine officers of O.T.C. were on loan to national and international telecommunications organisations, including five to the Papua New Guinea Department of Public Utilities. A course in submarine cable systems was conducted in Madang for that Department. Two O.T.C. officers were made available to the Tongan administration for specialist installation work. Training in a wide range of topics in Telecommunications was provided for personnel from Kenya, Tanzania and Uganda. O.T.C. also accepted a number of fellowship holders under Australian development assistance or I.T.U. programmes from India, Korea and Saudi Arabia.

The Australian Department of Posts and Telecommunications is currently involved in projects in Pakistan and the Solomon Islands. This involves the provision of low power broadcasting stations to serve rural areas for agricultural extension and community education purposes in Pakistan (total cost — $A670,000). For the Solomon Islands 22 single sideband Marine Transceivers are being provided to improve communications facilities on Government ships (total cost — $A43,000).

Other government departments are involved directly in Telecommunications aid projects in Bangladesh, Cook Islands, Fiji and Tonga. Assistance was requested from Bangladesh for the rehabilitation of H. F. transmitting and receiving equipment for overseas telecommunications and the development of local operational and maintenance skills. The Department of Transport (Air Transport Group) have responsibility for this project (total cost — $A165,000). Also in Bangladesh the Australian Broadcasting Commission is upgrading the studio facilities of Radio Bangladesh by supplying equipment and training at a total cost of $A466,000.

Projects currently undergoing project analysis, include

Papua New Guinean staff in Sydney for Submarine Cable Jointing Instruction.

(photo, courtesy of O.T.C.)

the upgrading of the Tongan Telephone System by installation of a crossbar exchange on the main island of Tongatapu to replace the existing manual exchange. Study groups are involved in the New Hebrides where a design study of a telecommunications network linking the main administrative centres of the New Hebrides is in progress. In the Cook Islands there is a study of alternative methods of improving telecommunications in isolated islands of the northern group.

The Australian Government has played a major role in assisting the growth of Papua-New Guinea's telecommunications network. In addition to the provision of management assistance and technical personnel, Australia sponsored Papua-New Guinea as a partner in the Commonwealth Telecommunications Organisation providing international telephone links for Papua-New Guinea via the SEACOM cable. At independence, (1973), Australia provided a Government loan ($A.1M) and grant in aid ($A0.5M) to allow Papua-New Guinea to purchase the O.T.C. assets.

THE AIMS OF TELECOMMUNICATIONS AID AND TRAINING

An I.T.U. seminar of Latin American countries took place in Quito Ecuador in 1974. The report is a declaration of objectives for the development of rural telecommunications in developing countries. A major part of the report deals with the need for tutorial assistance, management aid and training schemes for technical staff.

Partly as a result of this seminar, a new C.C.I.T.T. handbook on Rural Telecommunications is being prepared by a working party under the chairmanship of Mr. C. Rudilosso of the Italian administration.

SOME PROBLEMS ENCOUNTERED IN DEVELOPING COUNTRIES

The extension of Telecommunications facilities in developing countries is likely to be hampered by one or more of the following conditions:

- Scarcity of primary power;
- Climatic problems affecting equipment life;
- Topographic obstacles and lack of access roads;
- Scarcity of locally available technical personnel;
- Economic constraints — restrictions on investments and service costs subsidies. High construction and operating costs together with low economic capacity of the users.

Any major project in a developing country produces its own unique set of difficulties. A.T.M. staff in Indonesia have experienced the need for tiger-proof shelters and the necessity to transport local staff from site to site when petrol funds are exhausted. (Ref. 6).

In India a number of modifications to crossbar exchange equipment became necessary due to the high traffic and low average conversation time. Cross-bar equipment, well-proven in North America and Europe, produced high failure rates in Calcutta where, due to the low telephone density, queueing for the use of all telephones is commonplace. This resulted in an unprecedented load on the common control elements and premature register failures.

An outcome of this experience is a system referred to as 'Indian Crossbar' — a modified B.T.M. (Belgium) System, which may be suitable for other developing countries with a low telephone penetration and a high calling rate.

CONCLUSION

The three organisations constituting the 'World Bank' contribute to the telecommunication facilities of developing countries and hence to their commercial activity, economic growth and life-style.

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Changes in Subscriber Trunk Dialling Charging Facilities

T. S. WONG, B.Sc., B.E., C.Eng., M.I.E.E.

This paper describes the introduction of new subscriber trunk dialling (STD) tariff equipment to upgrade the STD tariff equipment in minor and secondary crossbar switching charging centres.

The following apsects of charging for STD calls are described:

- A general outline of Telecom Australia STD tariff structure.
- An examination of new tariff equipment and comparison with earlier tariff equipment.
- New tariff facilities which are available for the benefit of both Telecom Australia and user.

Some unique installation and maintenance aspects of the new STD tariff equipment are also covered in the paper.

INTRODUCTION

Telephone communications have been with us for just over a century. They have progressed from the very elementary telephone invented by Dr Alexander Graham Bell in 1876 to the latest technology of stored programme controlled switching. The aim of telephone communication is to provide a facility to the public for voice frequency communication. Charges for use of the facility are generally applied in accordance with the principle that the user pays for costs. Application of the principle in practice is not as simple as might be imagined as many factors have to be considered and weighed to determine a suitable tariff structure for a complex telecommunications system.

Telecom has recently upgraded the STD charging equipment in its charging centres so as to have much more flexibility in managing the tariff structure.

AUSTRALIAN SWITCHING AND CHARGING PLANS

Switching Plan

The Telecom switching network has been planned to exploit switching facilities in a systematic manner. The switching hierarchy is defined in National Trunk Network Planning Letter No. 3 as follows:

- A Terminal Exchange is an exchange which performs no through-connection of calls on inter-exchange circuits.
- A Minor Switching Centre switches calls on the final routes for terminal exchanges only.
- A Secondary Switching Centre switches calls on the final routes for minor switching centres and also, if required, terminal exchanges.
- A Main Switching Centre switches calls on the final routes from secondary switching centres and also, if required, minor switching centres and terminal exchanges.

Charging Plan

Broadly the charging for telephone calls is dependent upon three main factors:

- the distance
- the time of the day
- the duration of the call

When calls were manually switched, charging was generally performed by writing dockets. As automatic switching systems have been introduced the charging function has also been automated.

In conjunction with the development of a national switching plan, it has been necessary to develop a complementary national charging plan. Telephone exchanges are grouped into charging zones which are in turn grouped into charging districts for the purpose of calculating call charges. The charge for STD calls between any two exchanges is then calculated on the following bases:

- Zone Basis — A district normally consists of a number of zones. Calls within a district or between adjacent districts are charged at STD rates based on the distance between zone centres. Calls within a zone or between adjacent zones are charged as local or unit fee calls.
- District Basis — Non adjacent district calls are charged at STD rates based on the distance between district centres.

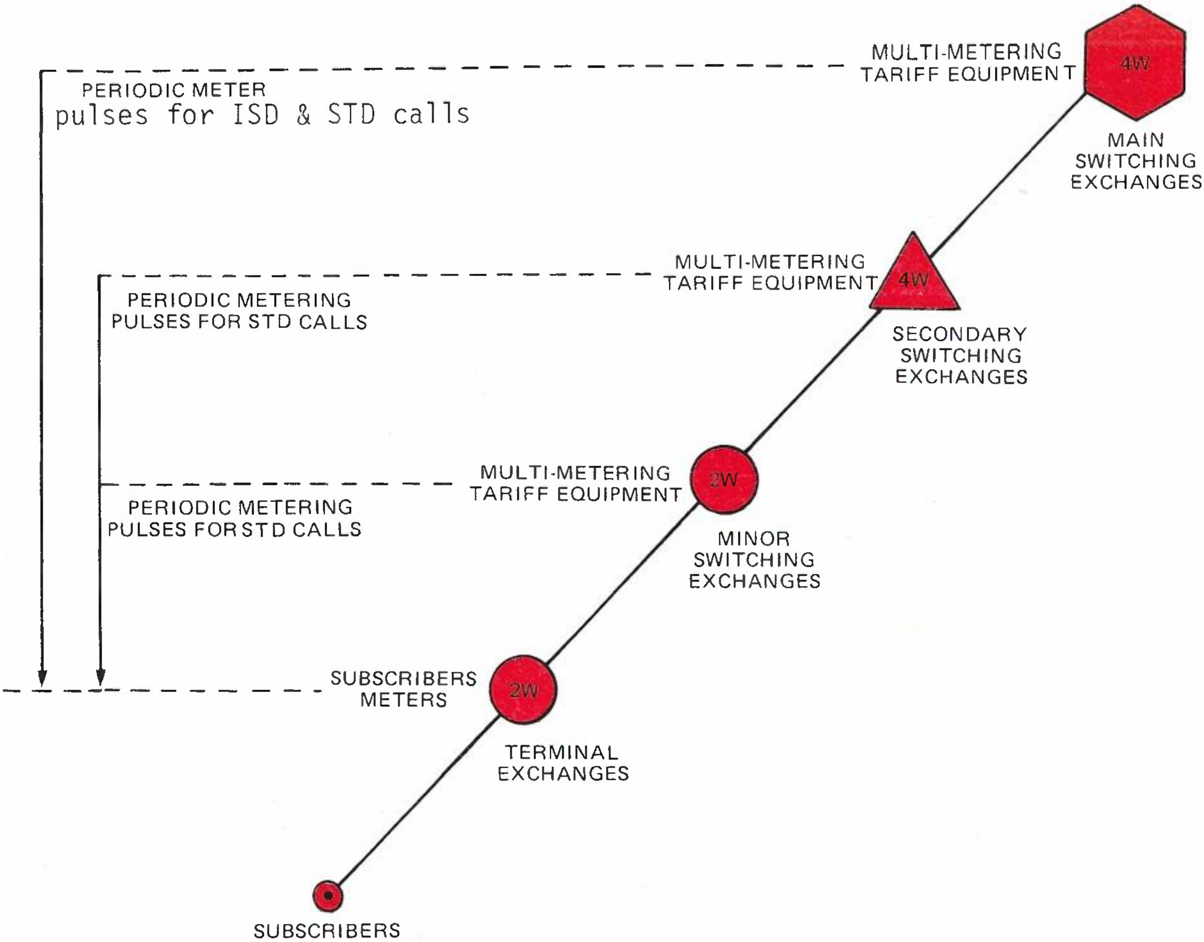

Fig. 1 — National Telephone Switching Plan and Multi-metering Equipment Arrangements.

T. S. WONG, graduated with a B.Sc. from the Nanyang University, Singapore in 1963 and a B.E. from University of Canterbury, New Zealand in 1967. He joined Telecom Department, Malaysia for three and a half years and was engaged with telephone switching equipment installation and maintenance and was responsible for setting up a Telecom Training School in conjunction with the ITU in 1970. In 1971 he joined the Postmaster-General's Department as Engineer Class 1 at Headquarters. During the next three years he was attached to Data and Telegraph Equipment Branch engaged in datel equipment, data transmission and the C.U.D.N. project. In 1974 he was promoted to Engineer Class 2 in Telephone Switching Construction Branch, Headquarters. He spent about one year in co-ordination of installation and implementation of the Interim Tariff Scheme during 1976 and 1977. At present, he is engaged on the ISD/AMA project on commissioning tests and implementation.

CHARGING CENTRES

The four classes of switching centre used in the Telecom's switching network are shown in **Fig. 1**. Minor switching centres, secondary switching centres and main switching centres are all equipped with multimetering facilities. The number of charging centres in each State is shown in **Table 1**.

STATE	MINOR SWITCHING CENTRE	SECONDARY SWITCHING CENTRE	TOTAL
NSW	63	12	75
VIC	46	8	54
QLD	35	7	42
SA	26	4	30
WA	21	5	26
TAS	3	3	6

Table 1 — Number of Charging Centres With New Tariff Equipment in 1977

TARIFF STRUCTURES

Multi-metering

Telecom employs a modified Karlsson method for metering of STD calls. The calling subscriber's meter operates once, immediately on B-party answer. Then meter pulses at regular intervals are applied, except that the first of the regular pulses is suppressed so that the interval between the meter pulse at B-party answer and the next meter pulse will be equal to or greater than the regular meter pulse period. The periodicity of the regular meter pulses is determined by the particular tariff rate and charge scale applicable to the call.

Automatic Charging Equipment

The automatic charging equipment at charging centres determines the charge for STD calls by reference to the following parameters:

- Charge scale — This is set according to the time of day. The periodicity of the metering pulses on each tariff rate depends on which charge scale has been set.
- Tariff rate — There are 8 possible charge steps or tariff rates which may be set for each call in accordance with the charging plan.
- The duration of call.

The charging equipment compares the B-party's number with the A-party's zone of origin and determines the tariff rate applicable. The line signalling repeater over which the call is connected through the charging centre is then set to that tariff rate. After B-party answer, metering pulses are sent to line via the line signalling repeater. The periodicity of the metering pulses is a function of the tariff rate and the charging scale in operation at the particular time of day.

CHANGES TO TARIFF STRUCTURE

The original tariff equipment introduced with the crossbar system at charging centres provided two charge scales, day and night. For each charge scale there were 7 tariff rates in addition to unit fee and non-chargeable calls. Metering pulses were derived from a basic one second pulse source. Metering periodicities were all multiples of the basic one second pulse source. In 1973 Telecom commenced development of a more flexible STD tariff structure. Under this project, which was completed in June 1977, the Tariff equipment in charging

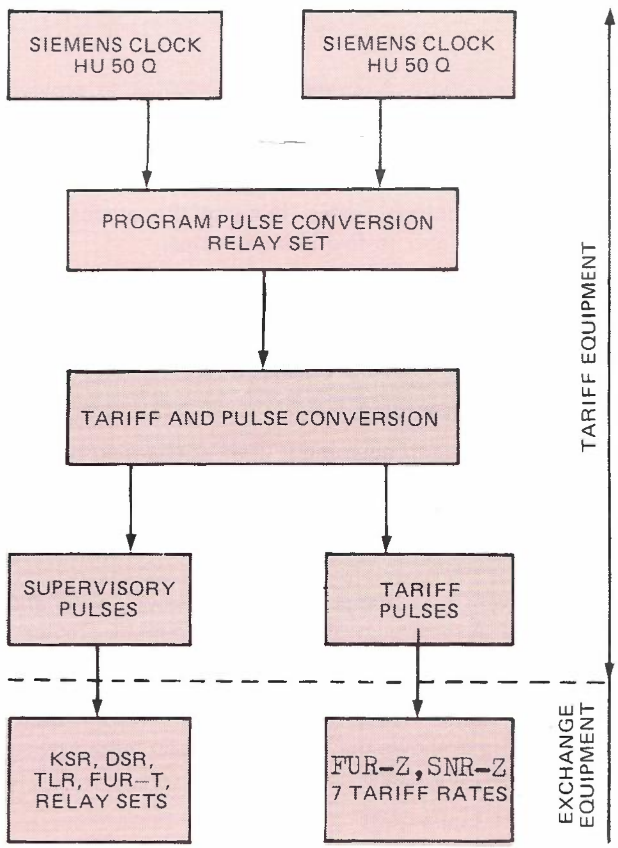

Fig. 2 — Pulse and Tariff Distribution

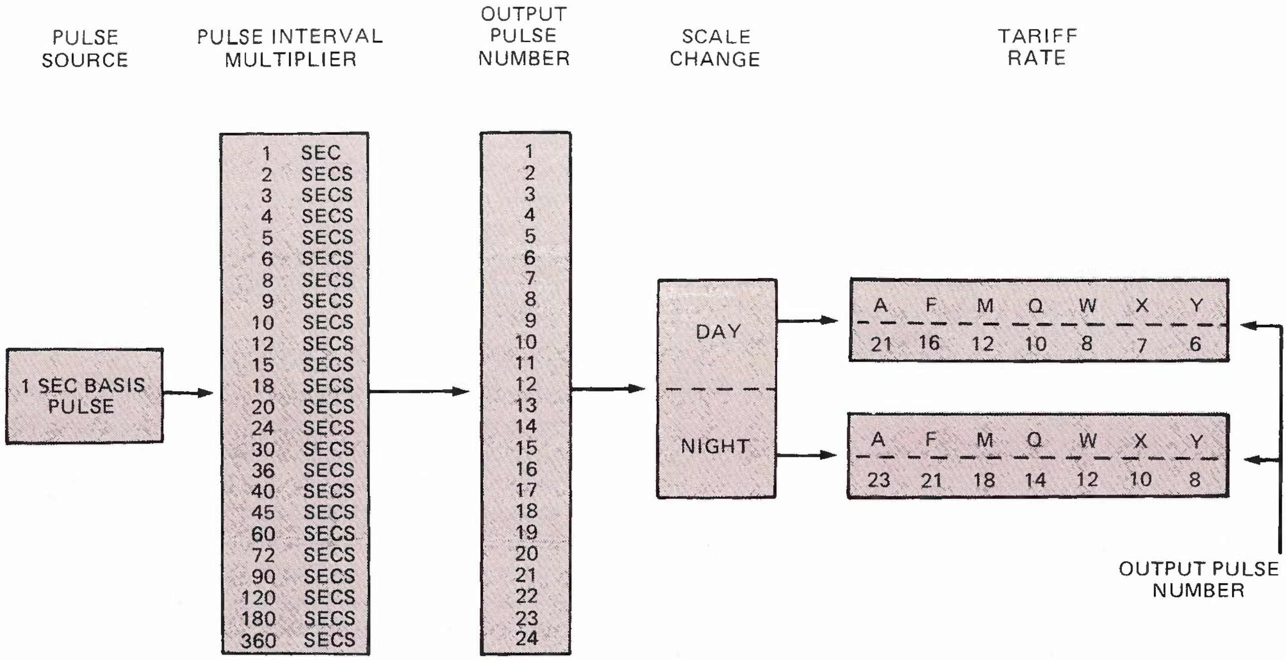

Fig. 3 — Day and Night Scale and Tariff Rates Prior to New Tariff Structure

centres throughout Australia was upgraded to provide the following additional facilities.

- An extra multi-metering rate, bringing the original 7 rates to 8 rates.
- Three extra charge scales, bringing the original two scales (day/night) to five charge scales.
- A variable basic pulse source to replace the original one second basic pulse. This enables multimetering pulses to be set over a much wider range.

CHANGES TO TARIFF EQUIPMENT

Early Tariff Equipment

The original tariff equipment used at charging centres consisted mainly of electro-mechanical components. A block diagram of Pulse and Tariff Distribution equipment is shown in **Fig 2** for a REG-ELP/H4 Minor Switching Centre.

There were two charge scales, namely day scale and night scale. A maximum of eight rates could be provided for each charging scale, however, only seven rates were ever used. A time clock provided a one second basic pulse from which was derived 24 periodic rates. A block diagram, **Fig 3** shows the relation between output pulse number and tariff rates.

New Tariff Equipment

The interim tariff scheme retains most of the original electromechanical tariff equipment with minor modifications and some additional solid state equipment to provide the new facilities. An additional rack is provided for accommodation of an electronic shelf, and its associated components **(Fig. 4)**.

A block diagram, **Fig. 7**, shows the major components of the new tariff equipment for minor and secondary switching exchange charging centres. An explanation of each block is given in **Appendix 1**.

10C Trunk Exchange STD Tariff Structure

Most 10C Trunk exchanges operate as Main Switching Centres and handle charging for International Subscriber Dialled calls as well as STD calls. The metering of STD and International Subscribers' Dialling calls is controlled by software in 10C exchanges. The existing 10C programs do not match the full range of options provided by the new charging equipment in other charging centres.

The shaded area in **Table 2** indicates the charging rates available in crossbar tariff equipment which are not available in 10C Trunk Exchange. The 10C software is being revised to provide the same facilities as the new crossbar tariff equipment.

USING THE NEW TARIFF EQUIPMENT

Setting the Basic Pulse (Table 2)

The selection can be made from basic pulses within the range of 0.8 to 6.0 secs. A basic pulse interval must be chosen for each of the 5 possible charging scales.

Output Number	Basic Pulse / Multi Factor	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	5.7	5.8	5.9	6.0
1	1	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	5.7	5.8	5.9	6.0
2	2	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0	11.4	11.6	11.8	12.0
3	3	2.4	2.7	3.0	3.3	3.6	3.9	4.2	4.5	4.8	5.1	5.4	5.7	6.0	17.1	17.4	17.7	18.0
4	4	3.2	3.6	4.0	4.4	4.8	5.2	5.6	6.0	6.4	6.8	7.2	7.6	8.0	22.8	23.2	23.6	24.0
5	5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	28.5	29.0	29.5	30.0
6	6	4.8	5.4	6.0	6.6	7.2	7.8	8.4	9.0	9.6	10.2	10.8	11.4	12.0	34.2	34.8	35.4	36.0
7	8	6.4	7.2	8.0	8.8	9.6	10.4	11.2	12.0	12.8	13.6	14.4	15.2	16.0	45.6	46.4	47.2	48.0
8	9	7.2	8.1	9.0	9.9	10.8	11.7	12.6	13.5	14.4	15.3	16.2	17.1	18.0	51.3	52.2	53.1	54.0
9	10	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	57.0	58.0	59.0	60.0
10	12	9.6	10.8	12.0	13.2	14.4	15.6	16.8	18.0	19.2	20.4	21.6	22.8	24.0	68.4	69.6	70.8	72.0
11	15	12.0	13.5	15.0	16.5	18.0	19.5	21.0	22.5	24.0	25.5	27.0	28.5	30.0	85.5	87.0	88.5	90.0
12	18	14.4	16.2	18.0	19.8	21.6	23.4	25.2	27.0	28.8	30.6	32.4	34.2	36.0	102.6	104.4	106.2	108.0
13	20	16.0	18.0	20.0	22.0	24.0	26.0	28.0	30.0	32.0	34.0	36.0	38.0	40.0	114.0	116.0	118.0	120.0
14	24	19.2	21.6	24.0	26.4	28.8	31.2	33.6	36.0	38.4	40.8	43.2	45.6	48.0	136.8	139.2	141.6	144.0
15	30	24.0	27.0	30.0	33.0	36.0	39.0	42.0	45.0	48.0	51.0	54.0	57.0	60.0	171.0	174.0	177.0	180.0
16	36	28.8	32.4	36.0	39.6	43.7	46.8	50.4	54.0	57.6	61.2	64.8	68.4	72.0	205.2	208.8	212.4	216.0
17	40	32.0	36.0	40.0	44.0	48.0	52.0	56.0	60.0	64.0	68.0	72.0	76.0	80.0	228.0	232.0	236.0	240.0
18	45	36.0	40.5	45.0	49.5	54.0	58.5	63.0	67.5	72.0	76.5	82.0	85.5	90.0	256.5	264.0	265.5	270.0
19	60	48.0	54.0	60.0	66.0	72.0	78.0	84.0	90.0	96.0	102.0	108.0	114.0	120.0	342.0	348.0	354.0	360.0
20	72	57.6	64.8	72.0	79.2	86.4	93.6	100.8	108.0	115.2	122.4	129.6	136.8	144.0	410.4	417.6	424.8	432.0
21	90	72.0	81.0	90.0	99.0	108.0	117.0	126.0	135.0	144.0	153.0	162.0	171.0	180.0	513.0	522.0	531.0	540.0
22	120	96.0	108.0	120.0	132.0	144.0	156.0	168.0	180.0	192.0	204.0	216.0	228.0	240.0	684.0	696.0	708.0	720.0
23	180	144.0	162.0	180.0	198.0	216.0	234.0	252.0	270.0	288.0	306.0	324.0	347.0	360.0	1026.0	1044.0	1062.0	1080.0
24	360	288.0	324.0	360.0	396.0	432.0	468.0	504.0	540.0	576.0	612.0	648.0	684.0	720.0	2052.0	2088.0	2124.0	2160.0

Table 2 — Meter Pulse Chart — Shaded Area Indicates Charging Rates Currently Unavailable in 10C Trunk Exchanges.

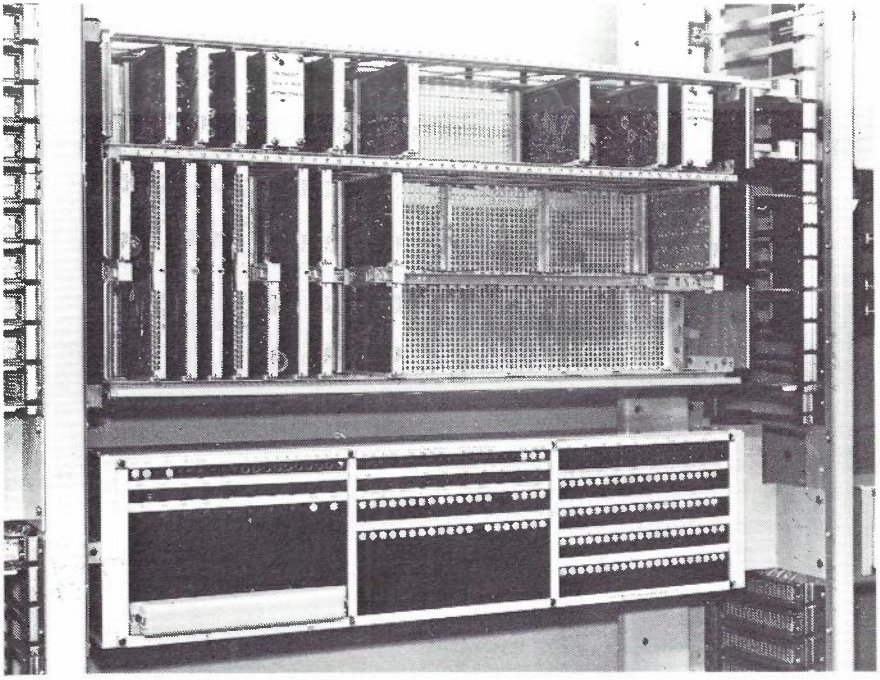

Fig. 4 — Front View of Electronic Shelf

Setting the Combination of Tariff Rates

Once the basic pulse has been decided a combination of 8 multiplication factors must be chosen from the 24 available for each charging scale. A maximum of 3 combinations of multiplication factors may be chosen with new tariff equipment. If more than three charging scales are being used, then one or more combinations of 8 multiplication factors must be repeated. **Fig. 5** shows the 4 charge scales used by Telecom since November 1978 for charging STD calls.

INSTALLATION

The installation of interim tariff scheme equipment commenced in June 1976 and was completed in June 1977 by the Construction Branch of each State, under the general co-ordination of Telephone Switching Construction Branch, Headquarters. To provide the technical expertise required to ensure that every installation was completely fault free, each State set up a number of special installation teams. These teams consisted of two to three technical personnel led by a technical officer.

A new BDH rack especially designed to house electronic equipment was installed in each charging centre, together with new cabling. Minor modifications were made to the existing tariff equipment. The new BDH rack is physically similar to conventional crossbar equipment racks and is illustrated in **Fig. 6**.

MAINTENANCE

Testing

The introduction of the new electronic rack into crossbar exchanges necessitated a new approach to maintenance techniques. For example, multimeters with low internal impedance and test lamps are quite inappropriate for testing the electronic equipment. A multi-

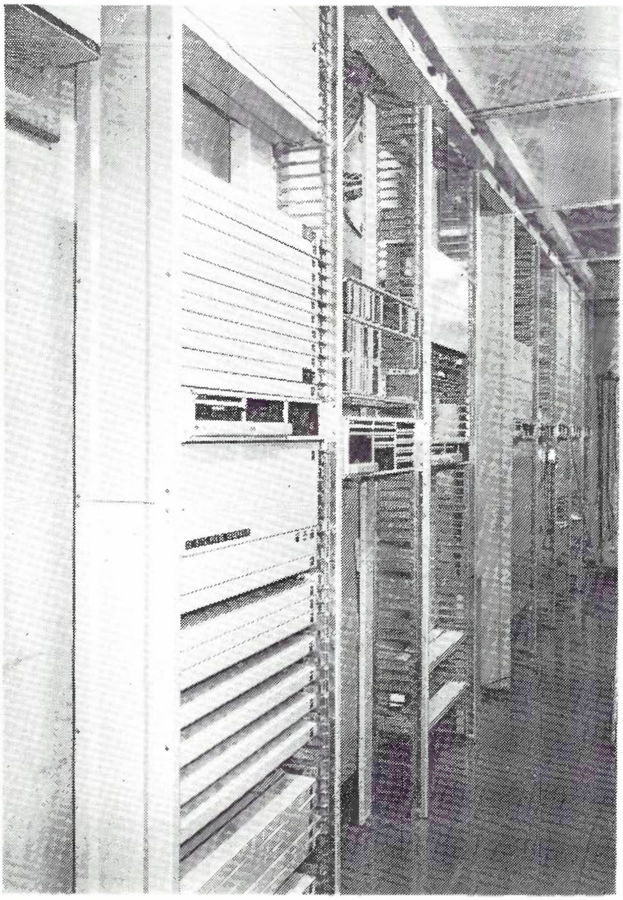

Fig. 6 — New Tariff Equipment Racks

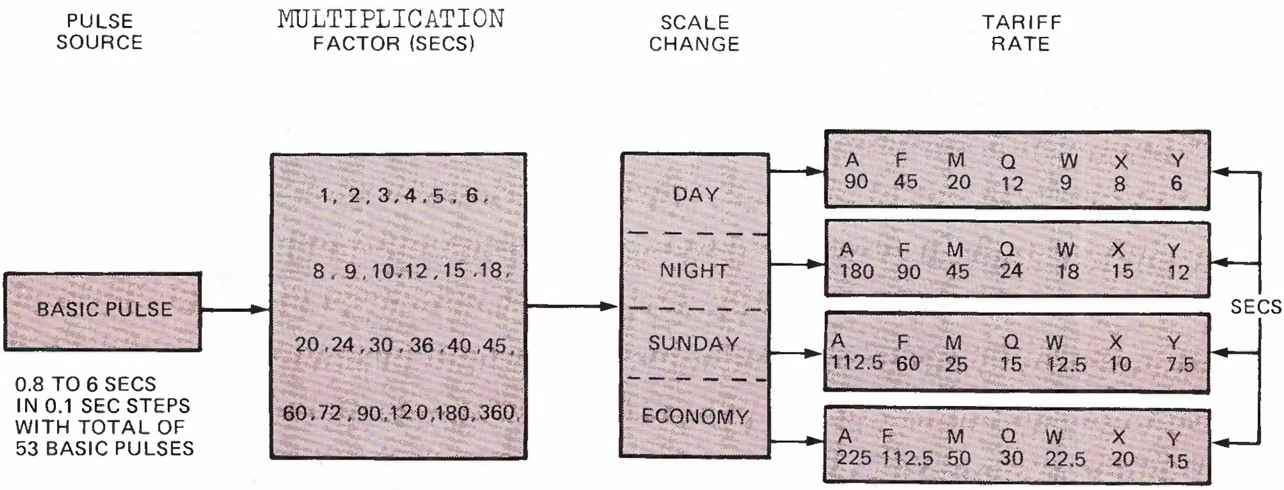

Fig. 5 — Current STD Tariff Rates

meter suitable for measurements on solid state components has been provided to each charging centre. Most States have set up training programmes for training exchange installation and maintenance staff to handle electronic equipment.

Tariff Change Co-ordinator

Each State has nominated a 'tariff change co-ordinator' who is reponsible for implementing tariff changes which may be required from time to time. These changes must of course be co-ordinated nationally. Telecom Headquarters will arrange preparation of programme tapes, supply strapping details and provide general implementation information to the State co-ordinators and set the cutover date.

AN 'INTERIM' TARIFF SCHEME

This tariff scheme has provided a more flexible choice of charging rates for STD calls. This has been achieved economically by maximum utilisation of existing plant. The new charging equipment has been termed "interim" because there is considerable scope for it to be further improved. Although further improvements have been considered, no firm plans have been formulated to date.

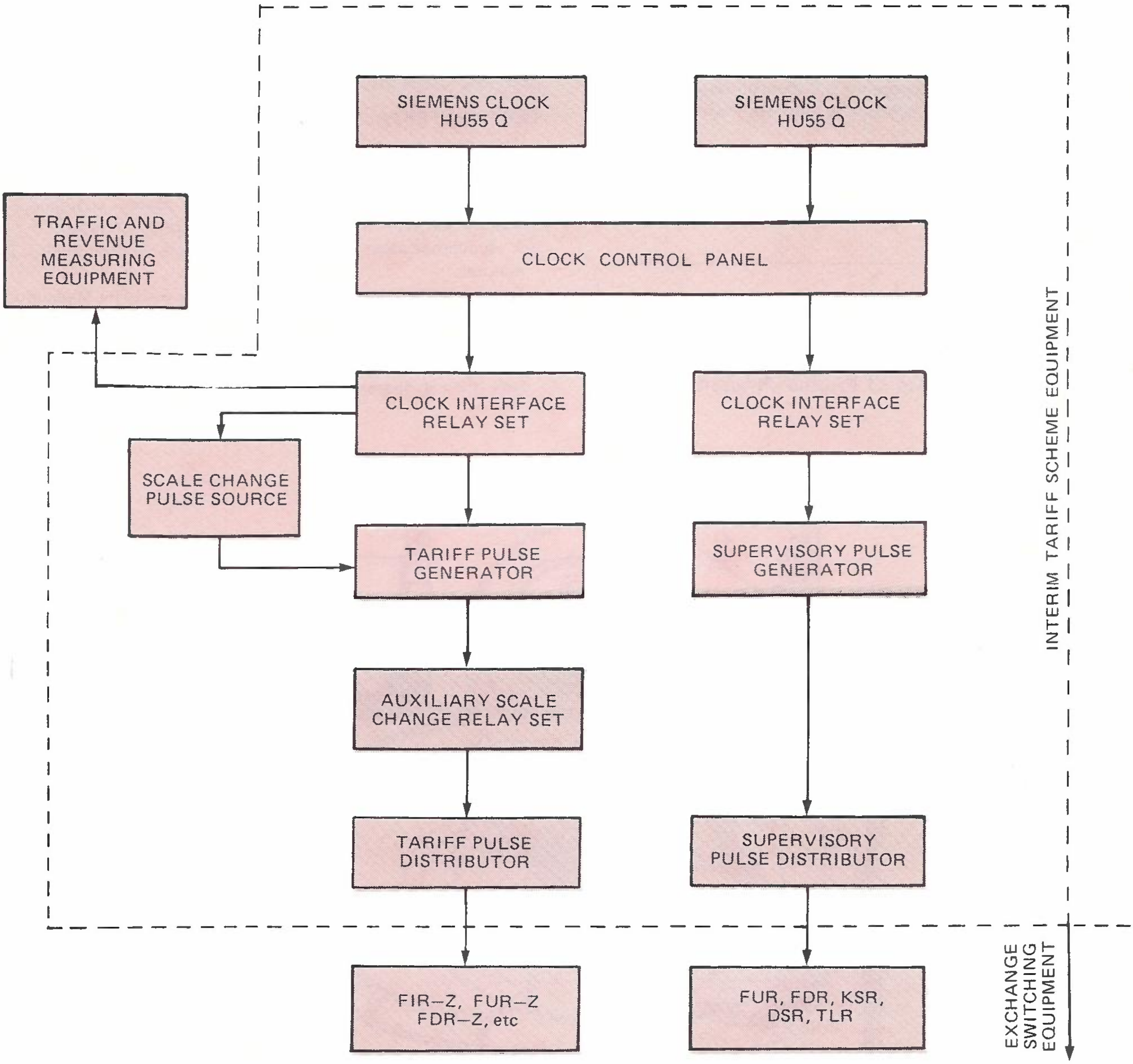

Fig. 7 — Block Diagram — Interim Tariff Scheme Equipment

APPENDIX 1 — Details of New Tariff Equipment, (Fig. 7)

CLOCK AND PROGRAMME PAPER TAPE

The paper programme tape controls the change of charge scales. — The tape is punched with sprocket holes at five minute intervals. Appropriate signs are printed on the tape (**Fig. 8**) which enable identification of the tape punchings in the following way:

Hour of the day, two digits	: ".0.8"
Day of the week	: "SUNDAY etc."
Half hour point, symbol	: ".(.)"
A code for the tape, four digits.	: ".1.0.0.2"

The programme tape is made up of an endless perforated tape, threaded in a magazine so as to form 10 loops which are advanced one full cycle in 7 days. Each clock is equipped with a program switch (**Fig. 9**). This is the mechanism for translating the perforations on the five track programme tape into electric potentials. At any period during the day, the clock output indicates the charge scale which has been set from the programme tape.

Most charging centres have been provided with two improved HU55Q master clocks (**Fig. 10**). Some tariff centres will retain existing HU50Q. master clocks until they are replaced by the model HU55Q.

The following measures have been taken to maximise the overall reliability of the clock equipment:

- Each charging centre has two clocks.
- If the mains supply fails the clocks continue to run on a 24V DC supply derived from the exchange battery.
- A crystal generator is incorporated within the clocks to provide a reliable and accurate frequency source.

Fig. 11 shows the major components of the HU55Q clock.

CLOCK CONTROL PANEL

The Clock Control Panel provides a connection point for the clock inputs and outputs and incorporates some additional control keys, lamps and alarms for supervisory purposes.

CLOCK INTERFACE RELAY SET

The Clock Interface Relay Set provides the following functions:

- Control of the five possible charge scales changed in conjunction with the clock programme tape operation.
- A synchronisation check of programme pulses every 5 minutes.
- Control of the charge scale change for the Revenue Measuring Equipment.
- Selection of the periodicity of the basic pulse.
- Supervision of the operation of the two clocks. If either clock fails, then it operates an alarm.

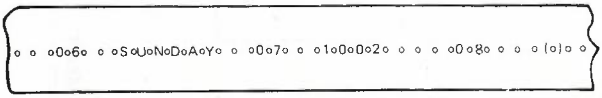

Fig. 8 — A Sample of Printed Programme Tape

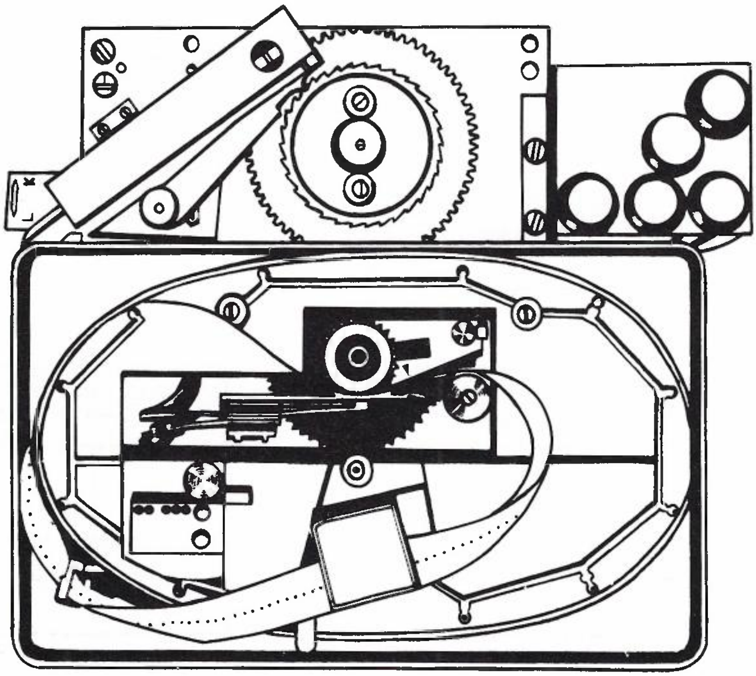

Fig. 9 — Tape-Controlled Programme Switch

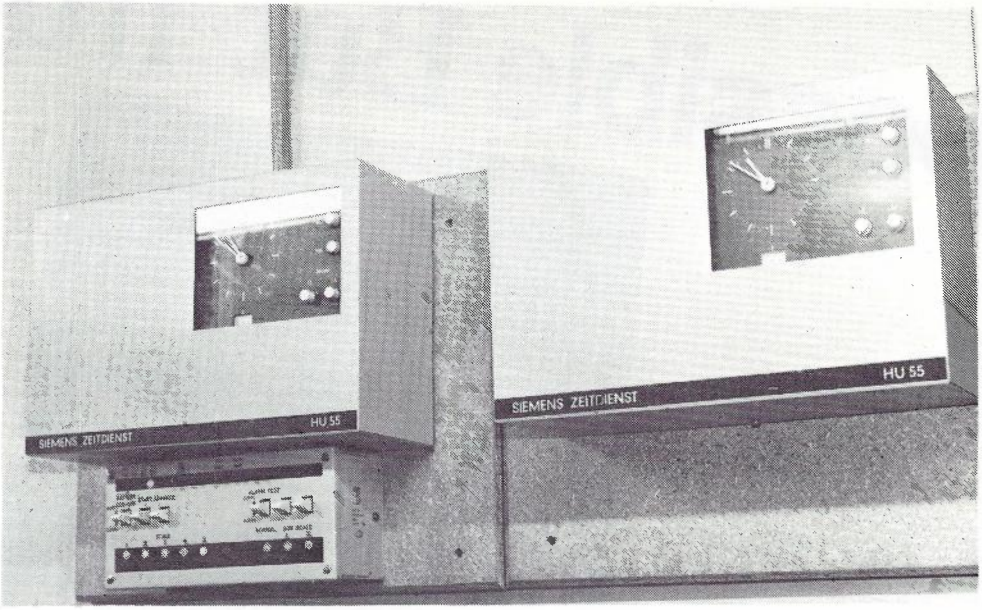

Fig. 10 — Siemens Clock Model HU55Q

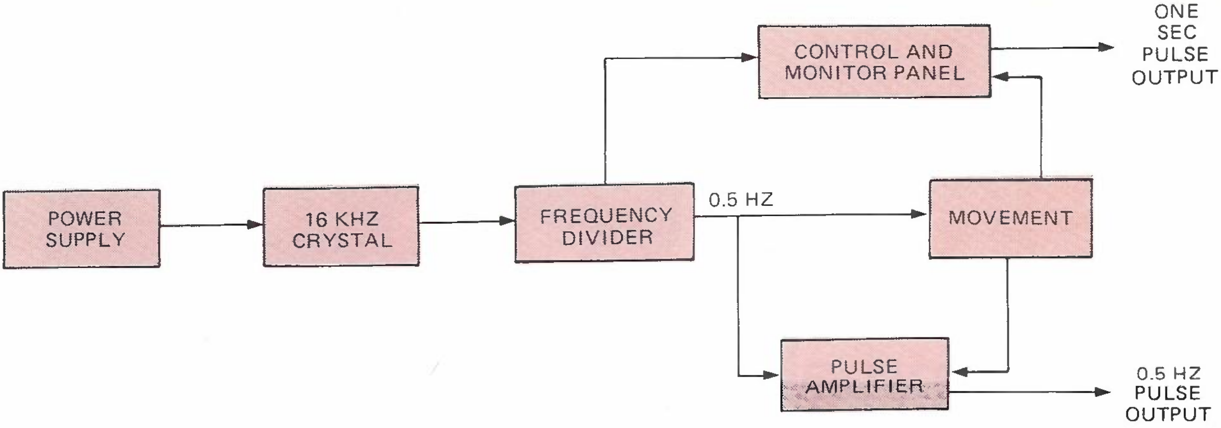

Fig. 11 — HU55Q Clock Block Diagram

SCALE CHANGE PULSE SOURCE

The output pulses from the electronic circuit can be varied over 0.8 to 6 secs. in steps of 0.1 sec. The periodicity of output pulse is selected by the Clock Interface and the selected basic pulse is supplied to the Tariff Pulse Generator.

TARIFF/SUPERVISORY PULSE GENERATOR

The Tariff Pulse Generator converts the basic pulse into twenty-four different pulse trains. The periodicity of each pulse train is a multiple of the periodicity of the basic pulse. The multiplying factors are: 1, 2, 3, 4, 5, 6, 8, 9, 10, 12, 15, 18, 20, 24, 30, 36, 40, 45, 60, 72, 90, 120, 180, 360.

The Supervisory Pulse Generator derives 5 secs., 10 secs., and 72 secs. pulse rates for time supervision of common switching equipment.

AUXILIARY SCALE CHANGE RELAY SET

This relay set is provided to select up to eight tariff rates for each charge scale from the 24 outputs of the Tariff Pulse Generator and connects this group of pulse rates to the Pulse Distributors.

PULSE DISTRIBUTOR RELAY SET

The Pulse Distributor Relay Set distributes the selected group of tariff, rates and supervisory pulses to the line signalling repeaters.

REVENUE MEASURING EQUIPMENT

This equipment consists of solid state Erlanghour Meters and Scale Change Relay Sets plus 5 digit meters to record details of revenue earned at each tariff rate on each charge scale. Circuitry is also provided which counts total effective STD calls connected through the charging centre.

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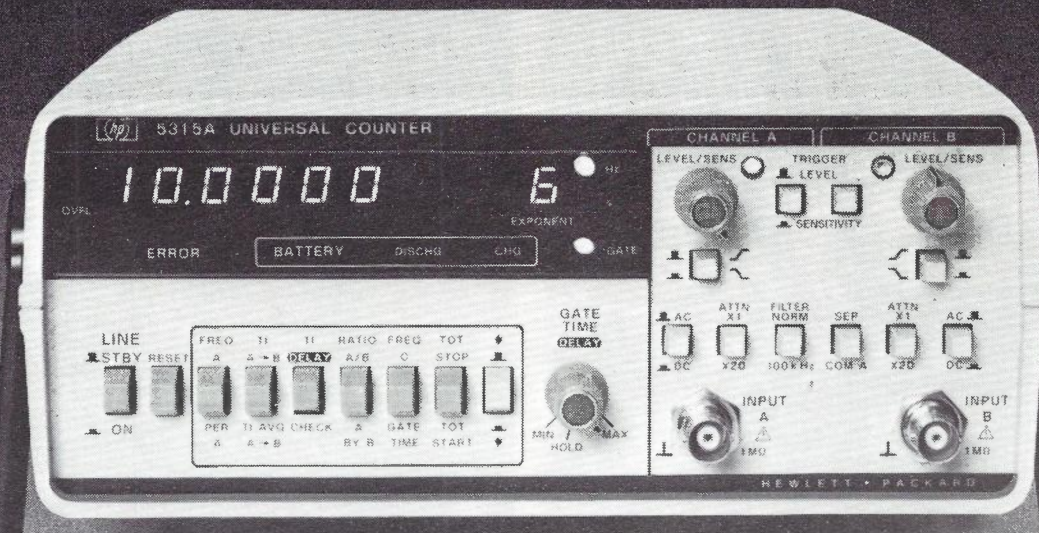

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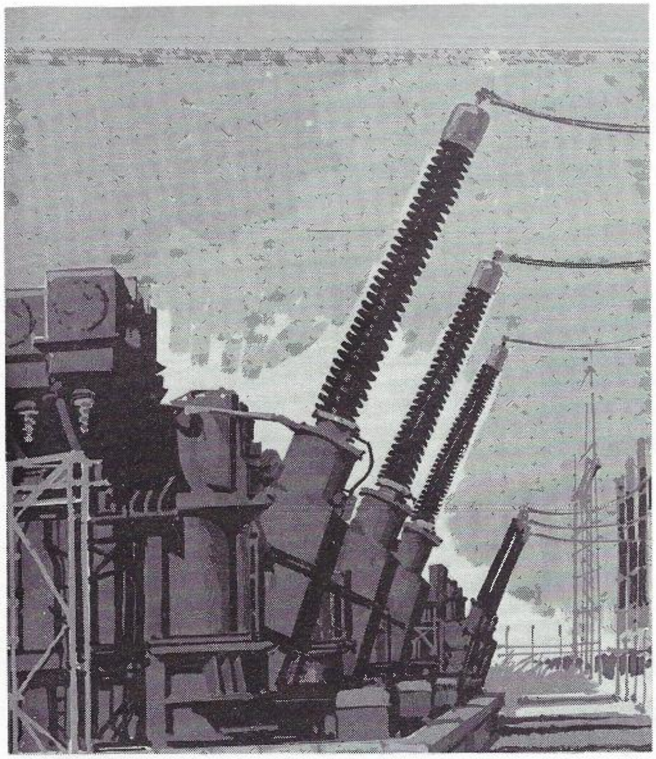

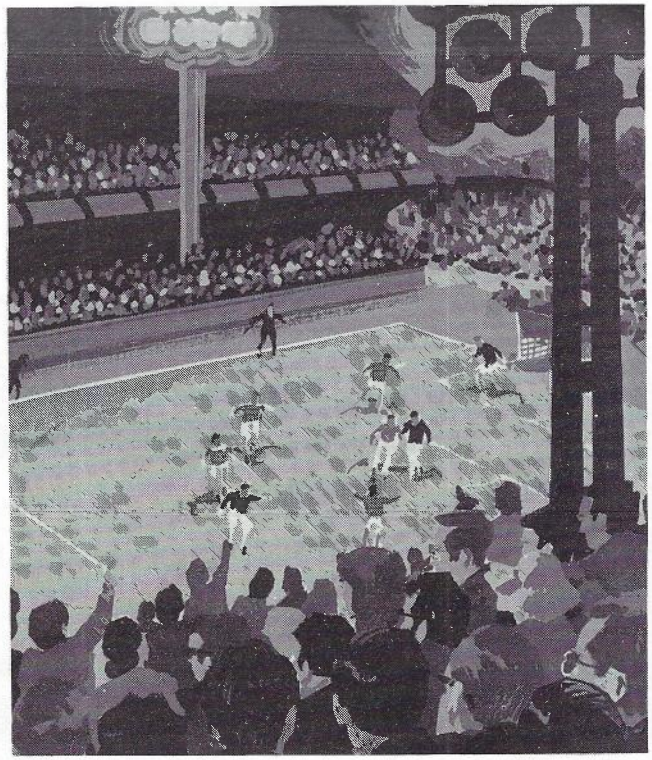

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ABSTRACTS: Vol: 29, No. 2.

DILORENZO, J. V. and SCHLOSSER, W. O.: "GaAs plus FET Equals Improved Microwave Systems"; Telecom Journal of Aust., Vol. 29, No. 2, 1979, page 143.

Newly developed low-noise and high-power gallium arsenide field effect transistors are beginning to improve reliability and performance of microwave transmission systems.

CARUANA, V. A.: "Telecom Australia Preparation for WARC-79"; Telecom Journal of Aust., Vol. 29, No. 2, 1979, page 129.

Some 1500 delegates representing over 150 nations will meet in Geneva, Switzerland on 24th September 1979 for the 10-week World Administrative Radio Conference (WARC-79). The Conference will be a major influence on radiocommunication development and on the use of the radio frequency spectrum for the next twenty years or so. Australia's preparation for this Conference commenced early in 1976 and Telecom, as the largest single user of spectrum in Australia, is heavily involved in the preparatory work.

EDWARDS, A. J.: "Conversion of the National MF Sound Broadcasting Service to a New Band Plan"; Telecom Journal of Aust., Vol. 29, No. 2, 1979, page 138.

The national network of Medium Frequency (MF) sound broadcasting stations in Australia was converted to operation on the basis of radio frequency channels spaced by 9 kHz on 23 November, 1978. The background to this change is described, along with the effect on a diverse network of stations and some of the practical aspects involved.

GERRAND, P. H. and PARK, J. L.: "Development of a Processor Monitoring Instrument for SPC Exchanges: Facilities and Application Areas"; Telecom Journal of Aust., Vol. 29, No. 2, 1979, page 113.

The Processor Monitoring Instrument (PMI) has been designed to monitor the activity of any processor employed in any Stored Program Controlled system in the Australian network, without requiring any changes in the normal operation of the system being monitored. More specifically, the PMI simultaneously displays and measures up to fourteen indicators of the processing load, including the Effective Processor Occupancy, a concept which is explained in this paper. It can be used efficiently to produce measurements for studies of processor capacity, and for more general traffic engineering studies.

A first PMI has been designed and built by Telecom Australia for application to the Metaconta 10C trunk exchanges in the Australian network. A second PMI is currently being built for application to realtime control projects in Telecom Australia's Research Laboratories.

This article describes the facilities of the PMI and its potential range of applications to system testing, operation and traffic engineering.

PRIEST, M. J. and CHAPMAN, S. A.: "Financial Aid for Telecommunications Projects in Developing Countries"; Telecom Journal of Aust., Vol. 29, No. 2, 1979, page 149.

Over the last decade large sums of money in direct aid or in 'soft' loans from the World Bank have been provided for Telecommunications Projects in underdeveloped countries. This article examines the international distribution of telephones and their relationship to population and G.D.P. per head of population. The activities of the World Bank in Telecommunications are reviewed and Australia's involvement in these projects is discussed. Comments are made on some of the practical difficulties encountered in their implementation.

SCOTT, C. J.: "Digital Storage — A Review of Current Technologies"; Telecom Journal of Aust., Vol. 29, No. 2, 1979, page 122.

Fast storage and retrieval of digital information is an essential feature in the operation of new and improved telecommunications equipment. Digital storage technology has developed over the last decade to become one of the most rapidly changing areas in the field of electronics. Continuing rapid improvements in the density, speed and price of digital storage devices confront the designer of telecommunications equipment with an everchanging wide range of storage options. A thorough understanding of the various technology options available assures reliable, efficient and cost effective memory implementation.

WAIN, N. L.: "Radio Relay System Path Survey Techniques; Part 1 — Why a Survey is Conducted"; Telecom Journal of Aust., Vol. 29, No. 2, 1979, page 107.

The major portion of trunk traffic in the national network is carried on broadband radio-relay systems designed to meet performance standards based on CCIR Recommendations.

The design of these systems is conducted within the State Administration Radio Sections in accordance with guidelines set by HQ Radiocommunications Branch and may be subdivided into three successive studies consisting of a feasibility study, a path engineering and survey study, and a transmission engineering study.

The most demanding of these functions in engineering time and effort is the path engineering phase which culminates in the preparation of a report giving exact details of path and route parameters for the final transmission design study.

This article gives an outline of the survey aspects associated with the path engineering study and is divided into two parts — the first deals with the reasons for surveying the system route and the second looks at the techniques used by the surveyors to obtain the survey information and prepare the necessary drawings.

WESSON, R. H.: "Waymouth 10C Trunk Exchange; Operational Experience"; Telecom Journal of Aust., Vol. 29, No. 2, 1979, page 99.

The Waymouth 10C Trunk Exchange in Adelaide was commissioned in August 1976. It was the third Stored Program Controlled Trunk Exchange to be installed in Australia, but the first to provide specialised manual assistance facilities.

This article deals with the operating experience in the first twenty one months after commissioning.

WONG, T. S.: "Changes in Subscriber Trunk Dialling Charging Facilities"; Telecom Journal of Aust., Vol. 29, No. 2, 1979, page 155.

This paper describes the introduction of new subscriber trunk dialling (STD) tariff equipment to upgrade the STD tariff equipment in minor and secondary crossbar switching charging centres.

The following aspects of charging for STD calls are described.

A general outline of Telecom Australia STD tariff structure.

An examination of new tariff equipment and comparison with earlier tariff equipment.

New tariff facilities which are available for the benefit of both Telecom Australia and user.

Some unique installation and maintenance aspects of the new STD tariff equipment are also covered in the paper.

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