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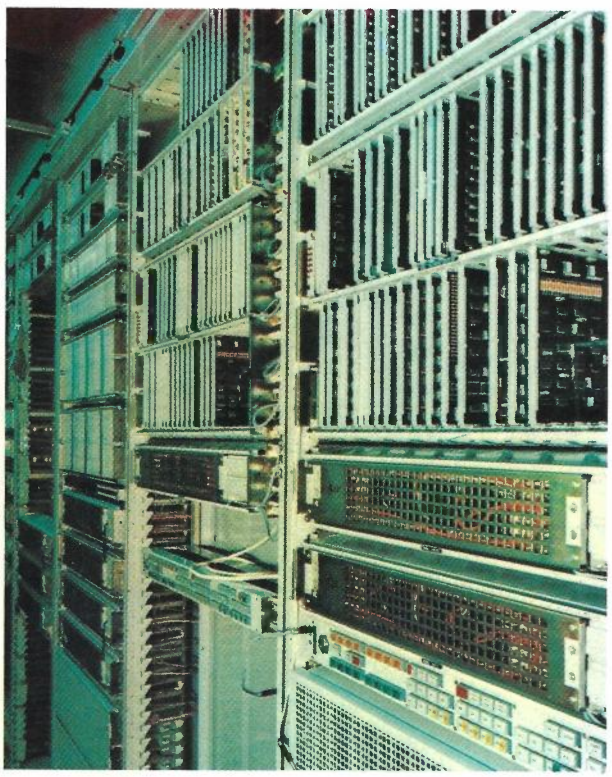

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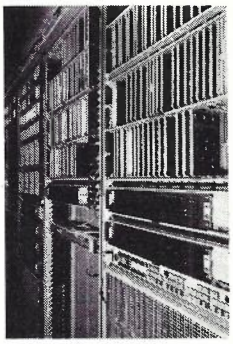

COVER
ARE 11 INSTALLATION

The Telecommunication Journal of Australia

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OVERSEAS APPLICATIONS

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ARE 11 System Appreciation

W. CLOSE, F.R.M.I.T., Grad. Dip. Mgt.

Telecom Australia is about to embark on a major modernisation programme to provide new facilities in the crossbar exchange network. Studies of these updating proposals for the crossbar network revealed an economic application for the ARE 11 exchange system in providing these new facilities in existing exchanges. On 1 March, 1976, the ARE 11 exchange system was accepted for use in the Australian network with an application in new exchanges and for the upgrading of existing ARF exchanges.

This paper, the first of a series, describes the system features, the advantages of the system compared with ARF and its application to the Australian network.

INTRODUCTION

L. M. Ericsson have developed an upgraded crossbar exchange switching system known as the ARE 11 exchange system that incorporates the crossbar switching stages of the ARF 102 exchange system and a new processor controlled common equipment sub-system (ANA 301). The development of the ARE 11 exchange system was the outcome of a design for an electronic register known as the ROM 30 which employed time division multiplex techniques. (ROM 30 was later re-designated ANA 30.) It was realised that the ROM 30 technique did not go far enough in control of common equipment functions, and the development of a processor controlled system was commenced in 1970. The system (ARE 11) which can control most of the common equipment functions in an exchange has been under examination for application in the Australian telecommunications network since late in 1971. As a result of the early studies of the system application in the network a contract was let in June 1973 for two trial exchanges at Elsternwick in Victoria and Salisbury in South Australia and for a model exchange in the Telephone Switching Design Laboratories of Headquarters.

The ARE 11 system incorporating the ANA 301 subsystem could be applied for both new exchange applications and for updating existing ARF exchanges. Elsternwick was selected as a new exchange installation of 4000 lines and Salisbury as an existing ARF exchange of 10,000 lines to be updated by replacement of the existing common equipment by the ANA 301 subsystem. Experience with the model exchange and the trial installations has confirmed the technical viability of the system.

Economic evaluation studies into the application of the system into the Australian network were finalised late in 1975, and on 1 March 1976 the system was accepted by Telecom Australia for use in the network as an alternative to the standard ARF exchange system.

SYSTEM FEATURES OF AN ARE 11 EXCHANGE

The ARE 11 exchange system consists of a common control system part (ANA 301 subsystem) with processors for the control of traffic and maintenance functions and a crossbar switch for the switching system part.

In the design of the system a balance has been achieved between the utilisation and complexity of the ANA 301 control system and the retention of the ARF basic switching functions utilising current electro mechanical technology. As a consequence, there has been little change to line relay sets and to some of the marker identification equipment.

The ANA 301 subsystem uses stored program control (SPC) technology for the analysis and logical control functions and replaces those parts of the existing ARF system where advantages can be achieved by centralisation of the control logic and analysis. These are for example the register functions, subscribers categories, PBX selection and GV route analysis and selection. Also, the inherent flexibility of an SPC system offers a simplified and more economical method of providing new subscribers and network facilities. This can be accomplished by alterations and/or additions of programme packages and functional units. The structure of the ANA 301 subsystem enables existing ARF exchanges to be modernised to provide some of the new network and subscribers facilities which are available with modern full SPC exchanges.

New improved operational and maintenance facilities are also offered. New techniques are required as the operation of the exchange is supervised by an operations and maintenance processor which can simplify the identification of exchange malfunctions and assist in fault diagnostics. The system also offers the potential for remote control of the exchange from a centralised location.

EXCHANGE STRUCTURE

The common control system of an ARE 11 exchange is capable of being expanded from performing only the basic register functions to controlling all the registers and all GV and SL switching stages. The options available and their grouping into levels of control for ARE 11 in the Australian network are discussed later.

An ARE 11 exchange has three groupings of equipment:

(i) The crossbar switching equipment.
(ii) The interface equipment.
(iii) The processor equipment.

Parts (ii) and (iii) form the ANA 301 common control subsystem and are shown in Fig. 1.

The interface equipment is required to enable the speed and operating voltages of the processor equipment to be matched to that of the crossbar electromechanical exchange. The equipment units consist generally of plug-in integrated circuit boards that are directly controlled by the processor.

The processor part consists of up to six traffic control processors (TCP), a single operations and maintenance processor (OMP) and the central data stores.

Interworking between the processor and other devices is by means of a processor bus system using balanced pairs. A bus system connects the processors to a multiplex switching device (MUX) on each of the interface racks to which the processor has access. This is indicated in Fig. 2.

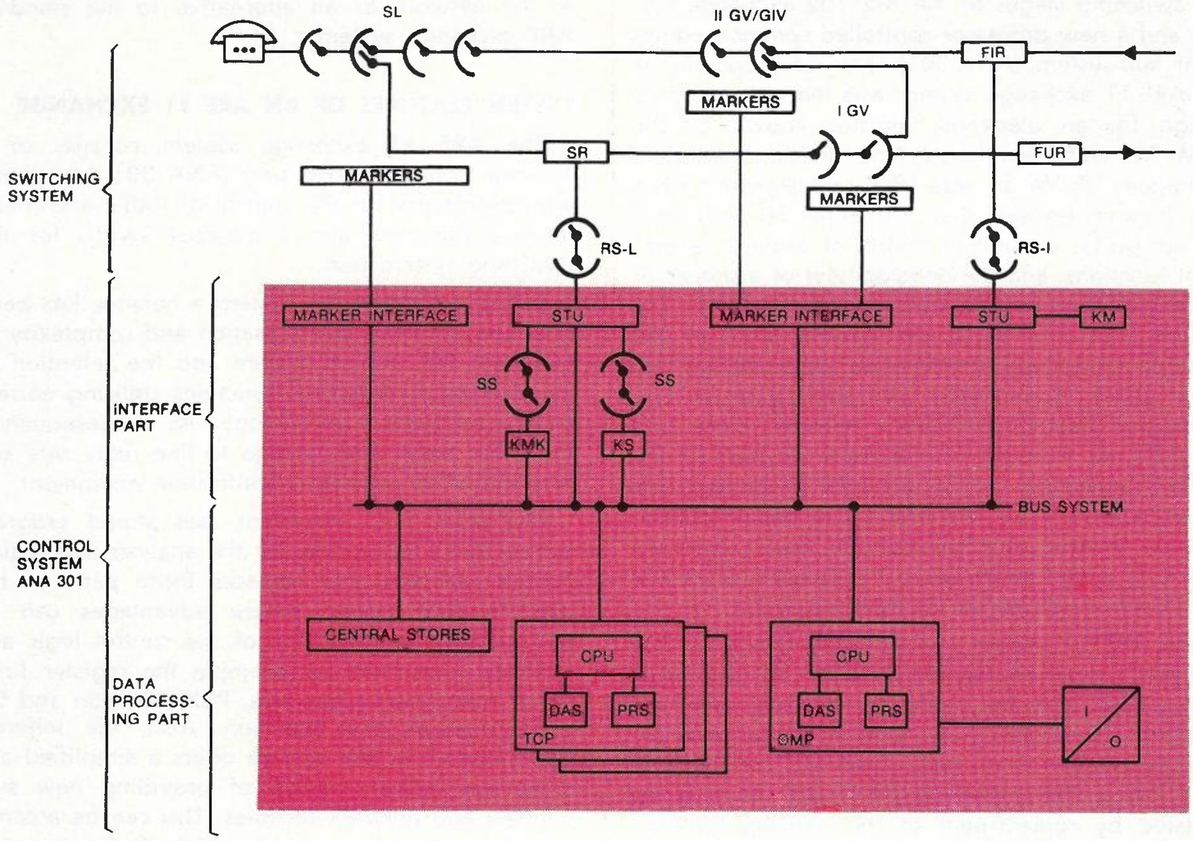

Fig. 1 — ARE 11 Survey Block Diagram.

FACILITIES AVAILABLE IN ARE 11 EXCHANGES

Exchange and Network Facilities

Operations and Maintenance

The ARE 11 exchange system provides improved equipment reliability and advanced operating features which will reduce the operations and maintenance costs. The system offers the potential for fault diagnostic work to be carried out remotely to the same degree as if on site, and thus the exchange can be maintained as an SPC exchange rather than crossbar. A new maintenance strategy will be required which will be different from that currently employed in the network.

Reduced operational and maintenance costs are expected to be achieved from the following features:

- Improved equipment reliability.
- The remote supervision aspects.
- Subscribers, exchange and network dependent data is held in data stores which enable remote alteration. For example alterations to subscribers category information, route analysis, the blocking and enabling of subscribers lines, etc.

GV Stage-Improved Capability

A number of the disadvantages of the present GV stage equipment are overcome by the introduction of ANA 301 control of the GV stage. The most significant amongst these include:

- Increased address capacity for the marker equipment to 256 addresses for a processor group in an exchange.
- Greater flexibility in allocating availability. A 2/160 stage can have route availabilities of from 5 to 80 in steps of 5. A similar arrangement also applies for the 1/80 GV stage which can have route availabilities of from 10 to 80 in steps of 10.
- Simplified extension of the 2/160 three stage GV availability to 1600 without the need for significant marker re-arrangements.

PBX Facilities

An extremely simple method of PBX connection has been devised with a single wire jumper wire only required to the PBX equipment. Current ARF 102 number restrictions are removed and PBX lines can be freely distributed through a 10,000 line group.

Metering Equipment

Current standard metering facilities are used but the system has potential for the introduction of electronic metering facilities and this is currently being investigated for possible introduction by about 1980.

New Signalling Schemes

Introduction of changes to the signalling schemes will generally only require amendments to program packages. However the provision of new program packages and new hardware for other alternative signalling schemes if these are required in the future is expected to be very much cheaper with ARE 11 because of the SPC techniques used. Common channel signalling could be one such scheme.

New Subscribers Facilities

An ARE 11 exchange can provide all the subscribers service facilities offered from an ARF exchange, together with the currently approved new network facilities of calling line identification (CLI) for international subscriber dialling (ISD) with automatic message accounting (AMA), revised trunk access barring capability, centralised interception and for voice frequency push button telephones.

The system could also be adapted to provide additional facilities if required in the future. Some of these facilities are:

- Abbreviated dialling — A subscriber need only dial a short code number to call regularly called numbers in either national or international networks.
- Hot line — The connection is established to a specified number from a designated telephone simply by raising the handset.
- Extra subscribers categories — Additional categories are available over and above those proposed for modified ARF exchanges.
- Follow me — Calls to a subscriber can be temporarily re-directed to another number.
- Cenpex — A group of subscribers connected to the exchange may be given additional facilities that are available in a PABX, e.g. short numbers, transfer and enquiry, etc.

SYSTEM DESCRIPTION OF THE ANA 301 SUB-SYSTEM

The ANA 301 subsystem is divided into two main parts as indicated in Fig. 1:

- A data processing part.
- An interface part.

The data processing part can be sub-divided into three sections; the traffic control processor, operations and maintenance processor and the central stores.

The processors in the ANA 301 system are the APN 110 type and have the same structure when used for either the traffic control application or as an operations and maintenance processor. Only the programs differ between the processors.

A processor consists of a central processing unit (CPU), a programme store (PRS) and a data store

(DAS). Both these stores consist of semi-conductor memories mounted on plug-in printed circuit boards. The PRS which stores the more permanent traffic programmes and operations and maintenance programmes is a read only memory. The DAS however is a read/write random access memory which stores temporary data applicable to individual calls. The CPU consists of a number of functional units internally linked together for the execution of the operations included in the programme instructions.

A maximum of six Traffic Control Processors (TCPs) and one Operations and Maintenance Processor (OMP) are combined to form a processor group.

Each TCP can serve 60 signal transfer units (STUs) which are interface units replacing the registers of an ARF exchange. A full processor group can serve 360 STUs which could serve up to a maximum of 40,000 subscribers, depending on the traffic capacity of the exchange. In very large exchanges with higher traffic requirements a maximum of four processor groups can interwork by means of an external communications buffer (ECB). Processor groups can then share the tasks of handling the traffic.

An operations and maintenance processor (OMP) is required for each processor group. The OMP supervises the operation of the TCPs, provides input/output facilities for communicating with the system and supervises the other units forming part of the ANA 301 system and provides for fault printouts and transmission of alarms. These input/output devices can include teleprinters, a visual display unit, a tape reader and data modems. In the case of a processor fault the OMP will transfer control of the corresponding equipment to another TCP within the processor group. Statistical traffic and switching data can be obtained for operational analysis and as an aid in fault tracing in the exchange.

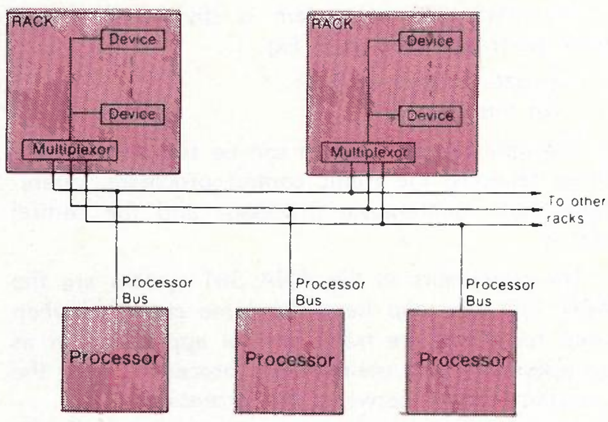

Fig. 2 — Connections between Processors and Device Racks.

Central Data Stores

The central store for the exchange and subscribers data are common to a processor group and consist of the subscribers category store (SCS), translation store (TRS) and the abbreviated dialling store (ADS). These stores contain alterable control information and have some logic functions which simplify the addressing requirements of the central processor. The SCS contains the category information for all subscribers as well as data for PBX subscribers. For economic reasons, the SCS is divided into a number of parts, which reduce the overall memory requirement for an exchange. One part contains the small number of common category combinations for all subscribers while the other parts contain the extended range of category and temporary categories required by a small number of the total subscribers.

The TRS contains the network data for the exchange. It is used for translation of the B number to the routing and charging information needed to establish the call.

Information concerning PBX equipment is shared between the SCS and TRS. The data required for connecting and testing of PBX lines is stored in SCS. However, the translation data to enable the PBX directory number (now not necessarily a double digit) to be replaced by the selected auxiliary number (now allocated from anywhere in a 10,000 line group) is stored in TRS.

The ADS is provided when required and contains special subscribers data for abbreviated dialling purposes. This store is used to translate a one or two digit number into a complete B number either national or international. A subscriber may have up to 100 abbreviated numbers. Also included are facilities for hot line where the ADS translates the A number with a category to a complete B number.

Interface Equipment

The interface equipment is needed to match the slower speed, higher voltage switching part to the higher speed, lower voltage data processor part as indicated in Fig. 1. The separate items of equipment providing these functions are shown in Fig. 4 and generally consist of plug in printed circuit boards which are directly controlled by the processor.

Levels of Control

The ANA 301 processor subsystem is modular in structure and consists of a number of autonomous functional units which allows various options of control in an exchange. Of the many options available, these have been grouped together to form four levels of control for use in the Australian network. These levels have been selected using both facility requirements and economic considerations.

TABLE 1 — FACILITIES AVAILABLE AT EACH LEVEL OF CONTROL.

Facilities Provided	ANA 301 Processor Control		
	Level 1 & 2 (Register Replacement)	Level 3 (Register and 1GV)	Level 4 (Registers, 1GV, GIV & SL)
Calling Line Identification	X	X	X
VF Push Button Telephone capability	X	X	X
Increased Subscriber Classifications (Originating & Terminating)	X	X	X
Abbreviated Dialling Capability	X	X	X
Network Analysis Determined by Processor	X	X	X
Remote Alteration of Subscriber Categories	X	X	X
New MFC Signals Available	X	X	X
Centralised Interception for Terminating Calls	X	X	X
Remote Supervision of ANA-301 Equipment	X	X	X
Improved Facilities for 1GV Stage		X	X
— Increased number of route addresses			
— Increased range of outlets per route			
— Deletion of GV strapping fields			
— Remote control of traffic routing			
— Increased statistical data			
Improved Facilities for GIV Stage			X
Improved PBX Facilities			X

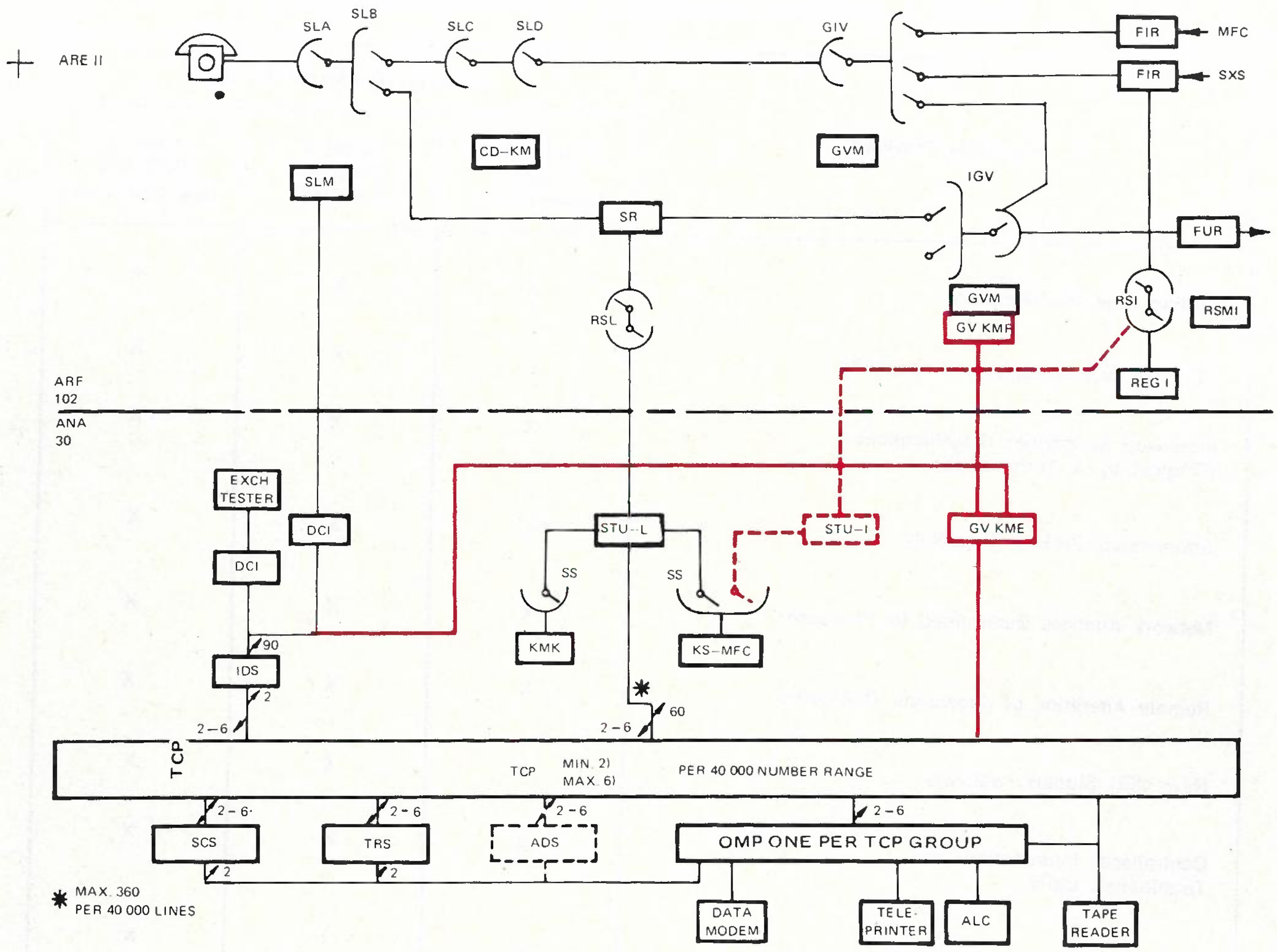

Fig. 3 — Level of Control; No. 1, No. 2 and No. 3.

The modular structure of the ANA 301 subsystem makes the system particularly suitable for converting existing exchanges. Functional control of the individual parts of the exchange can be transferred to ANA 301 control independent of the other operations of the exchange during the conversion process. The technical aspects of these conversion techniques have been investigated at the model exchange and at Salisbury crossbar exchange in South Australia. The levels of control that have been selected as appropriate for use in the Australian network are listed below together with the facilities provided at each level. Table 1 summarises the facilities available at each level of control.

Level No. 1 — Replacement of Local Register Functions

At the levels of control No. 1, the ANA 301 subsystem provides for the replacement of the local register functions of either the Reg LM or Reg LP. The incoming register equipment (Reg I's or a proportion of Reg LP for step by step decadic traffic with the associated SS and KS) are retained. Conventional MFC signalling is retained internally in the exchange between ANA 301 subsystem and the other common controlled equipment items. The following additional facilities can be provided with Level 1 control compared with an existing ARF crossbar exchange.

- Calling line identification required to provide AMA for ISD.
- Increased originating and terminating classifications.
- Ability to introduce VF push button telephones by addition of code receivers and coupling stage.
- Ability to remotely alter subscribers categories.
- Ability to introduce abbreviated dialling.
- Ability to provide centralised interception of terminating calls.

- Remote supervision and control of ANA 301 equipment.
- Introduction of new signalling arrangements to enable the new network facilities to be provided.
- Number length and TOTE analysis performed in ANA 301 equipment and requirement is eliminated from 1GV in former Reg LM exchanges.

ANA 301 equipment to be provided for a level 1 control exchange is indicated on Fig. 3 by the black outline.

Level No. 2 — Replacement of Local and Incoming Register Functions

At this level of control ANA 301 subsystem provides for the replacement of the incoming register functions for decadic traffic in addition to the local register functions. Depending on the type of line relay set equipment, the incoming register function will be provided by using STUL's where Reg LP (loop signalling to the register) incoming junction relay sets are proposed or by STUI's where Reg I (single wire signalling to register) incoming junction relay sets are provided. No additional facilities other than those available from Level 1 are available.

Additional items of equipment for Level 2 control where Reg I equipment is replaced is shown in Fig. 3 in the red dashed outline.

Level No. 3 — Direct Control of the 1GV Stage

At this level of control the ANA 301 subsystem is extended to provide control of the 1GV stage.

Direct control of the 1GV stage enables a number of enhanced facilities to be provided which overcome many of the present limitations. MFC signalling is no longer required for 1GV stage control which is now exercised by the GV KME, IDS and a new GV KMR relay set.

Levels of control No. 1 or 2 can be extended to provide 1GV control and the additional equipment required is indicated in Fig. 3 by the red outline.

The additional facilities available at this level arise from the improved capability of the GV stage. These improvements include the ability for remote alterations to the routing and analysis; additional address capacity, improved route availability, allocation and flexibility; and the ability to increase the availability to 1600 without the need for significant GV marker changes.

Level No. 4 — Full Control

At this level ANA 301 control is extended to the GIV and SL stages and thus controls all the common equipment functions in the exchange. For the incoming MFC traffic an interface relay set (RAR) is provided for connection between the MFC junction relay sets and an STU I (M) via an RSI stage. A code receiver is permanently associated with the STU I for MFC signalling. The need for intra-exchange MFC signalling is removed and a common group of STUI's can serve both MFC and decadic traffic.

Direct control of the GIV and SL stage in an ARE 11 exchange provides the following additional facilities to those above; improved PBX facilities, elimination of the need for MFC signalling internally within the exchange (thus provides savings in common equipment items through reduced holding times of common plant) and the capability for the exchange to become a terminating analysis point which could remove the need for distant end analysis for special requirements in the network.

Changes to the ANA 301 System for use in the Australian Network

A number of changes are proposed to the exchange system offered for use in the Australian network and to that installed at the trial exchanges, and these have been adopted for general use in all subsequent installations. These amendments have been as a result of experience with the trial exchanges and because of the need for adaptation to meet Australian network requirements.

- *SS Stage*

  The SS stage for the ARE 11 exchange system is a design incorporating a miniature relay system with electronic control. The system provides for 120 STUs to be connected to 15 devices. These could be either code senders (KS) or code receivers (KMK) for push button telephones or both. However, no grading facilities were provided.

  An examination of the existing ARF SS (20/12) currently used in Reg LM exchanges was made and it was found economically attractive to design an additional interface to the STUs to enable the ARF SS to be used in an ARE 11 exchange in lieu of the ARE SS (120/15) and this has now been adopted as standard. This arrangement will be particularly appropriate to enable re-use of the SS (20/12) equipment recovered where existing Reg LM exchanges in the network are upgraded with ANA 301. Separate groups of this SS (20/12) equipment will be provided for KS and KMK when appropriate.

- *Operations and Maintenance System*

  The basic operations and maintenance system in the ANA 301 monitored the ANA 301 equipment and did not effectively supervise the performance of the ARF type equipment in the ARE 11 exchange. Consequently, a significant amendment to the system has been specified and a comprehensive maintenance system evolved which encompasses the operational supervision of the whole exchange and enhances the facilities

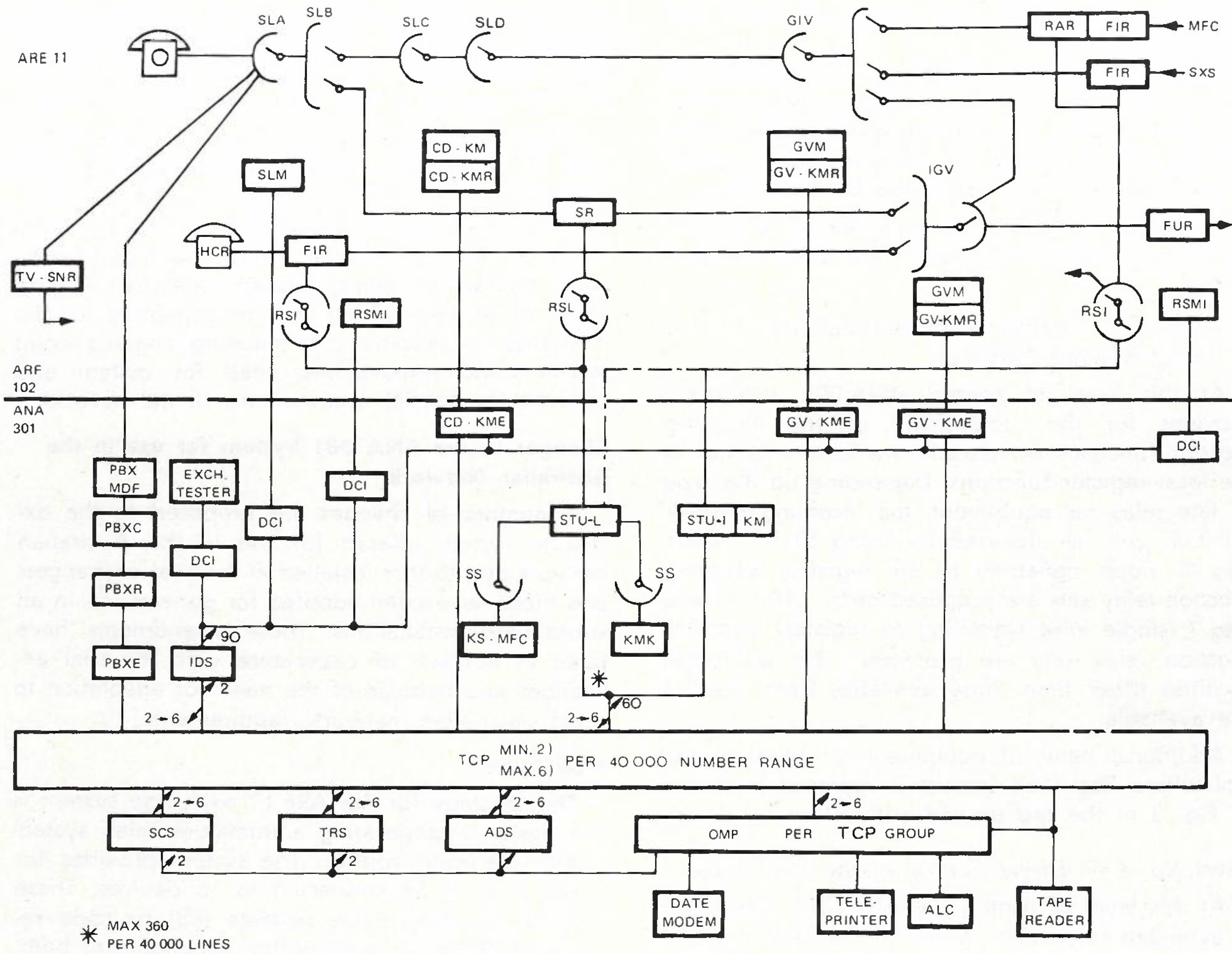

Fig. 4 — Level of Control; No. 4.

available from the ANA 301 system to interwork with a remote exchange maintenance centre.

- *Interception and Terminating Classification*

This facility is available at level 4 control. At other levels of control this facility was not initially available other than by the provision of the TV equipment proposed for ARF exchanges. However, the facility can now be provided by the installation of a CD KME relay set in conjunction with the CD marker. Access to the processor and category store thus enables terminating classifications to be determined. Provision of interception in the future is simplified as the TV equipment proposed in ARF exchanges is no longer required.

- *GV Stage Control*

The capacity of a processor group is presently limited to the control of a single 1GV stage and single GIV stage. Existing exchanges in the network which are expected to be converted to ARE 11 have more complex arrangements of switching stages than this, and it is proposed to modify the exchange programs to enable a number of 1GV switching stages and/or GIV switching stages in the same exchange to be controlled by the ANA 301 equipment. The number of switching stages to be controlled is still under consideration but a maximum of 16 controlled by a processor group is being investigated. Also, the 256 routes at present available for the GV stages under the control of the one processor group will be increased to a maximum of 512.

APPLICATION OF ARE 11 IN THE AUSTRALIAN NETWORK

The ARE 11 exchange system has been adopted for use in the Australian network as an alternative

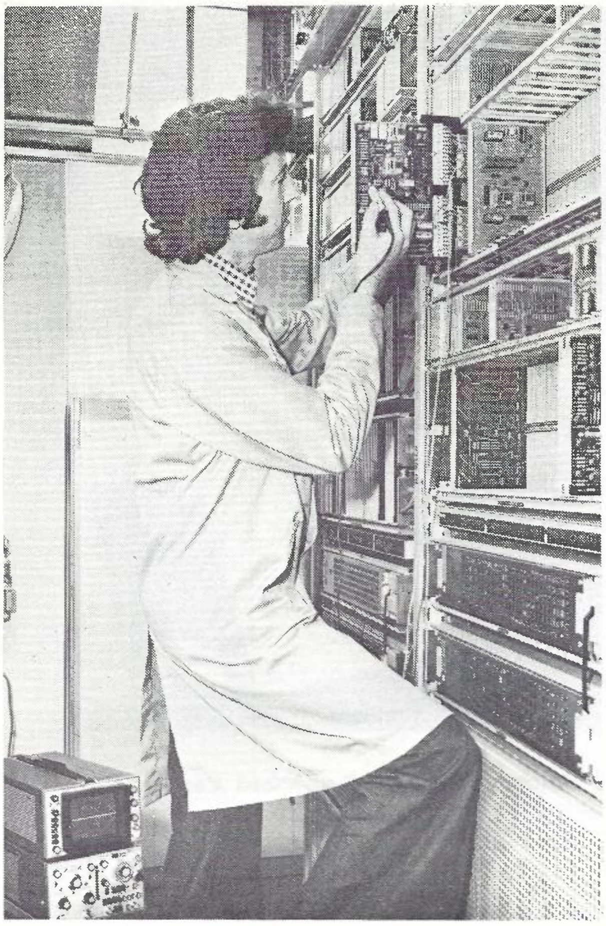

Fig. 5 — Typical example of ANA 301 Equipment Rack. Equipment shelves and printed circuit boards for a Signal Transfer Unit rack at the Elsternwick, Victoria, installation are shown.

to ARF 102 where this is economically justified. Studies of the economic application of ARE 11 have indicated that this system could be employed in urban networks for new exchanges and for the implementation of the proposed crossbar exchange modernisation programme. The modernisation programme provides for the modification of crossbar exchange equipment (in the main to registers) to enable provision of calling line identification, extended range of trunk access barring facilities, centralised interception and for the connection of VF push button telephone receiver equipment. The main role foreseen for ARE-11 in the Australian network is in this upgrading of the existing exchanges and subsequent growth.

In urban networks ARE 11 is expected to be used in new exchange installations and for initial installations in new switch rooms at existing exchanges, commencing in 1978. In new urban exchange installations Level 4 control would be recommended to obtain the economic and facility benefits of this level of control. In country locations however, the existing electromechanical (Reg LP) would be retained for new terminal exchanges and at minor switching centres. At this time, there would appear to be significant operational penalties in the isolated use of ARE 11 equipment in the country areas.

Existing Switch Room Installations

The application of ARE 11 in an existing switch room depends on the type of equipment installed.

The evaluation of the modernisation proposals for the existing Reg LM equipment in the network indicated that rather than modify this equipment it could be economically replaced with either ANA 301 or Reg LP equipment. Reg LM in country exchanges would normally be replaced with Reg LP equipment rather than ARE 11. It is not expected that the Reg I equipment at a Reg LM exchange converted to ARE 11 would be replaced.

The requirement for Reg I equipment is not expanding in the network and the modifications required to the Reg I to provide the new facilities are not expected at this time to be sufficiently extensive to warrant recovery to avoid the modifications required.

The costs for modifying Reg LP exchange equipment are not as high as that for Reg LM equipment but at selected urban Reg LP exchanges it is expected to be economically attractive to replace the registers, rather than modify them, provided that the equipment can be re-used for growth in other exchanges. The recovery for re-use of this equipment in urban areas is expected to curtail purchases of Reg LP equipment for future growth needs in urban or country exchanges of the network. Replacement of Reg LP equipment with ANA-301 equipment will prove particularly attractive at those locations where a high growth rate is expected and where both types of registers (Reg LM and Reg LP) have been installed because of the lower incremental cost of ANA-301 equipment compared with Reg LP.

At exchanges providing first stage crossbar facilities for Step-by-Step equipment (SRB exchanges) it is also expected that the registers would be replaced where appropriate. The additional facilities of the ARE 11 system would not however be available to the step by step subscribers without the ability to identify the A subscribers number.

In replacement exchanges a minimum of Level 3 control is being recommended. Level 3 control provides the enhanced facilities for the originating GV stages which offer significant potential network savings. These savings, particularly in large exchanges in the metropolitan networks would

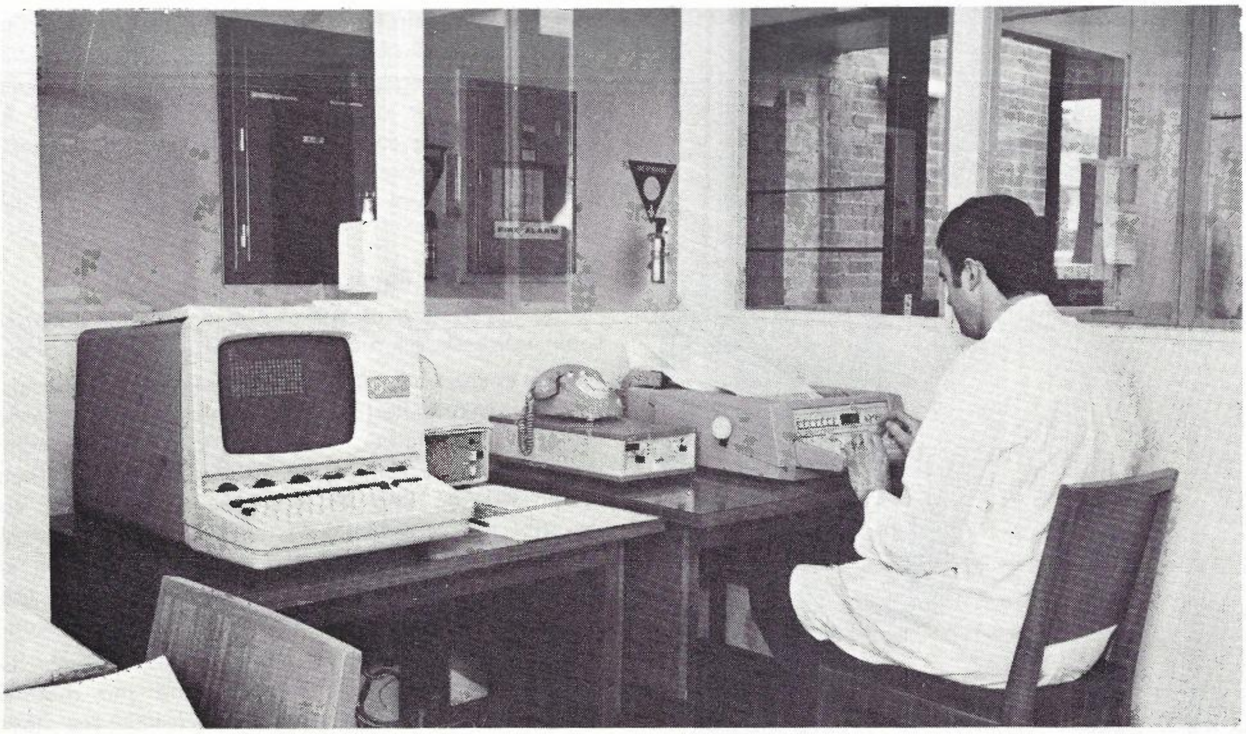

Fig. 6 — Man-Machine Communications at the Simulated Remote Operations Centre at Elsternwick Exchange, Victoria.

compensate for the additional marginal cost of this level compared with Level 1 or 2. Level 3 also provides additional operational benefits and the operational complexity in the network would be reduced if only two levels (3 and 4) were employed in the network.

Level 4 control in a replacement installation offers significant benefits, particularly in large busy exchanges, however there are considerably more costs involved because of the need to provide processor access to all incoming junction circuits (both MFC and decadic). These high initial costs are expected to limit the number of conversions possible at this level in the early years of the modernisation programme even though these may be economically attractive. Therefore, it is being recommended that extensions for growth should be at Level 4 control in a replacement ARE 11 exchange rather than Level 3. This approach ensures that the ultimate conversion to Level 4 is not prejudiced at some future time because the cost of the original replacement installation from Level 3 to Level 4 control is not increased and, in addition, the Level 4 facilities are available to subscribers terminating on the exchange extensions. These extensions at Level 4 are expected to cost about the same as those at Level 3 control.

In conjunction with the installation of ARE 11 in the network it is also proposed to equip the exchanges with the capability for VF push button telephones. In this way, a significant penetration of these facilities in the network can be achieved by the end of the modernisation programme thus reducing requirements for the more expensive decadic type of push button telephone currently being introduced into the network.

ARE 11 in Country Networks

ARE 11 is not generally economically or operationally attractive for use in the country at this time. However, studies are in hand for providing AMA facilities for STD and if the provision of the facility is adopted an option being considered in the country network is the provision of the AMA facilities in minor switching centres. ARE 11 may have an economic application in providing this facility together with other facilities required in the modernisation programme in these locations. Also, if ARE 11 were provided at a minor switching centre, the advanced facilities provided for subscribers at the centre could be more economically extended to the subscribers connected to the small country exchanges (ARKs, etc.) in the minor switching centre.

CONCLUSION

The introduction of the ARE 11 exchange system will have a significant impact in the Australian network. Although the system utilizes crossbar switching stages, both the common equipment and the installation, operational and maintenance techniques will embody many of the concepts of a full SPC type exchange system and this is a significant departure from present practices.

The adoption of ARE 11 will firstly enable cost savings to be achieved in providing new exchanges and in exchange extensions compared with providing the updated design of the current standard ARF 102 system. Secondly, it will provide benefits in operations and maintenance aspects through the greater equipment reliability and in the ability to introduce new maintenance concepts, including the remote alteration of exchange and subscribers data; and thirdly it will simplify the subsequent provision of additional facilities in these exchanges.

ARE 11 will have its main application in the upgrading of the existing crossbar exchange network as a consequence of the crossbar modernisation programme and the consequent growth in the converted exchanges. The use of ARE 11 for new exchanges will be limited because the SPC local exchange system, which will be introduced in the early 1980's as an alternative system, provides even greater economies in these applications than can ARE 11.

Currently an order has been placed by Telecom Australia for ANA 301 equipment to upgrade 13 exchanges in all States of Australia to enable the recovery of about 1500 Reg LM and 200 Reg LP. These exchanges are expected to be cutover in 1978. The modernisation proposals for the network are expected to be completed by 1982. By 1985 the penetration of ARE 11 into the network is estimated to be approximately 3.4m lines of the estimated total of 7m lines in the network at that time.

REFERENCES

1. Local Exchange System — ARE 11; L. M. Ericsson Publication 117 587 Ue, September, 1975.
2. 'Stored Program Controlled Register System ANA 30 for Crossbar Exchange'; Ericsson Review No. 4, 1973.
3. ARE 11 Switching System Planning Letters.
   No. 2: Principal Facilities of the ARE 11 System, Issue 1976.
   No. 4: Preliminary Implementation Planning Guidelines, Issue 1976.

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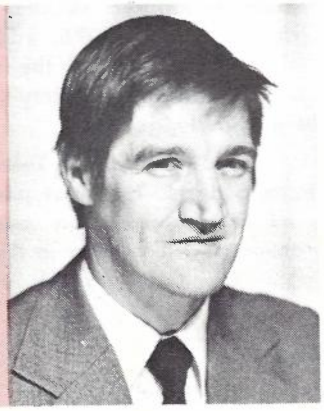

Data Communication – Basic Facts and Facilities Available – Part 1

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Data communications in Australia is mainly based upon utilisation of the transmission and switching network provided primarily for telephony. Some transmission characteristics which are of relatively minor importance in voice telephony are of greater importance for data, and these are described in a general way. The universal availability of the public switched telephone network make it an attractive medium for many data communication applications but the spread of transmission characteristics encountered imposes important limitations. The use of private lines overcomes most of these limitations where the generally higher costs are warranted. Maintenance and performance factors for both the public switched telephone network and private line applications are discussed. The facilities offered by the datel service are summarised and mention is also made of two specialised data networks.

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The paper is reproduced in the Telecommunication Journal in two parts. This first part considers the influence of the transmission path on data integrity; the second part to appear in the next issue covers the data facilities offered by Telecom Australia.

INTRODUCTION

In Australia as in other countries, data communication services are at present mainly based on utilisation of the transmission and switching network designed for voice communication within a nominal bandwidth of 300 to 3,400 Hz. Being a speech-oriented network, it has transmission characteristics that are acceptable for voice transmission but are not ideal for data transmission paths. As a consequence, much of the engineering effort in providing data services is directed to reducing the effects of these undesirable characteristics.

The overriding virtue of the existing general telecommunications network, however, is that it provides wide coverage and on this network there are two types of circuits that are available for data transmission:

- The public switched telephone network
- Private lines

Together they service many thousands of data terminals, with a network growth rate exceeding 50% per annum for each of the past four years. These modem operated services using the telecommunications network are termed datel services. There are at present in Australia some 9,000 terminals on the datel service and the distribution by speed of these terminals is shown in Table 1.

There are in addition two specialised networks carrying data traffic viz. the Common User Data Network (CUDN) and the telex system.

It is the purpose of this paper to concentrate upon the essential present day issues relating to the basic facilities available from these three services, datel, CUDN and telex, and to describe the regulatory, tariff and policy aspects which influence their use.

In each State and at the national Headquarters of Telecom Australia consultants who are experienced in the technical and commercial complexities involved in the provision of datel services are available to discuss customers' enquiries. These consultants are available to deal with the topics mentioned in this paper in greater depth. An intending user might wish to detail the broad outline of his communications requirements and seek the assistance of these consultants in the design and implementation of a network from both the technical and commercial point of view. Fig. 1 shows the pattern of build up of data services, from an administrative point of view.

INTERNATIONAL STANDARDS FOR DATA COMMUNICATIONS

A number of international bodies are concerned with the setting of standards for data, and data communications. Telecommunications authorities are particularly concerned with the operations in this field of the International Telegraph and Telephone Consultative Committee (CCITT) which co-operates with the International Standards Organisation (ISO) and the International Electro-technical Commission (IEC) according to rules defined in Recommendation A20 of the CCITT.

The CCITT has responsibility for those aspects of data transmission which require a knowledge of telecommunications networks or affect the performance of these networks e.g. signal conversion terminal equipment (modems). There are other topics such as standardisation of the junction (interface) between modems and data terminal equipment which require agreement between CCITT and ISO. Many other bodies, such as the Conference of European Postal and Telecommunications Administrations (CEPT) and the International Federation of Information Processing (IFIP), contribute to the development of the international standards in the data field which are the primary responsibility of CCITT and ISO.

The main impetus to CCITT of course comes from the telecommunications authorities of the member nations, and of ISO from the national standards bodies. In Australia, following a long tradition in the telecommunications field we have closely followed CCITT data transmission recommendations. These recommendations are intended to achieve uniformity for data transmission equipment operating via modems on existing telecommunications networks, both switched and private lines.

Existing telecommunications networks have evolved until recent years without taking into account the requirement for data transmission which has developed rapidly by means of modems. Existing data communications facilities therefore fall short of the ideal and specialised networks designed specifically for data communications are now being developed in several countries. Standards for modulation rates and interfaces for networks specialised for data are now being developed by CCITT and ISO.

TRANSMISSION PATHS FOR DATA

The Australian long-distance broadband transmission grid is frequency sub-divided into channels of lower bandwidth in a standardised multiplexing hierarchy which allows the derivations of 4 kHz separated voice channels, permits the through connection of larger slices of the spectrum for subdivision at other points into 4 kHz separated voice channels, and provides for wide-band TV links. (Pulse code modulation systems have not been exploited to a significant extent in Australia for economic reasons, and then not at all on long distance links.) The two bandwidths which have greatest relevance in data communication are the voice bandwidth link, with channel separation of 4 kHz and the group bandwidth link with channel

TABLE 1 — DATA MODEMS IN OPERATIONS (At 30 June)

Data Transmg. Speed	1970	1971	1972	1973	1974	1975	1976*
**							
200/300 bit/s	295	745	1,010	1,502	2,145	3,394	4,685
600/1200 bit/s	270	397	417	557	801	1,233	2,417
2400 bit/s	—	46	79	254	369	611	824
4800 bit/s	—	—	21	143	411	773	1,168
9600 bit/s	—	—	—	—	—	2	55
40.8/48 Kbit/s	—	—	2	2	2	6	15
TOTAL	565	1,188	1,529	2,458	3,728	6,019	9,164

** Bit/s = Bits per second. * Estimated figures.

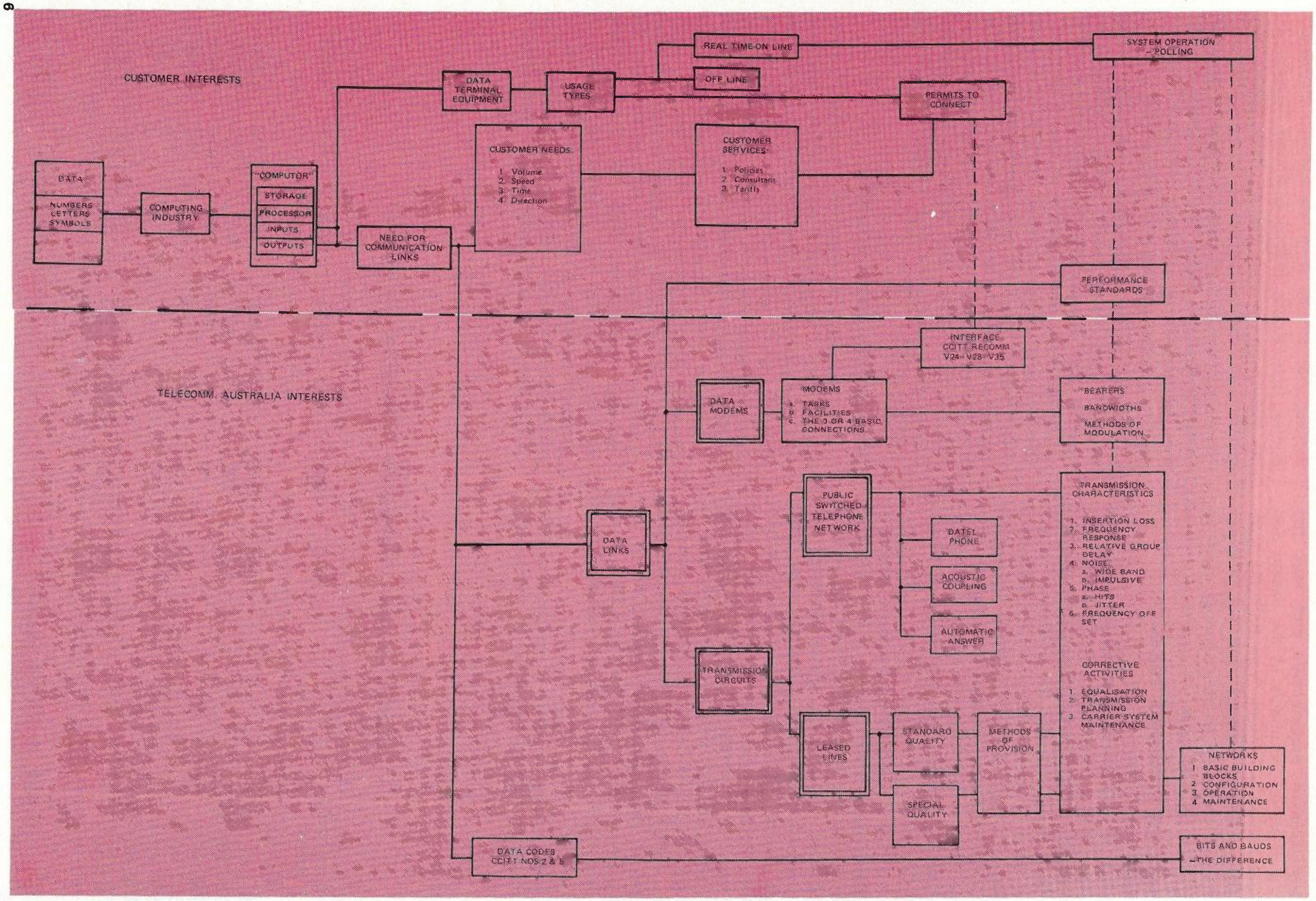


Fig. 1 — Interrelationships between Datel Service Components.

separation of 48 kHz, although greater bandwidths e.g. super group (240 kHz) are currently utilised in a special class of analogue data used in newspaper facsimile transmission. The great majority of data communication services use voice band links over which (depending upon the complexity of the digital/analogue conversion in the modem) quite high data signalling rates can be achieved.

The local transmission path is most frequently a physical cable pair and the typical interstate data communication service involves the interconnection of local physical cable pair "tails" with the long distance voice band link. All practical circuits depart from the ideal in ways which may be described under a number of headings, and may be quantified by measurement. A later section will describe the characteristic transmission impairments or departures from the ideal which occur in practice, their effects on data transmission and the various design and equipment approaches adopted to mitigate these effects. Before doing so, some of the terms used to link the computer and telecommunications technologies need to be discussed. (See also Glossary of Terms).

BANDWIDTH, BITS, BAUDS, AND MODULATION

The data signalling rate that can be achieved from data terminal to data terminal over a link is directly related to the bandwidth and methods of modulation used. The normally available bandwidth in 4 kHz separated channels is 300 to 3400 Hz.

At this stage it is necessary to define the term "baud". The baud is the unit of modulation rate. It corresponds to a rate of one unit interval per second. The modulation rate in bauds is then the inverse of the time duration of the shortest signal element transmitted to line in seconds. The unit baud can only be used for signals transmitted to line.

The theoretical maximum capacity of ideal voice frequency channel in bauds was given by Nyquist as being equal to twice the bandwidth in Hz. Therefore we might expect our standard voice channel of 3100 Hz bandwidth to have a maximum line signalling transmission rate of 6200 bauds. However, in practice the standard voice channel of the Commission or any other administration is far from the Nyquist ideal. At the moment the highest baud rate in use is 2400.

The data signalling rate is given in bit/s transmitted or received by a data terminal per second. It is the rate at the interface between the Data Terminal Equipment (DTE) and the Data Communications Equipment (DCE). The line signalling rate (bauds) and the data signalling rate (bit/s) may be numerically equal, or may differ, depending upon the method of signal conversion (modulation) used in the modem.

At speeds up to 1200 bit/s frequency shift keying (FSK) modulation techniques, as used for voice frequency telegraph systems, are used. The technique is robust with respect to immunity to noise interference and channel distortion where the ratio of bit rate to bandwidth is low. When a "I" is being transmitted by the terminal, a 1200 bit/s Plan 32 modem sends a signal of 1,300 Hz to line. When a "O" is being transmitted the line signal frequency is 2100 Hz. Thus the time duration of a "I" and its corresponding line signal are equal and hence the data signalling rate in bit/s is numerically equal to the modulation rate in bauds.

At higher data signalling rates new methods of modulation had to be found because the standard voice channel bandwidth is not wide enough to satisfactorily transmit the FSK modulation products. The solution to the problem of achieving higher data signalling rates within a nominal bandwidth of 3,100 Hz having the commonly achievable characteristics has been to increase the amount of information represented by each signal element that is transmitted to line.

This is achieved by changing the line signalling state according to the pattern of a group of bits rather than a single bit. This enables the modulation rate to be kept within the capability of the available bandwidth but requires more modulation states, and because of this more complex and expensive modems.

At data signalling rates at the next standardised speed above 1200 bit/s (2400 bit/s) designers choose to pair bits (dibits) for digital/analogue transfer on to the channel. There are of course four possible combinations of pairs of bits, i.e. 00, 01, 11, 10; see Table 2.

The signal elements that are transmitted to line present the information contained in two bit pairs and in the 2400 bit/s modems each of these four combinations is now represented by a defined shift in phase of the line carrier.

TABLE 2 — CODING PATTERN CCITT RECOMMENDATION V26

Dibit	Phase Change
00	+45°
01	+135°
11	+225°
10	+315°

Thus for a data signalling rate of 2400 bit/s the line signalling rate is 1200 baud, because each signal element to line is 1/1200 of a second long. At 4800 bit/s the modems group the bits in three's hence the line signals have a time duration of

1/1600 of a second or a rate of 1600 baud. These modems use differential eight phase modulation, one phase for each of the eight possible combinations of 3 bits.

At the 9600 bit/s the bits are grouped together in fours thus making each line signal 1/2400 of a second long (a line signalling rate of 2400 baud) and taking one of 16 possible "levels". The modems that the Commission is using achieve this by having combinations of eight phase levels and two amplitude levels.

TRANSMISSION IMPAIRMENTS

All circuits have a set of transmission characteristics that have a direct influence on the successful transmission of data over them. Data line signals can be considered as being made up of many component signals of different frequencies and amplitudes. For good performance, ideally (i) all these components should arrive at the receiver in the same amplitude and with the same time relationships to one another that existed when they were transmitted, and (ii) these signals should be free from any distortion due to non-linearity in active devices such as amplifiers and additions due to extraneous noise signals of a steady, transient or impulsive form. In practical circuits, to achieve the desired good performance special steps need to be taken to improve transmission characteristics of special relevance to data.
Table 3 shows the relative significance of these characteristics.

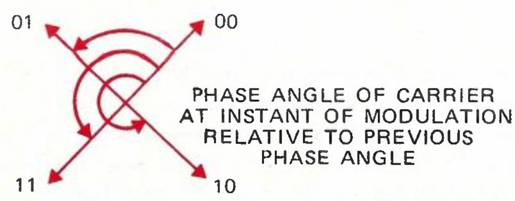
TABLE 3 — LINE TRANSMISSION PARAMETERS AND THEIR SIGNIFICANCE

	Degree of Influence	
	On Voice	**On Data**
Insertion Loss	XXX	XXX
Frequency response	X	XXX
White noise	XX	XXX
Impulsive noise	X	XXX
Out of synchronism	X	XXX
Crosstalk	XXX	XX
Phase hits	—	XXX
Phase jitter	—	XXX
Relative group delay	—	XXX

The group delay and phase characteristics do not affect speech because the human ear cannot detect differences in the phase of signals. It is possible, although annoying, to speak over a noisy line by repeating the statements as required. However, in data transmission phase distortion and noise can have a very serious effect on data reception.

These characteristics can be put into two classes

- Passive
- Dynamic



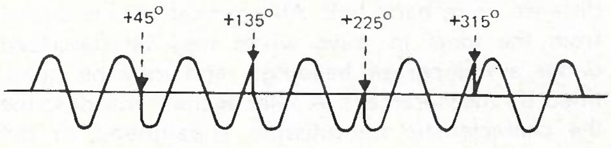


Fig. 2 — Phase Change Relationships for CCITT Recommendation V26 Modems.

Passive Characteristics

The passive characteristics are fixed by the make up of the line. They are:

- Insertion Loss
- Frequency Response
- Relative Group Delay

Insertion loss relates the amplitude of the line signal at the sending end with that received. The insertion loss is determined by the algebraic sum of the losses and gains along the circuit. Insertion loss can vary with time, but, with modern amplifiers and good automatic gain control facilities in carrier systems, these variations are small. Insertion loss is not in practice the same figure at all frequencies. It is normally measured at a particular frequency, and needs to be related to frequency response.

If the loss is too high, the induced noise, especially near the receiving end, will produce a low (poor) signal to noise ratio. The remedy is to provide amplification at points along the transmission circuit.

Frequency response relates the amplitude relationship of the components of the complex line signal at the sending end with those received. These may extend over most of the bandwidth of the transmission circuit. For an untreated line these signals would arrive at the receiver at an overall lower level (due to insertion loss) and a different amplitude relationship due to different insertion loss at different frequencies. The frequency response and relative group delay are determined by the physical make up of the cables and the characteristics of the filters, especially the channel band pass filters. These two characteristics do not change with time and therefore can be equalised, see Fig. 3.

Relative group delay relates the phase relationship of the components of the complex line signals at the sending end with those received. For an untreated line (especially one consisting of one or more system channels), these components would be received bearing a different phase relationship — especially those near the sides of the bandwidth. A group delay equaliser has a phase characteristic that compensates that of the line.

Fig. 3 is a circuit test sheet of an actual special quality circuit. It shows the group delay and frequency responses for a typical interstate Datel circuit. It also shows the limits within which these variables must lie to satisfy the special quality specification.

Dynamic Characteristics

The dynamic characteristics are:

- White Noise
- Impulsive Noise
- Crosstalk
- Phase Jitter
- Phase Hits
- Out of Synchronism

White noise is taken as being the usual wide band noise that is generated by thermal effects and power induction and which usually remains at a fairly steady value with respect to time.

Impulsive noise on the other hand is quite variable with respect to time and can depend upon

DATA PRIVATE LINES	Receive Level (800 ohm term) @ 1.6 kHz -13.5 -dbm	Flat Noise (600 ohm term) -56 -dbm	Near End X-Talk >50 db.

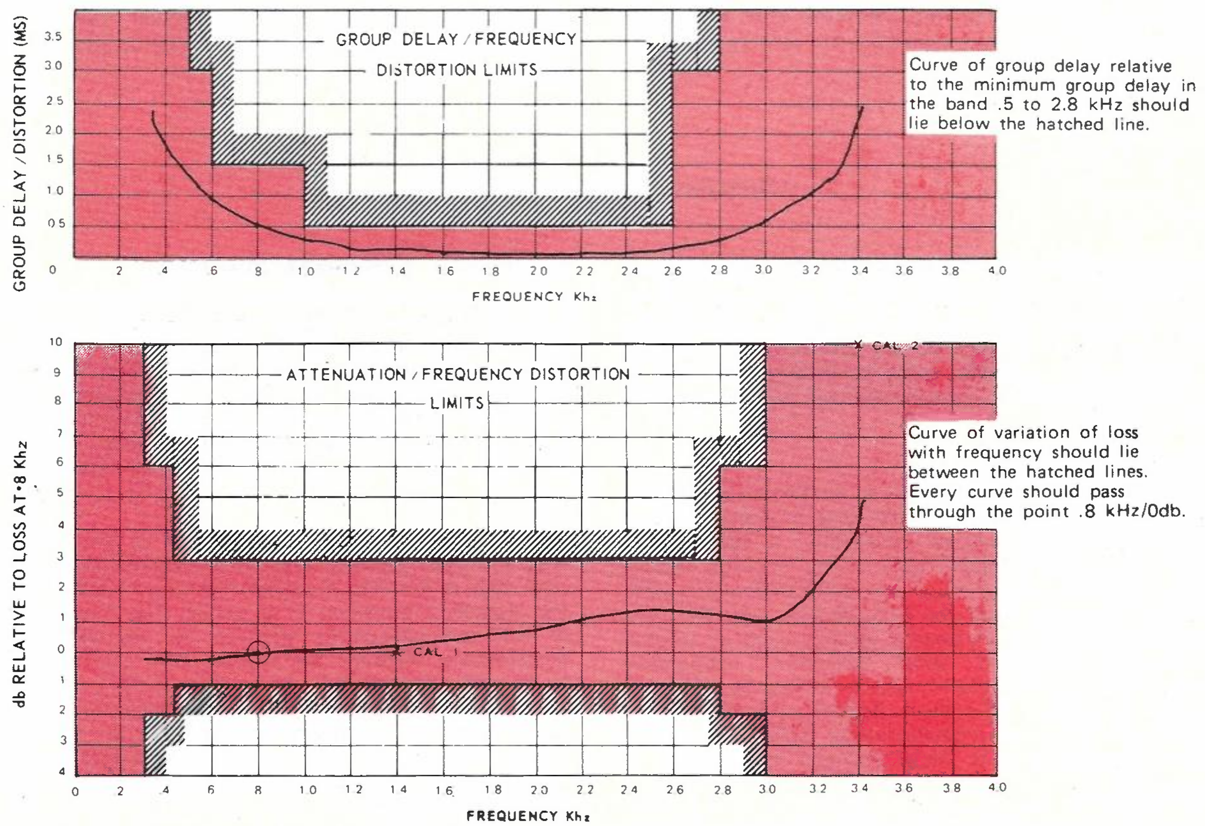


Fig. 3 — Typical Group Delay and Frequency Responses of an Interstate Datel Service.

the time of day and the routing of the circuits. Sources of impulsive noise are inductively or capacitively coupled dialling impulses and transients produced in exchanges by the operation of electro-mechanical switching equipment. However data modems are designed to withstand the effects of this coupled impulsive noise provided the network is maintained to specified limits.

When the network operates outside these limits the modem receiving circuitry might, at a particular sampling instant, interpret the receive line signal as being a 1 when it should have been a 0. The number of bits in error produced by a noise impulse depends on:

- The amplitude of the noise impulse
- The time duration of the noise impulse
- Whether a line signal element contains the information of one, two, or three bits.

Crosstalk can be obtained by direct crosstalk in cable pairs or by overload intermodulation in common equipment such as coaxial cable line repeaters. Crosstalk has a similar effect to impulsive noise.

It is not possible to equalise out crosstalk and noise, but their effects can be reduced by closer specification of all telecommunication equipment having regard to data requirements and additional emphasis on data requirements in maintenance of plant.

Phase jitter is the regular or cyclic variation from correct phase of the received line signal. Low phase jitter depends upon good design and maintenance and in newer equipment tighter design specifications have been used. Phase jitter must now lie between 15 degrees peak to peak and not vary cyclically outside specified limits.

A phase hit is a sudden jump in the phase of the line signal received by the modem. These sudden jumps are generally caused by the switching of radio bearer circuits from normal to stand-by and vice-versa. Phase hits are reduced by good design and good installation practices which ensure that for example, there will be no difference in the propagation time between radio bearers.

Out of synchronism is due to differences in systems carrier supplies, for example a 1000 Hz tone sent into a channel may be received at the distant end as 1005 Hz (the usual limit). This distortion causes serious errors in low speed modems using frequency shift keying. The solution to this is good maintenance practices with respect to the synchronisation of carrier supplies.

Generally the higher the speed the more significant is the effect of the line parameters. Hence there must be greater attention to the application of transmission planning principles and maintenance and operation practices as the speed of transmission increases.

APPENDIX: GLOSSARY OF TERMS

An Introduction To The Terms Used In Data Transmission

It is hoped that this introduction to the terms used in data transmission will help towards a better understanding of the basic concepts that are involved and perhaps in this way the mystique which is already beginning to be associated with data transmission will in some measure be dispelled.

Analogue Transmission

With analogue transmission a continuously variable signal as opposed to a discretely variable signal is transmitted. The normal way of transmitting a telephone or voice signal is 'analogue', that is, the physical speech waves from the human voice are converted into a sympathetic electrical wave for transmission over the telephone system. Many measuring devices such as electrocardiograph machines, level indicators, temperature gauges etc. are analogue in nature. It may be necessary to read the output from these devices and transmit the information over data communication links to a central point. This can be done using analogue transmission.

Anisochronous

The term 'anisochronous' is used in the situation where the signals employed may be of variable duration. Morse code is a simple example of anisochronous transmission where the dots and dashes are of different durations.

Asynchronous Transmission (Start/Stop)

In an asynchronous transmission system each character is preceded by a start signal which serves to prepare the receiving mechanism for the reception of a character; this is followed by a stop signal which brings the receiving mechanism to rest in preparation for the reception of the next character. Asynchronous transmission may use start and stop elements between blocks of characters rather than between individual characters.

Baud

The term 'baud' is often used loosely in data transmission. It should be used only when describing modulation rate; that is the rate at which changes can be made in the signalling condition of a circuit. The term is useful to the communications engineer in describing circuit performance. Perhaps the reason it is incorrectly used to describe information transfer rate is that, historically, telegraph systems and most data transmission systems have used two condition signalling, i.e. in transmitting a five unit code five consecutive signals would be sent to represent the information, each signal being in one of two possible states.

Bits Per Second (Bit/s)

In most data transmission codes each character is allocated a unique combination of binary digits (bits).

For example in a six unit code the letter 'A' might be represented by the following combination of bits: 01001. As data communication codes vary in the number of bits used to represent each character, it is often more meaningful and more accurate to use the term 'bits per second' to describe the information transfer rate which is possible on a circuit rather than the alternative term 'characters per second'. For example, the information transfer rate might be say 600 bit/s; if a six bit information code were used this could give a rate of 100 characters per second. If however, an 8 bit information code were used the rate would be 75 characters per second — apparently slower (redundancy is ignored in this simplified example). This can be misleading and it is preferable for the systems designer to use the term 'bits per second' if accuracy is required and 'serial' transmission is employed.

CCITT

The International Telegraph and Telephone Consultative Committee (CCITT) is one of the four permanent organs of the International Telecommunications Union (ITU) which is a specialised agency of the United Nations Organisation. The CCITT studies and makes recommendations concerning technical, operational and tariff aspects of International telephone, telegraph and data communications.

Data Transmission

Data Transmission can be described as the movement of information in coded form over some kind of electrical transmission system by breaking down letters and figures for example into simple codes in order to send messages by electrical means. The origins of data transmission lie in telegraphy, which is the branch of telecommunications concerned with the process of remote reproduction of documentary matter. Data transmission may be distinguished from telegraphy mainly by the fact that some form of processing is usually involved either prior to or after transmission.

Data Transmission Rates

The rate at which data should be transmitted and received is one of the problems facing the data communication system designer. The determining factors should ideally be the needs of the system i.e. the volume of data, the urgency, growth of traffic and other operational factors. However, the availability and costs of suitable terminals and communications facilities are often constraints on the systems design. Whilst the systems designer is primarily concerned with how much usable data he can send over the data communications link in a given time (information transfer rate), the communications engineer is concerned about the performance of a circuit in terms of the number of signal changes that can be made in a given time (modulation rate). This is perhaps the reason for the confusion which often arises when the two terms 'bits per second' and 'baud' are used.

Digital Transmission

With digital transmission, data characters are coded into discrete separate pulses or signal levels. Perhaps, in the future, digital data networks will aim to exploit the great potential of digital techniques for the transmission of data. Digital techniques can be used for the transmission of speech using Pulse Code Modulation (PCM). Paradoxically, whilst the initial approach to the problem of transmitting data has been to make it 'look like' speech, it now appears that in the future we may make speech signals 'look like' data signals.

Directions of Transmission

The following terms are used to describe the direction in which data is sent on a data transmission link. Some confusion often arises because there is a difference between the use of the terms when applied to telegraphy (as defined by CCITT) and their use in data transmission. The meanings ascribed to the terms here are those which are in common use in the computer and data transmission fields. Figs. 4, 5 and 6 indicate the direction of transmission only; not the number of wires necessary.

One Way

Transmission in one-direction only (Fig. 4).

Duplex

Transmission in both directions simultaneously (Fig. 5).

Half Duplex

Transmission in both directions, but not at the same time (Fig. 6).

Duplex

(See Directions of Transmission).

Frequency Division Multiplexing (FDM)

With frequency division multiplexing a relatively wide bandwidth (range of frequencies available for signalling) is divided into a number of smaller bandwidths to provide more channels of communication. For example the bandwidth required for the transmission of 50 baud telegraph signals is only 120 Hz, while the bandwidth of a good quality speech circuit is about 3000 Hz. Using FDM, 24 telegraph channels can be derived from one speech circuit.

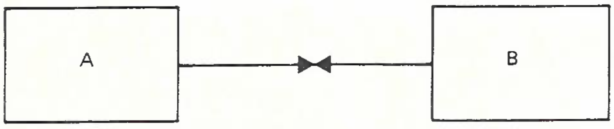


Fig. 4 — One-Way Working.

Fig. 5 — Full Duplex Working.

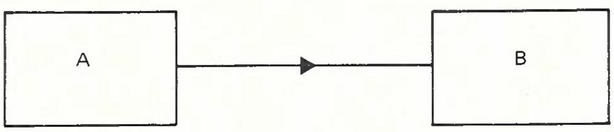


Fig. 6 — Half Duplex Working.

Half Duplex

(See Directions of Transmission).

Isochronous

The term 'isochronous' is used to describe a modulation system in which each signal is of equal duration.

Modems

The term 'modem' is derived from the functions performed i.e. modulating/demodulating. Data, in the form of letters and figures, is changed in a data transmission system into a code comprising binary digits. The direct current output from a data transmission terminal is not suitable for transmission over the existing speech network. These signals are, therefore converted into voice frequency signals for which, of course, the speech system is designed — this is the modulation process. The data now contained in the voice frequency signals transmitted to line have to be converted back again into signals suitable for acceptance by the data transmission terminal at the receive end — this is the demodulation process. There is, therefore, the need to have a modem at each end of a data transmission link when data is to be passed over the existing telephone system.

Multiplexing

Multiplexing is the division of a common path or circuit into a number of channels. (See also Frequency Division Multiplexing and Time Division Multiplexing).

One Way

(See Directions of Transmission).

Serial Transmission

Using this type of transmission each bit in a character is sent sequentially to line; by convention the least significant bit is usually sent first—0100011.

Synchronous Transmission

In this type of transmission, process synchronisation is maintained, i.e. the receiver is kept continuously in step with the transmitter throughout the transmission by electronic clocking devices.

Time Division Multiplexing (TDM)

Time Division multiplexing is a process whereby a channel, which is capable of a relatively high information transfer rate (in bit/s), is divided up into a number of time slots to provide a number of lower speed channels. For example, a line which is capable of carrying 2400 bit/s could, by the use of TDM, theoretically be divided into four 600 bit/s channels—or a combination of different speed channels up to a maximum of 2400 bit/s.

REFERENCES

AUSTRALIAN POST OFFICE; "Data Facilities Handbook"; 1974.

BOCKER, P.; "Data Traffic in Communications Networks"; Telecommunications Journal, Vol. 43, No. 1, 1976.

C.C.I.T.T. Green Book; Vol. VIII, "Data Transmission"; 1972.

EDMONDS, P.; "Modems as Part of Data Communications Systems" Communications International, March 1975.

LENKURT CORPORATION; "Data Transmission Principles and Problems"; Lenkurt Demodulator, August, 1974.

TAYLOR, G. P.; "Common User Data Network"; Telecomm. Journal of Aust. Vol. 25, No. 2, 1975.

McKINNON, R. K.; "The Development of Data Transmission Services in Australia"; Telecomm. Journal of Aust., Vol. 20, No. 3, October 1970.

SNOW, N. E. & KNAPP, N. JR.; "Digital Data System: System Overview"; Bell System Technical Journal Vol. 54, No. 5, May-June 1975.

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In Brief

INTERNATIONAL SYMPOSIUM ON SUBSCRIBER LOOPS AND SERVICES

Telecom Australia submitted two papers to this symposium in London during 1976. The first of the papers entitled "Code-division Multi-plexed Delta Modulation for the Subscriber Loop" by P.S. Jones, proposed a subscriber loop multiplexing system using a high performance digital coding technique. The multiplexing is achieved not by the conventional time-division method, but by the use of Walsh function based code words with a majority logic multiplexing technique which provides constructive redundancy in the transmitted stream when the system occupancy in low. Such a multiplexing characteristic with high redundancy at low system occupancy admits low bit rate coding whilst retaining desired performance. The coding technique chosen was instantaneously companded delta modulation. Detailed performance figures have not yet been presented for this system as studies are continuing towards the point where a precise economic comparison will be made with existing subscriber loop techniques.

The second paper was entitled "Demand Assignment System for Subscribers Digital Loop" by A. Even-Chaim. A four-wire closed loop subscriber digital system was proposed in which circuits are assigned to subscribers on a demand basis. In this case, a time-division multiplexed PCM code is used, operating at 2.048 Mbit/s with common channel signalling. The switching and the signalling aspects of such a system within a telecommunication network were discussed together with the possibility of new services and facilities for the subscriber.

Both papers attracted considerable interest and discussion, providing a worthwhile contribution to those sections of the Symposium devoted to the subscriber end of a digital network.

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Visual Communication over Telephone Lines

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Visual communication systems for use on normal telephone services can be expected to decrease in cost as use is made of currently emerging semi-conductor devices. An expansion of the market for at least some of these systems is likely to follow. This paper reviews some of the equipment used in the past and the present-day, and describes new developments that may have substantial impact on the industry in the near future.

INTRODUCTION

The use of telephone lines restricts both the transmission rate and methods used for visual communication. The 3 kHz bandwidth of the switched network cannot be fully exploited because of the necessity for compatibility with the existing signalling schemes and irregular behaviour of the group-delay characteristic near the band-edges. Noise also places restrictions on the channel transmission capabilities. On telephone lines burst or impulsive noise rather than Gaussian white noise usually predominates. Thus much of the classical communication theory is inapplicable.

The maximum recommended digital transmission rate over the Australian switched network is currently 2400 bits/s. This is likely to be increased to 4800 bits/s in the near future, but it is unlikely that 9600 bits/s will be adopted for some time, if at all. Thus the performance of any visual communications system designed for use in the present analogue switched telephone network is limited by a channel that has a useable bandwidth of less than 3kHz or a data rate capability of only, say, 4800 bits/s.

This article reviews some of the systems which have been designed to enable visual communications over telephone lines. The established alphabetical telegraphy systems such as telex and computer system peripheral devices (visual display units, etc.) are not considered. Emphasis is given to equipment now available or likely to become available on the Australian market.

FACSIMILE

In telecommunications, the term facsimile (or "fax") is used to describe systems which use a scanning technique to allow the reproduction, at a distance, of fixed images in permanent form. The fixed image may be photographic or otherwise, depending upon the system. The history of fax dates from an invention by Alexander Bain in 1842 (Ref. 1), well before the invention of the telephone. This first fax machine scanned images which were formed in metal, raised portions were detected and the resulting pattern of contact closures was transmitted. It was thus an ingenious extension of the existing telegraph technology.

Since that early invention there have been several interesting episodes in the history of fax (Ref. 1). Some of the most interesting were the trials in the U.S.A. in the 1930's, 1940's and again in the 1950's of newspaper broadcasting via radio using fax sets. The technical problems were solved, broadcasts commenced and many machines were installed in homes but the scheme never captured a large market. The attempt to popularise the system in the early 1950's probably failed because the attention of the public was drawn towards television.

Today there are several well established specialised markets for facsimile. News services use fax for the long distance transmission of photographs, weather maps are transmitted via fax. Some 30,000 machines are reported (Ref. 2) to be used by one company in the U.S.A. for the transmission of telegrams. Machines with high resolution and

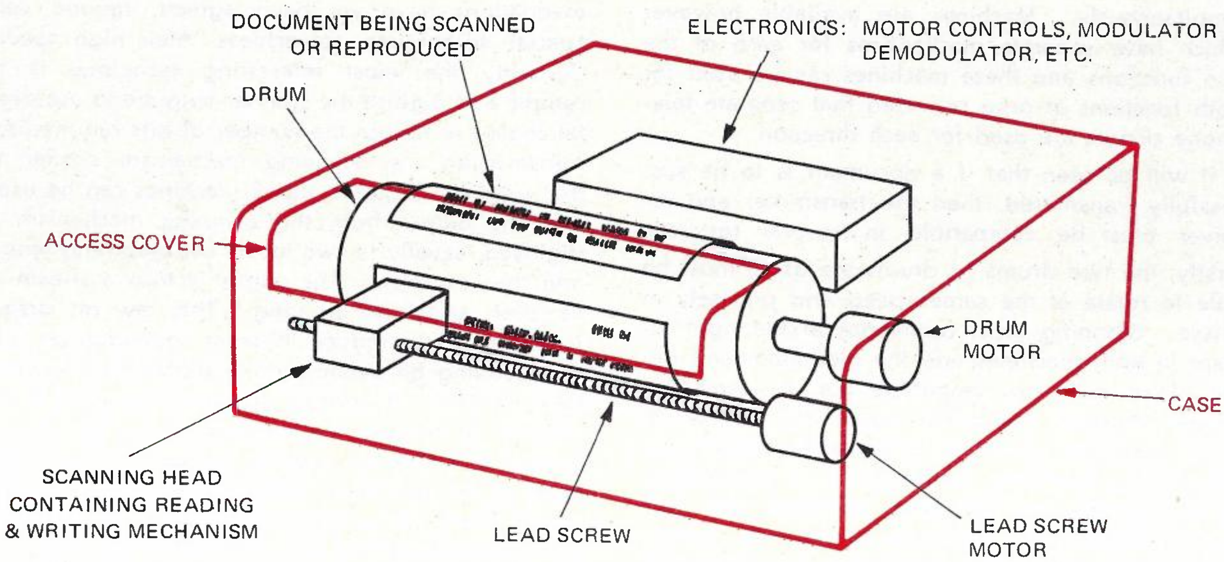

Fig. 1 — Common Layout for Facsimile Machines.

high speed are used for the transmission of complete newspaper pages thus allowing newspapers to be composed at one location and printed at other locations hundreds or thousands of kilometres distant (e.g. Ref. 3).

Some postal administrations offer a fax service as a fast alternative to the normal postal service. Fax machines are installed at major population centres and a document delivered to one of the centres can be transmitted to another centre (or centres) and then delivered by messenger. The service can be rather expensive; a trial service reported in Great Britain had announced charges of over $3 for the first page plus approximately 80c for delivery (Ref. 4). Following the opening in 1962 (Ref. 5) of the telephone network in the U.S.A. to subscriber-provided fax machines (via an appropriate interface), there has been a steady growth in that country of another specialised fax market. This is the market for "business fax" or "document fax" where machines are designed for the efficient transmission of business documents over a telephone bandwidth channel. Document fax machines have a resolution appropriate to the transmission of characters produced by standard typewriters and do not aspire to high quality half-tone reproduction. In fact some machines, particularly those which give the highest transmission speeds, are designed to reproduce only black or white and no shades of grey.

The document fax market has grown in many countries and in Australia several types of machines are approved for use on a permit-to-connect basis. Fig. 1 illustrates the type of mechanism which is common in document fax machines. Most of the machines available in Australia are similar to this. When the machine is used for transmitting, a document is placed around the drum, facing outwards. The drum then rotates, at a constant rate, and the scanning head moves slowly axially in front of the drum at a rate of about one millimetre for every four revolutions of the drum. A lamp in the scanning head illuminates a small area of the document below the head. Light reflected from the document is sensed by a photo-sensitive detector, also in the scanning head. The output from the detector is processed and transmitted to the fax receiver which is a similar machine but has wrapped around its drum the paper on which the document is to be reproduced. The writing mechanism which is built into the scanning head is activated in the receiver and supplied with the signal from the transmitter. One common technique used in fax receivers requires a special multi-layer paper; current passed through the paper via a stylus in the scanning head removes a small area of the upper white layer thus revealing the black layer beneath. A black on white image is thereby formed.

Obviously, the type of machine described above cannot be used for transmitting and receiving simultaneously. Machines are available however which have separate mechanisms for each of the two functions and these machines can be used for both functions at once provided that separate telephone circuits are used for each direction.

It will be seen that if a document is to be successfully transmitted, then the transmitter and receiver must be compatible in several respects. Firstly, the two drums (if drums are used) must be able to rotate at the same speed and precisely in phase. Scanning must commence at the right instant in both machines and the modulator and demodulator must be compatible (i.e. in respect of carrier frequency, AM or FM, polarity of modulation etc). These are just some of the factors which contribute to compatibility, or lack of it. Unfortunately, standardization has not been achieved and each manufacturer offers machines which are incompatible with those from most other manufacturers. Thus the document fax market is fragmented into several essentially incommunicado sub-markets and this situation precludes the development of document fax into a standard business facility. Two possible solutions to this problem are to either restrict the market, allowing only those machines complying to a single standard or alternatively, to provide in the interconnecting telephone network the capability of converting fax signals from the standard of the sending machine to the standard of the receiving machine. This second possibility is interesting because many other facilities could be provided at the same time; e.g. store-and-forward message transmission.

Recognising the problem of international compatibility, the C.C.I.T.T. has made recommendations on the standardization of document fax machines. As a starting point for these recommendations, document fax machines have been divided into three groups by definition:

- Group 1 machines transmit an A4 document in about 6 minutes,
- Group 2 machines require about 3 minutes and
- Group 3 machines take around one minute.

Group 1 and Group 2 machines are basically similar, the main difference being that Group 1 machines use double sideband transmission whilst Group 2 machines use vestigial sideband transmission or similar techniques. There is therefore little difference in the prices of the two types of machine and because the increased speed of Group 2 machines results in reduced transmission costs it can be expected that the market for Group 1 machines will be relatively small in the future.

Group 3 machines, for which no specific recommendations have yet been agreed, require very special techniques to achieve their high speed. Currently the most interesting technique is to sample and digitise the scanner output and use digital coding to reduce the number of bits required for transmission. A scanning mechanism similar to that used by Group 1 and 2 machines can be used and the output from the scanning mechanism is digitised, usually to two levels i.e. black and white, and then sampled. The output is thus a stream of samples, each one bit long. This raw bit stream is processed to reduce inherent redundancies and the resulting bit stream is transmitted to line via a data modem. A reverse procedure is used at the receiver to recover the original data. Run length coding is a popular way to process the raw data. Most of the raw data consists of runs, i.e. periods where every bit is black (or white). The principle of run length coding is to transmit a code for each run instead of the raw data. For example, the number 25 can be binary coded as 11001 thus a run of 25 bits length can be represented by a five bit code, a reduction in the number of bits of five to one. Although this example tends to make the problem appear to be more simple than it really is, it does illustrate the principle.

So far the C.C.I.T.T. has made recommendations which are sufficient if complied with to ensure compatibility between all Group 1 machines and between all Group 2 machines. One of the machines available in Australia (October '76) complies with the recommendations for Group 1 machines and none complies with all the recommendations for Group 2 machines. A set of recommendations for Group 3 machines may be drafted during the current C.C.I.T.T. study period 1977-1980. No Group 3 machines has yet (October '76) been approved for use on the Australian switched telephone network.

The Future of Fax

In the immediate future the facsimile-on-telephone-lines market will in all probability be dominated by document fax. Group 2 machines should enjoy the highest popularity and Group 3 machines are likely to be used in increasing numbers as the incorporation of more advanced semi-conductor technology reduces the high additional price which must be paid for these machines.

However, in the field of facsimile, forecasts about the future have a sorry history of being hopelessly wrong. There appears to be general agreement that the document fax market will grow but so far the forecasts have tended to over-estimate the growth rate. "Fax-in-the-home" may yet become a reality, but probably not in the near future because of the anticipated greater appeal of services such as Viewdata. Indeed, domestic fax sets will

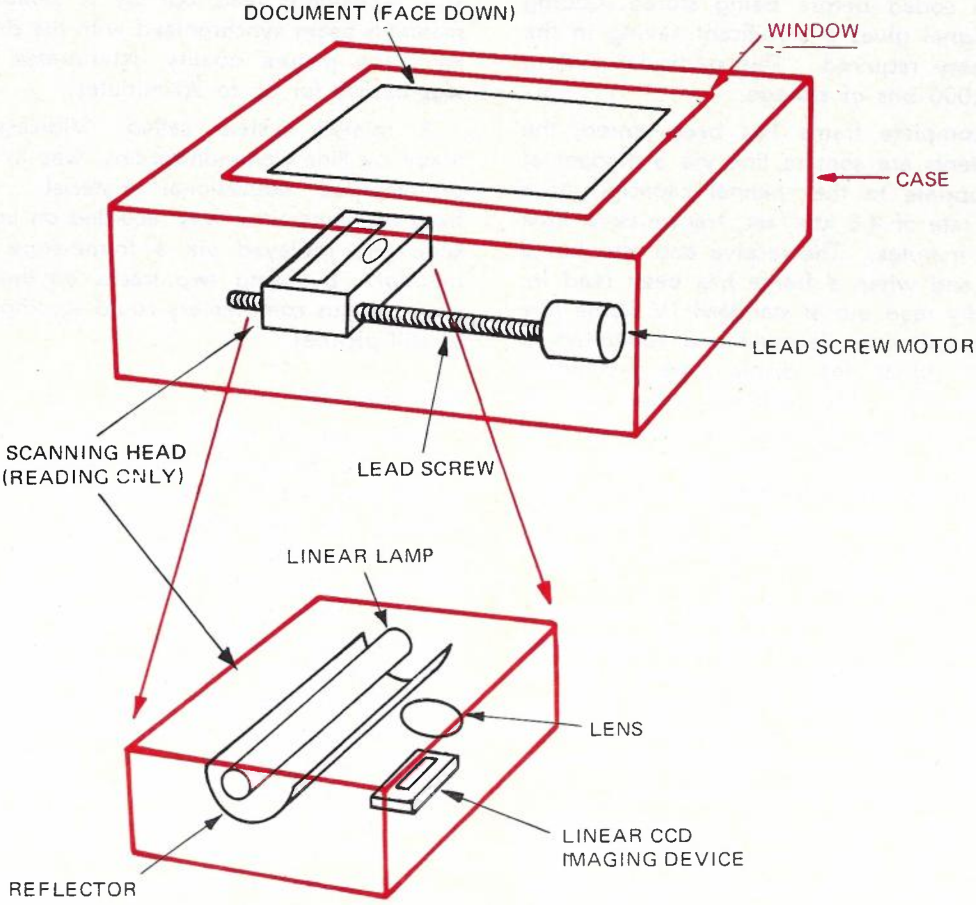

Fig. 2 — Possible Flat-bed Scanner using a Linear CCD Imaging Device.

possibly first become popular as a hard-copy option or accessory for systems such as Viewdata. Document fax machines will grow in popularity, especially as more businesses become aware that facsimile can often be cheaper, and requires much less staff training than telex., Technological advances can be expected to reduce the number of the precision mechanical parts which are required in the scanning mechanism of present fax machines. Devices such as charge-coupled device (CCD) imaging arrays can not only reduce the mechanical complexity but also allow relatively simple flat-bed scanners to be constructed (Fig. 2).

OTHER SCANNING SYSTEMS

The use of television equipment for the transmission of visual information over telephone lines is attractive because of the large amount of TV equipment already in existence and the relatively low cost of TV receivers. Subjective experiments in the early years of TV led to the existing standards; a frame rate of 25 or 30 per second and about 600 lines per frame, hence a bandwidth of 3 to 6 MHz. Thus before a TV picture can be transmitted over a voice grade telephone line, it must be reduced in bandwidth by a factor of one or two thousand to one.

Freeze TV

One system for transmitting visual information, developed by NEC, Japan stores a single frame from an NTSC (National Television System Committee) colour camera in a frame-store at the send end. A moving image can be scanned and stored in one thirtieth of a second, thus the image is effectively frozen, hence the name "Freeze TV". The video signal from the colour camera undergoes an analogue-to-digital conversion and is then differential-PCM coded before being stored. Coding the digital signal gives a significant saving in the size of memory required. This particular system requires 750,000 bits of storage.

When a complete frame has been stored, the memory contents are sent to line via a modem at a rate appropriate to the channel capacity. At a transmission rate of 4.8 kbit/sec, transmission time is about 2.5 minutes. The receive end also has a frame-store, and when a frame has been read in, it is repeatedly read out at standard TV frame rate and the information is decoded and converted to an analogue signal for display on a standard colour TV monitor. The received image can be maintained indefinitely with no loss in quality until another frame is received. One application could be the remote monitoring of hospital patients. One receiver could be used with, say six time-multiplexed transmitters so that each patient is scanned about every 15 minutes.

Colorado Video Inc., U.S.A. (Ref. 6) market a freeze TV system using a standard commercial grade camera and monitor normally used in closed-circuit TV, and a magnetic disc to store a frame. The transmission time can be varied to suit the channel, enabling the use of the switched network, or leased lines if higher speed is required.

A large amount of storage is required for a freeze TV system and using current techniques such as digital integrated circuits or magnetic discs/drums, this frame-store is both physically large and expensive. These factors will limit the acceptance of freeze TV system unless dramatic reductions occur in cost and size of suitable memory technology.

Telpix

In some situations such as signature verification and circulation of police identification photographs, the source material is a hard copy. A frame-store is not required at the transmitting end because the information rate can be matched to the channel capacity by reducing the scanning rate.

An example of this was the prototype "Telpix" system developed by Fine Communications (U.S.A.) which scanned the hard copy source in one minute at a stated resolution of 300 lines per frame using an electrostatically deflected TV camera. The analogue video signal was converted to a 3-bit digital signal (eight grey levels) before transmission. The small, portable transmitting unit was battery powered for field use and could be coupled acoustically to a telephone line. The receiver came in two versions: one produced a hard copy picture and the other had a volatile display (on a conventional TV monitor). The storage device used in the latter version was an image storage tube. Information was written in by a slow-scanning electron beam and repeatedly read out by a standard TV-rate scanning beam synchronized with the display monitor. The picture quality deteriorated slowly but was usable for up to 20 minutes.

A related system, called "Vidicassette", also made by Fine Communications, was in the field of pre-recorded educational material. The signal from the transmitter was recorded on an audio cassette and replayed via a frame-store onto a TV monitor. By using two tracks on the cassette, a simultaneous commentary could accompany a series of still pictures.

Slow Scan TV

Slow-scan TV (SSTV) is a technique which can reduce the bandwidth of a visual signal to the extent that it can be transmitted over a voice-grade channel. In recent years there has been an increasing interest in SSTV for application in various fields including educational and commercial TV broadcasting. SSTV has been rapidly growing in popularity amongst amateur radio enthusiasts for about the last ten years. The generally accepted amateur standards in areas with 60 Hz power mains (Ref. 7) are 120 lines/frame, no interlace, an aspect ratio of unity and a frame period of eight seconds. The video signal is used to frequency modulate a subcarrier; 1200 Hz being used for synchronizing signals, 1500 Hz for black and 2300 Hz for white.

High resolution SSTV systems could be devised to take advantage of the increased resolution that can be realized from vidicon tubes at low beam currents. This results because more time is available to discharge the screen when the scan time is increased, thus allowing lower beam currents. The lower beam currents give a smaller beam size, and thus resolution is increased.

The Videovoice system (Ref. 6) developed by RCA Global Communications has options for both freeze and slow-scan transmission. In the slow-scan mode the frame scan period is 55 seconds while for the freeze mode transmission time is reduced to 30 seconds. It uses a silicon diode video storage tube as the frame-store and this appears to limit the resolution in the freeze mode and thus reduce the amount of data to be transmitted. Reasonable picture quality can be maintained for up to 20 minutes in the freeze mode.

Slow-scan video can be stored on magnetic tape and displayed on either a storage cathode-ray tube (CRT), or a standard TV monitor via a scan converter similar to that described in the Telpix system above.

Random Scanning

Rather than use a sequential line-by-line scanning pattern, picture elements can be sampled at

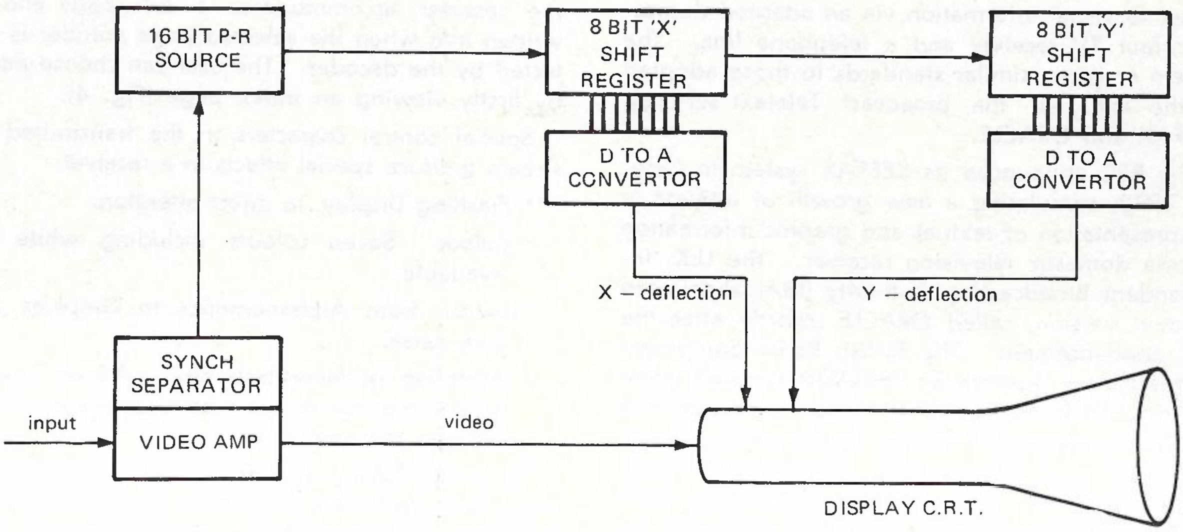

Fig. 3 — Pseudo-random Scan Receiver.

random. This method of scanning reduces the distracting effects of the low repetition-rate SSTV and usually follows a pseudo-random pattern i.e. repeats periodically, rather than being completely random. A pseudo-random scan ensures that every picture element will be sampled within a reasonable time. A system developed by Deutsch (Ref. 8) in U.S.A. in 1962 compresses the required transmission bandwidth to 10 KHz. Picture resolution is 192 by 256 elements (= 49,152) and is poor compared to a commercial quality TV picture of about 500,000 elements. However, Deutsch claims that an inexpensive domestic receiver has a bandwidth of about 2 MHz and is poorly interlaced. Therefore its picture may have a resolution of as few as 50,000 elements. The pseudo-random scan repeats every 2.67 seconds, so if a subject suddenly moves, it is seen to gradually fade from its old position, and progressively appear in its new location over a period of 2.67 seconds.

Human eye-brain characteristics are such that rapidly moving objects appear to show details and accuracy of outline even if these are not present. Most of the missing detail is reconstructed in the mind, especially when the object is seen clearly at the start and end of its motion. Thus although pseudo-random scanning reduces detail and accuracy during motion, the picture is reported (Ref. 8) to be subjectively more acceptable than similar but not pseudo-random scanning SSTV systems in which motion is discontinuous and appears unnatural.

In 1976, the University of Western Australia reported the development of a similar system. The 256 by 256 co-ordinates for their pseudo-random scan are obtained from a 16 bit pseudo-random number source giving 65,535 picture elements (see Fig. 3).

Although with pseudo-random scanning there is no frame flicker which can occur in SSTV, image storage is required in the receiver. Because each picture element is refreshed only once each pseudo-random scan cycle, it needs to be maintained over this period by storage. A long persistence phosphor can be used but its storage time needs to be reasonably long, otherwise the brightness of the older picture elements will decay and the picture has a mottled, noisy appearance, while if too long, movement is blurred and indistinct.

Although pseudo-random scanning offers some advantages when transmitting moving pictures there is little benefit when still pictures such as documents are to be sent. One disadvantage is that the video signal from a pseudo-random scan is not amenable to redundancy reduction. Also because of the need to deflect the electron beam rapidly over large distances for successive elements, electrostatically deflected cameras and receivers must be used rather than the more conventional magnetically deflected type.

VIEWDATA

Viewdata is an interactive information service proposed by the U.K. Post Office to provide online access to visual information via an adapted domestic colour TV receiver and a telephone line. The system employs similar standards to those adopted in the U.K. for the broadcast Teletext services, CEEFAX and ORACLE.

The BBC announced its CEEFAX system in October 1972, stimulating a new growth of interest in the presentation of textual and graphic information via the domestic television receiver. The U.K. Independent Broadcasting Authority (IBA) announced its own version, called ORACLE, shortly after the BBC announcement. The British Radio Equipment Manufacturers Association (BREMA) showed great interest and in March 1974 it was announced that discussions between the three bodies had produced a uniform code incorporating advantages of both systems (Ref. 9). The composite system has been given the collective name "Teletext", although the individual broadcasters are sticking to the original names for their services in all their publicity material.

September 1974 saw the start of actual broadcasting trials by the BBC, while the IBA started its experimental broadcasts of ORACLE in June 1975. The British Post Office then entered the arena, by announcing its Viewdata service, in which Teletext standards are used as far as possible, but data is derived from a telephone connection. Discussions between BBC, IBA, BREMA and BPO were held to ensure compatibility of the services. January 1976 was announced as the start of a pilot trial of the Viewdata system, but unready data suppliers caused a delay of some months. The start of a full public trial is still set for late 1977, but the viability of the service should be able to be gauged from results obtained with Teletext, scheduled for full-scale operation from late 1976.

Teletext Standards

Data is broadcast by TV stations on scanning lines No. 17, 18, 330, 331 situated at the top of the normal picture. Ordinarily these lines should not be visible. The data rate is 6.9375 Mbit/sec; the data lasts for approximately 52 microsec on each line, employs Hamming code correction for control and addressing instructions, and parity checks for all other data. Character font to be employed is left up to the decoder manufacturer, allowing legibility — complexity trade-offs to be evaluated separately. The presentation format is 24 rows of 40 characters each ("row" being preferred to "line", to avoid confusion). Each row of presentation, when coded, fills a line of the field blanking interval. Row address and page number information is included, hence rows and pages may be transmitted in any order, but will normally be sequential. A store of approximately 7000 bits in the receiver accommodates a full page and is written into when the selected page number is detected by the decoder. The user can choose pages by firstly viewing an index page (Fig. 4).

Special control characters in the transmitted bit stream produce special effects in a receiver:

- Flashing Display, to direct attention.
- Colour. Seven colours including white are available.
- Switch from Alphanumerics to Graphics and vice versa.
- Subtitling or Newsflash Box. Allows special announcements or subtitles to be displayed inset into the normal TV picture.

To avoid having to use control characters on every row, each row is assumed to start of "Non-flashing", "Alphanumeric", "White", and "Unboxed", corresponding to normal use. Once invoked, controls remain operative until cancelled, either by the end of the row, or another control code. The control characters used must be suppressed by the decoder, to avoid misleading displays. There are plenty of control codes still undefined, allowing future expansion of facilities.

The Viewdata System.

With a view to minimising transmission costs, the BPO decided that Viewdata computers need to be associated with exchanges, thereby allowing most user calls to be "local" calls. These centres can then be linked with larger regional centres, and perhaps also to a large national centre where infrequently-used information is stored. The smaller data banks can then be updated by trunk-line from higher centres, and by data suppliers at the local centre.

In order to provide a fully interactive service, a "full duplex" operating mode was adopted. Viewdata information is selected by registering the required page number, whereupon data is sent to the viewer at 1200 bit/sec via a data modem and a telephone line. The central computer can be interrogated via a return link of 75 bit/sec on the same line (Ref. 10). A "natural protocol" was worked out, obviating the need for users to learn complicated computer procedures. The user is guided to the information sought by a "tree" system of numbered sub-headings. The sub-heading chosen by the user is registered by depressing the appropriate key on the Viewdata key-pad, whereupon the next list of headings is presented. At the end of the selection process, the complete number is displayed, enabling it to be written down for subsequent use. Where complete page numbers are known, the selection process can be avoided by simply keying in the entire number.

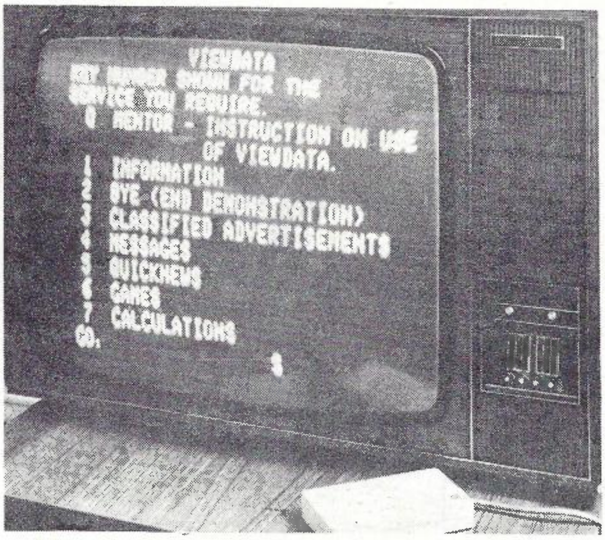

Fig. 4 — A Viewdata Demonstration Terminal with Associated Keypad (picture by courtesy of National Electronics Review, U.K.)

When a specific page has been selected, the computer transfers the designated page from its "hard" storage to a temporary store, from where it is sent to line for display to the viewer. This process is expected to take about 12 seconds normally.

The 12 control keys on the user's key-pad are labelled with the digits 0 to 9, and the symbols* and #. These latter two are used for special instructions, such as "jump back to last page", "jump back to start", and "ignore last instruction".

Storage for the local Viewdata computer will be provided by magnetic discs; each centre holding about 50,000 pages, consisting of 960 characters or bytes. Larger centres are expected to store up to 250,000 pages. If the system proves popular, even this could be expanded. A possible limit to the size of the system is the unwieldy nature of the long strings of digits necessary to cope with accessing so much information.

The Scope of the Information

Information will be divided into broad categories by the first digit keyed in. The following is a typical list of topics, giving a guide to the scope of the information to be provided:

1. General Information. News, sports, entertainment, economy, timetables, directories, services, leisure, hobbies, recipes.
2. Small Advertisements. Property, jobs, services, wanted, for sale.
3. Professional Information Services. Product data, technical library, abstracts, technical development news.
4. Economic Information. Company news, finance, government, internal telephone enquiry service, office services, circulars, book-keeping, personal.
5. Communication Services. Electronic telegram, telex to Viewdata connections and vice versa, press digest, telephone for the deaf.
6. Shopping Hints. Market prices, specials, discounts, mail order.
7. Education. Home tuition, homework, coaching, adult education.
8. Computation. Calculations for the businessman, statistician, scientist, engineer, etc.
9. Reservations. Hotels, motels, cars, buses, flights, holidays and tourist information.

Supply of Data

It will be the responsibility of the suppliers of data (businesses, government sources, etc.) to collect information, review and revise it and submit the result to the Viewdata centre. The BPO does not intend becoming a supplier of data except about its own services.

For the business community, it is planned to market the "Viewdataphone", a Viewdata display device, incapable of receiving broadcast TV signals, and rather similar to a computer VDU in concept. It will incorporate a normal telephone handset and dial; the BPO have also been examining the possibility of including a hard copy printer in the design.

Viewdata Reception

Initially almost all the market for Teletext and Viewdata will probably be that section of the public which already has, or is seriously contemplating getting a colour television receiver. For those who already have sets, adaptions can be made, either by putting extra modules in the set, or by plugging the aerial connector into a separate receiver-decoder-modulator. Technical difficulties are expected to make the latter approach unsatisfactory for some kinds of displayed material. A range of new sets will be available in the U.K. with the Viewdata/Teletext option fitted. With these sets a control key-pad must be built into the set or included in a remote control unit. With Viewdata the possibility exists of using the key-pad for telephone dialling.

Recording

Obviously in some instances users will want to permanently record what is displayed. At the present time the most readily available medium is probably the polaroid camera, although printers have already been designed to reproduce Teletext pages on paper. An alternative is to record the data onto magnetic tape. The tape can then be replayed into the decoder for subsequent viewing. Perhaps if this catches on, publishing companies will be tempted to bring out cassette versions of popular novels, produced automatically by typesetting computers.

The Future

Although the general U.K. public probably does not see a definite need for Viewdata or Teletext, there is some evidence to suggest the existence of an "interested minority" group (approximately 10% of the population) that would be keen and/or enthusiastic about the possibilities if they had colour receivers.

Commercial television stations are naturally worried about the likelihood of viewers switching to either of the text services during normal TV advertising. However, adept advertisers will probably include references, for instance, to "more information available on page XYZ of ORACLE" or "page ABCD of Viewdata", in the same way as telephone numbers are quoted now. Likewise, information in the text service can tell viewers about advertising schedules on particular products, so that an item can be demonstrated. This kind of cross-referenced information could create demand for Teletext and Viewdata. Advertising on normal television of Viewdata, showing example pages, and emphasising the scope of the system, could successfully create acceptance of the system.

Viewdata services in the home could offer a great deal in the next, say ten years. For instance, to obtain local information on a given topic, one makes a call to the local Viewdata centre; but for information local to a distant centre, a trunk call may be made to that centre.

If at some stage the system is asked for more detail than is available, that fact could be printed out or stored as a message for operating staff. In this way users of the system could influence the updating of system pages.

At some stage it may become desirable to include a full typewriter keyboard with the viewers' keypad; messages could be written by the user, stored up and delivered to the appropriate party when they call up the message facility. The current plan is to provide lists of standard messages which the user chooses from, using the simple key-pad. This facility is likely to be retained in the future, being useful even for practised typists, as well as amateurs. Eventually, the Viewdata message service could be expected to actively compete with the existing postal system. Providing adequate identification of users can be established, goods could also

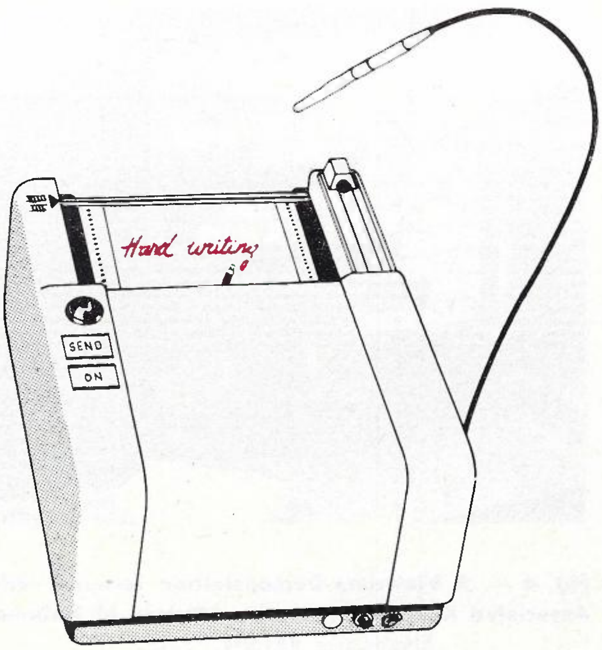

Fig. 5 — One type of Telewriter.

be ordered via Viewdata, after using the service to select the required items.

TELEWRITING

Another of the solutions to the problem of transmitting graphic or visual data via the telephone line is the Electro-writer (Fig. 5). This device transmits the pen motions of the person writing, with paper advance (new page) and pen-lift information. At the receiver, these motions are reproduced by a pen onto paper. Either the message is simply read by an attendant, or it is projected onto a screen, thus providing a "Remote Blackboard" (Fig. 6). Provision of three telephone lines is sufficient to give a complete remote lecture or "Telelecture", incorporating voice, writing, diagrams and a return sound channel to cater for questions from the audience. Alternative display systems involve the use of storage CRTs, cameras and monitors.

Both analogue and digital systems have been implemented. The analogue systems use two frequency modulated carriers to transmit the instantaneous 'X' and 'Y' co-ordinates. (In one case these are "curvi-linear" co-ordinates.) The Victor Electrowriter uses a pen and paper system, hence needs additional "pen-lift" and "paper advance" signals. The Sylvania ECS-100 Graphics device uses a storage CRT at the receiver, and displays the signal using a video camera and monitor; hence 'Z'

TABLE 1 — ANALOGUE TELEWRITERS

Victor Electrowriter	Sylvania ECS-100
X: frequency modulation 2200 Hz ± 6.4%	X: frequency modulation 2300 Hz ± 8%
Y: frequency modulation 1400 Hz ± 6.4%	Y: frequency modulation 960 Hz ± 8%
Pen lift: frequency modulation at 100-120 Hz on X carrier.	Z: frequency modulation at 100-120 Hz on Z carrier of 1700 Hz.
Paper Advance: Simultaneous overdrive of X and Y signals, moves pen to operate a switch in the receiver.	Erase: frequency modulation at 100-120 Hz on X carrier.

modulation and "erase" signals are needed. Table 1 shows the details.

There are two digital systems. both designated "Electronic Blackboards" by their designers, but they appear to operate in quite different ways. A Bell Laboratories device (Ref. 11) uses a resistance sheet behind the writing surface, which has edge contacts. Pressure from chalk on the writing surface pushes it against the resistance sheet, which is rapidly pulsed alternately in the X and Y directions. The conducting reverse side of the writing surface provides a signal identifying the instantaneous writing co-ordinates on a time-multiplexed basis. The information thus derived is digitized and sent over a 1200 bit/sec line to the receiver. Upon reception, the image is built up in an analogue scan convertor tube where it is read out at full video bandwidth and displayed on television monitors. Erasure of the board must be done by manually removing all chalk with a duster, *then* sending an "erase" signal to the far end.

The other "Electronic Blackboard" has been developed at Delft University in Holland (Ref. 12). The writing tablet incorporates two orthogonal printed wiregatings and a slightly modified ball point pen to record hand motions. Again, the output is displayed on a television screen by using a scan memory device.

Both digital systems lend themselves to tape recording of the line signal, as ordinary audio techniques should suffice. Recording of the analogue systems is not as successful, as wow and flutter cause gross distortion of letter shapes. Audio drop-outs in either case can cause serious errors and distortions.

CONCLUSION

In this article some of the visual communications devices suitable for use in the telephone network have been described. There are many other types which have been deliberately excluded, such as

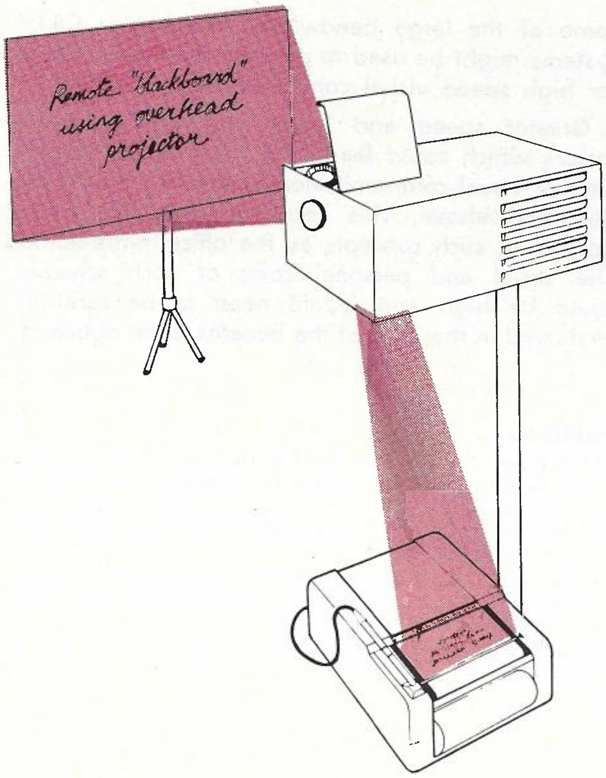

Fig. 6

alphabetic telegraphy (telex), VDUs and similar systems.

Most of the systems described above have been available for at least a decade but none has achieved widespread acceptance. A major reason for this is, no doubt, the high cost of the terminal equipments which in most cases is in excess of $1000. The cost of terminals can be expected to fall as more use is made of advanced semi-conductor technology. It is likely that most new systems which will appear will be hybrids of existing systems.

Channel bandwidth limits the effectiveness of most of the systems described because in combination with noise it limits their speed. In the future, wider bandwidth transmission capability can be expected to become available to a large number of telephone subscribers. There are several ways in which this wider bandwidth may become available. PCM systems are expected to be used in growing numbers in the junction network. This may lead to the use of PCM concentrators in the local network, thus making the extension of 64 k bit/s (or multiples thereof) service to subscribers relatively simple. Also fibre-optical transmission may become attractive for use in the local network. Alternatively, some of the large bandwidth available in CATV systems might be used to provide channels suitable for high speed visual communications services.

Greater speed and lower cost are important factors which could lead to a much wider acceptance of visual communication systems such as those described above. This could facilitate the introduction of such concepts as the office-in-the-home. The social and personal costs of such schemes could be high and would need to be carefully evaluated in the light of the benefits to be obtained.

REFERENCES

1. Costigan, D. M.: "Fax: The Principles and Practice of Facsimile Communication"; Chilton Book Company, 1971, pp. 1-4.
2. Mikhailenko, V. S. et alia: "Problems of the Development of Facsimile Links"; Telecommunications & Radio Engineering, Nov. 1973, pp. 9-11.
3. Bakhtov, I. S. & Stoyanov, M. N.: "Transmission of Newspapers by Facsimile Methods"; Telecommunications & Radio Engineering, Nov. 1973, pp. 4-8.
4. "Facsimile Postman Delivering Soon"; New Scientist, Oct. 3, 1974, p. 36.
5. Kaplan, G.: 'Fax: specs and projections'; IEEE Spectrum, September 1974, pp. 77-81.
6. Dickson, E. M.: "The Video Telephone"; Praeger Publishers, U.S.A., 1974, pp. 38-39.
7. Miller, D. C. & Taggart, R.: "Slow Scan Television Handbook"; a 73 publication, Dec. 1972, pp. 2-6.
8. Deutsch, S.: "Narrow Band TV Uses Pseudo-Random Scan"; Electronics, April 27, 1962, pp. 49-51.
9. "Specification of Standards for Information Transmission by Digitally Coded Signals in the Field-Blanking Interval of 625-Line Television Systems", issued jointly by BBC, IBA, and BREMA, October 1974 and presented with BBC Engineering No. 100.
10. Fedida, S.: "Viewdata — Development of Computer-Based Information Services for the General Public"; Record of the Second International Symposium on Subscribers Loops & Services, London, England, 3-7 May 1976, pp. 127-132.
11. "Electronic Blackboards Aid Long-Distance Lectures"; Bell Labs. Record, No. 52, June 1974, p. 201.
12. Four refs. in Tijdschr. Ned. Elektron.- & Radiogenoot. (Netherlands), vol. 38, No. 6 (1973):

    Kegel, A.: "The Electronic Blackboard", pp. 133-137.

    Nieuwkerk, L. R.: "A Writing Tablet for Converting Current Handwriting into Electrical Signals", pp. 139-143.

    Koudstaal, J. J. & Bons, J. H.: "The Display of the Electronic Blackboard System", pp. 145-150.

    Wester, C. P. J.: "Tape Recording of Scribosonic Signals", pp. 151-155.

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DAVID BLACKWELL was born in U.K, in 1945. His family emigrated to Australia in 1956 and settled near Melbourne. He obtained his B.E. (Elec.) degree at Melbourne University in 1966, and joined the then A.P.O. Research Laboratories the same year. During the last ten years, his work has included radio, digital, video, and long-line applications. Currently an Engineer Class 2 with Customer Apparatus Section, he is engaged on work involving negative impedance boosters for cable gauge reduction, and facsimile redundancy reduction techniques.

DOUGLAS KUHN joined the PMG in 1970 as a Cadet Engineer and obtained his B.E. (Elec) from the University of Melbourne in 1972. After completing an M.Eng.Sci. at the same university in 1974, he commenced work with the Customer Apparatus Section of the Research Laboratories. He is presently working on a high-speed facsimile system and the development of a telephone using voice-switching to control sidetone level.

Left to Right — D. Blackwell, W. Metzenthen and D. Kuhn.

Lightning Protection of Telephone Cables in Areas of High Soil Resistivity – Part 1: The Overhead Earth Wire Technique

D. R. KELSO, M.Eng.Sc., Grad. I. E. Aust.

In certain country areas, Telecom external plant must be installed and maintained where local conditions result in abnormally severe damage caused by lightning. Part 1 of this article describes some novel techniques developed for application in areas of high resistivity soil within the Stanthorpe Telephone District, Southern Queensland. Experience under operational conditions is also discussed and it is concluded that these techniques should find application where similar circumstances exist elsewhere. Part 2 will deal with other practical techniques, while Part 3 discusses operational experience with field installations. Parts 2 and 3 will appear in later issues of this Journal.

INTRODUCTION

The studies which preceded this paper were initiated with the Queensland Telecom Administration as a result of a persistent history of severe lightning damage reported from the Stanthorpe Telephone District, South West Section, Toowoomba. Investigations by the author at the University of Queensland (Ref. 1) resulted in a variety of proposals being applied with reasonable success to field situations. The techniques described in this paper are considered novel to Telecom operations, and their efficacy is affirmed by continued field experience at Stanthorpe.

The earliest record of Australian investigations into the intensity of lightning discharges induced into open-wire lines dates back to 1938-1940. At that time, Stanthorpe had a wide reputation for being the worst lightning district in the country. During 1958-1961, a second survey recorded the intensity and frequency of lightning discharges through arrestors connected to open-wire lines. Stanthorpe, with its poor pole earths, was noted as being subjected to a higher than usual number of arrestor discharges, with higher than usual current amplitudes.

With the aim of reducing maintenance, a deliberate change was made in local policy during the mid-1950's which led to the almost total replacement of open-wire by buried cable. While this approach was basically correct, it became evident after a number of years that the buried cable was suffering lightning damage to an even greater extent than before. Initial attempts to alleviate the problem involved increasing the insulation thickness (e.g. with plastic jacketed cables) and also improving the cable shielding (e.g. by using armoured cables). These changes did not significantly reduce the overall incidence of cable faults due to lightning.

It was only then that greater attention was focussed on the high resistivity of the soil — in fact, over 500 square miles of the district consist solely of igneous or granite rocks, typically characterised by soil resistivities in excess of 1000 metre-ohms. It does not necessarily follow that Stanthorpe must be subjected to more lightning strokes or possibly strokes of great severity. Data of this nature is extremely difficult to obtain, but it is known that the district experiences, on average, no more than 30 thunder days per year — not a high figure by sub-tropical standards.

The above facts coupled with a detailed analysis of lightning damage to buried cables in the 1960's, led to the development of new protection techniques. Clearly, one solution is to escape the effects of high potential rise of the soil — by going aerial! Part 1 of this paper considers the specific case of a screened aerial cable, shielded by an extra aerial conductor suspended above, so as to intercept almost all lightning strokes which would otherwise hit the cable.

The concept is not new — the overhead earth wire (O.H.E.W.) is widely used to protect power distribution and transmission lines from lightning. However, for telephone cable, a peculiar treatment is required in order that the insulation integrity is maintained.

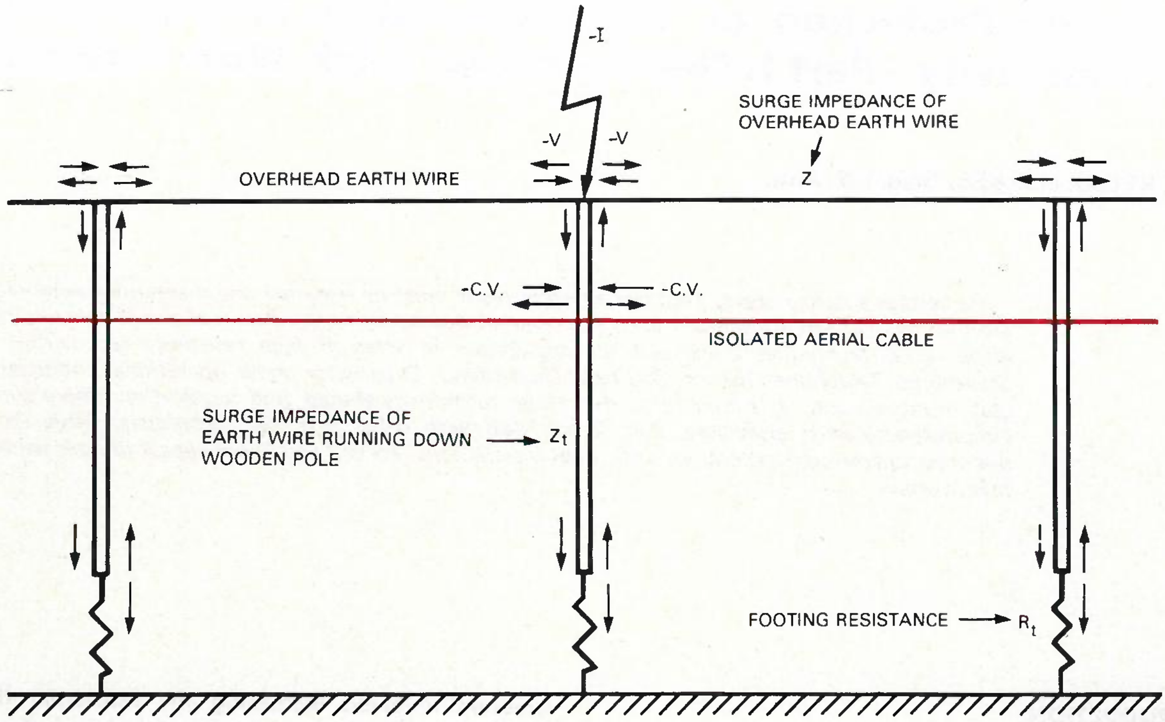


Fig. 1 — Schematic of Travelling Waves Caused by Lightning Stroke to Overhead Earth Wire.

DEVELOPING A DESIGN

When a lightning stroke contacts an aerial conductor earthed at intervals, the return stroke current flows from the ground through the pole earths and overhead earth wire to the point of contact, and from there proceeds to neutralize the residual stroke charges. The result is a complex sequence of voltage and current waves (see Fig. 1) created by a multitude of reflections from every impedance discontinuity encountered.

Such discontinuities occur at the top and bottom of every pole downlead. At any given instance, these waves summate to a distinctive potential 'travelling' along the O.H.E.W. at almost the velocity of light. It takes only a limited number of microseconds until all impedance discontinuities are replaced by the sum dc resistance to earth. However, the stroke current also exists for only a few microseconds, and it can be demonstrated (Ref. 1) that within this timespan, very high potentials are produced between the O.H.E.W. and ground.

The potential, P, is commonly expressed in units of volts per ampere of stroke current. Fig. 2 illustrates the highly transient nature of P. For a stroke to the O.H.E.W. at a pole, the potential at that pole rises smoothly in sympathy with the lightning current (Curve 1); similarly for a stroke terminating in midspan (i.e. equidistant between adjacent poles), as long as the pole downleads occur at regular intervals (Curve 3). The third variation (Curve 2) is the potential at midspan for a stroke to midspan. Since this point has no impedance discontinuity, the midspan potential rises extremely sharply until counteracted by large negative reflections from mainly the two adjacent pole earths, resulting in wild oscillations.

Due to electromagnetic coupling, each voltage wave on the overhead earth wire (e.g. - V) impresses on the aerial cable below, a proportional voltage (e.g. - C.V) where the coupling factor C is given by

$$C = \frac{\log (b/a)}{\log (2h/r)}$$

where

b = distance between the aerial cable and the earth wire image (at -h)

a = separation between the earth wire and aerial cable

h = height of the earth wire above ground

r = earth wire radius

It follows that the insulation between the O.H.E.W. and aerial cable is stressed by a voltage I.P. (1-C), where I is the stroke current magnitude. The basic design aim is to arrive at a configuration which minimises the impedance P. (1-C) as well as maximising the insulation strength between the O.H.E.W. and aerial cable. Since C tends to be insensitive to changes in configuration dimensions, most attention should be directed towards minimising P, i.e. by ensuring the span lengths are not too long and the downlead earthing resistances are not too high.

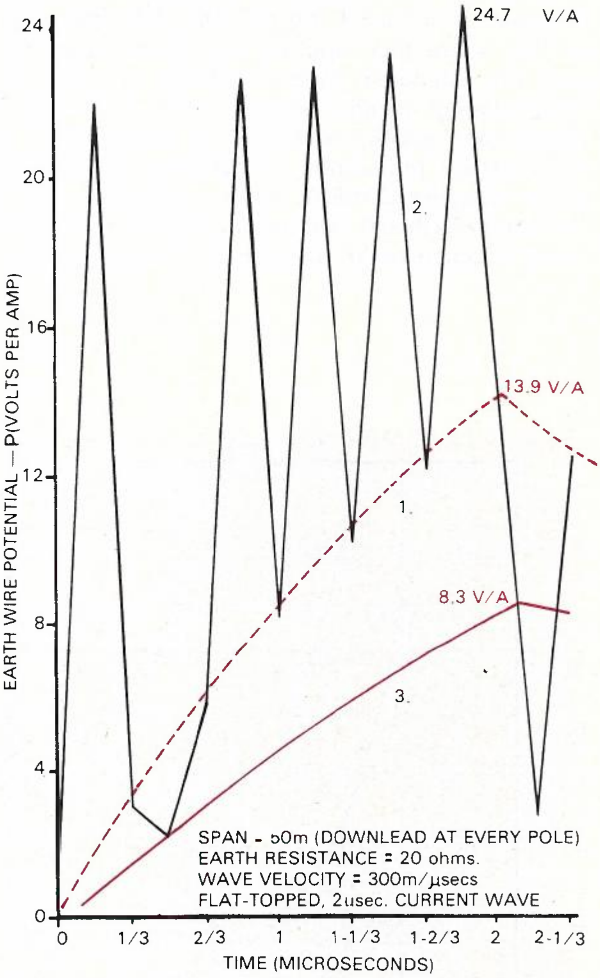


Fig. 2 — Example of Earth Wire Potentials for Strokes to Pole, and to Midspan.
Curve 1 — Stroke to Earth Wire at Pole; Potential at Pole.
Curve 2 — Stroke to Earth Wire in Midspan; Potential at Midspan.
Curve 3 — Stroke to Earth Wire in Midspan; Potential at Pole.

If a satisfactory compromise solution can be achieved, then the chance of a lightning stroke to the O.H.E.W. causing an arc to the aerial cable is greatly reduced. The prime physical requirement is for the leads earthing the O.H.E.W. to run down the poles in such a manner as to stay well clear of the aerial cable and its associated fittings, in order that the wood and air gaps between the O.H.E.W. and aerial cable retain a high impulse insulation strength.

The previous discussion can best be illustrated by means of the worked example presented in the Appendix. Two out of three possible mechanisms for breakdown must always occur, although from the worked example it is evident that one mechanism may be dominant. Many parameters of practical significance are involved in the calculations. So in practice each design must be examined in detail regarding its effectiveness. Unfortunately, every examination would require a new Fig. 2. The computational technique involves a "lattice or travelling wave diagram" which can be solved either manually or by digital computer. The former is most tedious and a program for the latter is not readily available.

Due to the low height of telephone poles, it is highly unlikely that any lightning strokes would bypass the overhead earth wire and terminate on the aerial cable. Furthermore, until field experience proves to the contrary, it may be safe to ignore the incidence of nearby strokes to ground causing back-flashover from the aerial cable to the O.H.E.W.

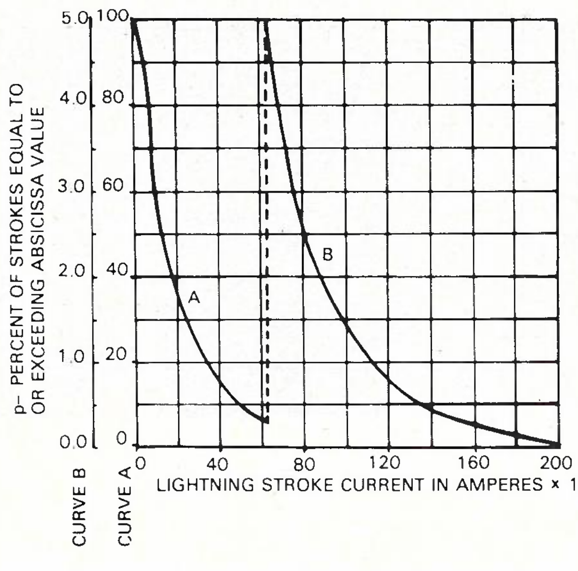
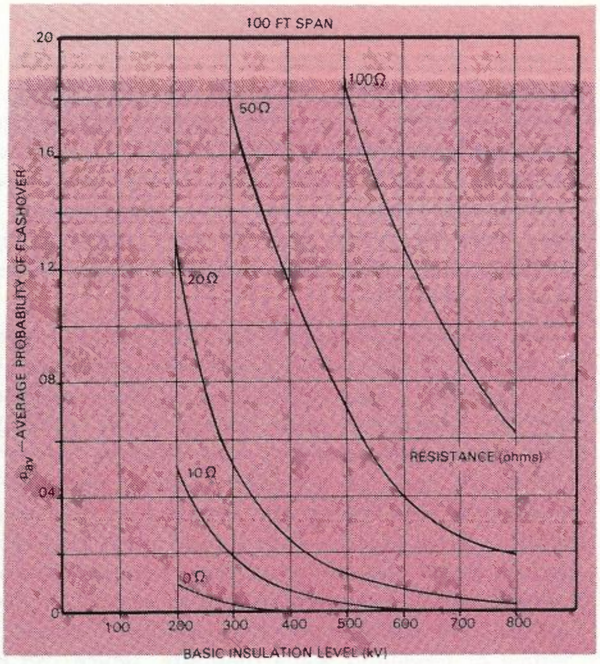


Fig. 3 — Probability Curve for Magnitude of Lightning Strokes to Aerial Conductors.



(a)

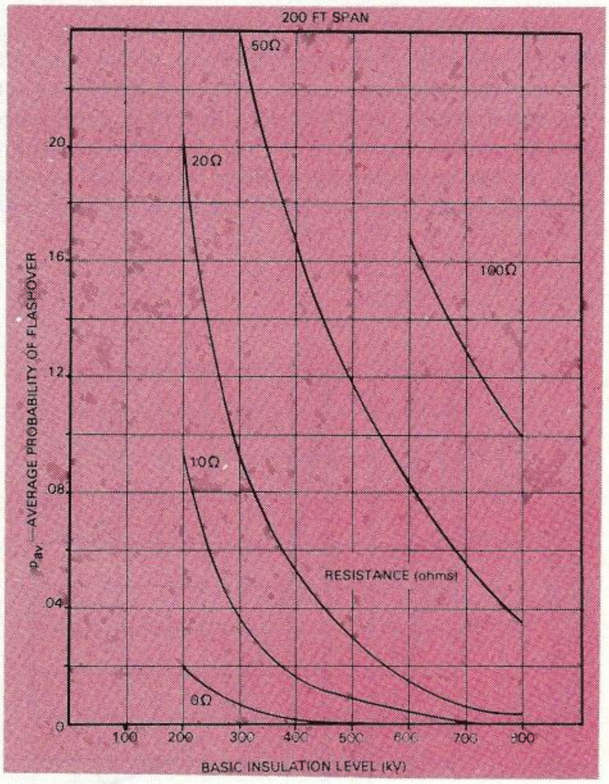
GENERALISED SOLUTIONS

A more general approach is based upon a prediction method originally devised for low voltage distribution power lines (Ref. 2) with short span lengths. In brief, this approach follows that outlined in the Appendix, but with respect to a certain reference configuration. If a practical example differs from this reference, then a correction factor must first be applied in order to compute the required basic insulation level (B.I.L.), viz.

$$\text{B.I.L.} = \frac{\text{Wood gap(ft)} \times 0.73 \times 60 \text{ kV/ft.}}{(1\text{-C})}$$

where C has been previously defined.

Provided the midspan O.H.E.W. - aerial cable clearance is at least 4 ft (preferably 5 ft), the graphs in Fig. 4 are then applied according to the B.I.L. and the estimated earth resistance at each pole. Interpolating linearly between the curves for adjacent span lengths, a solution is then obtained for the average probability of flashover to the aerial cable once the O.H.E.W. has been struck. Finally, the actual flashover rate (in times per 100 miles per year) is obtained as for Step 7 of the Appendix.



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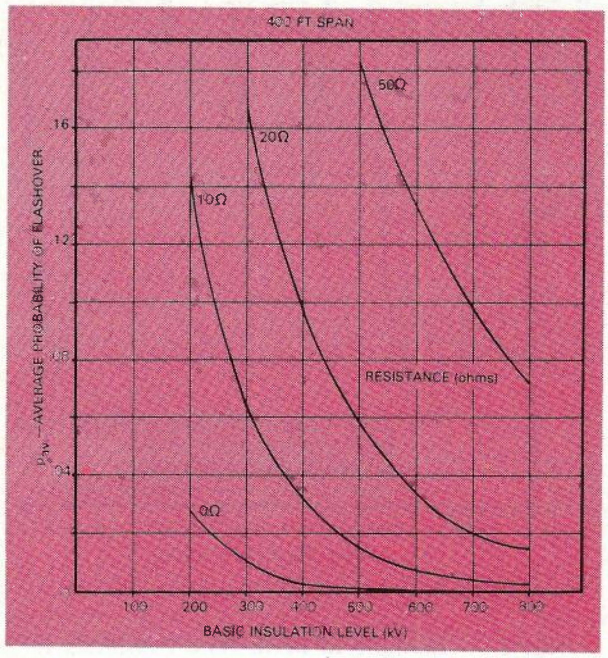


(c)

Fig. 4 — Curves for Estimating Lightning Performance of O.H.E.W. Aerial Cable. The numerals on curves indicate pole footing resistance.

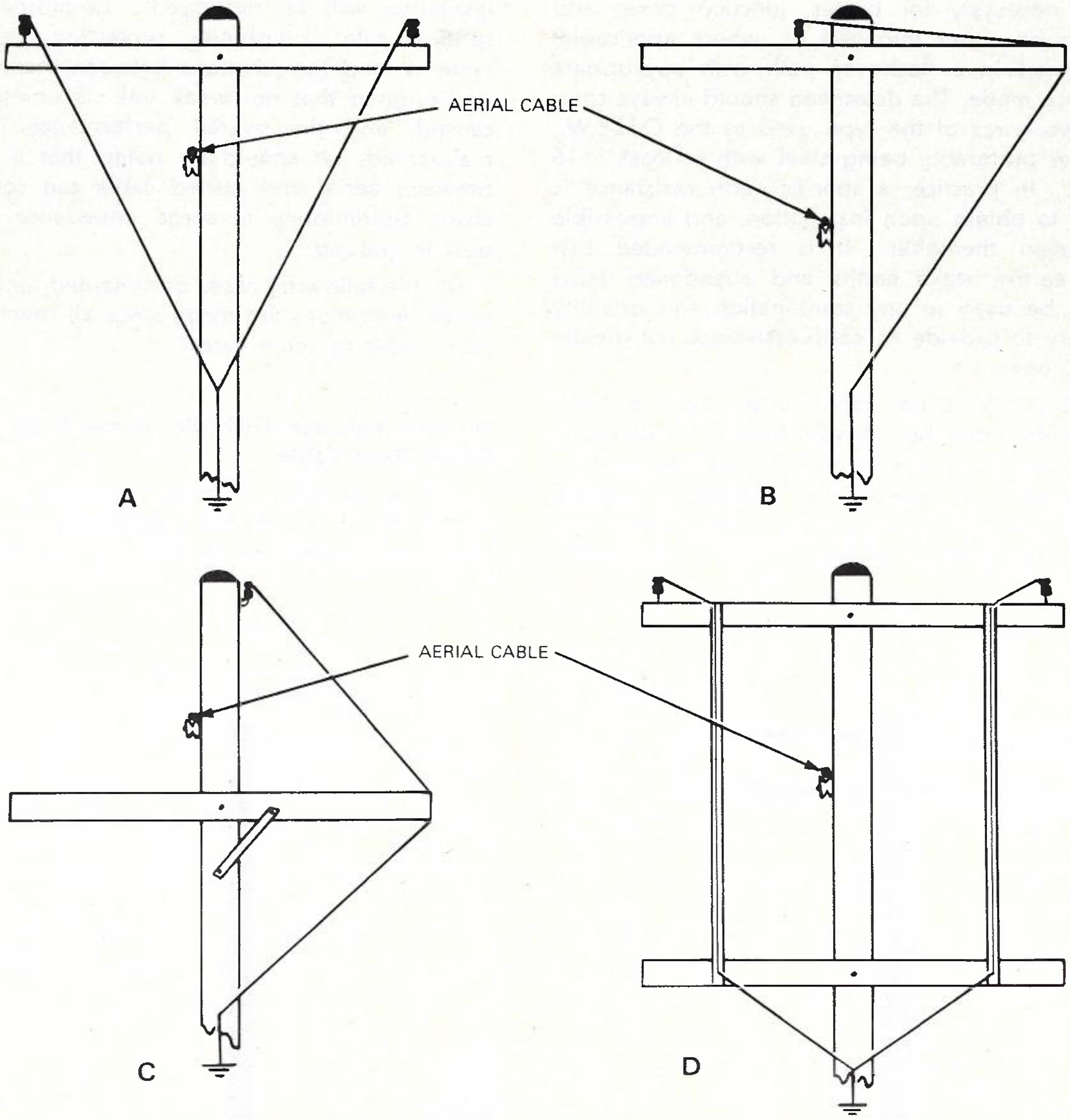


Fig. 5 — Alternate Pole-Top Configurations.

PRACTICAL ASPECTS

The pole-top configurations of Fig. 5 have been tested in the laboratory in order to confirm the insulation strengths obtained by standard poles and crossarms. All configurations could be created from old aerial routes, although types A, B and C could also be new constructions. Type A serves where aerial cable ground clearance is a problem. Fig. 6 illustrates a similar version installed in the Eukey exchange area. There is only one O.H.E.W. in this instance. Note the location of the braces. Fig. 7, also at Eukey, depicts a new installation employing a special downlead bracket fabricated from G.I. pipe. The head stay does not interfere with the wood gap insulation. Finally, where pole height (new or old) is inadequate, necessity may require an O.H.E.W. bracket of the type shown in Fig. 8. The stay could double as the earth wire downlead.

Any configuration will suffice, as long as it satisfies the general requirements explained in this paper. Above all, sufficient wood and air gaps must be provided. For wood, the most direct combined length is usually the critical flashover path. In the case of air gaps, the shortest air path is applicable and all metal surfaces should be smooth without tight curvatures.

It is necessary for braces, junction boxes and stays to be either removed or, where applicable, be retained in a flashover path with appropriate allowance made. The downlead should always comprise two wires of the type used as the O.H.E.W., the latter preferably being steel with at least 7/16 strands. In practice, a specific earth resistance is difficult to obtain upon installation, and impossible to maintain thereafter. It is recommended that trench earths, stake earths and abandoned cable sheaths be used in any combination and quantity necessary to provide an earth resistance not greater than 15 ohms.

An O.H.E.W. aerial cable route used for local distribution must be derived from a main cable, usually buried, and eventually is required to feed lead-in cables to subscribers. Hence, a practical installation is far from ideal, and unless special care is taken, the integrity of the O.H.E.W. - aerial cable insulation will be destroyed. Co-ordination is a cardinal rule of lightning protection, i.e. various systems, and the junctions between them must be so designed that no 'weak link' is unintentionally caused, and the overall performance is always maintained. It should be noted that a transition between aerial and buried cable can constitute a sharp discontinuity in surge impedance with respect to ground.

For the following cases documented, only general recommendations are made since all practical situations differ to some extent.

Junction between O.H.E.W. Aerial Cable and Buried Main Cable

Such a junction is almost impossible to protect from a direct stroke, but precautions can be taken which may lessen the severity and also provide an

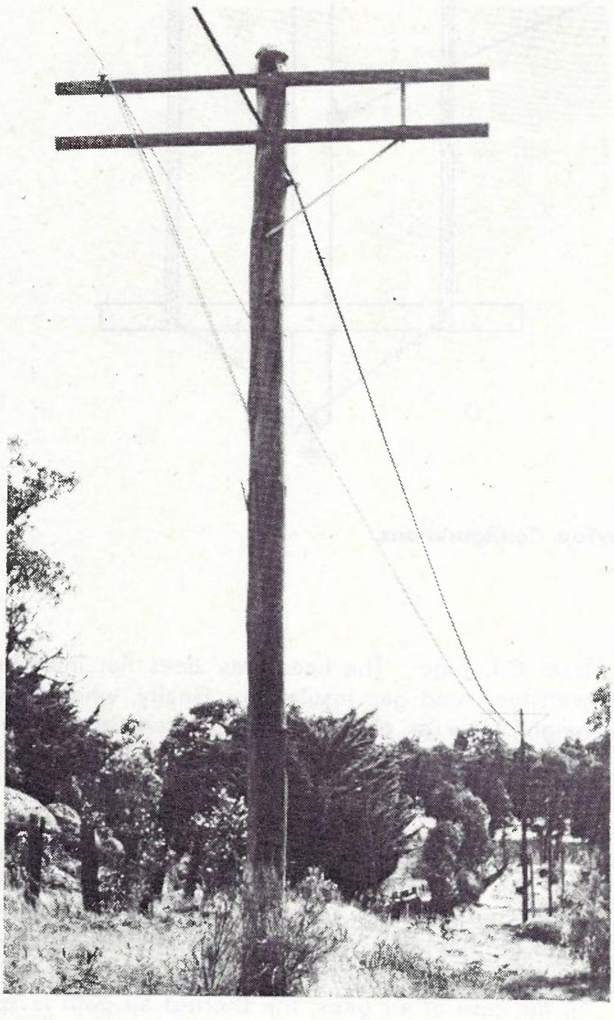


Fig. 6 — An Old Pole Route Converted to O.H.E.W.

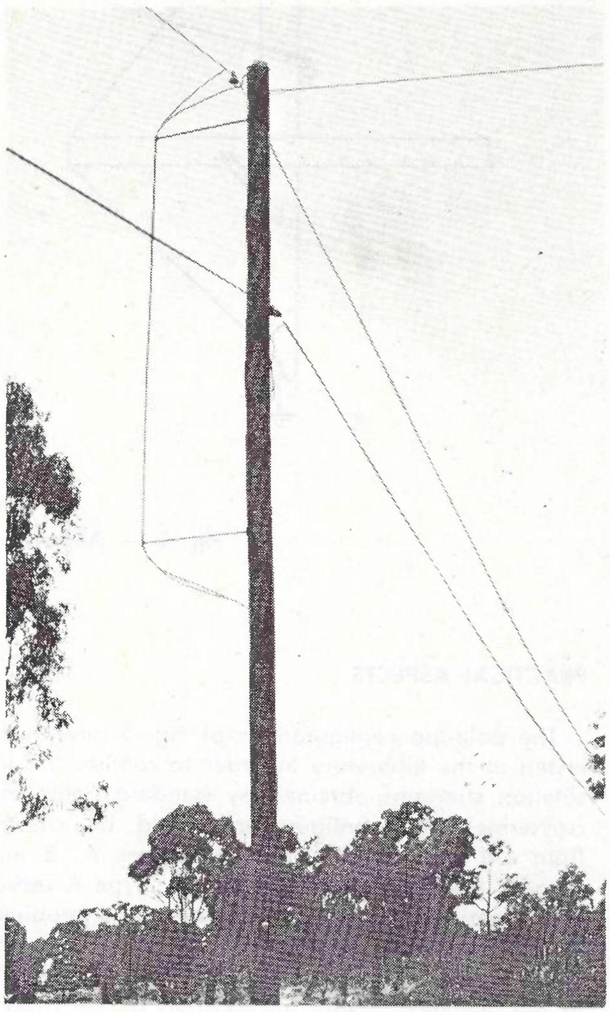


Fig. 7 — A New O.H.E.W. Installation.

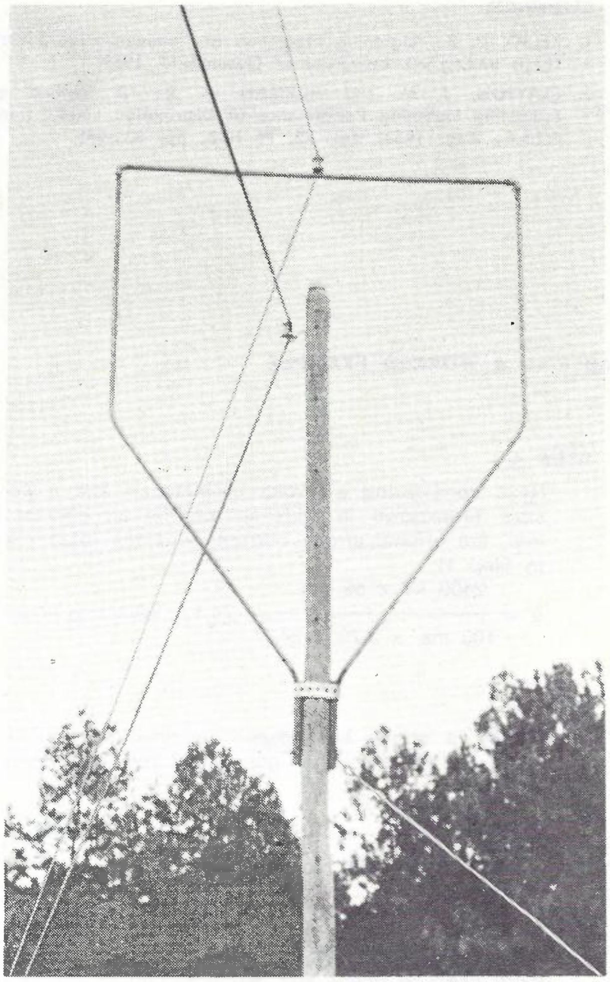


Fig. 8 — An Unusual O.H.E.W. Bracket where Pole Height was Inadequate.

even transition for lightning strokes elsewhere. The junction pole should have no downlead which could transfer any O.H.E.W. current to the buried cable. The O.H.E.W. could also continue onto a 'dummy' pole at a reduced span length and be directly earthed there, provided this earth is kept clear of any buried cable. At the actual cable junction, it is important to take steps to maintain the sheath-core insulation, and metallic sheath continuity between both cables.

Junctions with Subscribers' Lead-ins

Lead-in cables should always leave the O.H.E.W. route as aerial for at least one full span before going buied. if required. There should be no O.H.E.W. or earth downlead at the terminal pole and as above, all insulation strengths should be maintained. Where aerial drops continue to a subscriber, they should not exceed two or three span lengths since such cable is unprotected. Some form of "forward" protection may be worth considering. It is suggested that any lightning arrestors used (e.g. at the subscribers' premises) should be connected across a pair and not to ground.

A Recommended Design

The following is the specification of a design recommended for an O.H.E.W. aerial cable route:

- Span length — 4 chains (264 ft) .
- Pole length — 29 ft, set 5 ft in ground.
- Frequency of earthing — downlead at every pole.
- Midspan separation — about 9 ft.
- O.H.E.W. heights — 23'6" max., 21'6" av., 20'6" min.
- Aerial cable heights — 18'0" max., 13'6" av., 11'0" min.
- Overhead earth wire gauge — 7/16, steel stranded wire.

The estimated performance of this design is recorded in Table 1 for three values of the earth resistance at each pole. Even where high resistivity soil precludes the securing of low resistance earths, the predicted incidence of aerial cable breakdown is still quite low.

TABLE 1 — ESTIMATED PERFORMANCE OF O.H.E.W. AERIAL CABLE WITH 4 CHAIN (264 FT) SPAN

Earth Resistance (ohms)	P_1	P_3	P_{av}	Flashover rate per 100 mile-years (for T=30)	
				O.H.E.W.	Aerial Cable
10	0.1	0.03	0.06	1.7	$\doteqdot$0
20	0.2	0.07	0.14	4.0	0.1
50	0.38	0.28	0.33	9.4	0.4

CONCLUSIONS '

One technique has been described for protecting telephone cables from lightning in areas where the soil resistivity is high and conventional forms of buried cable are either ineffective or too expensive. A rough comparison indicates the cost as being typically half that of plastic cable in G.I. pipe, the same as that for buried wire armoured plastic jacketed cable, and twice as expensive as ordinary unprotected buried cable.

Experience with many miles of earth wire aerial cable construction has been favourable. Additional comments on this aspect will be made in Part 3 of this paper.

REFERENCES

1. KELSO, D. R.: 'Lightning Protection of Communication Plant'; Thesis (M.Eng.Sc.), University of Queensland, 1969.
2. CLAYTON, J. M. and HILEMAN, A. R.: 'A Method of Estimating Lightning Performance of Distribution Lines'; Trans A.I.E.E., Aug. 1954, Vol. 73, Pt III-B, pp. 933-945.

APPENDIX: O.H.E.W. AERIAL CABLE — A WORKED EXAMPLE

Consider the following specifications (also applicable to Fig. 2):

- Span length — 50 m (approx. 2½ chains)
- Frequency of earthing — downlead at every pole
- Earth resistance — 20 ohms (per downlead)
- Height of O.H.E.W. — 19 ft. (at pole); 17 ft. (in midspan
- Separation between O.H.E.W. and aerial cable — 5 ft. (at pole and in midspan; also equal to the wood-gap between downlead and aerial cable).

STEP 1—

Calculate the insulation strength, for a current wave with a 2 μsec. crest and an over-voltage correction factor of 1.5, viz.

Wood insulation strength = 5 ft. gap x 1.5 x 60 KV/ft = 450 kV.

This applies to a typical dry treated or wet seasoned pole. (If the wood is completely dry internally, the strength could rise to about 750 kV. On the basis of about 2400 kV for an air gap of 100 ins., an actual gap between the aerial cable and any earth downlead (via an air path) would have to be some 30 ins., in order that the air gaps do not behave as "weak links" insulation-wise, with respect to the wood gap.)

STEP 2—

Using the equation for the coupling factor, it is calculated that C = 0.21. Hence, for every volt produced between the O.H.E.W. and ground, (1-C) or 0.79 volts appear across the wood and air gaps between the O.H.E.W. and aerial cable.

The critical stroke current required for insulation breakdown is found from the equation:

$$I = \frac{V}{(1-C).P}$$

where V is the relevant insulation strength, and P is the peak "transfer impedance" in volts per amp taken from Fig 2.

Once a critical stroke current is known, its expected probability of occurrence, p, is read off Fig. 3.

STEP 3—

Firstly, consider the case of a stroke to the O.H.E.W. at a pole which causes breakdown across the wood gap at the pole. Referring to Curve 1 of Fig. 2, the above equation indicates a critical stroke current of

$$I_1 = \frac{450 \text{ kV}}{0.79 \times 13.9} = 41 \text{ kA; where } p_1 = 0.15$$

STEP 4—

Next, considering a stroke to midspan and a possible breakdown in midspan via the air gap of 5 feet, the critical stroke current becomes (also refer to Step 1)

$$I_2 = \frac{2400 \text{ kV x 60 ins.}}{100 \text{ ins. x } 0.79 \times 24.7} = 74 \text{ kA; where } p_2 = 0.03$$

STEP 5—

Finally, a stroke to midspan resulting in a breakdown at the pole wood gap would require a stroke current of

$$I_3 = \frac{450 \text{ kV}}{0.79 \times 8.3} = 69 \text{ kV; where } P_3 = 0.04$$

STEP 6—

Since I_3 is less than I_2, pole flashover would be more likely to occur first hence P_2 can be ignored. Assuming that half the strokes terminate at poles and half in midspan, then the average probability becomes

$$P_{av.} = ½ (p_1 + p_3) = 0.095$$

STEP 7—

Using the average O.H.E.W. height and a given isoceraunic level (T), an estimate of the mean number of direct lightning strokes to the O.H.E.W. route per 100 miles per year is given by

$$N\ell = 0.883 \times h \times \frac{T}{20} = 0.883 \times 17.5 \times \frac{30}{20} = 23$$

Hence, the average flashover rate (from the O.H.E.W. to aerial cable) equals

$N\ell \times p_{av.} = 23 \times 0.095 = 2.2$ times per 100 miles per year.

STEP 8—

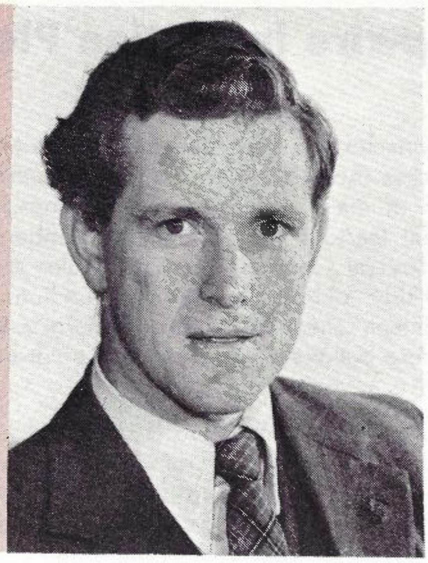
With regard to breakdown of the aerial cable insulation, it can be shown (Ref. 1) that an approximate value of the critical stroke current is given by

$$I = \frac{2300 \text{ kV}}{P}$$

Regardless of the flashover mechanism, the probability of breakdown within the aerial cable (for this example) can be found to be negligible.

D.R. KELSO joined the former P.M.G. Department in Queensland in 1963 as a Cadet Engineer and subsequently graduated from the University of Queensland, St. Lucia, with a B.E. at the end of 1966. Commencing in 1967, his studies towards a M.Eng. Sc. degree concerned lightning protection of communication plant and these studies continued until mid-1969 while he worked as an Engineer Class 1 at Toowoomba.

From 1969 to 1971 he served as an engineer-officer in the Australian Army, and upon discharge from National Service Training transferred to the P.M.G. Research Laboratories in Melbourne. At that establishment he studied line and network transmission theory and among other things, designed filter networks and cable equalisers. In early 1974 he joined Lines Branch, Engineering Division, as as Engineer Class 3 and commenced system and area design of cable television networks. Since July 1975, he has worked with the new Transmission Network Design Branch, Facilities Application Section, and is currently investigating the design of exchange transmission.



In Brief

INTEGRATED SWITCHING AND TRANSMISSION (IST) STUDIES

Telecom Australia is proceeding with study plans which explore the trend in the field of public telephony towards the introduction of digital technology and techniques. These developments provide the means of integrating the provision of transmission and switching facilities using the same techniques and thereby cheapening network costs.

As part of these plans, a digital tandem exchange was specified, designed and installed at Windsor exchange in the Melbourne Metropolitan network. The exchange was operated only during the day-time to enable performance to be monitored and faults quickly diagnosed.

Recently, the exchange was shifted and recommissioned at the St. Kilda exchange and plans are now in hand for continuous operation in order to widen the evaluation. These plans call for:

- A training program incorporating "first in" maintenance techniques for service personnel, and
- Supervision and surveillance systems which allow remote control of the operation of the exchange.

Training manuals are being prepared in conjunction with a one day course for service personnel who have some network connection with the exchange. Training will concentrate on testing techniques to diagnose whether or not trouble is internal or external to the exchange. Instruction will also be given in start/restart operations of the exchange and interpretation of alarms and man-machine reports. A comprehensive course for a limited number of personnel is also available, however, this requires attendance at Telecom Australia Research Laboratories for several weeks.

The alarm and surveillance systems of the IST exchange are being altered in both hardware and software terms so that the equipment can be remotely operated and controlled from the Clayton Laboratories. A standard modem facility is being employed for man-machine commands in association with physical pairs for alarm conditions.

Major aspects of the continuous operation are to compare the reliability of ceramic versus plastic packaging of integrated circuits, assessment of the efficiency of redundancy measures designed into the system together with system security and processor performance.

The exchange will be, for practical purposes, a working test bed permitting the introduction and the testing under live traffic conditions of new developments as they occur. For example, tone generation utilising a new technique employing ROM devices is under study and models, after laboratory testing, will be placed in service at the exchange. The exchange will also be the vehicle to extend knowledge of controlling principles and factors for the network management areas in the future. The aim will be to establish and explore design and control parameters which govern network management development for Telecom Australia switching systems.

The exchange will also act as a test bed for development in the digital switching field. It will provide the means whereby new control switching techniques can be rigourously tested with live traffic to highlight problems or advantages of new developments.

E. A. George, Telecom Australia Research Laboratories.

Dropwire Insulation Piercing Connector

A connector has been designed which is capable of piercing the thick, high density polyethylene insulation of the trefoil section wire (dropwire) used for aerial lead-ins to telephone subscribers' premises. Several commercially available connectors will reliably pierce the thinner, medium density polyethylene used to insulate underground cable conductors but piercing of the thicker dropwire insulation is a more difficult problem.

The connector in question is designed for fitting to an existing 3-pair terminal strip which connects aerial dropwire to underground cable wire. The need arose for such a connector following an unacceptable level of faults brought about by corrosion of conventionally jointed dropwire conductors. The present method requires stripping the polyethylene insulation from the end of the dropwire conductor and clamping the bare wire beneath a flanged washer using a 2BA nut and lock washer (Fig. 1). Due to the 50 volts dc line potential between adjacent terminals, the copper conductor tends to corrode completely through where it emerges from the insulation, particularly in marine/industrial environments.

Besides being capable of insulation piercing, which effectively eliminates conductor corrosion as well as removing the need to strip insulation, the jointed connector should comply with test requirements as follows:

- Mechanical vibration, to AS1099.2Fc-1971: "Basic Environmental Testing Procedures for Electronics and Telecommunications Purposes-Vibration".
- Initial electrical resistance, to Interim APO Specifications Nos. 1133 and 1138: "Connector Systems for Jointing Conductors in Dry Core Telephone Cable".
- Change in electrical resistance after heat cycling, also to Interim APO Specification Nos. 1133 and 1138.
- Ability to maintain connection with conductor after crushing due to over-tightening, also to Interim APO Specifications Nos. 1133 and 1138.
- A low tightening torque to achieve connection, set at 6 inch pounds maximum, a figure readily achievable with a hand tool.

Fig. 2 illustrates the newly designed connector in place on the terminal strip. The method of connection is to insert the dropwire through the rear aperture and under the cutting edge, then tighten

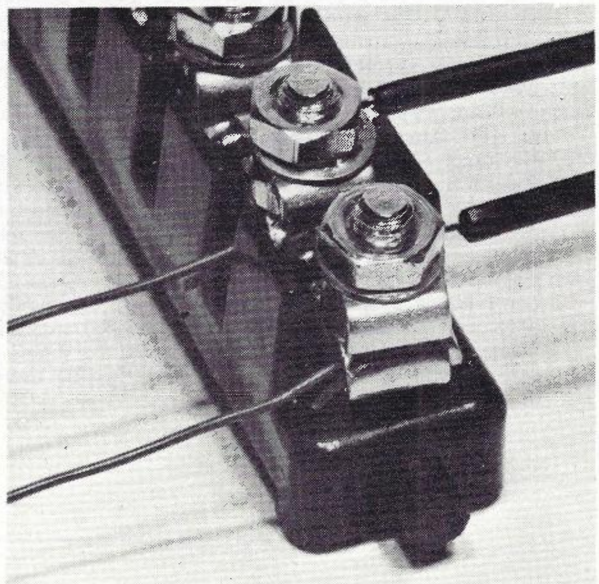


Fig. 1

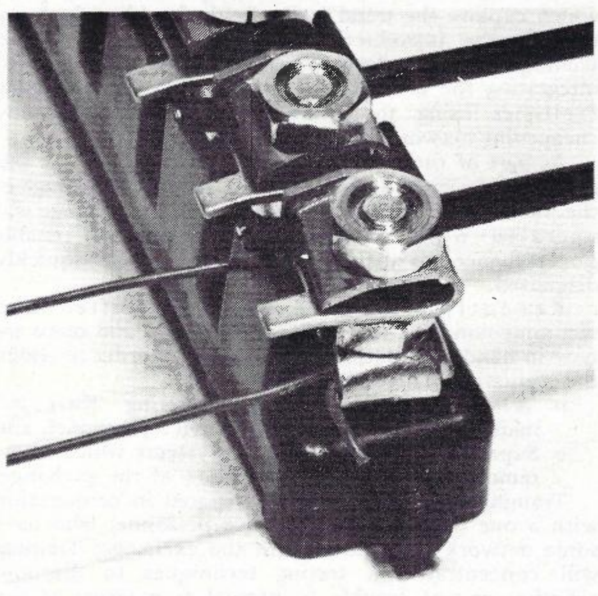


Fig. 2

the nut. The tab on the lower plate of the connector registers with the fanning tab on the terminal strip to prevent rotation during tightening, the up-turned side flange stiffens the lower plate to prevent unacceptable distortion and the additional aperture at the rear of the connector facilitates bending in that area. Fig. 3 shows an enlarged view of the connector.

The connector is of 1 mm stainless steel and is not intended to be reusable. It is currently undergoing field trials to establish its compatability with existing equipment and work practices used throughout the network. The connector is the subject of a patent application.

—C. R. Bomball, Senior Engineer, Equipment Design and Provisioning Section, Lines Construction Branch, Telecom Headquarters.

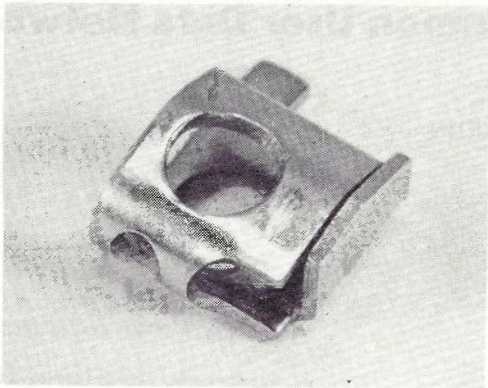


Fig. 3

Retirement of Mr D. F. Burnard

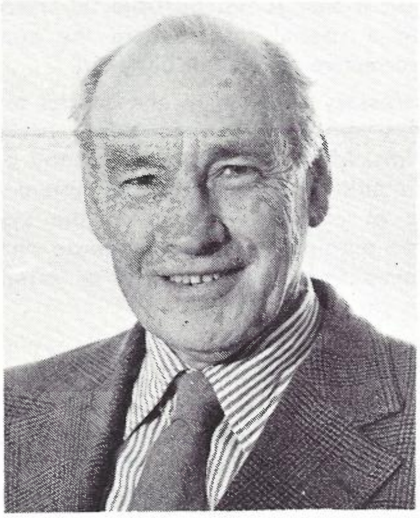
During July, 1976, the Chief State Engineer for Telecom Australia in South Australia, Mr D. F. Burnard, retired after 47 years' service. He joined the then PMG's Department in 1929 as a cadet engineer graduating with a BE (Electrical) degree from the University of Adelaide in 1935.

Mr Burnard's first eleven years as an Engineer were spent in Victoria, initially in the Telephone Equipment Section in Headquarters then followed by six years as the Divisional Engineer for the Ararat district. The remainder of his career was followed in South Australia, pre-dominantly in Country operations, and culminating in his appointment as Assistant Director, Engineering (now Chief State Engineer) in 1973.

A highlight of Mr Burnard's contribution to telecommunications was his close association with the early development of the extensive network required for the Woomera rocket range.

He has actively participated in community affairs and was the Society's State Chairman during 1963 and 1964.

On behalf of all members, the Board of Editors wish him and Mrs Burnard a happy retirement.



Common User Data Network – Part 3, Supervisory Facilities

G. MARTIN

This is the final article of 3 presentations designed to inform the reader of the Telecom Australia's processor controlled message switching system known as the Common User Data Network.

In this article, the supervisory and control facilities developed and implemented are presented in broad terms. Some detail of the man-machine communication is included as examples and explained.

INTRODUCTION

The Common User Data Network (CUDN) is a processor controlled store and forward message switching system. Thus, a complete package of data, or a message, is input in its entirety and stored before being routed and output to its destination. Because there is no physical connection between the various input and output lines, the system has to ensure that means are available to guarantee that all data input to the system is accounted for by being switched to its intended destination or, if that is not possible, by being intercepted to a special route where the appropriate manual corrective action can be taken.

The necessary supervision and control to achieve this end is complex and consists of system generated alarms which provide a hard copy diagnosis of abnormalities detected by the system and the actioning of commands input to the system by authorised terminals which may cause changes to the dynamic state of the system or extract status indicators for examination.

THE SUPERVISORY FACILITIES

The vital supervisory and control facilities that are provided may be summarised as follows:

- *Channel Sequence Number (CSN) Check.* All messages received on an input line are numbered sequentially by the operator and should the CUDN detect a number other than that which it expects, an alarm message is generated indicating a possible abnormality. Each message output to a line is numbered in sequence by the CUDN so that a sequence break at a receive terminal will indicate an abnormal condition that can be investigated.
- *Time Check.* It is possible to have, as an option. time checking on each line individually so that for CUDN input lines, if a message has not been received within the specified time set for the line, an alarm message will be generated indicating a possible abnormality. For CUDN output lines, if a message has not been output to a line within the specified time set for that line, the CUDN transmits a time check message to the line.
- *Identity of Origin and Validation of Address.* The CUDN, if required, checks input messages for the correct indication of origin by examining the unique channel identity (CID) which may be input in the header of the message. In addition, the address for the destination of the message is checked to ensure that it is a valid address and that the input line is allowed access to that address. Should any of the above checks be invalidated, the message will be intercepted to an intercept line with an appropriate alarm diagnosis of the reason for the intercept.
- *Input/Output Check.* It is possible in a CUDN centre to produce a comprehensive or abbreviated printout on the system line printer of input message header data matched to the corresponding output message header data. In this way, messages for which an input history exists but which have no corresponding output history can be readily detected and investigated as to the reason for non-delivery. In addition, it is possible to obtain the history for a single particular message by the use of a command if either the input or output header details (CID/CSN) are known.
- *Retrieval of Input or Output Messages.* Any message may be retrieved so long as either the

input or output history is known. The message to be retrieved may then, by using the appropriate command, be directed to its original destination or to any other valid address within the originating customer's sub-network.

- *Network Management.* Each customer can be provided with network control facilities which will provide him with the ability to supervise and control the flow of traffic within his sub-network. The type of control includes, for instance, the ability to open and close lines, hold and release traffic and divert traffic. In addition, the Commission supervises and controls the entire CUDN from the Traffic Supervisory Centre (TSC) which is situated in Melbourne. The TSC has the ability to assume full control of a customer's sub-network if required.

CUSTOMER NETWORK CONTROL STATION

A customer network control station (NCS) logically consists of the following routes:

(a) *A Two-way Supervisory Route.* The input channel is authorised to input specific commands to the CUDN whilst the output channel will receive acknowledgements to these commands, status reports resulting from commands and messages addressed to the terminal.

(b) *A One-way Alarms Route* which receives the alarm messages generated by the system for that particular sub-network.

(c) *A Two-way Intercept Route.* This route rereceives those messages, together with the relevant diagnostic alarm, which have originated in the sub-network and which cannot be delivered due to some abnormality detected by the CUDN (e.g. invalid address). The CUDN input channel of this route is intended to allow re-entry of these intercepted messages with the appropriate corrections to allow normal switching.

The supervisory route in (a) will have the ability to command itself into message or command mode so that it may originate messages or commands. The intercept route in (c) may be authorised as a command line and have all of the facilities of the supervisory route. All of the logical routes may be combined into one, two or three physical routes to meet the particular customer's requirements.

ALARMS

An alarm is a system generated message of fixed format which provides a diagnosis of an abnormal condition which has been detected by the system. Typically, alarms will be generated for the following conditions:

- No input messages received during the last time check period.
- Number of messages queued on an outgoing route has exceeded the specified limit.
- A message (or messages) has been queued to an outgoing route for an excessive time.
- Out of sequence incoming CSN.

The CUDN can generate some 77 different alarms. Some of these alarms are general and apply to all customers, some are peculiar to a particular customer's needs and others are common facility alarms which are directed to the TSC only. The TSC as well as receiving those alarms relating to the common facilities, such as the Telex interface, and the Commission sub-networks, also receives copies of those alarm messages which have been sent to a customer NCS relating to faults or unsatisfactory conditions in the customer's sub-network. All alarms appear in the following format:

- 1st line — Start of message, outgoing channel identity and CSN.
- 2nd line — Customer identity, CUDN switching centre identity, date/time of alarm generation and alarm diagnostic.
- 3rd line — End of message or the start of the intercepted message if it is an interception.

Fig. 1 refers to an alarm which was the thirteenth message received on channel MNCN and indicates that customer A has a Visual Display Unit (VDU) with an address of 041 on channel MNBN which did not respond to a poll. The condition was detected in switching centre M and the alarm was generated on the 10th day of the month at 1620 hours (Australian Eastern Time).

```
ZCZCMNCNO13
A M 101620 MNBN VDU NO RESP 041
NNNN
```

Fig. 1 — CUDN Alarm Message.

```
ZCZC CLO M TEA NNNN

MNCNO11
 CLO M TEA
VACA101619
NNNN
```

Fig. 2 — CUDN Action Command and Acknowledgement

```
ZCZC STC M TCD NNNN

MNCN015
 STC M TCD
      110912

              IN              OUT
           CN S CSN        CN S CSN        POLLED STATIONS
TCD        01 C 001        01 C 001
NNNN
```

Fig. 3 — CUDN Inspection Command and Acknowledgement.

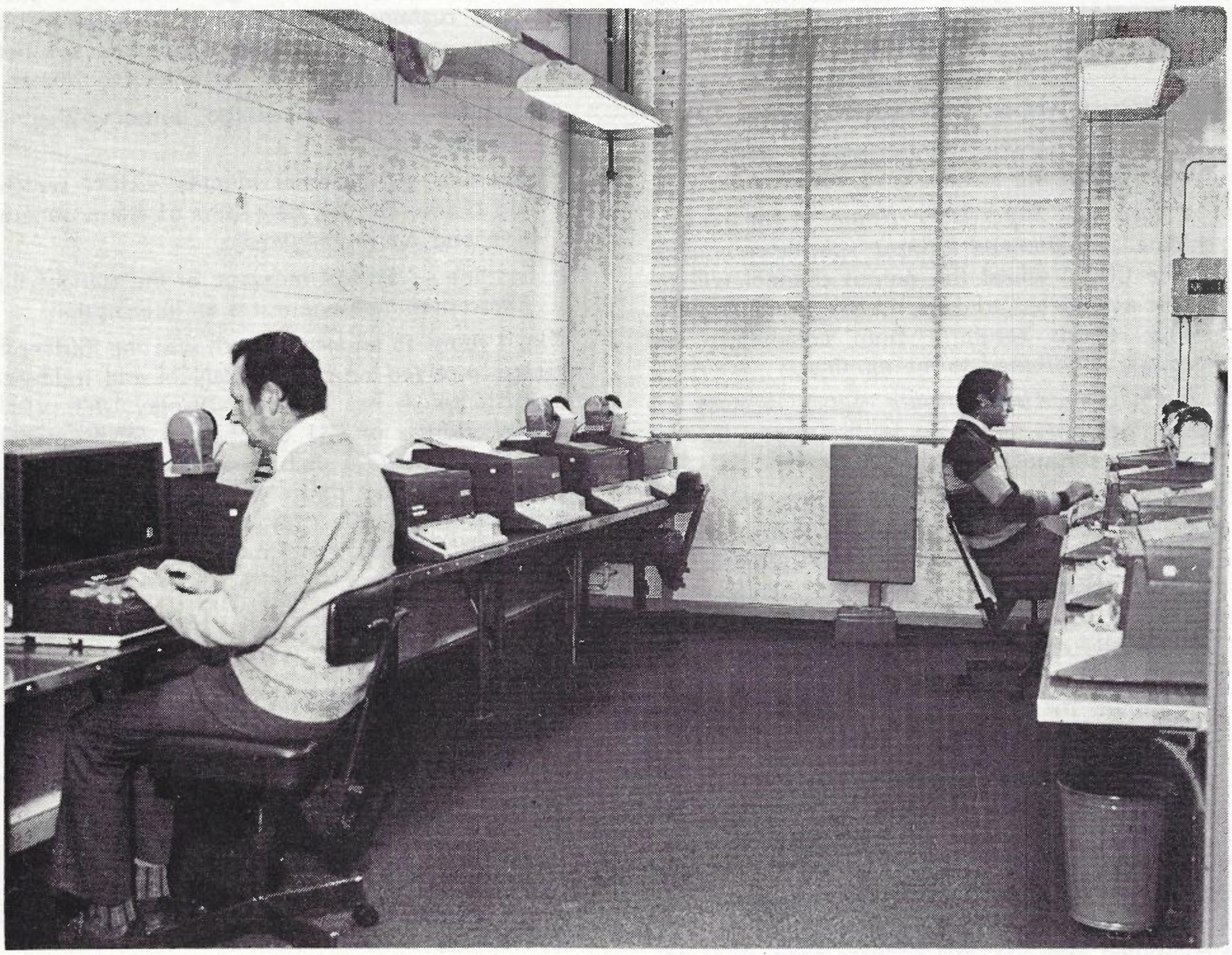


Fig. 4 — Telecom Australia's Traffic Supervisory Centre (TSC) for the CUDN.

COMMANDS

A command is a message of fixed format input by either the customer NCS or the TSC which causes either a dynamic change to the state of the on-line system or furnishes a report on the current state of the system. Commands therefore are used to *modify* or *inspect* the system tables.

Commands follow the general format of; start of message, command mnemonic, command specification, end of message. The command mnemonic specifies the action required of the system e.g. open or close a route, hold or release traffic for a route, divert a route or provide a status report. The command specification consists of a variable number of information groups of letters or figures which will be necessary for the system to execute the particular command.

There are approximately 70 commands which can be actioned by the CUDN system. Of this total, 23 are available to customer NCS's. These same 23 commands plus 5 more are available to the TSC and all of the commands are available to the Technical Service Area (TSA) which is responsible for the technical management of the system which includes the maintenance of the switching equipment and lines, connecting and disconnecting lines, the collection and securing of history and accounting data and system operating.

All commands are acknowledged by the CUDN to indicate whether or not the command was accepted. Any command which is input by a customer NCS which modifies the working system is acknowledged to the TSC. This acknowledgement is a direct copy of that which is returned to the CUDN to the NCS. Commands input by the TSC which modify a customer's sub-network are acknowledged to the customer NCS as well as the TSC and commands input by the TSA which modify a customer's sub-network are acknowledged to the customer NCS, the TSC and the TSA. Acknowledgements to inspection type commands or unsuccessful commands are returned only to the input source.

Successful modifying command acknowledgements take the following form:

- 1st line — outgoing CID and CSN.
- 2nd line — the command mnemonic and specification that has been actioned.
- 3rd line — the state letter and route identity of the input line and the date/time indication for when the command was actioned.
- 4th line — end of message.

Fig. 2 refers to a modifying command that requires the CUDN to make the necessary system table adjustments at centre M to close (CLO) the route identified by route mnemonic TEA. The acknowledgement indicates when this action was executed by the CUDN switching centre, M.

Successful inspection command acknowledgements take the form:

- 1st, 2nd and 3rd lines — as above.
- 4th and subsequent lines — the status report asked for.
- last line — end of message.

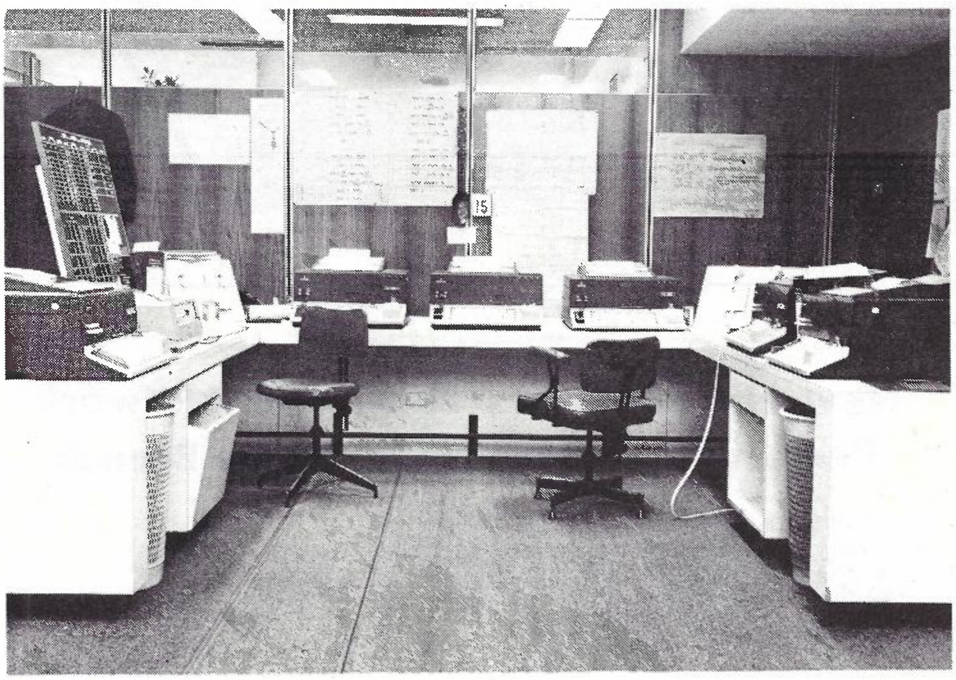


Fig. 5 — Trans Australia Airline's CUDN Network Control Station (NCS).

Fig. 3 refers to an inspection command that requests the CUDN centre M to inspect the necessary system tables in order to present a channel status report (STC) for the route identified by route mnemonic TCD. The acknowledgement restates the command and reports that route TCD has 1 input and 1 output channel (CN), the status (S) of both channels is closed (C) and the next expected CSN is 001 for both channels. The section headed Polled Stations would indicate the status and next CSN's for the separate stations (up to 9) if the route had been a polled route.

When a command is unsuccessful, the third line of the acknowledgement will appear either as INVALID or ??? The INVALID response is returned when an invalid operation is attempted e.g. attempting to modify a route which does not exist. The ??? response is returned when the command cannot be recognised e.g. the omission of a parameter in the specification.

CONCLUSION

The CUDN has been servicing its customers' requirements in a variety of contingency configurations since qualified acceptance of the Brisbane centre in December, 1972, leading up to the entry of the last CUDN centre in Perth in September, 1975. During the various stages of CUDN re-configurations leading up to the final network, the supervisory and control facilities outlined in this paper were proven to be operationally adequate.

The CUDN represents the Commission's first attempt at large scale processor controlled message switching and while it has a long history (as the Australian Post Office) in manual, semi-automatic (torn tape) and electro-mechanical automatic message switching systems and the management and supervision of these mediums, the effectiveness of the CUDN supervisory and control facilities as implemented has been due to close liaison during the development phase between the Commission, its customers and the contractor, Sperry Univac.

G. MARTIN is a Senior Technical Officer (Engineering) Grade 3 in the Data and Telegraph Switching Design Section of the Engineering Development Division, Headquarters.

He joined the Australian Post Office in 1950 as a Junior Postal Officer and entered the Technician in Training scheme in 1951. On qualifying as a Technician he was appointed to the NSW Telegraphs Division where he qualified as a Senior Technician in 1956. In 1965 he was promoted to Senior Technical Officer (Eng.) Grade 2 in Central Office where his duties involved the installation practices and design of Telegraph switching equipment.

His involvement with the CUDN commenced in 1970. He participated in a comprehensive training course with the CUDN contractor, Sperry Univac, for both software and hardware. His present duties include the management of the headquarters CUDN development centre and in-line hardware assistance to the CUDN sites.

New Headquarters Editor for Network Performance and Operations Branch

MR. J. COLLINS has been the Editor for the N.P. & O. Branch for some years, but is unable to carry on this task. Mr. L. Mitton is the new Editor. Welcome Lindsay to the fold, and thank you very much John for your contribution to the Journal over the last few years.

The Trans Sumatra Microwave System — Part 1

B. J. CLEARY, A.R.M.I.T. and V. W. LANGE, M.E., M.I.E.E.E.

This article describes the planning, design, implementation and operation of a major microwave project in Indonesia which utilised Australian personnel in a consultative and supervisory capacity. The basic theme of the article is to relate some of the problems encountered — problems which are not usually experienced in Australian projects of a similar type.

Part one of the article describes the planning, and system design phases of the project while part two, in a later issue, will cover equipment, project implementation and maintenance.

INTRODUCTION

When President Soeharto made the first STD call over the Trans Sumatra Microwave System (TSMS) on 7 August 1975, it marked the culmination of over seven years of project planning, design, negotiation and implementation involving an expenditure of over A$25M and countless manhours by Indonesian, Japanese, French and Australian staff.

As shown in Fig. 1, the TSMS connects Jakarta, on the Island of Java, with major cities and towns on the important export producing island of Sumatra. The system traverses a total of 2062 route km and consists of a main 4GHz high capacity bearer with minor 2GHz spurs which serve the smaller towns. The initial installation is capable of providing 1200 circuits on the main system and 120 or 300 circuits on the spur systems. All circuits have been designed and tested to conform to CCITT/CCIR standards. Traffic on the main system is protected against equipment failure and severe propagation disturbances by a standby bearer which is also equipped to provide an "occasional" TV relay service. Except for the spur to Tanjung Karang, spur systems are not protected, however, the design of the equipment allows protection bearers to be added at a later stage if this proves necessary.

The Indonesian Trunk Network

Most of Indonesia is characterised by inhospitable communications territory. Of the 10,000 islands which make up the archipelago, 3000 are inhabited and these generally consist of a mixture of rugged mountains, dense jungles and low lying swamps.

Before 1972, the Indonesian trunk network consisted of one microwave system between Jakarta and Bandung (200 km), three VHF 120 channel systems serving Sumatra, Bali and Madura, antiquated HF, ISB links and poorly maintained open wire lines (See Fig. 2).

The Java-Bali microwave system completed in 1972, together with the TSMS now provide a high capacity back-bone system interconnecting the major centres on the three most important islands. Projects for extension of the broadband network to the island of Kalimantan, the islands east of Bali, including eventually West Irian, and far north Sumatra are all in progress and should be completed by 1978.

The recent increases in oil prices have provided the impetus for a spectacular "great leap forward" in Indonesian communications. The government has recently signed contracts totalling over A$700M which include a domestic satellite system and stored programme controlled telephone exchanges as well as extensive quantities of telephone equipment and underground plant. All this tremendous expansion is programmed for completion within the next few years. From the authors' experience in Indonesia the training of staff, within the time required, to service such diverse and sophisticated technology will be a major problem.

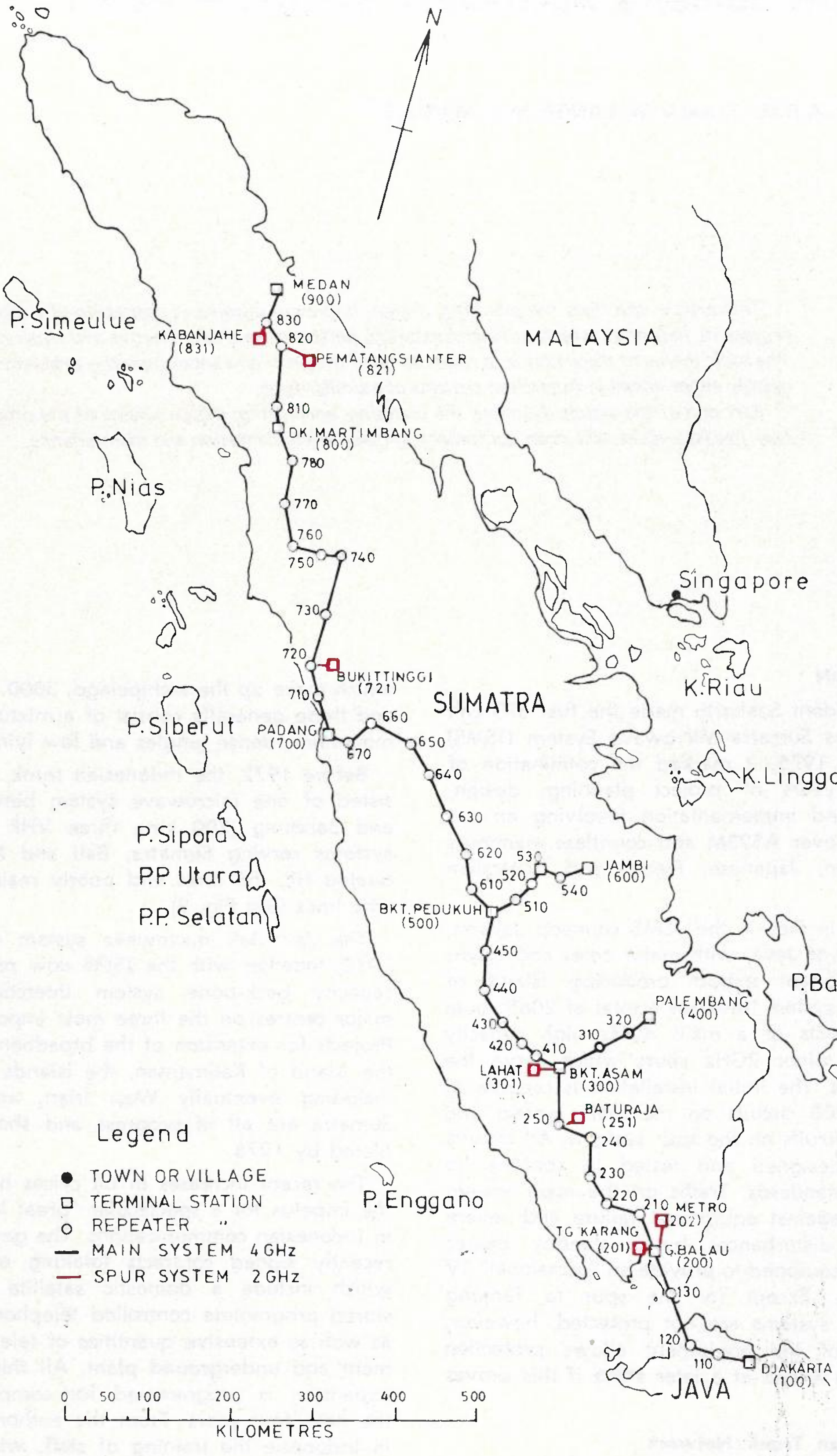


Fig. 1 — Trans Sumatra Microwave System Route Map.

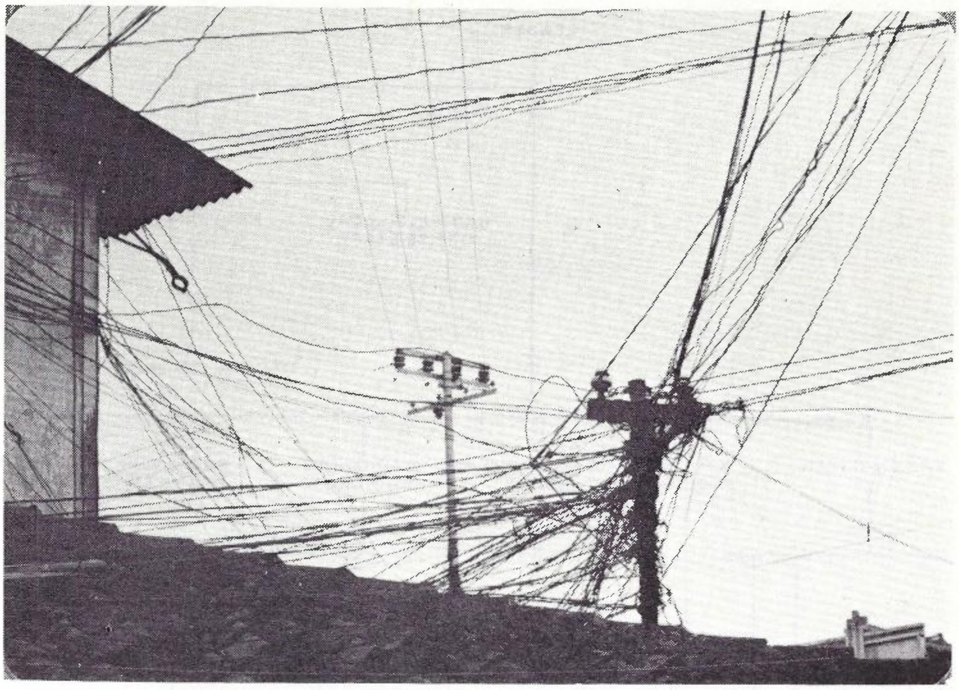


Fig. 2 — Open Wire Line Distribution.

THE AUSTRALIAN TELECOMMUNICATIONS MISSION

Establishment

In 1968 the Indonesian government introduced the first of a series of five year development plans (termed REPELITA) in an attempt to mobilise the economy for the development of Indonesia. Part of this plan was to improve the hopelessly inadequate telecommunications facilities in the country. (At that time the number of telephone services was among the lowest in the world — 0.145 per hundred of population compared with, for example, 27 per hundred of population for Australia.)

To assist in the development of the trunk network, the Indonesian government was granted a credit equivalent to US$12.8M from the International Development Association ("World Bank"). The majority of this credit was for the TSMS, however, the agreement stipulated that these loan funds were for overseas supplied equipment and services only. For civil works such as site access roads and where overseas contractors employed local subcontractors, e.g. tower erection, PERUMTEL were required to arrange internal funding. In the case of the TSMS this amounted to Rp 9000M (equivalent to approximately A$17M).

Most World Bank "soft" (low interest) loans to developing countries entail conditions aimed at securing their investment and in promoting self assistance schemes. In the Indonesian case, among other conditions the Bank required the Indonesian government to engage telecommunication consultants and also management consultants. The management consultants were to assist the Indonesian Telecommunications Authority (PERUMTEL) to reorganise itself on a sound commercial basis. After an investigation the Australian government agreed to provide telecommunication consultancy and also a grant of telephone equipment and underground plant as part of its contribution to the Colombo Plan Aid Scheme. To administer this assistance the Australian Telecommunications Mission (ATM) was established, in Bandung, in October 1968.

Scope of the ATM Mission

The initial activity of the mission was to guide PERUMTEL in the planning of projects and allocation of priorities. The consultative role was later expanded to include the planning, training and installation supervision associated with the telephone equipment and underground cable plant donated by the Australian government. When all projects are completed the total value of the Australian grant will be over A$12M. Most of the work has been concentrated in Sumatra with the objective of providing an integrated telecommunications network.

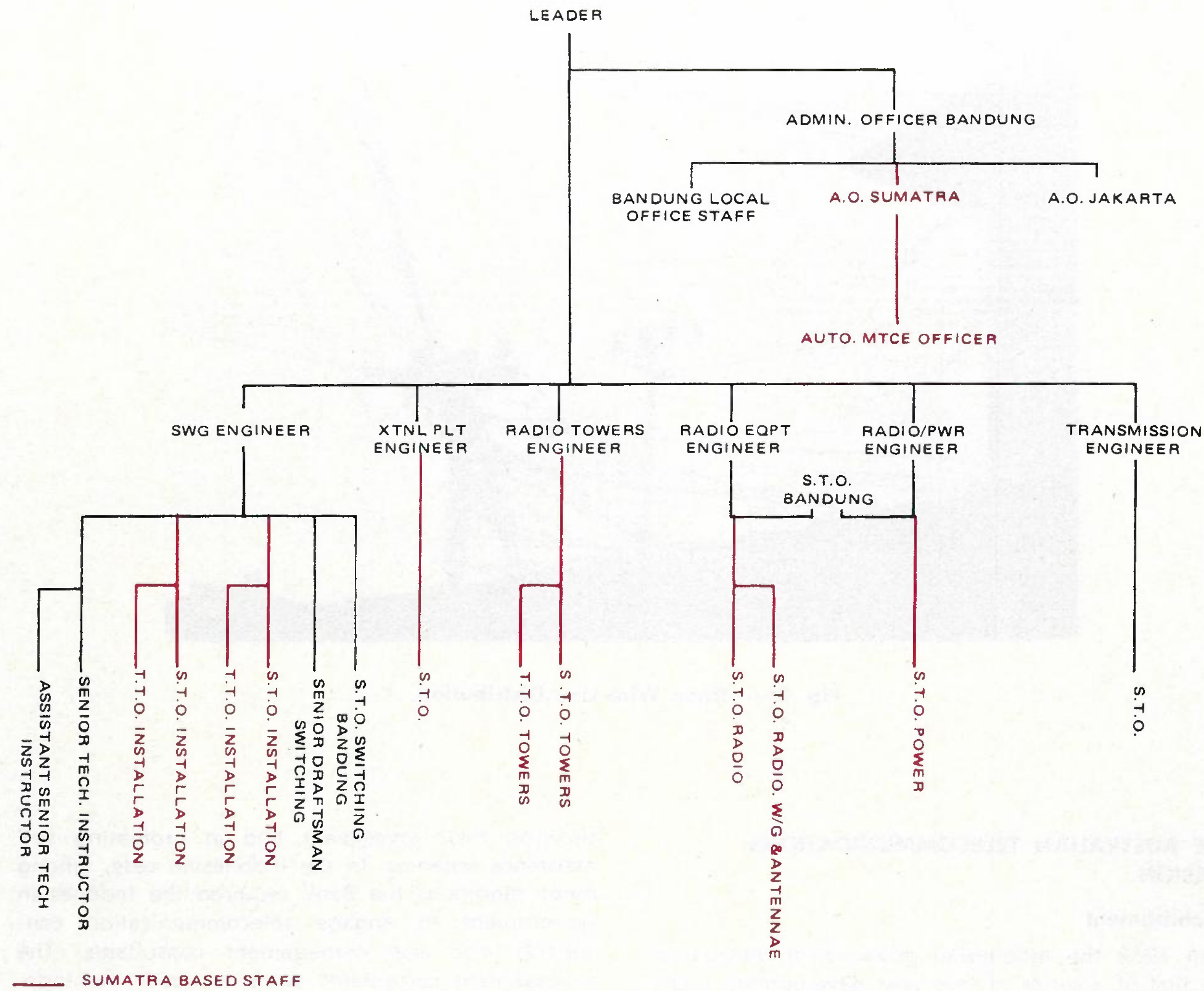


Fig. 3 — Australian Telecommunications Mission Organisation Chart, Dec. '74. (Sumatra based staff shown in red).

Staffing

The mission has been staffed by engineers and technical and drafting officers from the Australian Post Office (now Telecom Australia), a civil engineer from the Department of Works (now Department of Housing and Construction), administrative staff from the Department of Foreign Affairs (now Australian Development Assistance Agency) and locally engaged Indonesian support staff. Permanent staff were augmented by short term staff from the APO when the need arose to perform specialised tasks. The organisation chart in Fig. 3 shows the staff employed at the time of installation of the TSMS. In addition to Indonesian staff permanently attached to the Mission, PERUMTEL provided counterpart staff in each field of activity.

All radio and transmission staff have now returned to Australia and cable and telephone commitments are programmed for completion in 1978. It is planned that the mission will be terminated at that time.

PROJECT PLANNING AND DESIGN

Cost-Benefit Study

At the time the ATM mission began operating, PERUMTEL had no plans for a broadband network in Sumatra. To satisfy traffic requirements they were proposing to expand existing facilities including HF radio services. An early recommendation of the Mission was ". . . that to meet the existing and increasing requirements for telecommunications to centres of vital importance, a trans Sumatra microwave system should be constructed as a matter of national urgency". The Mission supported this recommendation with a cost-benefit study.

The study covered the following items:

Anticipated Telephone Traffic Growth. Traffic predictions were difficult as the inadequacy of existing and past facilities prevented patterns of traffic growth being developed. Estimates therefore were purposefully conservative and were based on busy hour call rates between Jakarta and Bandung where a good trunk line service existed (The trunk calling rate arrived at was an average of 240, three minute calls per year per subscriber corresponding to busy-hour trunk traffic of .005 Erlang per subscriber.)

Estimated Revenue. PERUMTEL had already established a system of trunk call charges and these rates were used in conjunction with the traffic predictions to estimate the revenue. The study stressed the need to continuously develop the local subscribers network in order to reap the full financial benefits of trunk network development.

Project Cost Estimates. These were derived from costs of the Surabaya extension, of the Jakarta-Bandung microwave system which was being constructed at the time. Costs of civil works and construction were adjusted to allow for the remoteness of Sumatra.

Project Timing. Project timing estimates were based on installation of equipment by PERUMTEL staff (as employed on the Bandung-Surabaya system). It was expected that all parts of the project could be completed approximately 5 years after approval.

Preliminary Map Studies. Alternative routes were studied on available maps and potential sites noted for closer investigation.

The conclusion of the study was that a trans Sumatra microwave system would be an outstanding financial venture, expected to recoup capital investment and cover operating costs within several years of project completion. PERUMTEL and the World Bank accepted this recommendation and approval to proceed was issued.

Survey Problems

As well as the normal topographical and climatic difficulties to be expected in surveying a microwave route in a tropical location, the survey of the TSMS was complicated by several other factors. The most serious of these was the lack of a co-ordinated map series for the area. During the original survey, which commenced in 1969, the only maps available were old Dutch maps from many different series. Although accurate these maps were of different scales and were not necessarily derived from the same source data. This made co-ordination of results from the various maps extremely difficult. The Dutch had established a system of survey reference marks but in many cases the "trig points" had been removed and documentation lost. Confirmation of altitudes and co-ordinates was thus virtually impossible. Yet another problem was the very poor condition of the main roads. During the wet season roads in central Sumatra can become an impassible quagmire and it may take a week of vehicle winching to travel only 200 km (Fig. 4). Wildlife, especially tigers, was an additional hazard in some areas.

Methods Employed

To offset these problems an attempt was made to organise a photogrammetric survey of the route but this failed due to funding difficulties and the very limited time available (2 months during the dry season) when weather conditions could be expected to be suitable.

PERUMTEL had undertaken to perform the survey using vehicles and equipment supplied by Australia. As the staff available had only limited experience the ATM conducted a four month course, in late 1969, on route survey techniques. Although 36 staff members attended the course only ten were finally able to be allocated to the actual task.

As might be expected the route survey progressed very slowly. In October 1971 when system contracts were issued, many sites and tower heights were still tentative. A basis for price variation due to system design changes was established with the contractor, and clauses were included in the contract accordingly. A major factor which enabled system design changes to be readily accommodated was the adoption of a standard "modular" tower design.

Check Survey

Early in 1972, it became obvious that a check survey was necessary to establish the validity of all sites and the adequacy of nominated tower heights. In March two propagation/system design experts and a specialist radio path surveyor were provided by the APO to guide the work. Fortunately the APO staff were able to obtain a complete series of 1:250,000 maps which covered the whole route. These maps and the provision of access tracks to most sites greatly facilitated the operation.

As time was short abbreviated route survey methods were developed. Each site was visited and a quick check made to ensure that topographical features likely to affect propagation along the radio ray line agreed with the map. Any discrep-

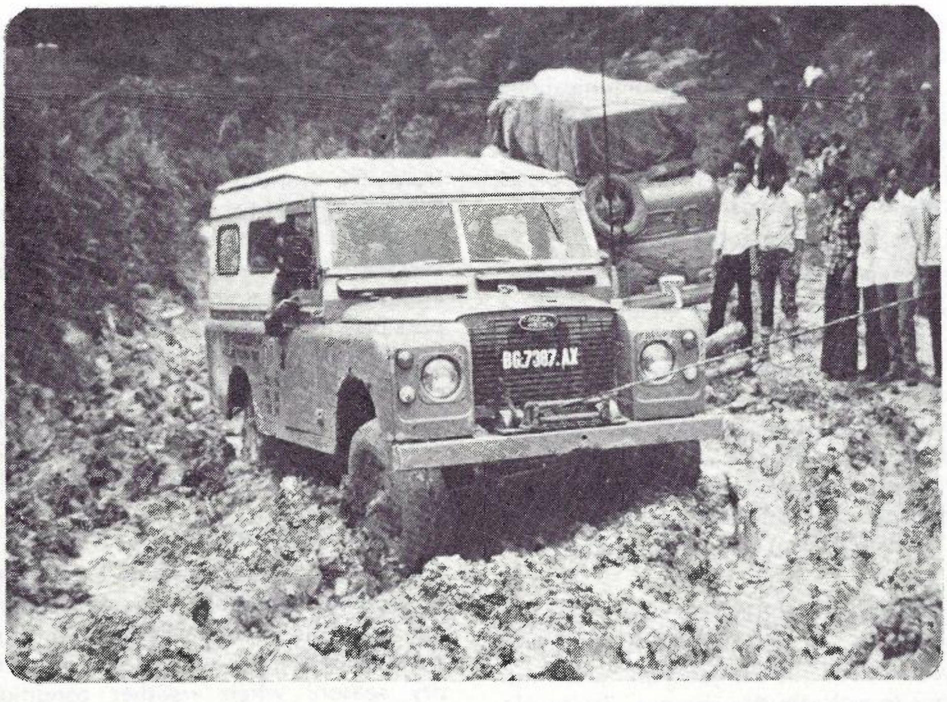


Fig. 4 — Typical Road Conditions — Central Sumatra.

ancy between map and observation was thoroughly investigated. Path profiles were then plotted on site, using map and (or) survey information and required tower heights calculated. Using these methods the entire 53 sites were rechecked in under four months. This achievement was really remarkable considering the exacting conditions under which the survey team worked. For example; due to danger from tigers it was not possible to camp outdoors and secure accommodation had to be obtained each night. Even in the larger towns there were no European standard hotels and it was often necessary to sleep in relatively primitive conditions. On one notable occasion, the two Australian team members (one of whom is 2.0m tall, the other 1.8m) had to share a 1.5m long double bed in a village hut.

The check survey revealed that in general PERUMTEL had chosen sites well but path clearance assessment tended to be optimistic. The outcome was a 34% increase in tower heights, but it was possible to eliminate one site and by relocating three others, access road costs were reduced by over A$0.75M.

Design Details

The final route generally follows the planned major national highway from Jakarta to Medan with branches to Palembang and Jambi on the eastern coast. Terrain varies from swampy rice fields, for a few paths near the coast, to rugged mountains along the foothills of the "Bukit Barisan" (Parade of Mountains) which bisects Sumatra. Site altitudes range up to 1600 metres.

Although the rugged terrain caused surveying difficulties there were compensating benefits for radio propagation. On all but three paths an obstruction clearance criterion of effective earth's radius (k) of 0.8 for 0.6 of the first Fresnel zone radius could be adopted. On the other three paths, over flat swampy ground, k = 0.6 was used. As an additional gain, space diversity protection against radio signal fading effects was deemed to be necessary for only four paths on the route.

The system design parameters can be summarized as follows:

- Mainline sites: 46
- Spur sites: 7
- Frequency band main system: 3770-4200 GHz
- Frequency band spur systems: 1900-2300 GHz
- Frequency plan: normal 2 frequency
- Average main system path length: 42 km
- Average spur system path length: 19 km
- Path clearance criteria: K=0.8 for 0.6 first Fresnel zone radius (49 paths)
  K=0.6 for 0.6 first Fresnel zone radius (3 paths)

Fig. 5 — TSMS Typical Access Road (during construction stage).

- Number of space diversity paths: 4
- Range of tower heights: 33 to 110m
- Minimum first overshoot: 5°
- Minimum second overshoot: 2.5°
- Synchronous satellite orbit minimum angle separation: 2°

Performance Objectives

The main performance objective of the radio system is that telephony noise performance meet the objectives stated in part 1.2 of CCIR Recommendation 393-1 and Part 2 of Recommendation 395-1, New Delhi 1970 viz: 3pWOp/km for not less than 80% of the month. In fact, system noise performance tests indicate that the system should meet 2.6 pWOp/km thus providing a maintenance margin.

Site Works and Access Roads

Construction of the 47 new buildings and site access roads proved to be a mammoth task. Road and building design and construction supervision were the responsibility of PERUMTEL Civil Works Division, while construction was handled by individual local contractors on a per site basis. Site works were carried out in almost mediaeval fashion with extensive use of labourers, many of whom did not possess steel tools but used pointed sticks and cane baskets. Mechanical aids were seldom provided although explosives were liberally employed. (During a site visit one of the authors narrowly escaped injury from a shrapnel-like shower of rock when standing a considerable distance from a blast where safety mats were not used.) In many cases access roads are up to 7 km long winding and climbing at maximum grade (1:5) for much of the way. (See Fig. 5.)

At some locations the site area available was so limited that it was necessary to install the tower and buildings on different levels with the building as much as 8m below the tower base. (See Fig. 6.) Rock facing and construction of rock/concrete drains was necessary at most sites. Considering the large number of contractors and the primitive construction methods the PERUMTEL Civil Works Division accomplished an amazing feat in maintaining construction progress ahead of the microwave contractor's installation teams.

Buildings

At the time of construction galvanised steel was virtually unobtainable in Indonesia and as local bricks were an unknown quality, a reinforced concrete structure was adopted. The repeater building, as shown in Fig. 7, consists of columns supporting a 30cm thick reinforced concrete roof. Rendered brick infill panels are installed between the columns and the floor is a concrete slab on the ground. Although the route crosses the equator most of the repeater sites are located at high altitudes where

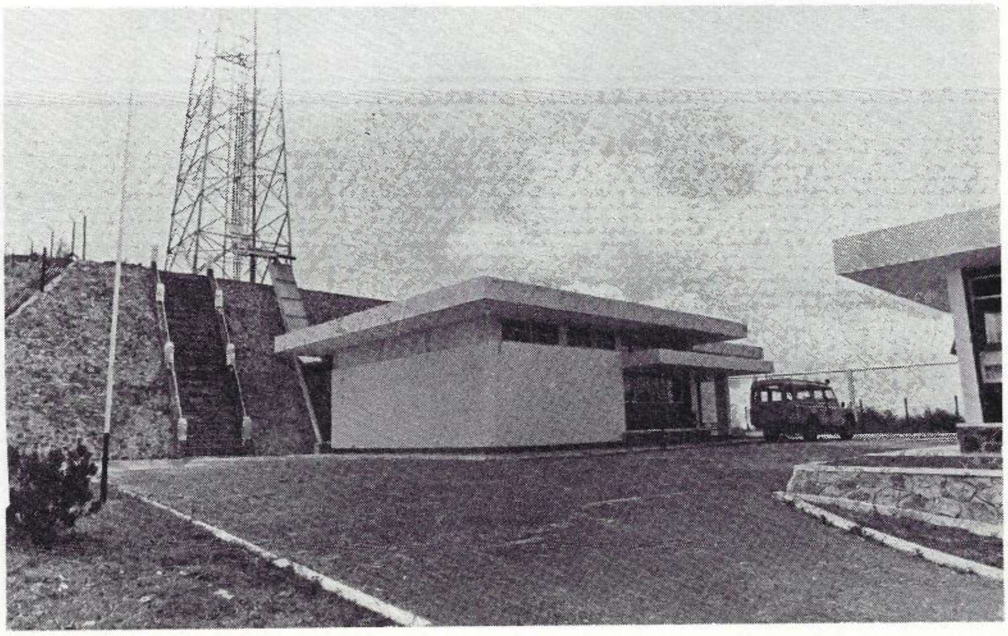


Fig. 6 — TSMS Multi-level Repeater Site.

temperature and humidity varied little throughout the year. Thus air conditioning was not considered necessary to provide a reasonable equipment environment. Buildings of this type were erected at 40 repeater sites with a larger version at 4 intermediate terminal sites. The remaining 9 buildings were either existing telephone exchanges or new multi-purpose telecommunications buildings constructed in conjunction with the project.

The repeater building equipment room measures 8.0 x 5.0m and provides ample space for full expansion of the 4GHz system as well as for installation of an additional system.

Site Security

Like most new Asian nations, Indonesia has had a stormy history and thus security assumes a prime importance. In addition to providing a standard 3m high security fence, each site is permanently guarded. The "penjaga" (guard) lives within the site boundaries in a small self contained house which is constructed in a similar method to the main building. The radio supervisory system (to be described later) allows for the extension of a telephone circuit to the Guard House for emergency use.

CONTRACTUAL ARRANGEMENTS

Invitation to Tender

In consultation with PERUMTEL, ATM prepared an overall system specification and Invitation to Tender on a "semi-turnkey" basis in which the one contractor would be responsible for supply and installation of all plant and equipment. PERUMTEL did however reserve the right to purchase the multiplex equipment from another tenderer, if considered advantageous, as there could be a clearly defined interface between radio and multiplex equipment. PERUMTEL also retained responsibility for civil works and system design and hence it was necessary to clearly delineate between the responsibilities of PERUMTEL and the system contractor(s) in these areas. This was achieved in the following ways:

Civil Works. An agreed timetable was negotiated based on the contractors tendered installation programme and a feasible civil works programme. Financial penalties were stipulated to be imposed on PERUMTEL or the contractor depending on which party caused a delay.

System Design. The expected system noise performance was calculated, using the guaranteed

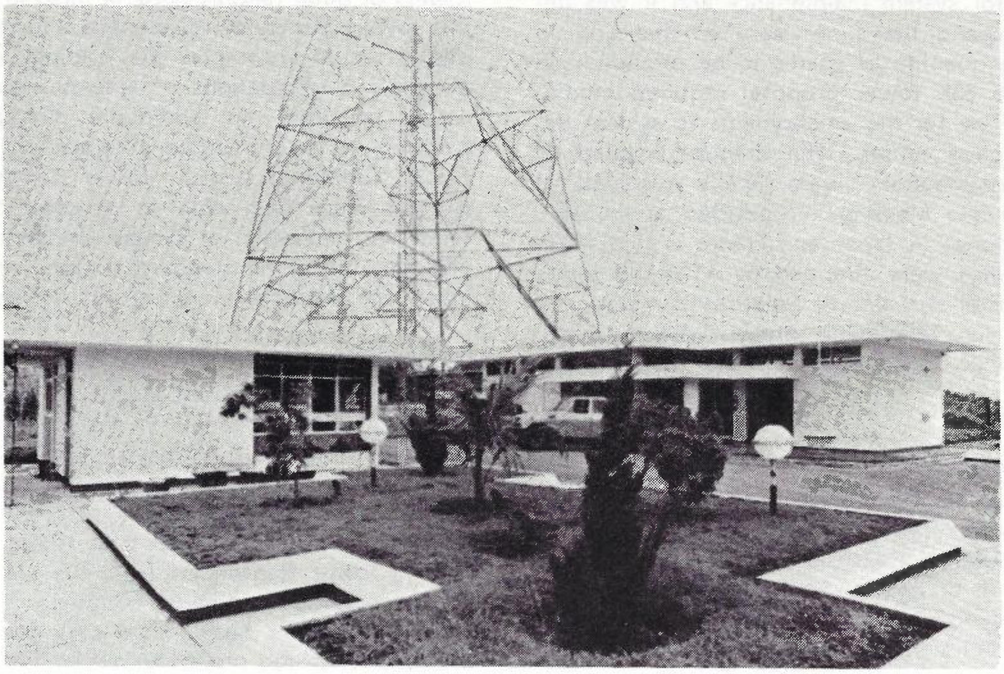


Fig. 7 — TSMS Repeater Site showing Guard House and Repeater Building.

equipment parameters tendered by the contractor and path details provided by PERUMTEL. The method of calculation produced a noise performance value assuming fade free propagation conditions on all paths. The calculated value was then adjusted by assuming a simultaneous 4dB drop in signal level on each path. This adjustment allows for unknown propagation conditions and it was considered that this situation simulates the 80% of the month noise performance criterion referred to earlier.

TENDER ASSESSMENT

Twenty four tenders were received from twelve major broadband equipment manufacturers representing six countries. The majority of manufacturers offered several alternative arrangements of conventional equipment closely related to the requirements of the specification. A novel feature of the tender procedure, by Australian standards, was that tenders were opened in public and prices were published.

Tender evaluation was carried out by a joint PERUMTEL/ATM Committee. Due to the large number of alternative solutions and the competitive prices offered, the committee was involved in a large amount of effort in rationalising tenders to provide a common basis for assessment.

After evaluation the committee made a recommendation to the PERUMTEL Board of Directors which resulted in the selection of

- Sumitomo Shoji Kaisha (S.S.K.) of Japan for:
  - —NEC radio equipment.
  - —Mitsui Deutz power plant with Yuasah batteries.
  - —Denki Kogyo Towers.
  - —Kabelmetal 4GHz elliptical waveguide.
  - —Denso Kogyo 2GHz coaxial cable.
  - —Toyota 4 wheel drive vehicles.

  Total final contract value: Yen 2.48 Billion plus Rp 254M (Equivalent to approx. A$6.7M)

and • Compagnie Industrielle Des Telecommunications (C.I.T.) of France for:
  - —Telephone and telegraph multiplex equipment of their own manufacture.

  Total contract value: F.F. 6.3M plus Rp 31.6M (Equivalent to approx. A$1.06M).

DESIGN REVIEW MEETINGS

After the issue of a Letter of Intent to the chosen tenderers, extensive negotiations were entered into so as to achieve the optimum solution from the various alternatives offered. An assessment was also made of the experience of PERUMTEL staff nominated for system maintenance and it was decided to expand the supervisory scheme and to increase the quantity of spares to be provided. In addition the SSK tower proposal required modification to allow for the amendments to system design, mentioned earlier. The changes entailed by all these negotiations were finally resolved at "Design Review Meetings" conducted at the contractors' factories in Japan and France in mid 1972. These meetings were attended by ATM and senior PERUMTEL staff and also in Japan by a member of the APO HQ Telepower group who provided specialist advice on power plant.

TOWER DESIGN

Design Conditions

Straddling the equator as it does, Indonesia experiences only relatively light winds and the maximum wind loading specification for the TSMS towers was 110 kph at ground level (cf normal Telecom minimum of 160 kph). Other design criteria were based on APO standards.

Steelwork Design

With any turnkey project, a problem invariably arises when it becomes necessary to request a contractor to change his original basis of tendering. Such a change became necessary in the SSK tower proposal. The Invitation to Tender permitted tenderers to offer either a range of standard tower designs for various antenna loadings, or an individual design for each site. This was done to give tenderers the widest possible scope to suit their preferred methods of tower design. SSK did in fact offer an individual design for each site.

Due to the delay in finalising system design details, mentioned earlier, it was soon apparent that SSK would need to provide a more flexible tower design so as to allow ample freedom in the choice of tower height and antenna positioning so as to avoid serious delays in the implementation programme caused by lack of final design details. SSK were thus prevailed upon to provide a standard tower design and, after protracted negotiation, they did so. Subsequently, the contractor acknowledged the considerable simplification of effort resulting from the adoption of the standard design.

The design finally agreed on was a single standard design based on a 90m tower with four 4m diameter antennas located at the top two levels. Towers of other heights became integral sections of this tower. Structural calculations showed that this design would encompass the loadings imposed by all likely configurations of antennas and, in most cases, provided an additional strength margin sufficient to accommodate antennas for a possible future additional system. Tower design and fabrication were thus able to proceed concurrently with the finalisation of system design information. The penalty of the standard design was increased steelwork resulting in marginally increased costs.

Footing Design

To offset the increased steelwork costs, and because obtaining concrete in the remote areas of Sumatra was difficult, ATM requested SSK to adopt a more efficient footing design than the mass concrete footing originally offered. The mass concrete footing relies on the mass of concrete to resist the overturning forces transmitted from the wind pressure on the antennas and tower members. As most site foundations were heavy clay with good cohesion the revised design proposed was an undercut footing in which the concrete base is extended into the area of undisturbed soil. This procedure enables advantage to be taken of the weight and shear resistance of an inverted pyramidal frustrum of soil above the undercut and thus requires less concrete for a specific antenna loading.

Disposition of Towers

Undercut footings were employed at 36 sites with mass concrete footings at 15 sites. A raft footing was employed at Padang and a piled footing at Palembang due to local foundation difficulties. The tower at Jakarta is a special design to allow for the greater number of systems emanating from the capital.

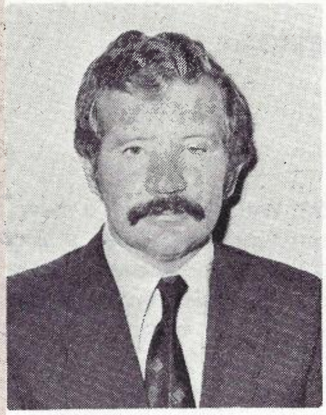
Standard towers were originally provided in five heights viz.: 33, 48, 60, 75 and 90 metre. At a later stage two 110 metre towers were necessitated by a route change near Padang which was undertaken to avoid difficult access roads. This manoeuvre resulted in a nett cost reduction of over A$0.5M.

PART 2

Part 2 of this article will cover
- Project Management
- System and Equipment Description
- Installation Testing and Commissioning
- Operation and Maintenance

BARRY CLEARY is a Senior Engineer in the Broadband Provisioning Section of Headquarters, Radiocommunications Construction Branch. He has been employed by APO/Telecom Australia since 1957 working as a Clerk in the Victorian Administration, a Technical Officer in the HQ Lines Section and since 1965 as an Engineer.

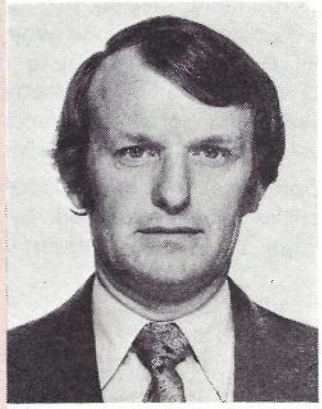
After graduating from the Royal Melbourne Institute of Technology with a Diploma of Communication Engineering he was appointed to the HQ Radio Section as Engineer Class 1. Since that time he has occupied various positions in the field of broadband radio relay system engineering. In 1971 he was seconded to the Australian Telecommunications Mission in Indonesia for a period of 3½ years of which 2½ were spent as the senior radio engineer. His main duties were concerned with the Trans Sumatra Microwave System being involved in the following stages of the project: tender evaluation, system engineering, contract negotiation and, implementation and testing of the first phase.



VOLKER LANGE joined the APO in 1958 as a technician in training. In 1967 he completed a Bachelor of Engineering (First Class Honours) at the University of Adelaide. He was subsequently awarded a Master of Engineering Degree from the same Institution for research work on active antennas undertaken between 1967 and 1969.

In 1969 he joined the South Australian Radio Section where he was engaged in installation and commissioning of broadband radio systems. From 1970 to 1974 he was project engineer on the Darwin-Mt. Isa microwave project team where he was also involved in all aspects of the Darwin-Nhulunbuy tropospheric scatter system.

From 1974 to 1976 he was the senior radio engineer (Engineer Class 4) with the Australian Telecommunications Mission in Indonesia where he was involved in commissioning of the Trans Sumatra Microwave System and establishment of a maintenance organisation. Since his return he has been a Senior Engineer with Headquarters Broadcasting Branch, Radio Australia Section, concerned with antenna design and provisioning. Volker Lange is a member of the Institution of Electronics and Electrical Engineers (America).



Walsh Functions

D. NIGHTINGALE

In 1923 Walsh devised a new complete set of orthonomal functions (Amer. J. Math., Vol. 45, p.p. 5-24, 1923) in order to demonstrate the comergence properties of Fourier type series. In the past ten years these Walsh functions have been suggested for a wide variety of applications, particularly in the communications field (e.g. C. A. Bass. "Applications of Walsh Functions", Proceedings of Symposium & Workshop, 1970).

Generally speaking, Walsh functions are defined on a unit interval 0 to 1 and in this interval they take on value of ± 1. They oscillate between $+1$ and -1 in a fairly regular and highly predictable manner in the same way as the basic trigonometric functions. Hence, in the same way that on-off type waves can be represented by a Fourier series of sines and cosines, a trigonometric wave can be represented by a series of on-off type functions, which may take the form of Walsh functions.

An incomplete set of periodic rectangular orthonomal functions was developed by Rademacher in 1922 (Einige Satze uber Rehan von Allgemeinen Orthogonal Functionen Math. Ann., Vol. 87, p.p. 112-138). The first step in defining these functions is to take a unit interval and divide it into 2 sub-intervals for $n = 1$, 4 sub-intervals for $n = 2$, 8 sub-intervals for $n = 3$, etc. Next ascribe $+1$ and -1 to the sub-intervals in turn and these will then result in the Rademacher functions, as shown symbolically in Fig. 1(a) and graphically in Fig. 1(b).

The period of these functions corresponds to a binary division of the interval, viz: 1, $\frac{1}{2}$, $\frac{1}{4}$ for each of the functions R_0, R_1, . . . The set involves odd functions only, which means that they have odd symmetry, about $t = \frac{1}{2}$, in the same way that a sine wave has odd symmetry, about 180° or half a period. These functions are not satisfactory for representing functions which are symmetrical, about $t = 0$ or $t = \frac{1}{2}$.

The Rademacher functions were combined in a certain way by Walsh to form a new set of functions. This new set called "Walsh Functions" is a complete set of Orthonomal rectangular waves. The "Gray code" and the "binary code" are used in the

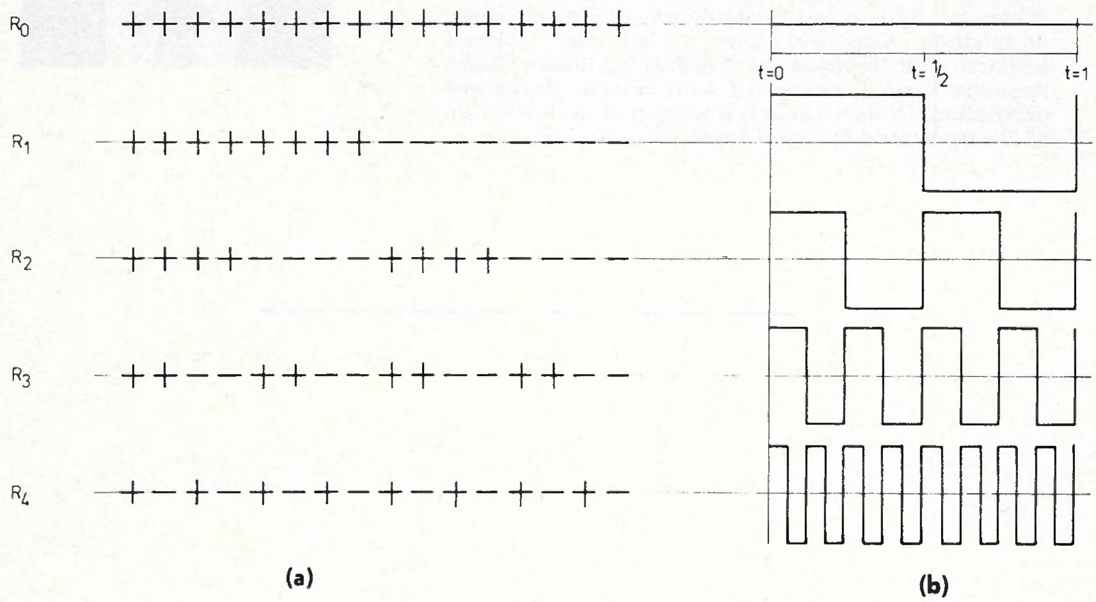


Fig. 1 — Rademacher Functions

conversion which appears below:

Decimal No.	Binary Code	Gray Code
0	000	000
1	001	001
2	010	011
3	011	010
4	100	110

Each move to an adjacent number in the Gray code occurs with an operation on one bit only. To obtain the Walsh function W(4,t) say, proceed as follows:

(a) Write 4 in binary form = 100
(b) Convert to Gray code = 110
(c) With bits numbering from right to left, multiply together the Rademacher functions corresponding to each bit number, where that bit indicates 1. In the above case we have:

Gray code = 1 1 0
Bit No. = (3) (2) (1)
∴ W(4, t) = $R_3.R_2$.

From Figure 1(a)

R_3 + + − − + + − − + + − − + + − −

R_2 + + + + − − − − + + + + − − − −

$R_3 \times R_2$ + + − − − − + + + + − − − − + +

By proceeding in this way, the first five Walsh functions have been developed and appear in Fig. 2.

The names on the righthand side of Fig. 2 indicate that sine and cosine equivalents of the

Wal (0,t) + + + + + + + + + + + + + + + + Wal (0,t)

Wal (1,t) + + + + + + + + − − − − − − − − Sal (1,t)

Wal (2,t) + + + + − − − − − − − − + + + + Cal (1,t)

Wal (3,t) + + + + − − − − + + + + − − − − Sal (2,t)

Wal (4,t) + + − − − − + + + + − − − − + + Cal (2,t)

Fig. 2 — Walsh Functions

Walsh functions, since it may be seen that there are two cycles in Sal (2,t) for example, and that Cal (2,t) is in advance by a quarter of a cycle, as is the case with normal circular functions.

Interest in Walsh functions was revived in the late 1960s and many applications of the techniques are being studied, among which are the following:

Image processing, filtering and filter synthesis, non-liner system analysis, spectroscopy, multiplexing, electromagnetic or acoustic radiation of Walsh waves, resolution of point targets, information transfer, speech synthesis and analysis, etc.

Mr. D. T. NIGHTINGALE obtained a B.Sc. in Engineering from the University of London in 1950, a Diploma of Electrical Engineering from West Ham College of Technology, London, in 1950, and a Master of Engineering Degree from the University of New South Wales in 1960.

Mr. Nightingale joined the P.M.G.'s Department in 1955 as an Engineer Class 1 in N.S.W., and following experience at various levels in the Country Installation, Traffic Engineering, Internal Plant Planning, Transmission Planning, Electronic Exchange, Telegraphs, Data and C.U.D.N. Sections, retired in mid-1976 from the position of Engineer Class 5, Design Co-ordination, Regional Operations Branch.

Exchange Network Planning; Use of the I.T.T. Computer Program – Part 2

M. J. PRIEST, B.Sc., M. Eng. Sc., M.I.R.E.E. and P. R. HALLAMS, B.E., M.B.A.

Part I of this article discussed the main features of the ITT computer program used in Network Planning of Urban Telephone Exchanges. Part 2 is concerned with application of the program to a provincial city network and the Sydney ELSA area.

APPLICATION TO PROVINCIAL URBAN AREA

At June 1973, Wollongong minor switching area was serving 35,378 subscribers on 8 large automatic exchanges. The majority of subscribers are connected to ARF exchanges, and a GVX/Y stage at Wollongong provides the X and Y tandem switching function for the crossbar network.

Development is confined to a fairly narrow strip of land between the coast and the Illawarra range. The width of this strip varies from about 1 Km north of Thirroul to 12-15 Km in the south. Southern development is further contrained by Lake Illawarra, which covers an area of 35 Km^2 (see Fig. 2).

The estimated growth over the next 8 years is about 8% p.a. to 74,000 subscribers by 1982. That is the network will double in size within the period required to plan and build a standard urban ARF exchange. The need for a network study is evident, and it was felt that Wollongong area was suitable to test the ITT program. It is virtually a closed area, it has routing constraints imposed by Lake Illawarra and Port Kembla Harbour, it is growing rapidly and has a need for new exchanges.

Applying a computer package of this sort for the first time, invariably requires considerable work in processing existing data to correct it to the format required for input. Data preparation can be divided into four independent sections:

- Preparation of a suitable grid and generation of the subscribers distribution matrix. For a 40 x 18 grid of 1Km squares, there was about 30 hours work for an Estimating Foreman, in preparing the grid and deriving the subscriber distribution matrix from exchange surveys.
- Generation of cost functions required about 60 hours of Engineer Class 2 work for the initial run. Existing data was not in the required format. Now that this data is available future studies of other areas should only require about two hours work.
- Consideration of local conditions required about 15 hours of Engineer Class 2 work. Items to be considered include, reserved areas, routing zones, traffic distribution, existing plant, maximum and minimum exchange capacities and application of different cost curves to existing exchanges.
- Coding for the first run required about four hours of Engineer Class 2 time. This work could easily be handled by technical staff.

Data Preparation

Costs: The input format of cost data for this model is generally in the form of total cost = fixed cost + cost /unit. Existing cost data was not in this form, but is relatively easy in the case of cable and switching plant to convert it. A difficulty arising from the cost format, is that it is not possible to include step functions, e.g. for a building or exchange extension, and costs can only be represented incrementally (i.e. per costs per suite). This problem can be overcome by careful definition of maximum and minimum capacities, but it may require two or three runs of the program to achieve the correct result.

Adjoining Areas: The model is based on the network being closed. Wollongong satisfies this assumption, except in the south. Since significant development is expected in this area we felt it was more realistic to include the adjacent exchange of Minnamurra in the network and allow the southern exchange boundary to be established by the

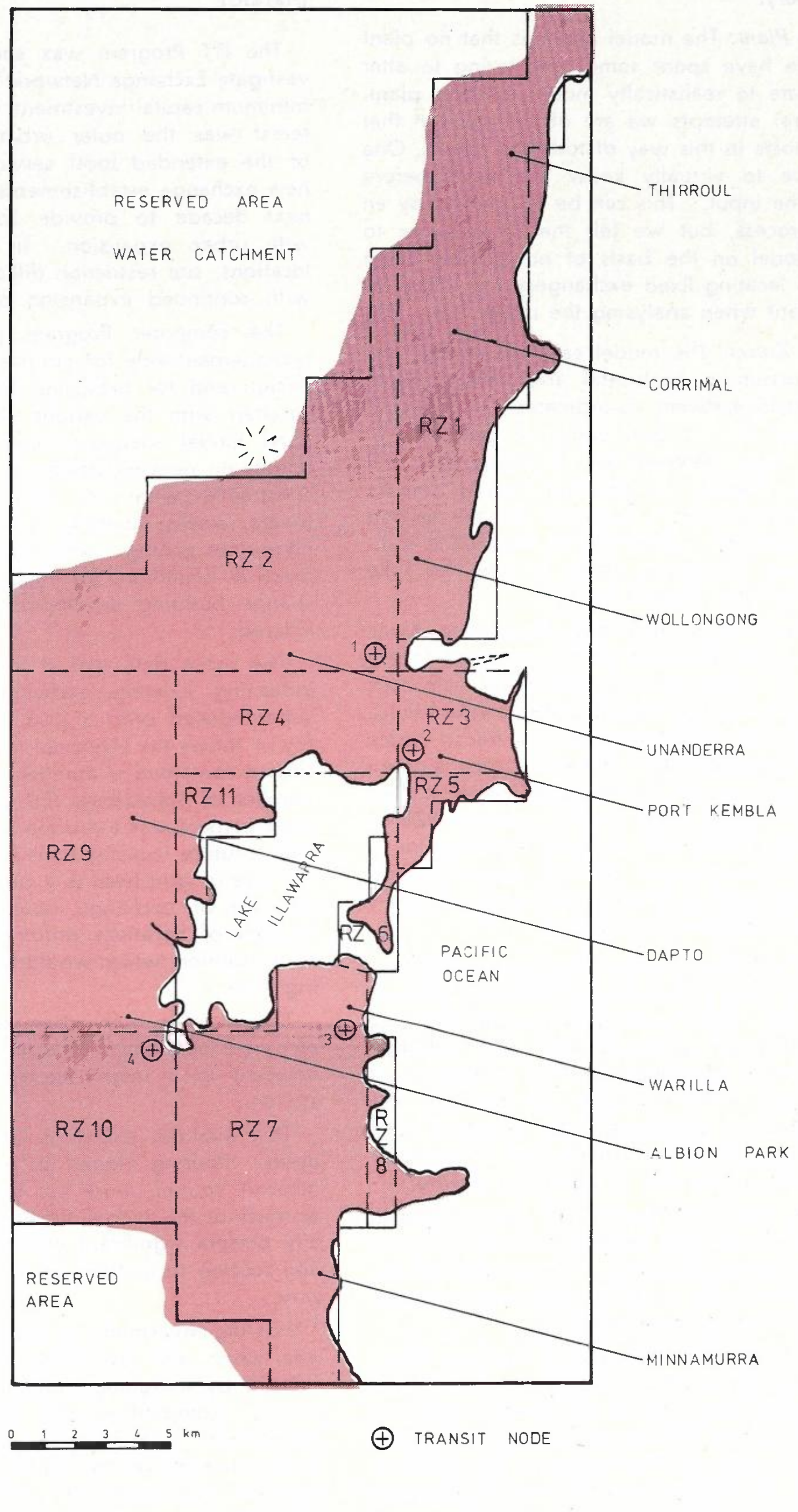


Fig. 2 — Wollongong Minor Switching Area Cable Routing Zones.

model, rather than to arbitrarily fix it by the existing boundary.

Existing Plant: The model assumes that no plant exists. We have spent some time trying to alter the cost data to realistically model existing plant. After several attempts we are of the opinion that adjusting costs in this way distorts the results. One would have to virtually know the result before adjusting the input. This can be approched by an iterative process, but we felt that it is better to run the model on the basis of no existing plant (other than locating fixed exchanges) and allow for existing plant when analysing the result.

Routing Zones: The model calculates cable distance by assuming horizontal and vertical feeds i.e. the distance between co-ordinates 3, 4 and 6, 7 is (6-3) + (7-4) = 6 grid units. If geographical constraints occur between any 2 points that will require two changes in direction then a dummy point or transit node is required, for the second change of direction. Wollongong required 4 transit nodes and 11 routing zones to cater for Lake Illawarra and Port Kembla Harbour.

Table 4 and Fig. 2 show how the routing zones and transit nodes are constructed and input to the computer. A matrix specifying the route from each routing zone to all other routing zones is established. For example RZ8 to RZ4 is routed via transit nodes 3 and 2. This combination of transit nodes is given a combination number 5. The route length is then determined in three steps, from a point in RZ8 to Node 2, Node 2 to Node 3, Node 3 to a point in RZ4. In this way cable can be routed around obstacles and made to follow predetermined routes (e.g. an established conduit route).

Results: The initial runs for Wollongong analysed the network with subscribers distribution forecast for 1982. The eight existing exchanges plus one from the adjoining switching area were included, and the network developed for 9 to 12 permanent ARF exchanges. The minimum cost network was achieved with 11 exchanges. The minimum cost network was $0.3m less than the cost of developing the existing network, a significant saving.

Sensitivity tests were carried out. For changes in cost structure of ± 20% the minimum cost network did not change significantly. The number of exchanges remained the same, the only minor changes occurred in exchange boundaries.

The model can also be used to compare alternatives generated by the planning engineer. For the Wollongong study it was felt that the minimum cost network determined above, could be improved on, by use of portable exchanges in two parts of the network. The results indicated that this approach would further reduce the total network cost.

APPLICATION TO THE SYDNEY TELEPHONE DISTRICT

The ITT Program was successfully used to investigate Exchange Network Development plans for minimum capital investment. The main region of interest was the outer urban development zones of the extended local service area (ELSA), where new exchange establishments are required over the next decade to provide for demand associated with urban expansion. In this area, at several locations, site restriction difficulties were associated with continued expansion of existing exchanges.

The computer Program provided a powerful management aide for optimising exchange network design and for providing total network costs associated with the various alternatives. The computer model adequately catered for practical limitations on network design at some locations. These constraints were in some cases topographical (rivers, creeks, ravines), or man made (reservoirs, non-urban zoning, communications corridors). Also practical limitations (or imposed restrictions) on exchange building development needed to be considered.

The input data was a map of the ELSA area, indicating existing exchanges (fixed exchanges), superimposed onto a grid of ($\frac{1}{2}$x$\frac{1}{2}$) mile squares. Fig. 4 shows the Liverpool tandem area study. Each square contained a number indicating the forecast number of subscribers (20 years). (The non-metric measurement was a residue from a previous manual study; future investigations will use $\frac{1}{2}$ Km squares). The size of grid used is a compromise between the accuracy of exchange boundary design and the number of iterations required to achieve an optimum solution, which would be wasteful on computing time.

Special uses, non-urban zoned land, reservoirs etc. were nominated as reserve areas, as was land adjacent to a major Electricity Commission Substation.

This avoided exchange establishment in these areas. Routing Nodes as constraints on junction network routing were not used. The topography of much of the Sydney ELSA region does not generally present significant boundaries to cable access, and routing restrictions were not considered necessary.

Existing investment in exchange buildings, common plant and switching equipment was considered by assigning minimum sizes to fixed exchanges compatible with the extent of existing installations. Maximum exchange size was selected at the users discretion. In the absence of any other practical constraint on exchange development 40,000 numbers was generally nominated as the

TABLE 4 — ROUTING MATRIX

I.T.T.L.S. PLACEMENT OF EXCHANGES VERSION15 DATE 24/09/74

WOLLONGONG MSA AT 2020. MAX NO.OF EXCHANGES 20

TRANSIT NODE	1	2	3	4
VERT. COORD.	21	24	33	33
HORIZ. COORD.	12	13	11	5

TRANSIT NODE COMBINATIONS

COMBINATION	1	2	3	4	5	6	7
TRANSIT NODE	1	2	2	3	3	3	4
	0	1	0	2	2	0	0
	0	0	0	1	0	0	0
	0	0	0	0	0	0	0
	0	0	0	0	0	0	0

MATRIX OF COMBINATIONS OF TRANSIT NODES

	1	2	3	4	5	6	7	8	9	10	11
1	0										
2	0	0									
3	1	0	0								
4	0	0	0	0							
5	2	3	0	3	0						
6	2	3	0	3	0	0					
7	2	3	0	3	0	0	0				
8	4	5	6	5	6	6	0	0			
9	0	0	0	0	3	3	7	0	0		
10	0	0	0	0	0	0	0	0	0	0	
11	0	0	0	0	3	3	7	7	0	0	0

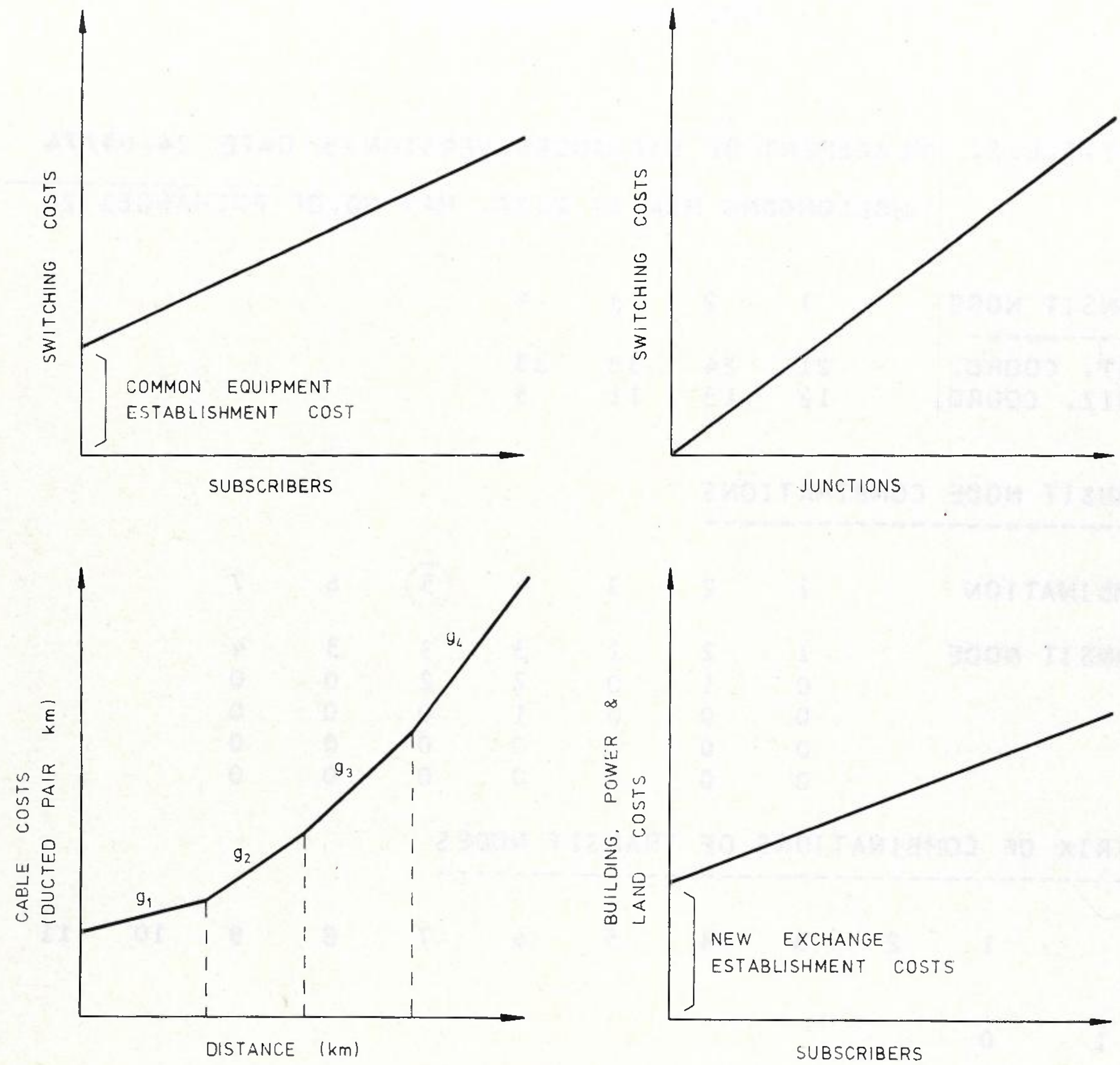


Fig. 3 — Typical Input Cost Data.

maximum terminal exchange size. (In fact, the optimum solution rarely designed exchanges greater than 20,000 numbers, and for the subscriber densities consider at 1994. no exchange above 30,000 numbers was indicated to be economically viable.

Switching equipment costs were assessed for crossbar equipment (M=6) with installations in 1000 line modules. Also, line relay set costs were included (i.e. switching costs as a function of junctions). Exchange common equipment was costed as a single payment on new exchange establishment. This included batteries and power equipment, building services equipment (air conditioning etc.) MDF and cable ironwork.

Building costs were assessed as floor space requirements for 10,000 number equipment extensions, with a major step cost discontinuity at initial building establishment. This allowed for cable chamber excavations, foundations, drainage, amenities areas. It was assumed that the ultimate site requirements were purchased at exchange establishment, 1 acre or approximately six suburban housing blocks being required.

Duct and cable costs were assessed as an average cost per ducted pair Km. This assumed PVC concrete encased conduits and large size moisture barrier sheathed cable. The cable cost curve expressing cost per subscriber as a function of distance from the exchange was approximated to a

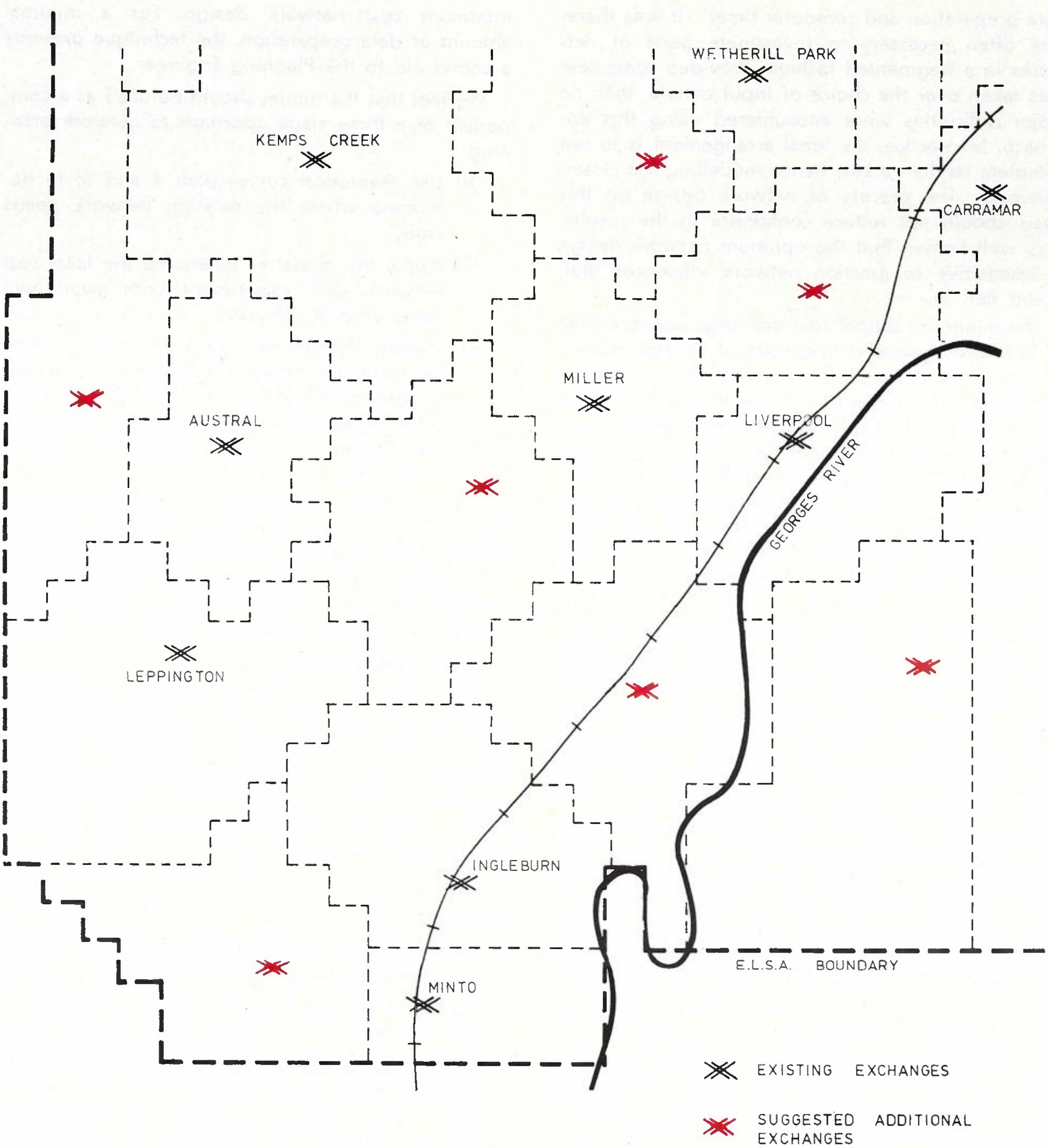


Fig. 4 — Liverpool Tandem Area Suggested Exchange Network at 1994.

series of straight lines. This increase in gradient away from the exchange includes the effect of tapering duct and cable size as well as the need for higher conductor weight cable to meet transmission limits.

An allowance was made for average cable occupancy. Costs for distribution cables were not included. It was apparent that riser cable would have little or no effect upon network design.

One aspect of the algorithm used by the ITT program is that the network is assumed to be a closed network. That is, all traffic generated is dispersed within the network. This could therefore present some difficulty of confidence in the results when only a part of a network is investigated. (It is impractical to run an analysis for the entire Sydney Network, and even the investigation of all ELSA exchanges places significant demands upon data preparation and computer time). It was therefore often necessary to investigate parts of networks in a fragmented fashion. Provided some care was taken over the choice of input criteria, then no major difficulties were encountered using this approach. In practice, the ideal arrangement is to run complete tandem areas; hence modelling the closed network. The process of network design on this basis should not reduce confidence in the results. It is well known that the optimum network design is insensitive to junction network influences (Ref. 2 and Ref. 5).

The minimum capital cost exchange network plan at 1994 was indicated to consist of 37 exchanges.

At present there are twenty-one (21) permanent exchanges and portable units are installed at seven (7) locations in the area studied. The program suggested the establishment of nine (9) additional exchanges over the next twenty (20) years and indicated that a boundary redesign between existing exchanges could be warranted at several locations. The capital cost savings inherent in the new exchange establishment were seen to be of the order of $5M.

The optimum network plan determined by the computer program conformed closely to network development proposals already documented (using other indicators) at most locations. There were some minor details of boundaries which differed from manual designs, these being largely the result of local topographical details not included in the input data. However it is also appropriate to note that the ITT Program suggested alternative network solutions at several locations which had not previously been considered. In this regard, it presents a planning aid which is superior to other manual applied indicators.

In several locations, new exchanges were placed in areas where extensive residential development had already taken place. This can create some difficulty in assessing the network plan appropriate, since extensive investment in plant (both at the existing exchange and in external plant into the area), may already have taken place. Hence, the new exchange establishment, although necessary from a theoretical total capital cost analysis, may be difficult to justify on a PVAC basis. Often the problem becomes one of timing. It will be appropriate to re-examine the proposal prior to any additional major investment; particularly in conduit or building extensions.

CONCLUSIONS

The ITT program together with other indicators (Refs. 4 and 5) presents a powerful tool for network investment planning. It enables the network plan to be examined prior to any major investment, and together with other indicators, assists the design and programming of installations compatible with minimum cost network design. For a minimal amount of data preparation, the technique presents a useful aid to the Planning Engineer.

We feel that the model should be used as a component of a three stage approach to network planning:

(i) Use theoretical curves (Ref. 4 and 5) to determine where the existing network needs study.

(ii) Apply the model to determine the least cost network, and experiment with your own ideas of best solutions.

(iii) Having determined the best network from (ii) carry out detailed PV studies of the alternatives, allowing for existing plant and other local detail that was not included in the model; e.g. site availability, junction routes, etc.

Also an important advantage of the technique is the facility to analyse the effects of cost structure or technological changes on network design. Hence the implications on long term exchange network configurations of future switching or transmission systems can easily be evaluated.

ACKNOWLEDGEMENTS

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REFERENCES

1. De Salamanca, E. M. and Zulneta, J.: 'Computer Aids to Network Planning of Telephone Exchanges in Urban Areas'; Electrical Communications, Vol. 46, No. 3, 1971.
2. Rapp, Y.; 'Planning of Exchange Locations and Boundaries in Multi-Exchange Networks'; Ericsson Technics, No. 2, 1962.
3. Alvarez, L. and Williams, P. H.: 'Influence of Different Factors on the Optimum Size of Local Exchanges'; I.T.T. Planning Symposium Report, Boksburg, 1972.
4. Smith, K. W.: 'Telephone Exchange Area Planning'; The Telecomm. Journal of Aust., Feb. 1969.
5. Priest, M. J.: 'Telephone Exchange Network Planning for Outer Urban Growth Regions'. (To be published).

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Wide-Band Crystal Filter Design

O. TENEN, A.R.M.I.T., M.I.E. Aust.

Conservation of frequency spectrum and/or reduction of transmission losses are always considered in the design of transmission systems. High Q and high stability resonators give smaller insertion loss in filters and higher selectivity in comparison with lower Q resonators. This may lead to the above objectives. Quartz crystals may be used for the fabrication of such high Q, high stability resonators. However their use has been restricted primarily to narrow-band and intermediate-band crystal filters.

This paper describes a design procedure for wide-band crystal filters consisting of LC resonators interposed with two-pole crystal lattices. Closed form design formulas are developed. The practical realisations are considered and applications for various types of available resonators are discussed. The fractional bandwidth limitation for quartz resonator filters is 1-10%, for ceramic resonator filters 5-25% and for surface acoustic wave resonator filters 0.5-10%.

INTRODUCTION

Components with high Q and low temperature coefficient are sought after in the telecommunication industry. The quartz crystal is such a component with quality factor exceeding 10,000 and reaching over 1 million together with a temperature coefficient below 0.5 ppm/°C. For this reason it is extensively used on channel filters in telephony equipment and IF filters in mobile radio receivers.

The design of crystal filters is not as straightforward as the design of inductor-capacitor (LC) filters. The crystal behaves somewhat like a series resonant circuit shunted by a capacitor. The equivalent inductor of the series resonant circuit is fairly well specified once the cut of the crystal and the resonant frequency are known. The shunting capacitor is a static capacitance and has a very definite lower limit. These restrictions on the range of obtainable parameters means that direct synthesis (insertion-loss design) will not always produce a design which can be built. Until recently, the design of crystal filters was on the basis of image-parameter method, primarily because of its flexibility. This method of design permits a filter to be designed as a cascade of simpler networks, each of which can be designed with the crystal peculiarities in mind.

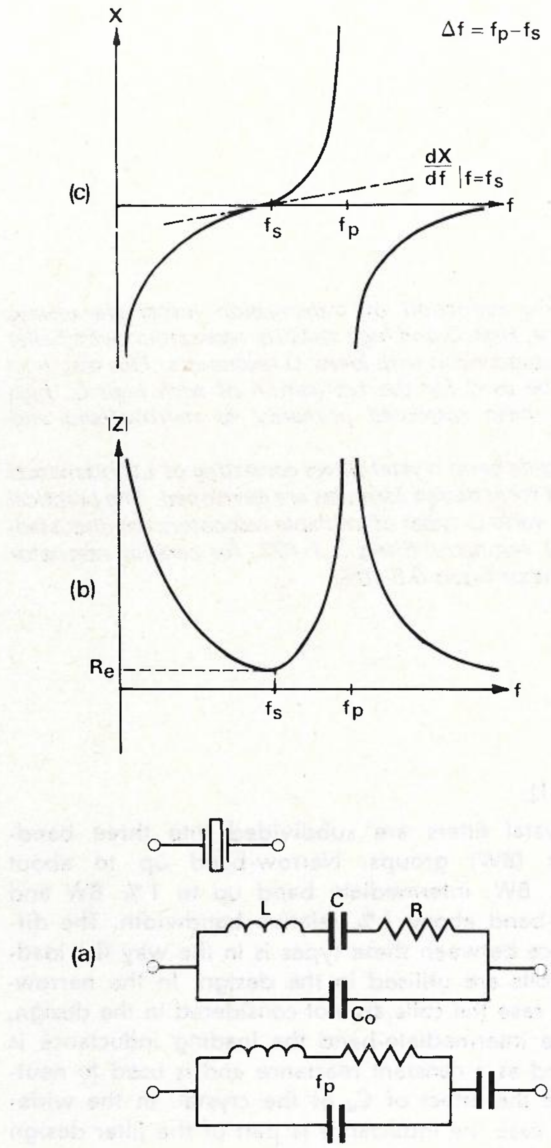
The crystal parameters used in design of filters are L_m, f_s, r and Q. L_m is the motional inductance, f_s is the series resonant frequency, r is the capacitance ratio C_o/C_1 and Q is the quality factor at f_s (Fig. 1).

Crystal filters are subdivided into three bandwidth (BW) groups: Narrow-band up to about 0.1% BW, intermediate band up to 1% BW and wide-band above 1% relative bandwidth. The difference between these types is in the way the loading coils are utilised in the design. In the narrow-band case the coils are not considered in the design. In the intermediate-band the loading inductance is treated as a constant reactance and is used to neutralise the effect of C_o of the crystal. In the wide-band case the inductance is part of the filter design and adds to the filter response.

In this paper a method for the design of wide-band polynomial type filters is presented. The filter consists of a cascade of LC resonators interposed with 2-pole crystal resonator lattices. The transformations used to develop the filter are first introduced, and are then followed by a step by step design procedure. The limitations and practical considerations are discussed.

TRANSFORMATIONS

In this section the transformations used in the design method will be outlined and illustrated on a filter derivable from a 7-pole low-pass prototype. The transformations required to convert a prototype into a crystal filter are low-pass to band-pass transformation, impedance inversion, Bartlett's bisection theorem and de-normalisation. Those familiar with the transformations may skip this section.



$$f_s = \frac{1}{2\pi\sqrt{LC}}$$

$$L_m = L = \frac{1}{2} \cdot \frac{dX}{df}\Big|_{f=f_s}$$

$$r = \frac{C_o}{C} = \frac{f_s}{2\Delta f}$$

$$R \simeq R_e = |Z|_{f=f_s}$$

$$Q = \sqrt{\frac{L}{C}} \Big/ R = \frac{\omega_s L}{R}$$

Fig. 1 — The Crystal Equivalent Circuit and its Parameters (a), Impedance Diagram (b), and Reactance Diagram (c).

LP - BP Transformation

The LP-BP (low-pass to band-pass) transformation is the standard transformation — (Ref. 1)

$$s_n = a(s/\omega_o + \omega_o/s) \qquad \ldots\ldots (1)$$

where s_n — normalised low-pass complex frequency variable

$a = \omega_o/\Delta\omega$ — constant of transformation equal to inverse relative BW

$s = j\omega$ — radian frequency variable.

In terms of network elements each low-pass inductor is scaled in value and resonated by a series capacitor at the centre frequency, and each low-pass capacitor is scaled in value and resonated by a shunt inductor at the centre frequency. This is shown in Fig. 2b.

Impedance Inverters

The impedance inverter (Ref. 2) acts like a quarter-wave transmission line, which when terminated in Z_i at one end gives an impedance inversely proportional to Z_i at the other end as follows:

$$Z_{in} = X^2/Z_i \qquad \ldots\ldots (2)$$

where X is the inversion constant (characteristic impedance of the quarter-wave line). The same effect of impedance inversion can be obtained by symmetrical T and π constant reactance networks (Ref. 3). If inductors and capacitors are used to replace the constant reactances in the inverter, then the inverter is useable to about 25% bandwidth. Although negative values have to be used for these networks they are absorbed by positive elements that flank the inverters. Fig. 2 shows an inductive T impedance inverter. The inverter is used to transform the network on one side of the inverter to its dual (Ref. 2). That is, shunt arms become series arms and L's are replaced with C's and R's with G's and vice versa.

Bartlett's Bisection Theorem

The next transformation applied in the design procedure makes use of Bartlett's bisection theorem (Ref. 4). This is used to convert a symmetrical ladder section into a lattice section containing resonators in its series and lattice arms. This is shown in Fig. 3b. By dividing the symmetrical network at the centre of symmetry, the lattice section arms are given by the short-circuit and open-circuit input impedance of the half sections. A further consequence of the theory is that equal series impedances on either side of a lattice section or shunt admittance on either side can be incorporated in both arms of the lattice as a series impedance or shunt admittance respectively. This is demonstrated in Fig. 3c, where equal amounts of shunt capacitance on either side of the lattice have been put across the series resonances to form equivalent circuit crystals.

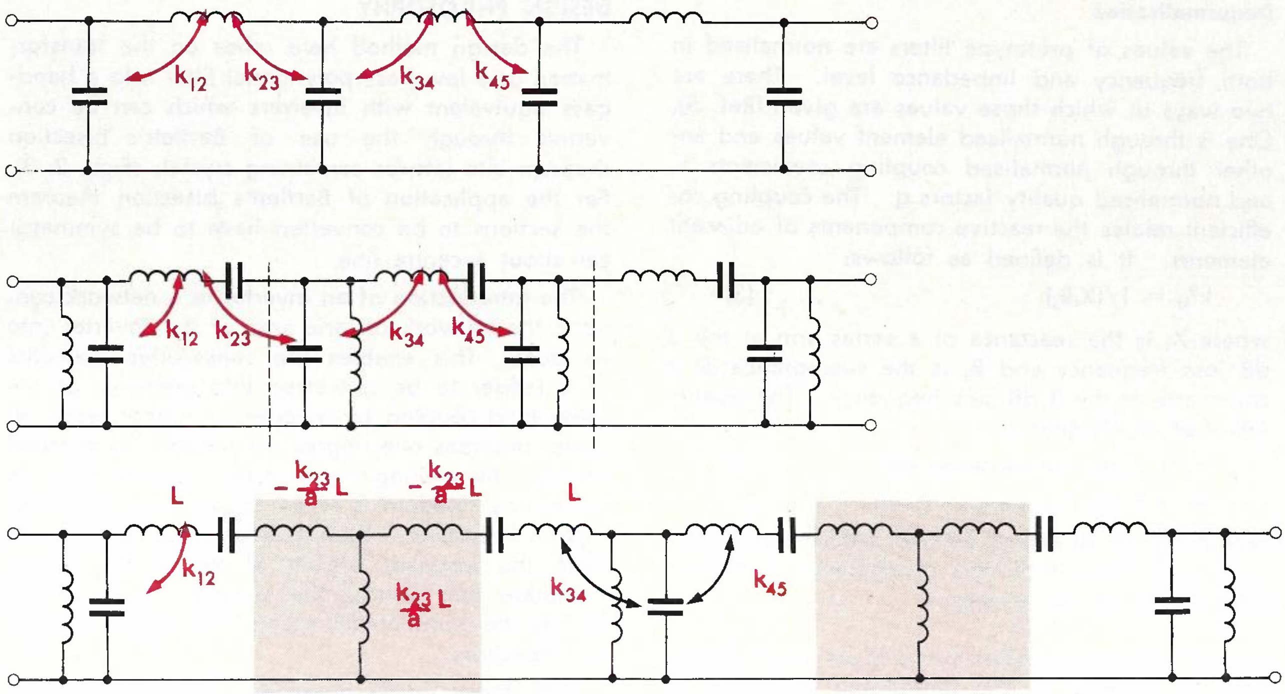


Fig. 2 — 7-Pole Low-pass Prototype (top), Bandpass Transformed Filter (middle), with Impedance Inverters Inserted at Dotted Lines and Shown in Colour (bottom).

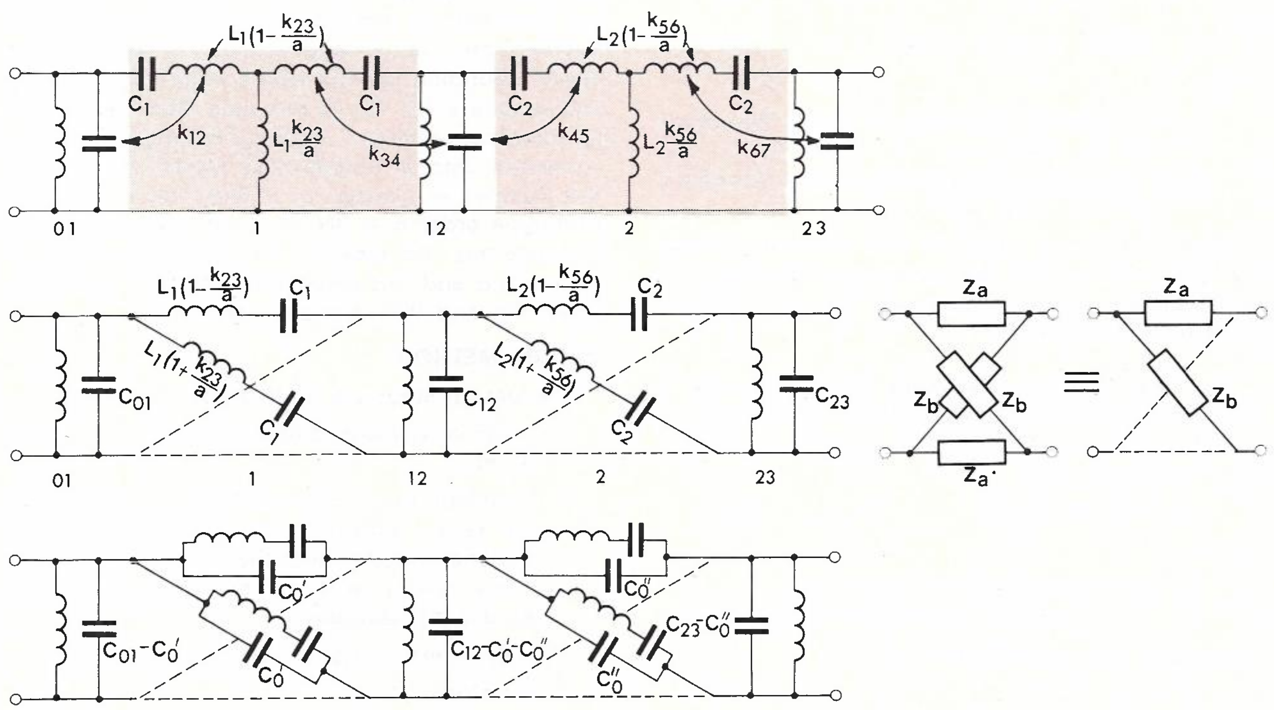


Fig. 3 — Conversion of Mesh Coupled Bandpass Filter (top), to a Crystal Filter (bottom), Using Bartlett's Bisection Theorem (middle and bottom). Coloured portions in top show symmetrical sections.

Denormalisation

The values of prototype filters are normalised in both frequency and impedance level. There are two ways in which those values are given (Ref. 5). One is through normalised element values and another through normalised coupling coefficients k, and normalised quality factors q. The coupling coefficient relates the reactive components of adjacent elements. It is defined as follows:

$$k^2_{ij} = 1/(X_i B_j) \quad \ldots\ldots (3)$$

where X_i is the reactance of a series arm at the 3 dB loss frequency and B_j is the susceptance of a shunt arm at the 3 dB loss frequency. The quality factor of an element is

$$q_i = X_i/R_i \text{ for the series arm} \quad \ldots\ldots (4)$$

$$q_j = B_j/G_j \text{ for the shunt arm} \quad \ldots\ldots (5)$$

where X_i and B_j are as defined before and R_i and G_j are the resistance and conductance associated with the respective elements.

In BP filters parameters K and Q are specified and they are related to the normalised coefficient of coupling and the quality factor as follows:

$$K = k/a \quad \ldots\ldots (6)$$

$$Q = qa \quad \ldots\ldots (7)$$

Using the transformation (1) on reactances in (3), (4) and (5) and substituting (6) and (7) gives

$$K^2_{ij} = 1/(X_i B_j) \quad \ldots\ldots (8)$$

and

$$Q_i = X_i/R_i \text{ or } Q_j = B_j/G_j \quad \ldots\ldots (9)$$

where:

X_i — inductive reactance at centre frequency of the series arm

B_j — capacitive susceptance at centre frequency of the shunt arm.

Note that k_{ij}, q_i and q_j are invariant under transformation (1) for the same type elements, i.e. coupling and quality factors are the same for the corresponding elements.

For direct coupled resonators the relationship is similar but because of the inverter, one element is inverted and multiplied by an inversion constant. For mesh resonators

$$K^2_{ij} = 1/(X_i X_j/X^2) \quad \ldots\ldots (10)$$

where:

X_i, X_j —series inductive reactance

X —impedance inversion constant.

Therefore, the coupling element

$$X = K_{ij} \sqrt{X_i X_j} \quad \ldots\ldots (11)$$

With inductive T coupling and using (6) above this becomes

$$L_{ij} = (k_{ij}/a) \sqrt{L_i L_j} \quad \ldots\ldots (12)$$

DESIGN PHILOSOPHY

The design method here relies on the transformation of a low-pass polynomial filter into a bandpass equivalent with inverters which can be converted through the use of Bartlett's bisection theorem into lattices containing crystals (Figs. 2. 3). For the application of Bartlett's bisection theorem the sections to be converted have to be symmetrical about a centre line.

The introduction of an inverter in a network converts the network on one side of the inverter into its dual. This enables the consecutive elements of a ladder to be converted into elements of the same kind coupled by inverters. Further, each inverter provides one degree of freedom for element values. By making the inverter coupled elements equal, the freedom is taken up and a symmetrical section is formed. Such a symmetrical section can form the resonant branch of the crystal To incorporate into lattices the capacitance C_o of the crystal the symmetrical section has to be flanked by capacitors.

With those points in mind, it becomes possible to transform low-pass prototypes into bandpass crystal structures. For the symmetrical sections to be flanked by capacitors means that they are part of resonators in the BP structure. As the symmetrical section contains two resonators, the smallest prototype filter is a 4-pole (see Fig. 3). The next prototype possible is a 7-pole as two resonators are reserved for the next symmetical section and another resonator is required for the flanking capacitor. Building up this way a more complex filter will require a 10, 13, 16 etc. pole filter with 3, 4, 5 symmetrical sections. Each symmetrical section is converted into a double-pole crystal lattice. Let the number of lattices in a filter be N, then the prototype order $n = 3N + 1$. It is also clear that the inverters are inserted in the BP structure between 2nd and 3rd resonators, 5th and 6th resonators, 8th and 9th resonators etc.

DESIGN METHOD

The design steps are as follows:—

- Select a suitable prototype with $n = 4, 7, 10$. etc.
- Transform the LP into a BP (Fig. 2b) setting the first series inductance equal to the available motional inductance of the crystal. This sets the source resistance R_S for the filter. By utilising (8) and (9) relations,

  $1/R_S = \omega_o C_1/(q_1 a) = 1/(\omega_o L q_1 a k^2_{12}/a^2)$

  Therefore.

  $$R_S = q_1 k^2_{12} L \Delta\omega \quad \ldots\ldots (14)$$

- Insert impedance inverters in the BP filter between 2nd and 3rd, and 5th and 6th resonators, etc. (Fig. 2c). Because a symmetrical section is to be formed the element values can be calculated consecutively using equation (8) for consecutive ladder elements and equation (12) for mesh coupled elements. Other elements can be calculated by noting that they resonate at ω_o with their branch elements (Fig. 3a).

- Apply the Bartlett bisection theorem to form lattices (Fig. 3b). The series arm is the short-circuit impedance of the symmetrical half-section and the lattice arm is the open-circuit impedance of the symmetrical half-section. Note also, that $L_1 C_1$ and $L_2 C_2$ resonate at ω_o. Therefore, the resonant frequency of the series arm is

$f_{1+} = f_o/\sqrt{(1 - k_{23}/a)}$ . . . . . (15)

and the resonant frequency of the lattice arm is

$f_{1-} = f_o/(\sqrt{1} + k_{23}/a)$ . . . . . (16)

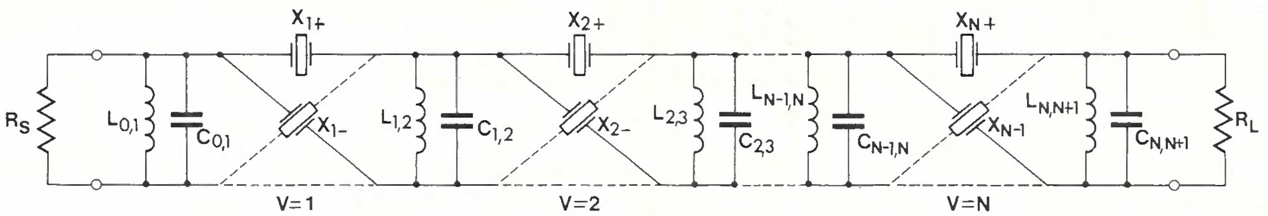
Note, that they correspond to the series resonant frequency of the equivalent circuit crystals.

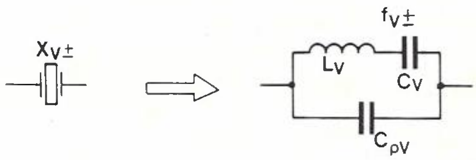
- Incorporate crystal capacitance C_o into lattices (Fig. 3c). This reduces the capacitances flanking the lattices by an amount of capacitance required by the adjoining lattice crystals.
- The load resistance R_L is calculated from the knowledge of last capacitance (Fig. 3b) and relation (9) and (7).

$R_L = q_n/(\Delta\omega C_n)$ . . . . . (17)

The Appendix illustrates how the design philosophy is implemented through the application of the procedure described above, using the transformations outlined previously. With the introduction of some auxiliary parameters the procedure leads to general closed form formulas for the design of this type of filter. The formulas for the elements of the crystal filter are given in Table 1.

TABLE 1 — FORMULA FOR ELEMENTS OF WIDE-B AND CRYSTAL FILTERS





$r = \frac{C_{pV}}{C_V}$ n = order of filter = 3N+1

Given k, q of lowpass prototype filter and L, r of crystals

$$\bar{R} = \Delta\omega L, \quad \bar{C} = \frac{1}{\omega_0^2 \bar{R}}, \quad P_v = \left(\frac{k_{3(v-1),3(v-1)+1}}{k_{3(v-1)+1,3(v-1)+2}}\right)^2 \prod_{i=1}^{v-1} P_i \text{ for } \{v \mid 2 \leqslant v \leqslant N\}, \quad P_1 = 1, \quad a = \frac{\omega_0}{\Delta\omega}$$

$$R_s = k_{1,2}^2 q_1 \bar{R}, \quad R_L = k_{n-1,n} q_n P_n \bar{R}$$

$$L_{0,1} = \left(\frac{k_{1,2}}{a}\right)^2 L, \quad L_{N,N-1} = \left(\frac{k_{n-1,n}}{a}\right)^2 P_N L, \quad L_{V,V+1} = \left(\frac{k_{3v,3v+1}}{a}\right)^2 P_v L$$

$$C_{0,1} = \frac{a}{k_{1,2}^2}\left(1 - \frac{r k_{1,2}^2}{a^2}\right)\bar{C}, \quad C_{v,v+1} = \frac{a}{k_{3v,3v+1}^2}\left[1 - \frac{r k_{3v,3v+1}^2}{a^2}\left(1 + \frac{P_v}{P_{v+1}}\right)\right]\frac{\bar{C}}{P_v}, \quad C_{N,N-1} = \frac{a}{k_{n-1,n}^2}\left(1 - \frac{r k_{n-1,n}^2}{a^2}\right)\frac{\bar{C}}{P_N}$$

$$X_v; \quad L_v = L P_v, \quad C_{pv} = \frac{r\bar{C}}{a P_v}, \quad f_{v+} = f_o/\sqrt{1 - \frac{k_{3v-1,3v}}{a}}, \quad f_{v-} = f_o/\sqrt{1 + \frac{k_{3v-1,3v}}{a}}$$

Realisability condition $C_{i,i+1} > 0$ for $\{i \mid 0 \leqslant i \leqslant N\}$

Maximum bandwidth $\left(\frac{1}{a}\right)$ max. $\simeq \frac{1}{\sqrt{2r}\,(k_{3v,3v+1})\text{ max.}}$

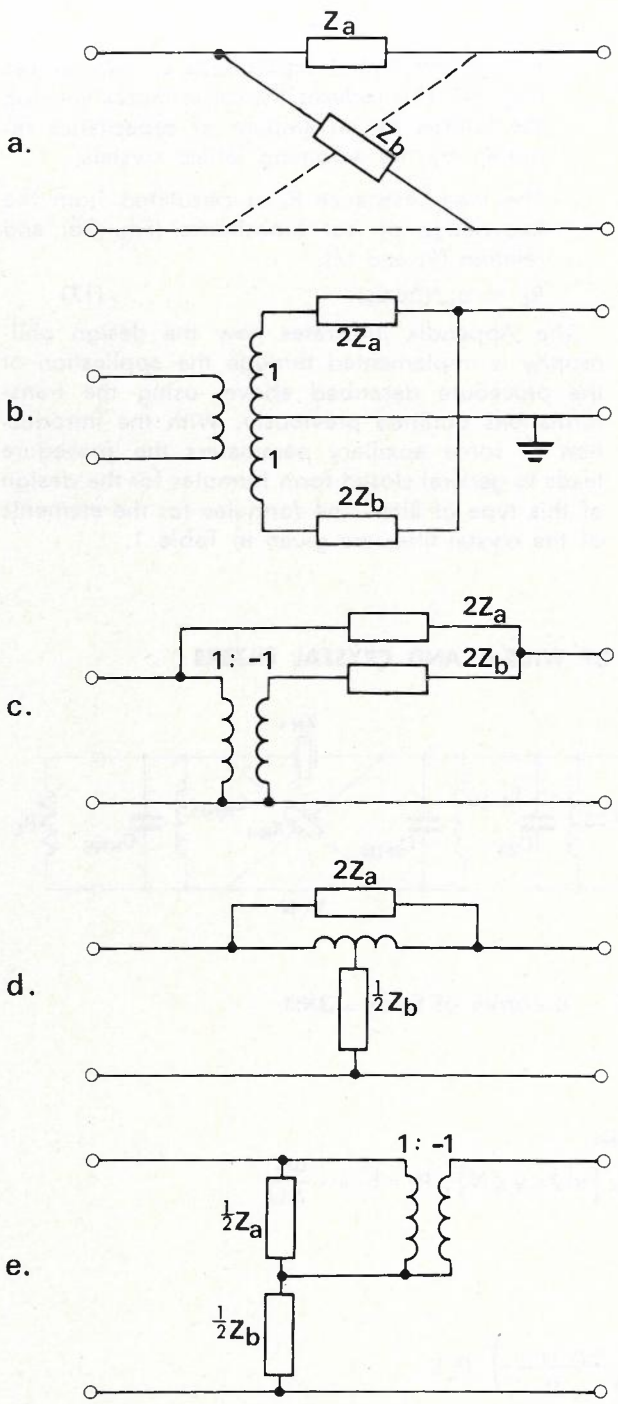


Fig. 4 — Practical Realisations of Full Lattice (a), Semilattices (b) and (c), Bridged T (d), and Cauer Equivalent (e).

PRACTICAL CONSIDERATIONS

The maximum bandwidth that can be obtained depends on the positiveness of the capacitances flanking the lattices. These were obtained by splitting the capacitances of the flanking resonator in such a way so that one of the capacitances formed the static capacitance of a crystal in the lattice. The equations for the capacitances flanking a lattice are (A14), (A15), (A16) and in Table I $C_{o'1}$ and $C_{v'v+1}$ and $C_{N'N+1}$. For the capitances to be positive the factor containing the difference of terms has to be positive. This condition determines the realisable bandwidth. The maximum realisable bandwidth is found by setting the factor to zero and finding the minimum value of fractional bandwidth from all such factors. The equation for $C_{v'v+1}$ contains a factor $(1 + P_v/P_{v+1})$, which reflects the fact that two capacitances are extracted from the flanking capacitance. This equation will usually give a smaller bandwidth. From (A15) the condition for realisability gives a fractional bandwidth

$$1/a \leqslant 1/[k_{3v'3v+1} \sqrt{1+P_v/P_{v-1}}\, r] \quad . . (18)$$

The largest $k_{3v,3v+1}$ will give the smallest bandwidth.

Therefore, for the largest realisable bandwidth

$$(1/a)_{max} = 1/[(k_{3v,3v+1})_{max} \sqrt{(1+P_v/P_{v+1})}\, r] \quad (19)$$

For example a 7-pole Butterworth filter will give $P_1/P_2 = 1.0$ $k_{34} = 0.5268$ and with $r = 125$
$(1/a)_{max} = 0.012 => 12\%$ bandwidth

There is also a lower limit on the bandwidth and this is associated with the losses of the coils which sets the limit to about 1-2% depending on the filter selectivity requirements.

The full lattice structure as required by the filter design is avoided in practice, because there is no earthing point and the lattice requires more components than its unbalanced equivalences. The unbalanced lattice equivalences are shown in Fig. 4. They contain two lattice impedances and a transformer, compared with four impedances in a full lattice. The most popular realisations of the lattice are semi-lattices of Fig. 4b and Fig. 4c. They provide an earthing point for the transformers as well as the network. The inductance of the semi-lattice transformer can be incorporated into the shunt inductance. The transformer can be used to adjust the termination to the required level. The stray capacitance and self-capacitance of the inductance can be incorporated into the shunt capacitance. The effect of stray and self-capacitance is to reduce the realisable bandwidth, which can be calculated by

$$(1/a)_{max} = 1/[(k_{3v'3v+1})_{max} \sqrt{1+P_v/P_{v+1}+S_v}\, r] \quad . . . . . (20)$$

where $S_v = C_s/C_{pv}$ ratio of stray to static crystal capacitance.

TABLE 2 — COMPARISON OF RESONATORS

Resonators	Frequency Range f/MHz	Quality Factor Q/1000	Capacitance Ratio r	Temperature Coe....cient TC ppm/°C	Elements in Ideal Circuit Representation
LC	0.001-0.5	0.1-1.0	—	20	LC
LC	0.1-100	0.05-0.2	—	50	LC
Helical resonator	30-300	0.3-3.0	—	20	LC
Strip line resonator	300-3000	0.3-5.0	—	10	LC
Quartz crystal	0.01-100	20-5000	125-30,000	0.2	LCC_0
Ceramic resonator	0.01-10	0.2-2	6-100	20	LCC_0
SAW resonator	30-2000	2-10	100-2000	2	LCC_0

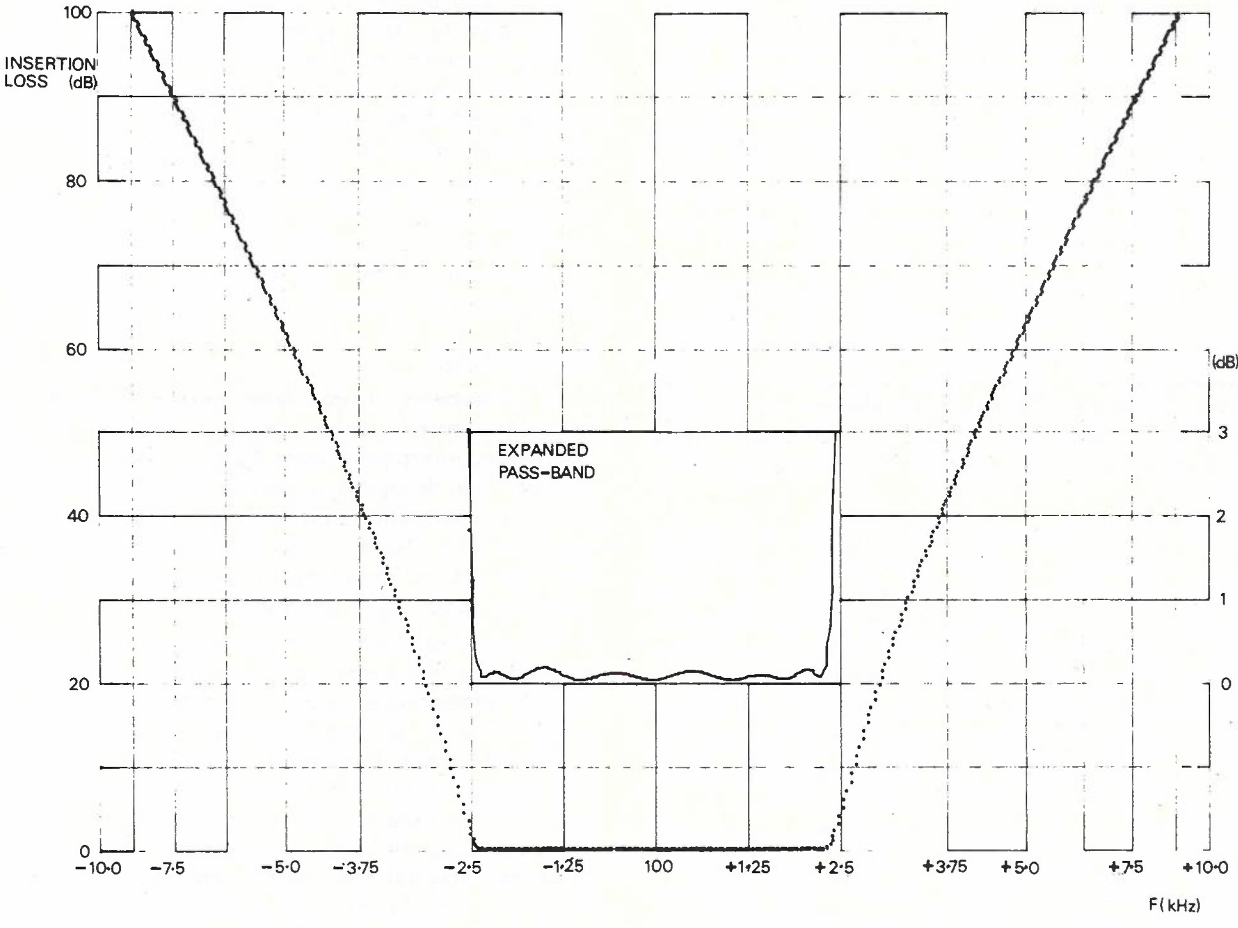


Fig. 5 — 7-Pole Crystal Filter Responses.

The shunt inductance is proportional to the crystal inductance and fractional bandwidth squared. For the available crystal L_m the shunt inductance is realisable with ferrite material over the range of 1%-10% BW.

Fig. 5 shows the response of a 7-pole crystal filter, which has been designed with the method.

APPLICATIONS OF THE METHOD

The design method developed in the preceding sections was directed towards filters with quartz crystal resonators and LC resonators. The LC resonator has a 2-element structure, whereas the crystal resonator has a 3-element structure. There are other resonators available that have 2 or 3-element equivalent structures and can be used at different frequency ranges. The parameters of some of those resonators are given in Table 2. They can be used in constructing filters with the design method described in this paper.

From the table it is seen that the crystal is an outstanding 3-element resonator with the highest Q and stability. However, there is no matching 2-element resonator in terms of Q and stability to go with it. The use of LC and crystal resonators means that the smallest bandwidth attainable is only 1-2%. However, in comparison with an all LC filter, the combination of crystal and LC resonators gives lower insertion loss, higher selectivity and more stable response with environmental and time changes. For the design described herein these advantages improve with the complexity of the filter, because the higher order filters require relatively more crystals than LC resonators.

A recent 3-element resonator brought on the market is the ceramic resonator. The frequency range, Q and temperature coefficient are similar to the LC resonator. The ceramic resonator can be used up to 25% BW. As it is much cheaper and smaller than an LC resonator, the ceramic resonator is likely to capture a large portion of the LC resonator market.

The other 3-element resonator that is likely to have an impact on filter technology is the SAW (surface acoustic wave) resonator (Ref. 6). It can operate in the frequency range of 30-2000 MHz and it has better Q and stability than other resonators in that range. The SAW resonator has an adjustable 'r' ratio, to suit the design, and negligible spurious (inharmonic) response. Together with a strip line resonator the SAW resonator should achieve bandwidths between 0.5%-10%.

With the above points in mind the main application of the design is restricted to roughly 1% to 25% bandwidth and/or where high selectivity requires high Q and stability from the components.

In telephony the major application of crystal filters is in basic group filters for FDM systems using the direct modulation process, which requires filters of 3.8% to 6.5% BW. With ceramic resonators available it is possible to use them in sub-group, group and super-group filter systems with single, double and triple modulation respectively, which have bandwidths of 9% to 22%. This would enable new flexibility in channel modem arrangements. One has to keep in mind that current engineering practice has been developed around other components e.g. LC, mechanical resonators, monolithic filters.

Other possible applications are in the broadcasting field with the use of CTV and CATV transmission systems where it may be required to separate closely packed channels. For example a 7 MHz TV channel at 45 MHz (channel O) occupies 15.5% BW and at 202 MHz (channel 9) occupies 3.5% BW. Similar considerations would apply for FM broadcasting band of 20 MHz which occupies the band between 88 MHz and 108 MHz which is 20% BW. A wide-band SAW resonator filter would fit these applications.

Another application of a SAW resonator at the high end of its frequency range is a closely packed high capacity radio system. With a 0.5% BW it would increase the flexibility of channel arrangement. The advantages of SAW resonator filters against SAW filters are smaller insertion loss, readily designable response, ease of manufacture.

Generally speaking, the implementation of filters of bandwidth of 1% to 10% in high capacity systems has the potential of more flexible channel arrangements with the possibility of spectrum economy and more economical modulation plans.

CONCLUSION

A wide-band crystal filter design method has been presented which uses a cascade of LC-resonators interposed with 2-pole crystal resonator lattices. The design is a polynominal filter with no peaks of attenuation and theorder of the prototype must be 4, 7, 10, etc. The theoretical limits of the filter are that of impedance inverter approximations, which is about 25% bandwidth.

The practical bandwidth limitations of the filter depends on the resonators used for the filter. The crystals capacitance ratio r limits the upper bandwidth. The Q of the inductors in LC-resonators limits the lower bandwidth. For ferrite inductors and quartz crystals the filter is restricted to 1-10% bandwidth. Ceramic crystal resonators can realise bandwidth up to 25%. and surface acoustic wave resonators (crystal equivalent) with strip-line resonators (LC equivalent) can realise filters between 0.5%-10% bandwidth. The crystal Q is much higher than LC-resonator Q and as a result, the Q of the LC-resonator dominates the loss in the pass-band. Because of this it is worthwhile obtaining high Q coils. An advantage of this method is that higher order filters require relatively more crystals than LC-resonators easing the coil Q requirements.

The impedance level of the filter is high because it is proportional to motional inductance of the crystal and bandwidth. As the crystal inductance is high the terminating impedance can be very high. However, because the filter has shunt inductances at its terminals, a transformer to the required impedance level can be constructed.

Other practical considerations include the effect of inharmonic and harmonic mode spurious responses of the crystals, which should be considered, and the realisation of peaks of attenuation, that can be created by judiciously unbalancing the lattices.

The possibility of using different combinations of crystal and LC-resonator equivalents extends this design method in frequency range and applications. The applications of the wide-band crystal filter are in FDM systems (quartz and ceramic crystal and LC-resonators), CTV, CATV transmission and high capacity VHF and UHF radio systems (SAW crystal and strip-line resonator).

REFERENCES

1. Kuo, F. F.: 'Network Analysis and Synthesis'; Wiley, 1966, p. 407.
2. Zverev, A. I.: 'Handbook of Filter Synthesis'; Wiley, 1967, p. 559.
3. Tenen, O.: 'Wide-band crystal filters'; Telecom Australia R.L. Report 7075, Appendix II.
4. Carlin, H. J.: 'Network Theory'; Prentice-Hall, 1964, p. 161.
5. Ref. 2, Chapter 6.
6. Staples, E. J.: 'UHF Surface Acoustic Wave Crystal Resonators'; Proc. 28th Annual Symposium on Freq. Control 1974.

APPENDIX—DESIGN FORMULAE DERIVATION

Let us introduce three auxiliary parameters.

$$\bar{R} = \triangle\omega L \qquad (A1)$$

where L is the inductance of the first symmetrical section in Fig. 2c and $\triangle\omega$ is the 3 dB radian bandwidth

$$\bar{C} = 1/(\omega_0 R) \qquad (A2)$$

where ω_0 is the centre frequency
and

$$a = \omega_0/\triangle\omega \qquad (A3)$$

Note that (A1) to (A3) is

$$\omega_0{}^2 = 1/(LC/a) \qquad (A4)$$

Therefore, L resonates with C/a at the centre frequency.
We will relate all inductances in terms of L, all capacitances in terms of C and all resistors in terms of R. This gives an immediate feel for element values.

The inductance of other symmetrical sections in relation to L can be derived from repeated application of equation (8). The second symmetrical section inductance is removed twice from the first section inductance. Therefore, in terms of K values

$$K^2{}_{j,j+1} = 1/(X_j B_{j+1})$$

and

$$K^2{}_{j+1,j+2} = 1/(B_{j+1} X_{j+2})$$

where j is the resonator number.
Dividing one by the other and substituting (6) gives

$$L_{j+2}/L_j = k^2{}_{j,j+1}/k^2{}_{j+1,j+2} \qquad (A5)$$

All inductances of consecutive symmetrical sections are similarly related. As the inductances of symmetrical section are the same, relating other section inductances to the first symmetrical section inductance gives

$$L_v = LP_v \qquad (A6)$$

where

$$P_v = \prod_{i=2}^{v} (k^2{}_{3(i-1),3(i-1)+1}/k^2{}_{3(i-1)+1,3(i-1)+2}) \qquad (A7)$$

and

$$P_1 = 1{\cdot}0 \qquad (A8)$$

where v, i are lattice numbers.
The series capacitance of the symmetrical section resonates at ω_0 with inductance. Therefore from (A4) and (A6)

$$C_v = (C/a)/P_v \qquad (A9)$$

The coupling element in the inverter is from (12).

$$L_{cv} = L_v k_{3v-1,3v}/a \qquad (A10)$$

From Fig. 4b after the Bartlett bisection has been applied the resonant frequencies of the crystals can be worked out from C_v and L_v modified by $+$ or $-L_{cv}$. Therefore, using (A4), (A6), (A9) and (A10) one gets

$$f_{v-} = fo/\sqrt{1+k_{3v-1,3v}/a} \approx fo(1-k_{3v-1,3v}/2a) \qquad (A11)$$

$$f_{v+} = fo/\sqrt{1-k_{3v-1,3v}/a} \approx fo(1+k_{3v-1,3v}/2a) \qquad (A12)$$

The parallel capacitance of the crystal is $C_p = rC_m$ where C_m is the motional crystal capacitance, which is the series capacitance in the lattice, so from (A9):

$$C_{pv} = rC_v = r(C/a)/P_v \qquad (A13)$$

The shunt capacitance preceding the first lattice Fig. 3b is from (6), (8), (A4) with $X_i = \omega L$ and $B_j = \omega C_{(01)T}$

$$C_{(01)T} = \bar{C}a/k^2{}_{12}$$

However, the crystals parallel capacitance has been extracted from $C_{(01)T}$ (see Fig. 4c). Therefore,

$$C_{01} = C_{(01)T} - C_{p1} = C(1-rk^2{}_{12}/a^2)a/k^2{}_{12} \qquad (A14)$$

The capacitance between v'th and (v+1)'th lattices (Fig. 3b) is

$$C_{(v,v+1)T} = aC/(k^2{}_{3v,3v+1}P_v)$$

This time two capacitors have to be subtracted, one for each lattice crystal C_p on either side of $C_{(v,v+1)T}$. Therefore,

$$C_{v,v+1} = C_{(v,v+1)T} - C_{pv} - C_{p(v+1)} =$$
$$[1-rk^2{}_{3v,3v+1}/a^2(1+P_v/P_{v+1})]a\bar{C}/(k^2{}_{3v,3v+1}P_v) \qquad (A15)$$

Finally, the last shunt capacitance

$$C_{N,N+1} = C_{(N,N+1)T} - C_{pN}$$

$$C_{N,N+1} = aC[1-r(k_{3N,3N+1}/a)^2]/(k_{3N,3N+1}P_N) \qquad (A16)$$

where N = no. of lattices.

The shunt inductances can be obtained from the equations of total shunt capacitances noting that they resonate at ω_0.

Therefore,

$$L_{v,v+1} = LP_v(k_{3v,3v+1}/a)^2 \qquad (A17)$$

Finally the source and load can be worked out from the equation for Q. As it is a shunt resonance, equations (7) and (9) are used.

$$G_{01} = C_{01T}\triangle\omega/q$$

Therefore, the source resistance using equation for C_{01T} and (A2) is

$$R_S = 1/G_{01} = k^2_{12}q_1\overline{R} \qquad (A18)$$

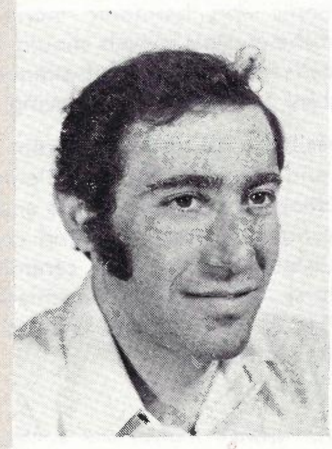
Similarly for the load resistance

$$R_L = 1/G_{N,N+1} = k^2_{3N,3N+1}q_{3N+1}\overline{R}P_N \qquad (A19)$$

The above equations were derived for a mesh coupled crystal filter. Another structure a node coupled crystal filter has been derived and analysed in terms of practicality in Ref. 3.

OREK TENEN graduated A.R.M.I.T. in Radio Engineering in 1967. He worked at that time with the State Electricity Commission of Victoria. In 1968 he joined Pye P/L and worked on the design of crystal filters, matching of crystals and energy trapping in crystals. In 1972 he joined the then APO Research Laboratories. He was involved in design of filters and equalizers for transmission systems, and development of wide-band crystal filter design. He took part in the Radio Australia – Carnarvon project. He has contributed to the final development of a program to optimise equalizers in PCM regenerative repeaters with respect to noise, phase jitter and intersymbol interference.

He is an Engineer Class 2 and is currently working on extending a program to optimise relevant parameters in subscriber, TV, facsimile and carrier systems with respect to their respective objectives such as K-factor probability of error, crosstalk and noise.



Trans-hybrid Loss: An Approximation and Its Error

R. G. KITCHENN, B.Sc. (Eng.), C. Eng, M.I.E.E.

The loss between the 4-wire 'receive' and 'send' ports of a terminating set is usually assumed to be 7dB plus the balance return loss between the balance and 2-wire line impedances. The article shows that this is an approximation, the actual loss being this sum plus two reflection losses involving the (common) impedance closing the 4-wire ports, minus the reflection loss between the balance and 2-wire line impedances. However, this 3-term 'error' is shown to have a negligibly small amplitude in most practical applications in the telephone network. It is just as likely to be negative as positive in sign.

The Loss Across a Hybrid*

The loss across a hybrid's
Of a very funny sort.
The theory says it's three dB
From two to four-wire port;

It's also three from four to two,
So I hope you will agree
That from four to two, then back to four
The loss is two times three.

So six dB's the smallest loss
Between the four-wire ports,
But another factor intervenes
To cause some second thoughts.

You see, transformers are not pure
(At least, this side of heaven)
So the minimum's always *more* than six:
In fact, it's close to seven.

It's fortunate for stability
There's another loss in store
Which adds to the three plus three plus one
And makes transhybrid more.

Balance return loss is the name,
So, according to reports,
You add it to the seven to give
The loss between the four-wire ports.

If balance Z and two-wire Z
Are equal, one to t'other
Then balance return loss's infinite
And so's transhybrid, brother.

'Cos when you add infinity
To seven dB, you see,
Infinity is still the sum,
Mathematicians will agree.

But in real life this case is rare;
We can ignore it, I am sure:
'Tween five and thirty's more the mark;
Transhybrid loss is seven more.

So that's the way we work it out;
But alas, it isn't good enough
For cases where precise results
Are needed, not too rough.

Three other factors enter now
If you really want precision:
Two you add, and one subtract,
Before you end your mission.

Reflection losses, these three are,
And the first two we define
Are 'tween balance Z and four-wire Z
And 'tween (four-wire Z), (Z line)

You've added those? That's very good.
Now take the other pair:
Reflection loss 'tween balance and line;
Subtract it, then you're there!

These three reflection losses
Are usually rather small
And for many, many cases
Can be neglected, after all

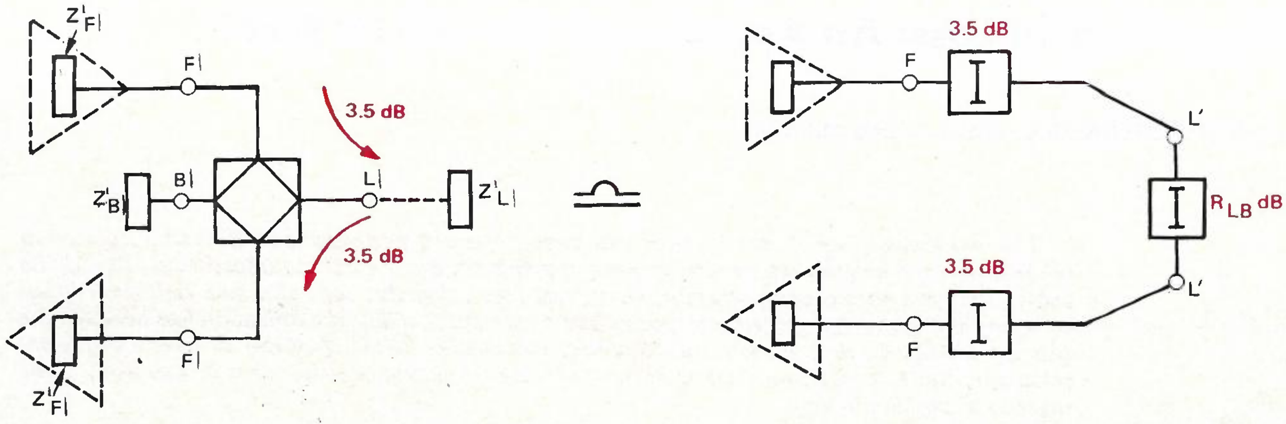
They'll mostly total rather less
Than ½ dB or so
But three times this is sometimes found
So you cannot *always* throw

Those little error terms away
When working on your slate
To calculate trans-hybrid loss,
So consider well their fate!

* A 4-wire terminating set is usually a 2-transformer device; it is properly called a hybrid (transformer) only if it comprises a single transformer. To refer to the 'trans-hybrid' loss of a 2-transformer terminating set is therefore contradictory, and is loose terminology. However, the term is well established and (hopefully) unambiguous; and the more accurate term 'loss between the 4-wire ports' is perhaps too cumbersome to expect its popular adoption. Appendix 1 discusses the terminology in more detail and shows the one and two transformer devices schematically.

INTRODUCTION

When estimating the stability of a telephone connection involving the use of 2-wire and 4-wire circuits the transmission planner usually makes an assumption about the loss between the 4-wire ports of each terminating set in the connection. This loss is popularly but improperly* described as the trans-hybrid loss.



Transhybrid loss = loss between F and F = L_{FF}|

$L'_{FF} = L'_{FL} + R'_{LB} + L'_{LF}$|

$= 7 + R'_{LB}$| dB|

R'_{LB}| = balance return loss; i.e. return loss of line impedance Z'_L against balance impedance Z_B

$$= 20 \log \left| \frac{Z'_L + Z'_B}{Z'_L - Z'_B} \right| \text{dB}$$

Note that the 4-wire terminating impedance Z'_F does not enter this approximation.

Fig. 1 — The Usual Assumption about Trans-hybrid Loss.

The assumption is that the trans-hybrid loss (Fig. 1) comprises three components:

- The loss from a 4-wire port to the 2-wire port, plus
- The balance return loss between the balance and 2-wire line impedances Z_B and Z_L plus
- The loss from the 2-wire port to the other 4-wire port.

Theoretically, the first and third of these losses is each equal to 3dB; in practice, about ½dB of additional loss is incurred in each due to iron and copper losses in the transformer(s), bringing their sum to about 7dB.

The assumed trans-hybrid loss is then

$$L_{FF} = 7 + R_{LB} \text{ dB}, \qquad (1)$$

where $R_{LB} = 20 \log \left| \frac{Z_L + Z_B}{Z_L - Z_B} \right|$ dB

When the balance and line impedances are equal, R_{LB} (and therefore L_{FF}) becomes infinite. This is the desired condition in a telephone circuit.

In practice the balance and line impedances are not equal at all frequencies over the voice-frequency band, and R_{LB} has a finite value, which it is the objective of the transmission engineer to maximise. Its minimum value is likely to occur towards the extremities of the nominal bandwidth of the telephone circuit, and is critical in studies of the stability of 2w-4w-2w connections in the telephone network.

It will be noted that the assumption (1) does not involve the impedances Z_F, assumed equal, which terminate each 4-wire port F (Fig. 1). Yet the relationship of Z_F to the impedances presented by the 4-wire ports of the terminating set must have some influence on L_{FF}, in view of the possibility of mismatch losses incurred at these ports.

The precise value for L_{FF} does in fact take account of Z_F, and it can be shown (e.g. Ref. 1) that

$$L_{FF} = 7 + R_{LB} + 20 \log \frac{(Z_L + Z_F)(Z_B + Z_F)}{2Z_F(Z_L + Z_B)} \text{ dB}. \qquad (2)$$

THE 'ERROR' TERM

This expression for L_{FF} is greater (or less) than (1) by the third term. Let us examine the nature of the third term in (2) and explore its physical meaning and magnitude.

Firstly, we note that it becomes zero if
$Z_L = Z_F$ or
if $Z_B = Z_F$
In practical terms, this means that if the return loss of the 4w impedance Z_F against *either* Z_L *or* Z_B is high, the error term approaches zero.

Next, noting that the error term contains only Z_L, Z_F and Z_B, we now seek to manipulate it into discrete terms, each having a physical meaning. Call this term T; then multiplying numerator and denominator by $2\sqrt{(Z_L Z_B)}$ we have:

$$T = \frac{(Z_L + Z_F)(Z_B + Z_F)}{2Z_F(Z_L + Z_B)} \cdot \frac{2\sqrt{(Z_L Z_B)}}{2\sqrt{(Z_L Z_B)}}$$

$$T = \frac{Z_L + Z_F}{2\sqrt{(Z_L Z_F)}} \cdot \frac{Z_B + Z_F}{2\sqrt{(Z_B Z_F)}} \cdot \frac{2\sqrt{(Z_L Z_B)}}{Z_L + Z_B}$$

$$T = \frac{k_{LB}}{k_{LF} \cdot k_{BF}} \qquad (3)$$

where a term like $k_{12} = 2\sqrt{(Z_1 Z_2)}/(Z_1 + Z_2)$ is the *reflection factor* (see, e.g. Ref. 2) of impedance 1 against impedance 2, and k is generally a complex number.

REFLECTION LOSSES

Physically, a term such as $k_{12} = 2\sqrt{(Z_1 Z_2)}/(Z_1 + Z_2)$ describes the ratio of the 'mismatched' volt-amps in a load impedance Z_2 to the 'matched' volt-amps in a load impedance Z_1 when the generator has a source impedance Z_1 in each case. For a measure of power loss, we are concerned with the modulus of k_{12}, and recall that *reflection loss* $r_{12} = 20 \log|1/k_{12}|$dB.

We are more concerned with 20 log|T| than with T, however, and noting that $|x.y| = |x| \cdot |y|$, we translate (3) to:

$$20 \log T = 20 \log \frac{\left|\frac{1}{k_{LF}}\right| \cdot \left|\frac{1}{k_{BF}}\right|}{\left|\frac{1}{k_{LB}}\right|} = r_{LF} + r_{BF} - r_{LB}; \text{ whence}$$

$$L_{FF} = 7 + R_{LB} + r_{LF} + r_{BF} - r_{LB} \qquad (4)$$

We note that if $Z_L = Z_F$, r_{LF} becomes zero and r_{LB} becomes r_{BF}, the error term then becoming $0 + r_{BF} - r_{BF} = 0$.

Similarly, if $Z_B = Z_F$, r_{BF} becomes zero, r_{LB} becomes r_{LF}, and the error term becomes $r_{LF} + 0 - r_{LF} = 0$, thus confirming the earlier conclusion.

Now what are the likely magnitudes of the last three terms in (4)? Under what circumstances can they be ignored?

HOW LARGE IS THE ERROR?

There is no simple or unique answer to this question, since each of the error terms depends on the modulus of a term like $(Z_1+Z_2)/2\sqrt{(Z_1 Z_2)}$ which itself is a complex quantity, in turn dependent on the modulus *and* angle of each of the component impedances.

However, we can approach it in a way which will provide some appreciation of likely practical magnitudes.

Firstly, we can test a number of likely 'real' impedances presented to the four ports of the terminating set, then calculate and compare the magnitude of each term. This will at least give a 'feel' for the significance of the terms we wish to neglect, but it cannot yield a 'proved' conclusion of significance.

In addition, we can analyse the expressions for r_{LF} etc., for the possible and probable ranges of values.

SOME 'REAL' IMPEDANCES

From fairly precise models of loaded cable circuits it is possible to calculate the impedance Z_L presented to the line terminals of a terminating set for given line make-ups, distant- end terminating conditions and applied frequency. We halve this impedance to account for an assumed 2:1 impedance-ratio transformer between the line and the 600-ohm line terminals of the terminating set. (See table 1).

We may take for Z_B a common value of compromise balance impedance used in terminating sets in Australia: 600 ohm in series with 2μF. This gives a value of 600 - j265 ohm at 300Hz; at higher frequencies the reactive component is — j99 (800Hz), — j26.5 (3000Hz) and — j24 (3300 Hz).

The 4w ports of the terminating set will generally be terminated in equal impedances, determined in the case of carrier systems by the return loss specification of the modulator input and demodulator output ports: more than 20dB over the range 300 to 3400Hz, with respect to 600 ohm resistive.

Values of Z_F corresponding to the extreme values of this specification are 491 and 733 ohm resistive and 612 ± j121 ohm. Any of these four values may be used for Z_F; the only limitation is that (2) assumes that equal values of Z_F apply to both 4w ports whereas in practice they could be different, though still complying with the return loss specification. The nominal value of Z_F is of course, 600 ohm resistive. In a more thorough approach, values for

Z_F corresponding to those used for Z_L would also have been explored, representing the case where the 4-wire ports of the terminating set were connected to half-section-terminated loaded cable pairs. instead of to carrier modulator and demodulator.

We now apply various combinations of Z_L and Z_F to the appropriate value of Z_B to determine r_{LF}, r_{LB} and r_{BF}. In addition to test for any correlation of 20 log $|T|$ with R_{LB} we calculate the balance return loss.

TABLE 1: MODELS AND LINE IMPEDANCES

No.	Frequency (Hz)	Z_L (ohm)	Model	Treatment
1	300	1190—j550		Nil (1–12)
2	3000	1730—j145	Mid-section image impedance, 0.64 mm loaded	
3	3400	2430—j334		
4	3300	2782—j113	0.64 mm; 5 coils, 1000 ohm termination.	
5	300	1516—j596		
6	300	1579—j660		
7	800	945—j181	0.64 mm; 12 km, 7 coils, Pier-Cottesloe, W.A. 600 ohm term.:	
8	3000	1522+j99		
9	300	1066+j122		
10	1000	1538+j133	0.64 mm; 3.7km, 2 coils, Pier-Maylands, W.A. 600 ohms term.:	
11	3000	1293+j742		
12	3300	3723+j1323		
13	1000	960—j121		Note 1 (13–16)
14	2000	976—j41		
15	3000	1020+j0.5		
16	3300	861—j6		
17	1000	962+j19	0.64 mm; 5 coils, 1000 ohm termination	Note 2 (17–20)
18	2000	993+j159		
19	3000	1017+j8,4		
20	3300	872—j224		
21	1000	1023—j161		Nil (21–24)
22	2000	1158—j178		
23	3000	1426—j131		
24	3300	2782—j113		
25	1000	921—j139		Note 3 (25–28)
26	2000	950—j48	0.64 mm; 5 coils, 910//0.03 μ F	
27	3000	911+j155		
28	3300	1562+j116		

Notes:
1. 0.6m-section termination
2. As used by the A.T. & T. Co. U.S.A.
3. As used in South Australia.

TABLE 2: RESULTS OF CALCULATIONS WITH SAMPLE NETWORK IMPEDANCE

	r_{LF}	r_{BF}	r_{LB}	$20\log\|T\|$	R_{LB}	
Mean	0.17	−0.05	0.18	−0.05	16.93	dB
Standard deviation	0.42	0.11	0.4	0.24	6.92	dB
Smallest sample	−0.53	−0.41	−0.3	−0.75	4.97	dB
Largest sample	1.88	0.22	1.34	0.58	41.39	dB
No. of samples	64	64	64	64	28	dB

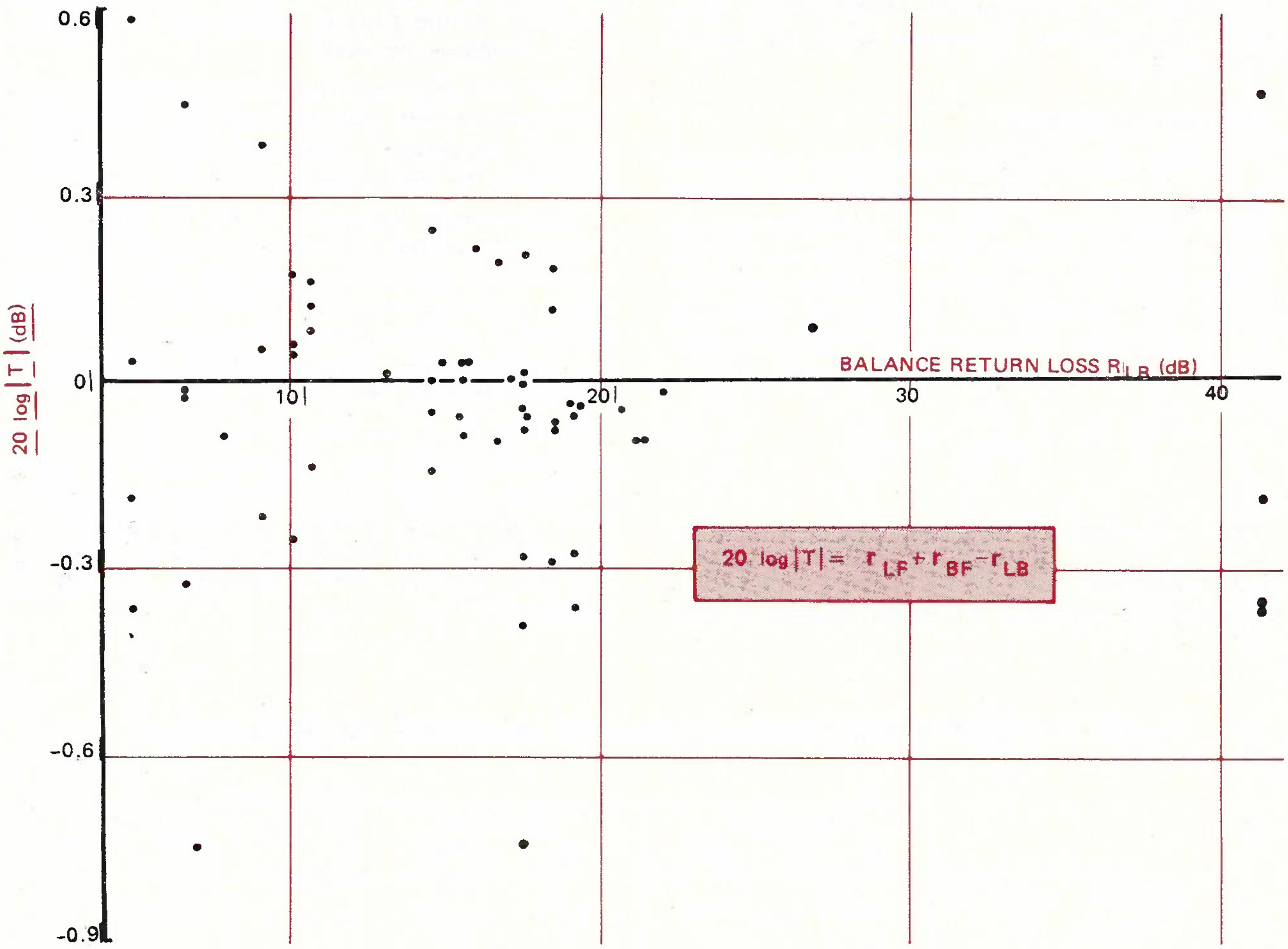


Fig. 2 — Error Term Log |T| as a Function of Balance Return Loss R_{LB}.

RESULTS

The calculations yield 64 values for each of r_{LF}, r_{BF}, r_{LB}, 20 log $|T|$, and R_{LB} which are too numerous to reproduce. The information is distilled in Table 2 and Fig. 2, however, which give an idea of the magnitudes likely to be encountered in actual network situations.

SAMPLE NETWORK IMPEDANCE

Table 2 and Fig. 2 represent only a small proportion of the combinations of Z_L, Z_B and Z_F which could have been tested. However, even this small sample gives some confidence that for the development of planning rules the error in taking the approximation (1) instead of the accurate expression (2) is negligible for most practical values of impedances found in the telephone network.

There may be some hint in Fig. 2 of an inverse relationship between R_{LB} and the error term: i.e., the smaller R_{LB}, the larger the probable error, but a much larger number of samples would be needed to confirm this.

ANOTHER APPROACH

Another approach is to analyse the expressions for r_{LF}, r_{BF}, r_{LB} and R_{LB} to explore their possible and probable ranges. We recall that terms such as r_{12} and R_{12} each involve the impedances Z_1 and Z_2, where Z_1 and Z_2 are complex numbers. It is convenient to examine r_{12} and R_{12} in terms of $y = Z_1/Z_2$. Obviously, y is also a complex number: $Y\angle\varnothing$. It can be shown (Appendix 2) that

$$r_{12} = 20 \log \left|\frac{y+1}{2\sqrt{y}}\right| \text{ dB, and} \quad (5)$$

$$R_{12} = 20 \log \left|\frac{y+1}{y-1}\right| \text{ dB,} \quad (6)$$

and it is evident:

(a) that for a given Y $(=|Y|)$ the value of r_{12} and R_{12} will be known only if $\varnothing$ is also known; and

(b) that r_{12} and R_{12} will vary cyclically as $\varnothing$ changes over its possible range of values. By expanding (5) and (6) we obtain expressions involving $\sin\varnothing$, $\cos\varnothing$ and find that the moduli in (5) and (6) have minima when $\varnothing = \pm 90°$ and maxima when $\varnothing = 0$ or $\pm 180°$. The possible ranges of r_{12} and R_{12} are therefore within the limits set by these values of $\varnothing$; they are shown in Fig. 3. together with curves for $\varnothing = 30°$ (the purpose of which is explained later) as a function of Y.

The values emerging from this analysis are shown in Table 3.

Note that when $\varnothing$ approaches $\pm 90°$ both reflection loss and return loss can reach high negative values. Are such values likely to arise in the network?

They can arise when Z_1 (or Z_2) is purely resistive and Z_2 (or Z_1) is a pure reactance: — an impossible condition for the pairs of impedances encountered in the telephone network.

They can also arise when the angles of Z_1 and Z_2 are of opposite sign and add up (regardless of sign) to 90 degrees. These conditions are shown graphically by the broken lines in Fig. 4.

The maximum values ($\varnothing = 0°, \pm 180°$) occur, for practical values of Z, when the angles of Z_1 and Z_2 are equal and of the same sign. The maximum values occurring when the angles of Z_1 and Z_2 are 90° and of opposite sign are impossible in the context of this article. These conditions are shown in the full lines in Fig. 4.

Analysis of $\varnothing$ for each of the impedance-pairs used above shows that values greater than about $\pm 30°$ are unlikely to be encountered in any of the pairs L-B, B-F, L-F. Because of duplicated pairs in the samples, only 28 samples were available for $\varnothing_{LB}$ and for $\varnothing_{BF}$, while the data yielded 64 samples for $\varnothing_{LF}$.

TABLE 3: MAXIMUM AND MINIMUM VALUES OF REFLECTION AND RETURN LOSSES

	Maximum ($\varnothing = 0°, \pm 180°$)	**Minimum** ($\varnothing = \pm 90°$)	$\varnothing = \pm 30°$
Reflection loss = 20 log →	$\frac{1}{2}(\sqrt{Y} + 1/\sqrt{Y})$	$\frac{1}{2}(\sqrt{Y} - 1/\sqrt{Y})$	$\frac{1}{2}(Y + \frac{1}{Y} + \sqrt{3})^{1/2}$
Return loss = 20 log →	$(Y + 1)/(Y - 1)$	$(Y - 1)/(Y + 1)$	$\left[\frac{Y + \frac{1}{Y} + \sqrt{3}}{Y + \frac{1}{Y} - \sqrt{3}}\right]^{1/2}$

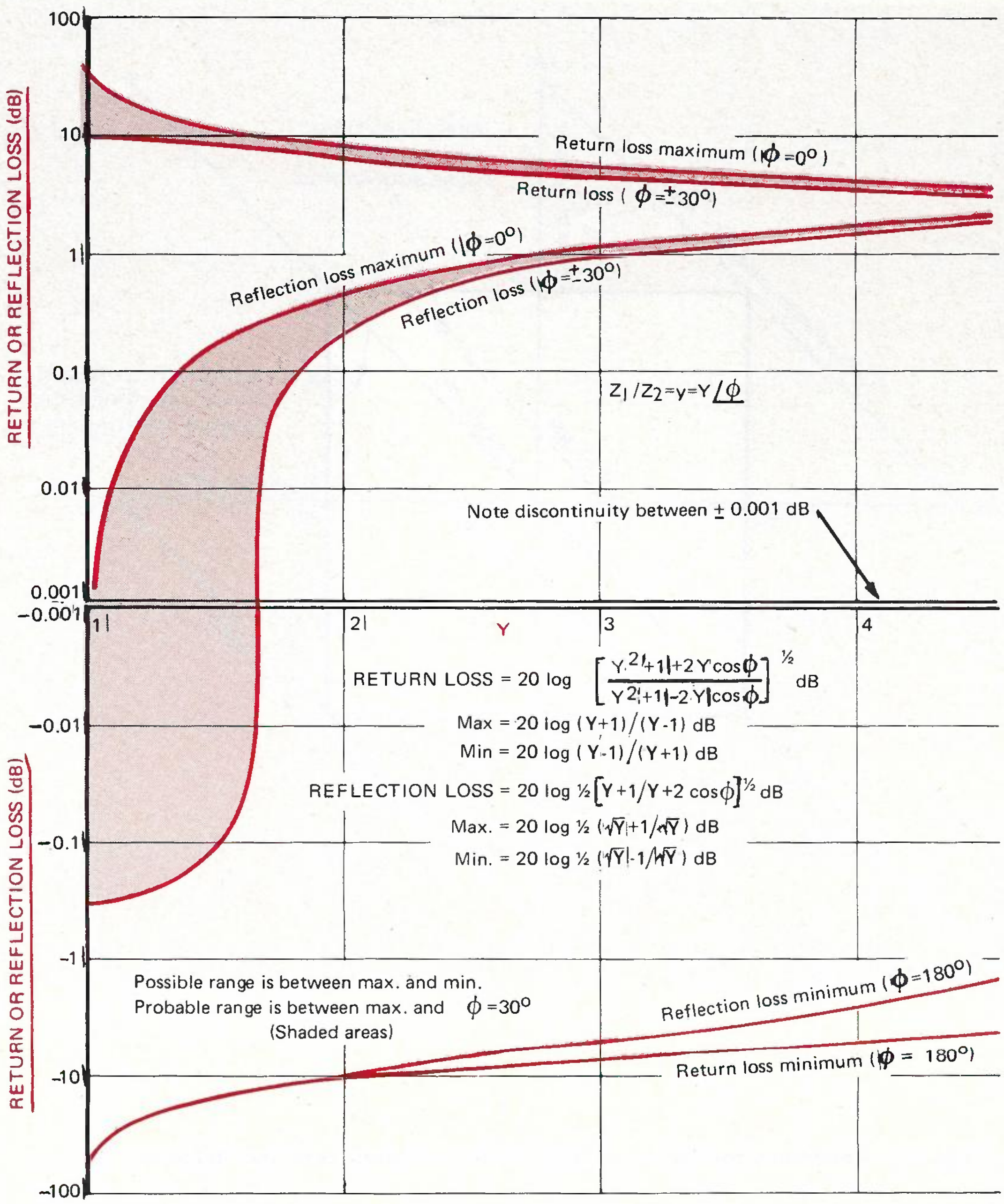


Fig. 3 — Possible and Probable Ranges of Return and Reflection Losses.

The results strongly suggest a Gaussian distribution for the population from which the samples were drawn, with the parameters of Table 4.

It will be seen that the probability of occurrence of angles greater than ± 30° is fairly small, and that the mean values are also quite small. We may have some confidence then, that most practical values in the telephone network will lie within the shaded areas shown in Fig. 3.

TABLE 4: CHARACTERISTICS OF ∅

	Degrees		
	∅LF	**∅BF**	**∅LB**
Sample mean	−4.03	−7.98	3.74
Sample std. deviation	16.79	10.87	11.11
No sample greater than	42	10	34
No sample less than	−36	−36	−20
No. of samples	64	28	28

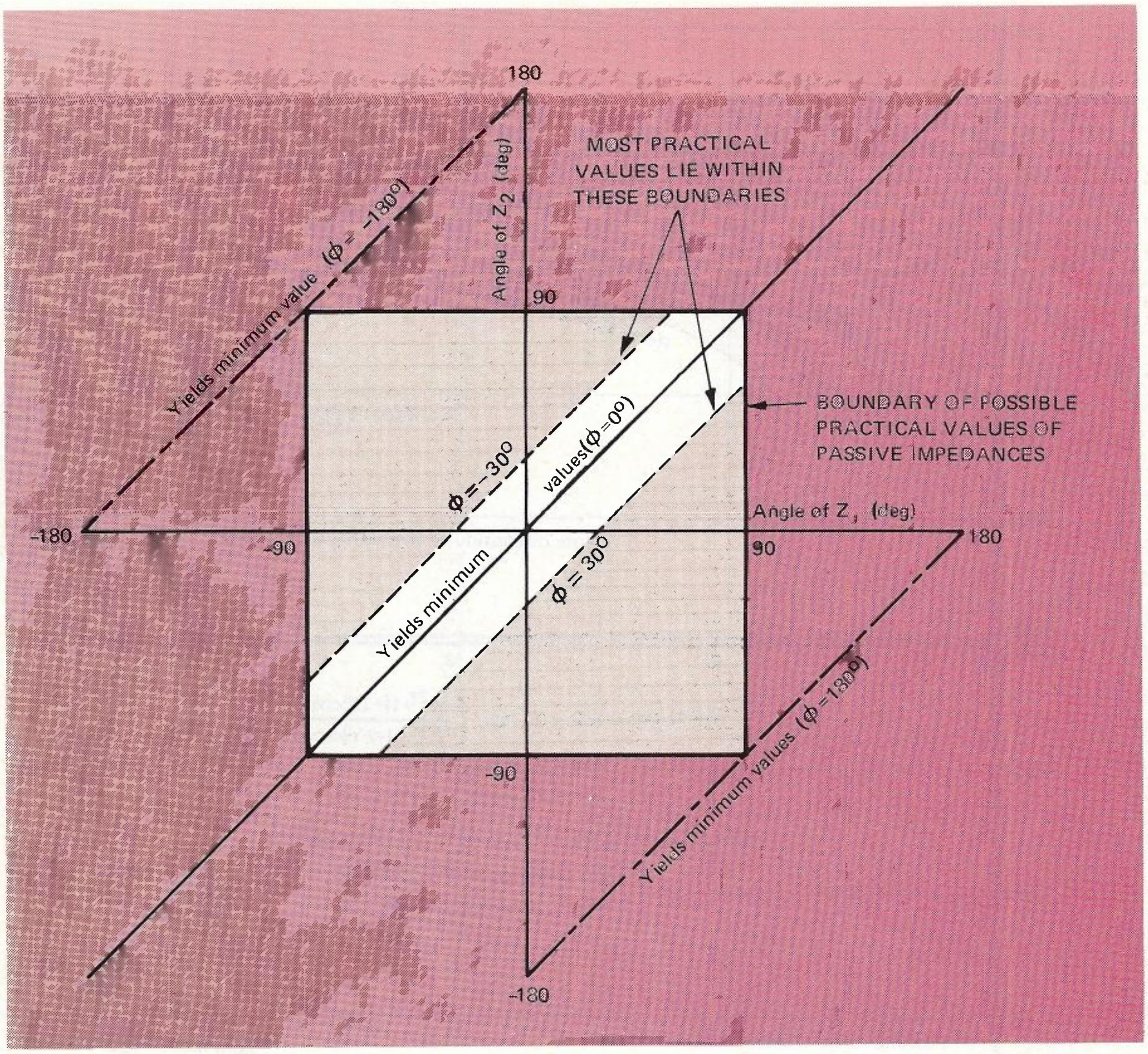


Fig. 4 — Conditions for Maximum and Minimum Return Loss and Reflection Loss.

It will be seen that return loss has to be less than about 5 dB before reflection loss exceeds 1 dB, and that for return losses of about 10 dB and more, (which should be expected for the pairs of impedances found in the telephone network, even towards the band edges) reflection loss is likely to be within +0.5 to —0.3 dB.

Fig. 5 expresses this broad conclusion in a different way: reflection loss is shown as a function of return loss for various values of ∅. At 10 dB of return loss, the reflection loss passes from +0.44 dB to —0.17 dB as ∅ moves from 0° to ± 30°; for higher values of return loss the range decreases.

Thus if the return loss between pairs of impedances selected from Z_B Z_L and Z_F can be at least 10 dB, the error term in (4):

$$r_{LF} + r_{BF} - r_{LB}$$

has possible extreme values given by

$$\begin{matrix} +0.44) \\ -0.17) \end{matrix} + \begin{matrix} (+0.44) \\ (-0.17) \end{matrix} - \begin{matrix} (+0.44) \\ (-0.17) \end{matrix}$$

which, if both extreme values are equally probable, leads to the conclusion that there is a 75 % chance of the error term lying between +0.44 and —0.17 dB, and a 25 % chance of it reaching the extremes of +1.05 and —0.78 dB.

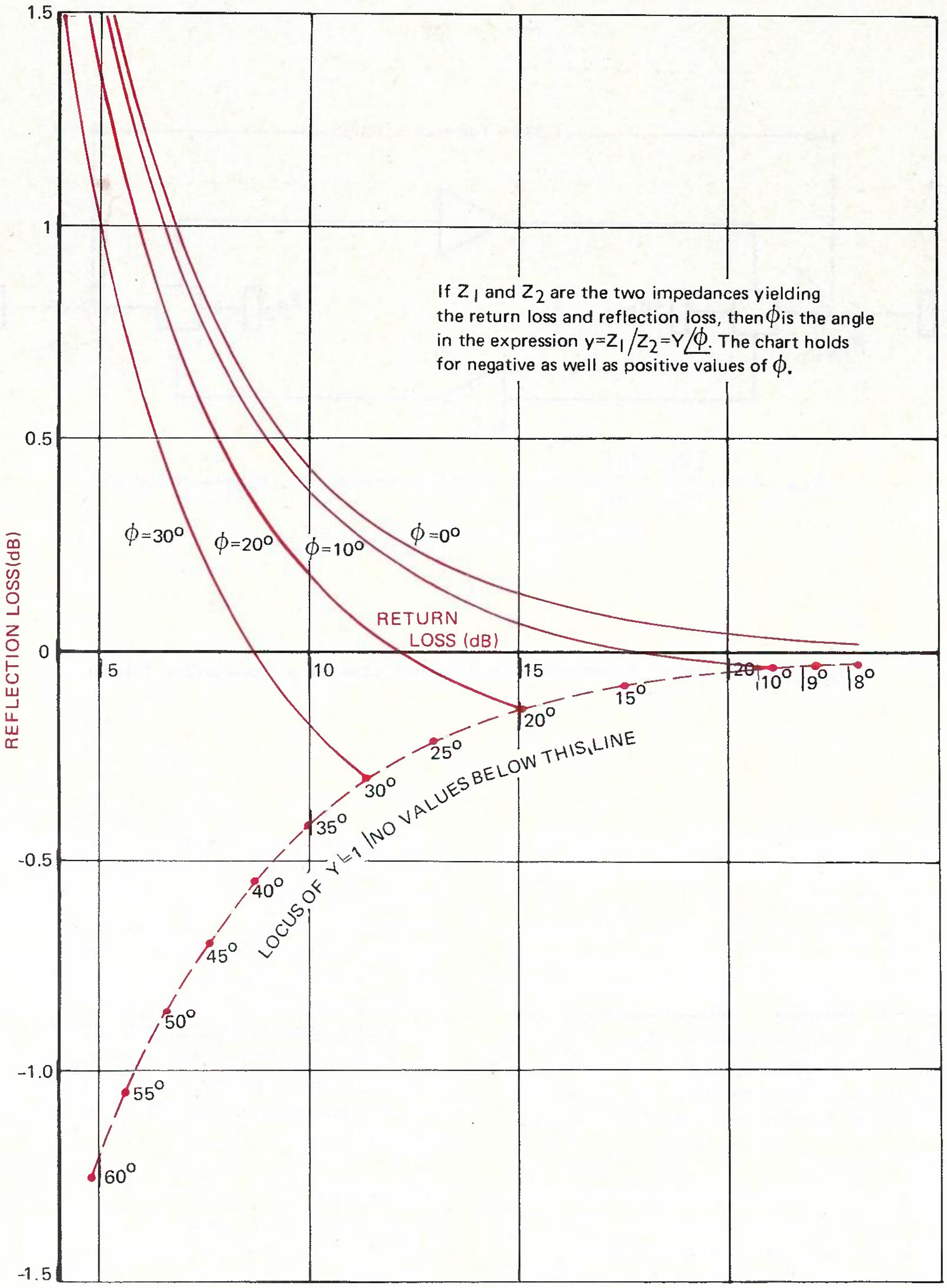
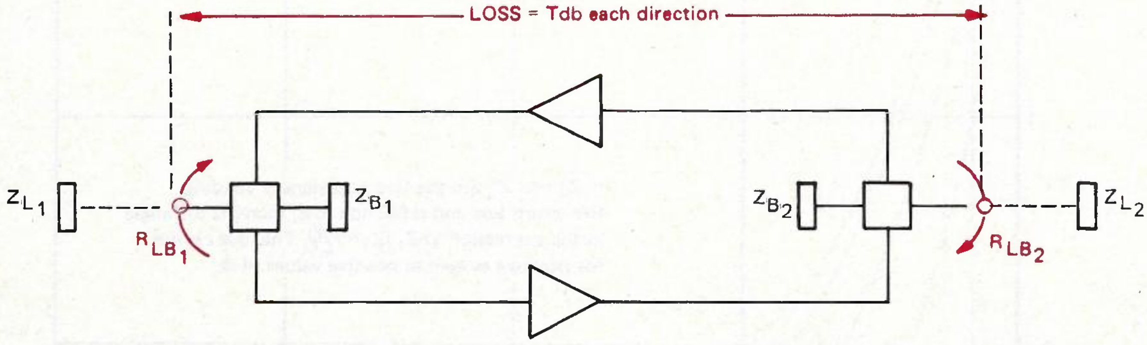


Fig. 5 — Return Loss and Reflection Loss as a Function of ϕ.



$$R_{LB} = 20 \log \left| \frac{Z_L + Z_B}{Z_L - Z_B} \right| \text{dB}; \quad Z_L = \text{2w line impedance}; \quad Z_B = \text{balance impedance}$$

$$\text{Loop loss} \triangleq (2T + R_{LB_1} + R_{LB_2})\ \text{dB}$$

Fig. 6 — The Usual Assumption about Loop Loss in a 2w-4w-2w Circuit.

Obviously, a higher return loss than the 10 dB chosen to illustrate the point would result in a narrower range of 'error'.

This example gives only an idea of the extreme magnitudes of error which may be encountered, and cannot give a guide to the statistics of probable error in the network. Nevertheless it is evident that even if only moderate values of return loss are achieved between the pairs of impedances involved, the total error term will be quite small relative to the sum of the other two terms in (4).

CONCLUSION

It is noted that the usual convention of Trans-hybrid loss $= 7 +$ (Balance return loss) dB is not accurate, and that for a particular case, account must be also taken of terms involving three reflection losses between the impedances closing the 2-wire, 4-wire and balance ports of the terminating set.

However, when developing transmission planning rules depending on a statistical distribution of trans-hybrid losses, the error in the convention will be negligibly small for the ranges of impedances found in the switched telephone network, and probably only of the same order as is involved in the assumption of $\frac{1}{2}$ dB $+$ $\frac{1}{2}$ dB for transformer losses in the constant 7 dB term.

A particular application of this conclusion is in the estimation of the stability characteristics of a 2w-4w-2w circuit or switched connection (Fig. 6) where the nominal 7 dB losses in (4) are absorbed into the loss of the circuit(s) concerned. In this case, if Tdb is the loss between 2-wire points in each direction, and R_1 and R_2 are the balance return losses at opposite ends of the circuit or connection, the loop loss (which must be positive at all frequencies if the circuit or connection is to be stable) may be assumed to be $(2T + R_1 + R_2)$ dB with negligible error.

REFERENCES

1. Berglund, B-L, and Ohman, K.: "Calculation of the Trans-hybrid Loss of 4-wire Termination Sets", Tele No. 2, 1975, pp 36-39.
2. Everitt, W. L. "Communication Engineering", Chapter V, 2nd Edition 1937, McGraw-Hill, New York.
3. "Glossary of Electrotechnical, Power, Telecommunication, Electronics, Lighting and Colour Terms", British Standard 4721, Part 3, Group 01, 1971. British Standards Institution, London.
4. "Glossary of Terms Used in Telecommunication (including radio) and Electronics", British Standard 204, 1960. British Standards Institution, London.
5. International Electrotechnical Vocabulary Publication 50(55), 2nd Edition 1970, International Electrotechnical Commission, Geneva.

APPENDIX 1 — HYBRID COILS (TRANSFORMERS) AND TERMINATING SETS

The current British Standard on terminology (Ref. 3) and the I.E.C. international glossary (Ref. 5) both define

Terminating Set:

An assembly of apparatus used to terminate the go and return channels of a four-wire circuit and to enable connection to be made to a two-wire circuit. (B.S. term 301-4029; I.C.E. term 55-20-280).

This is a quite general term and encompasses all methods of providing a 4-wire-to-2-wire connection, including the special case of the hybrid coil (hybrid transformer).

The latter term is no longer included in Ref. 3, but was in its predecessor (Ref. 4), and appears identically in Ref. 5:

Hybrid Coil (Hybrid Transformer):

A differential transformer having effectively three windings and four pairs of terminals so arranged, that, provided the impedances connected to two of the pairs of terminals fulfil certain conditions, the application of a voltage to the third pair of terminals produces no potential difference between the fourth pair of terminals. (Superseded B.S. term 33078; I.E.C. term 55-20-275).

This term clearly excludes the 2-transformer type of terminating set which is in universal use in telephone interexchange circuits. However, examples of hybrid coils (hybrid transformers) will be found in the telephone set (the anti-sidetone induction coil) and in 2-wire hybrid-type amplifiers where two one-way amplifiers are combined by the use of two hybrid coils.

The derivation of the adjective 'hybrid' is obscure, and the popular contraction of the term 'hybrid coil' (or 'hybrid transformer') to the supposed noun 'hybrid' no doubt compounds the obscurity. The device described by the adjective is hardly 'an offspring of two different species', or something which is 'composed of incongruous elements', (O.E.D.) and its continued use in the face of the unambiguous and functional 'terminating set' can hardly be defended.

It is of interest to note that the French equivalent term for hybrid coil (Ref. 5) avoids the connotation of 'hybrid'. Literally translated, the French term is 'balanced differential transformer', which is quite unambiguous. And the French equivalent of 'terminating set' is simply one word : 'termineur' : a commendable contraction.

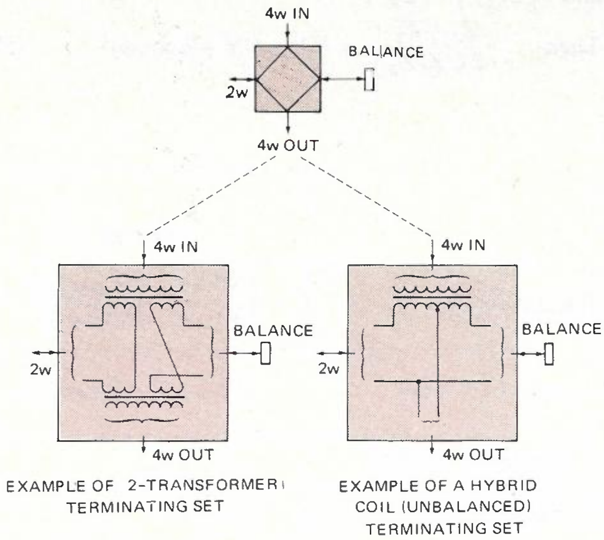


Fig. 7 — Two Terminating Sets; One Hybrid Coil.

APPENDIX 2—RETURN LOSS AND REFLECTION LOSS IN TERMS OF Z_1/Z_2

Return Loss

By definition, return loss $= 20 \log \left|\frac{Z_1+Z_2}{Z_1-Z_2}\right|$ dB

Let $\quad Z_1/Z_2 = y = Y \angle\phi = Y(\cos\phi + j\sin\phi)$

Then $\quad \frac{Z_1+Z_2}{Z_1-Z_2} = \frac{y+1}{y-1}$

and $\quad \left|\frac{Z_1+Z_2}{Z_1-Z_2}\right| = \frac{|Z_1+Z_2|}{|Z_1-Z_2|} = \frac{|y+1|}{|y-1|}$

$$y+1 = Y\cos\phi + 1 + jY\sin\phi$$

and $\quad |y+1| = [(Y\cos\phi+1)^2 + Y^2\sin^2\phi]^{\frac{1}{2}}$

$$= [Y^2\cos^2\phi + 1 + 2Y\cos\phi + Y^2\sin^2\phi]^{\frac{1}{2}}$$

$$= [Y^2+1+2Y\cos\phi]^{\frac{1}{2}}$$

$$y-1 = Y\cos\phi - 1 + jY\sin\phi$$

and $\quad |y-1| = [(Y\cos\phi-1)^2 + Y^2\sin^2\phi]^{\frac{1}{2}}$

$$= [Y^2\cos^2\phi + 1 - 2Y\cos\phi + Y^2\sin^2\phi]^{\frac{1}{2}}$$

$$= [Y^2+1-2Y\cos\phi]^{\frac{1}{2}}$$

Then
$$\left|\frac{Z_1+Z_2}{Z_1-Z_2}\right| = \left[\frac{Y^2+1+2Y\cos\phi}{Y^2+1-2Y\cos\phi}\right]^{\frac{1}{2}} \qquad (1)$$

This has a maximum value when $\cos\phi = 1$ ($\phi = 0°$):

$$\left|\frac{Z_1+Z_2}{Z_1-Z_2}\right|_{max} = \left[\frac{Y^2+2Y+1}{Y^2-2Y+1}\right]^{\frac{1}{2}} = \frac{Y+1}{Y-1} \qquad (2)$$

It has a minimum value when $\cos\phi = -1$ ($\phi = 180°$):

$$\left|\frac{Z_1+Z_2}{Z_1-Z_2}\right|_{min} = \left[\frac{Y^2-2Y+1}{Y^2+2Y-1}\right]^{\frac{1}{2}} = \frac{Y-1}{Y+1} \qquad (3)$$

It is also of interest to determine the value as a function of ϕ when $Y = 1$:

$$\left|\frac{Z_1+Z_2}{Z_1-Z_2}\right|_{(Y=1)} = \left[\frac{1+\cos\phi}{1-\cos\phi}\right]^{\frac{1}{2}} \qquad (4)$$

Reflection Loss

By definition, reflection loss $= 20 \log \left| \frac{Z_1+Z_2}{2\sqrt{Z_1 Z_2}} \right|$ dB

Let $Z_1/Z_2 = y = Y \angle\phi = Y(\cos\phi + j\sin\phi)$

Then $\frac{Z_1+Z_2}{2\sqrt{Z_1 Z_2}} = \frac{y+1}{2\sqrt{y}}$

$$y+1 = Y\cos\phi + 1 + jY\sin\phi$$

and $|y+1| = [(Y\cos\phi+1)^2 + Y^2\sin^2\phi]^{\frac{1}{2}}$

$= [Y^2\cos^2\phi + 2Y\cos\phi + 1 + Y^2\sin^2\phi]^{\frac{1}{2}}$

$= [Y^2 + 1 + 2Y\cos\phi]^{\frac{1}{2}}$

and $|2\sqrt{y}| = 2\sqrt{Y}$

Then $$\left| \frac{Z_1+Z_2}{2\sqrt{Z_1 Z_2}} \right| = \tfrac{1}{2}(Y + 1/Y + 2\cos\phi)^{\frac{1}{2}} \quad (5)$$

This has a maximum value when $\cos\phi = 1$ ($\phi = 0$):

$$\left| \frac{Z_1+Z_2}{2\sqrt{Z_1 Z_2}} \right|_{max} = \left[\frac{Y^2+2Y+1}{4Y} \right]^{\frac{1}{2}} = \tfrac{1}{2}(\sqrt{Y} + 1/\sqrt{Y}) \quad (6)$$

It has a minimum value when $\cos\phi = -1$ ($\phi = 180°$):

$$\left| \frac{Z_1+Z_2}{2\sqrt{Z_1 Z_2}} \right|_{min} = \left[\frac{Y^2-2Y+1}{4Y} \right]^{\frac{1}{2}} = \tfrac{1}{2}(\sqrt{Y} - 1/\sqrt{Y}) \quad (7)$$

And when $Y = 1$, (5) may be expressed as a function of ϕ:

$$\left| \frac{Z_1+Z_2}{2\sqrt{Z_1 Z_2}} \right|_{(Y=1)} = \left[\frac{2+2Y\cos\phi}{4} \right]^{\frac{1}{2}} = \left[\frac{1+\cos\phi}{2} \right]^{\frac{1}{2}} \quad (8)$$

Summarising the results in terms of $Y = |Z_1/Z_2|$ and its angle ϕ, the table below gives the quantities whose logarithms, multiplied by 20, give the decibel values of return loss and reflection loss.

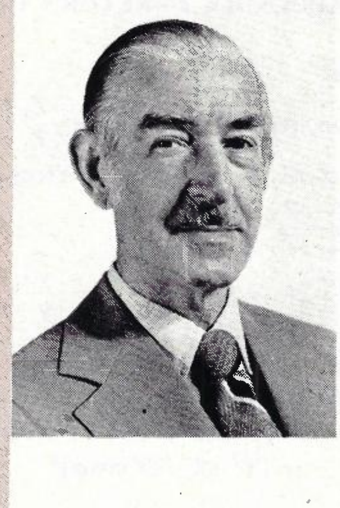
	General	Maximum	Minimum	Function of ϕ
Return Loss	$\left[\frac{Y^2+1+2Y\cos\phi}{Y^2+1-2Y\cos\phi} \right]^{\frac{1}{2}}$	$\frac{Y+1}{Y-1}$	$\frac{Y-1}{Y+1}$	$\left[\frac{1+\cos\phi}{1-\cos\phi} \right]^{\frac{1}{2}}$
Reflection Loss	$\tfrac{1}{2}(Y+1/Y+2\cos\phi)^{\frac{1}{2}}$	$\tfrac{1}{2}(\sqrt{Y}+1/\sqrt{Y})$	$\tfrac{1}{2}(\sqrt{Y}-1/\sqrt{Y})$	$\left[\frac{1+\cos\phi}{2} \right]^{\frac{1}{2}}$
Condition for both return loss and reflection loss	None	$\phi = 0°$	$\phi = 180°$	$Y = 1$

R. G. KITCHENN graduated from London University in 1948, during his service in the Engineer-in-Chief's Office of the United Kingdom Post Office, where his main experience was in the development, installation and maintenance of transmission-related plant, and as a lecturer.

Joining the Australian Post Office in 1951, he spent four years in N.S.W. associated with broadcasting transmitters and studios.

Headquarters service has included work in radiocommunications and h.f. broadcasting, in the trunk aspects of systems planning, and, since 1960, in transmission planning aspects of the national network. He is currently responsible for the determination of transmission performance objectives for Telecom Australia services.

He is a past contributor to the Journal and to the work of the C.C.I.T.T., for which he is Special Rapporteur for studies on the transmission characteristics of circuits in the switched international network and on stability and echo. He is Vice-Chairman of C.C.I.T.T. Study Group XVI for the 1976-79 study period.



In Brief

IMPULSE NOISE AND 48 Kbit/s DATA TRANSMISSION

The impulse noise level is one of the key parameters when planning digital data services, for instance, at 48 kbit/s on junction and subscriber cable sections. Measurements of such noise have been made previously using a filter with a 1-37 kHz bandwidth which closely approximates the spectrum of the currently used 48 kbit/s Datel signals. However, if we wish to correlate the level of this noise with the error rate of the data signals, we need to consider the level of the impulsive noise at the *receiver decision point* where both the received data signal and the noise will have been filtered and equalized. Depending on the length of the repeater section, the higher frequencies of the data signal and the impulse noise may be amplified up to about 20 dB with respect to the lower voice-band frequencies.

Hence, some knowledge of the spectral distribution of the impulse noise is required if we are to relate its level (as measured on the line) to the expected performance of the data receiver. Accordingly, a series of measurements was made by Telecom in two junction cable sections in the Melbourne metropolitan area. To obtain comparative information on impulse noise levels with different weightings, the impulse noise level was measured with four different filters; viz:

- Psophometric (Bell system C – Message weighting)
- "Flat"
- 1-37 kHz filter
- Data equalizer filter corresponding to a 48 kbit/s receiver operating on 0.9 mm cable with a 14 km repeater section.

A preliminary study of the results has indicated the very interesting result that the three wider bandwidth filters give levels of impulse noise about 17-20 dB higher than that of the C-message weighting and, hence, show that the energy spectrum of the impulse noise extends well above the voiceband. The impulse noise level with the data equalizer/filter is only about 3 dB lower than the 1-37 kHz filter; hence, previous measurements made with this latter filter are still useful in planning repeater sections for 48 kbit/s data services.

It is hoped, at a later date, to carry out further measurements to confirm the above results and, also, to perform some data transmission tests to correlate measured error rates with those predicted from the impulse noise levels.

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ABSTRACTS: Vol. 27, No. 1

CLEARY, B. J. and LANGE, V. W.: 'The Trans Sumatra Microwave System — Part 1'; Telecomm. Journal of Aust., Vol. 27, No. 1, page 51.

This article describes the planning, design, implementation and operation of a major microwave project in Indonesia which utilised Australian personnel in a consultative and supervisory capacity. The basic theme of the article is to relate some of the problems encountered —problems which are not usually experienced in Australian projects of a similar type.

Part one of the article describes the planning, and system design phases of the project while part two, in a later issue, will cover equipment, project implementation and maintenance.

CLOSE, W. A.: 'ARE 11 System Appreciation'; Telecomm. Journal of Aust., Vol. 27, No. 1, page 3.

Telecom Australia is about to embark on a major modernisation programme to provide new facilities in the crossbar exchange network. Studies of these updating proposals for the crossbar network revealed an economic application for the ARE 11 exchange system in providing these new facilities in existing exchanges. This paper, the first of a series, describes the system features, the advantages of the system compared with ARF and its application to the Australian network.

KELSO, D. R.: 'Lightning Protection of Telephone Cables in Areas of High Soil Resistivity — Part 1; The Overhead Earth Wire Technique'; Telecomm. Journal of Aust., Vol. 27, No. 1, page 35.

In certain country areas, Telecom external plant must be installed and maintained where local conditions result in abnormally severe damage caused by lightning. Part 1 of this article describes some novel techniques developed for application in areas of high resistivity soil within the Stanthorpe Telephone District, Southern Queensland. Experience under operational conditions is also discussed and it is concluded that these techniques should find application where similar circumstances exist elsewhere. Part 2 will deal with other practical techniques, while Part 3 discusses operational experience with field installations.

KITCHENN, R. G.: 'Trans-Hybrid Loss; An Approximation and its Error'; Telecomm. Journal of Aust., Vol. 27, No. 1. page 81.

The loss between the 4-wire 'receive' and 'send' ports of a terminating set is usually assumed to be 7dB plus the balance return loss between the balance and 2-wire line impedances. The article shows that this is an approximation, the actual loss being this sum plus two reflection losses involving the (common) impedance closing the 4-wire ports, minus the reflection loss between the balance and 2-wire line impedances. However, this 3-term 'error' is shown to have a negligibly small amplitude in most practical applications in the telephone network. It is just as likely to be negative as positive in sign.

McKINNON, R. K., ENDERSBEE, B. A. and BOUCHER, J. M.: 'Data Communication; Basic Facts and Facilities Available — Part 1'; Telecomm. Journal of Aust., Vol. 27, No. 1, page 14.

Data communications in Australia is mainly based upon utilisation of the transmission and switching network provided primarily for telephony. Some transmission characteristics which are of relatively minor importance in voice telephony are of greater importance for data, and these are described in a general way. Maintenance and performance factors for both the public switched telephone network and private line applications are discussed. The facilities offered by the datel service are summarised and mention is also made of two specialised data networks.

MARTIN, G.: 'Common User Data Network — Part 3, Supervisory Facilities'; Telecomm. Journal of Aust., Vol. 27, No. 1, page 46.

This is the final of three articles designed to inform the reader of the Telecom Australia's processor controlled message switching system known as the Common User Data Network.

In this article, the supervisory and control facilities developed and implemented are presented in broad terms. Some detail of the man-machine communication is included as examples and explained.

METZENTHEN, W. E., BLACKWELL, D. M. and KUHN, D. J.: 'Visual Communication Over Telephone Lines'; Telecomm. Journal of Aust., Vol. 27, No. 1, page 24.

Visual communication systems for use on normal telephone services can be expected to decrease in cost as use is made of currently emerging semi-conductor devices. An expansion of the market for at least some of these systems is likely to follow. This paper reviews some of the equipment used in the past and the present-day, and describes new developments that may have substantial impact on the industry in the near future.

PRIEST, M. J. and HALLAMS, P. R.: 'Exchange Network Planning; Use of the ITT Computer — Part 2'; Telecomm. Journal of Aust., Vol. 27, No. 1, page 64.

Part 1 of this article discussed the main features of the use of the ITT computer program used in network planning of urban exchanges. Part 2 is concerned with the application of the program to a provincial city network and the Sydney ELSA area.

TENEN, O.: 'Wide-Band Crystal Filter Design'; Telecomm. Journal of Aust., Vol. 27, No. 1, page 71.

This paper describes a design procedure for wide-band crystal filters consisting of LC resonators interposed with two-pole crystal lattices. Closed form design formulas are developed. The practical realisations are considered and applications for various types of available resonators are discussed. The fractional bandwidth limitation for quartz resonator filters is 1-10%, for ceramic resonator filters 5-25% and for surface acoustic wave resonator filters 0.5-10%.

THE TELECOMMUNICATION JOURNAL

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Vol. 27 No. 1, 1977

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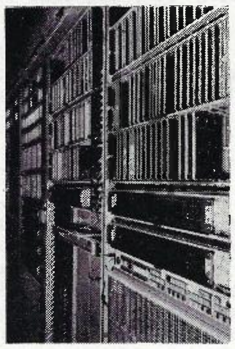

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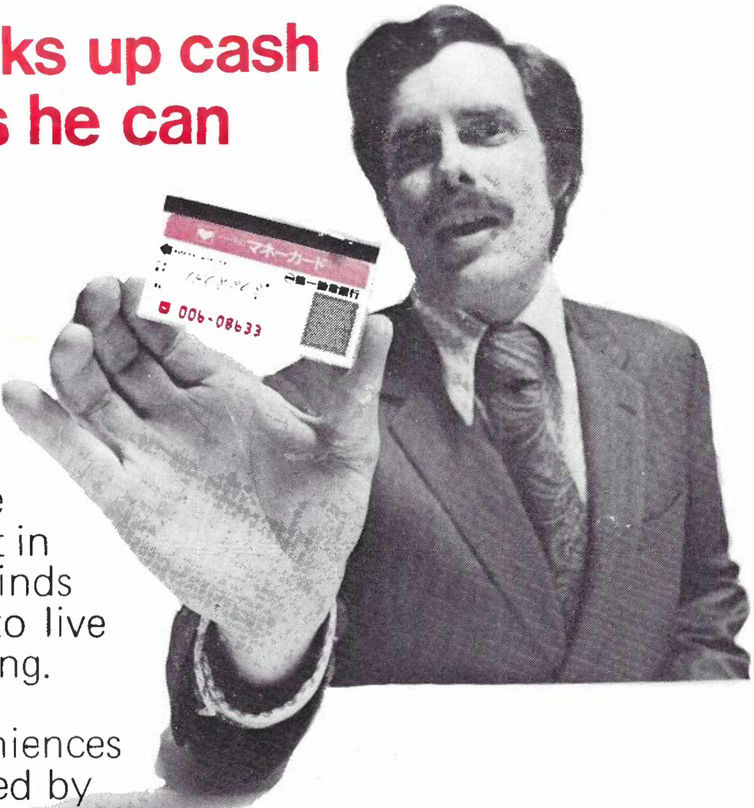

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