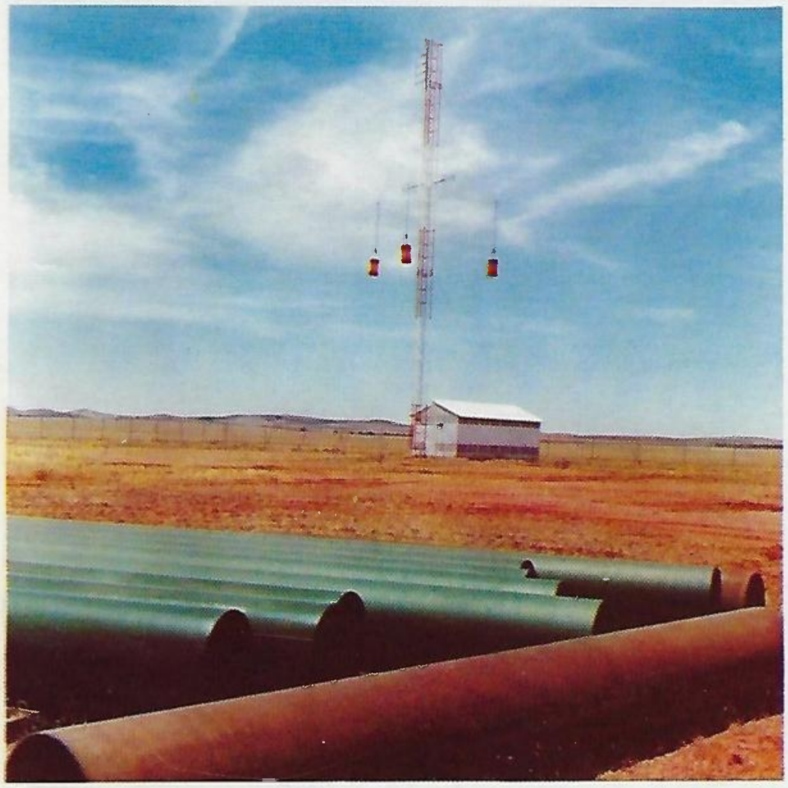
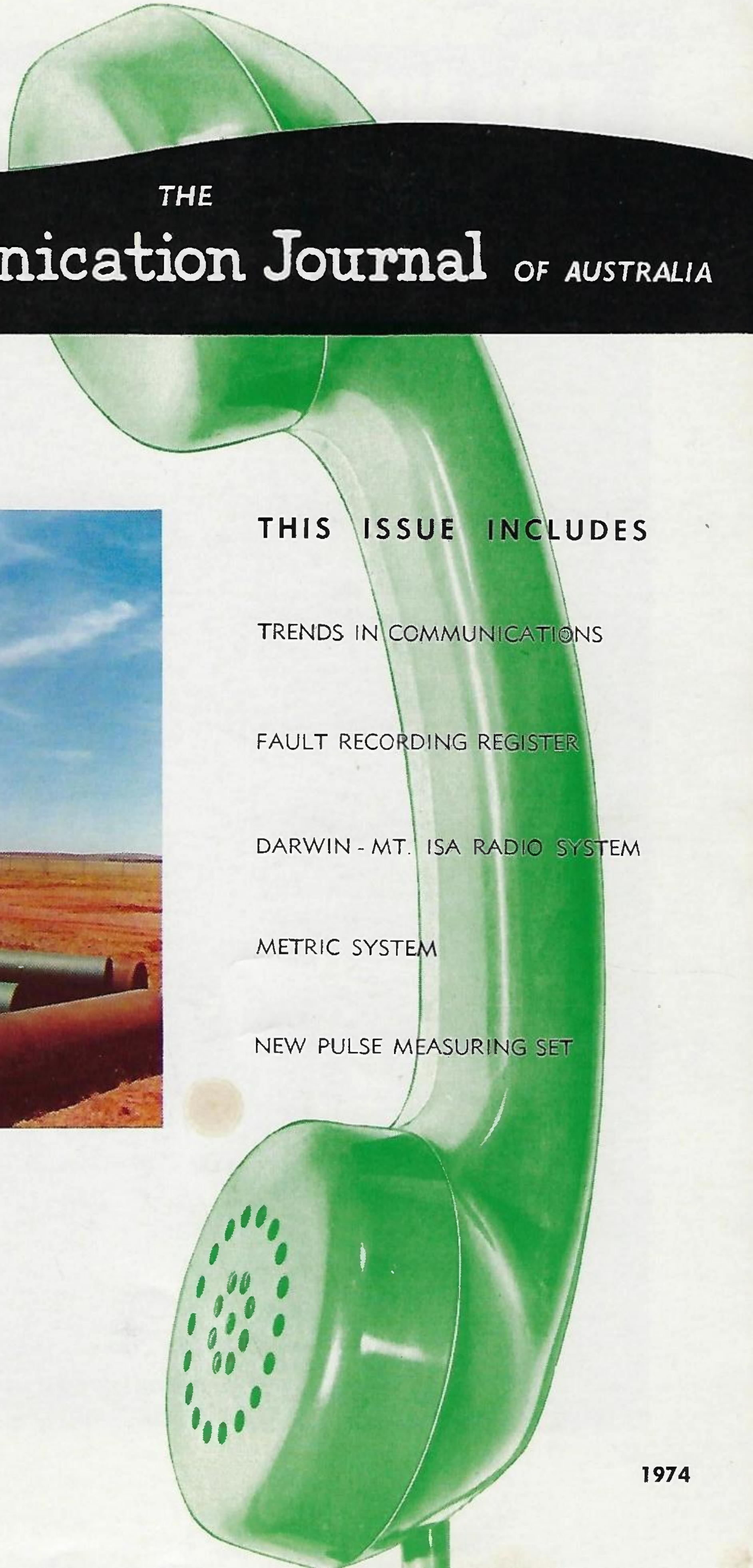
THE
# Telecommunication Journal OF AUSTRALIA





## THIS ISSUE INCLUDES



**Vol. 24, No. 1** **1974**

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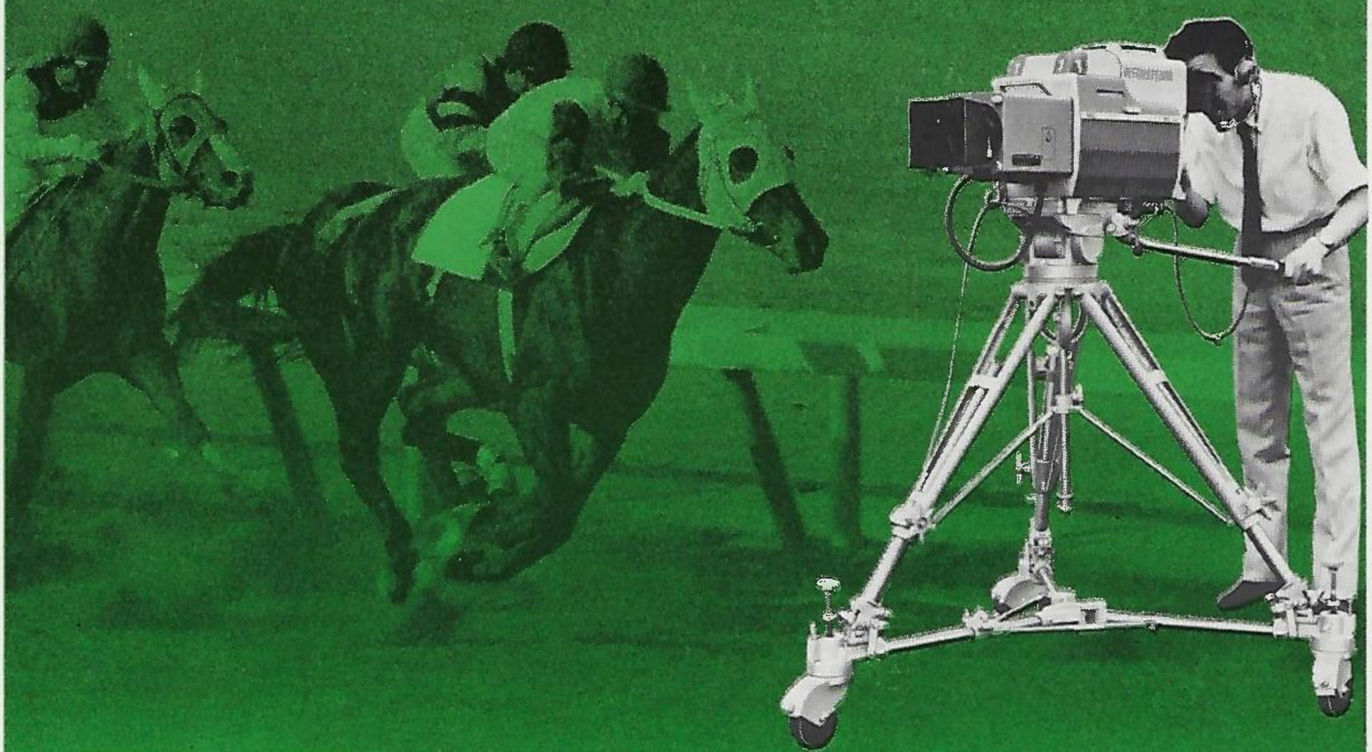

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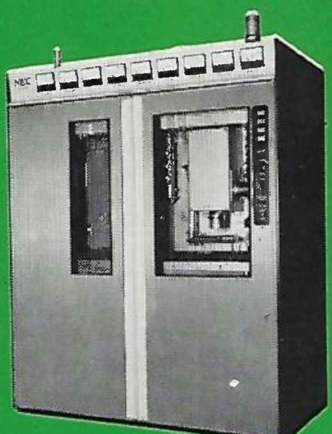


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# THE TELECOMMUNICATION JOURNAL
## OF AUSTRALIA

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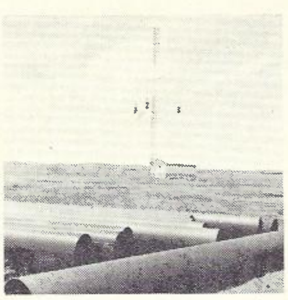

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# The Telecommunication Journal of Australia

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**The State Secretary,** Telecommunication Society of Australia,

Box 6026, G.P.O., Sydney, N.S.W. 2001.
Box 1802Q. G.P.O., Melbourne, Vic. 3001.
Box 1489, G.P.O., Brisbane, Qld. 4001.
Box 1323, G.P.O., Adelaide, S.A. 5001.
Box T1804, G.P.O., Perth, W.A. 6001.
C/o P.M.G. Engineering Division, Hobart, Tas. 7001.

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

**Agent in Europe:** R. V. Martin, Canberra House, 10-16 Maltravers St., Strand, London, W.C. 2R3EH.

# Trends of Development in Telecommunications

C. JACOBAEUS

*This article is an address delivered by the author at the 'Swedish Technical Week' held in Brazil in May 1973. It surveys trends in telecommunications technology, and deals with basic components such as resistors, filters and relays, and the main items comprising telecommunications networks, i.e. telephone instruments, external plant, exchange switching plant and transmission equipment.*

## INTRODUCTION

Telecommunications is the transmission of information, the exchange of information consisting of facts, assertions, suppositions, propaganda, political or religious messages, deliberate falsehoods, feelings, and everything else which people can think of to pass on to one another. Telecommunications is associated with hearing and sight, and may also affect the sense of touch. It transmits speech and music, still and moving pictures, text, data in written form, and so on.

One may wonder what it is that has produced the expansion in telecommunications since the second world war. The expenditure on telecommunications has increased on an average roughly twice as much as the rise in the national product. Naturally there is an interplay between several factors. One of them, presumably, is man's distinctive characteristic of being able to communicate information to his fellows and to receive information from them, and to make use of, perhaps find pleasure in (or be angered by), information. Man's intelligence is to a very great extent built up around his ability to process information — this, perhaps, is in fact the only kind of intelligence. The very nature of man must therefore be a powerful stimulant to the development of telecommunications.

Another factor underlying the development of telecommunications is modern society itself and its mode of functioning. An interplay takes place between the service provided by modern telecommunications and the organization of society. The direction of the various organs of society, the mode of operation of our public institutions and business enterprises, are dependent on telecommunications. They are built on the basis of what telecommunications can give them, and often change when new service facilities are introduced.

The technical development has been very intense since the second world war. A number of inventions have matured into products which have been usable with technical or economical advantage. The production of telecommunications equipment has grown very vigorously. The price trend in fixed monetary values has been very favourable, owing equally to increased volume and to cheaper equipment.

In this address I shall present a survey of the expected developments during the seventies. I shall not deal with mass media, radio and TV broadcasting, nor with systems for special purposes, such as aircraft and navigation systems. My account will be predominantly concerned with telephony, telex and data transmission. It will be based, of course, on the present situation, to some extent on the developments which have led up to the present situation, and what one may expect from new discoveries and technologies.

Obviously a prediction of this kind must be hedged about with reservations. We know with a fair certainty what will happen in the next few years. But in the longer term it is not impossible that new advances both within the basic sciences and technology may influence the evolution in unexpected ways. Similarly new impulses may come from changes in consumers' (subscribers') evaluations. It appears definite, however, that the main function of telephony will remain the same as at present, namely communication between two subscribers.

## COMPONENTS

A feature common to the entire development within the components field in the period since the second world war has been the emphasis on quality. Research within the components field has given us a deeper insight particularly into life mechanisms, while materials research has given us new materials with better electrical and magnetic properties. New technologies have been introduced which, backed up by mass production, have been able to give us cheap components without loss of quality.

This general development may be expected to continue during the years to come. Whether it will be as quick as during the fifties and sixties will depend probably on whether new classes of materials can be produced. The prospects in this respect are not clear.

### Semiconductor Components

Within the components field the main interest during the fifties and sixties has been in semiconductor components. Hardly anyone at the beginning of the fifties could presumably imagine the enormous technical development that was to take place in this field. Performance in respect of electrical properties has been drastically improved, reliability and life have reached unguessed values, and under the pressure of industrial overcapacity the price development has been favourable.

The break-through of the semiconductor components may be ascribed essentially to the discovery of the silicon planar technique which created the conditions for mass production of a reliable and cheap product. The development has been in the direction of IC (integrated circuits) of different types, monolithic circuits, thin and thick film circuits, and hybrids between them. This means that we have obtained components of a higher order, containing for example an amplifier or a flip flop. An IC thus assumes an intermediate position between a discrete component and an equipment unit. A disadvantage in conjunction with this development, however, is the difficulty of producing inductances in integrated form.

An interesting feature is the trend to integrate increasingly complicated circuits, systems of circuits, and also memory matrices with address decoding in a single silicon crystal, known as MSI (Medium Scale Integration) and LSI (Large Scale Integration). A refined planar technology has been developed which allows the manufacture of 150,000 circuit elements per $cm^2$. This has been made possible through the use of thinner epitaxial layers than previously, approx. 1 $\mu$m, and through a new method for the mutual insulation of the individual circuit elements. The MOS (Metal Oxide Semiconductor) technique, with its advantages from the manufacturing point of view, has also come into use on an increasingly wide scale for MSI and LSI.

In connection with the development of MSI and LSI circuits CAD (Computer Aided Design) has been an effective tool. Likewise electron- and laser-beams have been useful for making photo-masks. Ion implantation is likely to increase performance and yield in the near future.

Among the latest additions within this field may be mentioned especially:

- Hyper-rapid signal diodes (Schottky diodes) for switch use
- Gunn diodes for high frequency generation
- Varactor diodes for automatic frequency tuning and for high frequency generation (frequency multiplication)
- Step-recovery diodes for harmonic frequency generation
- Light emitting diodes (LED) and displays
- Optically coupled devices
- Power diodes for high power and high reverse voltages
- Thyristors of different types, including bidirectional
- Field effect transistors, especially of MOS type
- Silicon transistors for high power (hundreds of watts) and high frequencies (up to the GHz range)
- Integrated digital circuits of MSI and LSI (especially MOS) type
- Field programmable read only memories (PROM)
- Integrated amplifiers of different types and regulators for up to several watts
- Hall devices and magnetoresistive devices
- Lasers

There is a strong tendency to plastic encapsulation, but there are still problems with moisture protection and long term stability.

### Resistors

As a complement to conventional carbon resistors, metal oxide and metal film resistors have come into increased use. The latter are attractive especially for circuits with requirements of narrow tolerances, good stability and high reliability.

Pads in the form of thin and thick film resistance networks, with satisfactory properties and at an acceptable price, are now coming out on the market. New, improved pastes for thick film circuits have conduced to this.

Variable resistors with Cermet path appear to be more and more superseding the older types with wire-wound or carbon path.

As regards varistors and thermistors, the properties have been further improved in recent years, with a wider usage in consequence.

### Capacitors

Plastic capacitors have now entered the field in earnest — polystyrene, polyethylene, terephthalate (polyester), polypropylene and polycarbonate. Teflon capacitors (polytetrafluoroethylene) are also marketed, but their price is still high. As regards the use of polystyrene as dielectric in capacitors, this is no new departure, but the material has been improved so as to withstand higher temperatures than before.

There has also been a marked change-over to metallized capacitors, which has led to a considerable reduction of volume and improved reliability.

Through the introduction of the tantalum capacitors, wet and dry, of which the dry, sintered type has now definitely made its entry, it was thought that the old aluminium electrolytic capacitor would no longer be able to compete. This has proved wrong, however. Through the use of purer aluminium foil and new types of electrolytes as well as improved manufacture, aluminium electrolytic capacitors of long-life type have been produced which are usable within a far wider temperature range than before and are cheaper than the tantalum capacitors.

The ceramic capacitors as well have undergone a metamorphosis through the introduction of the multi-layer method for types with low dielectric constant and by raising the reliability and stability of the high-epsilon types.

For use in hybrid integrated circuits chip capacitors (ceramic capacitor chips and dry tantalum capacitor chips) have been put on the market.

It should be added that spark arresters both of RC type (with discrete components) and CR type (integrated) have found an extremely wide use.

Finally it may be emphasized that nowadays plastic encapsulation of capacitors is widely used.

### Filters

Within the filter field considerable efforts are being directed to active RC filters and miniaturized monolithic crystal filters, especially for use as channel filters in transmission equipment. Mechanical filters have also come into use for the same purpose.

### Coils and Transformers

Through the successive development of the ferrite materials in the direction of higher permeability, lower losses, better stability (lower disaccommodation), the core dimensions have been reduced and their use at higher frequencies is promoted. The modification of the shape of the cores (X and wing cores) has also meant that the mounting space on PC cards can be better utilized.

On the power side the C cores have now a predominant role.

### Memories

The ferrite core memory has become well established. Though the performance of the cores has recently been improved and their cost reduced, it is apparent that development points to semiconductor memories. These memories offer advantages in terms of speed, costs, reliability, size and weight. They also offer both electrical and mechanical compatibility with other integrated circuits in the computer logic.

Semiconductor read-write random access memories (RAM) are available in either bipolar or MOS technology. The former offer shorter access time while the latter have the advantage of lower cost and lower power dissipation.

MOS random access memories are usually dynamic, i.e. the storage element is the inherent gate capacitance of a MOS transistor. Due to leakage current dynamic memories have to be "refreshed".

A very common type of memories programmed by the manufacturer according to the customer's specification is known as Read Only Memories (ROM). Programming is accomplished by using specific masks during production. A special type of ROM is the PROM, i.e. the field programmable ROM. In this case the customer can program these memories himself, for example by fusing very thin nichrome resistors. This type of PROM is bipolar and is used in high speed applications.

**Relays**

The PC technique has brought a need for small relays for mounting on PC cards, and the trend is in the direction of relays not only of conventional design but also of reed type, both dry and mercury-wetted. There are already miniature relays of all these types on the market.

**The PC Technique**

One may say that the PC technique has gone hand in hand with semiconductor engineering and has become of enormous significance for the mounting and wiring of electronic components. From the originally single-sided printed circuit cards we have come via double-sided cards to the considerably more complicated multilayer technique. This has solved the problems of crossing conductors. At the same time, however, it has been necessary to produce a method for wiring between conductors in different planes. This is now done by galvanic metallization of holes (plated through holes).

The PC technique requires special terminations, and one may say that the goldplating method developed for terminals for PC cards has also found applications for other types of separable terminals.

**TELEPHONE SETS**

Within the telephone set field it has been possible to work for a longer time than in any other sector with components deriving from the very earliest days of telephony. The carbon granule microphone was invented in the 1890's, and the receiver goes back to Bell's invention. The bell is also from the 19th century, and the dial is essentially the same as at the turn of the century. In the course of the technological developments all these main components have naturally been greatly improved. This has been brought about by a better understanding of the underlying physical principles, as also by a greater knowledge of the functioning of our senses. New materials and better manufacturing methods have led to longer life and lower price. it must also be said that these main components of the telephone set have reached a high degree of perfection and, on first thought, there is not much left to desire.

The world's telephone industry, however, has new developments in progress in some respects, especially as regards microphones and signalling devices. There is also a great interest in key signalling.

As regards the microphone, the carbon granule microphone has the advantage that it delivers a very satisfactory power output. It has a troublesome frequency response, however, and also harmonic distortion. Its efficiency often diminishes with time, which creates a maintenance problem. Through the introduction of cheap semiconductor amplifiers the way has been opened for better microphones. Work is at present being done on microphones with direct pressure on semiconductors, microphones of piezoelectric and of electromechanical type, and with electrets. The latter appear to be the most promising, as we have now learned to make electrets with satisfactory life. This gives a microphone with less harmonic distortion and better frequency response, which, purely subjectively as well, provides a clearer and more pleasant reproduction of speech.

The receiver, too, can be made on piezoelectric or electret principles, in which case of course an amplifier must also be incorporated for incoming speech. The advances in this respect are perhaps of less significance than for the microphone.

The bell has been greatly improved during the sixties through better design and the introduction of sound level adjustment. The new high impedance bells also permit the connection of several bells in parallel. To a growing extent, however, an acoustic sound source is being considered as a signalling device, possibly the receiver itself. A transistor circuit converts the ringing current to a frequency of 1500 - 2500 Hz, which is also given some modulation. A more pleasant signal is thereby obtained, which actually attracts the attention better than an ordinary ringing signal. With modern semiconductor technique the price of the transistor circuit can be kept down.

One might expect administrations to be very interested in these new features. During a trip to the U.S., Canada and Australia, however, we found that people where generally satisfied with the existing telephone set technique. They are inclined to disregard the maintenance problem with carbon granule microphones. Naturally the far higher price of the alternative design, including the amplifier, has a certain importance. In Europe, Norway has introduced an "electronic" telephone with a receiver as microphone.

Editorial Note: The APO is investigating alternatives to the carbon microphone.

The dial will of course continue to be the predominating signalling device to the exchange in the seventies as well. It may be expected, however, that keysets will gain ground at the cost of the dial. The keyset will be rather more expensive, but is preferred by subscribers — even at the price of a higher tariff — owing to its being more convenient to handle and quicker to use. Another advantage is that the keyset can be made with 12 keys, so that special code combinations can be arranged for various special services.

A number of systems for key signalling to the exchange have been proposed. It is probable that the system recommended by CCITT, with two groups of four frequencies each, will come into general use. It permits transmission to computers, and also signalling through exchanges and on all types of circuits, even quite poor circuits.

Within CCITT a discussion has also started about introducing 4 more buttons on the keyset, thereby making use of all possible 16 signalling combinations. By combining the keys two by two, alphanumeric signals can be produced which are directly understandable by a computer. It is not likely that this service will be needed on a wide scale until the eighties.

A technical-economical difficulty in the introduction of key dialling is the fact that the registers at the exchanges must be adapted to receive the signals from the keysets. That means that the registers very often must be replaced by new ones even when only a moderate number of subscribers are on a key basis. Designs of keyset equipment have, however, now appeared and come into some use, from which the key signals are stored temporarily at the telephone instrument and are then spilled out as usual dial pulses.

The external design of telephone sets has been fairly standardized, and no great differences have arisen between telephone sets made by different manufacturers. Around 1960, however, some new types were introduced, the Ericofon being the most radical departure. A more unconventional design of telephone sets may undoubtedly be expected in the future. Administrations will be forced to allow subscribers to buy telephone sets of their own choice. The subscriber can then choose the type which suits his environment and can also procure a new telephone if he becomes tired of the old one.

**VIDEOPHONE**

A new service which has attracted public interest to a great extent is the videophone. Several years ago Bell Laboratories in the United States started a large scale research and development program. In 1970 commercial picture telephone service (under the trade name "Picturephone") was introduced by AT&T in Pittsburgh and Chicago. Picture telephone research and development has also been carried out by telephone administrations and leading telephone manufacturers in a great many other countries, and some field tests are under way. Since 1970 the concept of "visual telephone service" (or picture telephone) has been under study by one of the working parties of the CCITT with the aim of international agreement on certain standardization aspects.

When the Picturephone project was nearing its commercial phase (1968-1970) the art of "picture telephone service" seemed to be well understood in its main aspects. Starting from a few basic concepts of the future service, Bell Laboratories had evolved the Picturephone system in a number of logical steps. The forecasts of Picturephone service growth were very encouraging. Many telephone administrations in other countries planned to adopt an almost identical kind of service in their own network in the future, although a few dissenting voices were heard. Today the outlook is more confusing, mainly because the commercial introduction of Picturephone service has been far from successful as yet. There are a number of reasons for this, such as the temporary economic recession in the U.S. and the need for improving the normal telephone service in some key areas before any new advanced service is introduced. The Picturephone subscriber also has a very limited number of persons to call in the beginning. The most salient fact, however, is maybe that the present Picturephone service seems to have a low market appeal due to limited performance, i.e. the basic Picturephone concepts do not include some of the latent important market needs.

Meanwhile other advanced point-to-point visual communication system proposals have emerged. The most discussed ones are various evolutions of CATV systems — "the wired city" concept. In these the present one-way TV distribution function is extended to two-way communication of various degrees of sophistication, ranging from a simple yes-or-no polling facility via a narrow-band back channel to information retrieval by means of so-called "frame snatching" as well as fully duplex audiovisual point-to-point communication. Many papers have been written on the subject.

Other proposals for a more flexible type of picture telephone service than the Picturephone have also been put forward by telephone administrations, and CCITT will in all probability widen the scope of the study on "visual communication". At least one telephone administration (the Swedish) is also carrying out a field test in accordance with this other approach. As yet very few papers have been published in the general technical press on this newer system approach, although some proposals were submitted already in 1970 to the CCITT committee.

Most published papers on picture telephone systems, videophones or Picturephone belong to the "optimistic" phase of the Picturephone project, i.e. before the commercial factor entered the picture. They do not necessarily represent the most likely evolution to be expected today with regard to visual communication. Visual telephone communication is a **new** medium. It is more than telephony with a picture, just as television is much more than radio with a picture. Although we can already foresee many important applications, the full impact on our daily life will only come gradually, when we have learnt to use the medium properly.

**LOCAL CABLE PLANT**

The local cable plant represents more than half the cost of telephone plant. Over the years much work has been done on reducing the cost of cable plant. At the same time, however, cables have varied considerably in price due to great variations in the price of copper.

The majority of multipair local cables are now made with 0.4 mm wire. Serious efforts are also being made to come down to about 0.32 mm. The difficulty here is that the wires become too weak and that great care must be observed in termination and splicing.

The rise and variability in the price of copper has stimulated an interest in the use of aluminium as conductor. There are problems in the use of aluminium as regards splicing and termination because of its low mechanical strength and oxidized surface. One may expect, however, that if the price of copper continues to rise, aluminium will come into wider use. Techniques are being developed which eliminate its weakness. It should be pointed out, however, that aluminium cables are larger. It may therefore be difficult to find space for them in existing conduits.

Polythene has replaced paper as insulating material in small local cables. It is likely to come into use also in multipair cables, in which paper is still the predominating material.

Lead will soon disappear entirely as sheathing material for local cables. It is being replaced by polythene combined with thin metal foil or tapes. For underground trunk and toll cables an extruded and corrugated aluminium sheath with corrosion protection and, where necessary, a steel armouring is a very favourable alternative to an armoured lead sheath.

It is sometimes necessary to introduce loading coils on long subscriber lines. Special repeaters are required in such case for the current feed. It appears, however, that loading of subscriber lines will have a very limited significance. Special, cheap carrier systems have been developed for subscriber lines, with which, by being lavish with bandwidth and being content with simple performance characteristics, it has been possible to reduce the amount of equipment to a minimum. The efforts in this direction, however, have not yielded especially good results — nor can one predict that, even with a cheaper circuit technique, systems of this kind will come into any great use.

Probably, however, carrier systems may find a use in subscriber networks for temporarily meeting a circuit requirement until there has been time to set up new cable circuits.

The new transmission systems with PCM (Pulse Code Modulation) for 30 channels were specially developed for use on existing pair or quad cables to extend the number of circuits. Often one cable is used for both directions of transmission. The main problem is then to keep the pairs for the two directions well separated from each other. This can of course be done by inserting shields in the cable.

The X-stranded unit cable developed by L. M. Ericsson's Cable Division is a good cable primarily for the low frequency range, but due to its well defined and suitable structure and simple rules for splicing, it is also excellent for PCM without any extra cost.

It is often maintained that a fully satisfactory telephone system can be obtained only if there are 4-wire connections to the telephone sets. On grounds of cost, however, the introduction of 4-wire connections on a broad basis is hardly likely.

In the long run one may reckon on a fairly complete transformation of the subscribers' cable networks. When desires for connections with larger bandwidth become common, e.g. for videotelephony, data viewing screens, TV from central aerials, it will presumably be cheaper in many cases to use small-diameter coaxial cables in a large part of the network. This will also make 4-wire connection possible to telephone sets. In such case a number of office rooms or flats could be served from one coaxial pair. There must then be a multiplex equipment prior to the branching point to the various telephone sets.

## TRANSMISSION TECHNIQUE

Transmission developments have hitherto mainly followed the analogue technique with FDM (Frequency Division Multiplex) systems, but during the last decade digital technique with PCM (Pulse Code Modulation) systems has acquired an important role.

### FDM Multiplex and Coaxial Cable

The development of carrier systems on coaxial cables started at the beginninng of the fifties. The stages have been: 960 channels in the early fifties, 2700 channels at the end of the fifties. Last year the first 10 800 channel system was taken into operation in Sweden. This system uses 60 MHz. The next version will probably go up to 200—300 MHz, but here problems with linearity of the components must be solved. Some preliminary investigations of systems of this kind are in progress in various parts of the world.

Coaxial cables and radio links are the most important transmission media for long distance communication. For intercontinental telephone transmission there are special coaxial cables in submarine systems and special radio links in satellite systems.

Coaxial cables now exist with 9.5 mm and 4.43 mm inner diameter of outer tube, the smaller cable being usable with advantage up to 2700 channels. Both smaller and bigger diameter tubes have been discussed, but these ideas have been abandoned, so far at least, as there is hardly any economical benefit.

### Submarine Cable Systems

The development in the submarine cable field has been very rapid since the first transistorized systems appeared a decade ago. This year a 1840-channel system was laid between Canada and the U.K. The administrations are today planning for even bigger systems between the U.S. and Europe with capacity of up to 3500 channels.

### Radio Links

Today most of the radio links are equipped with all-solid-state components. Only the highest capacity systems with 1800 and 2700 telephone channels are still using TWT tubes in the output amplifier stage. In a few years components will be available to equip also these high capacity systems with semiconductor devices. These developments have increased the economy of radio links very greatly. During the seventies there will be a continued development of new components towards miniaturization, better performance and reduced costs. Today the frequency spectrum up to 8.5 GHz is very extensively used. For future radio links still higher frequencies will be necessary. Developments are in progress for radio links using 12 GHz frequencies. However, the fading problems are severe at these frequencies, and therefore these equipments will probably be used for shorter distances.

So far the radio links have been used only with frequency modulation of FDM systems, but in the future PCM systems will be available. Very probably the higher frequencies above 12 GHz will be mostly used for PCM transmission, the noise requirements of which are not so severe as in the FDM systems.

### PCM Multiplex

There is an interest in multichannel connections, however, also for shorter distances, as in local networks. Systems have been designed on an FDM basis with greater bandwidth in order to obtain cheaper apparatus. Attempts have also been made with FM modulation. The most promising technique, however, is the PCM systems, which with the falling price level for digital circuits have been able to expand their economic range to increasingly short distances. The original systems have 24 channels with 7-bit definition. Within Europe a system has been developed with 32(30) channels and 8-bit definition, which will be the future standard.

Studies are at present being made in many quarters on wide-band systems for coaxial cables with PCM. In the long run these should be able to compete with the FDM systems. For the videophone these systems should also, purely technically, be a better solution.

In the U.S., mixed systems with analogue and digital transmission are being discussed. It seems to be possible to take out a group of 1800 channels from a coaxial system and establish digital transmission on it. The capacity of such a group will be around 80 Mbit/s or, per telephone channel, 44 kbit/s. One makes use of 16 primary levels on the bitstream.

### Wave Guides

When videophone services become available in the future, the requirements for transmission capacities cannot any longer be met by today's transmission systems. One way of solving this problem is to use wave guides as transmission media. Frequencies between 30—90 GHz will be used and transmission capacities of 400,000 telephone circuits will be available. Field trials on a commercial scale will be carried out in the U.S. and the U.K. within a few years.

During the last years wave guides using glass fibres have also been studied. Frequencies in the same range as visible light will be used.

## SATELLITE COMMUNICATION

The International Telecommunication Satellite Consortium, INTELSAT, has now four of its largest telesatellites (INTELSAT 4) together with four of the next largest telesatellites (INTELSAT 3) in operation above the Atlantic, Pacific and Indian Oceans. These eight satellites carry today over half of all intercontinental telephone traffic. At the same time all exchange of TV programs over the oceans passes via satellites. With the introduction of the domestic Canadian telesatellite system and with the planned operation of domestic systems in the U.S., it is fair to state that even for long distance transcontinental communication the satellite will take 1/3—1/2 of teletraffic. A regional European telesatellite system is under development by European industry under the management of ESRO.

Regional systems are also planned for South America. Here, however, it will not be a separate satellite development but it may be expected that South American countries will hire preassigned transponders for their services from INTELSAT.

## TELEPHONE EXCHANGES

The technical development since the second world war has been dominated by the crossbar switching technique. In the early fifties there were already commercial exchanges for all requirements. Fully engineered systems for rural and trunk automatization could be offered. International subscriber dialling started in the sixties. The production of crossbar exchanges is rising sharply throughout the world. Crossbar switches are now being used for new automatization projects and for replacement of earlier equipment. In various parts of the world new factories have been built, nearly all of which produce crossbar switches. One may expect that, even if the development now proceeds on partially other lines, the crossbar switching systems will continue for a long time to predominate among new installations all over the world.

During the fifties the development laboratories of telephone manufacturers started to become interested in electronic switching. As prototype and source of inspiration there was the allied computer technique, which started to overcome its teething troubles in the early fifties. It was thought that the logic and memory functions, which in automatic exchanges were performed by electromechanical switches and relay sets, could with advantage be built with electronic components. The enthusiasts for electronic switching were, however, overhasty. The requirements of reliability were much greater than could be achieved with electronic components of that time. There was also a special problem in the fact that the speech paths in the exchanges could not, with electronic contacts, both transmit speech currents and signal currents to the telephone bell.

The exchanges, furthermore, appeared to be hopelessly expensive. The greater speed of electronics, which is of value in other contexts, was not a sufficient compensation.

One may say that it was not until the break-through of the semiconductors that the conditions were created for a successful approach to the problem of electronic exchanges. As regards reliability, life, current economy, and cheapness, the semiconductors have surpassed anything that could have been dreamt of only 10 years ago. Despite these advances electronic exchanges have not as yet been competitive other than for certain types of exchanges. Examples have been the all-electronic exchanges built by the Ericsson Group for the U.S. Air Force in the early sixties. These were designed for time division multiplex on a 4-wire basis. They had special 4-wire telephone sets and very complicated traffic conditions, which were the technical motive and economic basis for an all-electronic solution.

In recent small- and medium-size systems electronics has been used in the wired logic mode of operation to realize control functions, whilst miniature relays perform signalling functions and metallic contacts provide the speech paths.

However, the outstanding feature in the present development of automatic switching is of another form, the introduction of stored-program-control. The prerequisite for stored-program exchanges is created by the cheap mass-memories with short access time that electronics makes possible. Electronics is motivated by the possibilities it provides, not by its own value.

In exchanges of older types the mode of functioning of the exchange is determined by relay sets, registers and markers. In the stored-program exchanges the determination of functions is done by a program read into a memory. This provides a very great flexibility, both in respect of different signalling systems and traffic facilities, and of changes which may be desirable in the future. For the introduction of a new traffic facility or the connection of lines with a different signalling system, no other changes are usually required than to read a new program into a program memory.

Stored program control also means that the exchange to a large extent can trace and diagnose faults which arise. There are programs for fault tracing which enter into operation periodically or on detection of a functional fault.

The stored program-controlled exchanges of type AKE represent, with certain other equipments, a system in which the centralization of functions has been taken a very long way. This was natural in view of the circuitry and memory techniques available for the design of the system. With new components of IC type now available, some of the functions, especially those which are standardized from exchange to exchange such as scanning and perhaps also the setting up of connections, might have been realized in circuits or in memories of "read only" type. The variable program memory would then be used chiefly for functions in which there are differences from exchange to exchange and for changes in the traffic conditions and signalling systems.

The new component technique will also lower the limit for the stored-program-controlled exchanges as economic alternative.

Stored program control brings us into a new epoch — perhaps the most radical advance since the introduction of automatic exchanges. The stored program exchanges in Europe and America have hitherto been constructed with metallic contacts in the speech network. Stored program control, however, can also — and with great advantage — be used for an electronics speech network as soon as a suitable switch is produced.

The motives for the use of mechanical switches in the speech network are partially concerned with cost, but also with the fact that there is a greater freedom on the line side. One can thus transmit both direct and alternating current and also change the polarity of the direct current, which may be required for example for pay stations. Remote measurement of circuits will be possible. One can also transmit a larger bandwidth.

For a certain class of exchanges, namely the trunk exchanges, the superiorities of the mechanical switches are no advantage. There are no subscriber lines connected, and therefore one need not transmit direct current or ringing current. Futhermore, the bandwidths are limited to the ordinary telephony range of 300—3400 Hz. For this purpose one could undoubtedly use eletctronic switches in space division. Of greater interest, however, is time division multiplex, especially on a PCM basis.

In integrated systems one has the same information carriers on lines and in exchanges, and the point of interest in this respect hitherto has been PCM. It has been asserted that the consistent use of PCM in exchanges and outside plant would lead to a cheaper and technically better overall solution. The PCM code is transmitted in the entire system without demodulation. As a channel which carries a conversation must change pulse position when it passes through the exchange, and once again when it passes out of the exchange, a buffer register is required in the exchanges both at the inlets and at the outlets. Another reason for these registers is that the speed of propagation will differ on different types of lines. As the majority of trunk circuits for many years to come will be on frequency divided carrier, and junction circuits on the local plane will be D.C. type, the natural inertia of these investments will delay the establishment of integrated systems.

Delta modulation has been proposed as an alternative to PCM. Delta modulation is probably better adapted to the circuit between telephone set and exchange and to cheaper modulator and demodulator equipments. Its disadvantage, of course, is that no transmission systems with delta modulation either exist or are planned.

As regards traffic facilities, trunk automatization has been an obvious goal in most countries and has already been achieved in many. The next step is international subscriber dialling. This has already been introduced between several countries in western Europe and also between the U.S. and Canada. From the technical aspect there is hardly any obstruction to automatic telephony throughout the world. The limitations lie in the insufficient number of circuits. Furthermore, registers for the large number of digits must be inserted in the local networks. The comparatively expensive conversations often require the introduction of automatic toll ticketing.

The stored program local exchanges have made possible the introduction of various traffic facilities for subscribers at a low additional cost (see separate list). It is not yet known to what extent these will be used and appreciated by subscribers. Information on this point will be gained through field trials. Probably, however, these traffic facilities, and perhaps others which may be invented, will be provided by administrations in future. This does not mean, naturally, that all subscribers will use them. It will be necessary to offer these traffic facilities in older exchange areas as well.

The telephone industry is in actual fact now working on equipment for older exchanges which allows the introduction of these traffic facilities.

Within the **PBX field** the development has not been so striking. This technique was already very far advanced at the start of the second world war. A facility that will gain in importance is indialling which, however, also necessitates changes in the public exchange which might hamper a development in this direction. What we may further foresee during the seventies is an increased use of centralized private branch exchanges, i.e. exchanges which contain equipment for a number of PBX customers. This brings great savings in installation and maintenance costs. Within another sphere one may also foresee a continuing development, namely in the interconnection of several PBX systems to serve different establishments belonging to one enterprise.

**TELEX**

Telex has been the service that has grown most vigorously within public telecommunications since the war. The same rate of growth may be expected to continue during the seventies. At the same time the ordinary telegraph service will be pressed back more and more.

Teleprinters are at present being designed on a mechanical basis. In several quarters there is a trend to full, alternatively partial, electronization. It is electronic versions of transmitters and receivers for the telegraph signals that have been realized initially.

From a technical point of view there is a possibility of making an electronic printing unit, but it may take some time before an economic solution is attained. Various electronic nonimpact printers have been developed today, however, but these are not yet in practical telex use.

The exchanges have hitherto been designed on an electromechanical basis. In actual fact telex exchanges are better adapted than telephone exchanges for electronization, and one may expect a development in this direction during the seventies.

A special kind of telex and telegraph exchange is the so called message-switching exchange. In these an intermediate storage of telex messages takes place until transmission circuits become free. One or a couple of message-switching exchanges are established in each country, preferentially for international traffic. These exchanges are now stored-program-controlled.

The standard speed for telex is 50 baud. The international telex network is designed for this speed. Many administrations are today considering speeds of 200 baud. Certain types of asynchronous data communication — of which so called time sharing is one – will perhaps in the near future be carried by the telex networks.

**DATA COMMUNICATION SYSTEMS**

Data transmission is a child of the sixties. Originating in a military requirement for rapid transmission of information concerning, perhaps mostly, hostile air movements, it has now become a very quickly growing service. It is the increased use of computers within government, industry and research that has stimulated the interest in data communication. One may foresee a very greatly increased use of data communication during the seventies.

Perhaps, however, earlier forecasts have been exaggerated. It is believed now that the U.S., which is the forerunner in this technique, will in 1980 have about 5% of its telephone channels in use for data transmission.

The transmission of data may be based on parallel or series transmission of the flow of data. In the parallel systems the available channels are divided into subbands, each of which carries a signal current. The serial systems, however, appear to be more common. In these systems the entire bandwidth is used for the flow of data in serial form.

The transmission within the frequency band takes place with a carrier frequency which in principle can be amplitude-, frequency- or phase-modulated.

On an ordinary telephone channel it seems at present possible to transmit up to 9600 bit/s. For speeds higher than 3600 bit/s is is generally necessary to have special equalisers which compensate delay distortion over the circuit. These equalisers can be manually operated or automatic.

With a more developed technique it will probably be possible to use higher speeds in the future on a given bandwidth.

The applications are many. Enterprises with several computers at different places have communication between the computers for joint planning of production, reporting, financial statements. Banks have communication between their main and branch officers for direct entries of deposits and withdrawals on their customers' accounts, for statements of account etc. In some countries government departments have a data service with which one can send a data processing order to a central point and receive an answer when the order has been carried out. Business managers can from their homes have communication with the company computer and receive statistical data from it, e.g. concerning the order or cash situation, on their home data viewing screen.

In the future cashless and chequeless society it is envisaged that all payments will be made in the form of accounting transactions in large central computers which are actuated from other computing centres and decentralized data terminals of a fairly simple kind. Many administrations in Europe are today planning separate data networks. Over these networks computers of different kinds can be reached, i.e. serving various functions in society such as registers of population, real estate, post office bank accounts, police register, automobile register etc. Bank and other systems can also be integrated with countrywide coverage. A network of this kind can generally accept different data speeds. The switching units will be of a special kind, requiring a much higher connecting speed than a telephone exchange due to the shorter average holding time of a data message compared with ordinary telephone calls. Data communication is a natural complement to data processing. In actual fact data communication is a condition for continued development of the processing technique. A tempestuous development may be expected during the seventies.

## GENERAL ADVANCES

General advances within the natural sciences and mathematics will, of course, play a great role also in the purely technological development. Certain more general tendencies may be distinguished, which I shall go into.

Within the field of applied statistics and operations analysis the telecommunications technique has been a prime mover. In actual fact, in its traffic research, telecommunications was among the first sectors to take this branch of mathematics into its service. Telecommunications technicians have made essential, purely mathematical, contributions in this field. As regards the calculation of congestion in switch groupings of different kinds, all main forms have presumably now been covered. What remains is various special problems, but above all the calculation and planning of large networks with different forms of alternative routing. A better survey will undoubtedly be obtained during the seventies. The present work will also be carried further in the form of data programs for calcu lation of these networks. Other questions in this context are forecasts of subscriber growth and rules for the selection of stages of equipment expansion to provide the best economy.

During the seventies we shall also obtain a full insight into how the processors in the stored program exchanges are to be dimensioned. We do not know at present with full certainty how the different priority levels affect one another.

It should perhaps be pointed out that traffic research and operations analysis have found an invaluable aid in the computer. Computers will in future permit solutions of difficult and laborious problems. They are used both as pure calculators and for the simulation of traffic.

One may say that telecommunications technique, especially telephony, has always been directed to human beings. It is a question of transmitting information from man to man. Studies have therefore been made of the functions of speech and hearing, from which essential parameters such as attenuation, crosstalk, noise, etc. could be delimited.

In recent years, however, we have gone further and more systematically studied the interplay between man and communication-machine. An example of this is traffic research, in which much still remains to be done as regards the question of how telephone traffic arises, mathematical models for traffic in small groups, the subscribers' behaviour on encountering busy condition etc. This aspect of traffic research has lagged behind and may be expected to be more intensely studied in the seventies.

Human factor research includes such matters as subscriber reactions to new traffic facilities, the most appropriate procedure for international traffic, the location of the digits on the dial, the design of operators' positions and much else. All this, to be sure, is nothing new, but a more conscious effort is being made to take human factors into consideration.

Within the operations sector continued intensive work will be done on rationalization of installation and maintenance. Administrations and industry must continue to cooperate in producing equipment which has high reliability and requires low maintenance. The equipment must be designed to provide the performance required and must be so arranged that faults can be easily found and corrected.

Mention has been made of the role of computers in traffic research. They also have a great importance, however, in the multitude of calculations of different kinds which preceded the production of new equipment. Within filter technique the computers have entirely revolutionized the method of calculation. Also for circuits. One may count on still more refined programs permitting, for example, tolerance analysis. Simulations may also be appropriate in many cases.

To sum up, it may be said that telecommunications technique will become a more electronic technique, but still with very essential elements of mechanics. One must reject the possibility of the use of new non-electrical techniques such as fluidistors and chemical relays. The advantages and the lead of electronics and electromechanics are so great that they cannot be superseded within the foreseeable future. Likewise the fundamental sciences of physics and chemistry show no new discoveries which appear to lead to new principles of design.

It is therefore a very well founded judgement that telecommunications technique will continue to develop on its previous lines, still carrying, of course, the stamp of the often ingenious and devoted technicians in industry and administrations.

## LIST OF TRAFFIC FACILITIES FOR STORED PROGRAM EXCHANGES

*Abbreviated Calling.*

This means that a subscriber who frequently calls certain other subscribers only has to dial short code numbers instead of their complete directory numbers.

*Follow Me.*

A subscriber temporarily can have all calls to him automatically transferred to another instrument.

*Alarm Clock Service.*

The subscriber has the possibility to register in the exchange the time of day or night at which he wishes to be called. For this registration the subscriber dials four digits in accordance with the international 24 hour cycle.

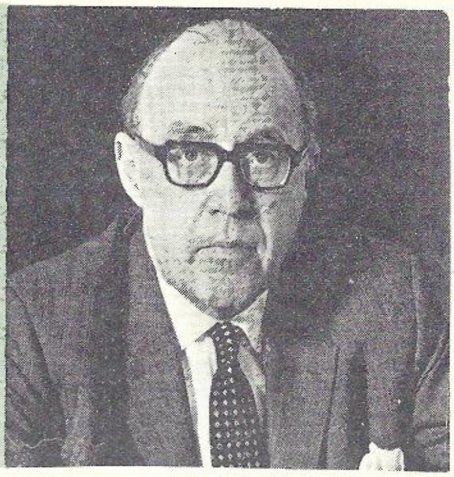
*Call Back.*

A subscriber who has dialled an engaged number dials a further code digit and replaces his handset. He is then called back automatically as soon as the busy subscriber has become free.

*Transfer on Busy.*

A call incoming to a busy telephone is automatically transferred to another number.

Dr. CHRISTIAN JACOBAEUS is Executive Vice President in charge of Research and Development at the LM Ericsson Telephone Company, Stockholm, Sweden. Dr. Jacobaeus graduated from the Royal Institute of Technology in Stockholm in 1933 and joined LM Ericsson two years later. He has served this company in various capacities ever since. He was appointed Vice President in 1953 and Executive Vice President in1963. Dr. Jacobaeus is responsible for many inventions relating to telecommunications equipment and has written numerous articles on telecommunications subjects in the technical press. In 1950 he was awarded the degree of Doctor of Electrical Engineering.



# Technical News Item

NATIONAL TELECOMMUNICATIONS PLAN (NTP 2000)

A National Telecommunications Plan Group has been established in the APO's Planning and Research Division at Headquarters to formulate broad policies for the total telcommunications needs of the nation up to the year 2000 and to develop long-term plans to enable these objectives to be met. The group comprises a small number of engineers together with some non-engineering professionals, covering respectively the fields of Economics, Market Research and Social Sciences.

During the late 1950's the APO prepared a Community Telephone Plan which provided the framework for extended automatic telephone service (national STD) in Australia and successfully guided its development into the 1970's. The Community Telephone Plan confined itself to the traditional type of telephoning service. However, recent advances in telecommunication technology—particularly in visual and data transmission areas with computer access from remote locations—foreshadow a potential for many new service offerings of the future.

In principle, technology now can provide almost anything that an be imagined in catering for the transfer of information by visual, aural and data format, using a range of new terminal facilities that could be offered and new methods of reticulation to customers' premises.

It has been international experience that a lead time of the order of 20-25 years is needed to substantially transform a telecommunications network, and if the APO is to cope with the customer needs for new classes of services required by the beginning of the 21st century, and with a number of key technical and policy decisions expected over the next few years, then planning must begin in the 1970's.

Possible future services offered by a wideband subscriber distribution network using, for example, optical fibres, could include high capacity television (30 or more channels) for entertainment, education and public access, person-to-person picturephone and visual display of information stored in computer banks. Prospects also include telemail, home production of selective newspaper items by facsimile, and widespread mobile telecommunications services.

The changed nature of the possible range of customer facilities as well as their method of provision means that the APO should not only be technologically and customer oriented but should also consider the sociological and economic effects on he community. For example, the interaction of telecommunications with areas such as education, transportation and urban planning must be explored.

# A Communications System for the Moomba Natural Gas Pipeline (Part 2)

A. MONTGOMERY, B. Tech. and B.G. HAMMOND, B.Sc, MIE (Aust.)

*Part 1 of this article, which appeared in a previous issue of the Journal, described the development of a communication system for a natural gas pipeline in South Australia. It included a description of the external plant used. This present Part 2 describes the internal plant such as mobile radio, supervisory system, power plant, and various installation aspects.*

## THE CARRIER SYSTEM

Two discrete carrier systems were provided to meet the requirements of the Natural Gas Pipeline Authority, namely:

- The end-to-end carrier system (12 channels).
- The omnibus carrier system (3 channels).

The end-to-end carrier system was installed at the terminal stations only (Moomba and Peterborough). The omnibus carrier system was installed at all intermediate repeater sites. Standard STC carrier equipment to APO Specification No. 972 and the relevant "1000" series specification was provided although the modem equipment was repackaged to suit this particular application.

The end-to-end carrier system provides general communication facilities between Moomba and Peterborough. Each terminal is equipped with standard modem, carrier supply and associated equipment to modulate 12 telephone channels to their allotted 60 to 108 kHz band in the transmit direction and to demodulate the 12 channels in the receive direction. Each of the 12 channels is equipped with E and M signalling which utilises a signalling sub-carrier of 3825 Hz. The M-lead of a channel accepts an earth to give the signalling tone. The E-lead of a channel gives an earth on receipt of the signalling tone. The group-end at each terminal is supplied from a duplicated carrier supply having automatic changeover to standby in the event of a failure of the normal carrier supply. The channel modem equipment in the end-to-end carrier system is not duplicated. However, spare channels are available in the subrack and in the event of a fault on the working channels traffic can be transferred to the spare channels by patch cord changes.

The present allocation of channels on the carrier system is as shown in Fig. 7.

A simplified block diagram of the overall carrier system is shown in Fig. 8 and Fig. 9 shows the 12 channel and omnibus carrier racks of the Peterborough terminal.

## THE OMNIBUS CARRIER SYSTEM

The omnibus carrier system is a low density carrier system designed to suit the requirements of communication networks which require traffic to be inserted and extracted at several points. The system operates in the 12 to 24 kHz band, i.e., channels 1, 2 and 3 of the 24 channel system. The omnibus carrier system combines (collects) the modulated outputs of all channels from all repeater sites and transmits them to the master terminal (Adelaide) in the return direction known as the "Collector" direction. At the master terminal the channels are demodulated and may be re-modulated for retransmission (distribution) to all repeater sites in the go direction known as the "Distributor" direction. Thus the information collected at each repeater in the Collector direction may be retransmitted to all sites in the Distributor direction, allowing voice or data communications between any two points in the system. The system controller (NGPA Despatcher) can communicate from the master-terminal to the remote sites with priority over any Collector information.

Although the master terminal is situated in Adelaide, the actual modulation and demodulation of all channels takes place at Peterborough. The channels are then transmitted to and from Adelaide as VF circuits. It is emphasised that in both the 12 channel and omnibus systems any information translated into any channel remains in that channel to its ultimate destination. Whilst traffic inserted at Peterborough will be demodulated to VF at each repeater site and at Moomba, operation of the system does not involve demodulation and

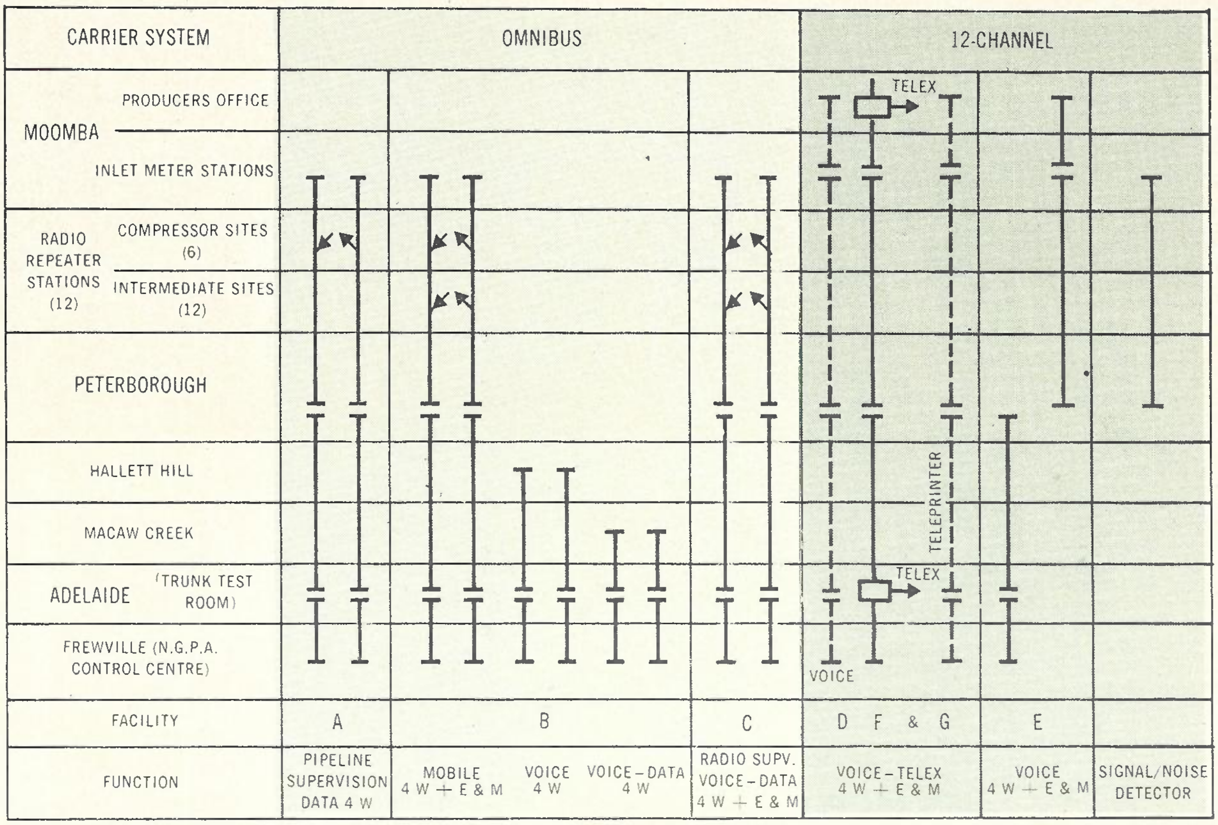



**Fig. 7 — Communication Circuit Requirements.**

re-modulation on a tandem basis at each site. In the Collector direction traffic inserted at the remote sites will not be demodulated until Peterborough.

All omnibus channels operate in the parallel redundant mode. The inputs and outputs of two identical channel modems are combined through hybrid transformers.

Channel 1 (12 to 16 kHz) has been allocated as a collector and distributor for mobile communications (Facility B). Associated with this channel is an 11·5 kHz carrier employed in the Collector circuit only as part of a best-signal selection system. The E-lead of this channel is utilised to operate the press-to-talk on the VHF transmitters and the M-lead is used to indicate that a particular base receiver has received a signal of sufficient strength to lift its mute.

Channel 2 (16 to 20 kHz) has been allocated as the circuit for the supervision of the radio system (Facility C). Supervisory tones are generated by the supervisory transmitting equipment at each repeater station and are received by corresponding supervisory receiving equipment on display racks in the NGPA Maintenance Depot at Peterborough and at the Control Centre in Adelaide. 14 tones from the 14 stations north of Peterborough are transmitted in the range 1.7 to 3.4 kHz in the Collector direction. Since the radio system is self-monitoring and has automatic changeover facilities built-in, remotely transmitted control and/or interrogating signals are not necessary. For this reason the Distributor direction of this channel is not used but is fully equipped and operational. The E and M-leads of this channel are used for an omnibus carrier test facility.

Channel 3 (20 to 24 kHz) has been allocated to operate in an omnibus mode for bothway transmission of control, supervisory (compressor station) and telemetry data signals (Facility A). The E and M-leads of this channel are not used. Since this facility is required only at compressor stations, the modem equipment necessary has only been installed at those radio sites which are co-sited with the compressor stations. Fig. 10 shows the frequency allocations in the baseband.

Three unique concepts are associated with the omnibus carrier system. These are the carrier test facility, the 132.037 kHz tone for the synchronisation of the VHF base transmitters and the best-signal selection system associated with the VHF network.

The carrier test facility is used in conjunction with

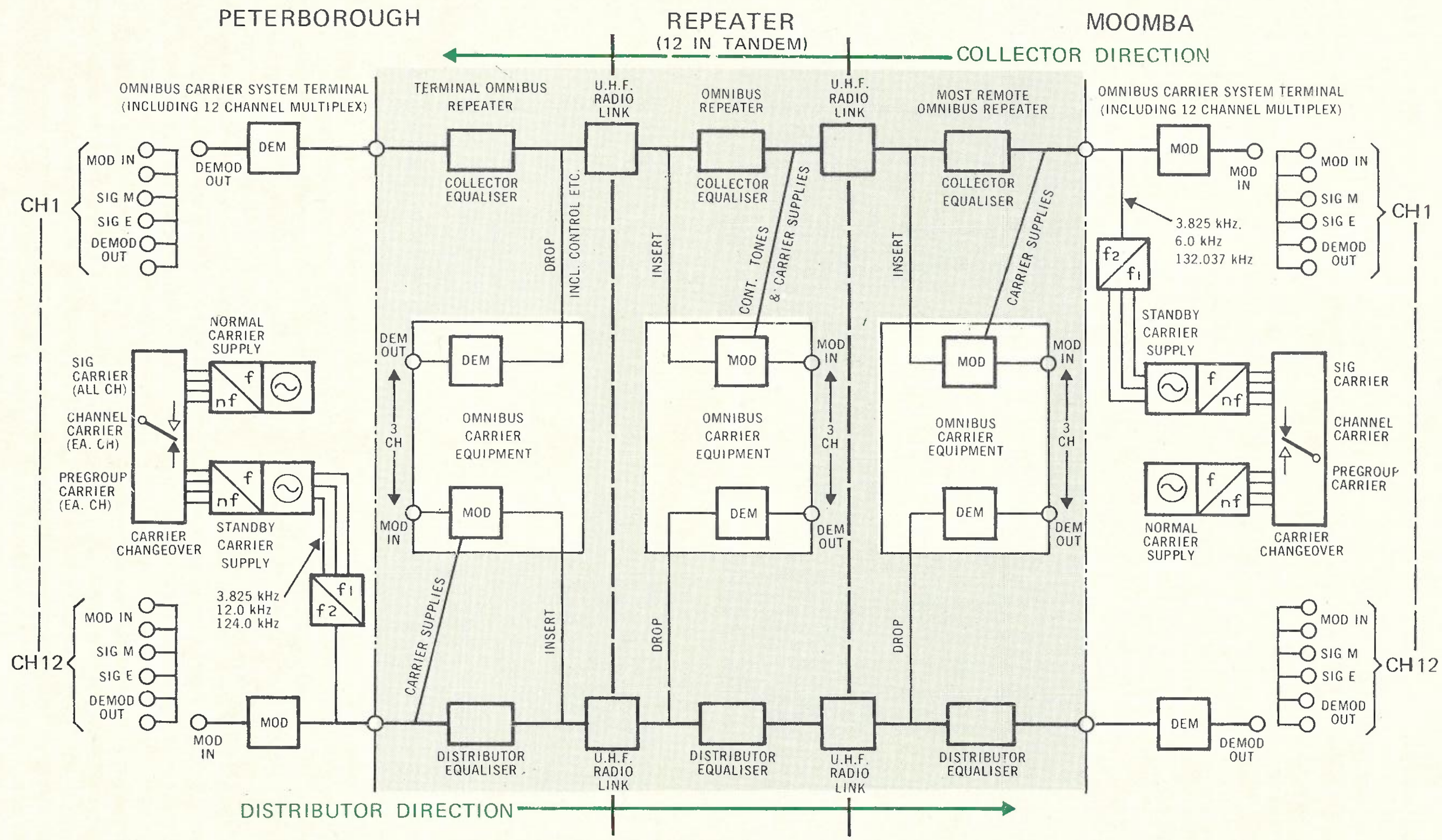



Fig. 8 — Simplified Block Diagram of Carrier Transmission Circuits.

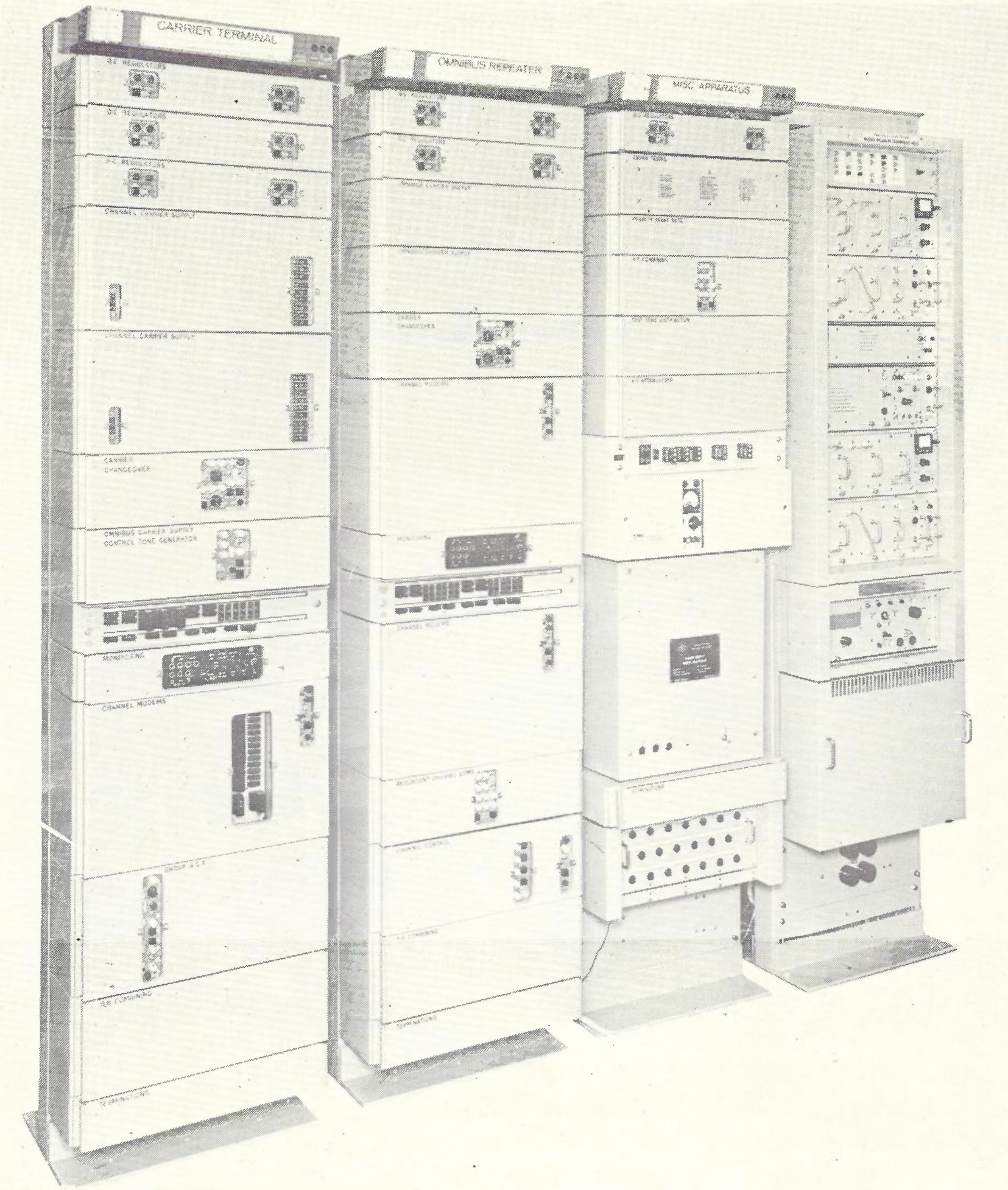



**Fig. 9 — Rack Layout of Carrier System, Peterborough Terminal.**

the systems supervisory equipment. Failure in the redundancy of the duplicated carrier equipment (non-urgent alarm) is sensed at the various remote sites and Peterborough but is not displayed until the carrier test cycle is initiated. Initiation of the test cycle is performed manually by the Despatcher. The test cycle seeks the omnibus carrier modems, signalling transmitters and receivers and the continuity of the VHF radio bearer. If both diesel engines fail to start (when asked to do so by their control system) after their three attempt sequence, the carrier test cycle will reset the diesel control system and initiate another three attempt start sequence.

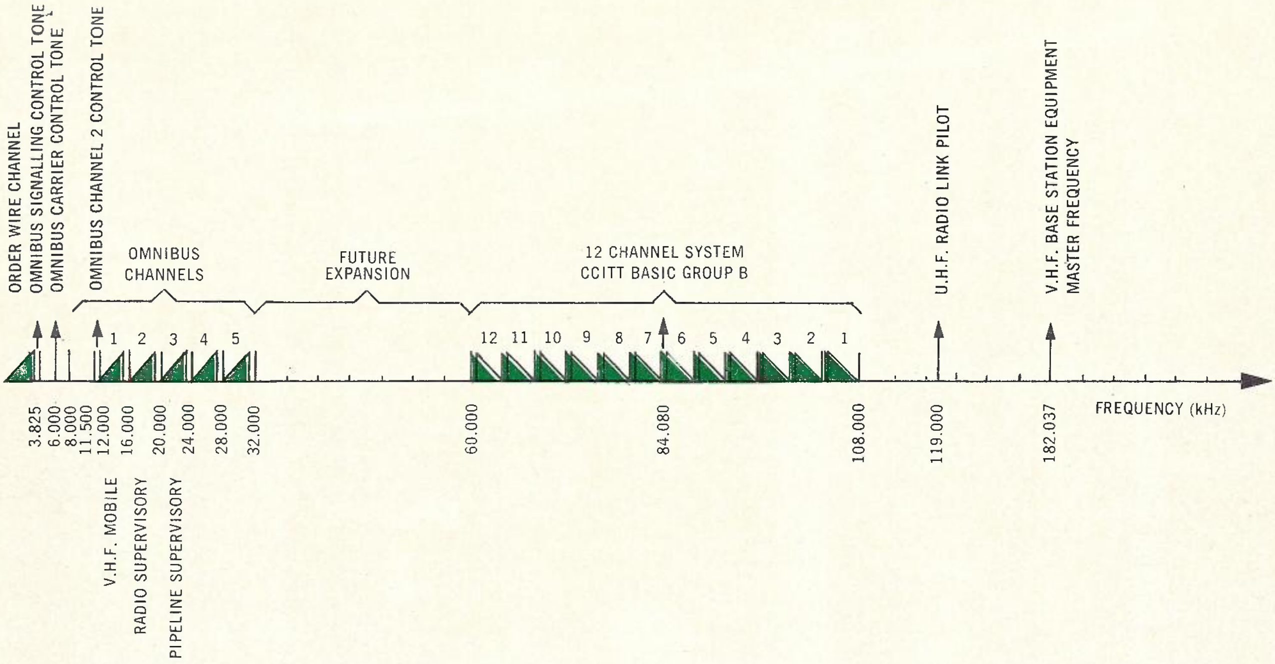



**Fig. 10 — Baseband Frequency Allocations.**

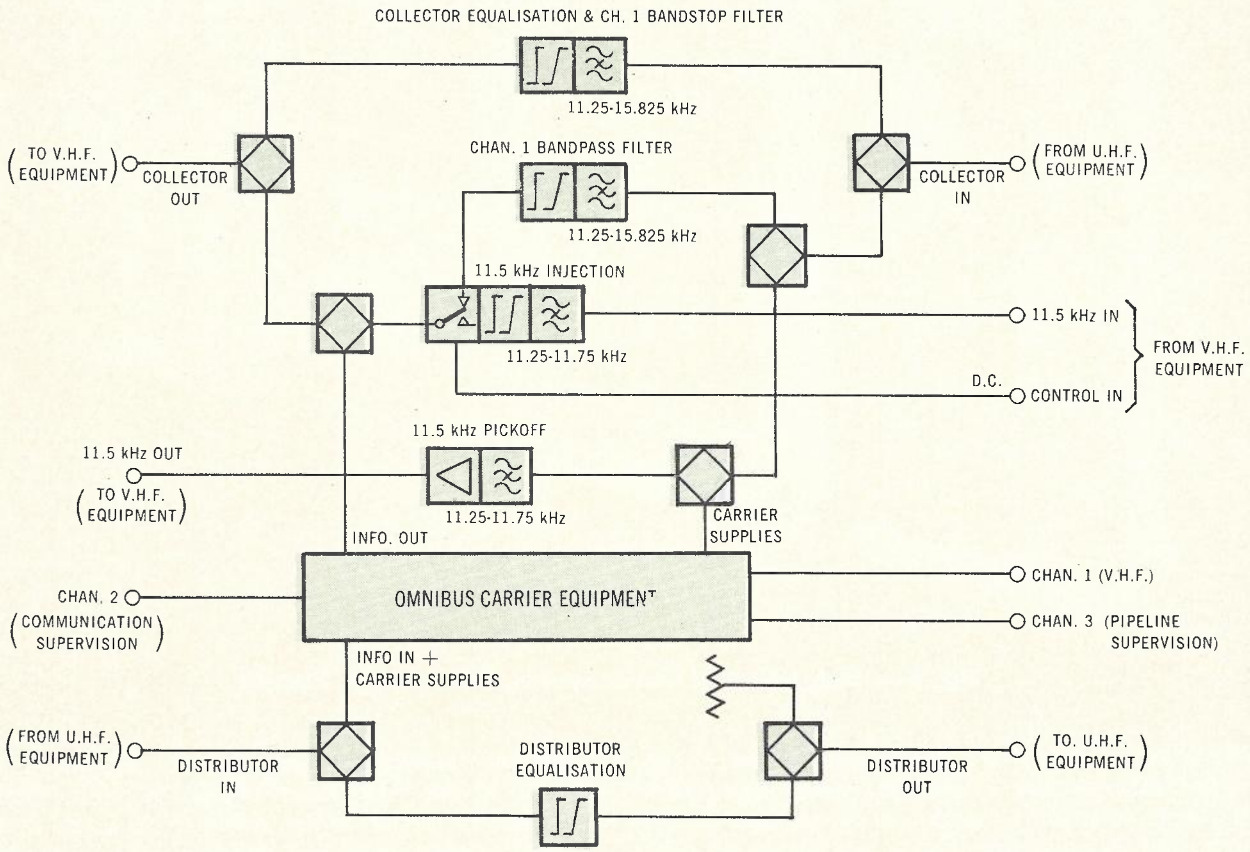



**Fig. 11 — Omnibus Repeater.**

The method of synchronising the VHF base transmitters is described in the section headed Mobile Radio System.

The best-signal-selection system ensures that only the best mobile voice signal is injected into the Collector baseband. This system actually compares the quality of the signals in the VHF receivers at two or more base stations and injects only the best signal into the Collector circuit. The comparison takes place in the VHF equipment and will be described later but the equipment for injecting the best signal into the network is contained in the carrier rack. Fig. 11 gives a simplified block diagram of the best-signal-selection equipment in a repeater station.

The complete carrier system met all the require-

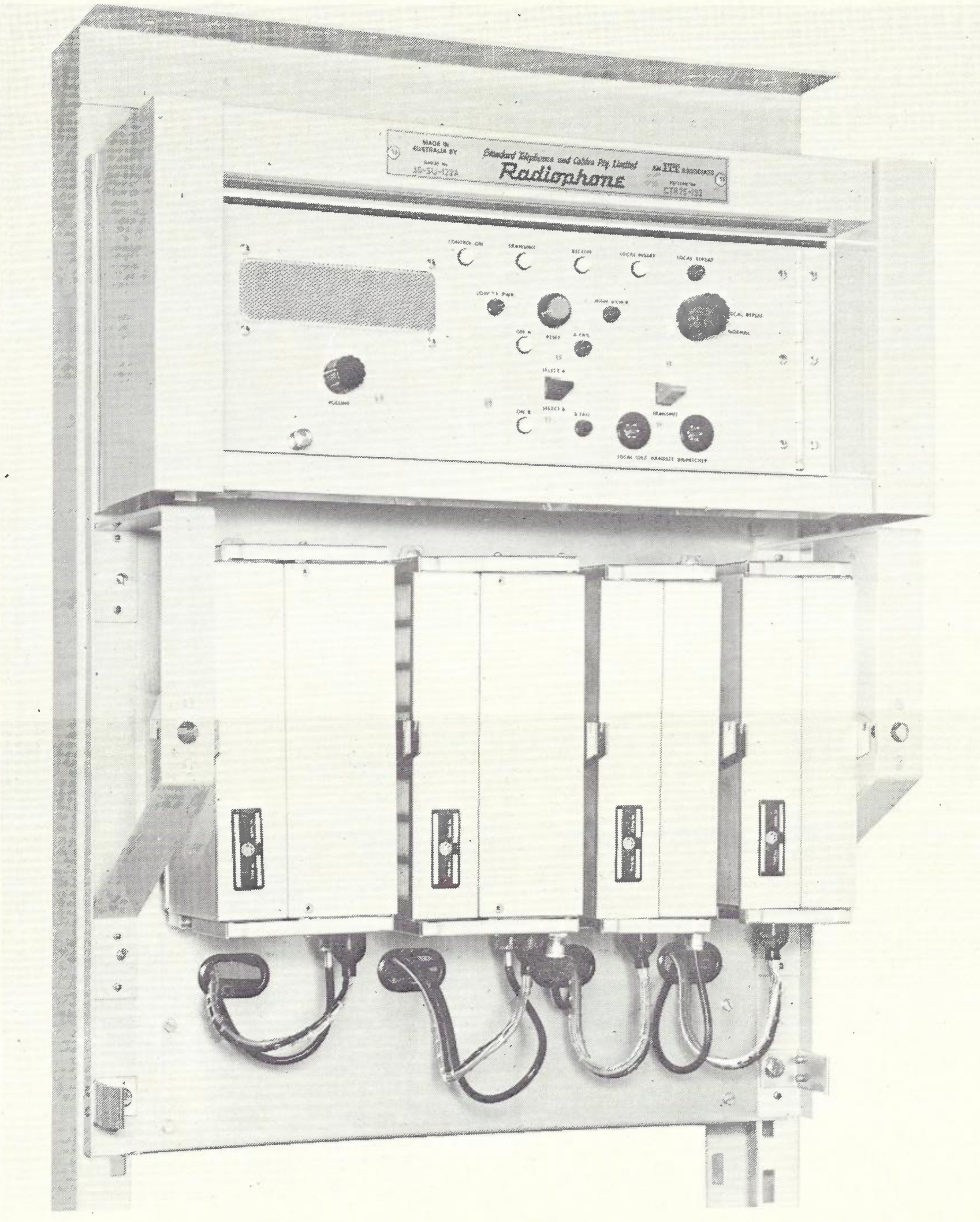



**Fig. 12 — Mobile Base Station Equipment.**

ments of the specifications when acceptance tested. All channels had a frequency response conforming to CCITT Recommendation G511. Crosstalk measurements were typically –55 to –60 dBmO, with the worst case –43 dBmO, intermodulation was typically –45 to –50 dBmOp and channel noise was –51 dBmO in the worst case.

## THE MOBILE RADIO SYSTEM

The mobile radio communications system is designed around the basic STC mobile equipment, Type MTR151. The base stations operate as talk-through repeaters in which the transmitter and receiver simultaneously operate from a common aerial. To ensure that mutual interference does not occur the transmitter and receiver are separated. The transmitter and receiver are specially packaged for fixed base station operation and are fully duplicated. An associated control sub-rack contains all the circuit boards and modules for local and remote control, self-monitoring and automatic change-over of the mobile equipment. The mobile base equipment is housed on the same rack as the UHF radio equipment as shown in Fig.9. A close-up of the mobile equipment with the bottom cover removed is shown in Fig. 12. The transmitters operate with a power output of 20 watts on a frequency of 171.12 MHz and the receivers operate on a frequency of 160.00 MHz into a common aerial of 10 dB gain. Fig. 13 is a simplified block diagram of the VHF system.

The VHF base station is a fixed frequency duplicated talk-through repeater designed for continuous operation. Normally the receiver output passes to the Collector circuit whilst the input to the transmitter comes from the Distributor circuit. Comprehensive automatic testing and fault indications are provided together with automatic changeover from "main" to "standby" on the failure of the working unit. The unique features, referred to earlier, incorporated in the mobile system are:

- Synchronisation of the transmitter carrier frequency on all base stations.
- Automatic testing of the complete VHF system.
- Best signal selection (or best path) system.

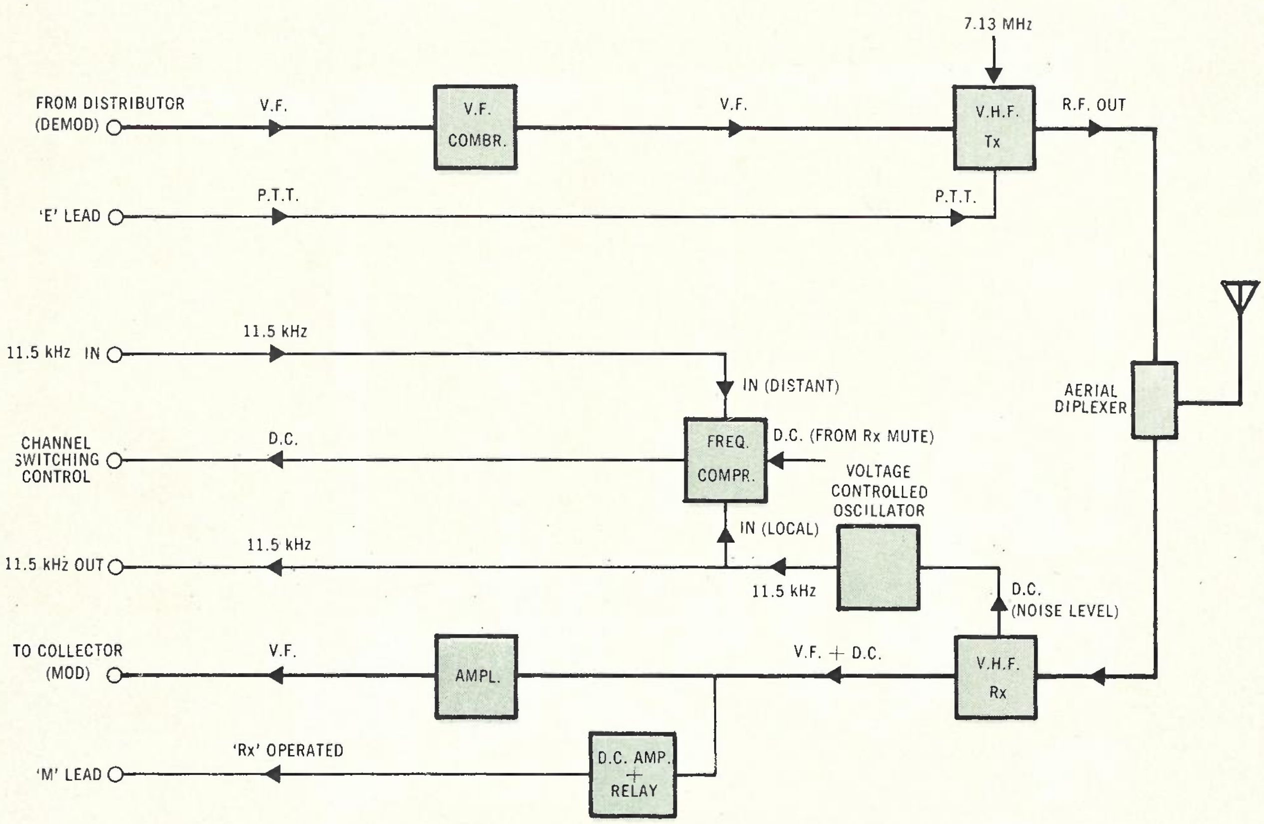



**Fig. 13 — VHF System.**

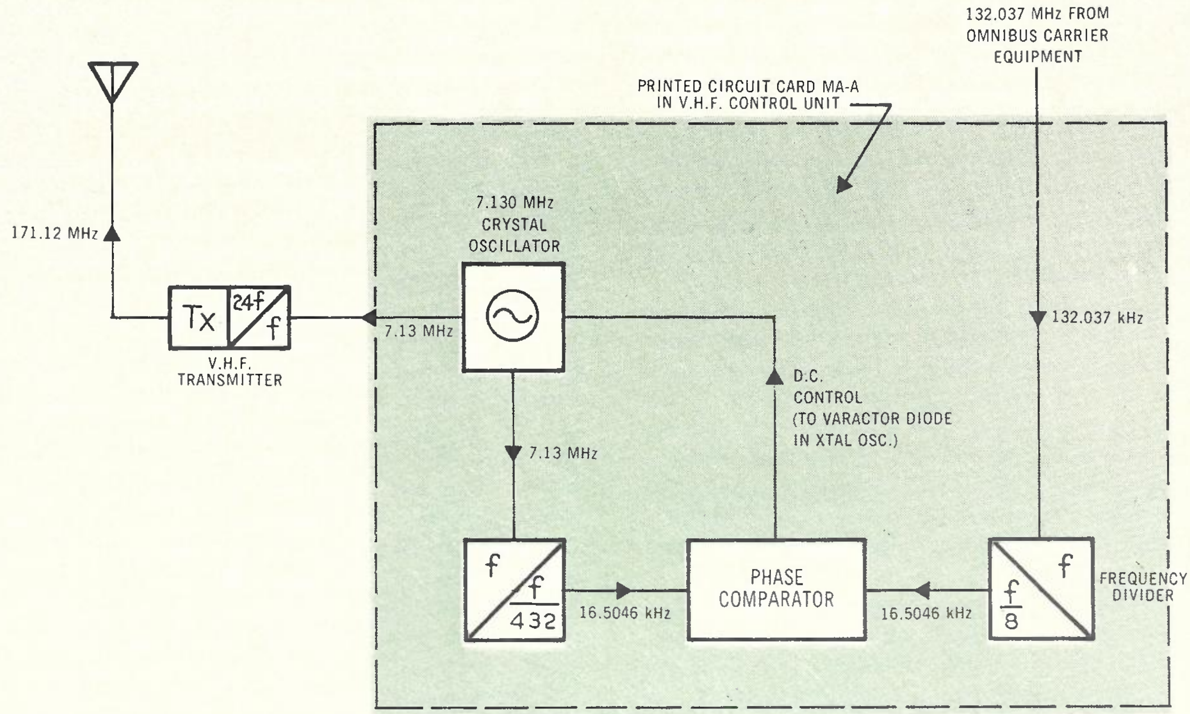



**Fig. 14 — VHF Frequency Synchronisation.**

**Synchronisation of Transmitter Frequency**

In any network where two stations operate on the same nominal frequency, but are not absolutely synchronised, a beat note will be generated in a receiver which is receiving the two stations with approximate equal strength. The beat frequency will be the sum or difference of the two transmit frequencies. This spurious tone can fall within the speech band and produce annoying interference. By synchronising all the transmitter frequencies in the system the beat interference can be removed.

A control tone of 132.037 kHz is generated at each terminal station from the 124 kHz carrier equipment and is passed to each VHF base station over the Collector or Distributor circuits. The tone normally used for the synchronisation is injected into the Collector circuit at Moomba but if this 132.027 kHz carrier fails then the tone generated at Peterborough is automatically injected into the baseband of the UHF system on the Distributor circuit. The transmitters at each base station operate on a carrier frequency of 171.12 MHz which is derived from a 7.13 MHz crystal oscillator followed by a 24 times multiplier. Control circuits contained in the control sub-rack divide down the 7.13 MHz and 132.037 kHz frequencies to a common frequency of 16.50462 kHz. A phase comparison of the frequencies at this point and the voltage developed due to any phase differences is applied to change the capacity of a varactor diode in the 7.13 MHz crystal oscillator accordingly (see Fig. 14).

By this means all VHF base station transmitters are frequency locked to a common high stability master frequency source. Should a failure occur on the 132.037 kHz carrier in both directions simultaneously or should the phase locking circuit fail, the 7.13 MHz crystal oscillator will continue to drive the base station transmitters within the frequency stability tolerances for which the equipment is designed but under this condition frequency locking to adjacent stations is not achieved.

**Automatic Testing of Mobile System**

To enable the base station equipment to be checked for adequate performance at regular intervals of time, an automatic test sequence is incorporated. Every five minutes, in the absence of traffic on the system, a short burst of two audio frequencies is transmitted from the control console in Adelaide over the Distributor circuit to each base station. The tones are extracted at each station and passed to a logic board which in turn energises a turn-around mixer. The mixer converts a small portion of the transmitter RF signal to the base receiver frequency. Thus the two tone modulation of the transmitter input appears at the receiver output. The level of the RF signal converted to the receiver frequency is pre-set so that unless the transmitter is operating at an output power sufficient for communication purposes, the receiver mute will not be lifted. A decoder on the output of the receiver acknowledges receipt of the signal from the transmitter. Provided that all signals are returned to the logic board in the correct form, no action is called for and the system is deemed to be operating satisfactorily. If the test fails, however, then action is required as a fault exists on either the transmitter or the receiver.

The action taken by the logic board is two-fold. Firstly, it sends an alarm signal to the supervisory transmitter, which records a VHF failure locally and also in the Peterborough and Adelaide control centres. Secondly, it causes a changeover to take place whereby the tested transmitter/receiver combination is replaced by the standby transmitter and receiver. These will be tested during the next test cycle and if satisfactory the supervisory alarm will be cleared.

The test cycle originating in Adelaide is automatically initiated five minutes after the last system usage and thence repeated every five minutes. The test cycle can also be initiated manually at any time from the control consoles at Adelaide and Peterborough. When the test cycle takes place the two tones are transmitted to air from all stations which assures all users in vehicles that their own receivers are operating correctly.

The frequencies of the test tones used are 1620 Hz and 1740 Hz. The duration of the test is about 1 second every five minutes (in the absence of normal traffic). The use of the two tones reduces the chances of normal speech causing the test to be initiated accidently. The testing system itself can be checked at the control consoles by forcing the test to fail. This can be done by initiating a test whilst holding all the transmitters off.

**Best Signal Selection System**

Because of the topography of the pipeline route and the spacing of repeaters, the signal from a mobile unit may be received at more than one base station. This multiple path coverage, whilst providing useful diversity reception, creates two unacceptable side effects which must be controlled. Firstly, the additive audio values of the signals received at more than one station, if injected directly into the Collector channel, would seriously overload that channel causing intermodulation interference on other channels of the carrier system. Secondly, whilst an excellent signal might be received at one station, this signal can be seriously degraded by the high noise injected into the Collector circuit from another station which is receiving a signal from the mobile with a level only just adequate to operate the mute but inadequate to quieten the noise output of the receiver. To prevent this overloading and degradation of signals, special circuitry is included in the base station equipment which allows only the best signal to be injected into the Collector baseband circuit (refer to Fig. 13).

The noise in the IF pass band of an FM receiver is inversely proportional to the received signal strength. The noise voltage is extracted from the IF band, amplified and rectified to produce a dc voltage ranging from approximately zero volts at full receiver quieting to 0.8 volt on a signal which is just sufficient to operate the muting gate (approximately 0.3 microvolt). As this dc voltage cannot be directly transmitted over the Collector circuit, it is used to control the frequency of a carrier centred at 11.5 kHz. The amount of shift in the 11.5 kHz frequency is proportional to the noise voltage. The resulting nominal 11.5 kHz, together with the 12 to 16 kHz modulated speech, is transmitted to the next VHF base station in the Collector direction. Meanwhile, at this next base station the same process has taken place. The locally produced 11.5 kHz signal is compared in frequency with the incoming 11.5 kHz signal.

Quality of signal is indicated by the shift of the nominal 11.5 kHz carrier over the range of 11.35 kHz (a noise free signal) to 11.65 kHz (a low quality signal). At each station the quality of the signal already on the Collector circuit from the preceding site is compared with the quality of the signal at that site (if any) and the better one passed on to the next leg of the Collector. Thus when a mobile unit energises more than one base receiver only the best signal is injected into the Collector channel for onward transmission.

To prevent the transmission of speech information from preceding stations when the comparator circuit has determined that such information is inferior in signal-to-noise ratio to the locally received signal, an 11.5 to 16.0 kHz stop filter is included in the baseband circuit at each repeater station. If, the locally received signal is inferior to that from the preceding station the stop filter is bypassed and the information from the preceding station is transmitted onward via an 11.5 to 16.0 kHz bandpass filter at the base station. This avoids the effect of changes in level of other baseband information when switching occurs.

**Vehicular Installations**

Generally speaking, inspection patrol and maintenance vehicles using the mobile system travel through isolated areas and are of the Land Rover or Toyota four wheel drive type. These vehicles and their mode of operation being open to road, wind and engine noise do not present a satisfactory environment for sedan type radio installations. Special techniques were necessary to ensure reliable communications.

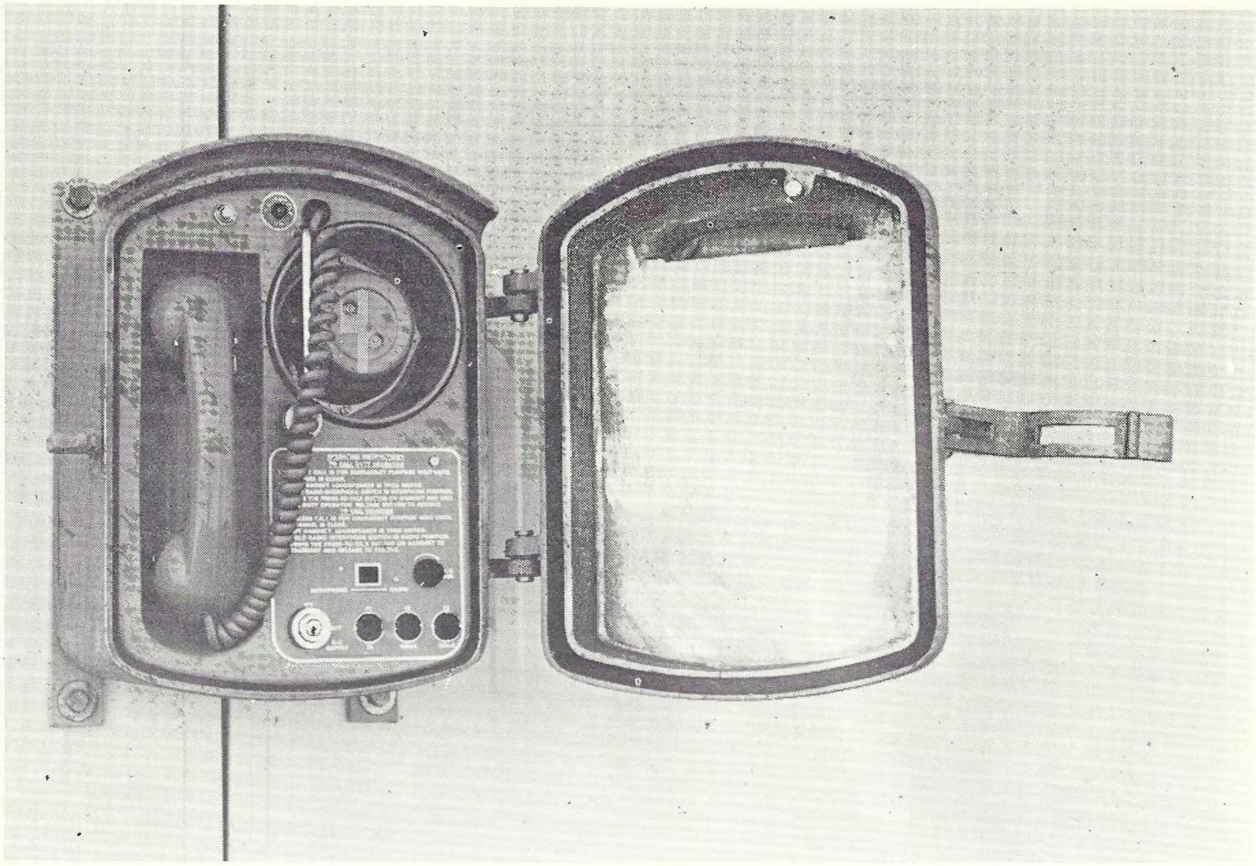


**Fig. 15 — External Fixed Mobile Radiotelephone Unit.**

The first variation from standard automotive two-way radio installations involved the reduction of noise picked up by the microphone and producing an adequate level of noise free audio close enough to the driver to overcome the high ambient acoustical level of his environment. A special kit was supplied for these installations which included a small re-entrant horn of 3 watts power handling capacity in lieu of the standard inbuilt loud speaker in the transceiver. This horn is installed inside the vehicle close to the driver's ear but placed so that it does not present a safety hazard in the event of an accident. To ensure good speech clarity from the vehicle, STC installed their star noise cancelling hand microphone. Also, since there is a strong tendency for vehicle operators to raise their voice levels when in a high noise area, the microphone circuit was desensitised.

Although single channel (synchronised carrier frequency) systems have substantial advantages over multiple channel networks there are some side effects which can be disturbing if corrective measures are not employed. These include:

- The possibility of phase distortion or cancellation when the vehicle aerial passes through an area in which the signals from two adjacent base stations are out of phase.
- The elimination of heterodyne interference in the unlikely event that the synchronisation circuit failed.
- That only the signals arriving over the best path are selected for loudspeaker operation.

To overcome these effects a unique system involving directional aerials and logic circuits was developed and installed. The entire installation consists of two transmitter/receivers, logic circuits and audio amplifier mounted in a rain and dust proofed metal box which is shock mounted to the floor of the vehicle. Each vehicle is also fitted with two modified yagi aerials consisting of a reflector, an active element and two directors providing a forward gain of approximately 5 dB with respect to isotropic. One aerial is connected to one of the duplicated transceivers and points forward, whilst the second aerial is connected to the second transceiver and points rearward. The two aerials are installed such that half-wave relationships between the active elements are avoided.

Once again using the characteristic of FM receivers that the noise in the IF band of the receiver is inversely proportional to the received signal strength the noise in this area is extracted, amplified and rectified to produce a dc voltage in the range zero to +0.8 volts. The dc voltages obtained from the two receivers are compared in the logic/control circuit which determines and selects the receiver which has the best quality signal (corresponding to the lowest dc voltage). The logic/control circuit can also recognise a defective receiver and will not lock onto it even though the noise voltage might be zero. If one of the transmitters becomes faulty the driver has facilities available to him to lock onto the other transmitter.

**Weatherproof Fixed Mobile**

It was realised that staff working at compressor station sites (e.g., during establishment of the compressor station) would require direct access to the mobile channel in order to communicate with the Adelaide Despatcher or vehicles operating in the vicinity. To provide this feature each radio repeater at compressor station sites was equipped with an external mobile radiotelephone mounted on the southern side of the radio building. The unit is self-contained in a dust and waterproof lockable box which can be removed to the compressor station building if and when required. It also provides a convenient emergency telephone for the pipeline maintenance staff who do not have access to the radio building. Fig. 15 illustrates the external phone.

**The Mobile Control Console**

The VHF control equipment at both Adelaide and Peterborough comprises two parts; the control console and the logic sub-rack. These are connected by a multicore cable. The logic sub-rack is mounted in a freestanding, floor mounted 19 inch rack.

Two mobile control consoles were required, one at the Peterborough Maintenance Depot and one in the Adelaide Control Centre. Fig. 16 shows the desk-top console supplied for Peterborough which is identical to that in Adelaide except for the "Control Selector Switch" on the bottom righthand corner of the unit. This switch permits the northern system to be looped at Peterborough and the despatcher at Peterborough can then assume control of the VHF system in the event of a failure in the

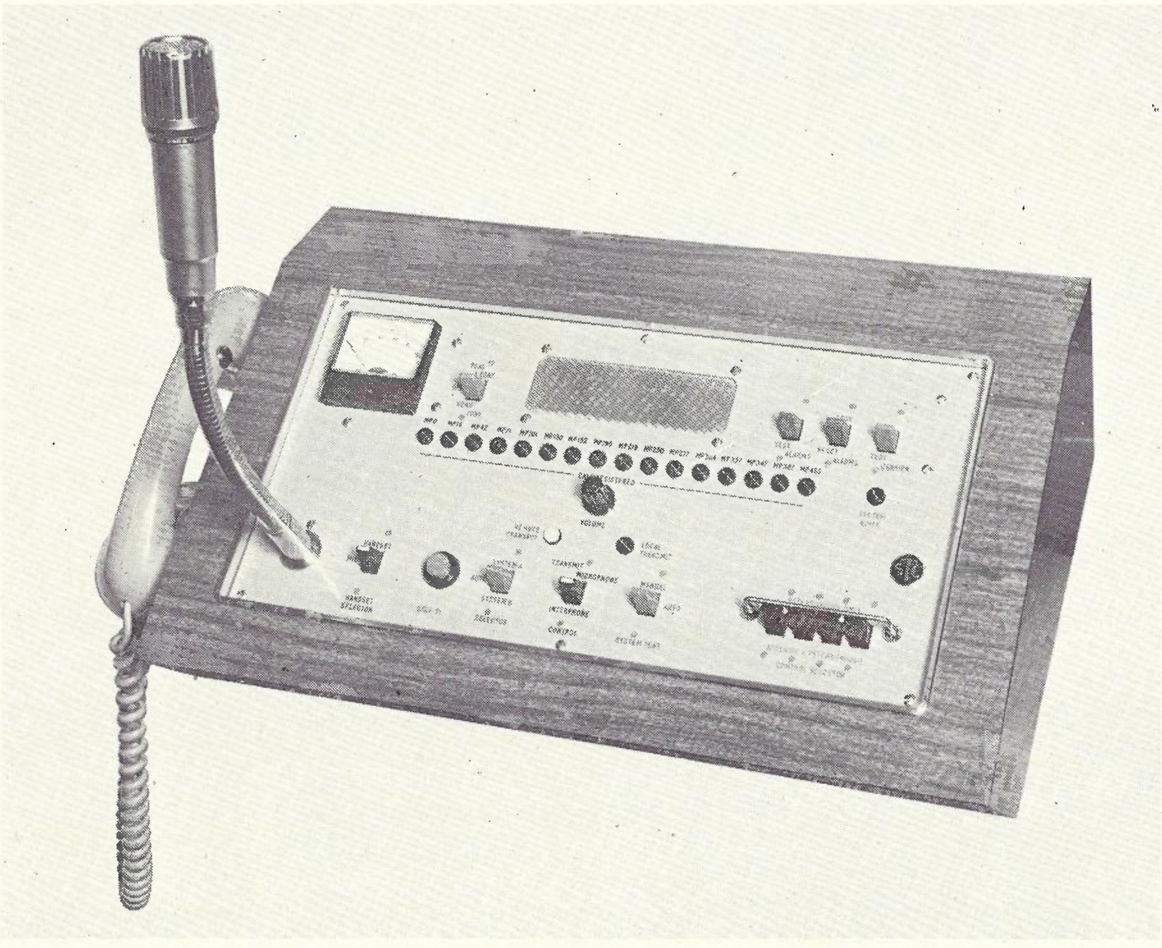


**Fig. 16 — Mobile Control Console.**

APO lines between Peterborough and Adelaide. The switch is not required on the Adelaide console because when the switch is locked to the "Adelaide-Peterborough" position (the normal position), the Adelaide Despatcher has system control priority.

**Radio Bearer System**

The STC proposal recommended the use of their Type ML5F UHF radio equipment for the point-to-point radio relay link. The ML5F is fully solid state equipment with self monitoring and automatic changeover facilities. The equipment uses frequency modulation, operates over the frequency range 403 to 500 MHz, and is designed to carry 24 frequency division multiplex telephone channels.

The radio bearer equipment is of the "hot-standby" type. This means that all equipment in the system is powered and fully operative with both transmitters operating on frequency F1 and both receivers operating on F2. Only one antenna per transmitter/receiver combination is required. Upon failure of the normal transmitter, the standby transmitter is switched to the aerial. In the receive direction switching takes place at baseband. The "hot-standby" mode of operation was chosen primarily to conserve radio frequency spectrum. The pipeline and therefore the radio route are basically in a straight line running from Peterborough to Moomba. In order to avoid interference as a result of overshoot, the frequency plan is such that frequencies are repeated after 5 hops thus making the allocation of five different frequencies in each direction necessary. Obviously, if a fully duplicated system had been installed, the frequency allocations would have doubled, i.e., twenty frequencies would have been required. The disadvantage of the hot-standby system of operation is that maintenance of one bearer whilst the other carries traffic is not possible. Routine tests, etc., must therefore be performed with the system withdrawn from service.

Fig. 17 shows the rack layout of the duplicated system and Fig. 18 is the block schematic.

The radio bearer system extends for a distance of 347 miles from Moomba to Peterborough and, in the main, the terminal and repeater sites are close to the pipeline. The one exception is the site MP250 which is approximately 8 miles from the pipeline. MP250 had to be sited away from the line in order to avoid high path attenuation due to hills obstructing the path between MP250 and MP276.

Path calculations were based on a Freznel zone clearance of 0·4 and an equivalent earth radius figure of k = 0.8. The calculations indicated an overall noise performance of about 2500 pW for median conditions (i.e., a signal-to-noise of —56 dBmOp or a noise power ratio of 43 dB for the 24 channel system). Actual measurements on the system during acceptance testing showed a noise power ratio of 39.5 dB in one direction and 40.5 dB in the other. The specification called for a median noise performance of 12,000 pW which is a noise power ratio of 36.2 dB, so the system is performing well inside this figure.

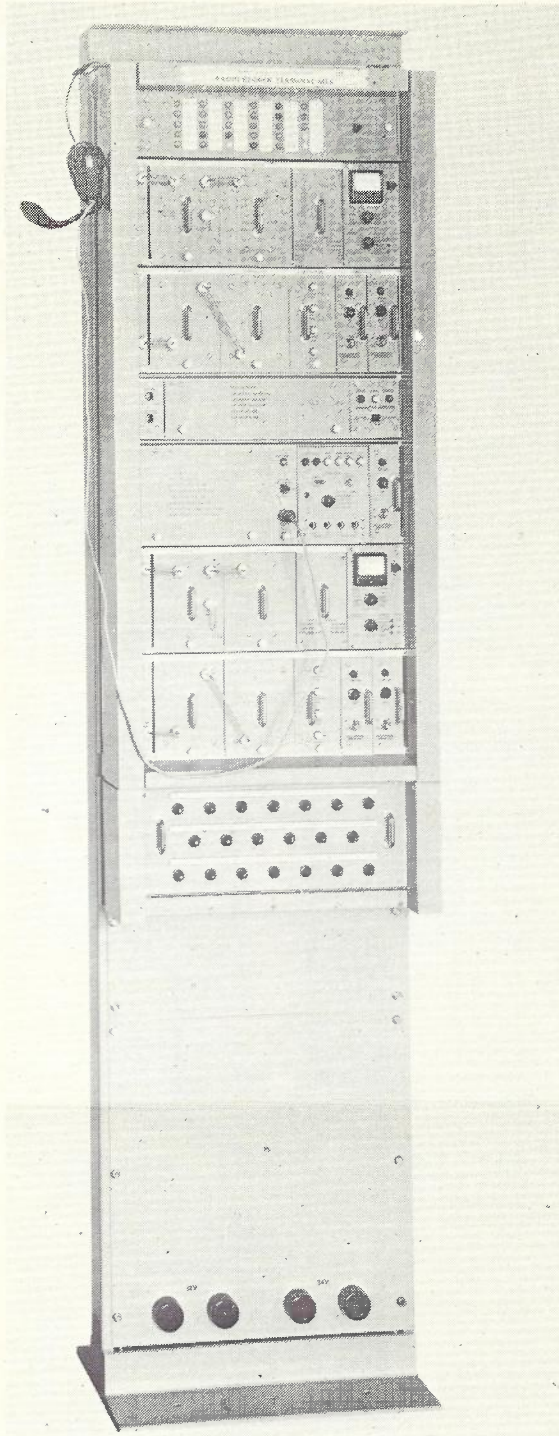


**Fig. 17 — ML5F Duplicated Radio Bearer Equipment.**

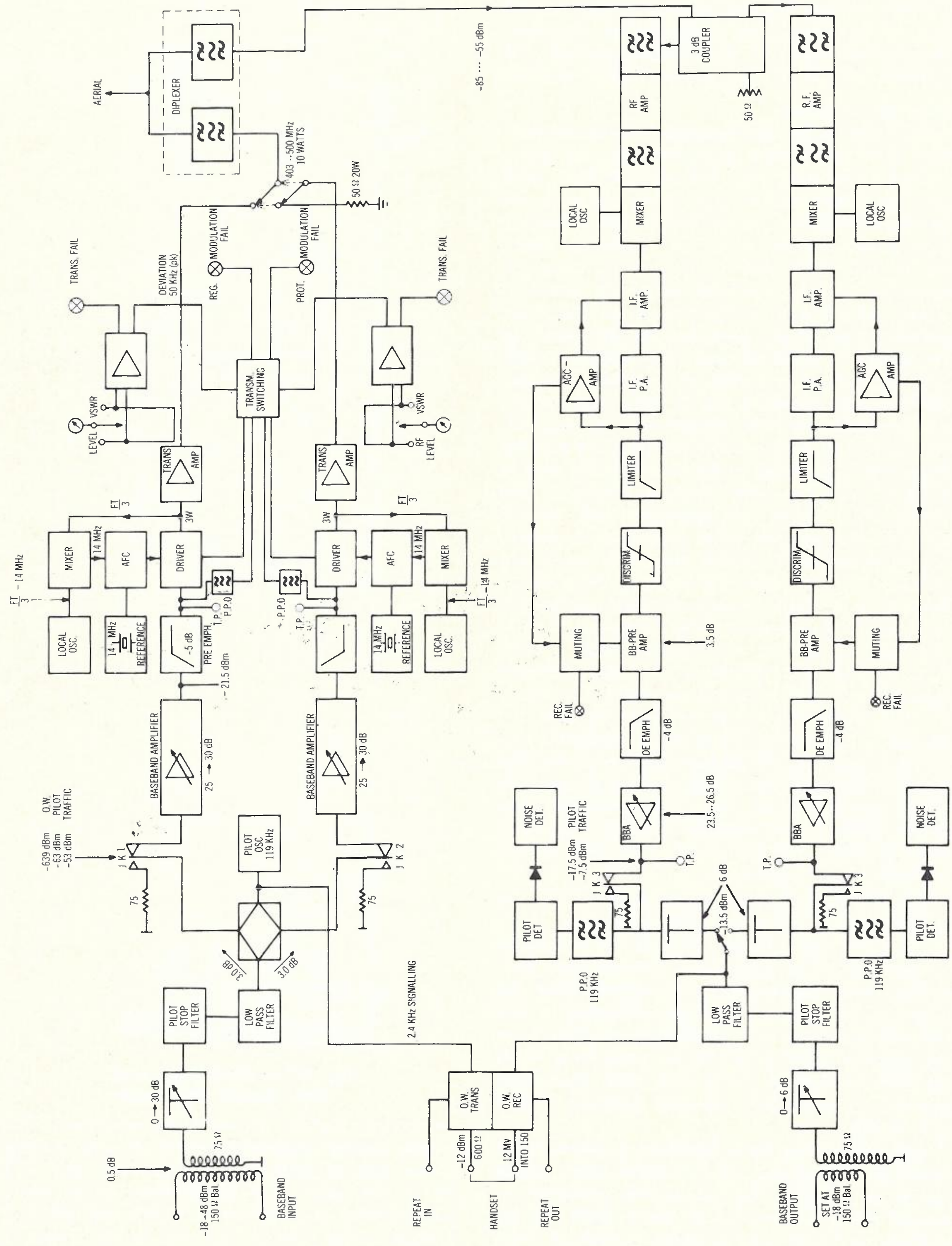



**Fig. 18 — Block Diagram of Duplicated Radio Bearer Equipment.**

Table 1 is a summary of the principal performance characteristics on the ML5F equipment and Table 2 is a summary of field measurements of the system performance.

**The Supervisory System**

The Moomba telecommunications system is designed to provide self-monitoring of the status of equipment with automatic changeover from main to protection equipment in the event of a failure. No part of the system depends on human detection and manual changeover by either local or remote methods. Consequently, the supervisory system does not include provision for remote control.

The supervisory system is designed around the STC MLS-3 Supervisory Transmitter and Receiver. This is a standard type time division multiplex (TDM) sequential scanning system and only a brief description is given in this article.

The MLS-3 supervisory equipment is an alarm signalling system capable of reporting 30 alarm conditions from each remote site. In the transmitter a TDM system is used, the rate being such that the information can be carried over a standard 40 baud telegraph circuit. Reporting is continuous without interrogation and under the no alarm condition the 30 alarms are scanned in 1.8 seconds. When alarms are present the scanning time is extended by approximately 50 milliseconds per alarm. Separate telegraph channels with 120 Hz spacing are required for each reporting station and the telegraph equipment is incorporated within the

**TABLE 1 — SUMMARY OF PRINCIPAL PERFORMANCE CHARACTERISTICS OF ML5F EQUIPMENT**

| | |
|---|---|
| **UHF Equipment** | |
| Frequency Range | 403-500 MHz |
| RF Channel spacing for parallel radio links | 2.0MHz |
| Frequency Separation between transmit and receive for common aerial operation | 10.5 MHz |
| Frequency Stability | +0.005% |
| Transmitter Power Output (at power amplifier output) | 10 watts minimum |
| Spurious Radiation | 60 dB below carrier output |
| Receiver Noise Figure (at diplexer input) | less than 6 dB |
| Receiver Intermediate Frequency | 35 MHz |
| Receiver I.F. Bandwidth | 1.2 MHz between 3 dB points |
| Receiver Image Rejection | 70 dB |
| RF Output and input Impedance | 50 ohm unbalanced |
| Type of Modulation | Frequency Modulation with ± 4 dB pre-emphasis |
| **Baseband Characteristics** | |
| Overall Baseband | 0.3 to 135 kHz |
| Traffic Baseband (24 channels) | 6 to 108 kHz |
| Baseband Impedance | 150 ohm balanced or 75 ohm unbalanced |
| **Baseband Characteristics (ctd.)** | |
| Baseband Input Level per Channel | -45 dBm |
| Baseband Output Level per Channel | -20 dBm |
| Frequency Deviation (median Channel) | 35 kHz rms |
| Pilot Frequency (duplicate terminal) | 119 kHz |
| Pilot Deviation | 20 kHz rms |
| **System Performance** | |
| Baseband Frequency Response | ± 4.4 dB 6 to 108 kHz |
| Stability of Transmission Equivalent | ± 0.25 dB |
| Power Supply | 21.6 to 32.5 Volts dc |
| Power Consumption (maximum with all Display lamps actuated) | 160 watts |
| Allowable Ambient Temperature Range | 0°C to 55°C |
| Thermal and Intermodulation Noise between one pair of terminals with white noise loading of + 4.5 dBm | 63 dBmOp for worst telephone channel for receiver input - 55 dBm (hot channel duplicated) |

**TABLE 2 — SYSTEM PERFORMANCE DATA; FIELD MEASUREMENTS**

| | |
|---|---|
| Overall Transmission System Frequency Response, including omnibus interface for 13 paths, 6 kHz to 108 kHz | Each direction within ± 0.8 dB (reference 84 kHz) |
| Noise Power Ratio (24 channel loading), Moomba baseband input to Peterborough baseband output | 14 kHz slot 40 dB<br>70 kHz slot 40.8 dB<br>108 kHz slot 40.5 dB |
| Noise Power Ratio (24 channel loading), Peterborough baseband input to Moomba baseband output | 14 kHz slot 39.5 dB<br>70 kHz slot 39.6 dB<br>108 kHz slot 39.7 dB |

**Note:** For a 24 channel system:
Weighted Signal-to-Noise (dBmOp) = Noise Power Ratio + 12.89

units. At the receiver the alarm indication is given by an alarm lamp and a closing relay for each alarm being reported. An added facility is provided on certain alarms which "latch-up" the alarm lamp and relay and hold this condition until manually reset. Fig. 19 shows the layout of the supervisory alarm indications at Peterborough which is identical with the Adelaide display.

The allocation of the alarms and their layout on the racks was arranged to suit the NGPA maintenance policy in regard to the recall of staff after hours. Only the Adelaide Control Centre is staffed 24 hours per day by a Despatcher who is not a qualified technician. All alarms, therefore, indicate a specific malfunction, i.e., it is not necessary for a failure to be determined by the analysis of a combination of alarms.

The alarms are divided into four categories and a particular coloured lamp is allocated to each category as follows:

- Most Urgent Alarm — Red
- Alarm — Amber
- Favourable Response — Green
- Information Only — White

The Authority considered it necessary to have an audible as well as visual alarm under the Most Urgent alarm condition. Accordingly the activation of a Most Urgent alarm causes a distinctive alarm tone in the Control Console loudspeaker. The tone is stopped when the fault is corrected or a lock-out switch is operated.

The Most Urgent alarms are limited to the following functions:

- Status of the power supply and logic circuits associated with the supervision of the receivers and transmitters at each station. If failure of this function occurs then the eight alarms associated with receiver and transmitter failures would not register. The fact that such failures would not register warrants immediate attention even though the system continues to carry traffic.
- Total failure of a carrier or channel modem in the omnibus system. A standard alarm is registered should there be a failure of any equipment. This is transformed to a most urgent alarm if total failure occurs.
- Failure of the protection diesel to start. A standard alarm (amber) occurs if the main diesel fails to start. This is transformed to a most urgent alarm if the protection diesel also fails to start.

The standard alarm indications register when there is a failure in any part of the equipment in which there is redundancy still available.

The Favourable Response alarm registers when the diesel is running.

The Information alarm registers for high temperature at the station and when a VHF receiver is unmuted and the signal injected into the Collector channel.

The two mobile base stations south of Peterborough have a limited number of functions which do not warrant a 30 alarm system. However, in the interest of standardisation the MLS-3 system was also provided at these stations.

## LOGISTICAL DIFFICULTIES

As stated earlier in this paper, the greatest single problem encountered throughout the project was the remoteness and nature of the area itself. Civilisation north of Peterborough along the pipeline route is virtually non-existent. Because of these conditions all supplies and living equipment had to be carried with the various installation teams. The supplies included petrol, water, food, bedding and the usual installation tools and equipment.

During transportation of the shelters to the various sites considerable damage occurred necessitating a special visit by the workshop staff to restore them prior to the installation of the equipment. Again, many of the mast sections were damaged during transit and had to be returned to Adelaide for repair. Both these activities contributed to delay in completion of the project.

At the site MP18 (the site closest to Moomba), wind caused very rapid erosion of the sand around the site, which is on a small hill. This very rapid erosion was probably due, in part, to the activity

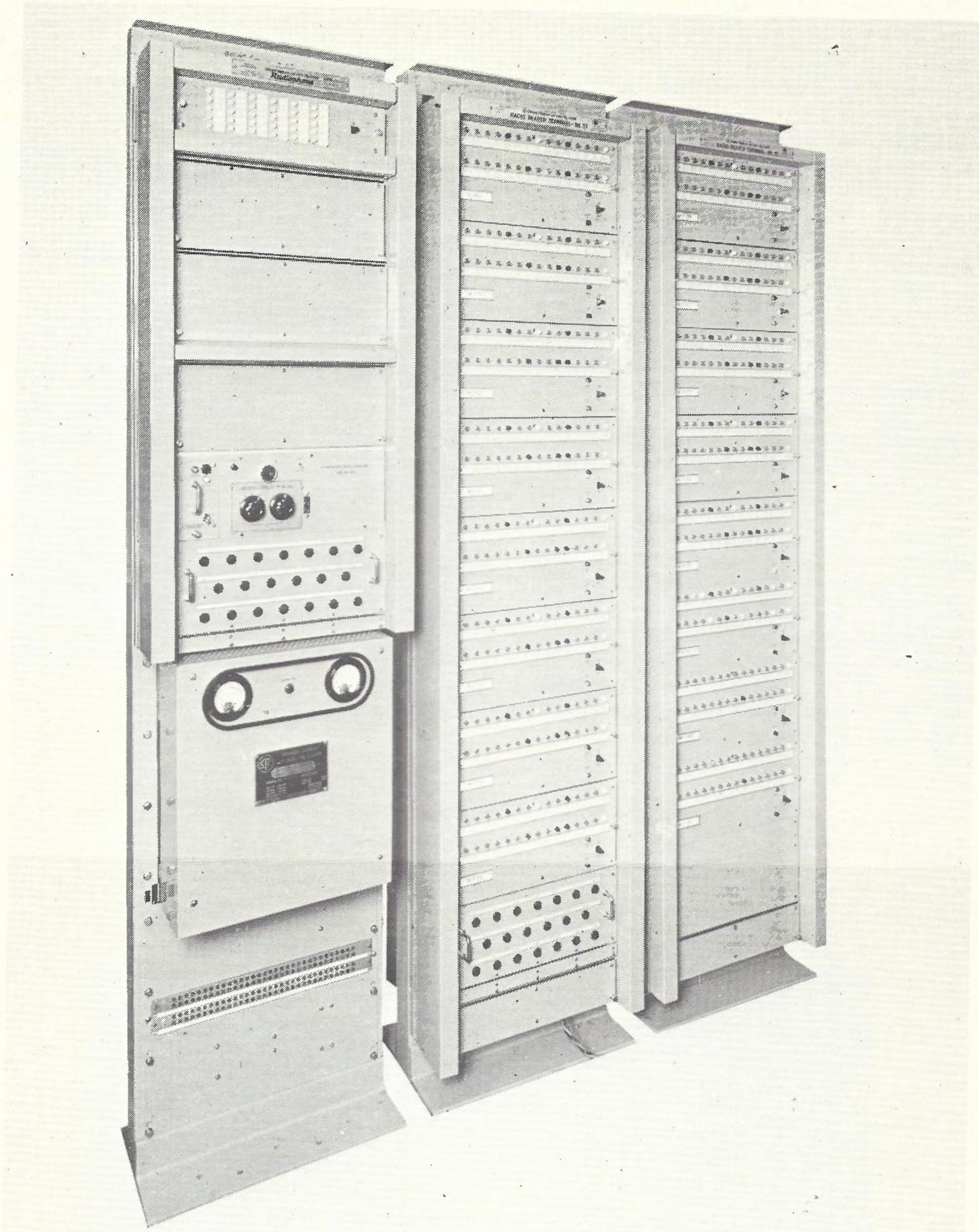


**Fig. 19 — Peterborough Supervisory Equipment (Miscellaneous Rack and two Alarm Display Racks).**

which had disturbed the surface of the sand during the establishment of the mast and shelter. Within three months of the shelter being erected the equipment building had collapsed due to this sand erosion (see Fig. 6, Part 1). The outer shelter remained intact, supporting the inner shelter from slipping further into the hole. The contractor had to re-establish the site. In order to do this STC arranged for the outer shelter to be dismantled, the inner shelter to be moved, several tons of clay to be transported from a nearby claypan and deposited on the site and consolidated. The shelters were then re-erected.

When the site selection survey was carried out in April 1970, the area was suffering from a drought which had lasted many years. The track was very dry and virtually 'bulldust' for its entire length from Peterborough to 100 miles south of Moomba, where the dust changed to fine dry sand. Fig 20 is a photograph taken at this time. The erection of the masts and shelters commenced shortly after the survey. In March 1971, 15 inches of widespread rain fell in two weeks making the area inaccessible and stranding two installation teams for 10 days. The pipeline track was in very poor condition and difficult to traverse for many months following the rain. Fig 21, a photograph taken in May 1971, typifies this problem, as does Fig. 22 taken in July 1971. Heavy rains again fell in September 1971, and even travel on the main roads was difficult (see Fig. 23). However, the project progressed and acceptance testing was completed in November 1971.

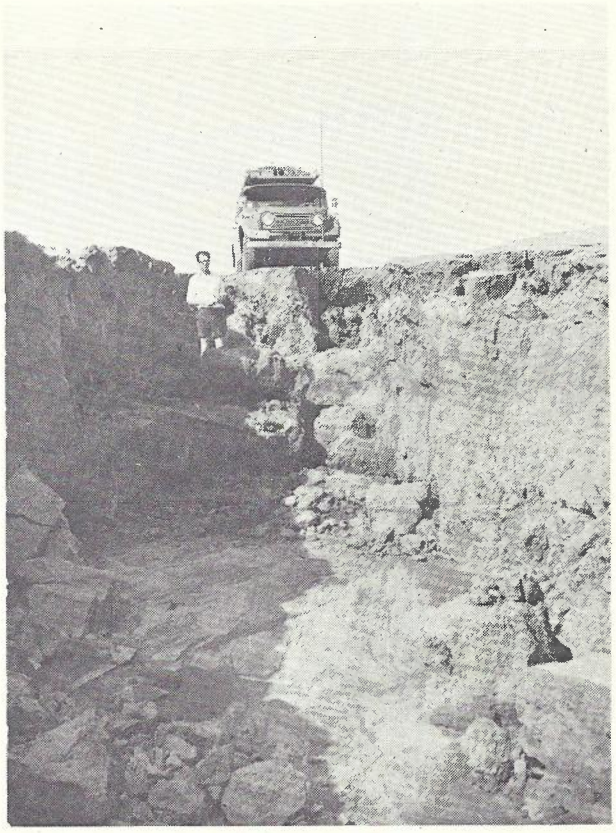


**Fig. 21 — Pipeline Track at MP 275; May 1971.**

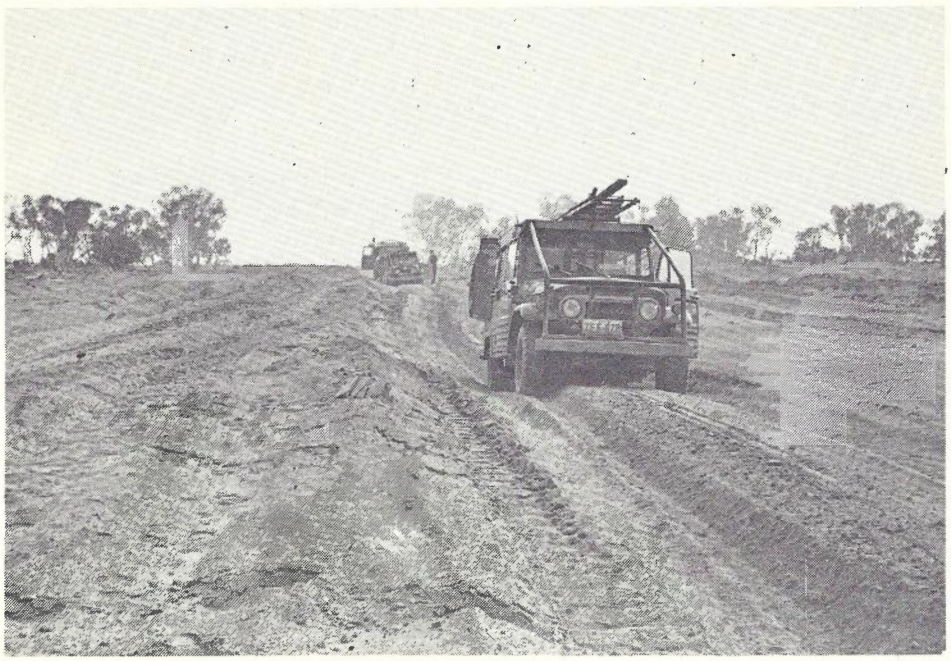


**Fig. 20 — Pipeline Track During Route Survey.**

Fig. 22 — Pipeline Track at MP 65; July 1971.

Fig. 23 — Main Road 7 miles north of Leigh Creek; September 1971.

**CONCLUSION**

The Moomba-Adelaide communications system comprises high quality APO lines between Adelaide and Peterborough and the longest privately owned communications system in Australia between Peterborough and Moomba. Installation teams had to contend with extremely poor road conditions north of Peterborough causing breakdown of vehicles and damage to the equipment being transported. Storms, rain, high winds and intense heat also added to their discomfort during the construction period.

In spite of the many difficulties good relationships and co-operation existed at all times between the Contractor, the Authority and the Department. The overall system met all he requiremens of the Specification and in many cases exceeded them. The entire system north of Peterborough and the mobile radio base stations are maintained by the Authority. The system is designed to be maintained on a changeover, plug-in module basis. At the present time faulty units are returned to Adelaide for repair and re-alignment.

Since installation of the communications system described above the Authority has had a selective calling system (the STC Seacode) added to the mobile network. This allows the Despatcher in Adelaide to call individual compressor stations and mobiles by dialling a 3 digit code.

Fig. 7 shows, in simplified form, the facilities available on the system as at July 1972.

A. MONTGOMERY is Project Engineer, Moomba, Communication's Project, Radio Communication Installation Sub-Section, Adelaide. See Vol. 23, No. 2, page 125.

B. G. HAMMOND is Supervising Engineer, Buildings, Engineering Services, Adelaide. See Vol. 23, No. 2, page 125.

# Technical News Item

## AUSTRALIAN POST OFFICE RESEARCH LABORATORIES GOLDEN JUBILEE

During August 1973 a number of events marked the celebration of the Golden Jubilee of the APO Research Laboratories. These included:

o A 2-day Symposium on the theme "Whither Communications?" held at the Union Theatre, Melbourne University on 15th and 16th August. Eminent international and local speakers from telecommunications administrations, industry and universities delivered a total of 13 papers to present a range of views on the future development in communications services and technology and on their social implications. Key note speakers included Professor W. J. Bray, Director of Research, of the British Post Office, Dr. W. A. Tyrrell, Executive Director, Technical Relations, Bell Laboratories, U.S.A.; Professor S. Encel, Professor of Sociology, University of New South Wales; Mr. P. R. Brett, Senior Assistant Director-General, Research, APO; and Professor A. E. Karbowiak, Professor of Electrical Engineering—Communications, University of New South Wales. Other eminent speakers, both local and from overseas, extended the range of topics discussed and an audience of about 650 took part in three panel discussion sessions.

o A week of Open Days, opened by the Postmaster-General and during which official guests and the general public were invited into the Laboratories to see about 110 exhibits and displays selected to demonstrate the work of the Laboratories. During the week (20/8/73 to 24/8/73), an estimated 5000 people visited the Laboratories, some of whom had been attracted by a less extensive display at the State Savings Bank, corner Bourke and Elizabeth Streets, Melbourne, several weeks before the Open Days proper.

o The issue of a special Golden Jubilee edition of the annual APO Research Laboratories Review of Activities. This special edition not only reviewed selected current activities of the Laboratories as is usual, but also devoted a significant number of pages to an historical review of the activities and achievements of the Laboratories since their inception in 1923.

The events drew compliments from those attending and it is obvious that they were most successful in enhancing the public image not only of the Laboratories but also of the Department as an enterprise which is abreast of the technology and science of modern communications.

# A New Pulse Measuring Set

R. PERTZEL and C. GREEN

*A new Pulse Measuring Set AKOO1 has been introduced to replace the Ratio Test Set No. 30. The new Test Set features solid state construction, small size and weight, high stability and a digital readout.*

## INTRODUCTION

The Pulse Measuring Set described in this article is a new unit designed and built by Siemens Industries Limited to APO Specifications to replace the existing Ratio Test Set No. 30. The new Test Set has, in addition, facilities for testing carrier circuit E and M lead signalling and T. pulse signalling.

Ratio testing in a telephone system is a method of measuring the amount of impulse distortion introduced by a particular element in the system, for example, the impulsing relay in a relay set repeater. A knowledge of the distortion and its control within acceptable limits, is fundamental to the correct operation of the step-by-step telephone switching system. In the crossbar system, the greater tolerance of registers in accepting distorted impulse trains allows some relaxation of the distortion limits, but decadic outpulsing from registers to step-by-step exchanges still requires accurate measurements and control.

Until the introduction of the new Pulse Measuring Set, impulse distortion was measured in terms of the speed and ratio of the incoming train. This method as employed in Test Set No. 30 has the disadvantage that it does not give the duration of the make and break periods directly, except at speeds of exactly 10 impulses per second.

Pulse distortion limits as plotted on target diagrams, have axes scaled in make or break time in milliseconds and so a measuring set, giving the measured performance of a relay set directly in terms of make and break pulse lengths, is more logical and convenient. It also avoids the need for any calculation and the consequent risk of arithmetic error.

Test Set 30 had a number of other shortcomings:

- reading on pulse trains of normal duration not obtainable.
- moving coil meter was moderately accurate only.
- required frequent calibration.
- bulky and heavy.
- no indication of any contact bounce period.

## DESCRIPTION OF THE NEW PULSE MEASURING SET (AK001)

To overcome these disadvantages, the new Pulse Measuring Set AK001 was developed (Fig. 1). It is a self-contained measuring system, combining an accurate pulse generator, a digital pulse meter and an adaptor unit in one portable case.

Except for the five gas-filled read-out tubes, the circuitry is all solid state and employs digital principles. This approach makes the instrument virtually immune to mains-borne interference.

All timing functions, for both the generator and the meter, are controlled by a crystal oscillator. This makes calibration of the instrument unnecessary and ensures very good long-term stability.

### Pulse Generator

The pulse generator provides a series of accurately timed impulses (contact closures) which can be used to activate the system being tested. The output device is a mercury wetted relay which is switched at one of two fixed rates by a digital timing circuit.

The make/break ratio is controlled by the range switch and is variable in two ranges, each containing 11 steps, i.e., from 15/85 ms to 85/15 ms in the x 1 range, and 150/850 ms to 850/150 ms in the x 10 range. The pulse repitition rate is 10 Hz in the x 1 range and 1 Hz in the x 10 range.

Inhibit facilities are provided. These allow the generator to be stopped with the output relay contact open or closed, as desired. In addition, the instrument has a 'single pulse' button. This operates only when the relay is inhibited in the open state and causes the relay contact to close for one make period.

**Pulse Meter**

The pulse meter is independent of the generator. It can be switched to measure make time, or break time, or period or distortion from 0 to 200 ms in the x 1 range with a resolution of 0.1 ms, or alternatively from 0 to 2000 ms in the x 10 range with a resolution of 1 ms. In both cases the accuracy is approximately 0.05 %.

The time in ms is displayed on a four-digit readout. The decimal point is positioned automatically. A flicker-free display is obtained by the use of internal storage of the reading between measurements.

The make time, break time and period are each measured by counting clock pulses for the duration of the unknown time interval, thus generating a number which corresponds to its time in ms. However, to measure distortion, an ideal make period must first be generated internally. The unknown make period is then compared to this reference. The difference between the two is the distortion, which is measured as before by counting clock pulses. The result is displayed in ms or fractions of ms. Distortion may be positive, when the unknown period is longer than the reference; or negative, when the unknown make period is shorter. This is indicated by a plus or minus sign which appears in the display along with the reading. Twenty-two different reference make periods are available. They are set by the range switch, so

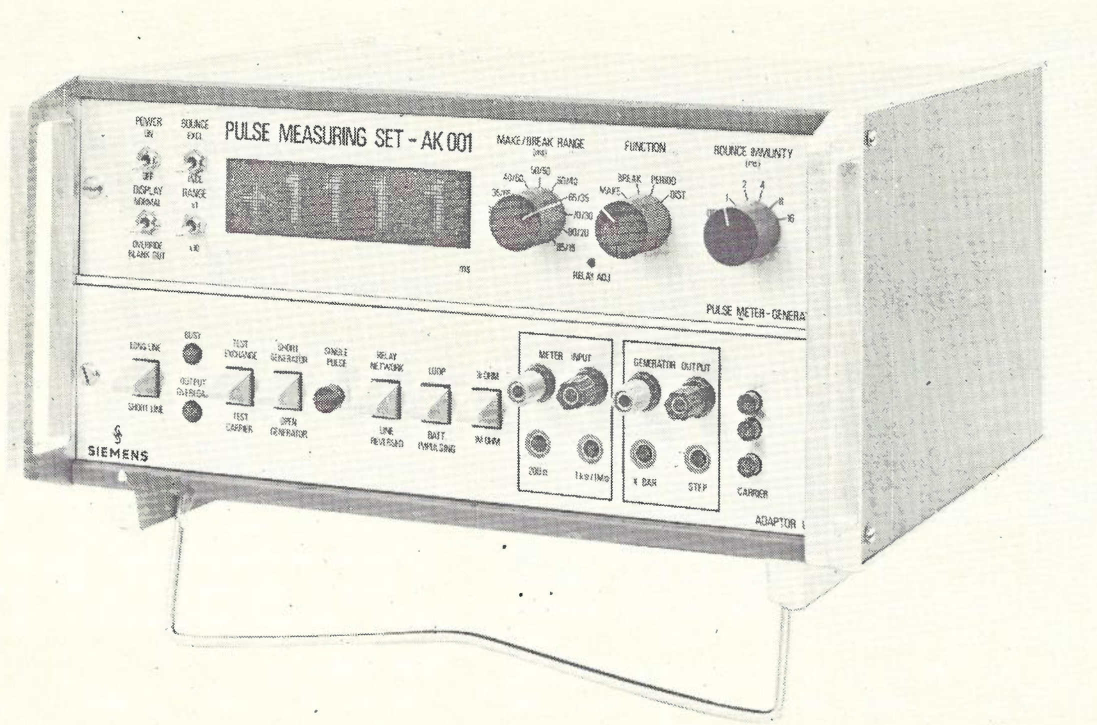



**Fig. 1 — Pulse Measuring Set — AK001**

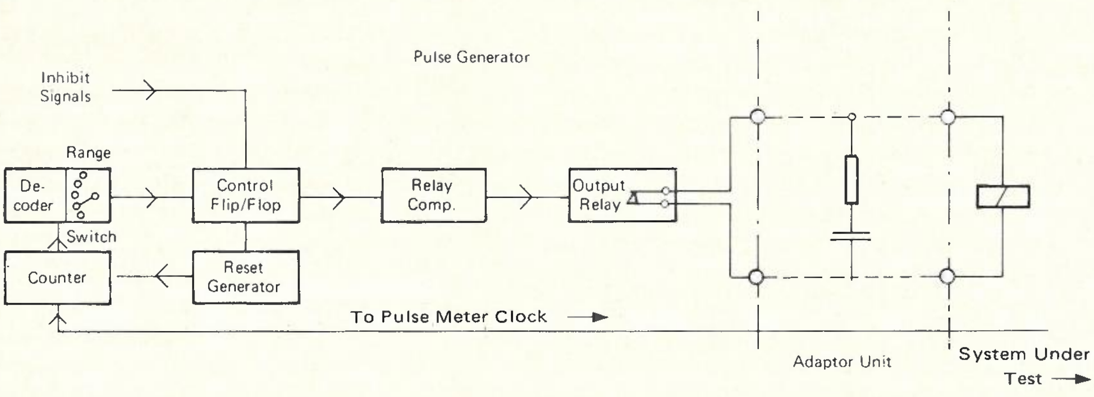



**Fig. 2 — Block**

that the correct reference is automatically connected when the generator make/break ratio is chosen. The reference is the same length as the generator make period, but starts only when a make is received by the meter. Delays in the system under test, therefore, have no effect on the distortion measurement.

Since digital instruments are fundamentally non-averaging, contact bounce can be a problem, unless special techniques are adopted. A measurement is started by the transient at the beginning of a make period and any further transient, caused by contact bounce, restarts the counter and falsifies the reading. In the AKOO1 this difficulty is overcome by disabling the input circuit for a period of time after the beginning of a make period. The time during which the input is blocked is called the bounce immunity period. It is adjustable in 12 steps from 0.1 ms to 16 ms in 6 steps on the x 1 range, and from 1.0 ms to 160 ms in 6 steps on the x 10 range. A switch allows the total time of the bounce to be subtracted from the measured value, so that two make measurements are possible, i.e., one including bounce and one excluding bounce.

Contact bounce also occurs to a lesser extent at the end of the make period. It is usually caused by the wiping action of the contacts, rather than true bounce, and continues for a short period of time. The effects of these transients are eliminated by once again blocking the input circuit for a fixed time of 1 ms at the end of the make period.

Errors are possible with a digital instrument whenever the counter is allowed to run for more than one cycle. If the counter cycle is 200 ms, for example, and a measurement of 250 ms is attempted, the reading will be 50 ms. In the AK001 this problem is overcome by blanking the display after the first run of the counter is completed. The possibility of making an incorrect reading is, therefore, eliminated. In addition, when the display is blanked out, the plus/minus indicator tube in the display is switched to indicate the state of the input — plus for a short circuit, minus for an open circuit. In this way the operator is warned when the system he is testing has failed, or when the measurement he is trying to make is outside the range of the instrument. A special display switch can be used to override the blank-out function and allow the last reading to be displayed indefinitely.

**Adaptor Unit**

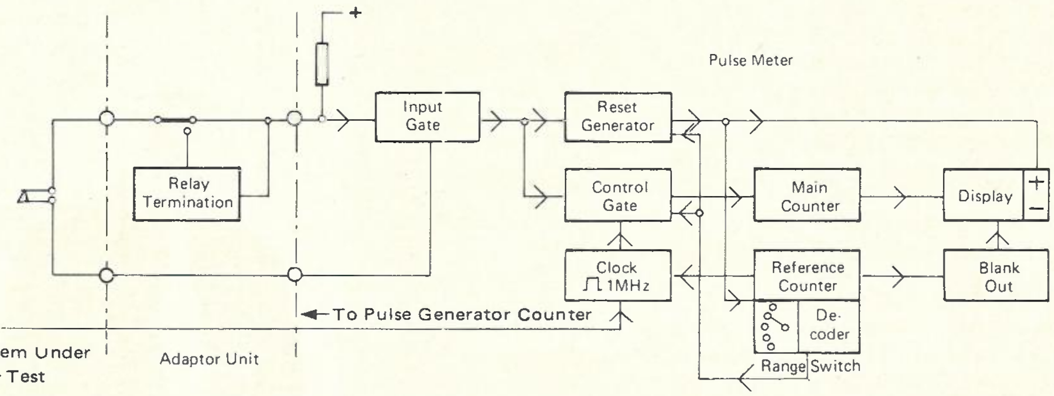
The adaptor unit is a separate panel which slides into the bottom half of the housing. It provides the interface between the pulse generator and pulse meter on the one hand, and the telephone exchange or carrier equipment being tested on the other (see Fig. 2).

The adaptor unit has separate jacks for carrier systems, step-by-step relay sets and for cross-bar relay sets. Each jack has the appropriate spark quench connected to it and can be isolated by a switch, so that connections can be made without affecting the operation of the system. In addition, four banana terminals allow direct in/out connection.

A 'circuit busy' lamp, which operates independently of the isolating switch, indicates whether the line to be tested is engaged. A second warning lamp is controlled by the relay protection circuit. This circuit disables the output relay and activates the lamp whenever excessive current flows in the output circuit.

Simulation of a long line or a short line is possible by pressing the appropriate key which connects an artificial network in series or in parallel. In addition, the adaptor unit is fitted with the inhibit key and single pulse button, whose functions were described earlier.

The high impedance meter termination has alternative impedances of 1 kilohm for terminating junctions and 1 Megohm for bridging carrier signalling leads. –50V is used for contact wetting via




**Schematic**

a 1 kilohm or 1 Megohm resistor. To avoid noise problems, the threshold of the meter termination network has been set to −9V with respect to exchange earth. 50V Negative battery or loop disconnect-pulses may be measured.

**Power Supply**

The AK001 is suitable for operation from AC mains or from a 48V station battery. The power input to be used is selected by a switch. Both inputs are fused. The power consumption is approximately 20 VA on mains operation and 16 W on battery operation.

**Mechanical Construction**

The instrument is built into a housing which measures 320 x 280 x 150 mm. A diecast frame is used so as to withstand the rigours to which portable instruments are normally subjected. Top, bottom and side panels are plastic coated aluminium. A spring-loaded support allows the instrument to be tilted at an angle of approximately 20° for easy viewing. The front panels are mounted directly on to the relevant circuit boards to form easily exchangeable assemblies. These slide into guides on the sides of the housing.

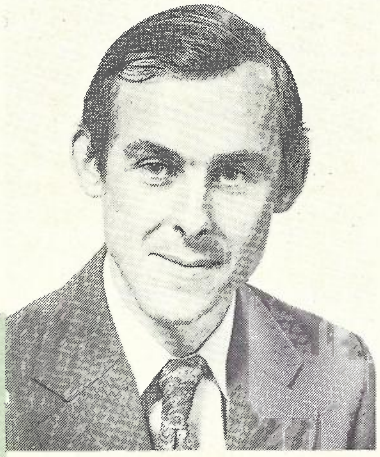
Electrical connections are made via edge connectors at the back of each circuit board. Three assemblies are used. The meter-generator and the adaptor unit fit into the front of the housing, while the power supply fits into the rear. A fourth compartment at the rear of the housing is covered by a hinged door and is used for cable storage.

## CONCLUSION

In the past, accurate measurement of the signalling performance of carrier telephone equipment, the associated transmission lines, and of telephone switching equipment required different types of commercially available instruments which were rather bulky and frequently needed recalibration. The Pulse Measuring Set AK001 described in this article is a small, accurate and versatile instrument which satisfies many of the specialised measuring requirements in one unit. Using digital methods and integrated circuits, the AK001 has been designed primarily for field use with emphasis on ease and convenience during line-up and maintenance. However, because of its high accuracy it can also be used in the Quality Control process during equipment production.


## ACKNOWLEDGEMENT

The agreement of Siemens Industries Limited to the publication of this article is gratefully acknowledged by the authors.


R. PERTZEL joined Siemens in 1964. Initially he was employed in the Quality Control Department specialising in the design and application of test equipment. In 1969 he transferred to Communications Design where he was principally engaged in the development of measuring equipment, including the AKOO1. At present he is attached to the Laboratory specialising in the design of digital circuits.

C. GREEN was recruited by the A.P.O. in the U.K. in 1971 as an Engineer Class 1. He has since worked in the Network Performance and Operations Branch at H.Q. mainly on exchange test equipment, acting as Engineer Class 2.

His previous experience included 3 years in Canada as a Research Associate with the R.C.A.—Victor Company in Montreal working on electronic systems and 3 years with the U.K. Ministry of Aviation (Supply) as an Experimental Officer, working on satellite communications at the Signals Research and Developments Establishment, Christchurch.


# Technical News Item

### SATELLITE COMMUNICATIONS FOR AUSTRALIA - RAIN ATTENUATION STUDIES IN THE TROPICS

The Australian Post Office is currently investigating the technical and economic aspects of a possible national satellite communication system. Applications considered likely for such a system are broadband bearer trunks for telephony and television between major centres, multiple access telephony for smaller regional centres, remote subscribers telephony for individuals in the outback and other isolated areas, and television distribution to the regional transmitters of the national television network. Other possible applications include broadband links between capitals for such services as television conferencing, videophone, and data communications; direct television broadcasting to community receivers; and educational television.

One factor which must be considered is frequency bands to be used by the satellite system. The effects of rain on signal attenuation for frequencies above about 10 GHz have a major influence on such a choice. The bands below 10 GHz, while technically attractive, have the disadvantage of heavy use by other services. To this end the APO Research Laboratories are investigating attenuation effects in wet, tropical regions of Australia.

Two solar (sun-tracking) radiometers are being used to continuously measure noise radiation from the sun, and separately the sky, at 11 GHz, and by only one also at 14GHz. The sun radiates a virtually steady noise signal in the 11-14 GHz band of interest, and by day, any attenuation of this signal caused by rain, cloud, etc. can be directly measured. At night, the noise radiated by the attenuating rain or cloud is recorded, and because attenuation and radiation by an absorbing body are related by physical laws, it is practicable to obtain attenuation by calculation. A network of tipping-bucket raingauges adjacent to the radiometers provides rainfall intensity records with averaging times of under one minute.

One radiometer, operating at 11 GHz only, was installed at the Army Tropical Trials Establishment near Innisfail, Queensland (lat. 17° 41'S, long. 146° 07' E) in October 1972, and has provided virtually continuous records throughout 1973. Innisfail lies in one of the wettest regions of Australia, with an annual rainfall of about 350 cm.

The highest attenuation observed at Innisfail, up to December 1973, has been about 15 dB, which occurred at 90° elevation on two occasions. The duration of this attenuation level was under one minute, and was associated with a rainfall intensity of about 3.5 mm per minute.

The most prolonged period of attenuation resulted from a tropical cyclone. The attenuation on that occasion, at 11GHz, reached 8.5 dB for 15 minutes, exceeded 6dB for almost one hour, and 3 dB for 3½ hours.

The rainfall intensities observed at raingauges only 2 km apart have generally varied markedly from one to another, suggesting good space-diversity performance.

The Innisfail measurements will continue through into 1974.

The second radiometer is a dual-beam (sun beam and sky beam) dual frequency (11 and 14 GHz) unit, which, like the first, was designed and built by the APO Research Laboratories. It was installed in December 1973 near Darwin, at the Radio Australia receiving station on Cox Peninsula (lat. 12° 29' S, long. 130° 44' E). Darwin, with an annual rainfall of around 150 cm, experiences a different type of rainfall pattern from Innisfail. At this stage only some initial results are available, indicating, as expected, that attenuation is more severe at 14 GHz than at 11 GHz.

The suntracking mode of the radiometer provides a more accurate attenuation measurement than is possible by using sky noise alone. A disadvantage, however, is that the elevation angle of the measuring path is continually varying with the sun's motion. To study the effects of elevation angle on attentuation, the Darwin radiometer is being supplemented by an additional sky-noise radiometer, operating from a fixed-elevation antenna.

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# Development and Application of Telephone Traffic Measuring Equipment — Part 2.

L. A. TYRRELL, B.E. M.I.E. (AUST).

*This is the second of two articles about traffic data and equipment for gathering it. Part 1 described the data requirements for planning and supervision of the telephone network. Part 2 describes how the data to be acquired are available in a number of different forms from a variety of devices in the switching path of the telephone exchange. In the design of the data gathering equipment, the fundamental problem was to translate the data as presented by the switching equipment into suitable binary patterns, to assemble these patterns into ordered formats and write them as punched paper or magnetic tape. The philosophy of the system design and the operation of the equipment are explained. Several devices within the system are described in some detail.*

## GENERAL SYSTEM DESCRIPTION

The traffic measuring equipment consists essentially of three main parts:

- Equipment to collect and assemble the data from the various sources within the exchange.
- Equipment which controls the recording of the data which has been collected.
- The data recording equipment.

Fig. 1 illustrates the inter-relationship of the different equipments for ARF crossbar exchanges.

### Collecting and Assembling the Data

For each type of switching equipment there is a complete traffic measuring system which collects both dispersion and occupancy data from the telephone exchange. The occupancy equipment is the same for all types of exchange, but many differences occur between the dispersion equipment for ARM and the various types of ARF exchanges. As may be seen from Fig. 1 the data to be acquired is presented in different forms and is dispersed over various devices in the switching path of the telephone exchange. Collection of the dispersion data is initiated by circuit conditions within the switching equipment as calls are set up and disconnected; whereas the the traffic measuring equipment, through the agency of its time clock, controls the collection of occupancy data. The data collection equipment translates the data as presented by the switching equipment into binary signals, assembles the binary information into a suitable pattern and extends a signal indicating that data is ready for recording.

The main functions of the data collection equipment may therefore be summarised as:

- Detection of conditions which indicate that data is ready for collection.
- Generation of circuit conditions to enable the data to be collected.
- Assembly of the data in its correct format.
- Extension of a signal to indicate the availability of data for recording.

The data collection equipment for *route occupancy* measurements enables the number of devices occupied within a group of up to 200 to be recorded. A total of 400 groups, each containing up to 200 devices, can be measured in less than one minute.

The data collection equipment for *circuit occupancy* measurements identifies each device within a group and records its condition. Whereas the previous measurement merely sums the number of devices within a group which are occupied, this measurement records the condition of each individual device. The equipment can record the condition of more than 40 devices per second.

The data collection equipment for *dispersion* measurements records the following information about each call monitored:

- The inlet identity.
- The dialled digits.
- The outgoing route.
- The call starting time.
- The call finishing time.

The methods of obtaining dispersion data are dictated by the type of exchange equipment on which the measurements are taken. As previously described, the Australian Post Office operates a number of different switching systems so that it has been necessary to design data collection equip-

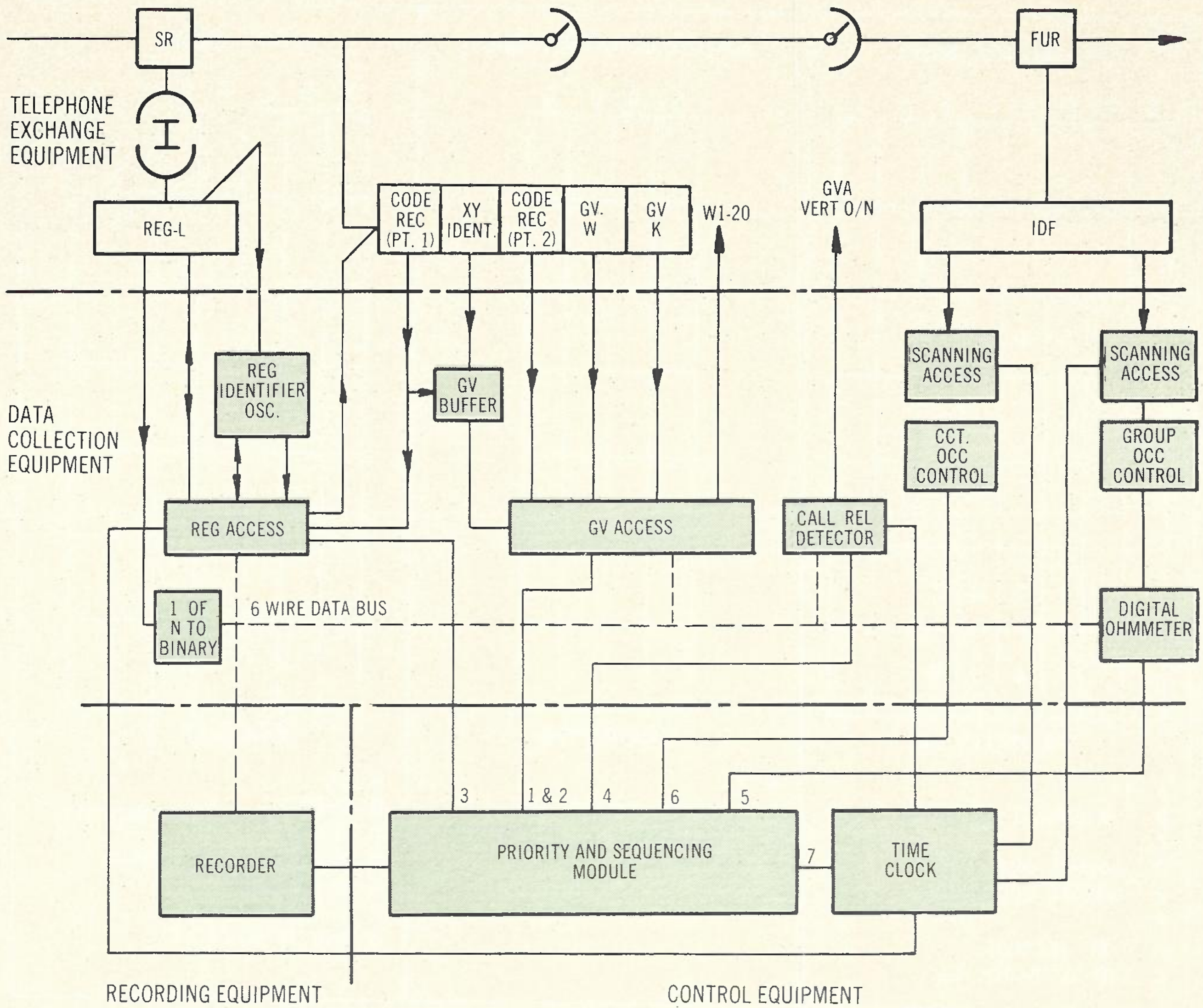



**Fig. 1: Block Diagram of Traffic Measuring System for ARF Exchanges.**

ment to suit each case. There is however a common approach to each system of obtaining traffic dispersion data in that a number of inlets to a switching stage are observed, and the information mentioned above is obtained for all traffic passing through these inlets. For ARF exchanges up to 320 inlets are observed to obtain the traffic sample, while for ARM exchanges 400 inlets are observed, yielding a sample of up to 5,000 calls per hour.

All the data collection equipments assemble data in a format suitable for storage on the recording medium, which is punched paper or incremental magnetic tape. Typical blocks of data are illustrated in Fig. 2. The first frame in the block is a header character which identified the source of the data within the block. The block finishes with an end of block character. Between the header character and the end of block character (always binary 62), are recorded the relevant data.

It may be observed that each frame comprises six bits of data plus a bit in the seventh track to provide odd parity. The parity bit provides a simple check of the correctness of each frame of data. It is subsequently checked by the tape recorder before recording and again by the data processing equipment to ensure that the data has not been disturbed by noise, faulty tape or any other agency.

**Selection of the Data Sources and Presenting the Data to the Recording Equipment**

The complete traffic measuring system for any type of telephone exchange incorporates, as described, a number of devices for collecting data

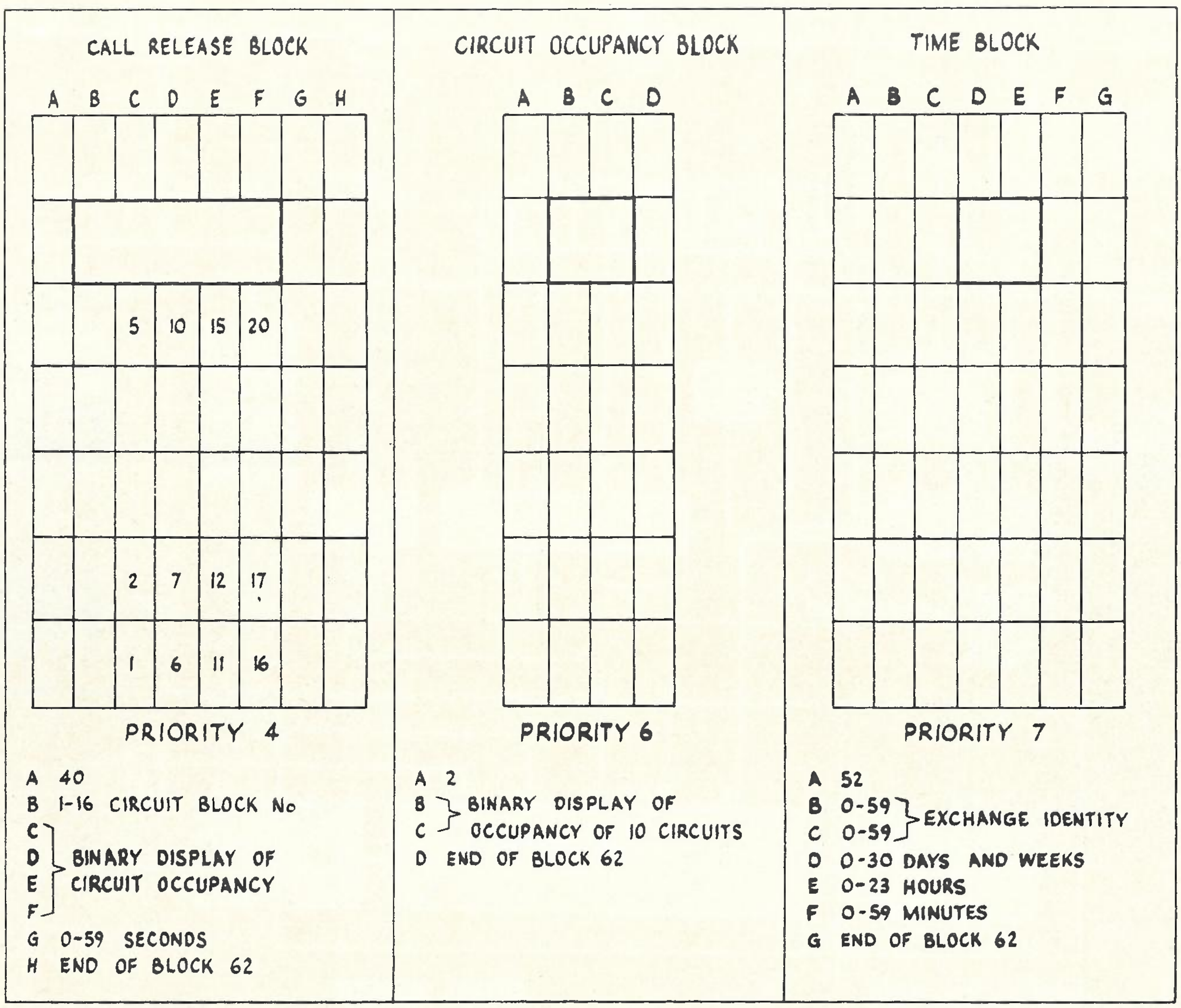



**Fig. 2: Typical Block Formats.**

and assembling the data into blocks. Since the data from several devices may be available for recording at the same time, a system is needed to determine the order in which data from the various sources is to be recorded. In addition to selection of a particular source, provision must be made for the data from that source to be extracted frame by frame in the correct sequence.

The data from those sources involved in the setting up of calls is available for relatively short durations, in some cases as little as 200ms. In addition, up to four calls may be switched simultaneously through the inlets being observed. The magnetic tape recorder can record a character every 3.3ms. It is therefore necessary to employ a system of priorities for recording the various blocks to minimise loss of data. A different system of priorities has been devised for each exchange system. The typical blocks illustrated in Fig. 2 have recorded against them the priorities that apply within the ARF traffic measuring system. Dispersion data which are generated by the switching equipment itself are given the higher priorities. Route occupancy and circuit occupancy data are given the lower priorities since these measurements are generated by the traffic equipment itself and can therefore be controlled to allow the dispersion data first use of the recording equipment.

The extraction of data, frame by frame, from the data collection equipment is performed under the control of a stepping chain. There is, however, a complication that arises from the non-uniformity or the lengths of the blocks of data. Provision is made in the circuitry to determine the length of the block appropriate to each data source and to control the extraction process accordingly.

### Recording the Data

Punched paper machines or magnetic tape recorders record the data. Both types of recorder are purchased from commercial sources. The paper tape machines, depending on their type, are capable of recording 20 to 100 characters per second, while the incremental magnetic tape recorders can record 300 characters per second. The relatively higher speed of the magnetic tape recorders is essential for the complete traffic measuring systems. In the past, paper tape has been used extensively since traffic dispersion equipment has not been available and the speed of paper tape machines is adequate for occupancy measurements. However, the limited period during which data are available during the setting up of calls, as described above, indicates the need for magnetic tape recorders in conjunction with traffic dispersion measurements.

As mentioned earlier both the paper tape machines and magnetic tape recorders write the data in computer legible format. The magnetic tape recorder warrants a more detailed description in this regard. It is a seven track machine which uses an incremental movement to record 200 characters per inch on ½-inch magnetic tape. The data is written onto the tape in a format which accords with the specifications of British Standard 3968 : 1968, which are in effect a definition of the conditions that must be observed for the data on the tape to be legible to a computer equipped with a suitable reader. To this end the tape recorder checks the parity of each frame of data which it receives. Incorrect parity is corrected and a unique character, called a parity error character, is written after the corrected frame of data. The presence of the parity error character is used later in the data processing phase to identify characters of doubtful validity. British Standard 3968 : 1968 also requires that the data be assembled into blocks of up to 2048 characters, each such block of data to be terminated by a longitudinal check row of even parity and separated from adjacent blocks by an inter-record gap of 19 millimetres. The tape recorder incorporates the logic needed to satisfy these further requirements of the format specification.

The recording density of 200 characters per inch on the magnetic tape is quite low. The selection of a format incorporating such a low character density was made considering that the recorders would often operate in environments where there was only limited control over temperature, humidity, or dust levels. In these circumstances a low character density offers a certain protection against the intrusion of errors.

## DESCRIPTION OF THE EQUIPMENT

The traffic measuring equipment has been designed in modules, or building blocks, so that the measuring systems which are required to perform the occupancy and dispersion measurements in the different types of exchanges may be built from different combinations of standard modules. A total of 25 modules was required to cover all circumstances. Brief descriptions of several modules are set out below.

### The Data Bus

Before examining the system in any detail it must first be understood that all devices which collect and assemble data are permanently connected to a common bus comprising six wires. The six wires (or data bus) are the medium by which the data is transferred from the collection points to the recorder. Buffer amplifiers to adjust voltage levels and filter out noise disturbances are introduced into each of the six wires at the interface to the recording equipment.

### Digital Ohmmeter

The measurement of route occupancy, that is the number of occupied devices within a group, is essentially a measurement of resistance. Each device within a group, while it is occupied, applies earth via a 100 kilohm resistor to a commoning point. Consequently the resistance between the common point and ground is an indication of the number of circuits occupied. A simple block diagram demonstrating the operation of digital ohmmeter is sketched on Fig. 3. The digital ohmmeter basically consists of a Wheatstone bridge which has a differential amplifier across the balance arms. To balance the bridge the differential amplifier causes a series of resistors to be switched in and out of the balance arm until a null is achieved. There are in fact eight resistors and the sequence in which they are applied to the balance arm is such that when a null has been obtained the setting of the resistors indicates in binary the number of devices occupied. The digital ohmmeter is capable of measuring the occupancy of 1 to 200 devices.

A number of protection circuits are incorporated to guard the bridge against the effects of foreign electrical potentials.

### Register Identifier

In ARF exchanges the dialled digits associated with each call are stored in what is known as a register. For a group of 320 ARF inlets up to 100 registers may be required to perform this function. Since an inlet through which a call is to be switched may be connected up to any of the 100 registers it is necessary to be able to identify the register

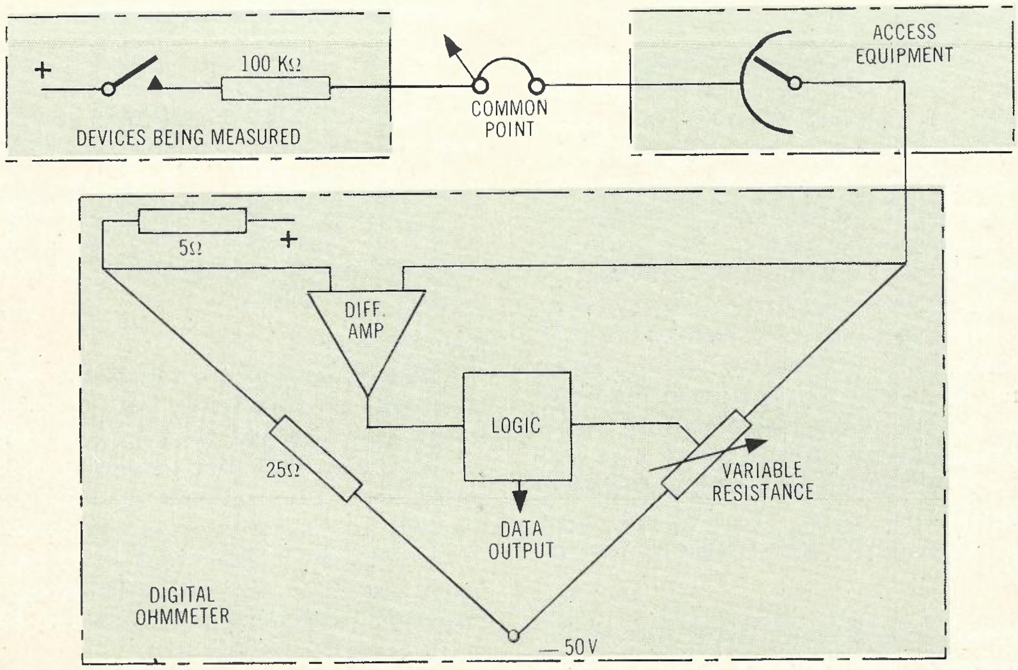



**Fig. 3. Block Diagram: Operation of Digital Ohmmeter.**

which is connected and has stored the digits for the call, so that these digits may be extracted and stored on the magnetic tape.

The register identifier consists of 20 phase detectors and a 10 x 10 transformer matrix corresponding to x and y co-ordinates of the 100 registers. A block diagram illustrating the circuit arrangement is shown on Fig. 4. To identify the register connected to a particular inlet, a 15 kHz signal is fed out through the inlet over the switched connection to the associated register. The tone is then fed to the register identifier, where the phase sensitive detectors compare the phase of the incoming signal with that of a reference signal. Only the detectors corresponding to the x and y co-ordinates of the register to be identified will be activated, as in all other cases the incoming signal and the reference signal will be approximately 180 degrees out of phase.

The identity of the register is used by other equipment to access the digit store of the register, encode the digits in binary coded decimal and insert parity in preparation for the data being recorded on tape.

**Standard Priority and Sequencing Module**

The Standard Priority and Sequencing Module (SPASM) performs the following functions:

- Identifies the various data collection equipments with data available for recording.
- Selects the source of data to be recorded in accordance with a standard set of priorities.
- Scans each frame of data from the data collection equipment, commencing with the header character and through the data proper in the correct sequence.
- Inserts an end of block character after the last frame of data from each recording source.
- Controls the operation of the recorder by signalling forward to the recorder whenever data is available for recording.

The sequence of operation by which SPASM controls the recording of a block of data is described below:

- Of those data collection equipments which have signalled that they have data ready for recording SPASM selects the one with the highest priority
- SPASM then applies an enabling condition to extract the six data bits of the first frame of data.
- At the same time a signal is sent to the recorder commanding it to record the frame of data presented to it. The frame comprises the six bits of data which appear on the six wire data bus plus one bit of parity generated from the data proper. The first frame of data will as previously described be the header character for the block.
- The recorder sends a revertive signal back to

SPASM as soon as the data has been recorded.

- On receipt of the revertive signal SPASM repeats the second and fourth steps above until all the frames of data for the block have been recorded.
- After the last frame of data has been written SPASM causes an end of block character to be added to indicate the limit of the block of data.
- SPASM then selects the next source of data as described in the first step above.

**CIRCUIT PRACTICES**

As an introduction to the circuit practices within the traffic measuring equipment it is instructive to first consider the circuitry of the exchange switching equipment. The crossbar switching equipment designed by L. M. Ericsson and operated by the Australian Post Office consists mainly of relays operating from a 50 volt d.c. supply. To gather the requisite data from this electro-mechanical equipment that measuring equipment must in general operate an order more quickly than the switching equipment to avoid loss of data. This in turn implies the use of semi-conductor devices for many functions where high speed is necessary. Whereever possible discrete components were used to obtain the required speed of operation, but in those

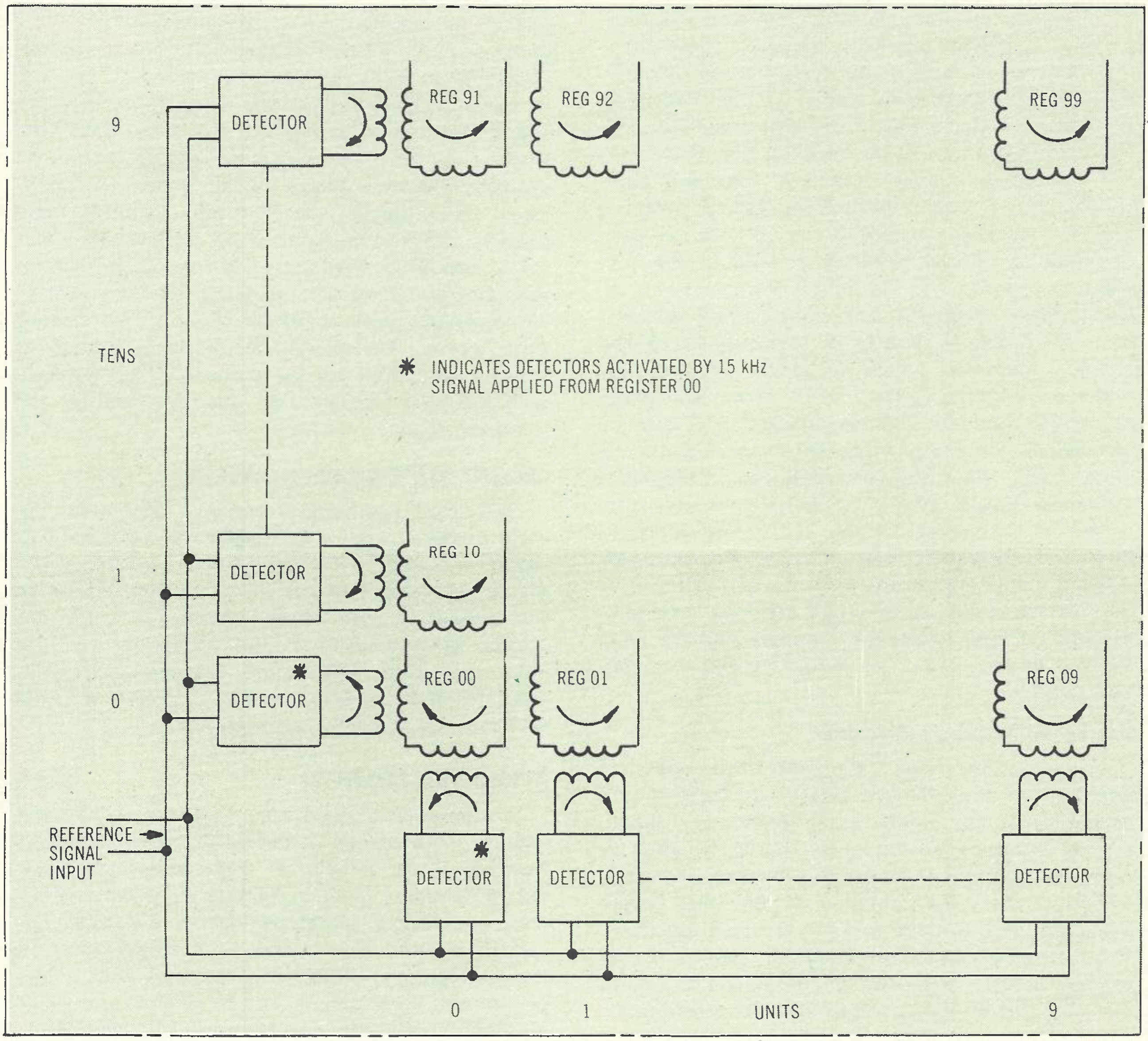



**Fig. 4: Block Diagram: Operation of Register Identifier.**

cases where the circuits operations were complex, integrated circuitry was exploited for its compactness and cheapness relative to discrete components.

### Choice of Components

The various considerations mentioned above have led to a system which incorporates a wide range of devices:

- Electro-mechanical equipment to access and store the data in those circumstances where speed of operation is not a significant constraint.
- Discrete semi-conductor components to access and store data which are only present for short periods (less than 200ms), and also to perform certain analogue functions.
- Low voltage integrated circuitry (the RTL family) to handle relatively complex logical functions which must be performed at high speeds.

The electro-mechanical logic of the switching equipment is characterised by large inductive voltage surges and contact bounce. This behaviour does not affect other electro-mechanical logic but semi-conductor components performing logical functions will not function satisfactorily in such an environment unless special attention is paid to the suppression of noise and the effects of contact bounce. Under these conditions electro-mechanical solutions to circuit problems tend to be relatively cheap and simple. Therefore wherever speed of operation was not the prime factor, electro-mechanical equipment was used. In all other circumstances discrete semi-conductor components or integrated circuits were used. Discrete semi-conductor components operating directly off the 50 volt supply were preferred to integrated circuitry for simple functions in spite of their inefficient utilization of space. Low voltage integrated circuits were the choice for complex logical processes although their use was complicated by their low noise immunity and the need to provide d.c. to d.c. converters for the low voltage supply.

### Compelled Sequence Operation

In view of the large differences in the speed of operation of the different systems of logic it was decided that any interworking equipment should operate in compelled sequence. That is, the circuitry was arranged so that where two devices interwork, one must check the condition of the other before being enabled to move to its next circuit condition. This method of operation avoids the need for timing conditions to be exploited or introduced to ensure that circuit operations proceed in their correct order.

### Noise Protection

Extensive precautions were taken to protect the low voltage logic from the effects of noise introduced from high voltage logic by either capacitive or inductive coupling. The digital ohmmeter and SPASM already described are two of the devices which employ low voltage logic. The low voltage circuitry was physically removed as far as possible from wires or components energised directly from the normal 50 volt exchange supply. The wiring forms within the system were carefully designed so that wires carrying low voltage logic and those carrying high voltage logic either ran at right angles to each other or were maintained at a separation of at least five centimetres.

### Contact Bounce

The contacts of relays can bounce for varying periods depending on a number of factors: the type of relay, the number of contacts, the state of adjustment and so forth. Under some conditions the contacts may bounce for periods of up to 20ms. High speed semi-conductor logic on the other hand generally requires that any input signal should be characterised by a single unambiguous change of state. Accordingly wherever relay contacts were used to drive high speed logic various interfaces were introduced after the relay contacts to monitor their electrical conditions. A typical interface ignores all transitions until a period of 4ms has elapsed since the last transition. Then a single change of state is generated on the output of the interface with the rise time or fall time required by the following logic.

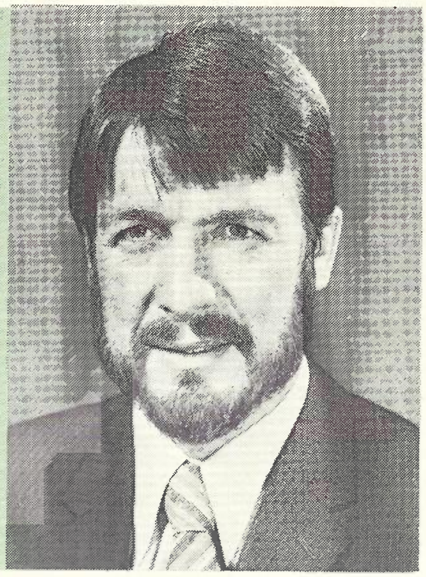
## PRESENT STATE OF DEVELOPMENT

The circuit and route occupancy equipment has been manufactured in reasonably large quantities. Equipment from early production runs has been giving satisfactory service for some two years. The first production run of equipment for traffic dispersion measurements in ARF exchanges has just been completed. The testing of prototype equipment for traffic dispersion measurements in ARM exchanges is currently in progress.

## ACKNOWLEDGEMENTS

A large and complex project such as the one described, executed over a period of years, inevitably involves many people at both professional and sub-professional level in all phases of its development — design, prototype testing, documentation and field trials. The authors wish to acknowledge the contributions of all those persons with a past or present involvement in the project, especially N. M. H. Smith who was the original prime mover, and the numerous technical officers whose efforts made the project possible.

Mr. LEO TYRRELL joined the Department as a Clerk in 1956. After advancement to Cadet Engineer and later qualifying as an Engineer he worked in the Victorian Administration on Trunk Service, Regional Works and Exchange Installation. In 1969 he was appointed as Engineer Class 3, in the Telephone Switching Equipment Branch Headquarters, where he has since worked, mainly on the design of service and operational equipment for the switching network.



## Errata – Vol. 23, No. 2

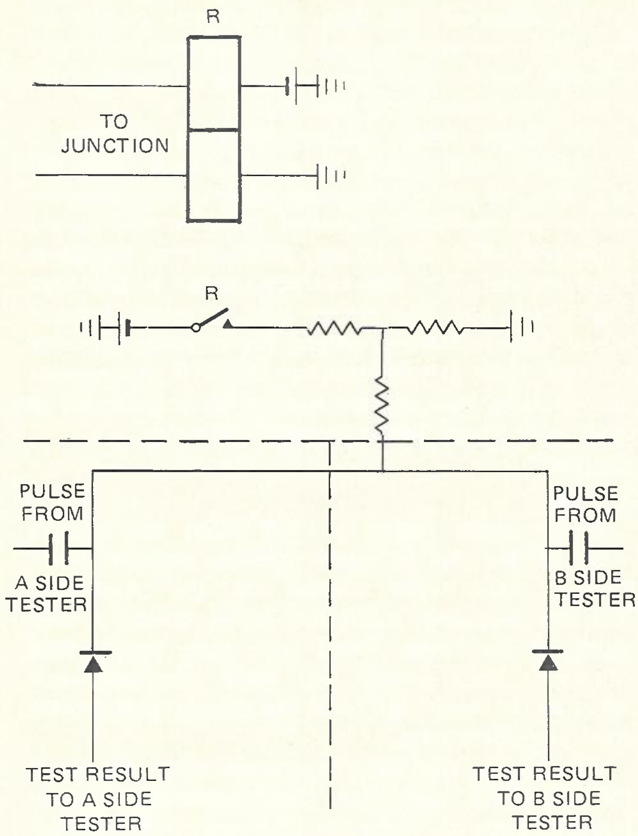
Several errors were included in the above issue and the corrections shown below should be made to the articles listed.

**An Introduction to the 10C Trunk System (Page 88).**

Fig. 2 was intended to illustrate the principle of the testing operation and in developing the sketch, two errors occurred. The errors, which have been rectified in the sketch opposite, were:

- Positive instead of negative potential was shown behind the relay contacts
- The pulse interrogation and the test result leads to the tester were reversed.

**Answers to Examination Questions (Pages 164, 165).**
**Answer 14 (a): Answer should be (61)10, not (63)10.**
**Answer 14 (b): Last column of answer should read (from top) 0110 instead of 0010.**



# The Darwin - Mt. Isa Radio Relay System

M. J. KIMBER B.E. (Hons.), M.I.R.E.E.

*Australia's expanding needs for communication services and its large areas of sparsely populated land make it necessary for the Australian Post Office to use special techniques in the design and implementation of the broadband bearer network. The Darwin—Mt. Isa microwave system spans 1600km of inhospitable terrain to provide advanced telecommunication services to remote parts of Australia. The special techniques used to ensure reliable unattended operation of such a long system are described in this paper.*

**INTRODUCTION**

With the completion of the Darwin-Mt. Isa Radio Relay System, Australia's broadband network will span some 10,000 kilometres from Port Hedland in Western Australia to Darwin in the Northern Territory and link all capital cities. This network is already providing subscriber trunk dialling and a large range of data, telex and facsimile facilities to customers of the Australian Post Office from Port Hedland to Mt. Isa and the completion of the Darwin-Mt. Isa system will extend these services to the Northern Territory, which has previously only been served by open wire systems stretching through remote and desolate areas of South Australia and Queensland (Ref. 1).

The Radio Relay System traverses no less a forbidding countryside as can be seen from the map (Fig. 1) and photograph of a typical repeater station on the wide desolate plain of the Barkly Tableland, (Fig. 2) where mid-summer temperatures exceed 50°C and average rainfall is less than 25cm per year. The system also traverses tropical areas close to Darwin where the relative humidity rises to 95% at temperatures of 35°C. All aspects of this long haul system had to be engineered to cope with these environmental extremes.

**DESIGN**

**Survey**

Design work began in 1969 when map studies were carried out to select possible repeater sites. Firstly, sites were plotted on the Australian National Mapping 1:250,000 Series during a map study of the route. These were then investigated during a field survey and some locations were adjusted to cater for local conditions and access road considerations.

All these preliminary sites were accurately fixed by surveyors from the Commonwealth Department of Interior, (now the Commonwealth Department of Services and Property) and marked by large plastic targets. An aerial photographic survey was carried out at a height of 3,650 metres and stereo photographs were produced. Photogrammetric techniques were then used to obtain 1m and 2m contour intervals on paths between sites in a strip 5km wide.

By the use of this detailed contour information, path profiles were plotted and the positions of sites were modified to optimise path lengths, overshoot, ground reflections, access road lengths and tower heights.

**Path Criteria**

The general criteria used in the path design were:—

| | |
|---|---|
| Frequency Band | : 3770-4200 GHz |
| Frequency Plan | : Interleaved |
| Average Path Length | : 40 km |
| Maximum Tower Height | : 76 m |
| Minimum first overshoot | : 5° |
| Minimum second overshoot | : 2.5° |
| Synchronous satellite orbit minimum angular separation | : 2° |
| Values of 'k' | : 0.6 Camooweal - Katherine<br>0.8 Remainder of route (See Fig. 1) |

**Propagation Hazards**

Because the route traversed approximately 500 km of treeless flat plain between Camooweal and Tennant Creek, the route design had to incorporate adequate allowance for space diversity. Of the 13 paths in the area, 11 were deemed to require diversity.

Studies into propagation phenomena at Julia Creek in Queensland indicated that subrefractive conditions occurred on frequent occasions and severe median depressions were common.

Since the topography and vegetation of large sections of the Darwin-Mt. Isa route closely resembled the Julia Creek area, an unusually low value of 'k' (equivalent earth's radius) was chosen as a design criterion. Based on the published works of Takasu, Tanaka, Pearson and Ugai (Refs. 2, 3, 4) the propagation outages for the whole route were finally assessed to be 0.0018%.

**Performance Criteria**

The primary design criterion adopted for the route was that it should meet the noise performance specified in CCIR Recommendations 393-1 and 395-1 Oslo 1966, viz., 3pWop/km for not less than 80% of the time. In fact, the final route design indicates that the system will perform at better than 2.15pWop/km, thus allowing an adequate maintenance margin.

## IMPLEMENTATION

**Project Management**

During the design phase, various methods available for installation of the system were considered. Such a large project could be given to one contractor who would arrange to carry out all works associated with its installation. This method had been used on the East-West Radio Relay System (Ref. 5) and while the result was satisfactory, some co-ordination difficulties were encountered. The APO therefore chose to manage the entire project and let separate contracts for each phase of the installation. All responsibility for co-ordination was vested in the APO.

It was decided to consider the route as one entity, controlled by one group responsible to the South Australian administration, even though about 185 km of the route was in the State of Queensland. A project team consisting of approximately 30 personnel under the control of a Project Manager was assembled to manage all phases of installation of the project.

In addition, the professional engineers in this team assisted materially with the route design, the writing of specifications, and the examination of tenders. This resulted in close liaison between Headquarters and the State administration in the management of the project.

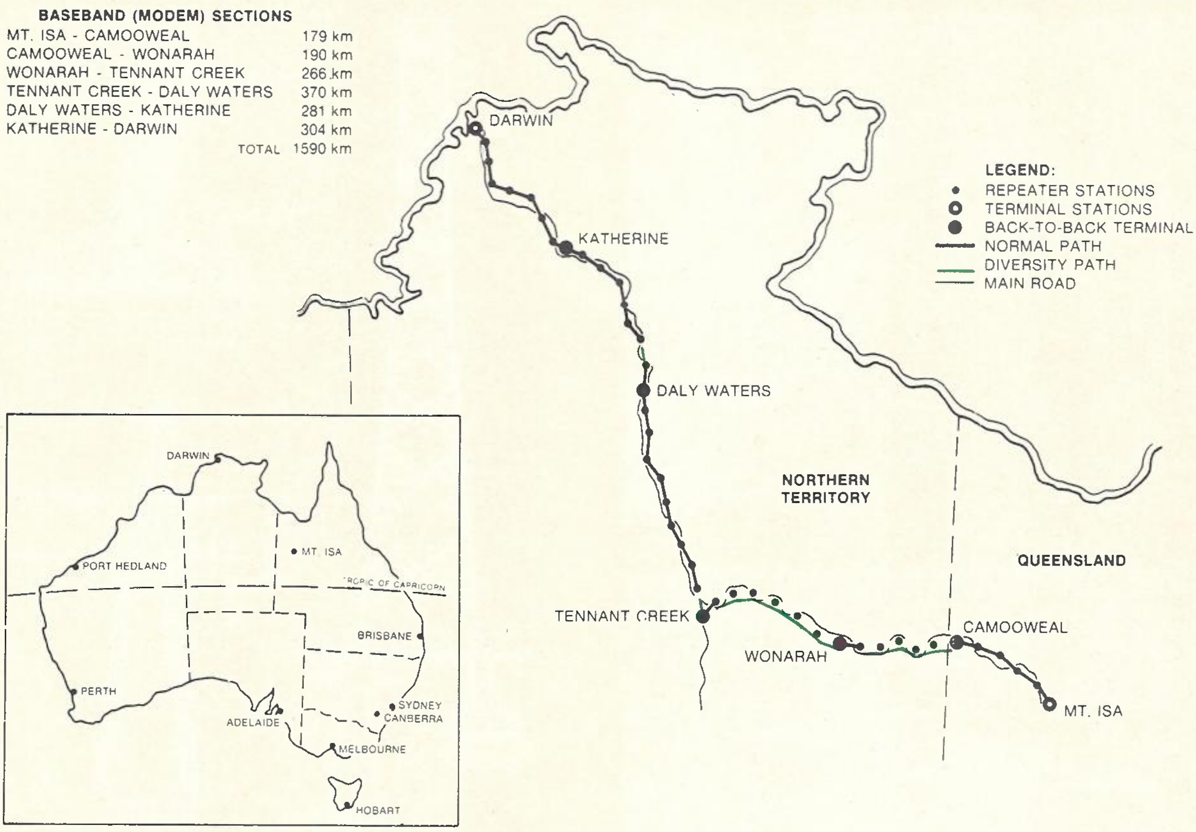



**Fig. 1—Route Map of Darwin-Mt. Isa Radio Relay System.**

**Contract Arrangements**

The installation was divided into the following phases for the convenience of calling tenders:

*Civil Works:*
- Roads
- Site Levelling

*Towers:*
- Supply and installation
- Tower foundations
- Building foundations
- Fuel tank
- Tower structure

*Buildings:*
- Design

*Buildings:*
- Construction and installation
- Building
- Air conditioning

*Power Generating Plant:*
- Supply and installation
- Diesel engines
- Alternators
- Control circuits

*Batteries:*
- Supply and delivery

*Antenna Systems:*
- Supply and installation
- Antennas
- Waveguides
- Antenna circulators
- Pressurization equipment

*Radio Equipment for 1 + 1 system:*
- Supply and installation
- Branching networks
- Transmit/receive equipment
- Modem equipment
- Switchover equipment
- Sub-baseband injection equipment

*Supervisory equipment:*
- Supply only
- Remote indication equipment
- Remote control
- Sub-baseband multiplex
- Display equipment

It should be noted that immediately after the completion of the route design, the Commonwealth

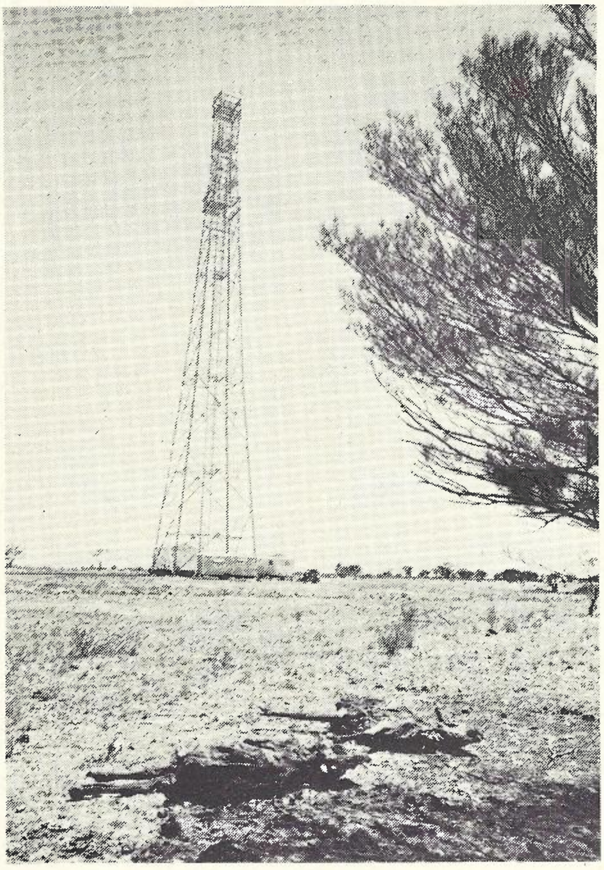


**Fig. 2—Typical Repeater Station.**

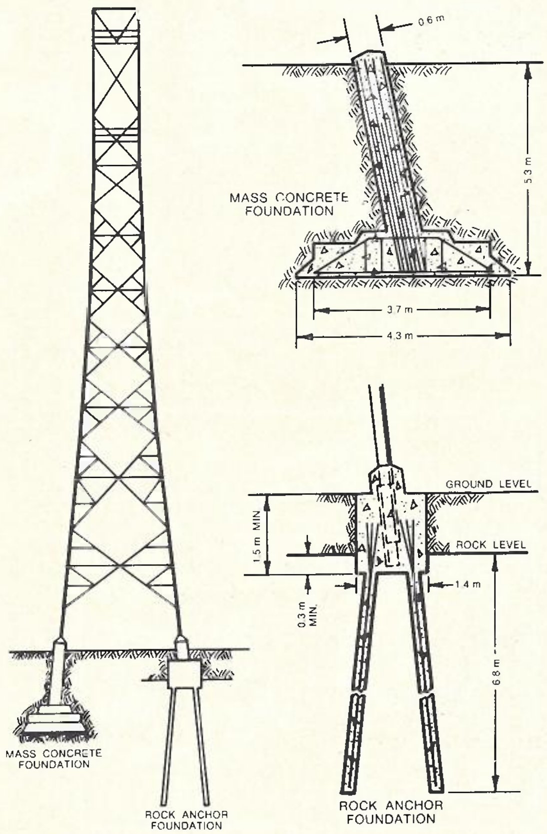



**Fig. 3—Self-Supporting Tower and Foundation Design.**

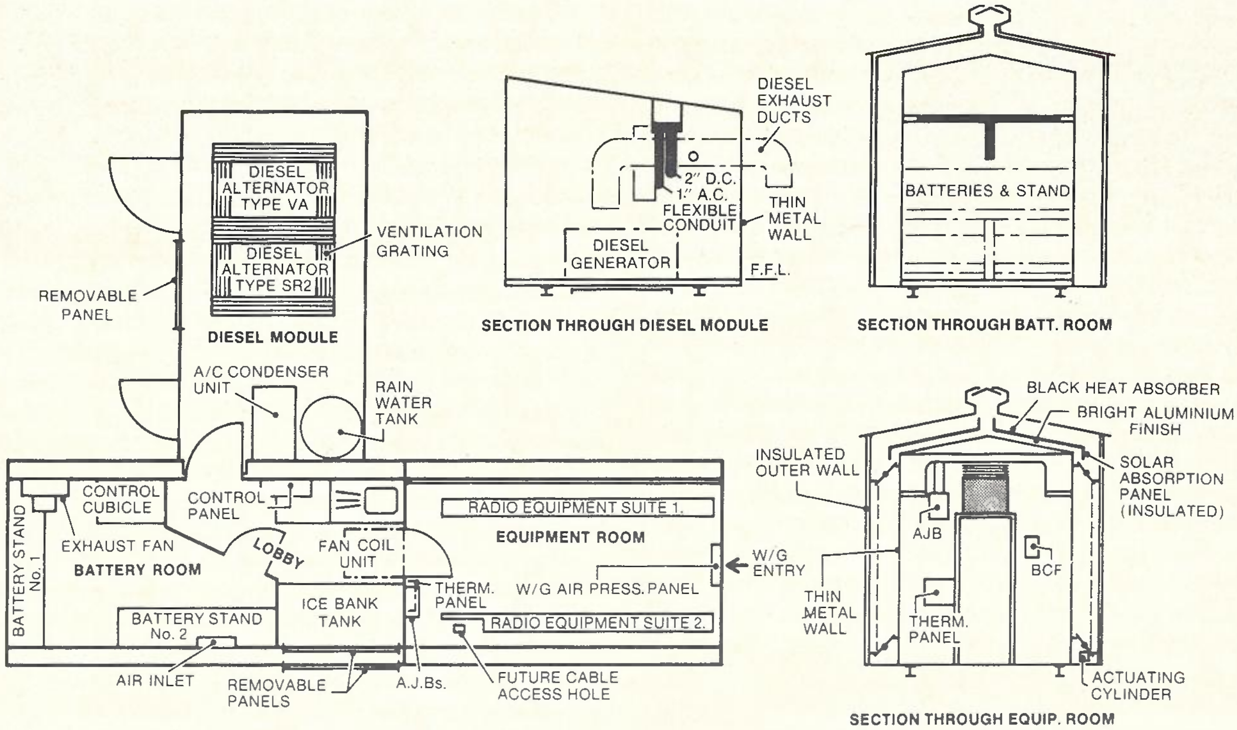



**Fig. 4—Repeater Equipment Shelter.**

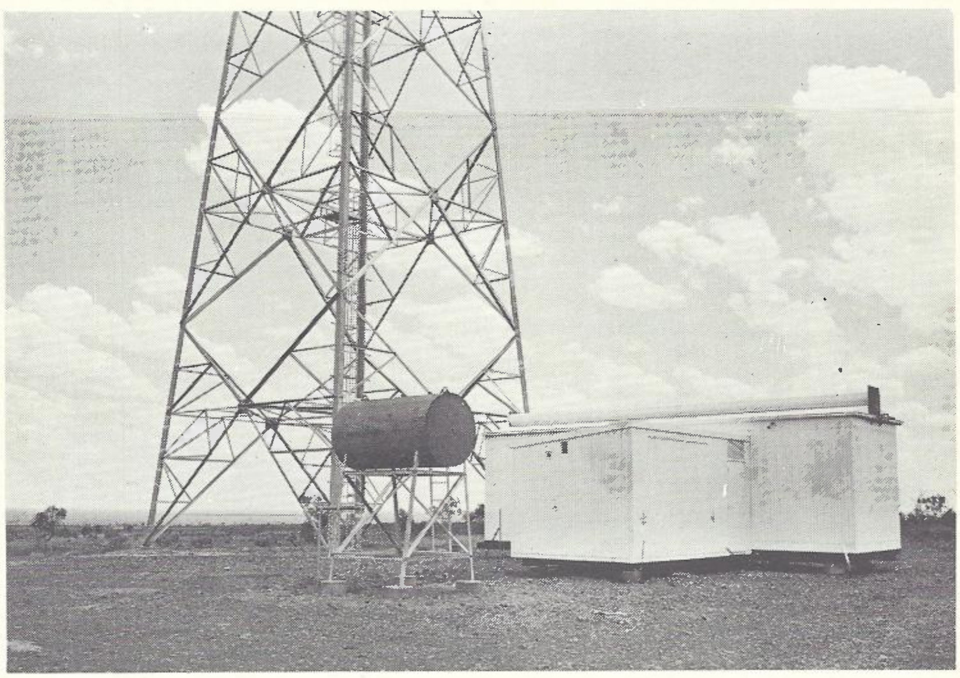


**Fig. 5—Repeater Equipment Shelter.**

Department of Works was briefed for the design and construction of all access roads and the preparation of all sites. That Department then called the appropriate tenders and supervised the work. In addition to site works, the Commonwealth Department of Works arranged construction of masonry buildings at Tennant Creek and Katherine. Buildings at Mt. Isa and Darwin terminals had already been completed for other parts of the Post Office network. Members of the project team were responsible for co-ordination of these aspects through the Queensland and South Australian Buildings and Properties Sections.

In each of the other categories of equipment the project team and Headquarters co-operated to determine the approach necessary to ensure that the equipment was satisfactory for the environment and would perform adequately. Many decisions were taken on the basis of experience gained on other long-haul radio systems in Australia, such as the Townsville - Mt. Isa system (825 km) and the East - West system (1,600 km). Each category incorporated various innovations as a result of this experience.

## DESCRIPTION OF SYSTEM COMPONENTS

### Towers

A new series of towers was developed for this system, based on earlier designs. These utilised two different types of foundation, namely, rock anchor in circumstances where the rock on the site was of sufficient strength to support the towers, and mass concrete foundation where excavation was economical. The rock anchor foundation consisted of three or four piles per leg formed by drilling the rock and pouring in high strength concrete around high tensile deformed reinforcing bars. These bars terminated in a leg cap which formed the bond between the piles and the stub leg. Fig. 3 shows the general assembly of the towers and the configuration of the foundations.

### Buildings

Of the 45 sites on this route, only four are of standard masonry construction. The remainder are transportable steel clad 'equipment shelters'. Thirty-eight of these are standardized shelters, indicated by Figs. 4 and 5, and house repeater equipment. The remaining three are much larger structures designed to house demodulation equipment.

This concept of transportable equipment buildings was chosen because any other type of building would have required a large amount of field work, resulting in high cost and programme delays. It should be remembered that the whole route traverses extremely inhospitable terrain and this makes it difficult to attract and retain a large force of skilled workers.

Instead, all buildings were manufactured in Adelaide and transported, fully assembled to the various sites by a co-ordinated system of road and rail transport (see Fig. 6). Field work was then limited to the repair of transport damage and manufacturing deficiencies with the subsequent commissioning of the air conditioning plant.

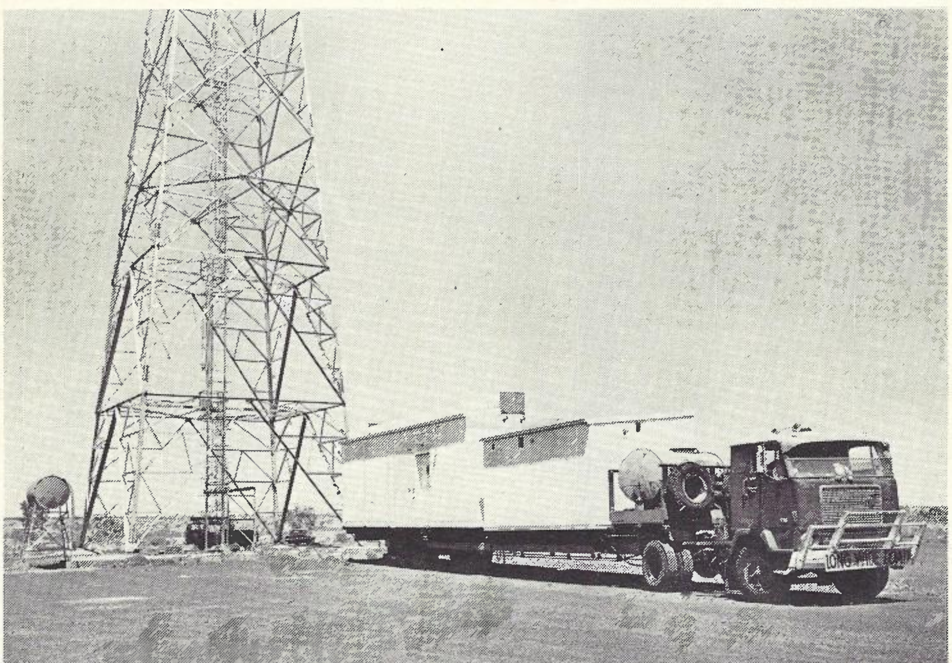


**Fig. 6—Transport of Equipment Shelter.**

The standard repeater building consists of two essentially different modules, the first of which is a thin walled metal structure housing the diesel generators, the air conditioning compressor unit and the water tank. Ventilation for the diesel generators is provided through a grating in the floor which surrounds each plant. The hot exhaust air is ducted outside the building. Further ventilation is provided through louvres above the main entry door.

The second module is a double-walled structure which accommodates radio equipment, batteries and control equipment. The outer wall of this building is of sandwich construction insulated with fibreglass. The inner wall is single thickness V-crimp light gauge sheeting. The roof is also constructed in a similar manner except that the area over the equipment room has an intermediate section of roof between the sun screen and the inner cladding. The function of this intermediate section is to absorb solar energy and thus promote convection flow between the inner and outer walls to carry away heat conducted from the equipment room. The air flow between the two walls of the equipment room is regulated by means of shutters which are controlled by thermostats within the equipment room. The shutters are operated by air-rams driven with compressed air from the wave-guide air dehydrator. Should the temperature within the equipment room fall below 16°C the shutters will close, preventing air flow past the walls and effectively insulating the room. In these circumstances, the equipment's own heat dissipation will ensure the room temperature does not fall significantly below 16°C. Should the temperature within the equipment room rise above 38°C the shutters will again close and the air conditioning system will be brought into operation. At intermediate temperatures, the interior of the equipment room is within 4°C of ambient temperature.

The air conditioning system consists of a 0.75kW condensing unit with a capacity of 1.75kW. This condensing unit is connected to an evaporator immersed in a 1,820 litre tank of water. Operation of the condensing unit freezes about 1,360 litres of this water. When air conditioning is required the remaining water in the tank is circulated through a heat exchanger which in turn extracts heat from

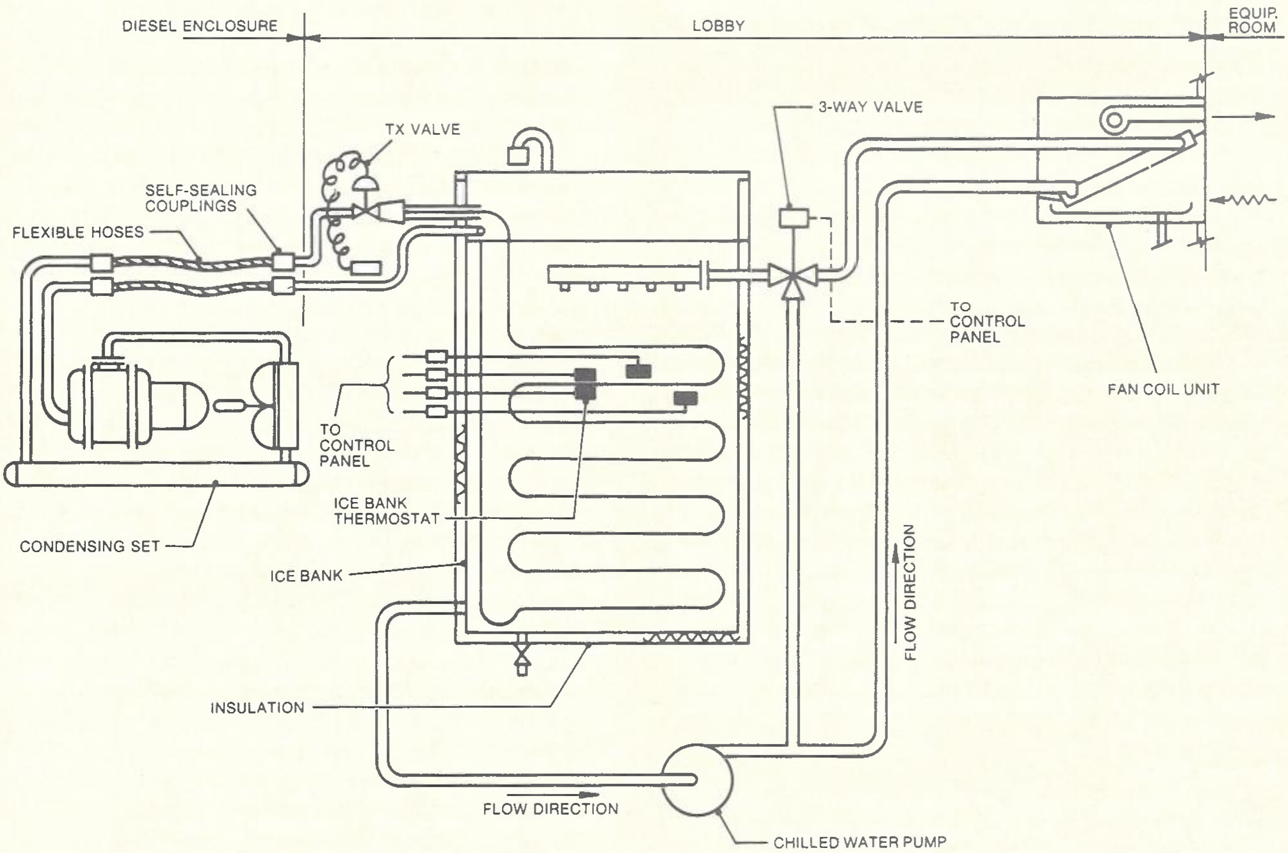



**Fig. 7—Schematic Diagram of Shelter Ice-Bank Air Conditioning System.**

the equipment room. The capacity of the heat exchanger (so-called 'fan coil' unit) is approximately 4.4kW. A schematic diagram of this system is shown in Fig. 7.

In addition to reducing temperature peaks, the air conditioning system fulfils another role, that of dehumidification. Since the surface temperature of the heat exchanger in the fan coil unit approaches 0°C, condensation of water vapour in the room air occurs, thereby reducing the humidity — a very necessary function on the northern section of the route.

If staff occupy the site for maintenance reasons, the heat exchanger can be brought into operation at a much lower temperature to provide comfortable conditions.

The demodulation station buildings utilise identical techniques to those described above but are equipped with two 'ice bank' air conditioning systems, each of which is identical to those used at repeater stations. The floor area of these shelters is approximately twice that of the repeater shelters.

Fire protection within the diesel module is provided by a 4.5kg capacity automatic extinguisher containing the chemical bromochlorodifluoromethane (BCF). Three 1.36kg BCF hand extinguishers are also provided at convenient locations within the building.

**Fuel Tank**

The fuel tank was supplied as a part of the tower contract and consists of a cylindrical tank with domed ends made from 6 mm mild steel. The tanks at repeater stations have a capacity of 2,270 litres, while those at the demodulation stations have a capacity of 6,820 litres. Both sizes of tanks are supported on galvanised steel stands approximately 2 m high. The tanks have been coated by an inorganic zinc process. All tanks are fitted with a filling arrangement accessible from outside the security fence which surrounds every site. Filling is accomplished by means of a pump connected to a 75 mm 'cam-lock' fitting attached to a non-return valve and a stop-cock. Arrangements have been made with oil companies to ensure compatability of couplings. A high level alarm has been provided on the tank fuel gauges and indicates to the fuel delivery operator when the tank has reached capacity (with 100-litre margin). This will allow fuel deliveries to sites without supervision by APO personnel and will not require access to the site by the contractor.

**Power Plants**

The batteries consist of two banks of eleven 500 ampere-hour cells. This number was chosen to meet the equipment manufacturer's specification relating to maximum allowable voltage variation. These limits were set at 20.0 to 26.0 volts and if it is necessary for the batteries to be operated on a charge/discharge cycle, the use of twelve cells would take the voltage limits outside those defined above.

The batteries are float charged by the continuous operation of a single cylinder type VA Lister engine driving, via two V-belts, a 4kw 24 volt dc generator and 4kVA 240 volt ac alternator. (It must be noted that the maximum total continuous rating of the type VA engine for both ac and dc is 3.0kw.) This particular type of engine was chosen because it is expected that it will give very long service since it operates at 750 rpm. This Lister VA engine is fitted with an extended 22-litre sump to allow long intervals between oil changes.

The VA engine and its associated alternator are mounted on a skid base attached to the engine bed subframe by means of eight high tensile bolts. In the event of a major engine failure which requires extensive maintenance, it is envisaged that this complete plant will be removed from the stand, using a truck and special hoist. Two specially equipped 5 tonne capacity trucks are being supplied for Tennant Creek diesel service centre and one such truck is being supplied for Darwin.

In the event of failure of dc output voltage from the VA plant, a dc voltage sensor initiates the start sequence of a Lister type SR2 plant. The type SR2 engine is directly coupled to a generator/alternator (maximum continuous ac and dc load is 5.6kw). This plant has no extended sump or make-up tank and therefore is not designed for continuous long-term operation and is installed primarily as a normally stationary plant. This plant is connected to its subframe by means of four bolts and can be removed by the same hoist arrangement as the type VA engine. Special access panels to allow removal of both plants have been provided in the diesel module.

A typical repeater installation is shown in Fig. 8. The access panels have been removed.

The power plant control cubicle is installed in the power room of the equipment module and contains automatic voltage regulators, control circuits, alarms, etc., which are associated with the power plant.

At Wonarah, Daly Waters and Camooweal three HR2 diesel engines driving 10kVA, 240 volt single phase alternators are installed. One of these plants operates continuously with the remaining two sets for sequential standby. Two 12-cell 500 ampere-hour batteries are float charged through two single phase rectifiers, and diode voltage droppers are used to ensure correct voltage limits.

The above plants are mounted in a similar fashion to those plants at repeater stations and can be removed for maintenance purposes.

## Antennas

Both 3 metre and 3.7 metre antennas are used on the system; the size being dependent upon path length and overshoot criteria. In the latter case where side lobe radiation is important, high performance antennas have been used. Flexible waveguide, type EWP-37, has been used. This waveguide is terminated within the equipment room by means of an isocirculator which separates transmit and receive directions. The transmit and receive ports terminate in type 'N' co-axial connectors which allow for flexible connection between the isocirculator and the branching network. This is illustrated in Fig. 9. Great care has been taken with both antennas and isocirculators to ensure that high orders of return loss have been achieved to minimise echo distortion.

The reasons for selection of integrated antenna/feeder/antenna isocirculator systems with flexible connections are:

- One contractor is responsible for the entire system, and therefore closer control of all components is possible.
- There are well defined contractual interfaces.
- Relative positions of antenna circulators and branching circuits are not critical.
- If relative movement of tower and building occur (due to variations in the soil's water content) the flexible cables allow movement without damage to either the waveguide or the branching network. This effect is further

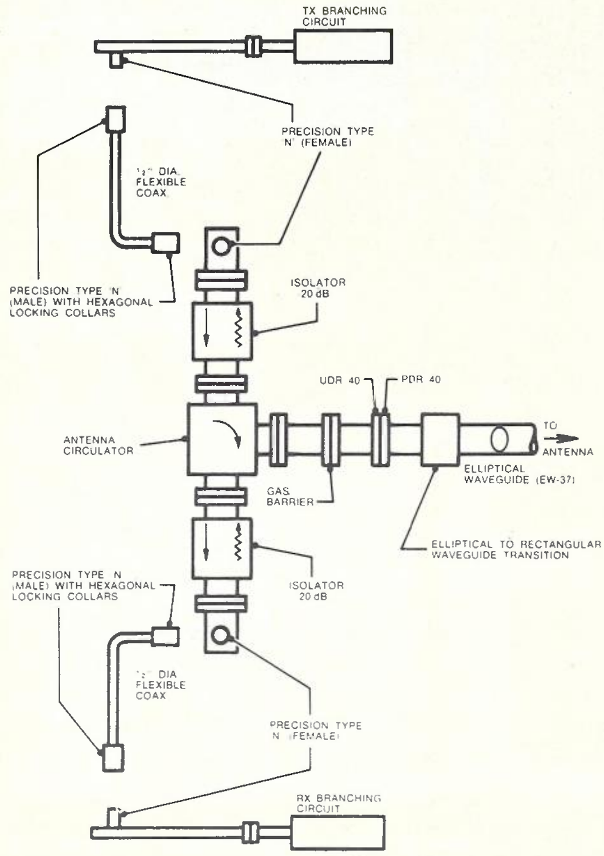



**Fig. 9—Antenna Isocirculator Schematic.**

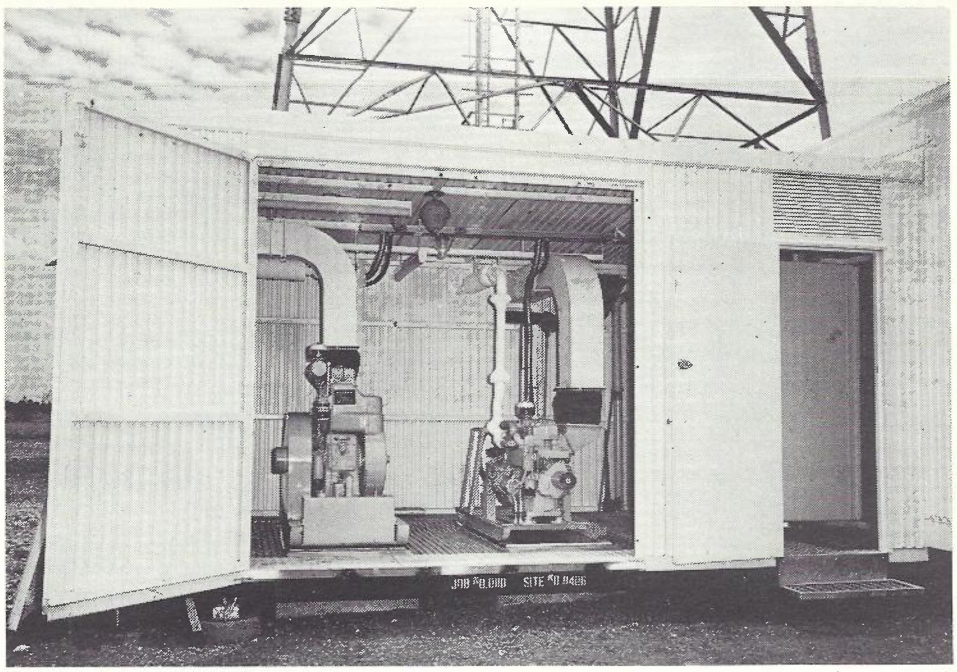


**Fig. 8—Diesel Generating Sets. The Type VA Engine is on Left and SR2 is on Right.**

**Fig. 10—Repeater Waveguide Gantry. Note Attachment to Shelter Main Members.**

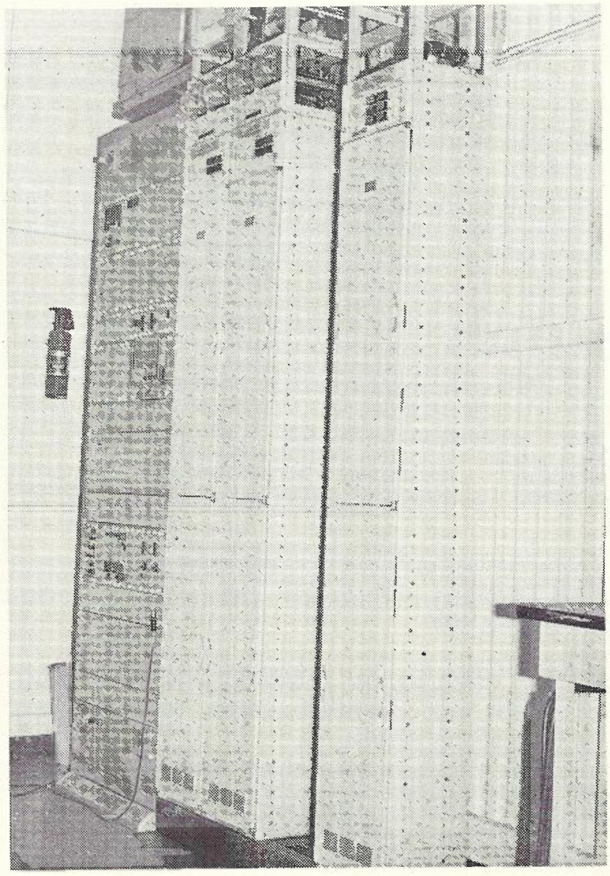


**Fig. 11—Equipment at a Repeater Station.**

reduced by actually attaching the horizontal waveguide gantry to the main floor members of the equipment shelter. The construction arrangement is shown in Fig. 10.

**Radio Equipment**

The initial installation provides for one main and one standby bearer operating in the 4GHz band between Darwin and Mt. Isa. Each bearer has a capacity to carry 1,200 voice channels while the standby will have the facility to provide occasional colour television transmission. Continuity of this television signal is dependent upon normal performance of the main bearer. Should the main bearer fail, the telephony traffic will be automatically transferred to the standby bearer and television transmission will cease.

Automatic switching between the main and the standby bearers is initiated by both noise and continuity criteria which are measured on the end of each modulation section. Indications of bearer failures and switchovers are transmitted from switching stations to the route control terminal in Darwin and to the individual control stations for areas within their spans of control.

The repeater equipment at each repeater station operates on the heterodyne principle. The difference frequency between transmit and receive frequencies is 213 MHz and a local oscillator operating at that frequency is installed at each station. This oscillator is, in effect, a modulator and allows for the injection of sub-baseband channels at all repeater stations. The sub-baseband spectrum available at each repeater station is 0.3-275kHz. Fig. 11 shows a typical repeater installation at a shelter.

Each item of radio equipment (transmit/receive bays, modem bays, switching bays, sound/vision combining/separating bays and shift oscillator bays) is equipped with off normal indications and alarms, most of which are telemetered to control stations to allow complete monitoring of the system. The alarm's provided are sufficient to allow technical staff to equip themselves properly with maintenance spares and test instruments to clear faults.

### Supervisory Equipment

The design of the supervisory system has been carried out by APO engineers in association with the manufacturer. The equipment supplied has been installed by APO personnel. The equipment operates in a serial mode; each station is interrogated sequentially by a central station and alarms are indicated to operating personnel after a number of parity and bit count checks are carried out. The route has been divided into three control sections, centred on Mt. Isa, Tennant Creek and Katherine, and each is equipped with central interrogating units. The Mt. Isa central station interrogates all remote stations between Mt. Isa and Wonarah. Tennant Creek spans Wonarah to Daly Waters and Katherine spans Daly Waters to Darwin. The Darwin terminal is similarly equipped with three central control stations which are normally used for interrogating the three sections. However, should a section of the route fail or should failure occur in any of the Darwin central stations, the remote central station will take control.

At Mt. Isa, Tennant Creek and Katherine, alarms are displayed for each section within those stations' spans of control. Each display consists of a set of station alarm indications which simply indicates to the operator the presence of an alarm or a change of state at a particular station. The operator then interrogates the faulted station and has an alarm display presented to him. Only two alarm displays per section are provided to avoid the problem of overwhelming the operator with information. Alarm displays can either be rack or desk mounted. At Darwin access can be gained to all alarms at all stations but no alarms are immediately displayed, instead, a mimic diagram indicating bearer continuity and bearer status is provided. Should the bearer changeover or a bearer fault occur the operator will be able to interrogate the particular faulted station or stations and obtain a display of alarms.

In addition to the displayed alarm indications a real time log is kept of all faults and non-standard conditions. This log keeping is achieved by interfacing the central stations with a mini-computer which drives a teletypewriter.

It will be possible to programme this processor to allow suppression of printing of certain types of alarms, such as receiver alarms during periods of heavy fading.

## CONCLUSION

At the time of writing this article, the system had just been completed. The system performance has been well inside specification and in fact has resulted in less than 1.8pWop/km, with shorter demodulation sections being less than 1.0pWop/km.

More detailed papers covering design of individual items and project management techniques will appear in subsequent issues of this Journal.

## ACKNOWLEDGEMENTS

The reader should spare a thought for those who have installed and commissioned this long system. Both APO and contractors' staff have endured many months of isolation and hardship in rather desolate parts of Australia. Credit must be given to those people because they have borne those difficulties in a good spirit and have produced a fine system.

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M. J. KIMBER (Engineer Class 3) is the Project Manager for the Darwin—Mt. Isa broadband microwave system in he Darwin Office of the Australian Post Office. See Vol. 22, No. 3, page 224, of this Journal.

# An Improved Fault Recording Register for ARF Crossbar Exchanges

B. J. CARROLL, A.R.M.I.T.

*This paper briefly outlines the role and facilities of an improved Fault Recording Register being developed for use in ARF Crossbar Exchanges. This development, which will include facilities for network supervision is being designed to interwork with the Automatic Disturbance Recording (ADR) equipment to provide continuous details of faults detected, at the local exchange, or a remote control station. Moreover, it is proposed that the Network Performance Analysis Centre use this new RKR to assess performance or to assist in the determination of fault patterns.*

## INTRODUCTION

Apart from providing flexibility in network design, the development of common control switching equipment also provided potential for the development of powerful maintenance aids, both for the supervision of switching plant at individual exchanges and for the switching performance of telephone networks. The basic principle in the development of these aids is to automatically monitor performance under live traffic conditions. This article briefly outlines the main feature of an improved Fault Recording Register under development by L. M. Ericsson Australia for the Australian Post Office.

## ROLE OF THE NEW FAULT RECORDING REGISTER

A Fault Recording Register is a standard register to which is added a relay set known as an RKR. This particular register is then connected in the register grading in such a way that it is available to all subscribers in a particular 5000 line group or served by a separate group of registers. Under these conditions it is available to all subscribers connected to the exchange and therefore may be used for the setting up of calls to any destination via all switching stages and by all available routes.

In addition to improving the facilities offered by the original RKR for the supervision of the calling subscribers line with respect to line leakage and the electrical characteristics of the metering circuit, the new RKR is designed to provide detailed information with respect to all "no-progress" calls set up by the Fault Recording Register to both crossbar and step type exchanges. (A no-progress call is defined as a call which is not answered and does not receive a standard service tone eg. ring tone, busy tone, number unallotted tone or recorded voice announcement).

To further increase its value as a maintenance aid, and to provide continuous statistics with respect to both calling line and network surveillance, the RKR has been designed to interwork with the Automatic Disturbance Recording (ADR) equipment described in Ref. 1. By using the message switching facility of the ADR a detailed print-out of all fault conditions may be provided either on a teleprinter in the local exchange, or, during periods when the exchange is unattended, on a teleprinter located at a remote control station. The ADR equipment also enables different types of messages to be directed to different centres for attention. For example faults related to the calling subscribers line could be transmitted to the Subscribers Equipment Maintenance Centre whilst network and metering faults would be directed to staff responsible for exchange maintenance. As discussed later in this article the use of ADR equipment will enable details related to network faults to be transmitted direct to the Network Performance Analysis Centre (NPAC) to assess performance or to provide supplementary information for the determination of fault patterns. This new role for the Fault Recording Register is outlined in Fig. 1.

The RKR can also be set in the "hold and trace" mode, whereby the subscriber's line circuit is released so that further calls can be made, but the equipment used on the faulty call is held backwards to the Subscribers Line Stage and forward to the point of failure for fault location purposes. Where ADR equipment is not installed a local printer may be used to record detailed information set forth below. As in the case of the original RKR, a lamp display and statistical meters can also be provided if necessary. The new RKR includes facilities to provide a service alarm should the number of network faults exceed preset limits. Keys are provided

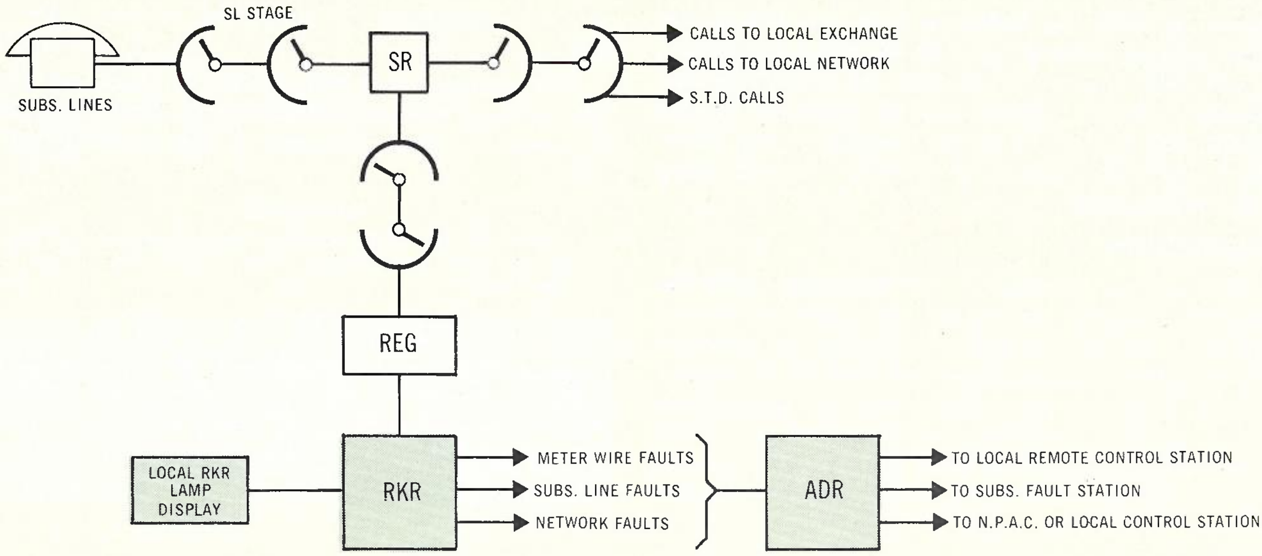


**Fig. 1 — Proposed Role of the new RKR for Calling Line and Network Supervision.**

to alter the line insulation settings in the range 15k ohms, 30k ohms, and 100k ohms and to cancel any particular test if necessary.

## DETAILED INFORMATION PRINTOUT

### Printout for Calling Party Supervision.

- Exchange identity
- RKR identity (one per 5000 lines)
- Fault number (see below)
- Number of the calling subscriber (last four digits of the number)
- Calling 1,000 line group. (SLM number)
- Number of the register finder used
- The A and B identity numbers of the SR used

### Printout for Network Supervision.

- Exchange identity
- RKR identity
- Fault number (see below)
- Called number (up to 9 digits)
- Calling 1,000 line group
- Number of the register finder used
- The P chain position of the register when failure occurred (indicates digit being transmited at point of failure)
- The number of re-start signals received (up to 5 to assist in routing analysis)
- The A and B identity numbers of the SR used (indicates GV stage and inlet in the originating exchange)

### Fault Number and Type of Fault.

1. Line leakage (insulation resistance each side to ground)
2. Meter shunted to negative 40 ohms - 5k ohms
   MR shunted to positive 40 ohms - 5k ohms (see note 1 below)
   Meter circuit open (faulty meter or open "r" wire in SL stage)
3. Meter shunted to positive 0-600 ohms
   MR shunted to positive 0-40 ohms
4. Meter shunted to negative 0-40 ohms
   MR shunted to negative 0-600 ohms
5. MFC signalling failure (no revertive signal received; indicates failure of forward or backward MFC signalling).
6. No-progress MFC call (call not answered and no service tone received)
7. No-progress step by step call (call not answered and no service tone received)
8. Stop-on-busy step by step call (triple connection in step network)
9. Plant congestion (B4 MFC signal).

*Note 1.* The MR is a relay set connected in the subscriber's line to repeat line reversals where these are required for supervisory purposes (e.g., Public Telephones, and coin attachments). The MR relay presents a 50V negative condition on the "r" wire to the RKR.

*Note 2.* An untuned tone detector is included in the RKR to detect service tones. The Fault Recording Register is released on receipt of a tone or an answer signal.

## SERVICE ASSESSMENT-NETWORK PERFORMANCE ANALYSIS CENTRE (NPAC)

Where ADR equipment is installed, the RKR, upon receipt of a signal from the NPAC will transmit details of no-progress calls encountered in a fixed sample number of calls to the NPAC. The sample size is determined by a call counter in the RKR and can be set in 100 call increments to 999 calls. The normal sample is 200 calls.

The ADR equipment will transmit signals to the NPAC to confirm the start of the observed run and will also include a signal in the printout to indicate the end of the sample. Whilst the RKR is operating in this mode it cannot be used for fault tracing and a lamp on the RKR display panel indicates that the RKR is being used by the NPAC.

Where ADR equipment is not available the start signal can be sent over the switched network and the results together with signals to indicate the start and finish of the sample can be printed out on a printer provided at the exchange. This information can then be telephoned to the NPAC. For the locations without printers the start signal will reset and activate a number of resettable call counters. These counters will be automatically disconnected at the end of the sample. In this latter case only the number of faults of various types will be recorded.

## CONCLUSION

The facilities specification for this new Fault Recording Register was based on modifications effected to the original RKR and the facilities provided by "No Progress Call Detectors" (NPCD) developed in the field, for the maintenance and supervision of a complex telephone switching network. Field staff have found the detailed information provided by the NPCD with respect to network faults useful when investigating the causes of service alarms, etc.

It is expected that with proper management the RKR used in the role outlined in this article affords a powerful means to supervise the switched network.


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B. J. CARROLL is Senior Engineer, Operations Studies Section, Network Performance and Operations Branch, Headquarters. For further information, see Vol. 19, No. 1, p. 78 of this journal.

# Technical News Item

## NETWORK ANALYSIS PROGRAM (NETANAL)

NETANAL is a steady-state network analysis computer program developed in the APO Research Laboratories. The network being analysed can contain resistors, capacitors, inductors, transistors, transformers, crystals, voltage controlled current generators and transmission lines. There are no restrictions on the network topology - the network can be fully connected. The basic network size is limited to 100 nodes; however if models are used a network containing several hundred nodes can be analysed.

One of the main features of netanal is the ease with which it handles transmission line networks. Two different models of transmission lines are included, one for unbalanced lines and the other for balanced lines. The model for balanced transmission lines is derived from the model for unbalanced lines, but includes additional components to model the effects of the proximity to the datum or ground node.

Another feature of netanal is its modelling facility. This facility enables sections of the network to be declared as models and then inserted in the network being analysed.

As an example, consider the analysis of an active filter. The first model may be that of a transistor containing say 10 nodes; the second model could be the operational amplifier in which say 5 of these transistors are used; the active filter may conatin 3 of these amplifiers. If this type of network is analysed without the use of models it would contain approximately 3 xs5 x 10 = 150 nodes. The use of models enables the active filter to be analysed in three stages each of which was less than 20 nodes. As another example, consider the analysis of a network involving 100 sections of loaded cable. The first model may be one section of loaded cable, the second ten sections (i.e. ten of the first model in cascade), and the whole network, 10 of the second model in cascade.

There are two main advantages obtained by using models. First, if a model occurs more than once in the network the components values need only be read-in once (whereas normally they would have to be read-in for each time the model is inserted in the network), and secondly, by declaring portions of the network to be models, much larger networks can be analysed before accuracy becomes a problem.

The input data to NETANAL is read-in in a free format manner so that very little care need be taken in preparing the data provided that no errors are made. The out-put can be quite extensive. NETANAL will calculate any transfer or driving point function. If a transfer function is required, the driving point impedances are automatically calculated. If the input and/or output is differential, then the impedances to ground are also calculated. If required, the group-delay can also be calculated. A facility has been included for estimating the sensitivity of the network responses to changes in component tolerances. This information is obtained by analysing the network ten times with the component values varied according to tolerances which are read-in with the data.

NETANAL is written for a CDC computer and is available in both source and object forms.

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## SEMI-CONDUCTIVE CABLE JACKETS

The use of semi-conductive cable jackets is being considered in the APO as a means of providing lower longitudinal resistance to induced currents from lightning surges and power contacts. The jackets are expected to withstand minor current surges without puncture whilst still providing protection against corrosion and water ingress.

Semi-conductive polymeric compounds based on polythene are available and have been used overseas as the jacket on paper insulated, lead sheathed telecommunication cable. Although they are based on polythene, the properties of these compounds are in no way comparable with conventional polythene due to the extremely high filler content. As good electrical contact is required between the lead sheath and the semi-conductive sheath, these cables are manufactured without an interlayer compound between the lead sheath and polymeric jacket, leaving the metallic sheath vulnerable to corrosive attack should an irregularity occur in the jacket.

Work in the APO Research Laboratories has shown that the standard interlayer compound, "Düssek" T1731, can be made semi-conductive by incorporation of 45 parts by weight of powdered graphite. Volume resistivity figures of around 38 ohm cm have been obtained. The compound is sufficiently fluid at temperatures of $120^{o}$ - $140^{o}$C to be pumpable and so capable of being applied by the normal application method, i.e. from a discharge pipe situated above the cable immediately before entry into the plastic extruder.

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# History and Principles of the International (SI) System of Units

G. W. G. GOODE, B.Sc. and J. A. LEWIS, B.E., A.M.I.E.E.

*In 1973 the APO converted to the use of the SI system of units in its activities. This article outlines some of the history of systems of units of weights and measures and then the history and development of metric systems. This is followed by a discussion of the SI system which is becoming the standard system of units for physical measurement throughout the world.*

## INTRODUCTION

Australian Post Office operations, both in telecommunications and postal activities, changed to the use of SI units in 1973. This article outlines the history and principles of the International (SI) System of Units, along with some of the historical background to the use of weights and measures.

## HISTORY OF THE METRIC SYSTEMS

Modern life relies extensively upon accurate reproducible measurements. Trade, technology and communications between nations are dependent on agreement on how measurements are to be made. It was not always so. There was little commerce outside each village in primitive societies and measurements were crude and simple.

Simple, inexact measurements served well enough for barter between friends and neighbours, but trouble arose when commerce developed between towns and countries. As a consequence, merchants pioneered the adoption of measurements that could be more widely used. Unfortunately, this process was quite haphazard and the relationships that developed between the various measurements were anything but simple. For instance in the 18th century British Empire the system of measurement which has become known as the Imperial System had relationships such as 12 inches to the foot, 3 feet to the yard, 16 ounces to the pound, 14 pounds to the stone and 20 hundredweight to the ton, and this variety of relationships has persisted to this day. This system was based in many ways on the system introduced to Britain by the Roman Empire before the time of Christ. There was confusion about the size of different measurements in the Middle Ages, there being at least five different pounds in use in England to measure mass. That confusion has persisted until the recent adoption of the SI system, an example being the difference between such units as the troy ounce and the avoirdupois ounce. As well as the multiplicity of measures in mediaeval England there was a similar variety of measures in Europe with the consequent range of conversion factors.

The metric system was fairly readily accepted by most countries of continental Europe not long after its introduction. Britain's involvement with its Empire and its distrust and avoidance of European entanglements following the rise of Napoleon helped to cement Imperial attachment to the Imperial System of units. The system of units which the USA used at the time of its independence was naturally the Imperial System. Following independence it proceeded to vary certain units. The US variant of the Imperial System has never spread far beyond the USA and its former possessions. It does not vary a great deal from the Imperial System.

The idea of the metric system was first suggested by Gabriel Mouton of Lyons in France in 1670. He proposed a unit of length obtained by dividing the length of a meridian arc of one minute, which he called a *milliare*, into 1000 *virgas*. The use of measures in decimal form followed from the earlier original work in 1585 by Simon Stevinus, a Dutch dike inspector, in which he set out the advantages of a decimal division of measures. Nothing came of Mouton's proposal at the time, but it is worth noting that two of the fundamental principles of the future metric system were to be found in these two proposals, namely a decimal division of measures and the choice of a "natural" scale of length.

It was not until 1790 that Talleyrand put before the French National Assembly a plan for the unification of weights and measures. In the Law that followed in 1795 the metre and gramme were defined, along with other units and prefixes. These definitions, which are included in the section below on base units, were based on natural phenomena and, being so, were of reasonable size for the common user. Four years later in 1799 these "natural" definitions were superseded, in order to obtain greater precision, by definitions in terms of a set of standards. Consideration was also given during this period to having a unit of time with decimal divisions and the unit chosen was the day, rather understandably. However, in 1794 further implementation of this concept was suspended indefinitely. This was a realistic recognition of the long entrenched and universal division of the day into hours, minutes and seconds.

It was Napoleon Bonaparte who introduced the metric system to the rest of Europe. His Empire collapsed but metric units stayed and were even adopted by countries with which Napoleon's army had had no contact. Further work was also being done by a number of scientists to extend this system of units. This included the work of Gauss in 1825 on electrostatics and the work of Weber in 1835 on electromagnetics. Meanwhile the development of the steam engine and, after 1840, the rise of electrical engineering had led to the creation of industry as we know it. The need for units of measurement was soon felt and following some haphazard development the British Association for the Advancement of Science set up a Committee on Electrical Standards in 1861 which eventually adopted the principles of Weber and put forward the definitions of the ohm, the volt and the farad. This committee was enlarged two years later and from its deliberations emerged the centimetre-gramme-second (CGS) System.

These units were used extensively by scientists and engineers in the years to follow. However, the CGS form was clearly unsuitable for industry and in 1913 the French proposed another coherent form based on the metre, kilogramme and second (MKS). Even units derived in this form were of a size inconvenient to heavy industry and in a French law of 1919 a third form was put forward based on the metre, tonne and second (MTS).

Meanwhile earlier in the twentieth century, in 1902, the Italian physicist Giovanni Giorgi proposed to rationalize the units of electricity and magnetism. His ideas were at first ignored, then extensively debated, and finally adopted by the International Electrotechnical Commission in 1935. Following this in 1960 the General Conference on Weights and Measures created the "Systeme International d' Unites" which owes much to the system of Giorgi.

## SI BASE UNITS

Ideally the simplest system of units is one which has as few units as possible which are defined arbitrarily and not in terms of others although this ideal is not always realizable. Those few units which must be defined arbitrarily are termed base units. Units are defined in terms of properties. The properties on which the definitions of the base units depend are described as 'fundamental' properties. The remaining units and their associated properties are described as 'derived'.

The fundamental properties that have been chosen for the base units of the SI system are length, mass, time, electrical current, thermodynamic temperature, luminous intensity, amount of substance, plane angle and solid angle. All other properties for which SI units are specified are defined in terms of these. Which particular fundamental properties were chosen is essentially a matter of convenience, precision and reproducibility of the standard properties in terms of which the base units are defined. The respective base units corresponding to the above-listed properties are the metre, kilogramme, second, ampere, kelvin, candela, mole, radian and steradian.

Instead of length being chosen as a fundamental property volume could have been. If the unit for volume chosen had been the present litre with symbol 'l' the present metre would, if expressed as a derived unit, be

$1\ \mathrm{m} = 10\ \mathrm{l}^{1/3}$, i.e. 10 cube root litre.

This of course is not so, as we prefer to say

$1\ \mathrm{l} = 0.001\ \mathrm{m}^3$.

Similarly velocity, which is at present defined in terms of length and time, or any other derived property could have been chosen as a fundamental property and some of the existing 'fundamental' properties would then be expressed in terms of them with respective units following suit.

The selection of those properties to be considered fundamental and those to be considered derived, is arbitrary, but above a certain minimum the actual number of fundamental properties is also an arbitrary choice. It is desirable that the proportion of derived units to base units should be as large as possible so that reference to the fewest possible standards is required, but this objective can conflict with the need to avoid extremely complex expressions for derived units in cases where the formula linking the derived unit to the base units is unwieldy. A good example of the latter is the choice of electric current as a fundamental property. Prior to the SI system certain units of current were defined in terms of length, mass and time alone. Unfortunately this resulted in complex confusing units for many electrical and magnetic quantities. Establishing electric current as a base unit avoided these difficulties.

Similarly temperature could be defined as the mean kinetic energy of the molecules of a substance and could be defined in terms of length, mass and time. This would produce undesirable complexity in units which include temperature in their definition and hence has been avoided.

Presumably, in the opinion of the majority of international representatives responsible for the SI system, the fundamental properties chosen for the system provided the smallest convenient number of fundamental properties and were the ones able to have units allocated more conveniently, reproducibly and precisely than any alternatives.

Developments in physics may result in certain derived properties becoming superior to the 'fundamental' properties in terms of convenience, reproducibility or precision of measurement. There would probably have to be a very strong case, however, before one or more 'derived' properties were declared 'fundamental' and vice versa owing to the confusion and disruption that would be likely.

The units allocated to each fundamental property are known as base units. If one examines the background of each of the present base units one finds that the three units most important in mechanics and everyday life—the metre, the kilogramme and the second—were defined very early.

**Metre, Kilogramme**

Soon after the French Revolution the Law of 18 Germinal Year III (7th April, 1795) defined the metre as equal to one ten-millionth of the meridian arc from the North Pole to the Equator and the gramme as the absolute weight (sic) of the pure water contained in a cube of side one-hundredth of a metre at the temperature of melting ice. This Law also introduced among others the prefix kilo indicating a multiplication by 1000.

This original definition of the metre and gramme only lasted till 1799, when they were redefined, although virtually unaltered in value, in terms of artifact standards. Thus the metre became the length of a particular platinum bar and the kilogramme became the weight (still not 'mass') of a particular cylinder of platinum each kept under standard conditions. This redefinition enabled very much greater precision and reproducibility of measurement of the standards than the 1795 definition.

The system of units remained at national level until a permanent international authority, the General Conference on Weights and Measures, was established in 1875, and had its first meeting in 1889. Subsequent meetings of the General Conference improved and simplified the system of units so that in 1960 it gave its official approval to an international system of units which, in French, the language of the conference, is described as the Systeme International d' Unites and is referred to in all languages by the initials SI.

The present SI definition of the metre is that it is the length equal to 1 650 763.73 wavelengths in vacuum of the radiation corresponding to the transition between the energy levels $2p_{10}$ and $5d_5$ of the krypton-86 atom. The definition thus no longer depends upon an artifact kept at a particular place.

The present SI definition of the kilogramme is that it is the mass of the cylinder that is deposited in the International Bureau of Weights and Measures and was declared by the First General Conference on Weights and Measures held in Paris in the year 1889 to be the International Prototype Kilogramme. The cylinder was made by a London firm of an alloy of 90% platinum and 10% iridium. Its diameter and height are each very close to 39 mm. The kilogramme is the only SI unit for which an artifact kept at a particular place is still the primary standard although originally the units of length and luminous intensity were also defined in terms of standard artifacts.

**Second**

The second as a unit of duration based on astronomical observations had been well established long before the introduction of the metre and kilogramme soon after the French Revolution. Until 1960 the second had been defined as the 1/86 400 fraction of a mean solar day. In 1960 the Eleventh General Conference on Weights and Measures changed the definition to base it on ephemeris time as the 1/31 556 925.974 7 fraction of the tropical year 1900. The purpose of this change was to improve the precision and reproducibility of the standard. Further such improvement was effected by the change in 1967 to the present SI definition which is that the second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium-133 atom.

Since the Law of 1795 there has been the introduction and refinement of the other base units the ampere, kelvin, candela, radian and steradian.

**Ampere**

The ampere was named in 1881 when it was defined in terms of an earlier electrostatic unit. This definition was soon replaced by an electrochemical one. One ampere was defined until 1948 as that current which deposits 1.118 milligramme of silver per second on electrolysis of a solution of silver nitrate. The present definition is that the ampere is the unvarying electric current that, when in each of two parallel straight conductors of infinite length and negligible cross-section separated by a distance of one metre from each other in free space, produces betwe..n them a force of 200 nanonewton per metre length of conductor.

**Kelvin**

The earliest thermometer scales appeared in the 18th century but the concept of thermodynamic temperature was not put forward until the 19th. The practical temperature scale still most commonly used throughout the world is the 18th century Celsius scale where the zero is arbitrarily defined. The SI system uses the thermodynamic zero temperature as its zero. The SI temperature unit, the kelvin, is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water.

**Candela**

The present SI unit of luminous intensity is the candela, which is defined as the luminous intensity in the perpendicular direction of a surface of 1/600,000 of one square metre of a full radiator at the temperature of solidification of platinum under a pressure of 101.325 kilopascal. Units in use before the SI system included such units as the 'International Candle', which was a specified fraction of a group of standard carbon filament lamps, and the 'Pentane candle', which was based upon the illumination produced by burning hydrocarbons in a standard manner.

**Mole**

Until the mole was adopted as the SI unit of amount of substance, chemists and physicists used slightly different bases for their respective units for this property. They had both used oxygen with an atomic mass of 16 as their base, but the physicists specified a particular isotope whereas the chemists did not.

The present SI definition is that the mole is an amount of substance of a system which contains as many elementary units as there are carbon atoms in exactly 0.012 kilogramme of $^{12}C$. The elementary unit must be specified and may be an atom, a molecule, an ion, an electron, etc., or a specified group of such particles.

**Radian, Steradian**

The SI definitions of radian and steradian simply formalize the existing conventional use of these terms in geometry.

## PRINCIPLE OF COHERENCE

A desirable feature for a system of units and one that is a key principle of the SI system is the concept of coherence. A system of units is said to be coherent when for each derived property which is defined in terms of base properties the corresponding unit is defined in terms of the corresponding base units using the same formula to relate the units as relates the properties. Throughout the above definition the term 'unit' refers to units without prefixes indicating multiples or sub-multiples of the original unit.

To illustrate this concept consider the example of the area of a rectangle which is proportional to its breadth and height. With the metre having been taken as the unit of length, the area of a rectangle 3 m by 2 m is 6 times the area of a square 1 m by 1 m.

The process of measuring off a unit of length in breadth, and another in height, does not of itself make a unit of area out of these lengths, area being a separate physical property, and therefore, although defined by means of lengths, it is physically not expressible in lengths. If a coherent system of units is chosen this relationship takes on its simplest and most direct form. In the above example the area of a square of side one metre is therefore defined as one square metre.

It follows from the definition above of coherence and the fact that each fundamental property is allocated only one unit that there can only be one unit for each derived property. Thus the situation permitted in the earlier metric systems where the unit of energy may be the joule or the calorie, depending on the particular sub-division of physics concerned, is avoided in a coherent system. The calorie has been defined as the amount of energy required to raise the temperature of one gramme of water at a specified temperature through one Celsius degree. Had energy been chosen as a fundamental property, the calorie as arbitrarily defined above would have been a possible unit. Energy is, however, a derived property in most systems whether coherent or not. It cannot in such systems be directly defined arbitrarily but must be defined so that it can be expressed in terms of fundamental quantities. Even if the definition of the calorie were to be recast mentioning only SI base units, e.g., the amount of energy required to raise the temperature of one kilogramme of water through one kelvin, it would still not be being defined as a 'derived' unit in terms solely of other units but would be being defined instead as a 'base unit' in terms of a property of the substance water. A definition of energy as a derived property is that it is the product of the force and distance through which the force acts when the energy of a system is wholly converted to mechanical work. Correspondingly the SI unit of energy, the joule, is defined as the energy expended when a force of one newton moves the point of application a distance of one metre in the direction of that force. The force of one newton is easily expressed in terms of the base units metre, kilogramme and second. The SI definition is coherent particularly in that it is ultimately based entirely on base units without any multiplying factor whatever. The calorie has to be related to the SI base units by the awkward factor of c. 4.18 as 1 calorie is approximately equal to 4.18 joule. An earlier unit since superseded, the erg, was defined in terms of units other than SI base units and is related to the joule by the exact but arbitrary factor of $10^{-7}$ as 1 erg equals $10^{-7}$ joule. The joule is the only energy unit related to the SI base units which does not include an arbitrary factor, other than unity, as part of its relation to them.

**DERIVED UNITS WITH SPECIAL NAMES**

Every SI unit with a special name has a unit symbol as well as a full name. These symbols and names are shown in Table 1. The relationships between these units and with the base units are shown diagrammatically in Fig. 1. Units without a special name are given unit symbols constructed from the unit symbols for units with special names by using the appropriate mathematical operator symbols. Thus the symbol for the unit of density, kilogramme per cubic metre, is $kg/m^3$.

The joule is a derived unit with a special name for convenience as is the newton. The newton could be called the kilogramme metre per second squared with its unit symbol being $kg\,m/s^2$ but the shorter special name is easier to use. The joule by analogy could be called the kilogramme metre squared per second squared the symbol of which would be $kg\,m^2/s^2$, or it could be called the newton metre. It is interesting that the SI unit of torque, the newton metre, would then have the same SI unit as energy. However, energy differs from torque in that energy is a scalar quantity whereas torque is a vector and the special name joule is confined to the former.

Examples of SI derived units for which no special names have been declared by the General Conference on Weights and Measures are the square metre, cubic metre, newton second per metre squared and watt per kelvin metre which are the units for area, volume, dynamic viscosity and thermal conductivity respectively.

**MULTIPLE AND SUB-MULTIPLE PREFIXES**

The prefixes and their symbols listed in Table 2 can, with the exception of the anomaly of the kilogramme discussed below, be applied to the base units or derived units to indicate the ratio of the multiple or sub-multiple of the unit to the unit itself. The prefixes should only be added to the first unit in the case of derived units without special names and should never be added to a unit

**TABLE 1: SI UNITS WITH SPECIAL NAMES**

| Physical Quantity | SI Unit | SI Unit Symbol |
|---|---|---|
| length | metre | m |
| mass | kilogramme | kg |
| time | second | s |
| electric current | ampere | A |
| thermodynamic temperature | kelvin | K |
| luminous intensity | candela | cd |
| amount of substance | mole | mol |
| plane angle | radian | rad |
| solid angle | steradian | sr |
| frequency | hertz | Hz |
| force | newton | N |
| pressure | pascal | Pa |
| energy | joule | J |
| power | watt | W |
| electric charge | coulomb | C |
| electric potential | volt | V |
| electric capacitance | farad | F |
| electric resistance | ohm | Ω |
| electric conductance | siemens | S |
| magnetic flux | weber | W |
| magnetic flux density | tesla | T |
| inductance | henry | H |
| luminous flux | lumen | lm |
| illumination | lux | lx |

**TABLE 2: SI PREFIXES AND THEIR SYMBOLS**

| Factor by which Unit is Multiplied | Prefix | Symbol |
|---|---|---|
| $10^{12}$ | tera | T |
| $10^{9}$ | giga | G |
| $10^{6}$ | mega | M |
| $10^{3}$ | kilo | k |
| $10^{-3}$ | milli | m |
| $10^{-6}$ | micro | μ |
| $10^{-9}$ | nano | n |
| $10^{-12}$ | pico | p |
| $10^{-15}$ | femto | f |
| $10^{-18}$ | atto | a |

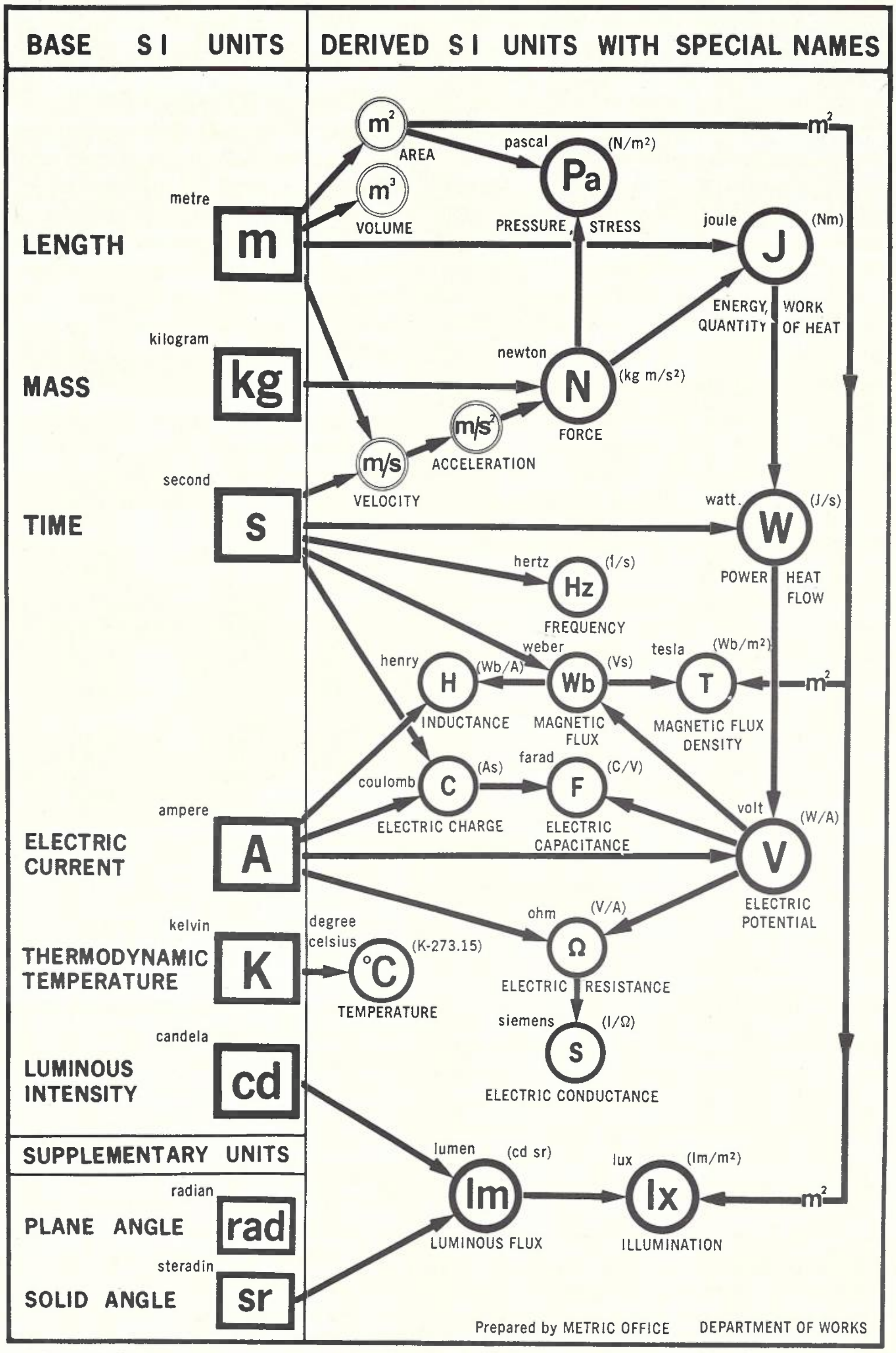


**Fig. 1 — Relationships between Derived SI Units and Base or Fundamental SI Units.**

which appears as a denominator in a derived unit written as a quotient, e.g., metre per millisecond is not permitted. Its numerical equivalent kilometre per second should be used instead. Older prefixes such as centi or deka which do not represent ten raised to a power which is a multiple of three, are not recommended for use in the SI system and their use should be avoided.

The base unit, the kilogramme, is anomalous in that it incorporates a prefix yet is actually a base unit. The unprefixed designation 'gramme' refers to a sub-multiple of the kilogramme which is one thousandth its value. Likewise 1000 kilogramme is not '1 kilokilogramme' but is 1 megagramme. Other multiples and sub-multiples of the kilogramme are formed in similar fashion. The megagramme is sometimes called a tonne but this is not an SI usage and is unnecessary. The General Conference on Weights and Measures should resist any intrusion of the tonne into the SI system and should consider a new name for the kilogramme so that a prefix is not built into the base unit and its symbol.

As shown in Table 2 each prefix has a symbol which should be prefixed to the unit symbol as appropriate. Thus, for example, the symbol for the picofarad is pF.

One anomaly that exists with the symbols is the use of m as a symbol for both milli and metre. This causes ambiguity and confusion in interpreting, for instance, the symbol mN. This is obviously the symbol for millinewton but some people may write it as the symbol for metre newton as a unit of torque. Obviously using Nm for newton metre is less confusing. Likewise the unit of thermal conductivity, the W/Km, if written W/mK may, although W/mK is not an SI unit because of the prefix in the denominator, be confused as being meant to be the equivalent to kW/K. This latter is certainly not a unit of thermal conductivity.

A further anomaly is that unfortunately, unless there is a special name for the units of area and volume and derivatives involving them, the normal SI use of multiple and sub-multiple prefixes cannot be applied to them. Special names would seem to be far more urgently needed for these units than special names such as watt or lumen being needed for power and luminous flux. One can, for instance, call 1000 joule one kilojoule or if there were no special name one kilonewton metre, but one cannot use the prefix kilo in an analogous way with the square metre or cubic metre. The units 'are' and 'litre' still exist from earlier metric systems and although not part of the SI system are one way of dealing with the above anomaly. Their use is not an ideal solution to the problem as one still has to remember their arbitrary relation to the metre and to each other even though the factor is ten raised to an integral power. Thus 1000 square metre can be expressed as 10 are; and 1000 cubic metre as 1 megalitre. Putting the prefix on the word 'metre' and talking about 'square kilometre' or 'cubic kilometre' is, of course, not analogous to the use of prefixes throughout the rest of the system as the prefix itself becomes squared or cubed as the case may be.

## CALCULATIONS USING SI UNITS

When it comes to substituting values of SI units into formulae giving physical parameters in terms of other parameters the principle of coherence demands that all values be expressed in terms of units and not multiples or submultiples thereof before being used in equations. When the value of each parameter being calculated has been established in terms of units, a multiple or submultiple prefix may then be added for convenience of presentation.

The following is an example of such a calculation.

To determine the mass, m, of a body having a velocity, v, of 500 mm/s and a kinetic energy, E, of 16 kJ:

$$E = 16\,000 \text{ J}$$
$$v = 0.5 \text{ m/s}$$
$$E = \tfrac{1}{2} mv^2$$

Therefore
$$m = \frac{2E}{v^2} = \frac{32\,000}{0.25} = 128\,000 \text{ kg} = 128 \text{ Mg}$$

## CONCLUSION

The development of systems of units has shown considerable variety. Nowadays the situation is being rationalized with the SI system being used by over 90% of the world's population and the Imperial System and its American variation being the only other systems of consequence. The majority of countries previously using the Imperial system are in the process of changing to the SI system. Very few countries, of which the U.S.A. is the most significant, have not yet formally announced a change to the SI system. The ideal of a single system of units being used throughout the world is likely to be realized in the foreseeable future.

Even though the SI system has been popularly accepted throughout the world it is still not perfect and several of its deficiencies have been discussed. It is hoped that further work in this field will lead to an even better system. Fortunately most changes will probably only change names of units and the numerical values of quantities should generally remain the same.

## ACKNOWLEDGEMENT

The diagram used as Fig. 1 was produced by the Metric Section of the Australian Department of Works and their permission to use it in this paper is gratefully acknowledged.

## FURTHER READING

The publications listed below provide material on this topic and are recommended for further reading.

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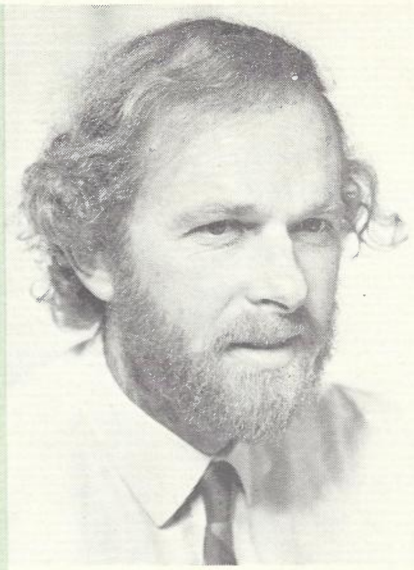
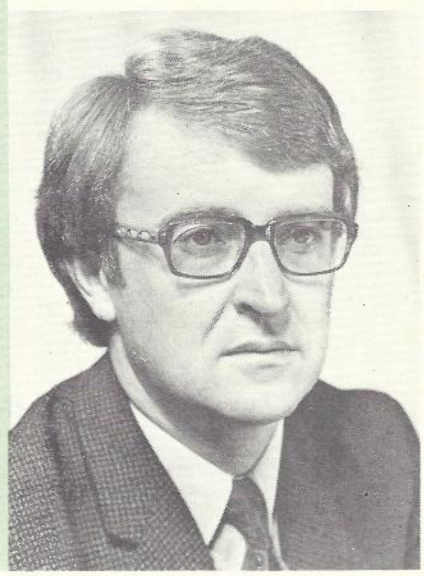
G.W.G. GOODE is a Physicist Class 3 in the Physics and Polymer Section of the APO Research Laboratories. He graduated from the University of Melbourne with a Bachelor of Science degree in 1958. After some time with the Signals Branch of the Department of Defence, he joined the then Physics Division of the APO Research Laboratories in 1962. Since 1967 he has been in charge of a group working on environmental physics aspects of Departmental problems.



J. A. LEWIS graduated from the University of Melbourne in 1961 with first class honours in electrical engineering, this period of study being taken under a PMG cadetship. He then worked in the line transmission field in the APO Research Laboratories as an Engineer Class 1 and Engineer Class 2. In 1972 he was appointed Executive Officer for Metric Conversion working for both the Headquarters Steering Committee and the Engineering Works Committee on metrication. Following this he was appointed to his current position of Engineer Class 3 in the Computer Systems Development Unit in the Engineering Management Systems Section of the Headquarters Engineering Works Division. His activities in this unit cover consultancy in and design of computer systems for engineering applications and co-ordination of computer usage in both Headquarters and State engineering operational areas.



# The First Australian Faraday Lecture

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

*The Faraday Lecture has been an annual event in the United Kingdom since 1924. It is sponsored by the Institution of Electrical Engineers, and presents technological developments in a popular manner to the general public.*

*In 1971 the Institution of Radio and Electronic Engineers, Australia, with the concurrence of the IEE, decided to sponsor an Australian Faraday Lecture, and invited the APO to present the inaugural lecture in 1972. The IREE suggested that the theme might be allied in some way with the centenary of the Overland Telegraph.*

*This paper is an outline of how the first Australian Faraday Lecture was planned and mounted in cities throughout Australia. The author was responsible for the co-ordination of these activities.*

## INTRODUCTION

In the United Kingdom, the Institution of Electrical Engineers has sponsored an annual Faraday Lecture since 1924. The lectures aim to inform the public of developments in electrical engineering and their impact on society. By tradition, each lecture is repeated at many centres throughout the U.K., and relies heavily on demonstrations and audio-visual aids for maximum impact.

In 1970 the Institution of Radio & Electronic Engineers, Australia, in association with Mullard Ltd., of England, brought to Australia the 1969 Faraday Lecture on Microelectronics. The success of this venture led the IREE to sponsor an Australian Faraday Lecture, and in late 1971 the Australian Post Office was invited by the IREE to produce the first Australian Faraday Lecture.

The invitation was accepted and Mr. A. H. Kaye, M.V.O., Assistant Director (Engineering) South Australia, was selected as the lecturer. The lecture, 'Telecommunications — The Nerve System of Modern Society', was presented from August to November 1972 on 47 occasions in 13 locations throughout Australia, in the same spirit as the original Faraday Lectures. A total audience of about 30,000 attended the lecture.

This article outlines the planning and mounting of the lecture.

## THE THEME

The year 1972 was the centenary of the opening of Australia's Overland Telegraph (Ref. 1) and it was considered appropriate to link the latter event to a semi-technical story of the development of Australia's telecommunications, from the visual semaphore telegraph of the beginning of the nineteenth century to the multitude of services taken for granted today. The theme to be supported by word of mouth, vision and sound, was that as society grows more complex it depends ever-increasingly on telecommunication services which grow not only in quantity, but in diversity of application.

## THE PLAN

The following guidelines were evolved:

- an historical approach, to provide a progressive and unifying thread;
- the use of 'oral' English in the script;
- an almost continuous flow of visual information, in colour;
- oral presentation to be relieved by audio effects and demonstrations.

## AUDIO-VISUAL SUPPORT

The method and equipment chosen for audio-visual support provided the following facilities:

- simultaneous presentation on three 3-metre-square screens (Fig. 2);
- programmed dissolves or cuts from one image to another on any or all of the screens;
- simple animation;
- programmed succession of images on any or all of the screens at intervals down to 2½ seconds;
- automated control of auxiliary equipment, such as movie projectors, p.a. system control, stage and other lighting, tape replay machine, etc.

## AUTOMATED CONTROL

To maintain spontaneity of presentation, it was decided that the initiation of audio-visual events would be under the manual control of an audio-visual (A-V) controller. The lecturer and A-V controller each had identical large-type scripts, with key words marked with a bold coloured 'blob' (Fig. 3).

As the A-V controller heard the marked word spoken, he pressed a 'start' button at the control console. This caused a paper-tape reader to read an 8-hole perforated tape (Fig. 4) at the rate of 16 instructions per second. Perforations on the tape controlled the almost-simultaneous operation of seven commercial 2" x 2" slide projectors, an audio tape replay machine, and other devices.

## TIMING

The method of presentation demanded meticulous timing, to ensure that images appeared on the screen at the same time as the appropriate words were spoken by the lecturer. One example of this was a simulated telephone conversation between Melbourne and Sydney in 1907, over the first (open-wire physical) trunk line between those cities. When the Melbourne speaker was talking (Fig. 5a), the 'Melbourne' voice was required to emanate from left-hand loudspeakers in the hall; when the Sydney talker spoke (Fig. 5b), 'his' voice was required to issue from the right-hand loudspeakers. The simulated conversation had been recorded using actual telephones of the era and networks simulating the loss and frequency response of the junction and trunk circuits involved.

In another example, telephones in public telephone cabinets were connected via a tape recorder/replay device which could introduce into the connection a round-trip time delay corresponding to transmission via a direct land connection, one satellite hop (600 ms) or two satellite hops in tandem (1200 ms).

Two members of the audience were invited to speak to each other via the telephone connection between the cabinets. Party A started by saying 'one', and party B responded by saying 'two' as soon as he heard 'one'; the exchange continued alternately up to 'ten'. As each party was trying to complete the count as quickly as possible, the relative duration of the exchange of numbers under the three conditions was an indicator of the impediment to conversation which resulted from the different transmission delays.

The demonstration was effective, and well-received by audiences.

## MOVIE PROJECTORS

Two 16mm projectors were used in the lecture. Precise control of soundtrack, movie and automated slide sequence speeds was necessary to ensure complete audio-visual co-ordination.

Although the automatic control system gave the

**Fig. 1 — The Lecturer, Mr. A. H. Kaye (right) and the Author Discuss the Script.**

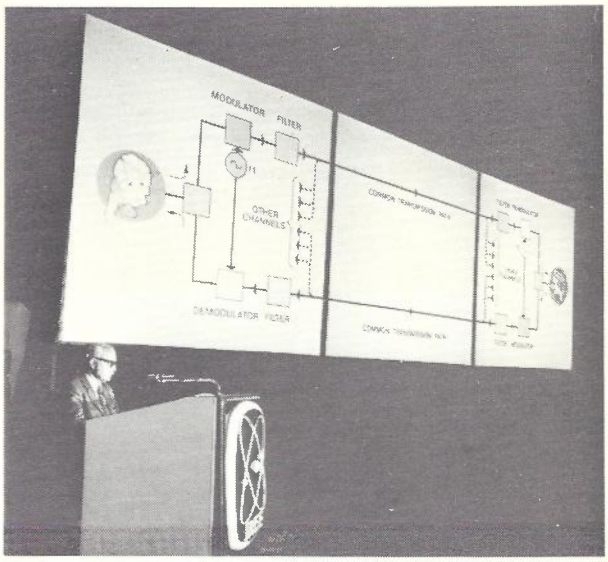



**Fig. 2 — Mr. Kaye Explains the Working of a Frequency-division Multiplex System.**

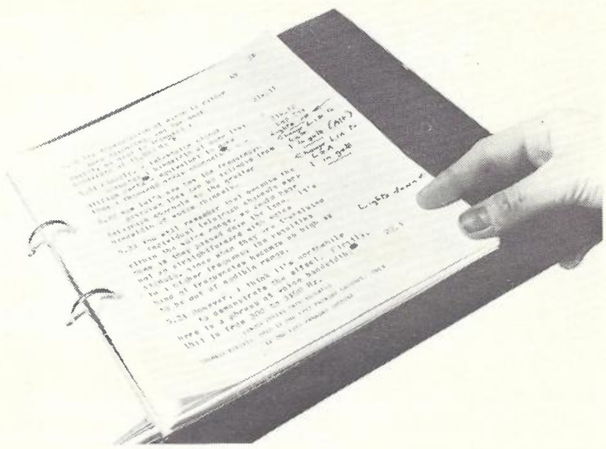


**Fig. 3 — A Page of the Script, Showing Cue Marks.**

possibility of switching the movie projectors from the paper tape, this was regarded as an unnecessary complication, in view of the small amount of movie material; therefore, the projectors were started and stopped manually. A block diagram of the equipment is shown in Fig. 6.

**Fig. 4 — Audio-visual Controller Alan Lancashire Follows Script and Initiates 'Start' Instructions for Paper Tape Reader (left).**

## COMMUNICATION

With the lecturer so dependent on the co-operation of the staff in the projection box it was essential to have effective communication between lectern and box.

One-way signals from the A-V controller to the lectern were via designated lamps on the lectern, operated by push-buttons in the box. They included "Pause", "Go ahead", "Faster" and "Slower", "Talk now" and "Stop". The "Pause" signal might be used, for example, when the changing over of a slide magazine on a projector encountered a mishap, and another few seconds were required to complete the operation. At such a signal, the lecturer might then appear to require a drink of water from his glass, and would resume on receiving the "Go-ahead" signal.

The A-V controller could also call the lecturer via a muted buzzer, and suggest by two-way telephone that certain paragraphs of the script should be omitted. Fortunately, the need for such emergency communications was rare in the actual lectures.

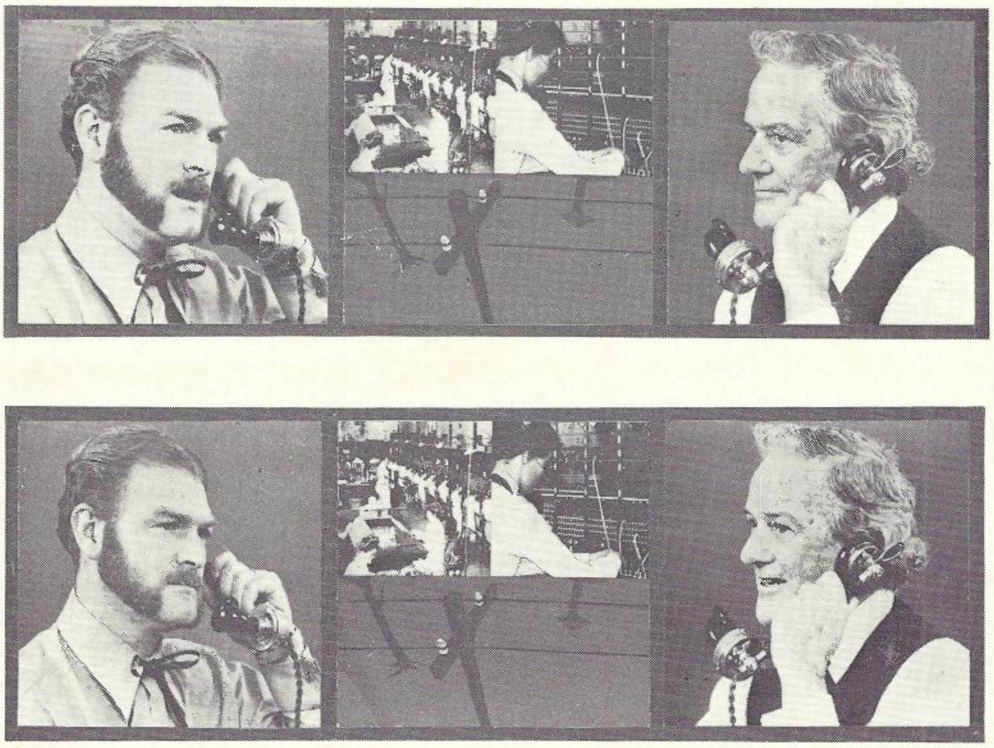
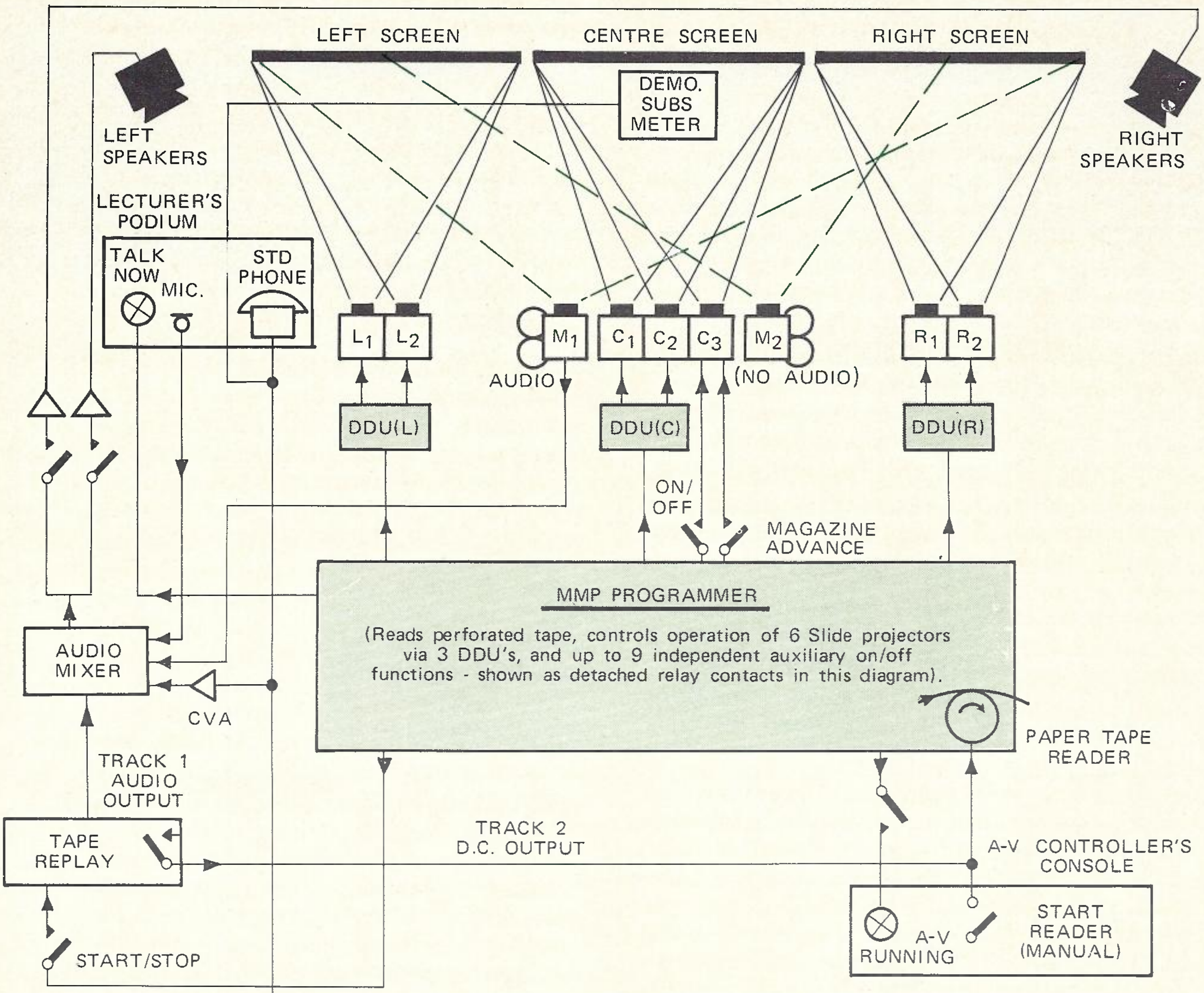


**Fig. 5 — How the screen showed:**
**(a) the 1907 Melbourne subscriber (left talking to Sydney;**
**(b) the Sydney subscriber (right) talking to Melbourne.**




$L_1, L_2$ - Slide projectors for left screen.

$C_1, C_2, C_3$ - Slide projectors for centre screen.

$R_1, R_2$ - Slide projectors for right screen.

$M_1$ - 16 mm. movie projector for 'overture' (wide screen).

$M_2$ - 16 mm. movie projector used with slides in part of left and right screens.

DDU - Dynamic dissolve unit (cuts, laps, dissolves between two slide projectors; advances magazines).

MMP - Tape reader and programmer.

CVA - Constant volume amplifier.

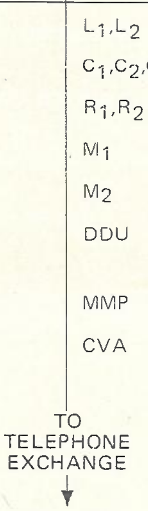



**Fig. 6 — Block Diagram of Audio-visual Equipment and Controls.**

## DIVERSE TASKS

The preparation period prior to the tour — from about February to September 1972 — was one of many activities, all under great pressure. Script-writing, the design of visual segments, audio segments and demonstrations all went on concurrently with the more detailed design, manufacture and ordering of equipment and other hardware. Members of the Australian telecommunications industry responded enthusiastically to requests for visual material and the construction of demonstration equipment.

An itinerary had to be planned in conjunction with the IREE and State Administrations, which, hopefully, would allow reasonable times for rest, as well as for transport, setting up and dismantling.

The art of programming the projector control equipment had to be learned, and programmes had to be tested, revised, and co-ordinated with the script. Demonstrations had to be devised and checked for effectiveness. The proper and reliable operation of the battery of projectors and its automatic-control equipment had to be proved.

But perhaps the largest contribution to the lecture came from members of the Drafting Section at Headquarters who translated sketches and instructions into artwork, photographs, and ultimately into more than 1000 transparencies in 23 x 23 mm format for use in the battery of slide projectors. Specially precise mounting procedures had to be developed to ensure registration of successive similar images on the same screen from different projectors — e.g., in 'animated' sequences. Furthermore, all transparencies were glass-mounted to ensure accuracy of registration and freedom from 'popping'.

## TRANSPORT

A 3-ton passenger bus (Fig. 7) with most of the seats replaced by special fittings to provide safe and convenient loading and unloading, and safe travel for the equipment was fitted out by the Melbourne Automotive Plant Workshops, and has since been returned to normal Departmental passenger service — minus the publicity along its sides. Later a Metro Van was added.

For the Tasmanian portion of the tour, the vehicles and drivers travelled 354 km (220 miles) by ship across Bass Strait, and for the Western Australian portion they travelled the 2410 km (1500 miles) section between Port Pirie and Perth by rail. In all, the vehicles travelled about 18,000 km (11,250 miles).

## SECURITY PRECAUTIONS

The planning of the lecture included provision for ensuring continuity of the lecture in the event of damage, loss, or failure of equipment. Naturally, spare projection lamps were carried; in addition, a spare slide projector was mounted ready to take over from any of the seven 'working' projectors.

It was decided that 'the show must go on' in the event of vehicle breakdown and an 'emergency lecture' was prepared. This comprised a separate script, written around the more conventional type of lecture, together with a small number of selected slides. Fortunately, the road/sea/rail itinerary for the equipment and technician team was adhered to without mishap, and the 'emergency lecture' did not reach the public.

A feature which gave rise to misgivings in the planning stage was a 'live' demonstration of STD calls all over Australia from a telephone at the lectern. The lecturer dialled numbers at different distances, and the audience listened to the result over loudspeakers in the hall, while watching a large-scale subscriber's meter operating as the normal charging impulses were extended from the local exchange (Fig. 8).

What if a faulty line were encountered, or faulty equipment at either end? It was decided that the picture of the Australian telephone network must be presented to the public — as with that of the Duke of Wellington — 'warts and all'. Nevertheless,


**Fig. 7 — The Faraday Lecture Bus.**

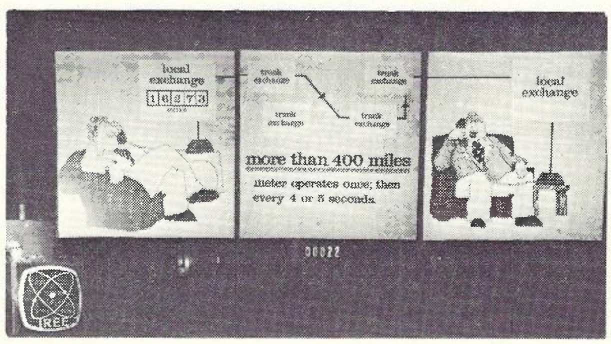



**Fig. 8 — The STD Demonstration.**

it would be embarrassing for the large meter in front of the audience to fail to register the expected charging pulses. Therefore, a potential source of deception was built into the control box to enable the meter to be activated by a push-button under the control of the operations manager, if the meter pulses failed to arrive from the exchange.

So much for the possibility of an indication of an undercharge; the possibility of an overcharge was considered to be so remote that no provision was made to conceal such an event from the eyes of the public!

In the event, no deception had to be practised and the 'as found' performance of the network proved a source of satisfaction to the lecture team and the audiences.

**CONCLUSIONS**

The opportunity for the engineer to present the fruits of his labours to large audiences of the general public is rare, yet such communication is one of the profession's important responsibilities.

It will have been evident from this brief description that substantial resources are required to undertake a project of this magnitude. Fortunately, the Post Office can draw on a wide range of skills from its own ranks, including those in the audio-visual and related fields, although 'outside' help had to be engaged in some areas.

Two indicators of the resources involved are:

- 5,100 man-hours were expended by lecture team staff in planning and preparation, and,
- 4,900 man-hours during the lecture tour itself.

As well, there was a very substantial contribution made by supporting groups and persons at Headquarters and in the States.

This article has only touched on some of the more important aspects of the planning and organisation of the lecture. No doubt, future Australian Faraday Lectures will improve the quality of and increase the audience for this important medium of popular technical communication.

**REFERENCES**

1. Woodrow, B.E., 'A Century of Telecommunications in the Northern Territory' Part 1; Telecom. Journal of Aust., Vol. 22, No. 3, Oct. 1972, p. 167

R. G. KITCHENN is Supervising Engineer, Transmission Performance Objectives Section, Planning and Programming Sub-Division, Headquarters. For further information, see Vol. 18, No. 1, P.69.

# Answers to Examination Questions

**Examination No. 6324 held 21st October 1972 and subsequent dates to gain part of the qualifications for eligibility for promotion as Telecommunications Technical Officer.**

PART 1 — ELECTRICAL TECHNOLOGY

**Note:** Although these answers are representative of the type of answer anticipated by the examiners, they are not necessarily typical of those received from candidates. However, any alternative answer submitted would have been assessed on the method of approach to the problem and the practibility of the solution.

When alloting marks in this type of examination the following general features of the candidate's paper would also be taken into consideration:

- In numerical calculations, accuracy to three significant figures is expected. Candidates who worked to only two significant figures, or who worked to a pseudo accuracy of five or more significant figures could expect to lose marks.
- The candidate would be expected to express himself clearly and concisely in good English.

## SECTION A

**Answer All Questions in this Section**

**Question 1**

*(a) What is the impedance of an inductor of 0.1 henries at a frequency of 1 kHz?*
*(b) What is the time constant of a capacitor of 1nF in series with a resistor of 3.3kΩ?*
*(c) What power ratio corresponds to 15dB?*
*(d) A transistor has a value of α of 0.98. What is the value of β?*
*(e) Find the absolute value, | Z |, of an impedance represented by (27 + j36) ohms.*
*(f) Give the truth table for a two input OR-gate.*
*(g) What value of resistor is required in parallel with a resistor of 6 ohms to give a combined value of 5 ohms?*
*(h) Express the binary number 10111 in decimal form.*
*(i) What power is developed in a load taking a current of 5 amperes from a 240 volt a.c. supply with a power factor of 0.85?*
*(j) What voltage is developed across an inductor of 5mH when the current through it is increasing at a linear rate of 3 amps per second?*

**Answer 1**

(a) $X_L = \omega L$
$= 2\pi fL$
$= 2 \times \pi \times 1 \times 10^3 \times 0.1$
$= 6.28 \times 10^2$
$= 628$ ohms.

(b) $T = RC$
$= 3.3 \times 10^3 \times 1 \times 10^{-9}$
$= 3.3 \times 10^{-6}$
$\therefore T = 3.3\ \mu s.$

(c) $10 \log \left(\frac{P_1}{P_2}\right) = dB$
$= 15$
$\log. \frac{P_1}{P_2} = \frac{15}{10}$
$= 1.5$
$\frac{P_1}{P_2} = 31.62.$

(d) $\beta = \frac{\alpha}{1 - \alpha}$
$= \frac{.98}{.02}$
$= 49.$

(e) $Z^2 = R^2 + X^2$
$= 27^2 + 36^2$
$= 9^2(3^2 + 4^2)$
$= 9^2 \times 5^2$
$|Z| = 9 \times 5$
$= 45$ ohms.

(f)

| INPUTS A | INPUTS B | OUTPUT C |
|---|---|---|
| 1 | 0 | 1 |
| 0 | 1 | 1 |
| 1 | 1 | 1 |
| 0 | 0 | 0 |

(g) $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$
$\frac{1}{5} = \frac{1}{6} + \frac{1}{R_2}$
$\frac{1}{R_2} = \frac{1}{5} - \frac{1}{6}$
$= \frac{6 - 5}{30}$
$= \frac{1}{30}$
$R_2 = 30$ ohms.

(h) $10111 = 2^0 + 2^1 + 2^2 + 0 + 2^4$
$= 1 + 2 + 4 + 0 + 16$
$= 23.$

(i) $P = VI \cos \phi$
$= 240 \times 5 \times 0.85$
$= 1200 \times 0.85$
$= 1020$ Watts.

(j) $e = -L\frac{di}{dt}$
$= -5 \times 10^{-3} \times 3$
$= -15$ mV.

**Question 2**

*A battery of e.m.f. 9 volts and internal resistance 25 ohms is connected to a load of R ohms.*
*(a) What is the value of the load when maximum power is developed in it?*
*(b) Calculate the power developed in the load resistor in part (a).*
*(c) Calculate the value of the load resistor when the power developed in it is one half of that in part (b).*

**Answer 2**

(a) For maximum power transfer, R equals internal resistance of battery, so R = 25Ω. (See Fig. 1.)


Fig. 1

(b) $P_{max} = \frac{(4.5)^2}{25}$ watts

$= \frac{20.25}{25}$

$= .81$ watts.

(c) Half the maximum power is .405 watts.
The voltage across R is now

$$V_R = 9 \times \left[\frac{R}{25 + R}\right]$$

$$\frac{V_R^2}{R} = .405$$

or

$$\frac{81 \times R^2}{(25 + R)^2 \times R} = .405$$

$$81R = .405\,(625 + 50R + R^2)$$

$$R^2 + 50R + 625 - \frac{81}{.405}R = 0$$

$$R^2 + 50R + 625 - 200R = 0$$

$$R^2 - 150R + 625 = 0$$

$$R = \frac{150 \pm \sqrt{150^2 - 2500}}{2}$$

$$= 75 \pm (0.5 \times 10) \times \sqrt{15^2 - 25}$$
$$= 75 \pm 5 \times \sqrt{225 - 25}$$
$$= 75 \pm 5 \times \sqrt{200}$$
$$= 75 \pm 5 \times 14.1$$
$$= 75 \pm 70.7$$
$$= 145.7 \text{ ohms (or 4.3 ohms).}$$

**Question 3**

*Describe how the gate and anode electrodes of a thyristor control the flow of current from the anode to cathode of a thyristor. The waveform shown in Fig. 2 is applied continuously to the anode supply terminal, A, of the circuit shown. If the gate is pulsed on from $t_1 = 200\mu s$ to $t_2 = 1700\mu s$ each cycle, calculate the average anode current in the thyristor.*

**Answer 3**

The thyristor can be regarded as a diode having anode and cathode terminals, together with a third electrode, termed the gate (see Fig. 3). Assume the anode is positive with respect to the cathode. If the gate is initially negative with respect to the cathode no anode current will flow. If now the gate voltage is made slightly positive with respect to the cathode, anode current flows. A latching action occurs inside the thyristor whereby control of the anode current passes from the gate to the anode. Thus even making the gate negative again will not turn off the thyristor, but making the anode negative will do so. If a variable resistive load is included in the anode circuit the thyristor can also be turned off by increasing the resistance of the load, so causing the anode current to fall. When the current reaches the so-called *holding current*, the thyristor will turn off. Most practical applications use the first method of controlling the thyristor.

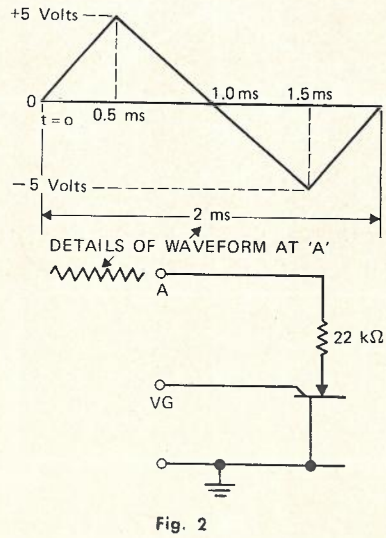



Fig. 2

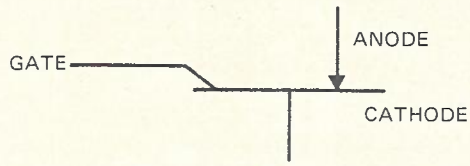



Fig. 3

If the gate is pulsed on from $t_1 = 200\mu s$ to $t_2 = 1700\mu s$ the thyristor will turn on at $200\mu s$ but will turn off at $t = 1000\mu s$ since the anode becomes negative with respect to the cathode at this time.
The average value of the anode current is given by:

$$I_{AV} = \frac{V_{AV}}{\text{anode load}}$$

where $V_{AV}$ is found by considering the applied voltage waveform during the time the thyristor conducts and averaging this over one complete cycle.
Consider first the voltage at the time $t_1$.

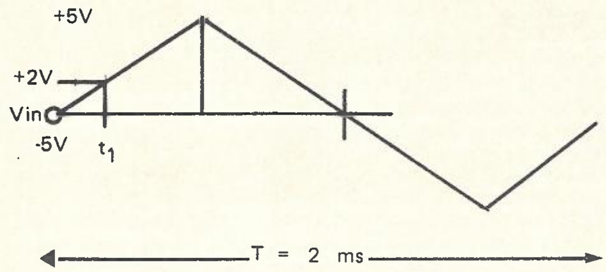



Fig. 4

Since the waveform rises linearly from OV at time $t = 0$ to $+5V$ at time $t = 0.5ms$, as shown in Fig. 4, it will reach a value of $+2V$ at time $t_1 = 200\mu s$.
The calculation of the value of $V_{AV}$ is made by comparing the area under the applied waveform from $200\mu s$ to $1000\mu s$ with the value of the area corresponding to 5V applied continuously throughout the cycle.

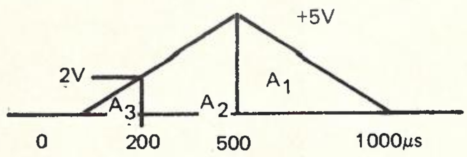



Fig. 5

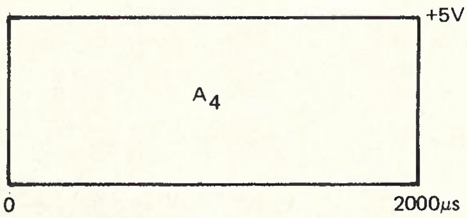



Fig. 6

Thus $$V_{AV} = \frac{(A_2 + A_1)}{A_4} \times 5$$

From Fig. 5,

$$A_2 = A_1 - A_3$$
$$(A_2 + A_1) = 2A_1 - A_3$$

Now, $$A_3 = \tfrac{1}{2}(200 \times 2) = \frac{400}{2} = 200$$

and $$A_1 = \tfrac{1}{2}(500 \times 5) = \frac{2,500}{2} = 1,250$$

$$(A_2 + A_1) = (2 \times 1,250) - 200$$
$$= 2,500 - 200$$
$$= 2,300$$

But area $$A_4 = 5 \times 2000 \text{ (Fig. 6)}$$
$$= 10,000$$

$$\frac{(A_2 + A_1)}{A_4} = \frac{2,300}{10,000}$$

$$V_{AV} = \frac{2,300}{10,000} \times 5$$
$$= 1.15 \text{ Volts}$$

Average current $$= \frac{1.15}{22} \text{ mA}$$
$$= .0523 \text{ mA or } 52.3\ \mu\text{A}.$$

**Question 4**

*(a) State Thevenin's Theorem.*

*(b) Find the voltage drop across the 1.5 ohm resistor and the the magnitude and direction of the current in each battery in the circuit shown in Fig. 7.*

**Answer 4**

(a) Thevenin's theorem states that any active network having terminals A and B can be replaced by a constant-voltage source having an emf. E and an internal resistance r. The value of E is equal to the open-circuit pd between A and B, and r is the resistance of the network measured between A and B with the load disconnected and the sources of emf replaced by their resistances.

(b) **Solution 1 (Thevenin's Theorem).**

Voltage levels relative to earth are shown circled. Replace the 6V and 12V batteries by one 6V battery (Fig. 8).

Remove the 1.5Ω resistor and re-draw (Fig. 9). Then open circuit emf equals 5 volts.

Resistance with sources of emf shorted (Fig. 10) equals 2Ω.

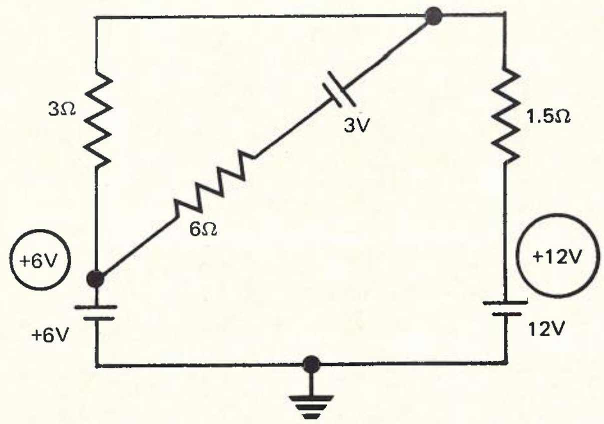



Fig. 7

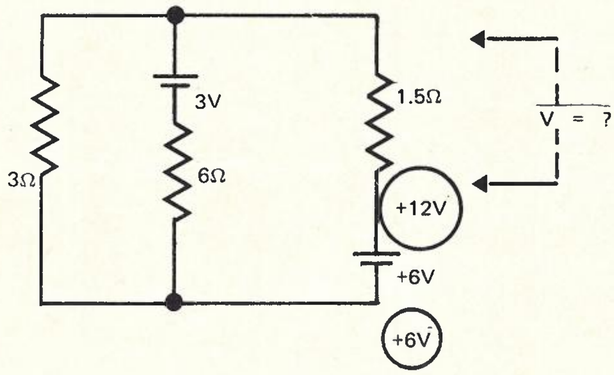



Fig. 8

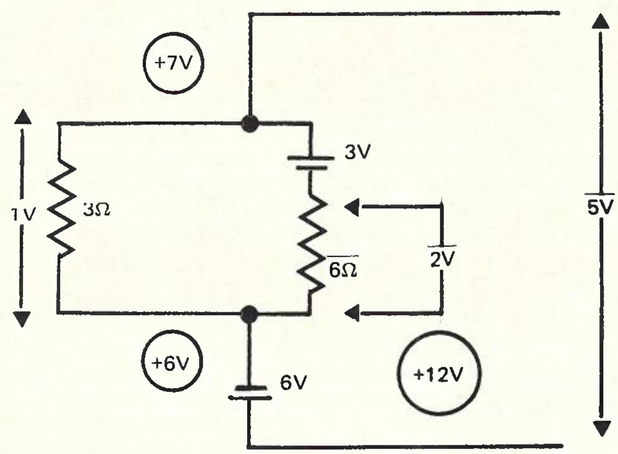



Fig. 9

Hence pd across the 1.5Ω resistor is given by,

$$V = 5 \times \frac{1.5}{3.5} = 5 \times \frac{3}{7}$$
$$= \frac{15}{7} = 2\tfrac{1}{7} \text{ V or } 2.15 \text{ V}$$

Voltage levels in the circuit are as shown in Fig. 11.

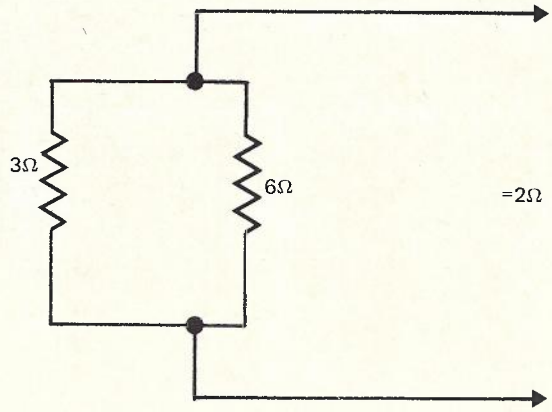



Fig. 10

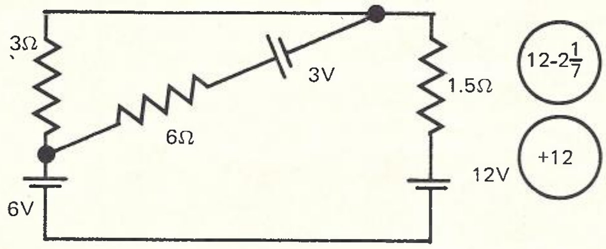



Fig. 11

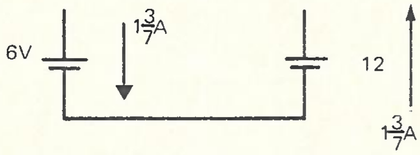



Fig. 12

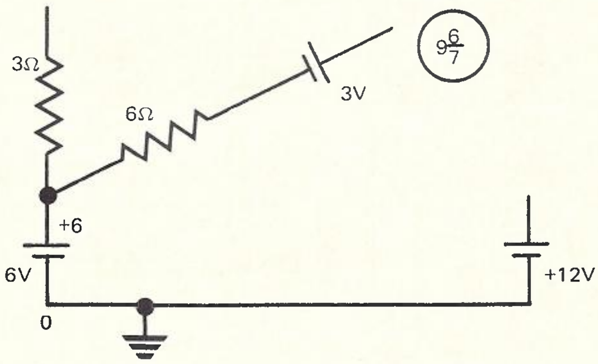



Fig. 13

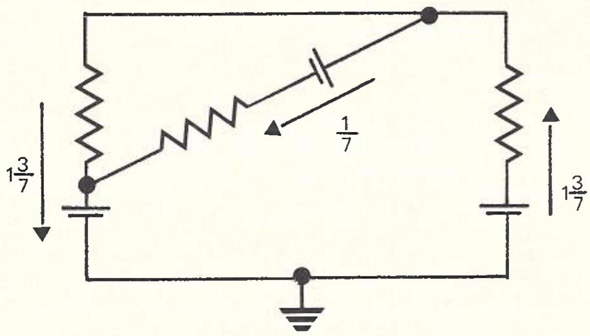



Fig. 14

V = $2\frac{1}{7}$ volts across the 1.5Ω resistor

$$I = \frac{15}{7} \times \frac{1}{1.5} = \frac{10}{7}$$

$$= 1\tfrac{3}{7} \text{ A (or 1.43A)}$$

Current in the 6V and 12V batteries is $1\frac{3}{7}$ A (Fig. 12).

Voltage at junction of 3V battery and 6Ω resistor is ($9\frac{6}{7}$ − 3) volts with respect to earth, i.e. $6\frac{6}{7}$ volts (Fig. 13).

Current through the battery = current in 6Ω resistor

$$= \frac{6\frac{6}{7} - 6.0}{6}$$

$$= \frac{\frac{6}{7}}{6} = \frac{6}{7} \times \frac{1}{6}$$

= $\frac{1}{7}$ amps (or 0.143 amps).

Current in the 3V battery is $\frac{1}{7}$ amps.

**Solution 2 (Kirchoff's laws).**

Redraw the circuit as in Fig. 15.

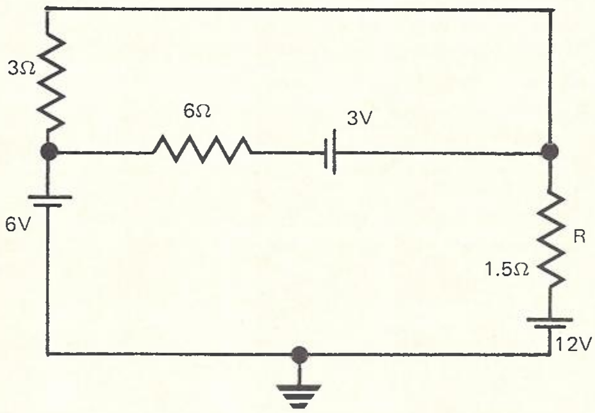



Fig. 15

Replace 6V and 12V batteries by one 6V (Fig. 16).

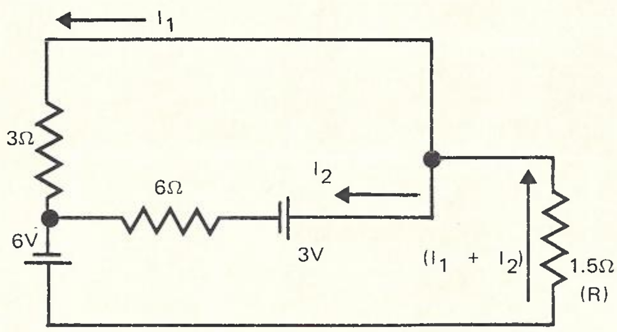



Fig. 16

Loop Equations:

$$6 = 6I_2 + 3 + 1.5(I_1 + I_2)$$
$$3I_1 = 6I_2 + 3$$
$$I_1 = 2I_2 + 1.0$$
$$6 = 6I_2 + 3 + 1.5I_2 + 1.5(2I_2 + 1.0)$$
$$3 = 7.5I_2 + 3I_2 + 1.5$$
$$10.5I_2 = 1.5$$

$$I_2 = \frac{1.5}{10.5} = \frac{3}{21}$$

$$= \tfrac{1}{7}\text{A (or 0.143A)}$$

$$I_1 = (2 \times \tfrac{1}{7}) + 1$$

$$= 1\tfrac{2}{7}\text{A (or 1.286A)}$$

Drop across $R = (\tfrac{1}{7} + 1\tfrac{2}{7}) \times 1.5$

$$= 1\tfrac{3}{7} \times 1.5$$

$$= \tfrac{10}{7} \times \tfrac{3}{2}$$

$$= \tfrac{15}{7}$$

$$= 2\tfrac{1}{7}\text{V (or 2.143V).}$$

## SECTION B

**Answer any SIX Questions in this Section**

**Question 5**

*(a) Define the cut-off frequency, $f_o$, of a simple RC filter. When the filter is connected between a generator of internal impedance $R_S$ ohms and a purely resistive load $R_L$ what are the formulae for the passband gain and for $f_o$ for:*
*(i) a high-pass filter?*
*(ii) a low-pass filter?*

*(b) Find the upper and lower cut-off frequencies for the circuit shown in Fig. 17. (Assume no interaction between the two filters.)*

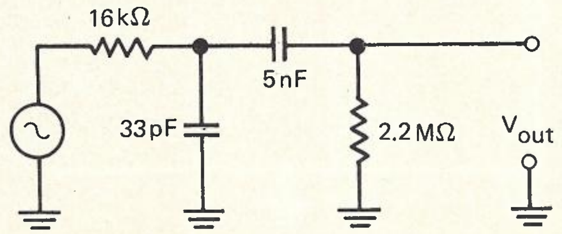



Fig. 17

**Answer 5**

(a) The cut-off frequency of a simple RC filter is that frequency at which the load power drops to one half of its pass band value.

(i) High Pass (Fig. 18).

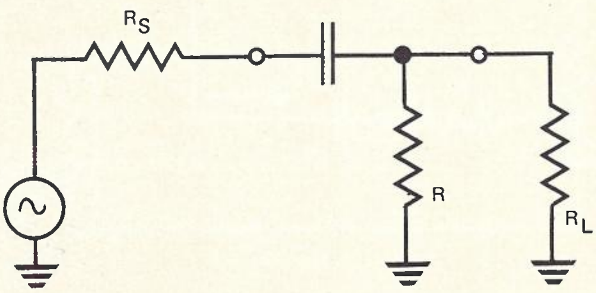



Fig. 18

$$\text{Pass band gain, } A = \frac{R \parallel R_L}{R_S + [R \parallel R_L]}$$

$$\text{Cut-off frequency, } f_o = \frac{1}{2\pi(R_S + R \parallel R_L)C}$$

(ii) Low Pass (Fig. 19).

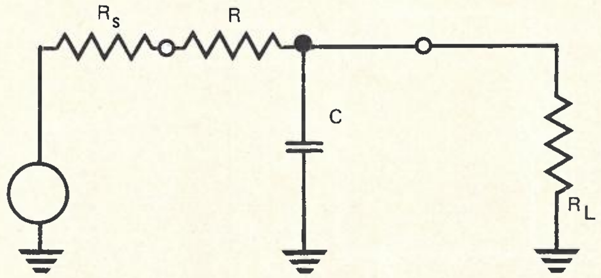



Fig. 19

$$\text{Pass band gain } A = \frac{R_L}{R_S + R + R_L}$$

$$\text{Cut-off frequency } f_o = \frac{1}{2\pi[R_L \parallel (R + R_S)]C}$$

(b) To find the cut-off frequencies $f_1$ and $f_2$, draw first the equivalent circuit as shown in Fig. 20.

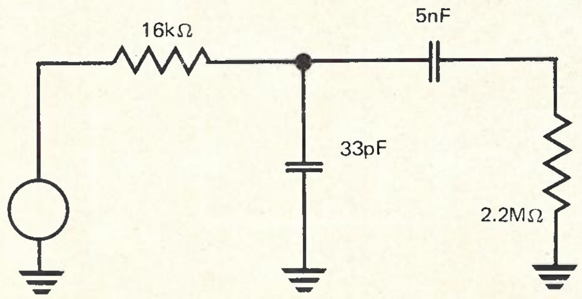



Fig. 20

Now $$f_1 = \frac{1}{2\pi \times (2.2 \times 10^6) \times (5 \times 10^{-9})}$$

$$= \frac{10^3}{2\pi \times 2.2 \times 5}$$

$$= \frac{10^2}{2.2\pi}$$

$$= 14.6 \text{ Hz.}$$

Also $$f_2 = \frac{1}{2\pi \times (16 \times 10^3) \times (33 \times 10^{-12})}$$

$$= \frac{10^7}{2\pi \times 1.6 \times 3.3}$$

$$= 300 \text{ kHz.}$$

**Question 6**

*(a) Explain why it is seldom correct in a.c. calculations to add voltages or currents together arithmetically.*

*(b) The instantaneous values of two alternating currents are given by:*

$$i_1 = 1200 \sin \omega t$$

$$i_2 = 500 \sin\left(\omega t - \frac{\pi}{12}\right)$$

*Calculate, or find graphically, the instantaneous value of:*
*(i) the sum.*
*(ii) the difference of these two currents.*

**Answer 6**

(a) In ac calculations voltages or currents must be considered in conjunction with their appropriate phase angles. Thus a voltage is in general represented by

$$v = v_0 \sin(\omega t + \phi)$$

where $\phi$ is the phase angle

Thus when two voltages are considered having phase angles $\phi_1$ and $\phi_2$, it is necessary to add by a process similar to the parallelogram of forces but using phasors (Fig. 21).

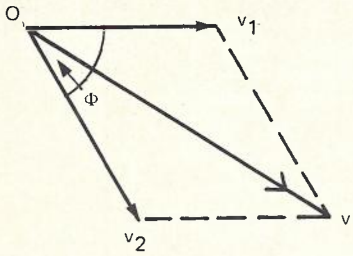



**Fig. 21**

The angle Φ is given by

$$\Phi = (\phi_1 - \phi_2)$$

The resultant Ov is the third side of a triangle, the other two sides of which have lengths proportional to $v_1$ and $v_2$. Since the third side of any triangle is shorter than the sum of the lengths of the other two, the resultant Ov will be less than the arithmetic sum of $v_1$ and $v_2$.

An exactly parallel argument applies to currents.

(b) The sum of the two currents is found as shown in Fig. 22.

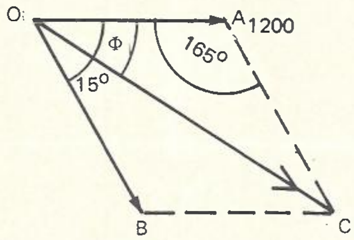



**Fig. 22**

Resultant is given by

$$OC^2 = OA^2 + OB^2 - 2\,OA.OB\cos OAC \left(\because \frac{\pi}{12} = 15^\circ\right)$$

$$= OA^2 + OB^2 - 2\,OA.OB\cos 165$$

$$(\because \cos 15 = -\cos 165)$$

$$= 1200^2 + 500^2 + 2.1200.500\cos 15$$

$$= 10^4(12^2 + 5^2 + 120(.9659))$$

$$= 10^4(144 + 25 + 116)$$

$$OC = 10^2\sqrt{285}$$

$$= 16.9 \times 10^2$$

$$= 1690$$

sin $\phi$ is found using the sine rule,

$$\frac{AC}{\sin\phi} = \frac{OC}{\sin 165}$$

$$\sin\phi = \sin 165 \frac{AC}{OC}$$

$$= \sin 15 \tfrac{500}{1690}$$

$$= .259 \times \tfrac{500}{1690}$$

$$= .0765$$

$$\phi = 4^\circ 23'$$

Converting to radians:

$$\phi = 4.78 \times \frac{2\pi}{360}\text{ radians}$$

$$= .076\text{ radians}$$

$$i = 1690\sin(\omega t - .076)$$

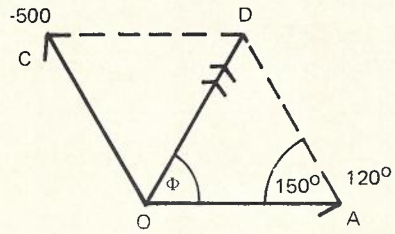



**Fig. 23**

To find the difference $(i_1 - i_2)$

The resultant OD, is given by (Fig. 23).

$$OD^2 = OA^2 + AD^2 - 2\,OA.AD\cos O\hat{A}D$$

$$= OA^2 + AD^2 - 2\,OA.AD\cos 15$$

$$= 1200^2 + 500^2 - 2.500.1200\,(.966)$$

$$= 10^4(169 - 115.5)$$

$$OD = 100\sqrt{53}$$

$$= 728$$

Sin $\phi$ is given by

$$\sin\phi = \frac{OD}{\sin 15}$$

$$= \frac{AD}{OD}\sin 15$$

$$= \tfrac{500}{728} \times 0.259$$

$$\sin\phi = .178$$

$$= 10^\circ 15' \text{ or } 10.2^\circ$$

Converting to radians

$$\phi = \frac{10.2}{360} \times 2\pi \text{ radians}$$

$$= .0175\text{ radians}$$

$$\therefore \quad i = 728\sin(\omega t + .0175)$$

**Question 7**

*Find the values of R, L and C for a parallel resonant circuit having the following characteristics.*

| | |
|---|---|
| *Resonant frequency* | *= 1 kHz* |
| *Impedance at resonant frequency (Dynamic Resistance)* | *= 10 kΩ* |
| *'Q' value* | *= 30* |

**Answer 7**

Let the resonant frequency be $f_r$ (Hz).

then, $$f_r = \frac{1}{2\pi\sqrt{LC}}$$

but $$f_r = 10^3$$

so $$\frac{1}{2\pi\sqrt{LC}} = 10^3 \quad (1)$$

The dynamic impedance is given by

$$Z_D = \frac{L}{CR}$$

so $$\frac{L}{CR} = 10^4 \quad (2)$$

The 'Q' value is given by

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}} = 30 \quad (3)$$

From (2) and (3)

$$\frac{L}{CR} \div \left[\frac{1}{R}\sqrt{\frac{L}{C}}\right] = \frac{10^4}{30}$$

$$\sqrt{\frac{L}{C}} = \frac{10^3}{3} \qquad (4)$$

Multiply (4) by (1)

$$\frac{1}{2\pi\sqrt{LC}} \times \sqrt{\frac{L}{C}} = 10^3 \times \frac{10^3}{3}$$

$$\frac{1}{2\pi C} = \frac{10^6}{3}$$

$$C = \frac{3}{2\pi} \times 10^{-6}$$

$$C = 0.478\ \mu F$$

But $\sqrt{\frac{L}{C}} = \frac{10^3}{3}$

$$L = \frac{10^6}{9} \times C$$

$$= \frac{10^6}{9} \times \frac{3}{2\pi} \times 10^{-6}$$

$$= \frac{1}{6\pi}$$

$$= 53.0 \text{ millihenries}$$

Now $\frac{1}{R}\sqrt{\frac{L}{C}} = 30$

But $\sqrt{\frac{L}{C}} = \frac{10^3}{3}$

so $\frac{1}{R} \times \frac{10^3}{3} = 30$

$$R = \frac{10^3}{3 \times 30}$$

$$= 11.1 \text{ ohms.}$$

**Question 8**

*A multi-range dc meter is to be constructed using a moving coil microammeter with a full scale deflection sensitivity of 100µA as the indicating instrument. If the voltage drop across the instrument is 75mV at full scale deflection, find the values of a 1 amp shunt and a 1 volt multiplier. Hence find the power dissipated in the shunt and the multiplier.*

*If the 1A shunt is to be made of manganin strip having a resistivity of 50µΩ-cm, a thickness of 0.8 mm and a width of 6 mm, calculate the length of strip required.*

**Answer 8**

**1 Amp shunt.**

Since the meter current is only 100µA compared with the current of 1A it can be neglected.

$$\therefore \text{ Shunt resistance} = \frac{V}{I}$$

$$= \frac{75 \times 10^{-3}}{1}$$

$$= 75\ m\Omega$$

$$P = I^2R = 75mW$$

**1 Volt multiplier.**

Drop across multiplier = 1 − .075 volts
= .925 volts.

Current through multiplier is 100µA.

$$\text{Resistance of multiplier} = \frac{V}{I}$$

$$= \frac{.925}{.1 \times 10^{-3}}$$

$$= 9.25\ k\Omega$$

$$P = I^2R = (10^{-4})^2 \times 9.25 \times 10^3$$
$$= 9.25 \times 10^{-5} W$$

**Length of strip.**

The resistance of the manganin strip is given by

$$R = \frac{\sigma L}{A}$$

$\sigma$ = resistivity
L = length
A = cross sectional area

$$75 \times 10^{-3} = \frac{50 \times 10^{-6} \times L}{6 \times 10^{-1} \times 0.8 \times 10^{-1}}$$

$$L = \frac{75 \times 10^{-5} \times 6 \times 0.8}{50 \times 10^{-6}}$$

$$= 72 \text{ cm.}$$

**Question 9**

*Define the* 'characteristic resistance' *of a symmetrical attenuator and explain briefly its importance in matching an attenuator to a source and load.*

*Calculate the values of resistors R and r required to form the single-section 30 db attenuator shown in Fig. 24, if its characteristic impedance is 600 ohms.*

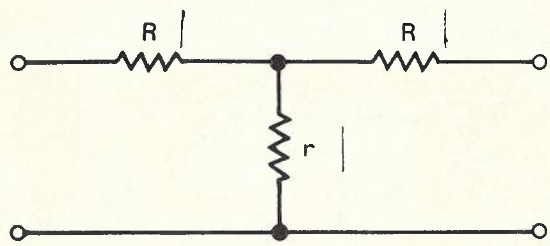



Fig. 24

**Answer 9**

The characteristic resistance of a symmetrical attentuator is equal to the value of load resistance that produces an input resistance equal to the load resistance.

In order to prevent reflections occurring when used in conjunction with the rest of the system it is essential for the characteristic resistance of the attenuator, the source resistance, the characteristic impedance of the line, and the load resistance to all be equal to one another; in this way matching is maintained. Hence when designing an attenuator for a given attenuation in a given system, the characteristic resistance must be chosen to equal that of the system.

Since the attenuation required is 30 dB, the equivalent voltage ratio is found from,

$$20 \log \frac{V_1}{V_2} = 30$$

$$\log \frac{V_1}{V_2} = 1.5$$

$$\frac{V_1}{V_2} = 31.6$$

Now looking into the terminated attenuator (Fig. 25), the impedance is $(R_0 - R)$

$$V_x = V_1 \times \left[\frac{R_0 - R}{R_0}\right]$$

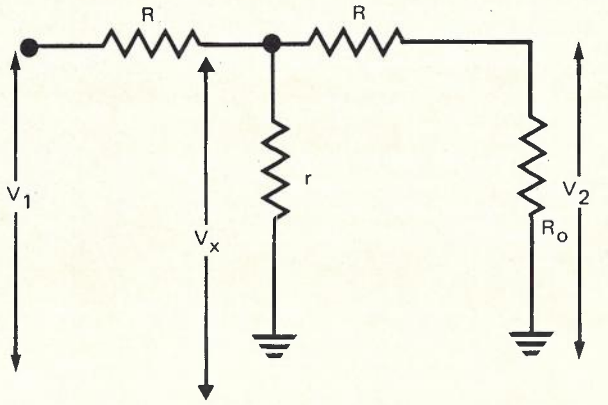



Fig. 25

$$V_2 = V_x \times \left[\frac{R_0}{R_0 + R}\right]$$
$$= V_1 \times \left[\frac{R_0 - R}{R_0} \times \frac{R_0}{R_0 + R}\right]$$
$$= V_1 \times \left[\frac{R_0 - R}{R_0 + R}\right]$$
$$V_2R_0 + V_2R = 31.6R_0 - 31.6R$$
$$30.6R_0 = 32.6R$$
but $R_0 = 600$ ohms
$$R = \frac{30.6}{32.6} \times 600$$
$$= 563 \text{ ohms}$$
also $(R_0 + R) \parallel r = R_0 - R$
$$(600 + 563) \parallel r = 37$$
$$\frac{1163r}{1163 + r} = 37$$
$$1163r = (37.1163) + 37r$$
$$1126r = 1163 \times 37$$
$$r = 37 \times \frac{1163}{1126}$$
$$= 38 \text{ ohms}$$

The values of the resistors required are r = 38 ohms and R = 563 ohms.

### Question 10

*Fig. 26 represents an ac Wheatstone bridge in which the impedances of the four arms are:*

*$Z_1 = (9 + j7)$ ohms*
*$Z_2 = (9 + j)$ ohms*
*$Z_3 = (3 - j)$ ohms*
*$Z_4 = (R + jX)$ ohms*

*Find the values of R and X in order that the bridge may be balanced.*

### Answer 10

The balance condition for the bridge is that

$$\frac{Z_1}{Z_2} = \frac{Z_3}{Z_4}$$
$$\frac{9 + j7}{9 + j} = \frac{3 - j}{R + jX}$$
$$(9 + j7)(R + jX) = (3 - j)(9 + j)$$
$$9R + j9X + j7R - 7X = 27 + j3 - j9 + 1$$

This resolves into two separate equations, one for the real part, one for the imaginary part.

$$9R - 7X = 28 \qquad (1)$$
and
$$9X + 7R = -6$$

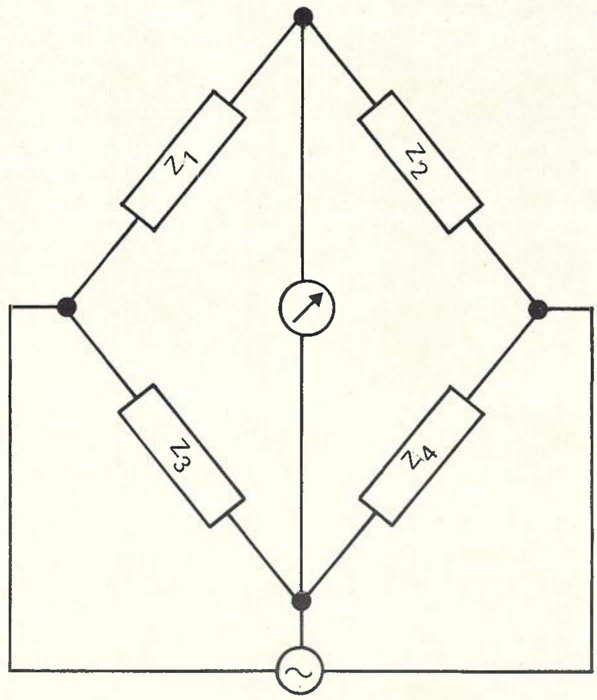



Fig. 26

These two simultaneous equations can be solved in the normal manner.

$$R - \tfrac{7}{9}X = \tfrac{28}{9}$$
$$R + \tfrac{9}{7}X = -\tfrac{6}{7}$$
$$\tfrac{9}{7}X + \tfrac{7}{9}X = -\tfrac{6}{7} - \tfrac{28}{9}$$
$$X = -\frac{(\frac{6}{7} + \frac{28}{9})}{(\frac{9}{7} + \frac{7}{9})}$$
$$= \frac{54 + 196}{81 + 49}$$
$$= \tfrac{250}{130}$$
$$= -\tfrac{25}{13} \text{ (or } -1.924)$$

From equations (1)

$$\tfrac{9}{7}R - X = \tfrac{28}{7}$$
$$\tfrac{7}{9}R + X = -\tfrac{6}{9}$$
$$\tfrac{9}{7}R + \tfrac{7}{9}R = \tfrac{28}{7} - \tfrac{6}{9}$$
$$R = \frac{(\frac{28}{7} - \frac{6}{9})}{(\frac{9}{7} + \frac{7}{9})}$$
$$= \frac{252 - 42}{81 + 49}$$
$$= \tfrac{210}{130}$$
$$= \tfrac{21}{13}$$
$$= 1.615$$
$$Z = (1.62 - j1.92) \text{ ohms.}$$

### Question 11

*Calculate the magnitude of the impedance and its phase angle as seen across terminals AB in the circuit shown in Fig. 27 at 100 Hz. The inductance of the transformer seen across its terminals PQ can be neglected. Assume perfect coupling between primary and secondary.*

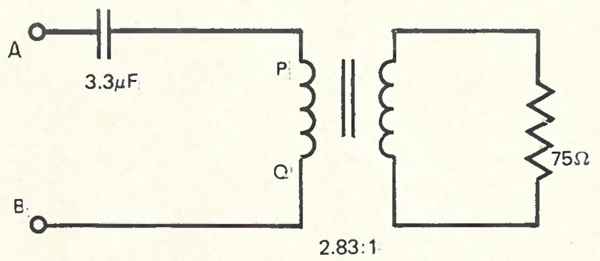



Fig. 27

**Answer 11**

The reflected value of the 75Ω resistor across PQ is given by

$$R = 75 \times (2.83)^2$$
$$= 75 \times 8$$
$$= 600\Omega$$

The reactance of the 3.3μF capacitor is given by

$$X_C = \frac{1}{j\omega C}$$
$$= \frac{-j}{2\pi 100 \times 3.3 \times 10^{-6}}$$
$$= \frac{-j10^4}{6.6\pi}$$
$$= -j484 \text{ ohms}$$

Total impedance seen across AB is

$$Z_{AB} = 600 - j484$$

The magnitude of $Z_{AB}$ is given by (Fig. 28):

$$|Z_{AB}|^2 = 600^2 + 484^2$$
$$= 100^2(6^2 + 4.84^2)$$
$$= 100^2(36 + 23.4)$$
$$= 100^2(59.4)$$
$$= 10 \times \sqrt{59.4}$$
$$|Z_{AB}| = 770$$

The phase angle is given by (Fig. 29):

$$\tan\phi = \frac{-484}{600}$$
$$= -0.807$$
$$\phi = -38^\circ 54'$$

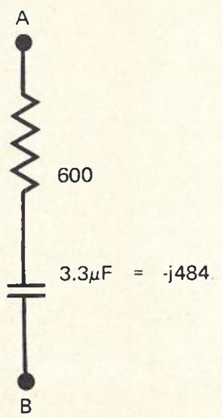



Fig. 28

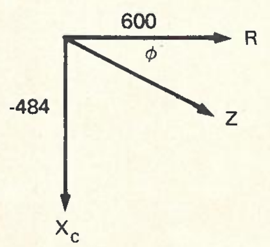



Fig. 29

**Question 12**

*Figs. 30 and 31 show the input and output characteristics of a PNP transistor in the common emitter mode.*

*(a) Draw a dc load line on the output characteristics to give an operating point of $E_C = -4.5$ volts, $I_b = 80\mu A$, for a collector supply voltage of $-9$ volts.*

*(b) What is the value of the load resistor represented by the load line you have drawn?*

*(c) What is the input resistance of the transistor at the above operating point?*

*(d) If the input power across the base-emitter terminals is $1.0\mu W$ for a sinusoidal input current modulating the standing bias current, find the power developed in the load resistor (assume no distortion takes place).*

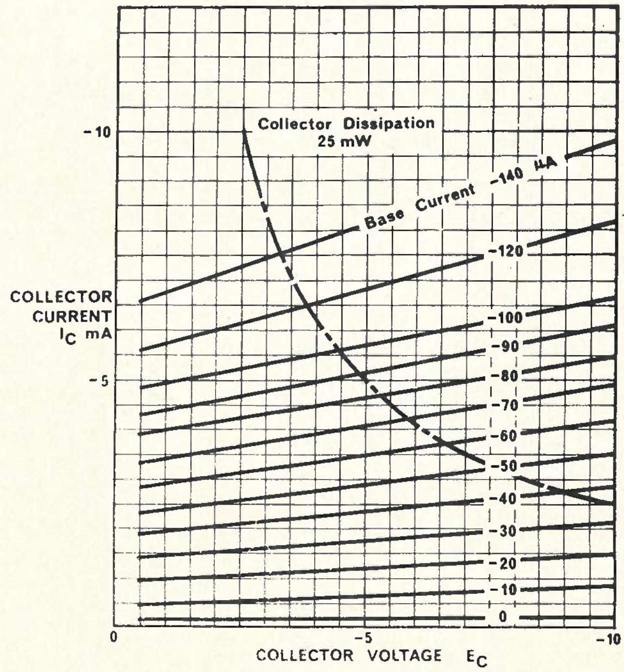



Fig. 30

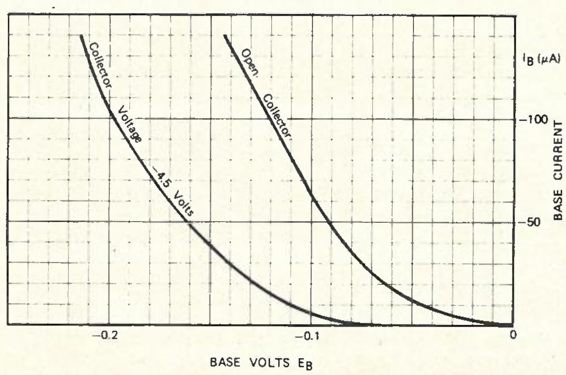



Fig. 31

**Answer 12**

(a) See Fig. 32.

(b) The load line joins the points 9V and 9 mA hence the value of the load is

$$R_L = \frac{9}{9 \times 10^3}$$
$$= 1k\Omega$$

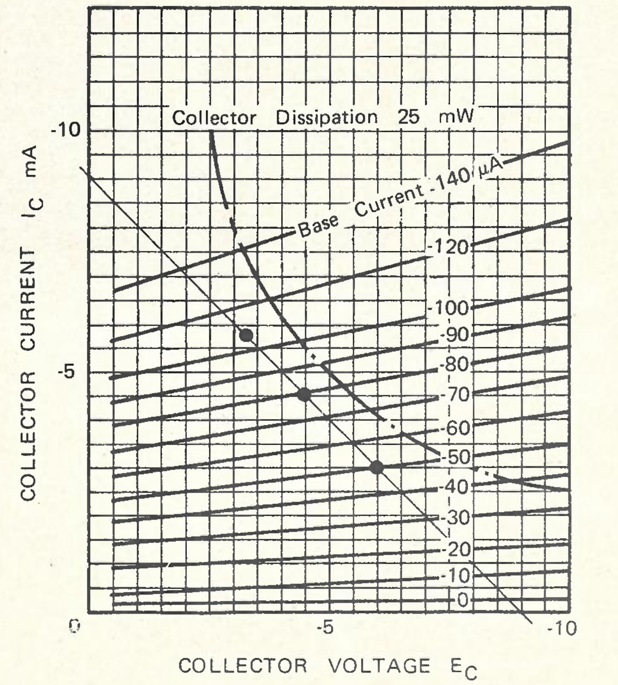



Fig. 32

(c) From the input characteristics (Fig. 33), the value of $E_B$ for a collector voltage of $-4.5$ V at a base current of 80 $\mu$A is $-1.85$ volts.

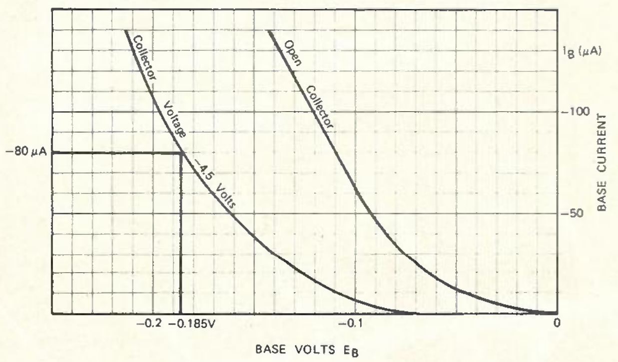



Fig. 33

∴ The input resistance is given by

$$R_{in} = \frac{0.185}{80 \times 10^{-6}}$$
$$= \frac{1.85 \times 10^{-1}}{8 \times 10^{-5}}$$
$$= 0.231 \times 10^{4}$$
$$= 2.31\text{k}\Omega$$

(d) If the power developed across the base-emitter terminals is 1.0$\mu$W, then the rms value of the sinusoidal base current is given by

$$i^2 \times 2.31 \times 10^3 = 10^{-6}$$
$$i^2 = \frac{10^{-9}}{2.31}$$
$$i = \sqrt{\frac{10}{2.31}} \times 10^{-5}$$
$$= \sqrt{4.32} \times 10^{-5}$$
$$= 20.8\ \mu\text{A}$$

The peak value of the base sinusoidal current is

$$i_{pk} = 20.8 \times 1.414$$
$$= 29.5\text{mA}$$

Since this modulates the bias current of 80$\mu$A, the total base current varies from $(80 - 29.5)\mu$A to $(80 + 29.5)\mu$A; i.e. from 50$\mu$A to 110$\mu$A.

From the load line on Fig. 32, the collector current swings from 3mA to 5.8mA.

Peak-to-peak collector current $= (5.8 - 3)$mA
$= 2.8$mA
Peak sinusoidal current $= 1.4$mA
rms sinusoidal current $= 1.4 \times .707$
$= 1$mA
Power developed in the load $= i^2R$
$= (1 \times 10^{-3})^2 \times 10^3$
$= 1$mW

**Question 13**

*(a) Describe briefly and give the name of the phenomenon expressed by the formula:*

$$C_{in} = C_{gk} + (1 + A)C_{ga}$$

*where $C_{gk}$ and $C_{ga}$ are valve interelectrode capacitances as shown in Fig. 34. and A is the stage gain.*

*(b) What is the input impedance across terminals AB of the circuit in Fig. 35?*

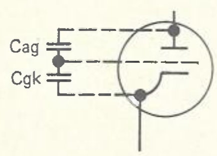



Fig. 34

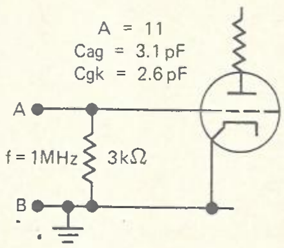



Fig. 35

**Answer 13**

(a) The formula describes the Miller Effect. This is the name given to the phenomena in which there is an apparent increase in the input capacitance of a valve due to feedback through the anode-to-grid interelectrode capacitance. The increase is related to the stage gain A as the formula indicates. $C_{in}$ is given by

$$C_{in} = C_{gk} + (1 + A)C_{ga}$$
$$= 2.6 + (12 \times 3.1)$$
$$= 2.6 + 37.2$$
$$= 39.8\text{pF}$$

(b)
$$\frac{1}{Z_{in}} = \frac{1}{R_{in}} + \frac{j}{X_{in}} \quad \text{(Fig. 36)}$$
$$= \frac{1}{3 \times 10^3} + j\omega C_{in}$$

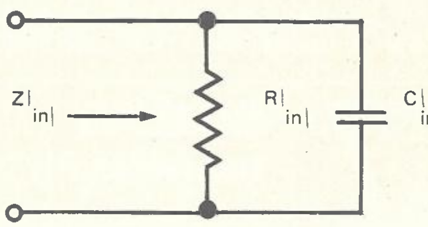



Fig. 36

$$= .33 \times 10^{-3} + j2\pi \times 10^{6} \times 39.8 \times 10^{-12}$$
$$= 3.3 \times 10^{-4} + j2\pi \times 3.98 \times 10^{-5}$$
$$= 3.3 \times 10^{-4} + j2.5 \times 10^{-4}$$
$$\left[\frac{1}{Z_{in}}\right]^2 = [3.3]^2 \times 10^{-8} + [2.5]^2 \times 10^{-8}$$
$$= [10.9 + 6.25] \times 10^{-8}$$
$$= 17.2 \times 10^{-8}$$
$$Z_{in} = \frac{10^4}{\sqrt{17.2}}$$
$$= \frac{10^4}{4.14}$$
$$= 2.42\text{k}\Omega$$

**Question 14**

*(a) Convert the decimal number 130 to binary form.*
*(b) Add the binary numbers 1001 and 10101.*
*(c) Explain in words what is meant by the Boolean equation:*
$$D = A.B + C$$
*(d) Draw a logic diagram to illustrate the equation in part (c).*
*(e) Construct a truth table for the equation:*
$$C = \overline{A}.B$$

**Answer 14**

(a) The decimal number 130 is equal to 2 + 128
$$= 2^1 + 2^7$$
$$= 10000010_2$$

(b)
$$\begin{array}{r} +10101 \\ 1001 \\ \hline 11110 \end{array}$$

(c) The expression A . B + C means that the output is logic one when the inputs A and B are logic one or when input C is logic one.

(d) See Fig. 37.

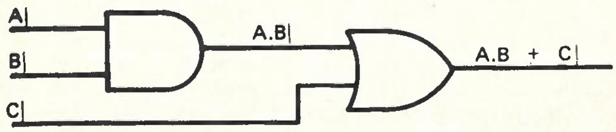


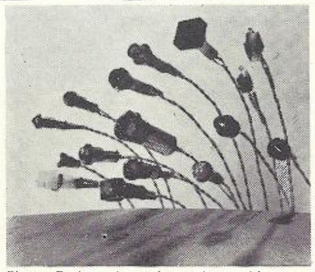

**Fig. 37**

(e)

| A | B | $\overline{A}$ | C |
|---|---|---|---|
| 0 | 0 | 1 | 0 |
| 0 | 1 | 1 | 1 |
| 1 | 0 | 0 | 0 |
| 1 | 1 | 0 | 0 |

# Australia

'PABX'—manufactured by Plessey Telecommunication Systems, this private automatic branch exchange system employs crossbar switching and componentry similar to that used by the Australian Post Office in the national telephone network.



Plessey Rodan indicator lamps designed for compatibility with and to enhance the presentation of electronic, electrical and industrial equipment. These indicator lamps are just some of the vast range available from Plessey Ducon.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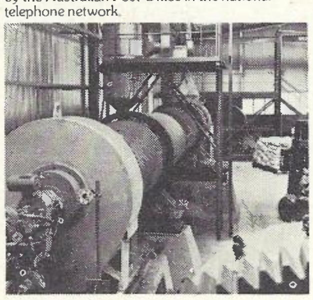
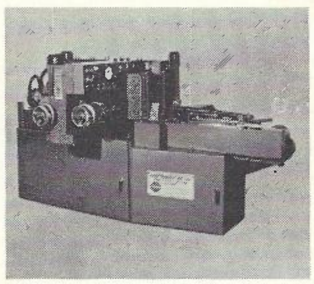
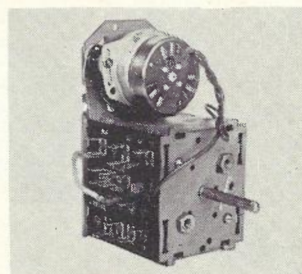


Plessey Rola is Australia's largest manufacturer of magnetic materials. Under agreement with B.H.P., Plessey have exclusive marketing rights for hematite and ferrite powders produced from Yampi Sound.

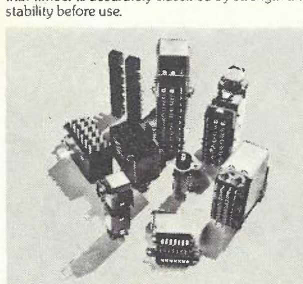


Designed and produced in Australia by Plessey Telecommunications, the 'Computermatic' timber grader completely eliminates the guesswork from visual timber grading. Electronic grading ensures that timber is accurately classified by strength and stability before use.

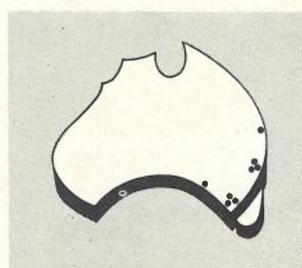


Plessey Mallory interval timer switch — commonly used in automatic washing machines and electric ranges are supplied by Plessey Ducon located at Villawood, N.S.W.


This direct reading digital clock is one of a wide range of models supplied by Plessey in Australia. Extremely accurate, the clocks are built for indoor use or weatherproofed and illuminated for outdoors.



Some of the wide range of multi-circuit connectors marketed by Plessey Ducon, all of which are reliability and quality proven.



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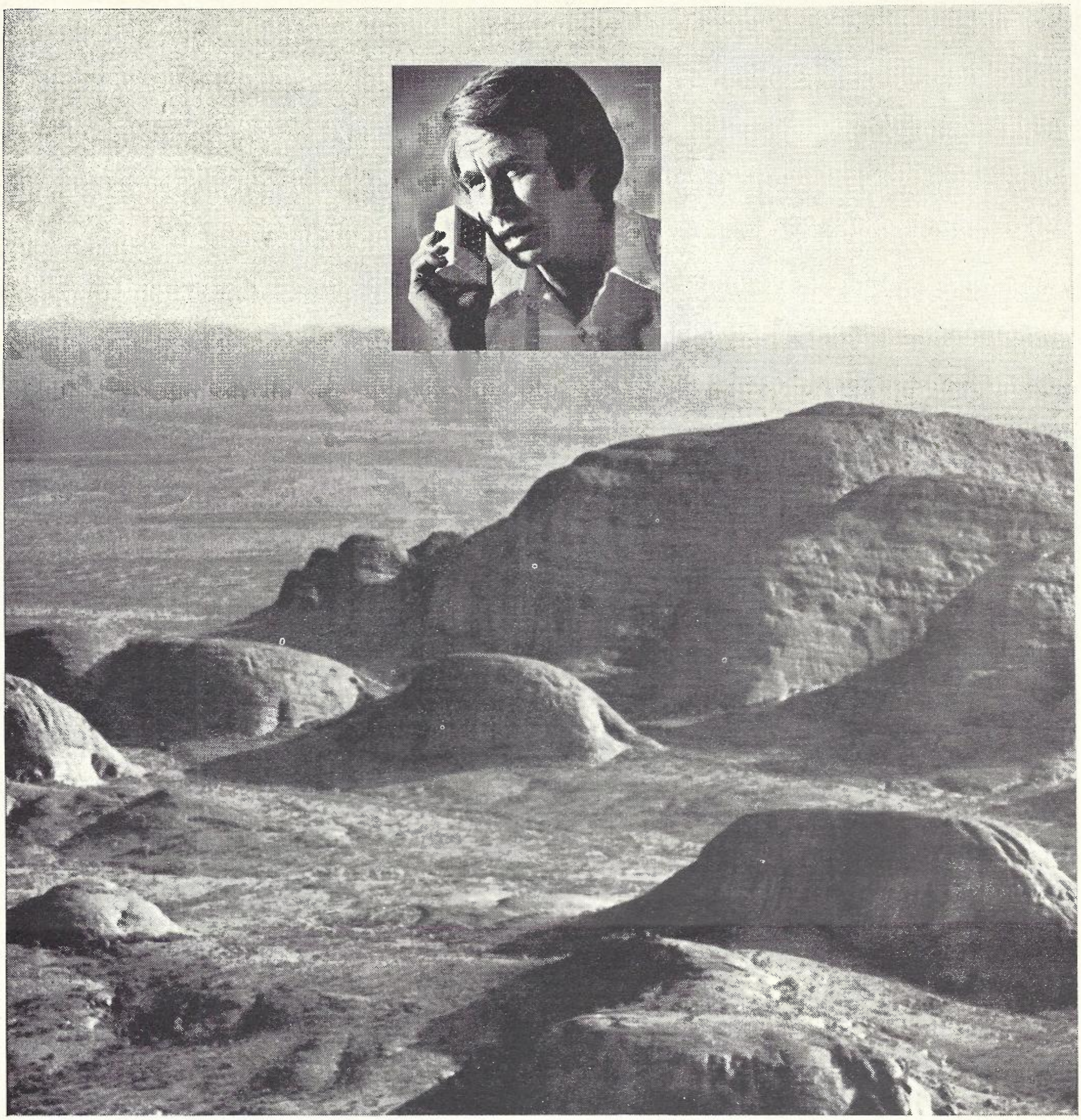

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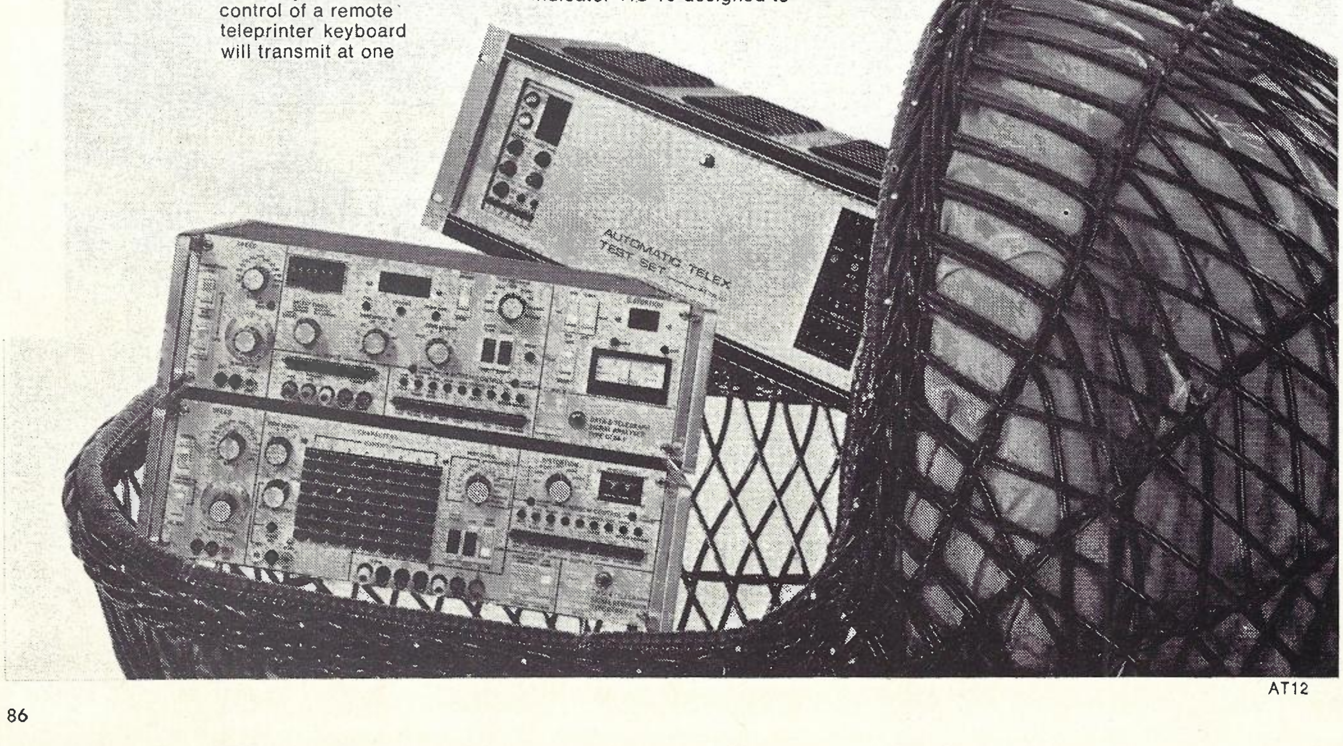


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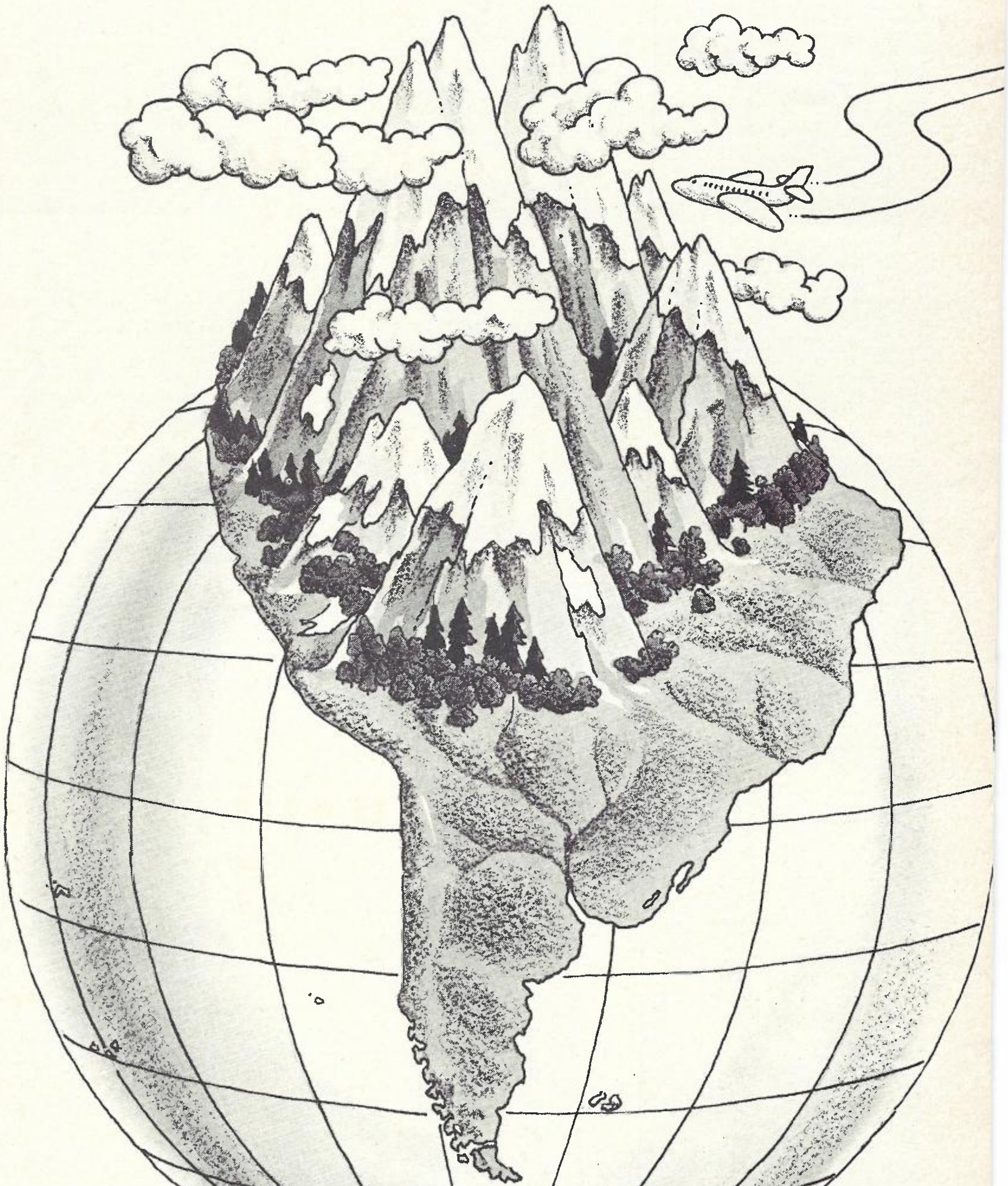

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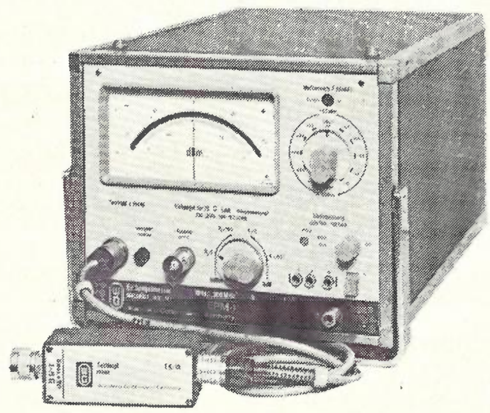

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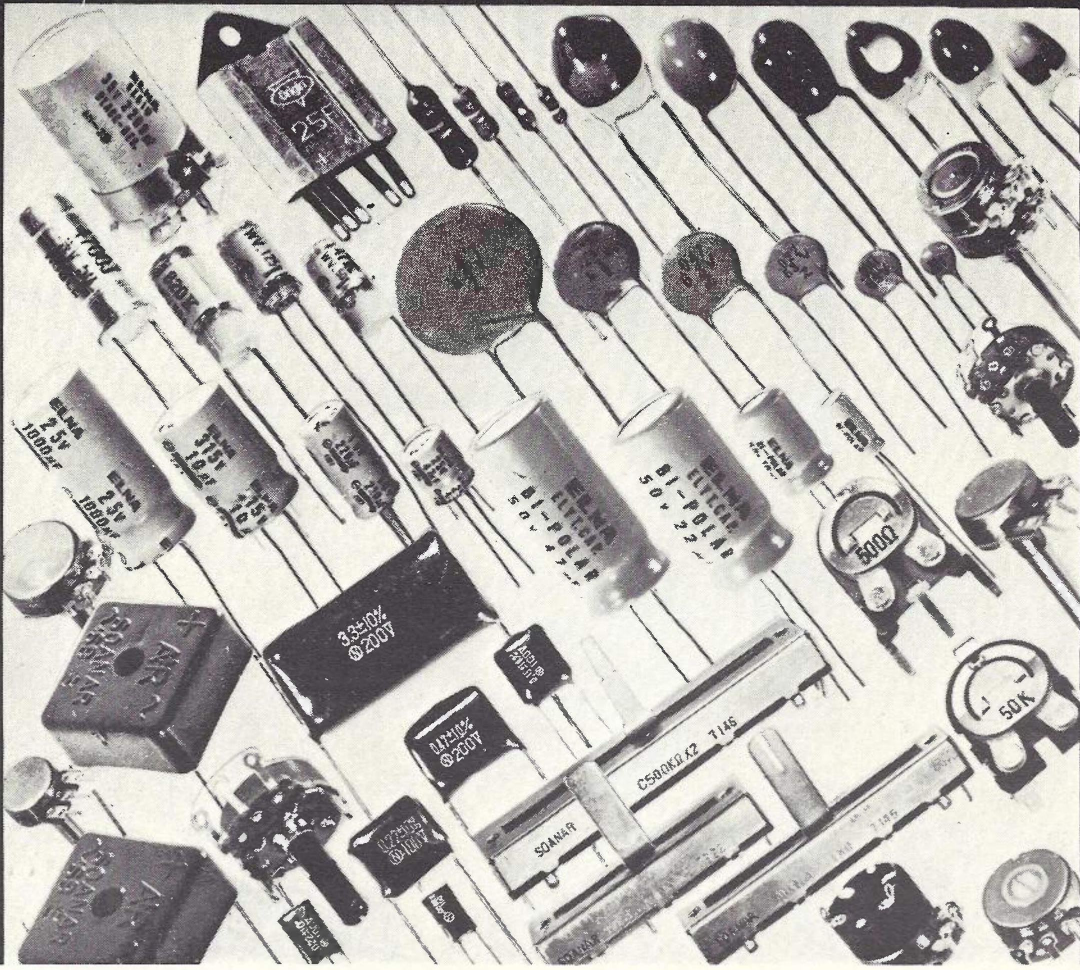


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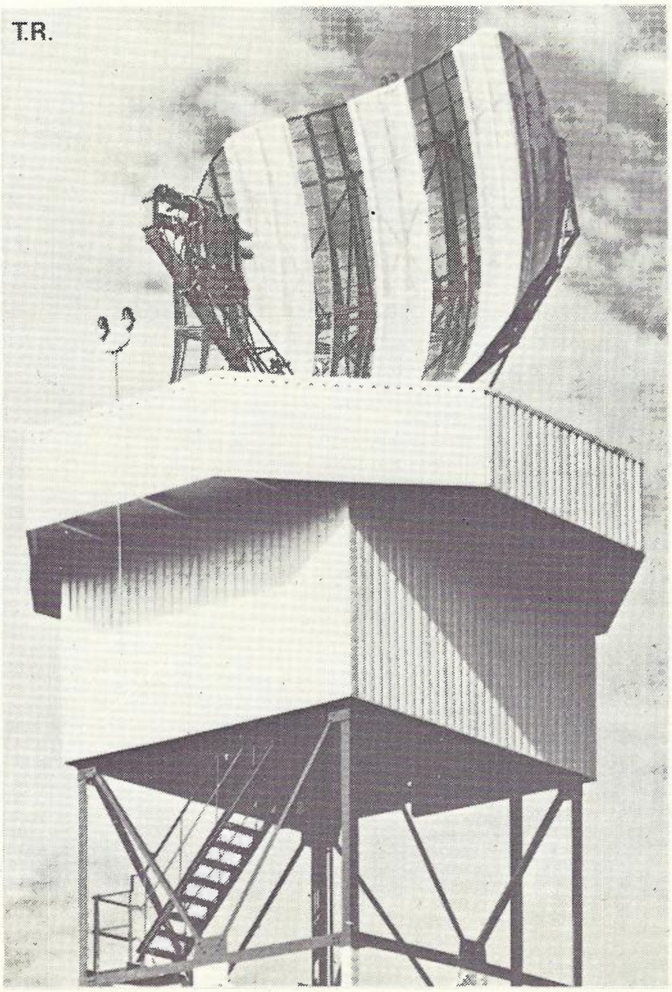


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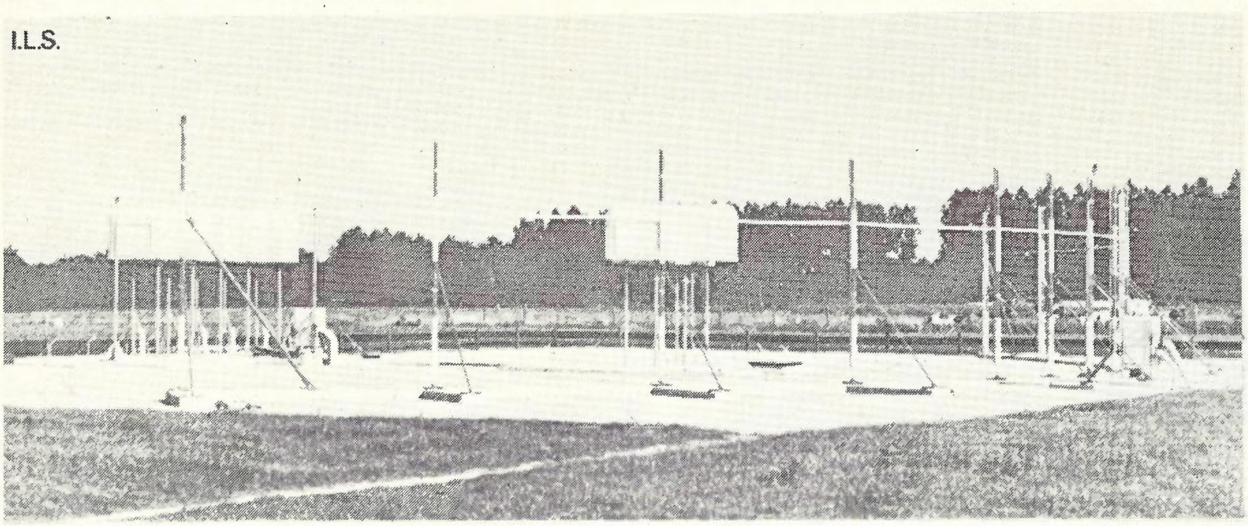


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# The Telecommunication Journal of Australia

## ABSTRACTS: Vol. 24, No. 1.

**CARROLL, B. J.: 'An Improved Fault Recording Register for ARF Exchanges'; Telecomm. Journal of Aust., Vol. 24, No. 1, 1974, page 54.**

This paper briefly outlines the role and facilities of an improved Fault Recording Register being developed for use in ARF Crossbar Exchanges. This development, which will include facilities for network supervision, is being designed to interwork with the Automatic Disturbance Recording (ADR) equipment to provide continuous details of faults detected, at the local exchange or a remote control station. Moreover, it is proposed that the Network Performance Analysis Centre use this new RKR to assess performance or to assist in the determination of fault patterns.

**GOOD, G. W. G., and LEWIS, J.A.: 'History and Principles of the International (SI) System of Units'; Telecomm. Journal of Aust., Vol. 24, No. 1, 1974, page 58.**

In 1973 the APO converted to the use of the SI system of units in its activities. This article outlines some of the history of systems of units of weights and measures and then the history and development of metric systems. This is followed by a discussion of the SI system which is becoming the standard system of units for physical measurement throughout the world.

**JACOBAEUS, C.: 'Trends in the Development of Communications'; Telecomm. Journal of Aust., Vol. 24, No. 1, 1974, page 3.**

This article is an address delivered by the author at the 'Swedish Technical Week' held in Brazil, in May 1973. It surveys trends in telecommunications technology and deals with basic components such as resistors, filters and relays, and the main items comprising telecommunication networks, i.e., telephone instruments, external plant, exchange switching plant and transmission equipment.

**KIMBER, M. J.: 'The Darwin - Mt. Isa Radio Relay System'; Telecomm. Journal of Aust., Vol. 24, No. 1, 1974, page 44.**

Australia's expanding needs for communication services and its large areas of sparsely populated land make it necessary for the Australian Post Office to use special techniques in the design and implementation of the broadband bearer network. The Darwin - Mt. Isa microwave system spans 1600km of inhospitable terrain to provide advanced telecommunication services to remote parts of Australia. The special techniques used to ensure reliable unattended operation of such a long system are described in this paper.

**KITCHEN, H. G.: 'The First Australian Faraday Lecture'; Telecomm. Journal of Aust., Vol. 24, No. 1, 1974, page 66.**

In 1971 the Institution of Radio and Electronic Engineers, Australia, with the concurrence of the Institute of Electrical Engineers, decided to sponsor an Australian Faraday Lecture, and invited the APO to present the inaugural lecture in 1972. The IREE suggested that the theme might be allied in some way with the centenary of the Overland Telegraph.

This paper is an outline of how the first Australian Faraday Lecture was planned and mounted in cities throughout Australia. The author was responsible for the co-ordination of these activities.

**PERTZEL, R., and GREEN, C.: 'A New Pulse Measuring Set'; Telecomm. Journal of Aust., Vol. 24, No. 1, 1974, page 31.**

A new Pulse Measuring Set AKOO1 has been introduced to replace the Ratio Test Set No. 30. The new Test Set features solid state construction, small size and weight, high stability, and a digital readout.

**MONTGOMERY, A., and HAMMOND, B.G.: 'A Communications System for the Moomba Natural Gas Pipeline (Part 2);' Telecomm. Journal of Aust., Vol. 24, No. 1, 1974, page 12.**

Part 1 of this article, which appeared in a previous issue of the Journal, described the development of a communication system for a natural gas pipeline in South Australia. It included a description of the external plant used. This present Part 2 describes the internal plant such as mobile radio, supervisory system, power plant, and various installation aspects.

**TYRRELL, L. A.: 'Development and Application of Telephone Traffic Measuring Equipment (Part 2)'; Telecomm. Journal of Aust., Vol. 24, No. 1, 1974, page 36.**

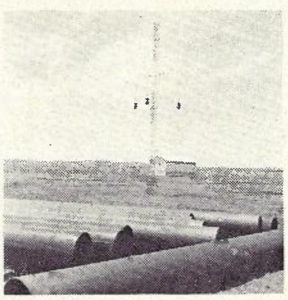
This is the second of two articles about traffic data and equipment for gathering it. Part 1 described the data requirements for planning and supervision of the telephonic network. Part 2 describes how the data to be acquired are available in a number of different forms from a variety of devices in the switching path of the telephone exchange. The philosophy of the system design and the operation of the equipment are explained. Several devices within the system are described in some detail.

# THE TELECOMMUNICATION JOURNAL OF AUSTRALIA

VOL. 24. No. 1. 1974


## CONTENTS





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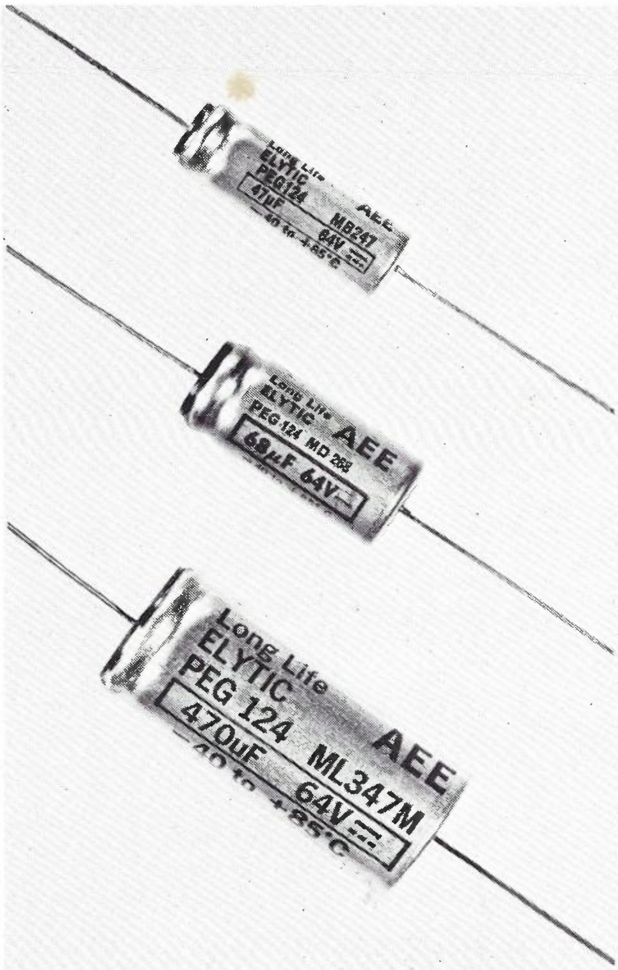


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