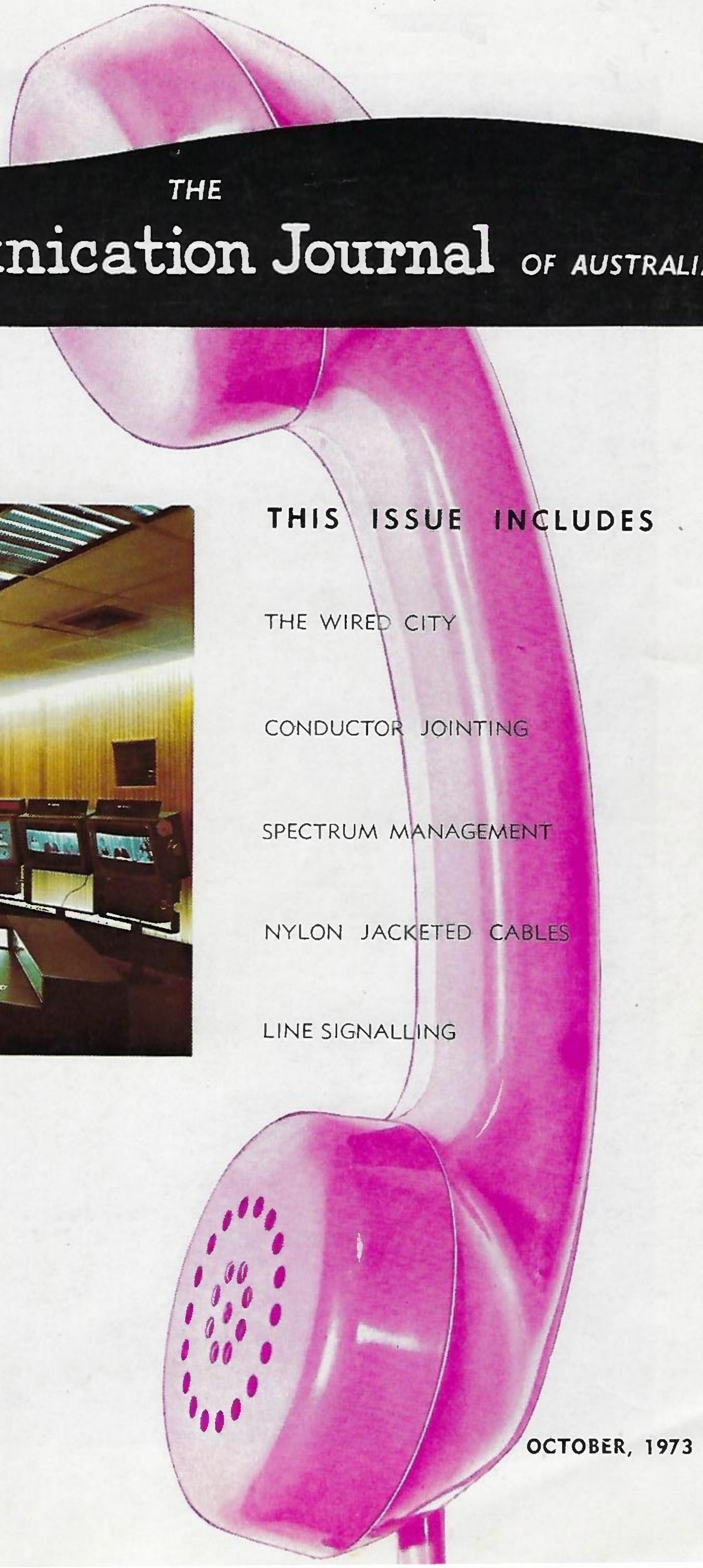
THE

# Telecommunication Journal OF AUSTRALIA



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CONDUCTOR JOINTING

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Vol. 23, No. 3

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# THE TELECOMMUNICATION JOURNAL OF AUSTRALIA

VOL. 23, No. 3, OCTOBER 1973

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FACILITY

# The Telecommunication Journal of Australia

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# The Wired City

A. KELLOCK, B.Sc., D.P.A., F.I.E. Aust.

*The Australian Post Office has just commenced a complex operation to plan the course of telecommunications in Australia beyond the year 2000 A.D. This article indicates the national significance of the undertaking and the complexities of the issues involved. The potential facilities which may be offered to subscribers are outlined, some of which call for a network of markedly different capabilities to the existing telephone networks. There are conceptual attractions in providing all facilities in a single wideband distribution network but there are also offsetting difficulties which must be examined. Even if a single distribution network is adopted there may well be several switching networks.*

*Facilities of the type envisaged will have far reaching impacts on major facets of society such as town planning, transport patterns, education, structure of the economy and behaviour patterns. The telecommunications planner is entering new and little-chartered fields which will call for close relationships with other professional disciplines and extensive consultation with relevant groups in society.*

**Editorial Note: This paper was presented as the opening paper at the UNESCO Seminar on the "Communication Revolution" held in Melbourne on 20-24 August, 1973.**

## THE EMERGENCE OF AN INFORMATION-BASED SOCIETY

A rapidly growing world literature testifies to the fact that we are passing through a technological revolution which will transform society as radically as did the industrial revolution. This post-industrial revolution is characterised by the emergence of "knowledge" industries and an information-based society. Emphasis is moving from the production and distribution of material goods towards the assembly and distribution of information.

As long as 10 years ago "Fortune" magazine estimated that one third of the total U.S. Gross National Product was accounted for by the information industry and if it has not already reached 50% of G.N.P., most estimates push it past that point by 1980. It has been predicted that during the 1980's the needs of the information industry alone will surpass the economic impact produced by the automobile and television industries combined during the past decade.

The technology of the post-industrial revolution is that of computers and communications. Communications have increasingly used the electromagnetic media of telecommunications and this trend will accelerate. The role of telecommunications gains even more significance from "the converging trend of the technologies of communications and computers, which is making it increasingly difficult to distinguish between the interactive services of data processing and transmission." (Ref. 1).

In many computer systems already in operation it is difficult to separate the communications and data processing functions; on the other hand, many communications systems use computers to switch either circuits or messages. In the long-term, technological advances are likely to completely blur the interface between the computer and the communications system giving rise to a new concept of teleprocessing.

Let me illustrate in more specific terms the symbiotic relationship between computers and telecommunications. Computers now exist which can store vast amounts of information in what are often referred to as "data-banks." These stores can be searched on request from a suitable terminal for particular pieces of information which can either be printed out at the terminal, or displayed visually on a screen or even spoken by a synthetic voice. Computers can also process information, passed in to them from the terminal, in accordance with predetermined programmes and either store the results or convey them to the originating or other terminals for hard-copy, visual or audio display.

Business applications of these facilities are well established, but they could be employed for domestic purposes such as providing information on a variety of items (for example skiing weather and sports results, making hotel and travel reservations, working out personal income tax). Libraries of books, informative articles, art works or films could be scanned for particular subjects or titles and conceivably the particular work could be displayed visually or alternatively (in the case of books and articles) printed out in facsimile.

The wide extension of these information retrieval facilities to offices, homes, libraries and educational institutions, remote from the computer, calls for a vast network of linking telecommunications. Already in the case of business operations the telephone network is being increasingly employed for transmission of data at limited speeds to and from computers. The full exploitation of computer/communication potentialities and their logical association with other forms of communications suggests the need for a new type of network, the joint impact of which on the major facets of society is likely to be fundamental. It is this concept to which the title of the paper alludes and which should now be examined in more detail.

**THE WIRED CITY**

As suggested by the examples given earlier, techniques are either available or close at hand which would allow a notable proliferation of the types of telecommunications services to be provided to customers through a single distribution medium (such as a cable) in either visual, hard-copy or audio form.

The possibilities are almost limitless but the following picture is representative of many visualisations:

> "(A subscriber's) home terminal might include some combination of a T.V. set, with or without single frame (alpha-numeric or video) hold and refresh, a high-speed printer and/or computer-driven electric teletype or electric typewriter, a telephone, video tape recorder or cassette, and a facsimile receiver. Innovative combinations of these home terminal devices coupled with appropriate head-end (e.g. a computer) will provide a spectrum of user services limited by the system designer's imagination and the cost of providing these services". (Ref. 2).

Some of these types of services would require a distribution facility with frequency bandwidth capacity beyond that provided by subscribers' pair cable distribution systems established by telephone administrations today.

An existing technique which is suitable for wide bandwidth transmission is coaxial cable. Technical development will undoubtedly offer better and cheaper systems and optical fibre cables are currently a promising contender. Waveguides are a further possibility. It is likely however that any wideband distribution network will be more expensive than a telephone type network.

Since the predominant cost of a telecommunications system lies in the distribution network, the replacement of the existing cable network by a wideband cable network would be a formidable resource undertaking. For the same reason, there are strong economic disincentives to the provision of more than one wideband network in any city.

Once a wideband distribution network has been established it enables a range of facilities to be offered to the public. Linking the network to a computer complex will significantly extend the range. The possibilities are extensive but most forecasts can be confined within the following framework:

- Local, relay, recorded and original TV (capacity for many channels)
- Recorded visual information
- Wideband data channels
- Facsimile services
- Standard telecommunications services (including videophone)

The facilities could be put to diverse uses among which have been suggested:

- Ordering merchandise or services, displayed through video channels, by using push-buttons on the telephone as a data source;
- Facsimile production of news or information material in the home;
- Distribution of mail by facsimile reproduction;
- Viewer participation in public preference polling with optional means for protecting the identity of the responder;
- Provision of warnings of fire, medical or intrusion emergencies in the home to central points;
- Provision of educational channels with student response capacity;
- Provision of statistical data relating to TV viewing preference;
- Provision of turn-on service in home for lights, heat, warning systems, etc.;
- Reading service direct into public utility computer for electricity, gas and water meters;
- Provision of restricted TV channels available only to authorised groups e.g. doctors, lawyers or public administrators;
- Provision of additional TV channels for cultural, educational, ethnically-oriented and religious programmes as well as entertainment;
- Provision of TV channels on a lease or free basis for use in programming by independent persons or agencies. (Public Access Channels).

These are only examples and a Stanford Research

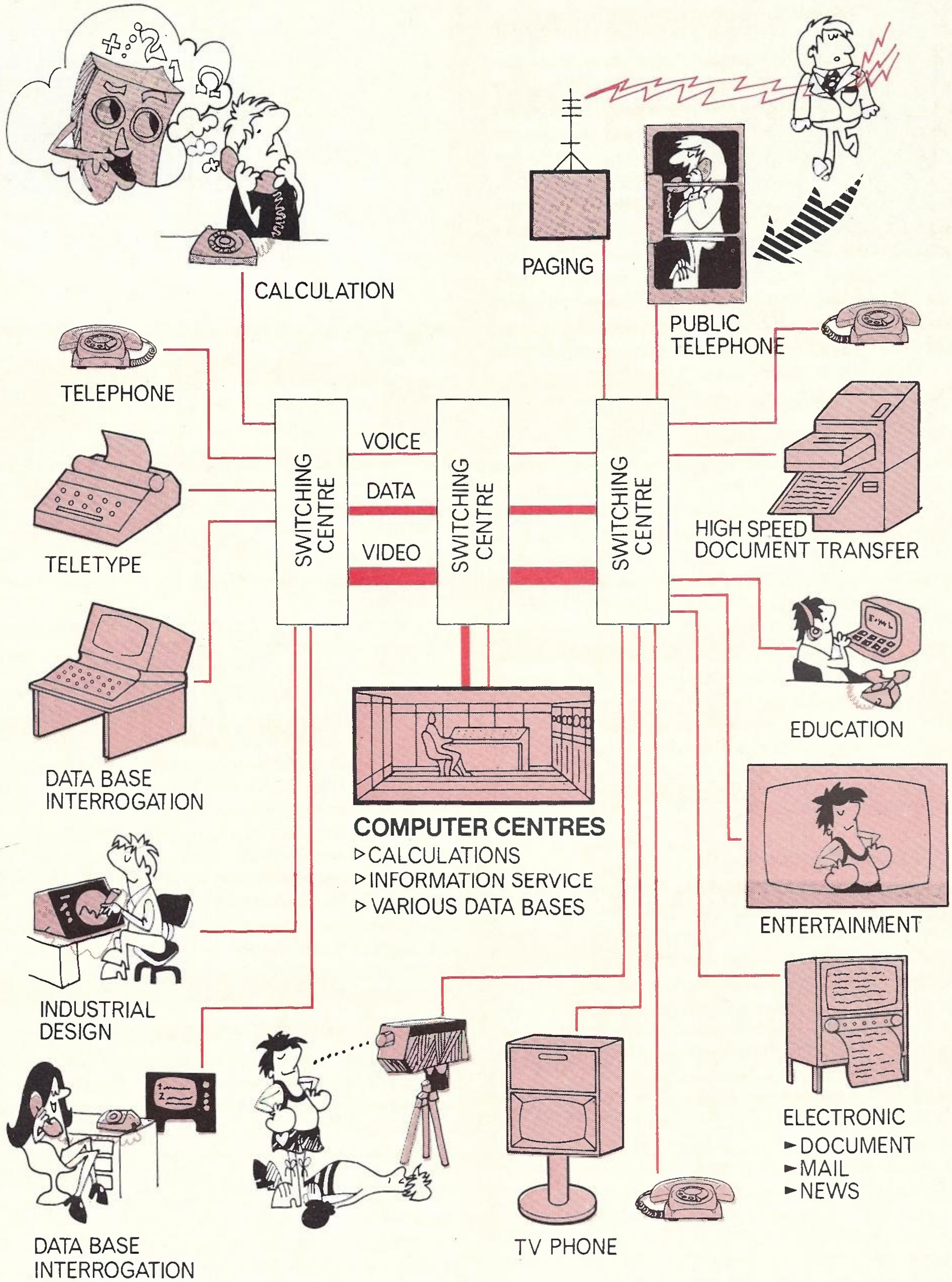


Fig. 1—Types of Information Facilities of the Future.

study has listed approximately 100 uses for the type of system described.

The particular services which do eventuate will depend largely on the needs of customers as measured against the cost of each service.

The general concept of access to an almost limitless range of information services in every home or office is generally referred to as "the wired city". It raises the possibility of the **home office** with a complete flow of data, aided by printouts, facsimile reproduction or visual display, for personnel in industries where this can remove the need for group offices at a central location. If every home and institution is connected to the information grid, the facsimile service may in addition provide a more rapid and economic alternative to much of the problems of mail distribution.

## THE SIGNIFICANCE OF CATV

In view of the uncertainty which veils the future demand for such services and the large-scale resources required to duplicate existing networks by wide-band distribution, it may be asked why we have to worry about it before specific demands emerge. Apart from certain social aspects, referred to later, there are two reasons why telecommunications operating administrations can not allow the situation to drift:

(i) The circular problem of requiring a network before the services can be offered to test demand, and

(ii) the need for the continuous development of existing networks to be focussed on a picture of their long-term nature.

Even more urgently, however, there is a current development which is forcing telephone administrations and Governments around the world to face up to decisions on the long-term probabilities of telecommunications services. This is the demand for Community Antenna Television (CATV) service now better known as Cable TV.

CATV was originally developed to distribute television signals to areas of inadequate "off-air" reception. Signals were picked up at a suitable reception point and distributed to buildings by an amplified cable distribution network over or under the public thoroughfares. Unlike telephone systems, CATV systems did not call for the establishment of city-wide networks and small localised systems were established one at a time, as justified by economics and reception characteristics. They developed with great rapidity in U.S.A., Canada and Great Britain in particular. From nothing in 1949, they have grown in the U.S.A. by 1972, to more than 2500 systems and 5.5 million subscribers.

As they developed, the CATV companies added programmes relayed from distant centres as well as programmes and other special services which they originated by insertion at the cable-head. Most systems built since 1970 have the capacity for 20 or more TV channels.

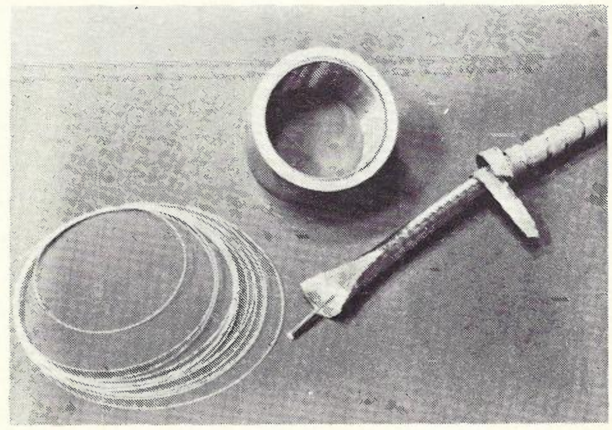

**Fig. 2 — Some Alternative Wideband Distribution Media:**
**Left — Optical fibre (single tube)**
**Centre — Waveguide (section)**
**Right — Coaxial cable (single tube)**

In most cases the enterprise is only rendered economically attractive for the CATV operators by expansion of their networks into areas where there is adequate direct TV reception and by the addition of services other than "off-air" television. The growth of the CATV networks results in the steady accretion of the basis for the distribution of broadband services.

The form which these cable television networks initially adopt however is likely to predetermine the type and distribution of facilities which can later be employed including non-CATV facilities. For this purpose, a close examination of the probable future of telecommunications services is required on a national basis before entering a large-scale programme of cable television, since it is becoming increasingly likely that cable television development represents the path into the "wired city".

## DEMAND ON THE RADIO FREQUENCY SPECTRUM

The probable extent of wideband service distribution in the cities and towns of Australia will largely be a function of costs and estimated benefits to customers. There is however an additional factor, not previously mentioned, which may accelerate its development at least in the major cities.

One of the national resources, which is under greatest pressure to meet practical demand is the radio-frequency spectrum. The spectrum is particularly inadequate to meet rapidly rising demands in the bands which are suitable for the transmission of TV programmes. Each TV channel is a relatively greedy consumer of spectrum bandwidth and the possibility has already been raised by the U.S.A. Federal Communications Commission that all TV programmes in U.S. cities may eventually need to be distributed by cable. Spectrum capacity could then be devoted to those services for which it is the only available medium of transmission (mobile telecommunications services to aircraft, ships, cars, etc., remote paging services, direct telephony and TV from satellites, navigation aids, emergency services, space communications and defence applications).

Mobile telephone service demand has already been significantly suppressed by spectrum inadequacy and it is in this area of demand that the most rapid growth is foreseen in near term if frequencies were available. In the longer term a variety of new types of mobile service can be expected, some of which may be essential for innovative solutions to major problem areas of developed countries. The Canadians for example contemplate limited operation of the "electronic road" by 1990; this describes a system of navigation aids on motorways providing fully automatic driving and navigation.

The cost penalty for undergrounding all TV transmissions is significant if considered in isolation. The extent to which it may be necessary in Australia must hinge on a careful examination of the probable future requirements for critical segments of the spectrum by services which must use radio to be effective. The degree of mutual support between the results of this study and forecasts of the long-term future course of telecommunications in Australia would tend to determine the nature and timing of the services projected.

## NETWORK PROBLEMS

There are certain network problems which arise from aggregating all information services described into one distribution network. The appropriate topography and form of a distribution network depends on the types of services which it carries. There is a marked difference between the optimum structure called up by some of the services which have been discussed. For example switched terminal-to-terminal (person-to-person, machine-to-machine, etc.) services such as telephone, videophone, telex or telemail differ from distributive services, such as CATV, news facsimile and information services, in being bi-directional whereas the distributive services may well be unidirectional. A further difference arises from the probability that the distributive service network may have nodal points (for example the TV programme source or the CATV cable-head) which focus the network on a different point from that of the exchange switching point. Moreover the same channel of information must be capable of being tapped simultaneously at each outlet for distributive services whereas terminal-to-terminal channels will normally be individual for any one connection.

Network compromises must therefore be made in the light of the services which seem likely to be required during the lifetime of the network. Even if a single distribution network is adopted, there could be a number of switching networks.

## IMPACT OF THE WIRED CITY

The impact of the type of telecommunications network envisaged could resonate far beyond the traditional patterns we have come to associate with telephone services. The distribution to all homes and institutions of information of many types, in many forms, aided by the powerful combination of computers and wideband communications, is expected to have a profound effect on the structure of urban development, patterns of transport, the scope and form of education and the development of the economy.

It is apparent that telecommunications are capable of substituting to some extent for physical transport and this will become more important as the scope of communication services widens and the difficulties of urban transportation rise. More significantly, these patterns of transport will change as people and industries (particularly "knowledge" industries) are freed by the availability of electronic information to determine their home and office location by other requirements than face-to-face interchange of information. If the "home office" does in fact become widespread, there would be significant modifications to the radial transport patterns of a large city.

The implications of the "wired city" or similar concepts run to other aspects of town planning, generally freeing it from the rigidity of many present constraints. For instance, the U.S. Academy of Engineering envisages that a city may become an assembly of neighbourhoods. There is however, a communications cost to offset against these advantages and, as with the change in transport patterns, it is a matter for study and assessment of where the balance lies under various approaches. The particular approaches selected for urban development will in turn strongly influence the network required.

Cheaper and more diverse telecommunications also offer a powerful aid to decentralisation, although it should not be overlooked that there are centralisation aspects implicit also. For example, diversity of electronic information and entertainment services in major urban complexes would tend to act as magnets to the rural population.

The relationship of the wired city to education stems from the vast amounts of knowledge which can be stored and produced for a student at a time and place of his own choosing and in accord with his ability to absorb. The detailed structure of that relationship is not so evident however. Three applications of computer technology seem promising: interactive instructional television, interactive community information retrieval and computer assisted instruction. The distinctive feature of interactive instructional television is that it is two-way allowing for student interaction, whereas the instructional television offered around the world has so far generally been one-way. The nature of the interaction remains to be determined; economic considerations may restrict the response to a keyboard type of communication. Although applied research has been commenced both here and overseas into the areas where the systems will be used, more work is needed to identify the true needs of their intended users. This task may be complicated by a wide spectrum of environmental and sociological conditions; cost is critical however and researchers should not forget that bandwidth is still likely to cost money in the foreseeable future so that television bandwidths would not generally be used if data bandwidths on voice channels would be adequate.

Easy access to TV channels by any members of the community to provide community information and interaction as well as entertainment has already been shown to have considerable appeal in some restricted experiments. Some proponents of community access television see it is an important factor in containing the growing isolation of individuals and the depersonalisation of human contacts, to which in other ways the "wired city" may well contribute.

The "wired city" would also have its impact on more tangible facets of society. The resources of the economy will constitute a constraint on the allocations which can be made to telecommunications but the relationship is a dynamic one. The industrial revolution supplemented and often replaced muscle-power; the computer/communications revolution supplements and extends brainpower and the information on which it feeds. The reach of the economy will respond to the degree of investment and consequent power in an information network.

## SOCIAL QUESTIONS

There has been general recognition of the radical changes to man's methods of living and even thinking which have flowed from the dissemination of the key technologies of the phonetic alphabet, the printing press, the telegraph, radio and television. The "wired city" promises to be such a key event with its implications for good and, unless adequate consideration is given in advance, for ill.

It is related to the other technologies mentioned, in increasing by an order of magnitude the amount of information disseminated—information that singular, non-depletive resource which is not lessened but gains by use. The prospect of a further escalation in information output provokes a strong reaction in those who believe that the individual could suffer from an "information overload". The corollary problem from a communicator's point of view is that the increase in the volume of information being made available might actually result in less effective information reaching the public.

The question in the future, as Professor Colin Cherry of the United Kingdom has said, will be the organisation of information not its quantity. To limit information would be to limit choice and therefore to restrict the very freedom and promise of genuinely democratic informed participation which the new technology promises. The individual is going to have to exercise greater selectivity as to the information he seeks and accepts. He will place a premium on ease and speed of access and it is in these areas that telecommunications have particular power.

Nevertheless communications operators are conscious of their responsibilities in this domain. As the communications planners move from reacting to the needs of society towards activities which may affect its behaviour patterns, certain aspects of the nature, volume and availability of information which is likely to be transmitted or stored raise new or intensified problems.

The Canadian Telecommission study emphasised "the right to communicate" as a socio-political right which belongs to every individual. This connotes the right of access of all individuals to the information system. Existing disparities in access (e.g. in television reception, S.T.D. access) will be even less desirable in a society which depends on a wide range of information services.

The counterpart to the "right to communicate" is however increasingly being referred to as "the invasion of privacy". Computerised databanks and information systems intensify by several orders of magnitude the possibility of gathering, consolidating and using information about people. Safeguards and remedies fall into three complementary categories: statutory, administrative and mechanical or electronic. Since the right of privacy should be tempered by recognition of the need for freedom of access to information, security standards for databanks should be directly related to the nature of the information stored; this may even necessitate uneconomic segregation of databank types.

As I have indicated, we are also conscious of the dangers of depersonalisation. The "wired city" should be configured so that the information flow supplements and enriches human contact and does not replace it.

## PLANNING FOR THE FUTURE

The materialisation of the "wired city" can not be taken as inevitable. The choices still lie before society as to the extent to which it will build the city and the nature of its structure and safeguards. Ultimately the individual as well, will express the valuation he places on the facilities offered by indicating whether he is willing to use them. There may not only be social qualifications but also economic constraints since the new network will probably cost more than the existing network and must be paid for, if not by the individual user then by the community in terms of diversion of resources from other national programmes. The additional cost of the wider range of information facilities must however be measured against the much greater national resources which will be available at the period when the "wired city" is attainable.

For the full concept, if it is to be achieved, will not be capable of realisation in the short term. The inertia of an existing distribution network is so massive that growth by additions of systems with greater capability (which can not be used effectively through limitations in the remainder of the network) has little effect for many years. The temptation is to grow by addition of systems similar to those existing, unless there is a fairly clear picture of the ultimate goal.

Even then it is international experience that it takes some 25-30 years to substantially transform the nature of a communications network. Difficult though it is to look forward for 25 years with a significant degree of certainty, we must make the attempt to discern the range of possibilities. Elaborating the "picture" will enable the network to be developed in a manner which does not foreclose possibilities which emerge as desirable or even essential in a future environment. For instance extension of our existing paired cable network of subscribers' distribution is likely to preclude establishment of a number of the wideband services discussed, when the demand for them appears. Given a planned development towards the objective, elements of the information facilities described may be expected to appear in near-term, particularly those which can be encompassed by the slow-speed capabilities of the telephone network.

The Post Office has embarked on a complex operation to encompass this long-term planning objective and the process is likely to take some years. During its course, questions of national policy are expected to arise which must be determined by Government. Enough has been said to indicate that social and political aspects may well condition solutions reached on economic and technical grounds.

There is a clear necessity for the planners of a national information system to determine the real needs and concerns of the users and society at large, not as an afterthought but as an integral part of planning and building the system. For this reason we will be embarking on a large-scale, continuing process of dialogue and interaction with all the relevant institutions and interest groups in the Australian society. This seminar and the associated seminar held last week to celebrate the Golden Jubilee of the Post Office Research Laboratories represents the initiation of that process. We shall therefore be more than casually interested in your proceedings and in your reactions to concepts such as the "wired city".

### REFERENCES

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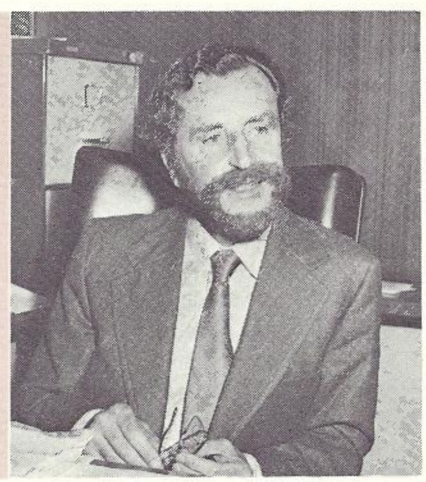
2. 'Communication Technology for Urban Improvement'; National Academy of Engineering Committee on Telecommunications, Washington, 1971, p. 203.

A. KELLOCK joined the Australian Post Office in 1941 and since completing an Engineering Cadetship has had experience in a variety of telecommunication fields in the Victorian State Administration and in Headquarters. He was seconded as General Secretary of the Professional Officers' Association in 1956-59 and was A.P.O. Liaison Engineer in London in 1959-63.

Since returning from a period of full-time study at the University of Melbourne to complete the Degree of Master of Business Administration, during which he received the Clemenger Award for best final year student in 1972, he has been engaged on special duties. These entailed preparation of a report on the issues involved in preparing a new National Telecommunications Plan and on the methodology and organisation by which this could be achieved. For further biographical data see the October 1970 issue of this journal.



# Connector Jointing of Telephone Cables.

N. W. PETERS, A.R.M.I.T.

*A review of the development of pressure crimped wire connectors for jointing telephone cable conductors is provided. Details of the types of connectors which are presently available and their application to, and compatibility with, the range of cable conductors in use in the Australian Post Office are discussed.*

*The cable joining machines and hand tools which serve to crimp the connectors are described, together with the methods to provide for quality assurance of field joints made with the systems to be adopted by the A.P.O. A brief look at future developments in the connector jointing area is included.*

## INTRODUCTION

The opportunity exists for providing a greater degree of uniformity and a higher average level of joint quality if manual methods of jointing telephone cables are replaced by machine crimped connector systems. This results from the lesser dependance of these systems on the skill of individual jointers.

An improvement in output per jointing man-hour sufficient to offset the additional costs of machines and connectors is achievable with current systems, while some of the tedium associated with the manual jointing of large size cables is removed.

Connector jointing makes available, as an extension of a standard method, a means of jointing aluminium conductors to themselves and to copper conductors, a factor which can be of increasing importance in the future extension of the subscribers and junction networks.

The use of connector jointing, which was first introduced to the field areas of the A.P.O. in 1970 on a trial basis, is currently being extended.

A summary of the general development of crimp connectors for application to telephone cables, plus comments derived from the evaluation and field trials of the presently available connector systems, form the basis of this paper. In addition a brief look at possible future developments in the connector jointing field is included.

## MANUAL TWIST JOINTING

Copper telephone cable conductors have traditionally been joined by hand twisting the bared wires together. A crank twist technique is used to provide a gas tight pressure contact between the wires. Several discrete operations are necessary to make each wire joint. These include stripping the insulation, twisting the wires together, trimming the twist to length, bending the twist in line with the conductor, and finally re-insulating with a paper or plastic sleeve.

If the resistance of a hand twist joint is to remain low and stable throughout the life of the cable, the contact pressure must be maintained by stored energy in the twist. While the gauge and temper of the wire and the presence of oxide or other surface films on the contacting surfaces are factors which affect the resistance of the joint (Ref. 1), its stability and reliability in service is largely dependent on the skill of the jointer making the twist.

Although hand twist joints have served us well for more than half a century, they are time consuming to produce, and while only small material costs are involved in their production, they are becoming increasingly costly with continually rising labour charges. Jointing output in pairs per day is dependent on the human elements of skill, dexterity and application to the task and is widely variable.

With a going rate of some 200 pairs per day and with jointing performed on a day shift basis only, some 12 days are required to manually produce a 2,400 pair cable joint. This gives rise to considerable non-productive effort being required to make the part completed joint safe from moisture ingress each night during the jointing period. It follows that additional handling of the unjointed cable units is unavoidable in laying them into the joint area to close the joint, and to subsequently fold them back again to recommence jointing. The probability of loss of twinning and of damage to the ribbon paper insulation is increased. In addition during the protracted jointing operations, the paper insulant may be subject to exposure to moist atmosphere for prolonged periods so degrading the insulation resistance characteristics of the cable, and making drying out techniques necessary before the joint may be closed.

The advantages to be gained from a reduction in the time to make each individual wire joint, as offered by machine jointing systems, are thus not confined to the actual wire jointing operation but such reduction gives rise to side benefits in the overall cable jointing process. Not the least of these is the reduction in time that our field staff must spend in sometimes uncomfortable and congested manholes.

In 1967 soldering or welding of all conductor joints on new work was introduced as general policy in the A.P.O. in order to increase the level of joint reliability having regard to the growing need for junctions and random subscribers circuits to transmit small amplitude signals not containing D.C. wetting potentials, e.g., PCM, data, etc.

Whilst the integrity of a soldered twist, given complete control of soldering conditions and materials, is high (Refs. 2, 3), this is not of course often possible in the field jointing environment. The introduction of soldering also served to reduce the jointing output.

## MECHANISATION OF TWIST JOINTING

From time to time various jointing machines have been designed to mechanise the basic stripping, twisting, cutting, and sleeving operations of the twist joint, with the aim of producing a more uniform quality twist and of reducing the time of its production.

The Miller Cable Splicer, and the Japanese Splicing Gun from N.T.T., were examples. Some success was achieved with these devices, but in order to present the wires to the machine for jointing, generally a form of fold back splicing not entirely satisfactory with our helically lapped ribbon paper insulated conductors was required, or other limitations, as to wire gauge or insulant type acceptable to the machine, pertained. Connector jointing systems then under development, were considered to offer greater potential advantages than the mechanical twist systems available and thus the latter were not introduced for general use in the A.P.O.

## CONNECTOR JOINTING

The concept of jointing cable conductors with pre-insulated metallic connectors applied under pressure to the wires has been exploited in the various systems which are now described. The perhaps understandable reservations of engineers with respect to the long term stability of electrical connections produced by such methods has led to rigorous test requirements being specified by telephone administrations as potential users, and indeed by the connector manufacturers themselves. Refs. 4 and 5, the B.P.O. and A.P.O. Specifications for connectors are typical, and include limits for the permissable initial resistance of joints having regard to the conductor material and gauge. The change in resistance subsequent to thermal cycling and to heat ageing is required to be not greater than specified values. Dielectric strength, insulation resistance, and tensile strength requirements must also be met. Confidence in the principles of connector jointing has now been justified by more than a decade of field experience with connectors of the "B" wire and Scotchlok types in wide scale use in overseas administrations.

## TYPES OF CONNECTORS

It is convenient to separate the present generation of connectors into two main categories, i.e.

- Single Ended "Pigtail" Connectors. Those in which the wires to be jointed enter the connector from one end only.
- Double Ended "In Line" Connectors. Those in which the wires to be jointed enter the connector from its two ends.

Examples of the former include "B" wire, Scotchlok UR and UY types, while the latter include the A-MP Picabond range of connectors, the B.P.O. Connector Wire Jointing No. 4 and the Utilux Type H2561. All of these connectors are single unit connectors which serve to joint two or more wires together in a common connection. A third category of connectors, i.e., multi pair connectors, in which a number of separate two or three wire connections may be made in a single module, are now available. The forerunners of the multi pair connectors were the U1 range of one pair, in line connectors from Minnesota Mining and Manufacturing (3M) Company. This Company now produces the Modular Splicing System ($MS^2$) which caters for 25 pairs per module. Siemens also have developed 10 pair and 20 pair modular connectors.

The mechanisms by which the electrical connections are made in the various connectors can be classified broadly as follows:—

(i) Insulation and wire piercing tangs, which are upset on the metal element are forced through the wire insulation and into the conductor material during the crimping operation (Ref. 6).

(ii) The "Wire in Slot" principle in which the wire complete with its insulation is forced into a slot in the connector element causing the insulation to be sheared and the wire to be deformed and to contact the sides of the slot.

(iii) A tapered metal sleeve and plug, which serve to shear the insulation and trap the wires for jointing between their mating surfaces when the plug is forced into the sleeve (Ref. 7).

## SINGLE ENDED "PIGTAIL" CONNECTORS

### Scotchlok Connectors

In the late 1950's the "Scotchlok" U element connector was introduced in the U.S.A. by the 3M Company.

This connector (Fig. 1) consists of a moulded polycarbonate body containing entry ports at one end which accept the insulated wires to be jointed. The body houses a plastic button containing a small metal element having parallel U shaped slots which are aligned with the entry ports. Insertion of the wires with the subsequent application of pressure to the button, forces the wires into the U slots shearing the wire insulation and contacting and deforming the conductors. The button locks in the body moulding and residual compression forces in the spread slots ensure the connections integrity with time and with temperature variation. A small quantity of silicone grease is incorporated in the connector to provide moisture proofing and to inhibit corrosion. A range of connector sizes is available to accommodate the common copper and aluminium conductor sizes, i.e., Types UY, UR, ULG, UAL. The U element principle is also exploited in pair type in line connectors Types UIB, UIR.

### "B" Wire Connector

A further significant move to replace the wire twist joint by a connector system occurred also in the U.S.A. in 1961 when the "B" wire connector, developed in the Bell System Laboratories and manufactured by the Western Electric Company was introduced for wide scale field use (Ref. 6). The connector is also of the single ended type wherein the wires to be jointed enter from the one open end of the device.

The connector consists of three parts, an inner, tin plated phosphor bronze element having inward pointing tangs serves to pierce the conductor insulation and make electrical contact with the wires when the connector is crimped. An outer soft brass shell envelopes the inner part and serves to prevent relaxation of the contact pressure. An insulating tubular part protects and insulates the connection.

The "B" wire connector in the United States reached a peak usage of about a billion connectors per annum (Ref. 8) and a European version in which the outer insulating part is of moulded P.V.C., and containing a quantity of petroleum jelly for moisture proofing has been adopted by the British Post Office as Connector Wire Jointing No. 1A (Fig. 2).

Both Scotchlok and B wire connectors eliminate stripping, twisting and soldering and are suitable for application to cable conductors insulated with pulp paper, longitudinally applied and adhesively

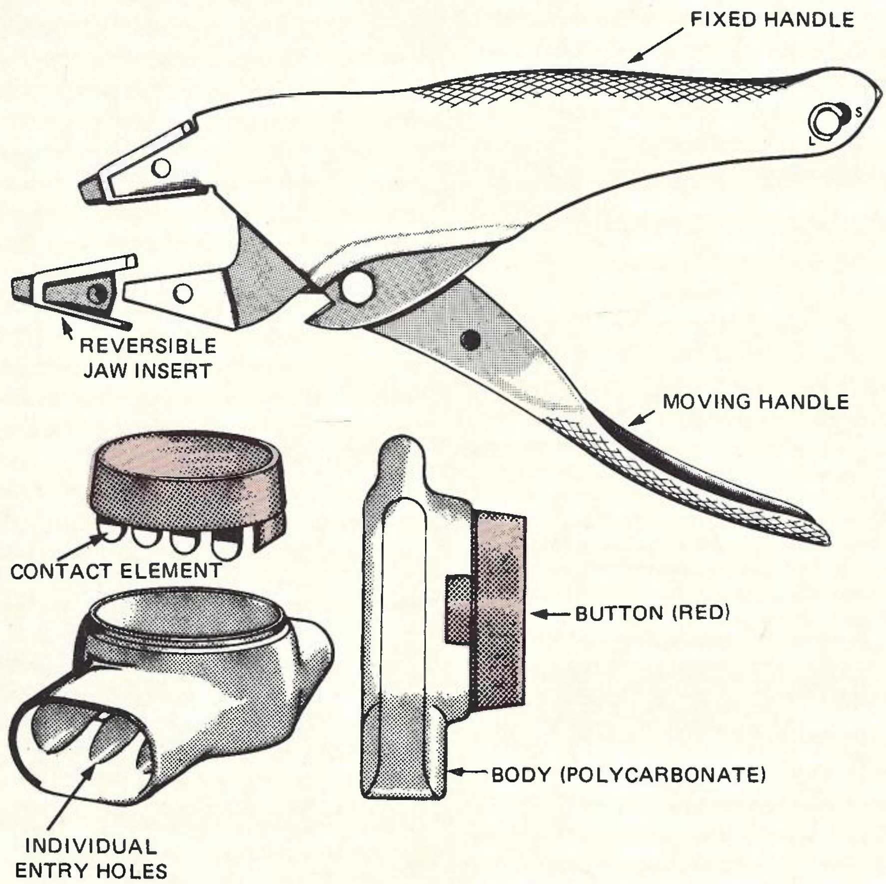



**Fig. 1—"Scotchlok" Type UR Connector and Hand Tool.**

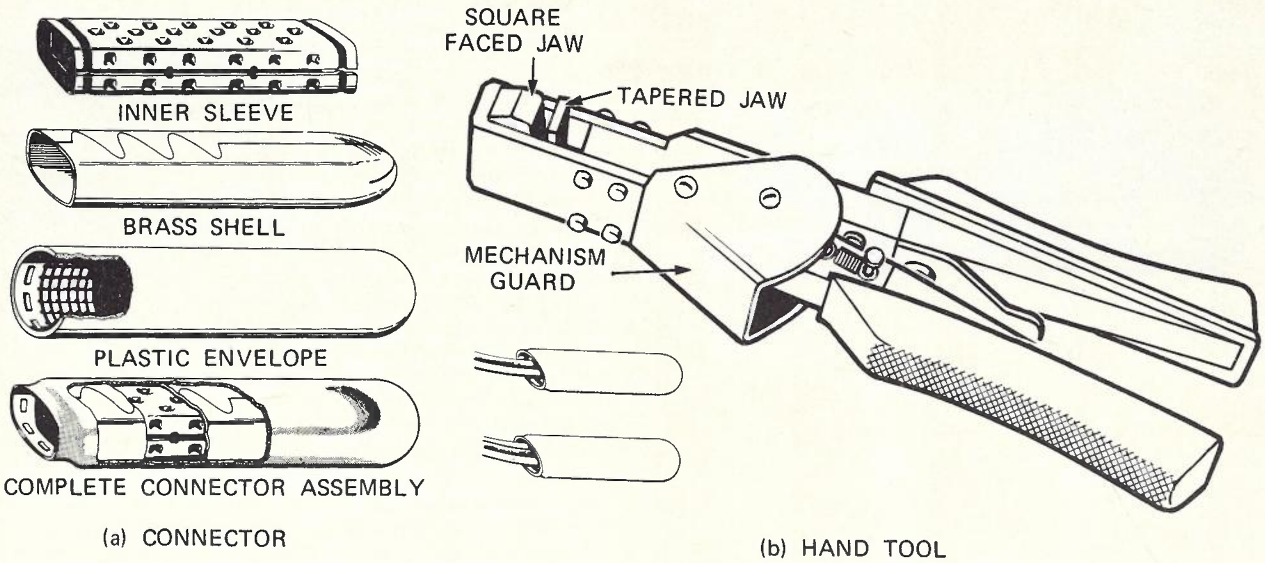



**Fig. 2—"B" Wire Connector and Hand Tool.**

fixed ribbon paper insulation or with plastic insulants. They are not however suited to the helically lapped ribbon paper insulation currently used in A.P.O. large cables and which has the tendency to unravel on insertion into these connectors. Attempts to "fix" the paper with plastic sprays, etc., have not produced an entirely acceptable method.

Both connector systems were introduced utilising hand tools to provide the crimping pressure, and these remain the preferred tool where low pair count jointing as in distribution cables is required. In addition pneumatically operated hand held tools capable of crimping either single connectors or two connectors per operation are available.

The "B" wire connector has found wide application for large size cable jointing in telephone administrations where pulp, longitudinal paper, and plastic cable insulents predominate. Tooling to facilitate the efficient application of large numbers of these connectors has been developed. Examples include the R-B Connector Presser and the Pair-a-matic machines. The connectors for machine application being supplied either in cassettes or on tape.

In order to crimp single ended connectors by machine, when jointing large size cables, a fold back or slack splicing technique is employed to permit the wires to reach the machine. While this technique permits two operators to work on a single joint, it introduces some additional capacitive coupling between circuits and there is a size penalty with respect to the joint closure required. These factors coupled with the relative incompatibility of the single ended connectors with our ribbon paper insulation provided little incentive to exploit these connectors in the A.P.O. subscribers main cable and junction networks. Their use in this Administration is seen as jointing plastic insulated distribution cables of 100 pair and under in subscribers distribution areas. Moisture protected versions are presently undergoing field trial in this application, with the aim of establishing their performance in conjunction with our present range of cables and jointing enclosures.

## DOUBLE ENDED "IN LINE" CONNECTORS

During the later 1960s world developments in the connector jointing field were watched with interest by the A.P.O. for the emergence of a connector suited to our requirements in the large size cable jointing application, and encouragement was given to local manufacturers to develop such a system to specifically meet these requirements.

In 1969, and as a result of co-operation between Headquarters Lines and Research Sections, a specification (Ref. 5) was compiled covering the precise requirements of the A.P.O. for double ended connectors and machines for this application, and a Schedule was subsequently issued in May 1970 for their supply.

## THE PICABOND SYSTEM

The A-MP Picabond connector (Fig. 3) was the first in line connector to be produced commercially which could be used successfully with helically lapped, ribbon paper insulated conductors. The connector has a trough shaped brass element, post plated with tin, after forming, and insulated with Mylar film, which is adhesively secured to the metal element.

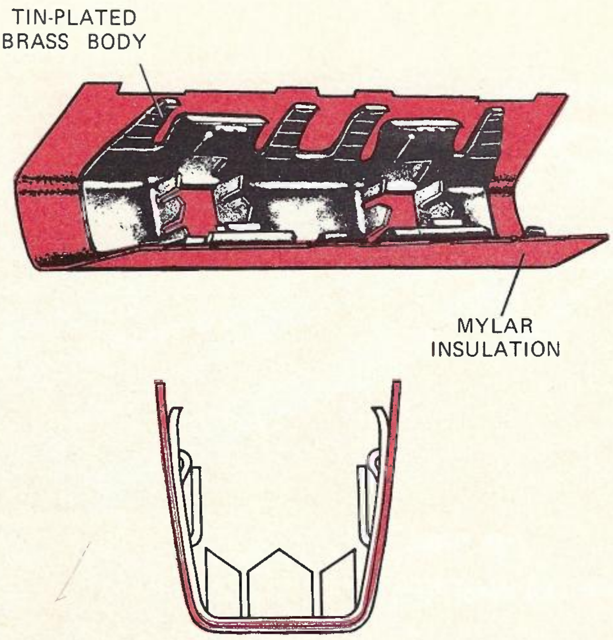



Fig. 3—A-MP Picabond Connector.

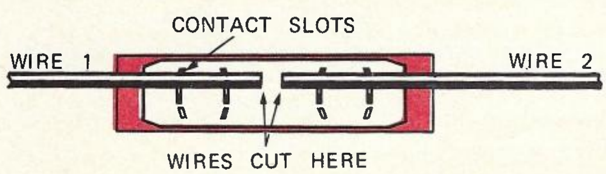



Fig. 4—Centre Cut Principle (A-MP Connector).

The connector utilises the "wire in slot" principle to effect the electrical connection, two slots being provided for each wire to increase the reliability of the connection. A centre cut technique is used in producing the joint, i.e., each wire that is led into the connector is cut near the centre region of the connector before crimping is effected. Each wire thus penetrates for slightly less than half the length of the connector which is some 28 mm long. Fig. 4 illustrates the centre cut principle.

The Picabond connector can accept a total of four wires and joint them together. This is achieved by the duplication of slot pairs on each side of the base of the trough. The connector design is thus versatile in permitting multiple jointing where this is required, and in addition, tap out joints without circuit interruption may be made in certain circumstances where wire slack is available. However, where the connector is used for straight two wire jointing only one half of its capacity is utilised and its cost is high in comparison with the smaller two wire connectors described later.

Three connector sizes in the Picabond range provide for the jointing of copper conductors from 0.32 mm to 0.90 mm diameter (2½–20 lb/mile) and moisture proof versions, containing a quantity of grease which is retained by a plastic membrane that ruptures during crimping, are also available. Tables 1 and 2 show the wire diameters accepted.

A range of tooling is available for crimping these connectors, which includes a hand tool Type MR1 (Fig. 5) and a rack mounted manually operated jointing machine, Type MA6B (Fig. 6).

Both of these tools accept separate loose piece connectors which are inserted individually by hand into the tool and each provides a single joint between either 2, 3, or 4 wires, per operation.

In addition a machine, Type MA8A, with the capability of making a pair of 2 wire joints per operation is included in the range of tooling (Fig. 7). This is a rack mounted chain feed machine which accepts connectors produced in strip form on reels of 500. The machine is also manually operated, its design does not permit of multiple jointing.

Manually operated machines and hand tools rely on the mechanical advantage of lever systems to produce the crimping pressure which is applied to the connector. The tools incorporate ratchet

**TABLE 1 — COMMON 2 WIRE COMBINATIONS OF COPPER CONDUCTORS JOINTED BY PICABOND CONNECTORS**

| Orange Connectors | | Green Connectors | | Red Connectors | |
|---|---|---|---|---|---|
| Wire Diameters (mm) | | | | | |
| Wire 1 | Wire 2 | Wire 1 | Wire 2 | Wire 1 | Wire 2 |
| 0.32 | 0.32 | 0.40 | 0.40 | 0.51 | 0.90 |
| 0.32 | 0.40 | 0.40 | 0.51 | 0.64 | 0.90 |
| 0.32 | 0.51 | 0.40 | 0.64 | 0.90 | 0.90 |
| | | 0.51 | 0.51 | | |
| | | 0.51 | 0.64 | | |
| | | 0.64 | 0.64 | | |

TABLE 2 — COMMON 3 WIRE COMBINATIONS OF COPPER CONDUCTORS JOINTED BY PICABOND CONNECTORS

| Orange Connectors | | | Green Connectors | | | Red Connectors | | |
|---|---|---|---|---|---|---|---|---|
| Wire Diameters (mm) | | | | | | | | |
| Wire 1 | Wire 2 | Wire 3 | Wire 1 | Wire 2 | Wire 3 | Wire 1 | Wire 2 | Wire 3 |
| 0.32 | 0.32 | 0.32 | 0.40 | 0.40 | 0.40 | 0.51 | 0.51 | 0.90 |
| 0.32 | 0.32 | 0.40 | 0.40 | 0.40 | 0.51 | 0.51 | 0.64 | 0.90 |
| 0.32 | 0.32 | 0.51 | 0.40 | 0.40 | 0.64 | 0.51 | 0.91 | 0.90 |
| 0.32 | 0.40 | 0.40 | 0.40 | 0.51 | 0.51 | 0.64 | 0.64 | 0.90 |
| 0.32 | 0.40 | 0.51 | 0.40 | 0.51 | 0.64 | 0.64 | 0.90 | 0.90 |
| 0.32 | 0.51 | 0.51 | 0.40 | 0.64 | 0.64 | | | |
| | | | 0.51 | 0.51 | 0.51 | | | |
| | | | 0.51 | 0.51 | 0.64 | | | |
| | | | 0.51 | 0.64 | 0.64 | | | |
| | | | 0.64 | 0.64 | 0.64 | | | |

mechanisms to ensure that once a crimping cycle is commenced the crimping anvil must travel forward to its fullest extent before release. This is to exclude the possibility of partially crimped connector joints being produced. However, wear on the components and linkages in these systems will, if not compensated for, progressively affect the extent to which the connectors are pressed and ultimately the contact resistance of the joints will be affected. While the "wire in slot" principle provides some tolerance in this respect the crimp height of the pressed connectors must be checked from time to time with a gauge to ensure that the tool is in satisfactory adjustment and the connectors are being crimped adequately. The Picabond system employs a light slotted "GO" type gauge which will fall away under its own weight from a sufficiently crimped connector, but will bind on one having excess crimp height. A different gauging slot width is applicable to each connector size.

## THE No. 4 CONNECTOR SYSTEM

The work of J. P. Harding and the staff of the British Post Office Research Department resulted in the development of the B.P.O. Connector Wire Jointing No. 4 and its associated tooling, Machine Cable Jointing No. 4 (Ref. 9). The system is available commercially as the 'Telecrimp" system from Plessey. The No. 4 connector is relatively small, being some 17.5 mm long, and is illustrated in Fig. 8.

It is manufactured from phosphor bronze strip, preplated with tin, and is provided with an outer PVC insulating member which encompasses the metal element. No adhesive is employed

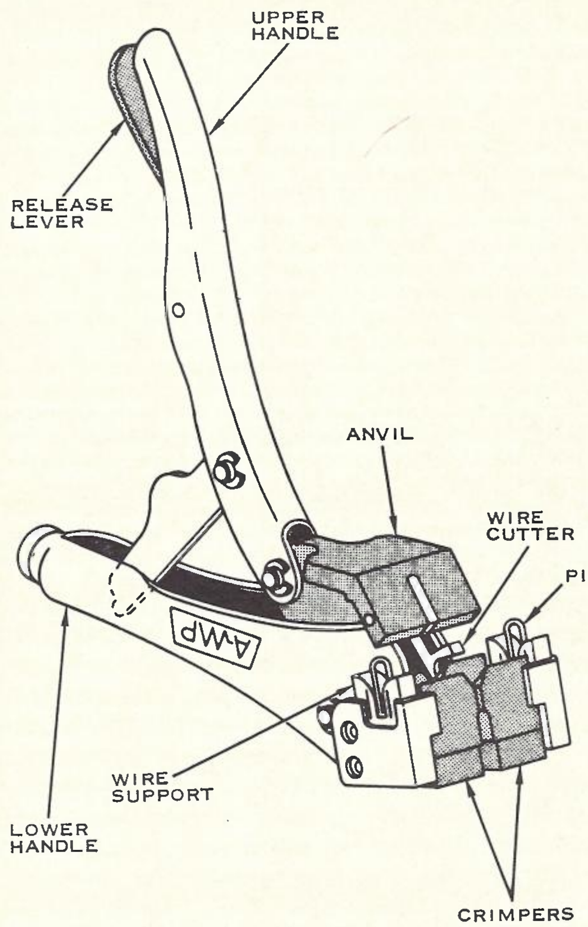



Fig. 5—Hand Tool Type MR1 (A-MP).

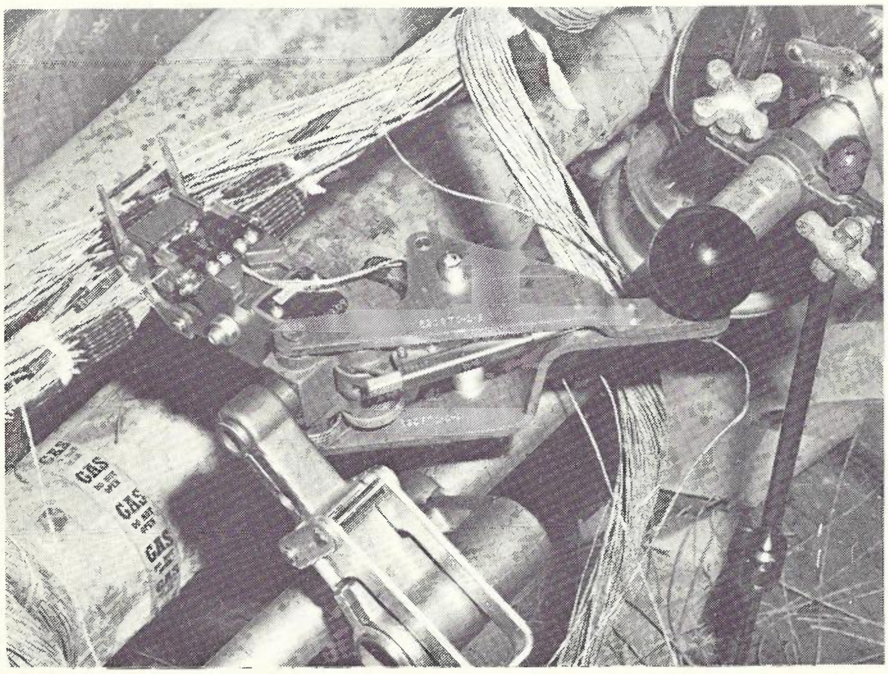


Fig. 6—Manual Jointing Machine Type MA6B (A-MP).

between the two components, the contours of the PVC trough being relied upon to secure the insulant in place.

The connector employs upset tangs to pierce the wire insulation and to provide the electrical connection to the wires. The design includes stuffing plates or tongues, to counteract the effect of relaxation with time and temperature and is described in detail in Ref. 9. The connector is essentially a two wire connector and its small size makes it particularly suited for jointing large pair count, small gauge, copper cables without unduly large joint closures being necessary. A factor which no doubt influenced the design of this connector and its tooling, is the greater use made of 0.32 mm copper conductor cables in the UK than is the case at present in the A.P.O.

An "end cut" principle is used with this connector in that the two wires to be jointed together, are arranged to be parallel to each other and enter the connector from its opposite ends. When crimped, each wire extends through the full length of the connector, the unwanted wire tails being cut away adjacent to the ends of the connector. Fig. 9 illustrates the "end cut" principle.

The No. 4 connector can accommodate our copper conductors having diameters of 0.32 to 0.50 mm and insulation of paper or polythene in accord with the relevant A.P.O. cable specifications. It is not suited to aluminium conductors.

The tooling to apply the connector was the first electro-hydraulic, "in line" telephone cable jointing machine to become commercially available, and is illustrated in Fig. 10. Connectors from a cassette containing 50 connectors are automatically advanced into the crimping head as part of the crimping cycle. The machine operates from a 24 V DC supply provided by lead-acid accumulators, or alternatively machines are available for operation from 110 V AC.

The wires for jointing are loaded into the head from its opposite sides, and on a start button being depressed, an electrically driven oil pump causes pressure to be applied to the ram. As the ram moves forward the connector in the breach

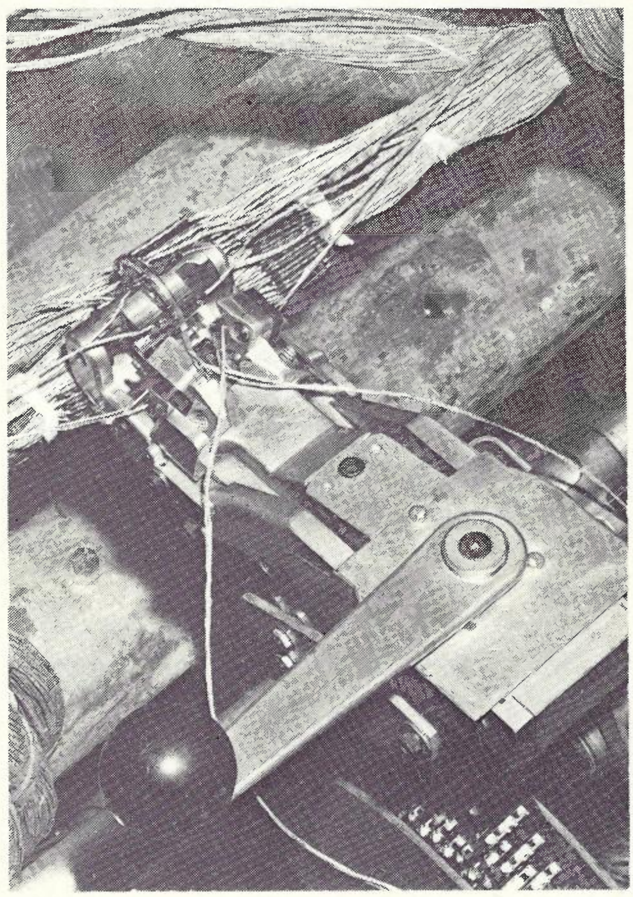


Fig. 7—Manual Jointing Machine Type MA8A (A-MP).

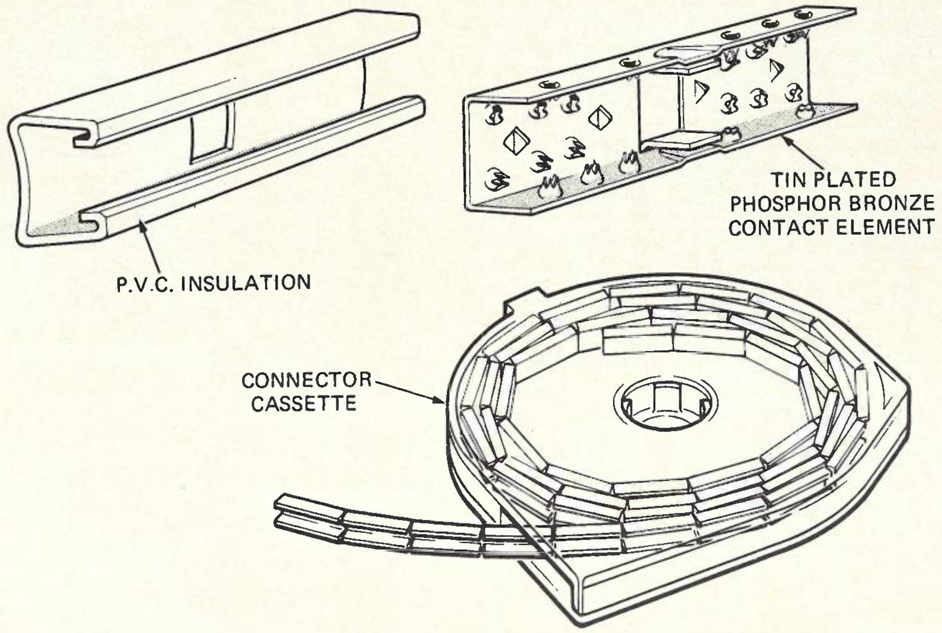



**Fig. 8—Connector Wire Jointing No. 4 (Plessey Telecrimp 24).**

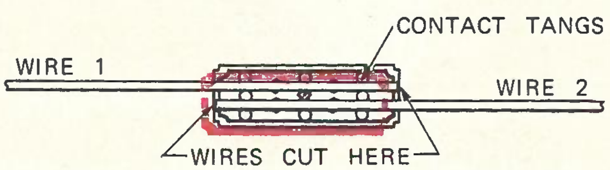



**Fig. 9—"End Cut" Principle (Plessey Telecrimp 24).**

is sheared from its strip and carried upward to encompass the wires. Two beaks which contain the contoured die halves close and as pressure builds up the connector is crimped. The wire ends are selectively sheared toward the end of the stroke and on a predetermined pressure level being sensed in the hydraulic line, the oil is directed to the top of the ram cylinder and returns the ram to its rest position, a new connector is advanced into the breech toward the end of the cycle.

The machine design lends itself well to the requirement for making compact joints with a minimum of slack wire within the joint, and the loading of wires and their removal after jointing is optimised for machines of this nature.

## THE UTILUX No. 50 SYSTEM

This system is the first to be developed by an Australian Company and results from the efforts of W. Karl and the design staff of Utilux Pty. Ltd., Sydney, to meet the requirements of the Australian Post Office.

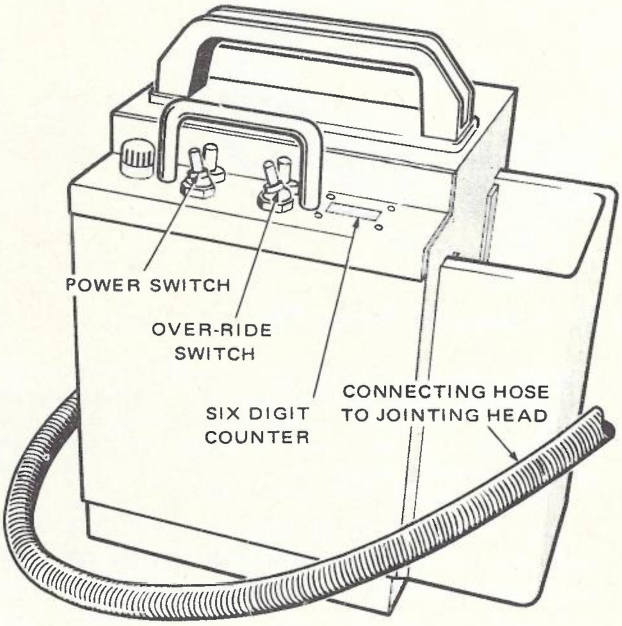
The H2561 connector (Fig. 11) which is used in this system is a small, channel shaped, two wire connector, of similar size to the No. 4 and it utilises the "end cut" principle. Connectors are supplied in strip form on reels of 1,000 as accepted by Machine Cable Jointing No. 50. The metal connector element employs upset tangs for the contact function and has small suitably placed nodules on the side walls of the channel to press the wires onto the tangs during crimping. Similar nodules near the ends of the connector grip the insulated wire and relieve stress from being applied to the contact area. It is manufactured from brass strip, tin plated after forming and punching operations are completed. The insulant is mylar which is adhesively bonded to the metal element.

The connector joints copper conductors from 0.40 mm to 0.64 mm diameter having paper or polythene insulation in accordance with the relevant A.P.O. Cable Specifications. These conductor sizes presently constitute the majority of jointing work offering in our subscribers and junction cables. The connector has also been used successfully with 0.52 mm aluminium conductors under conditions of controlled field trial.

Machine Cable Jointing No. 50 which serves to crimp these connectors incorporates a rack mounted, hydraulically operated, jointing head mounted on a support frame (Fig. 12). Oil pressure to operate the head is supplied from a hydraulic power unit driven from a 24 V secondary battery supply. The batteries are contained in a battery carrier to facilitate their transport.

The continuous strip of connectors is fed into the head of the jointing machine and the connectors are advanced one at a time into the crimping jaws by means of a manually operated feed lever. The conductors to be jointed are placed in wire guides on either side of the jointing head, where they are retained by pressure pads. When the hydraulic ram is activated the conductors are carried forward into the connector which is subsequently crimped by the rising pressure. The unwanted conductor ends are cut away and the connector is sheared from its strip. At a pressure of approximately 14,000 kPa a pressure switch is operated and opens a solenoid valve draining oil from the ram cylinder. The ram restores to its rest position under spring tension.

The 4 m flexible hose which provides oil pressure to the head is permanently attached by a swivel coupling to the side of the head, and is fitted with a self sealing, male, quick connect coupler at its free end to permit its connection to the hydraulic power unit. Rubber caps prevent the ingress of dirt when the units are not connected. Extension hoses are available to allow the jointing head to be operated up to 8 m from its hydraulic unit, and the flexibility provided by the interchange of jointing heads and hydraulic units has also proved useful in the field. Two button switches mounted on the ends of a pivot arm are arranged so that both of the operators hands must be employed to activate the machine and are thus out of reach of the crimping jaws during the crimping cycle.



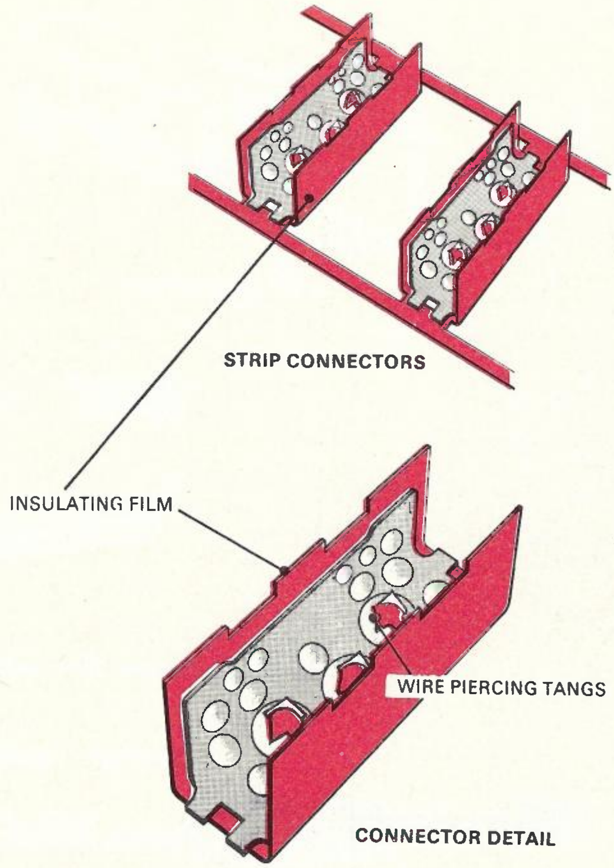
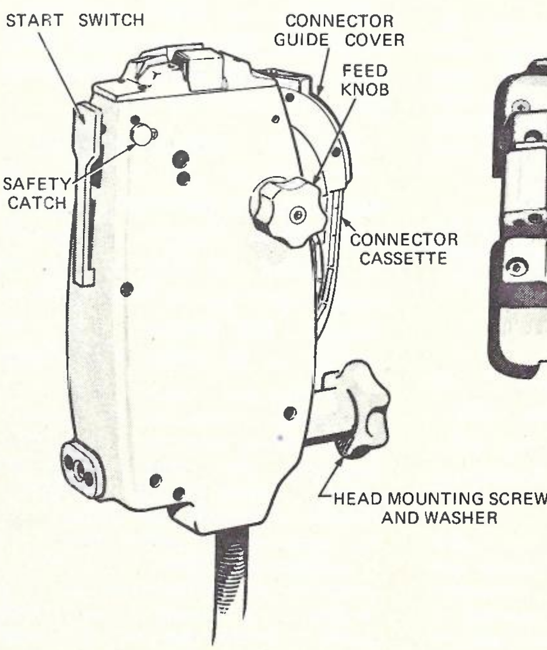




**Fig. 11—No. 50 System Connector Type H2561 (Utilux).**



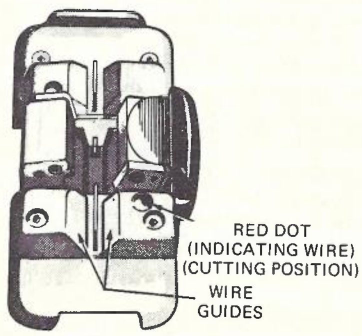




**Fig. 10—Machine Cable Jointing No. 4 (Plessey).**

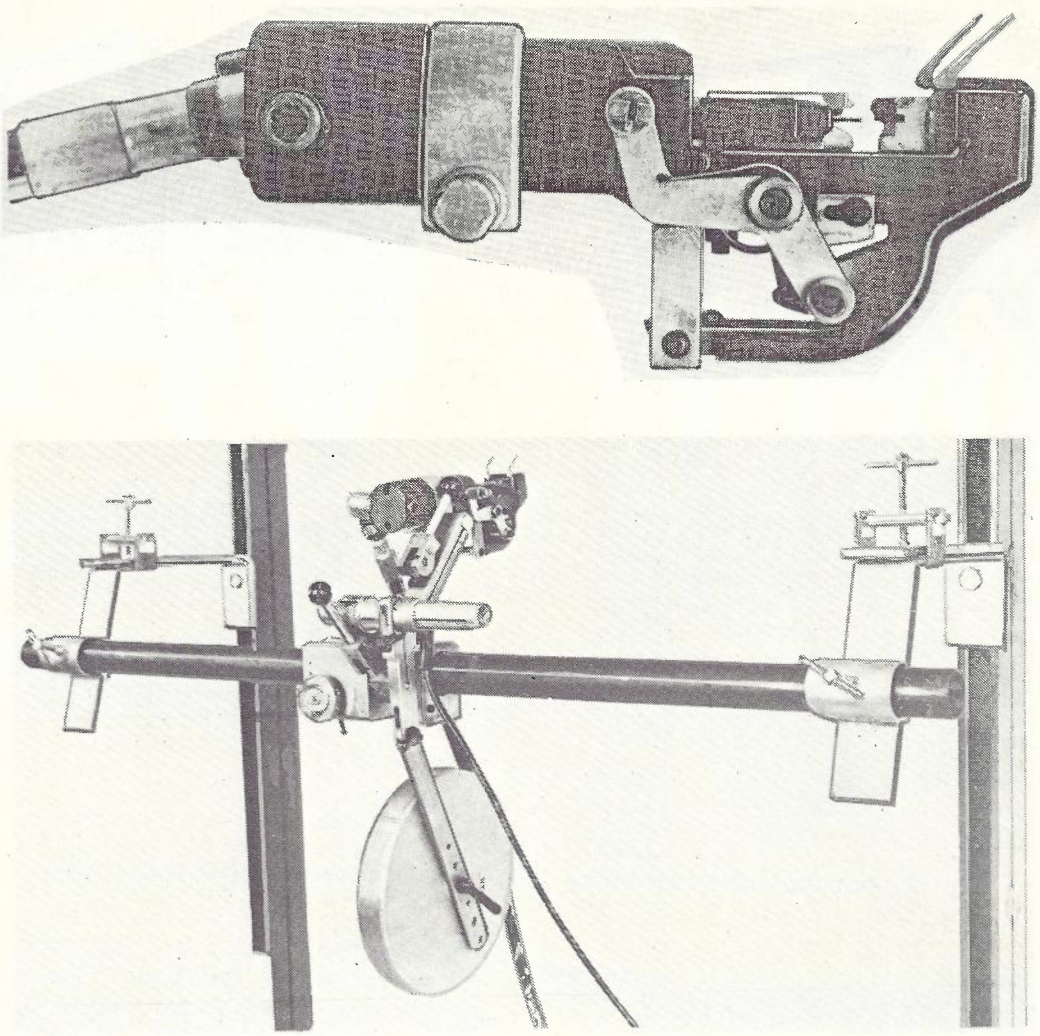


**Fig. 12—Machine Cable Jointing No. 50 (Jointing Head and Support Frame).**

The power operated systems described compensate for wear on dies, anvil, or linkages. The criteria for terminating the crimping cycle being the pressure which is applied to the connector. Irrespective of the time taken for a cycle, the pump will continue to operate until the preset pressure level to operate the pressure switch is obtained. This pressure is such as to provide the optimum crimping of the connector. These systems also make use of a crimp height test to check the degree of crimping attained by individual machines. The requirement for power of course involves the capital cost of providing batteries and the maintenance costs of their recharging. However a reduction in operator fatigue in comparison with manual machines should pertain.

## MODULAR SPLICING SYSTEMS

A unique development stemming from the Scotchlok U element connectors mentioned previously is the modular splicing system ($MS^2$) from the 3M Company where the jointing of 25 pairs of wires is accomplished in a single 3 element module. The system provides a bridging test point for each pair, and the pairs being systematically laid up are readily identifiable (Fig. 14).

The system is well suited to plastic, pulp and longitudinal paper insulated wires and trials have been conducted with ribbon paper insulated pairs. There is some size penalty with joint closures, and accomodating the closures on cables over 2,400 pairs in existing manholes presents some difficulty.

A recent addition to the modular connector scene comes from Siemens and makes use of 10 and 20 pair modules and the plug and sleeve method of connection, the plug being a serrated metal piece and the sleeve of plastic.

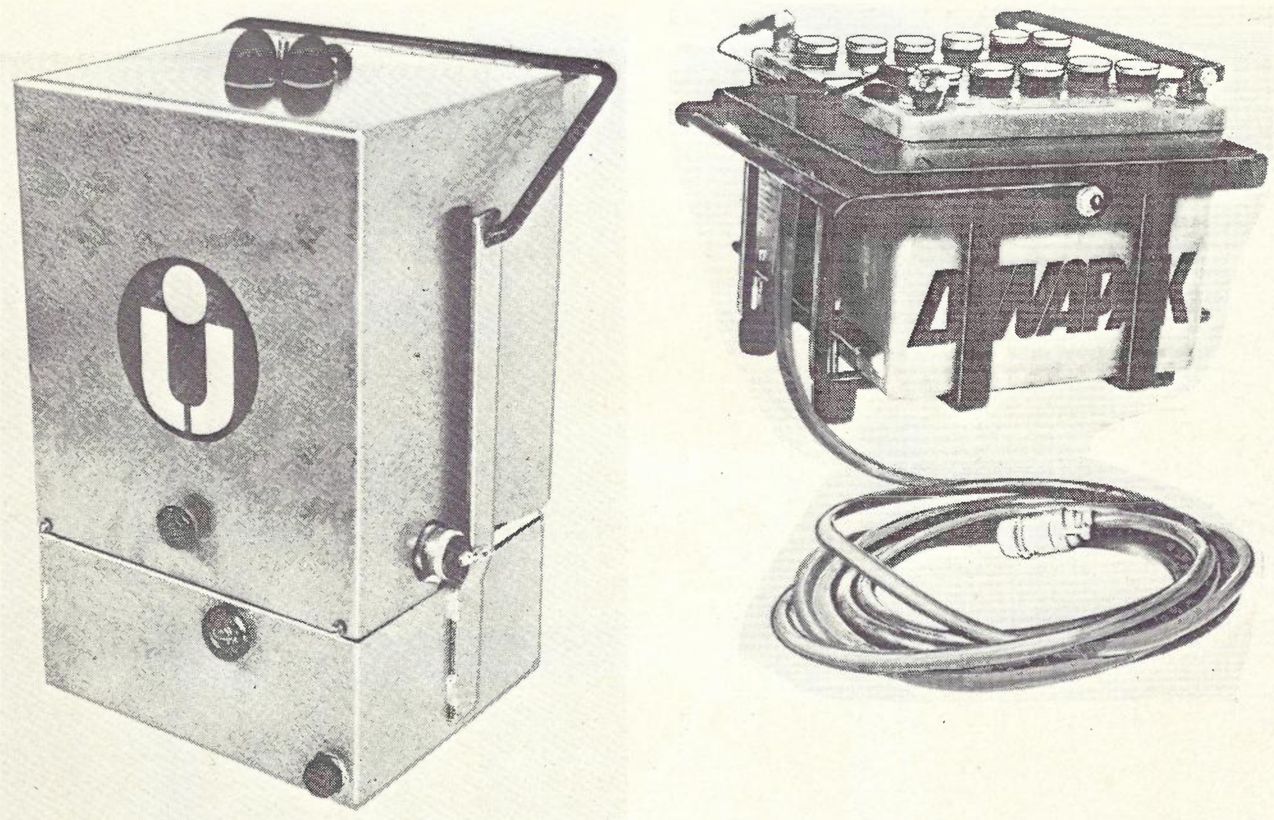


**Fig. 13—Machine Cable Jointing No. 50 (Hydraulic Power Unit and Battery Pack).**

**Fig. 14—Modular Splicing System (3M).**

## CONNECTOR JOINTING OF ALUMINIUM CONDUCTORS

The design of a satisfactory aluminium wire connector poses particular problems. The oxide film of $Al_2O_3$ that forms rapidly in normal atmospheres on the aluminium wire surface has a high electrical resistance and the connector contact elements must scrape away or pierce through this film and provide a sufficient area of oxide free asperities between the connector and wire surfaces to establish the low resistance contact required. Aluminium has a greater potential for creep under stress and movement under temperature change than copper and these factors must be allowed for in the design. Connectors to date have generally relied on tin as the plating material and tests conducted with those connectors which are post plated with tin, i.e., after the punching and forming operations have been completed, have provided sufficiently satisfactory contact resistance behaviour to justify limited field trials being conducted with them (Ref. 10). Recent developments have shown indium plating to be superior for use with aluminium and this is attributed to this soft metal smearing and providing a reliable gas tight seal during pressing. Aluminium wires are more subject to notching than copper, and this had led to failure by the wire breaking when it has been moved subsequent to jointing with some connectors, and where small gauge fully annealed conductors have been concerned.

## PRESENT STATUS OF CONNECTOR JOINTING IN THE A.P.O.

Connector jointing of cables has now been practiced on a large scale trial basis for some three years, employing the Picabond system in N.S.W. In addition field trials have been conducted with this system and also the No. 4 and No. 50 systems in the other States of the Commonwealth.

As a result of these trials, provisioning action is now proceeding in order to extend the use of machine connector jointing as a standard practice for our large size cables.

The ability of the MA6B machines and MR1 hand tools in conjunction with the Picabond connector to permit three wire multiple jointing and also the jointing of 0.90 mm (20 lb/mile cu) conductors has resulted in this tooling and these connectors being specified for Departmental use in these applications.

The smaller, cheaper, connectors of the power operated systems will not permit multiple jointing in a single connector, and although it is possible by using a two connector per joint technique to produce multiples, the procedure is unwieldy and the probability of splitting pairs is increased. The power operated system connectors do not presently cater for 0.90 mm conductor jointing.

For general two wire jointing of 0.40 mm, 0.50 mm and 0.64 mm conductors the No. 50 system will be utilised, while for the smaller 0.32 mm conductors, in addition to a component of the 0.40 mm jointing, the No. 4 system will have application.

## JOINT QUALITY ASSURANCE

Each of the systems put to field trial employs a crimp height test as a means of checking the adjustment of the jointing head. This type of test does not provide direct information about the contact resistance of the connector jointed wires but indicates only the extent to which the connector has been pressed. The integrity of the joints produced depends rather on the strict quality control which must be exercised during the production of the connectors.

To provide "in the field" quality assurance of the joints being made by any of the above systems, a Conductor Joint Resistance Measuring Set (Fig. 15) is utilised.

This instrument is basically designed for field usage and is of relatively rugged construction to meet this requirement. It allows the resistance offered by joint samples to be determined simply, rapidly, and with the required accuracy by a cable jointer in the course of his normal work. The resistance is measured between two points 40 mm apart on the wires and containing the joint. The range of the instrument is 0-15 milliohms and a table of acceptable resistance values, having regard to the different wire materials and diameters that may be jointed, is included in the instrument case. When power operated systems are in use the instrument may be operated from the 24V supply associated with these systems, and provision has been made for an outlet joint on the hydraulic power units for this purpose. When used in conjunction with manual machines or hand tools an internal 6 V supply incorporated in the instrument is used.

## FUTURE TRENDS IN CONNECTOR JOINTING

It is safe to say that we are still relatively at the threshold of the connector era in multipair cable jointing and that the future will see a proliferation of connector types, and tooling for applying them. The immediate developments now foreseen are concerned with the extension of the range of conductors and insulation diameters that individual systems can accommodate. The provision of hand held tools for the small in line connectors of the power operated systems to permit their application to low pair count jointing without the need to set up machines, will follow. Already in these areas Plessey have a connector for 0.64 mm cu (Telecrimp 22) in production and moisture proof and hand tool versions of their connectors are proposed, together with a hand tool designed to crimp them. The Utilex system must be extended to accommodate the smaller 0.32 mm and the larger 0.90 mm conductors. A new Connector Wire Jointing No. 6 for 0.64 mm diameter wires and capable of being crimped by the No. 4 machine has been tested and is under field trial in the B.P.O.

The Bell Laboratories development of the 700-2A and 700-3A connectors for aluminium and copper which employ indium plating and a polythene/polybutane filling for moisture proofing is well advanced. A new pigtail type of connector for

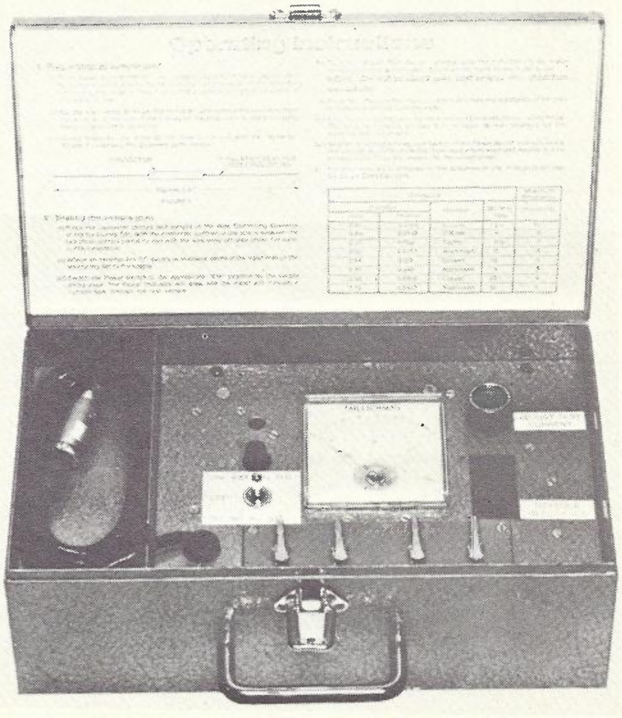


**Fig. 15—Conductor Joint Resistance Measuring Set MK1.**

aluminium conductors from Japan was recently reported by Tsuchiya Ichiro and others (Ref. 7), which utilises the plug and sleeve method of providing a connection and indium plating of the metal connector elements. The plug and sleeve principle is also exploited in machine applied connector systems under development in that country.

This author sees the further development of the small "end cut principle" connectors to accommodate two wires per side to allow multiple jointing. This should be achievable by suitably placed tangs on the side walls of the channel and attention to the crimp contours, and will serve to make these connectors even more attractive.

Modular splicing systems to accommodate the larger cable units of 100 pair per module with a conservation of size in the completed joint are likely when the usage of plastic insulated, jelly filled cables has been further established.


## ACKNOWLEDGEMENTS

The introduction of connector jointing in the A.P.O. has involved people in the Lines, Research, and Supply areas of the A.P.O. and from the telecommunications industry in Australia and overseas. The Author wishes to acknowledge his indebtedness to these people and to officers of the A.P.O. State Administrations who co-operated in the field evaluation of the various systems. In addition particular thanks are expressed to those system manufacturers from whose publications material for this article has been drawn.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Mr. Peters completed the Diploma of Communications Engineering at Royal Melbourne Institute of Technology in 1964 and was subsequently appointed as Engineer Class 1 to Metropolitan Branch, Conduits Division Victoria where he gained experience as a field engineer in the installation of major circuit routes in the Melbourne metropolitan area.

In 1968 he transferred to the then Subscribers Distribution Division, Lines Section Headquarters, where his duties involved the development, specification and promulgation of practices for external plant distribution areas. His present position is Engineer Class 3 Installation Practices (Electrical and Telecommunication) where among his current projects is that of the evaluation and introduction of machine cable jointing systems for the A.P.O.

# Development and Application of Telephone Traffic Measuring Equipment (Part 1)

C. W. PRATT, Ph.D.

*This is the first of two articles about traffic data and equipment for gathering it. Part 1 discusses the data requirements for planning and supervision of the telephone network. Data of two basic categories are required: occupancy (traffic load) and dispersion (origin-destination). Traffic measuring equipment has been developed within the Australian Post Office to provide comprehensive occupancy and dispersion data throughout the network. It is planned to use the equipment at key exchanges in the trunk network and the larger terminal exchanges (exceeding 2000 subscribers). This represents some 600 exchanges throughout the Commonwealth. The data will be computer legible since computer aid is needed for editing and processing. Part 2 will deal in more detail with the design philosophy of the equipment.*

## NETWORK SUPERVISION AND PLANNING

The calls in progress in the telephone network are collectively known as telephone **traffic;** these calls are, of course, the reason for existence of the network, the prime operational objectives being to switch calls from calling subscriber to called subscriber with a very low probability of failure due to technical faults or insufficiency of circuits, and at a satisfactorily low overall attenuation. Telephone traffic represents the revenue-earning life blood of the network and since this revenue currently runs at a rate of over $380m per annum, considerable attention must be paid to its smooth disposal.

The number of calls in progress at any point in the telephone network varies from moment to moment as calls are established and disconnected, and also varies throughout the day in response to business and social activity in the community. The momentary variations are of course quite unpredictable, but the daily pattern of traffic follows a more or less regular shape. In providing equipment in the network it is necessary to reach a compromise between cost on the one hand and service to subscribers on the other: to achieve an economical network it is necessary to insist that subscribers tolerate a small probability of encountering congestion during the busiest period of the day.

There are two fundamental requirements for ensuring that the network caters for all but the highest traffic demands. Firstly, the network must be supervised at regular intervals, and where inadequacies appear in switching equipment or numbers of circuits, short term action must be taken. Day to day supervision is done with the aid of erlang-hour meters, each one of which is associated with a key circuit group in the trunk or local network. Automatically switched on for the busiest two hours of the day, the meter accumulates the observed traffic volume, giving a historical record of traffic growth on the route which can be used to show when additional circuits or more detailed traffic measurements are required. These more detailed traffic measurements are the occupancy readings described later, and are taken when unduly high congestion is known or suspected in the exchange, or at regular intervals ranging from 6 months to years.

Secondly it is essential to plan the orderly growth of the network some years ahead since quite long lead times are required for extending buildings, and ordering switching equipment and large transmission systems. The planning process is aimed at ensuring that circuits and switching equipment are provided at the right places and in the right quantities. Very large capital expenditures depend on these plans and it is therefore necessary to base them on the best possible data. These data are obtained by traffic measurements, but before going into details, it is necessary to give a general picture of the Australian network.

## THE AUSTRALIAN TELEPHONE NETWORK

From 1912 up to 1960, the automatic telephone network was based on the step-by-step system which uses bi-motional Strowger selectors. Except for final selectors which deal with the last two digits of the called number, in general one rank of switches is required to deal with each dialled digit, and there is a close relationship between the dialled digits and the path by which a call is routed through the network. Discriminating selector repeaters permit a strictly limited amount of alternative routing: up to nine direct routes each with only one alternative route. Over the past 13 years, network growth has been implemented using the

Swedish Ericsson crossbar system which is a so-called register controlled common control system in which dialled digits are stored in a memory device (register), and analysed to the extent necessary to decide the appropriate path (outgoing route) to which to connect the call. This analysis of digits allows routing to be separated from numbering to some extent, and also allows economies to be achieved by comprehensive use of alternative routing techniques.

With alternative routing, there may be two or more alternative paths from origin to destination exchange, and these are searched in a fixed order of preference when attempting to establish a call. If all circuits on the first choice route are busy, then the call is offered to the second choice route, and so on.

There are three generic types of crossbar exchange: ARM exchanges for the 4-wire switched trunk network, ARF exchanges for 2-wire switching centres and terminal exchanges in larger cities, and ARK exchanges for small rural applications. Within each generic type there are some variations which in turn have a bearing on the traffic data which may be derived from them. The traffic data equipment under particular consideration in these articles has been designed for the ARF and ARM types.

## TRAFFIC MEASUREMENTS

As just described, the Australian network consists at the present time of a mixture of step-by-step and crossbar equipment. The traffic measurements required for supervision and planning purposes are of two kinds: **occupancy** measurements and **dispersion** measurements.

### Occupancy Measurements

Occupancy measurements are vital for exchanges of all types and involve observation of the numbers of simultaneous calls or occupations in the various groups of devices in an exchange. Here "devices" means all those items of equipment which participate in the disposal of traffic. The term includes the circuits which carry the conversations themselves but also items of common equipment such as registers, markers, code senders, etc., which are occupied for shorter periods during the establishment of calls but must be povided in adequate numbers to cater for all likely demands.

It would of course be possible to take occupancy measurements on a continuous basis using, say, chart recorders for all the circuit groups; this would be very expensive, but in any case it is not necessary since adequate accuracy is obtained by observing each group of devices at regular intervals of, say three minutes, and averaging the number found busy over an appropriate period of time. Current occupancy measurement practice therefore employs scanning techniques, and by use of suitably designed automatic equipment a large number of device groups can be observed within each scanning cycle (See Fig. 1 later).

Traffic conditions of course vary throughout the day, but for design purposes attention is focussed on the time consistent busy hour, which is the clock hour (commencing on the hour or half-hour) for which the traffic, averaged over the five business days of the week, is the highest. The measurement sessions during the day must of course be extensive enough to ensure that the busy hour is included. Time consistent busy hour traffic figures derived from the scanned observations yield the magnitudes of the traffic flows in the network in absolute terms, and these are used for network supervision, i.e., to demonstrate deficiences and surpluses of circuits in the existing network. They are also used, suitably adjusted for seasonal effects, as base data for traffic forecasts to plan the extension of the network in detail.

It is necessary to distinguish between two types of occupancy measurement, known espectively as **route occupancy** and **circuit occupancy.** In a route occupancy measurement the total number of simultaneous occupations in each group of devices is measured, and recorded, and this is the more usual type of measurement especially for larger exchanges. Circuit occupancy measurements are taken in ARK's or P.A.B.X.'s., or for special studies such as the analysis of gradings, when it is convenient and useful to observe each device individually, and record its status, i.e. busy or idle.

Figs. 1 and 2 show the principles employed in taking route and circuit occupancy measurements. All devices in an exchange, such as SR, FIR, FUR relay sets, registers, markers, code senders etc., whose occupancies are to be measured are equipped with traffic measuring (TKT) leads each of which consists of a 100k resistor wired via a make contact to an IDF. The contact is closed when the device is busy, so the TKT lead appears as either open circuit or 100k earth at the IDF depending on whether the device is idle or not.

At the IDF the individual TKT leads may be commoned together in groups (Fig. 1), and it is then seen that the number of busy devices in a group is simply the number of 100k resistors in parallel at any moment. The group leads are wired to a scanning switch so that they can be observed automatically in rapid sequence, and the switch is in turn connected to a sensing device. This may consist of a moving coil meter with a scale calibrated to give a direct visual indication of number of busy circuits, or a digital ohmmeter which can detect how many 100k resistors are instantaneously paralleled

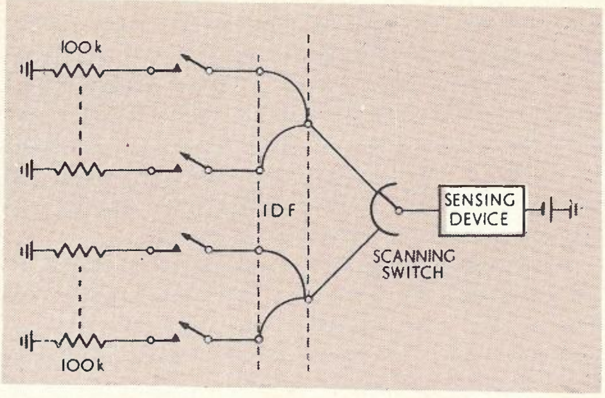



**Fig. 1 — Principle of Route Occupancy Measurements.**

and provide a digital coding of this number for recording by a paper tape punch or a magnetic tape recorder. A large exchange will typically have 100-300 circuit groups scanned at 3 minute intervals, and these set the requirements for the size and speed of the scanning switch. (The traffic data equipment to be described later has a switch which can scan 400 circuit groups in about 1 minute, and can be extended to 800 groups; each group can have up to 200 circuits).

For circuit occupancy measurements (Fig. 2), the individual TKT leads are wired directly to the scanning switch. As they are scanned, the sensing device detects whether each circuit is idle or busy and passes an indication on to the data recorder. Using a 400 point scanner, at most 400 circuits can be observed, so this type of measurement is confined to small exchanges, gradings, and the like.

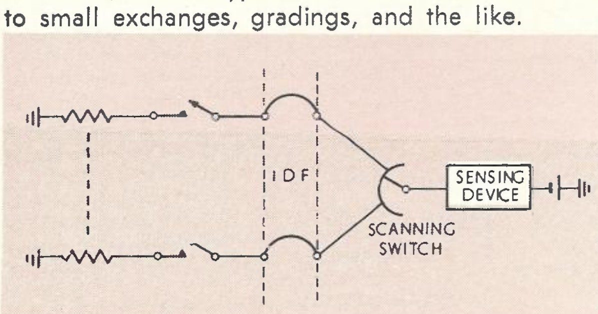



**Fig. 2. — Principle of Circuit Occupancy Measurements.**

### Dispersion Measurements

The discriminating selector repeaters (DSR's) of the step-by-step system with their limited alternative routing capability, and the crossbar switching system with its extensive alternative routing facilities have created a need for dispersion information, i.e. the percentages of traffic from an origin exchange to the various possible destination exchanges in the network. Dispersion information can be of two kinds: **call dispersion** which consists simply of percentages of calls to the various possible destinations, and **traffic dispersion** which consists of the percentages of traffic to destinations. As a generalisation, call dispersion is easier and cheaper to obtain as it requires only a count of calls to the various possible destinations, irrespective of their average durations. If calls to a particular destination are very short, then although they may be numerous, the average number in progress simultaneously will be quite low. Hence call dispersion can be a misleading indicator of origin-destination traffic and hence of the circuit requirements. By contrast traffic dispersion takes account of differences in call holding times in different traffic streams, and is therefore much to be preferred for network planning purposes.

As with call dispersion, traffic dispersion measurements are usually made by observing a sample of calls, but for each call the holding time as well as the destination exchange are recorded. If a sample of N observed calls has average holding time H, and if n of these with average holding time h pass to a particular destination, then the measured traffic dispersion to the destination is (nh/NH).

### MEASUREMENT PRACTICE

To plan the network the percentages of traffic to various destinations obtained from dispersion measurements must be used in conjunction with an absolute measure of the busy hour traffic as derived from occupancy measurements or from forecasts based on these measurements. Thus a comprehensive traffic measurement system must permit both occupancy and dispersion measurements to be taken.

Traffic measurements are of course not new, but have been taken for many years using a variety of equipment of steadily increasing sophistication. The earliest occupancy measurement techniques involved a visual count of occupied switches, but this was subsequently displaced by electrical scanning of device groups. Dispersion recorders were also built for the step-by-step system.

Traffic measurement field staffs in each State administration take measurement in exchanges periodically. The frequency of measurement varies with the importance of the exchange. Trunk switching centres are measured once or twice a year as are also tandem exchanges. Less important exchanges are measured at up to two year intervals, although it is hoped to reduce the interval to about one year. Measurements are taken throughout the year although as many as possible are concentrated in the busy season to reduce seasonal corrections.

Most measurements are made using portable measuring and recording equipment. The measurement procedure requires the portable equipment to be set up and thoroughly tested. Readings are then taken typically over the five business days of the week, with usually two (morning and afternoon) reading sessions per day, but sometimes three (an evening session as well) in residential areas where social activity can produce an evening peak. The sessions must of course be sufficiently long to ensure that the time consistent busy hour is included. Data are recorded on punched paper tape for subsequent computer processing, although the use of magnetic tapes is now commencing. When the measurement is complete, the portable equipment is dismantled and moved to the next exchange.

## THE TRAFFIC DATA EQUIPMENT PROJECT

Over the past five years the Australian Post Office has been developing traffic data equipment suitable for extracting data from crossbar exchanges. The equipment will be installed in the more important exchanges first, and it is planned to equip all switching centres, and terminal exchanges exceeding 2000 lines in capacity. This will require installations in approximately 600 of the 3400 automatic exchanges in the Australian network, at a cost exceeding $2M.

The equipment will consist of a mixture of permanently installed and portable units. A rack will be installed in each equipped exchange, and access wiring from the rack to the various measurement points throughout the exchange will also be permanent. Certain basic units will be placed permanently in the rack so that exchange maintenance staff are able to keep selected device groups under surveillance and observe any abnormal traffic behaviour. The rest of the equipment required for full scale measurements will be portable.

The equipment permits occupancy and dispersion measurements to be made simultaneously. Occupancy data are gathered and recorded at scan intervals which can vary between wide limits: 15 seconds up to 60 minutes. These scans are initiated by a time clock. On the other hand dispersion data are recorded in real time as calls are set up and disconnected. The output tape therefore contains a mixture of the two types of data which must be segregated and processed by the computer.

### Data Processing

The traffic data equipment project incorporates a centralised data processing system, called the TRA Application and physically based in Melbourne, to which data tapes will be submitted for editing, validation, and processing. The validation and processing phases require reference to data about the exchange itself: details of switching equipment,

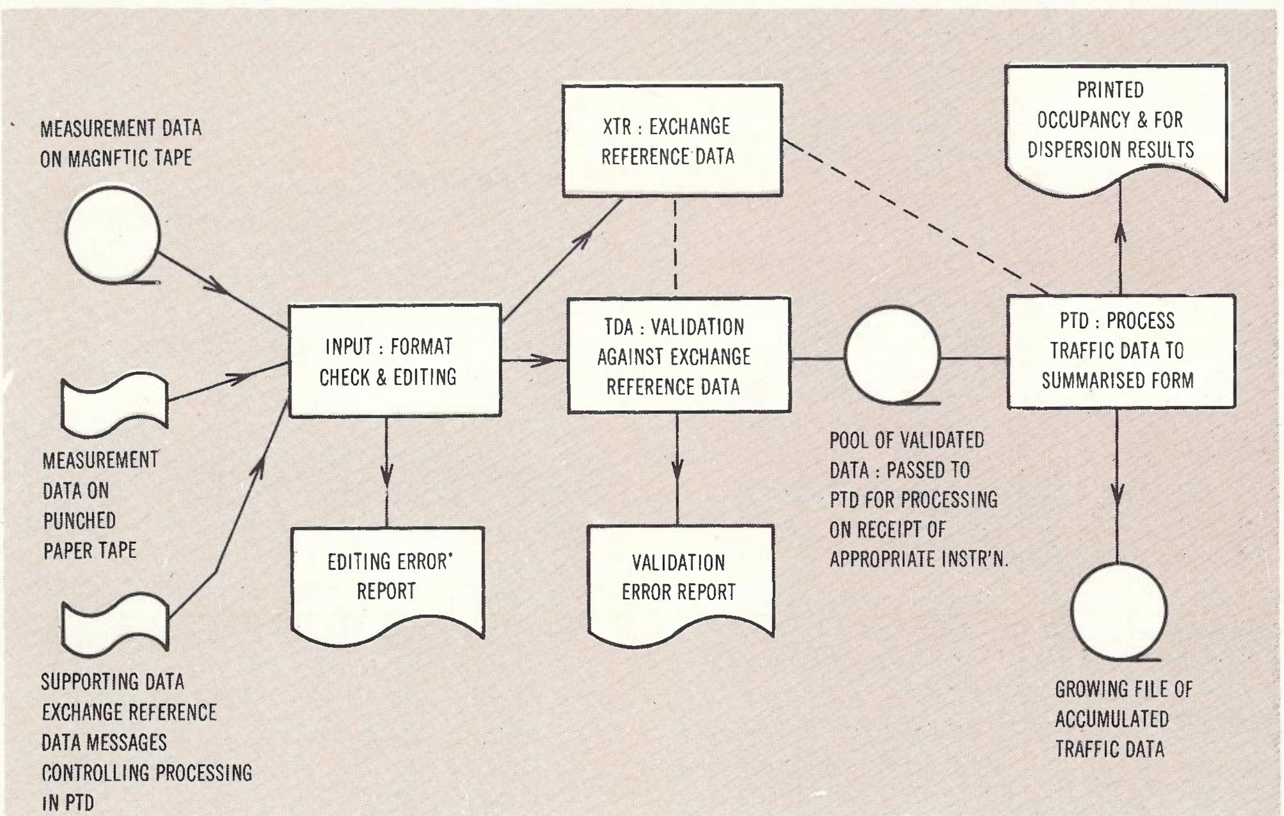



**Fig. 3 — Traffic Data Processing System (TRA Application).**

number of devices in each group and so on. For this purpose a special master file is to be created which will be updated as part of the overall measurements programme. Fig. 3 gives a simplified diagram of the data processing system.

The use of magnetic tape as a recording medium creates certain problems, since it is not possible to detect or read the data on the tape visually. Hence after setting up an exchange for measurement, data will be gathered for about half a day, and a short tape sent for editing and validation. In the meantime, measurement will continue using a second tape. Reports from the editing and validation of the initial tape will indicate whether errors have been made in setting up the measurement. It is then a matter of judgment whether the measurement can continue or must recommence after clearing all faults.

The output from processing includes the following:

*Occupancy:*

- Traffic averages (half-hour by half-hour) for every device group.
- The time consistent busy hour and its average traffic over a five day measurement period for each device group.
- Similar data for combinations of device groups.
- A summary of the time consistent busy hour, and the busy hour traffic, both measured and seasonally corrected.

*Dispersion:*

- Percentages of traffic, and average call holding times for all identified destinations, and for certain groups of destinations.

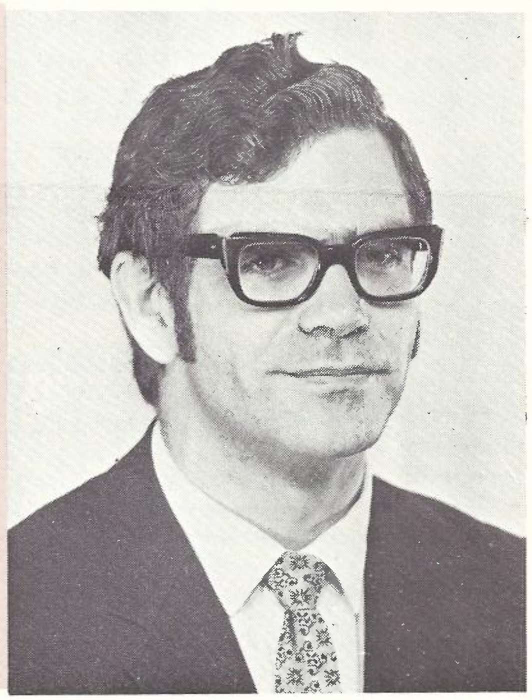
## CONCLUSION

It would be hard to over-emphasise the importance of traffic data for the supervision and planning of the telecommunications network. The need for basic occupancy and dispersion information is easily demonstrated, but as the current project has advanced, it has become apparent that additional data could be valuable, especially for all kinds of planning studies such as network, switching, tariff and revenue projections. For example, revenue studies would be easier if charged time were recorded as well as the circuit holding time; also traffic forecasting especially in the trunk field, would be more accurate if subscriber trunk usage rates could be separated from overall or unit-fee usage rates. Variations such as these may require changes to hardware, and would certainly require software changes. At present we have confined attention to fundamentals, but pressures to extract and process more sophisticated data will probably remain; specific proposals will of course have to be examined to assess costs and benefits.

In Part 2, Mr. L. Tyrrell will give details of design philosophies followed in developing the traffic data equipment.

CLEM PRATT is head of the Traffic Engineering Section in the Headquarters Fundamental Planning Branch. He was educated at the Universities of Queensland and London, and has had APO experience in Brisbane Workshops, Victorian Metropolitan Internal Plant Planning, and Headquarters Traffic Engineering. To many A.P.O. engineers he is best known for the residential traffic engineering courses he has conducted at Kalorama and Sherbrooke. In recent years he has represented Australia at meetings of the C.C.I.T.T.'s Working Party XIII/2 (Traffic Engineering), and the International Teletraffic Congress.

Dr. Pratt is active in the Statistical Society of Australia, and has held the offices of Victorian Branch President and Australian General President. He is a member of Advisory Committees on Mathematics at the Footscray and Royal Melbourne Institutes of Technology.



# The Evolution of Radio Frequency Spectrum Management

A. P. WALKER

**Editorial Note: Under the Wireless Telegraphy Act, the Postmaster-General's Department has the prime responsibility for the management of the Radio Frequency Spectrum in Australia and its Territories. The rapidly increasing demand for radio frequency allocations to provide terrestrial and satellite communication as well as broadcasting and television services requires Australia to understand and utilise, in partnership with the world at large, the greater part of the radio spectrum up to 40 GHz and higher frequencies.**

**In view of the increasing awareness of the special skills involved in the utilisation of a resource which is inexpandible and irreplaceable, the following after-dinner speech given by Mr. A. Prose Walker will be of interest to readers. Mr Walker is the Chief of the Amateur and Citizens' Division of the Federal Communications Commission in the U.S.A. Speech was given at the 63rd Annual Banquet of the Radio Club of America, Inc., in November 1972.**

Choosing a subject for tonight was not easy. I knew that the total expertise of all of you represents a great amount of knowledge and experience, accumulated over a long time. When one is called upon to speak before his peers, he is usually expected either to entertain or educate them. Those of you who know me, know that I'm not a comedian . . . at least intentionally. Although I have been involved in the allocation of the radio spectrum for more than 25 years, the aggregate of your experience so far outweighs mine that I seriously doubt I shall educate you. If I'm fortunate, many of you will have forgotten some of the details I shall recall to your mind.

Evolution, by definition, involves change regardless of what is being considered. Change takes place at some rate, or velocity. Considering the time span from the birth of Christ, knowledge in the world did not double until 1750; the next doubling by 1900; the third by 1950 and the fourth by 1960. I'm not sure whether the fifth has yet occurred but probably so. If one considers man's existence to be 50,000 years, that would represent about 800 average life-spans. That many people could theoretically cover that period; about as many as could have attended this banquet tonight.

Of those 800 people 650 would have spent their lives in caves, or something worse;

Of those 800 people, only the last 70 had any effective means of communicating with each other;

Of those 800 people, only the last six ever saw a printed word or could measure heat and cold;

Only the last four were able to measure time with any precision.

Almost everything that makes up our world was invented during the life span of the 800th person;

And more technological progress will be made during the life of the 801st person, than during the entire lifetimes of the previous 800.

Spectrum Management has existed ever since we learned to transmit information by means of electromagnetic waves. In understandable terms, it means reconciling in the best possible way the desired uses of the radio spectrum. Initially it was rather simple, as viewed from our vantage point of hindsight. But most things are that way. The usable radio spectrum has changed over the years from the first transmission across the Atlantic in 1901 on 328 kHz (915 metres), to the present complex of usable radio frequencies now extending up to 275,000 MHz, not including laser optical systems in use, and some other "electric" waves about which we know comparatively little. Consequently, the difficulty of the task of administering the spectrum has increased immensely since men began using wireless waves.

Probably the very first attempt at spectrum management occurred because the extremely wide bandwidth of early spark transmitters would blanket **everything** on **any** frequency within a hundred miles or more of the transmitter. The technique utilized to get a clear channel (when diplomacy failed) was merely to lay a book on the telegraph key so that no one else could hear any other signals. But a succession of disasters at sea, culminating with the loss of the Titanic in April 1912, brought forcefully to mind that such a technique was not really useful as a spectrum management tool.

It was 1903 when Prince Heinrich of Prussia, en route home from a visit to America, tried to send a courtesy message to President Theodore Roosevelt. He was refused service because the apparatus on board ship was of a different make than that of the shore station. That incident led to the first real attempt to manage the spectrum at the Berlin Conference of 1906, which was attended by representatives of 29 countries. The principal issues were, understandably,

- Obligatory communications regardless of the manufacturer of the equipment;
- Allocation of frequencies for public correspondence and maritime services,
- And agreement on the use of "S O S" as the distress signal.

Their discussions must have been totally foreign to the modern concept of spectrum management, which is judged by the criteria of bandwidth and signal-to-noise ratio required to transmit information at a given capacity in bits/second.

By 1912 progress in wireless communication had progressed to 479 coast stations and 2752 ship stations, of which 1964 were open to public correspondence. These developments led to the next radio conference in London in 1912, where three new services came into being:

- Radio beacons,
- Weather reports, and
- Time signals,

with frequency bands allocated to each. Such was the state of affairs in wireless at the beginning of WW-I in 1914. When nations next met, in Washington in 1927, three important scientific advances had been made in the field of radio:

- Broadcasting of radio programs had commenced;
- Radio sets had been installed in aircraft; and
- The frequency spectrum had been extended into the short waves above 3000 kHz primarily through the efforts of radio amateurs who had been denied the use of other frequencies.

Many of you in this room remember the thrills of those days when you finally got a UV200 or 201, a 210 or a 203, to oscillate on roughly 200 or 80 metres, or if you were lucky, on 40 metres; building your own chemical rectifier and filter, and gazing in awe at the Roller Smith hot wire ammeter (Model No. HWA-1041), which was **absolutely necessary** to measure your "radiation".

Herbert Hoover was chairman of that 1927 conference, and a most revolutionary procedure was adopted to use the English language as well as French, the traditional language of diplomacy. However, all delegates were cautioned to "use the privilege with discretion!" This was the beginning of the establishment of the official languages of the ITU, which now are English, French, and Spanish, with Russian and Chinese also included as working languages. In cases of dispute, the French text is still considered the official version. The work of the 1927 conference was so exhausting (it had nearly 2000 proposals before it) that it took what has proven to be a most important step in establishing a Consultative Committee which has withstood the test of time and is now known as the C.C.I.R. (from the French version of the title).

The usable frequency spectrum as then understood extended from 10 kHz to 60,000 kHz and the real difficulties of spectrum management had begun. After a table of frequency allocation was drawn up:

- How should the rights of conflicting parties be settled?
- If a station changed frequency or a new station started up which caused interference, which station had priority?

After lengthy discussions it was concluded that there was no possible way in practice to make adherence to the table of allocations obligatory. That principle is still true today as evidenced by the numerous reservations taken by many countries in the present International Radio Regulations, and the many transmissions which do not coincide with the Table of Allocations.

The period from 1932 up to the beginning of World War 2, encompassed two international conferences at Madrid and Cairo, where additional scientific developments were taken into account:

- Broadcasting had expanded into the short waves, as had also commercial interests and government stations which had "seen the light" uncovered by radio amateurs in their experiments;
- By 1934 there was a kind of radar in existence, and
- In 1936 the BBC in London was broadcasting a "high definition" television service using 180 lines, which had been received on this side of the Atlantic.

During these early days after broadcasting became established, the portion of the spectrum which gave most difficulty to allocation people was from 150-1500 kc/s. Little did they know what was to be the future of medium frequencies, later known as the standard broadcast band. As stations became more numerous, ways were sought to enable them to operate without causing undue mutual interference. One of the applicable techniques developed was the directional antenna, using vertical radiating elements with spacing, phasing and current ratios adjusted to produce the desired radiation fields in the wanted directions. The beginning of an era of consulting engineering was introduced by the installation in 1940 of such an antenna at WFLA in Tampa, Florida, by the late FCC Commissioner T. A. M. Craven, and Raymond Wilmotte. Since that time, the allocation, or assignment, of stations in the standard broadcast band has been on an engineering basis, with complicated directional arrays now in use by roughly 2500 AM broadcasting stations in this country.

Almost as soon as we realized congestion would become a future problem, we found the world engaged in another World War. In all countries involved in the scene of the struggle, terrible destruction of telecommunication facilities took place. Suffice to say that in France alone:

54,000 miles of overhead wires were down;
60 relay stations were destroyed;
30 cities had their underground cables cut;
110 telegraph offices lay in ruins;
50 submarine cables had been severed;
and of the original 42 French national broadcasting transmitters, only four were usable at the end of the war.

Wars are waste, however much they accelerate technological progress. During World War 2 more technical developments were made than in the entire previous history of telecommunication; which laid the base for everything that has occurred in spectrum management since that time.

Following the war, the Big Five powers met in Moscow to discuss preparation for the next international telecommunication conference, which had been recognized as absolutely essential to avoid utter chaos in peaceful applications of war-time developments. Only the United States was relatively unscathed by the war; and characteristically, we desired to use this advantage for the benefit of others. This led to the World Administrative Radio Conference, the Plenipotentiary Conference, and the first of a series of High Frequency Broadcast Conferences in 1947 at Atlantic City. Six hundred delegates from 76 countries attended to the post-war problems of the spectrum, not entirely aware of the tremendous added burdens to come into the scene with post-war developments and applications in the regions of the VHF, UHF and SHF. Television was still an experiment on VHF, but war-time radar techniques brought it into clear focus shortly after the end of hostilities. Fortunately for the United States, our government had recognized the impending spectrum utilization, and as early as 1944-45 before the war had ended, called General Allocation hearings on uses of the spectrum. This set the stage for the United States position at the Atlantic City WARC.

A significant problem of the post-war years, which still has not been solved, relates to international standards for television. At Atlantic City in 1947, delegates were unworried about the allocation of the spectrum from about 30 MHz to 10.5 GHz. They concluded that it could be allocated to radar, television, FM broadcasting and a few other "relatively minor services". What can happen even with considerable international liaison in our present world of telecommunication is typified by present television standards in use throughout the world. In the United Kingdom they use 405 lines on VHF, but on UHF they use the CCIR standard of 625 lines. In the United States we established our system using 525 lines, and the French use 819 lines. This perhaps wasn't so bad, although annoying, until along came color television. No other subject ever elicited such acrimonious debate among I.T.U. delegates as the subject of color television standards at meetings in Vienna in 1965 and Oslo, 1966. We had the NTSC simultaneous color system; the French had their SECAM systems; Germany introduced the PAL system; and Austria came up with what was called QUAM.

Some witty delegate coined some humorous descriptions for these systems which you might enjoy.

NTSC ... Never Twice the Same Color
SECAM ... System Elegante Contre L'Allemagne
PAL ... Pay for Additional Luxury
QUAM ... Quick Austrian Modification

So we not only have four different line standards but also different systems for encoding and transmitting color pictures. Fortunately the four mentioned (actually there were more) have been pared down to three. Every time you see a satellite picture coming from the European area, remember it had to start out with a different line scanning standard as well as a different color encoding system, and go through a standards converter in order for it to be seen on your color television set. I often marvel at the preservation of quality considering everything that has to be done. We have learned that spectrum management becomes dependent on technical standards. As you look at the various TV systems in use throughout the world we find great variations in such important parameters as channel width, spacing between sound and video carriers, width and attenuation of the vestigial sideband, type and polarity of modulation, ad infinitum. I mention these aspects only as examples of factors taken into account in considering how to use the spectrum. Other examples could practically fill a book, and still relate to only technical aspects.

Probably I should have stated initially that any attempt to comprehensively cover this subject would require much longer than you would like to listen. At this point we have just progressed beyond World War 2 and the technological revolution has just begun. You realize, I know, that any agency of the government which uses frequencies (and most of them do) has a group of spectrum managers overseeing their requirements. No agency can act alone in this field because of the interaction among the various uses of the spectrum. So there is a group of government spectrum managers called the Interdepartment Radio Advisory Committee (IRAC), which has existed since 1922 by various names. The broad main charter of this group is to take care of the frequency requirements of each agency of the government. The FCC is a liaison member, because its responsibility is to the civilian uses of radio, and therefore close coordination is required.

The IRAC has a membership of 16 departments or agencies, and three permanent subcommittees; Frequency Assignment, Spectrum Planning and Technical. The IRAC and its subcommittees are chaired by officials of the Office of Telecommunications Policy, whose Director is Dr. Clay T. Whitehead. The magnitude of the government's use of the spectrum almost staggers one's imagination. The dollar investment is over $50 billion; millions of transmitters are operating daily; government frequency assignments amount to about 120,000 and the number of governmental missions depending on radio is incalculable. No wonder such a group is required to exercise the President's responsibility in this area of spectrum management.

Although there are thousands of worthy post-war developments, I would choose the satellite as the one which will remain the outstanding example of technology covering a wide variety of fields. Satellite communication became a reality on July 10, 1962, a short ten years ago. TELSTAR I was designed and built by Bell Laboratories and launched by NASA in just 18 months. Its impact is still being felt throughout the world. Congress created the Communications Satellite Corporation three months after TELSTAR, and the international consortium known at INTELSAT now numbers 82 nations as members.

The evolution of international communications has proceeded rapidly through increased utilization of both cables and satellites. The INTELSAT system, now in fourth generation satellites, has increased its technological capacity from 240 voice circuits for INTELSAT I to 9000 such circuits in INTELSAT IV in the spot-beam mode, or 12 TV channels, or various combinations depending on modes, emissions and radiation configurations. In 1965 we had only two-point coverage over the Atlantic basin in the northern hemisphere, whereas today several satellites provide practically total coverage in the Atlantic, Pacific and Indian Ocean basins with more than 80 antennas at 64 earth stations in 49 countries. Technological investigations now under way indicate that whenever traffic volume justifies it, a new generation of satellites can be provided during the late 1970s capable of providing 20,000 to 30,000 voice circuits with a maximum degree of redundancy to achieve the highest standards of reliability and useful lifetime. Although evolution of cable capacity is not so dramatic as that of satellites, it has increased from 36 voice channels in the first cable authorized, to current and planned capacities of 3000 such channels or even higher, per cable. We now have cable connections from the United States to Europe via TAT-1 through 5, to Bermuda, Puerto Rico, Virgin Islands, Jamaica, Panama, Cuba, Hawaii, Japan, Hong Kong, Philippines and southeast Asia on to Australia.

Every service concerned with long distance and international communication has felt the impact of these achievements. Work in the CCIR, recent ITU conferences, and proceedings before the FCC emphasize that communications handled by the Fixed, Aeronautical and Maritime Services are either in process of transition now or are being planned for satellites in the near future. What happens to the HF spectrum which is currently allocated to these services? Well, obviously it will not mean a complete reduction of their HF spectrum allocation, because there will be a number of countries throughout the world without cable terminals and satellite earth stations. Such a major evolutionary development in communications makes it obvious that we must re-examine the utilization of the high frequency spectrum. The last over-all allocation from 3-30 MHz was in 1959 before we had a satellite system and prior to current cable expansion. Undoubtedly, new services and several old ones will clamor for more spectrum space.

The High Frequency Broadcast Service now assigns stations every 5 kHz, utilizing geographic sharing, time sharing, highly directional antennas, and restriction of maximum modulating frequencies to 6400 Hertz. They will want more bands; something like ten, probably 500 kHz wide. By 1980 it has been predicted that the Amateur population of the world will be between six and eight hundred thousand. Frequencies allocated to Amateurs have been gradually whittled away over the years, rather than increased, as with most other services; and if the prediction of their numbers should come even close to being true, they will desperately need additional spectrum space in the 3-30 MHz area. Large areas of the spectrum must not be pre-empted by stations moving into unoccupied regions of the spectrum in a haphazard manner. (Some of this is currently taking place.) That will only make the future administration of the spectrum more difficult. In my opinion, a study of the re-allocation of the HF spectrum will be inevitable. Services which have major blocks of HF spectrum allocated to them and which are going to cables and satellites with their traffic, will receive close scrutiny by the world's spectrum managers.

What does this mean to spectrum management? Well, in 1971 it meant a World Administrative Radio Conference specifically dealing with Space Telecommunication. Allocators now must think in new terms which ten years ago would have been foreign to their vocabulary except in specialized areas of communication. They now must deal with:

- Propagation effects on earth-space transmissions instead of just the usual phenomena of $F_2$ layer transmission, ducting, sporadic E, etc.;
- The atmosphere "window" through which signals pass without undue absorption;
- Signal levels in terms of $dBW/m^2$ of power flux density instead of signal strength in $\mu v/m$;
- Angle of elevation;
- Refraction phenomena;
- Scintillation and scatter;
- Doppler and Faraday effects;
- Station keeping of the satellite;
- Interference from the sun; and
- Echoes, noise temperature of the receiving system, and a host of others too numerous to list.

All problems of spectrum utilization are certainly not solved because we have a satellite system. The tremendous requirements for mobile communications by the countless users in the various Land-Mobile Services have led to extreme pressures on desirable regions of the VHF and UHF spectrum. Although frequency sharing has existed for years, our parochial system of frequency allocation has been by the block method. Within each allocated block, station assignments in particular services are made. But Land-Mobile needs more spectrum, which has been the subject of numerous papers, hearings, discussions, arguments and controversies over the past several years. Land-Mobile stations are now sharing certain of the UHF television channels under specified conditions. Still the growth continues and the squeeze on the spectrum has resulted in an attempt to bring modern technology into the Land-Mobile frequency management process.

No doubt many of you know about the spectrum management project which the Commission is now implementing in Chicago. This program will require building and maintenance of a complete administrative and technical data base containing the records of all the licences within a particular area. That data will be used as the FCC's automated record of the licenses, and will provide the engineering environment to enable making more optimum frequency assignments. The data bank will contain not only data from the Application Form 425, but also inputs from monitoring observations. There are differences of opinion whether sufficient benefits can be derived from such an endeavour to make the result positive in terms of cost-effectiveness. It requires considerable money to conduct such an operation. No one can predict yet with much reliability just how much more spectrum utilization can be obtained by these methods, nor at what cost per application or channel assignment. Only time will tell. For administrative purposes, plans and budgets are being prepared for extending the project into other areas of the country. Regardless of which side of the fence one may be inclined respecting this project, it is an attempt to utilize modern techniques involving magnetically stored data and a computer to improve the use which can be obtained from one area of the radio spectrum. It is a step in the right direction toward making a more effective value judgement of spectrum management. Its evaluation is awaited with interest.

There are always competing claims on the spectrum. There are five usually applied criteria in determining priority of use:

- Inability to use wirelines or other substitutes for radio;
- Contribution to maintaining safety of life and property;
- The number of people who would benefit;
- The demands of the public for the output of the service; and
- The technical suitability of the spectrum requested for the requirements of the service.

When all is said and done, and we have every transmitter on the right frequency operating in the best interests of its users, we have a lot of electromagnetic energy wafting around throughout the area here on earth where people live. You can't see it, but do you wonder if there are any effects on humans from all this electromagnetic energy to which we are all subjected? Is there any relationship between the known forms of radiation and those "waves" about which we know but little? There are some measurable side-effects of electromagnetic radiations:

- At 700 Hz we can produce electrical anaesthesia;
- Certain components of living cells in people are resonant in the aural and television broadcasting bands;
- We know that ants will align their antennae parallel to an electromagnetic field at 9 MHz;
- Radiation at 21 MHz increases the germination of gladiolus bulbs by 200%;
- Emissions at 27 MHz affect growing cells of garlic plants;
- You can kill bugs in bread with emissions at 29 MHz;
- Short exposure to energy in the 300-3000 MHz region expedites regrowth of severed nerve cells; and
- Radiations at 388 MHz are lethal to monkeys.

If one had the acumen to evaluate the present with the hindsight of the 802nd or 803rd person, I'm certain we would conclude that the science of communication is still in its infancy, despite the wondrous things that have come about. Perhaps certain of these unseen radiations will be discovered to be the catalyst which will enable people to communicate reliably by thought transmission. We know that some people have such limited powers now, although we don't understand yet the details of how it is done. There is much research in progress on the subject throughout the world.

After thousands of years of development in mechanical technology, we are now engaged in extending our thought transference by electromagnetic means throughout our globe. We are even probing outer space for some sign of life and intelligence there with which to communicate. If we do this, the final phase of the extension of mankind may well be, as Marshall McLuhan puts it,

> ". . . simulation of consciousness, when the creative process of knowing will be collectively and corporately extended to the whole of human society, much as we have already extended our senses and nerves by the various media . . ."

When that time arrives, God help the spectrum managers!

A.P. WALKER is the Chief of the Amateur and Citizens Division of the Federal Communications Commission in the U.S.A.

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# Mr. R. E. Butler Elected Deputy Secretary-General of ITU Conference.

Mr. Richard E. Butler of Australia has been elected to the post of Deputy Secretary-General of the Plenipotentiary Conference of the International Telecommunications Union (ITU) now meeting at Malaga, Spain.

Mr. Butler was elected by 78 votes out of 128. The Conference, which is the supreme organ of the ITU, is attended by 721 delegates, representing 143 countries.

Mr. Butler who was born in Australia on March 25, 1926 has served as Assistant Director-General of the Australian Post Office.

At the Post Office, Mr. Butler has also been adviser for International Relations, Planning, Investments and Inter-Governmental projects in telecommunications, as well as for the national services, including sound broadcasting and television. Mr. Butler took part in many Union conferences and in International negotiations connected with the conclusion of bilateral and multilateral agreements, particularly with regard to space Radiocommunications and submarine cable.

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# Colour Television Booklet for Society Members

The Council of Control of the Society is arranging for the publication and distribution of a booklet entitled "The Principles of Colour Television". This booklet, by D. Gosden, B.E., A.M.I.R.E.E. (Aust.), was originally published by the N.S.W. division of the Society, and distributed to members of that state. However, interest has been such in other State Divisions that the initial supply is now exhausted. Copies will be issued free of charge to Society members in Victoria, Queensland, South Australia and Tasmania. The Western Australian division has made other arrangements for making the information available to its members.

# The APO TV - Conferencing Facility

A. J. SEYLER, Dipl. Ing., M.E.E., D. Appl. Sc., F.I.R.E.E., H. BRUEGGEMANN, B.E. (Elec),
R. W. KETT, Dip. Comm. Eng., A.M.I.R.E.E., and J. DICKSON.

*In 1969 A.P.O. management decided that experimental studies should be undertaken to determine the human, technological and economic factors pertaining to the establishment of TV-conference facilities in the Australian telecommunication environment. This paper is intended to present the philosophy of approach, the technical implementation and the early operational experiences associated with the development of these facilities.*

*The validity of the human and technological approach, as apparent from favourable user feedbacks is already established; however, the economic viability of such a service is still to be ascertained by market studies which are currently in progress. Future technological and operational developments are expected to enhance TV-conferencing facilities as an integral part of developing Australian and eventually international telecommunication services.*

## INTRODUCTION

Telecommunications as we know it today, has developed over a period of some 100 years in two distinct streams:

- That of the "communicator" who provided for single subscribers the means of transmission and switching for any one subscriber to be connected bi-directionally with any other, one at a time; and
- That of the broadcaster who provided sources of sound and later pictorial matter and the means of transmitting such source programmes uni-directionally to many receivers simultaneously, regardless of and without effect on his system by the number of receivers that were in operation at a time.

This pattern of development has an obvious gap, namely, the absence of telecommunication facilities for a group of people to communicate with each other in a free-flowing open and mutual discussion.

Although provision is made in some telephone network operations for the setting-up of "teleconferences" between groups of individual subscribers, such facilities are at best a rather poor substitute for direct face-to-face meetings, because of the limitations imposed by the technical medium.

The next step with which a number of organisations have been and are still experimenting, has been to interconnect a group of people in one conference room with another group in a distant location by an open bi-directional sound channel. Although this type of teleconference was to provide telecommunication between groups of people, experience has shown that although information could be exchanged in some fashion, for this to happen, highly disciplined procedures had to be adopted and a strong-handed chairman was required to control the meeting. Typically such conferences tend to split up into "subconferences" within each room, since the presence of the physically separated group is not apparent, without the visual contact.

Thus the need became apparent to develop a "Television Conference" facility, through which audio-visual contact can be established over any distance between groups of people assembled in separate conference rooms.

When in 1969 the APO decided to undertake experimental studies in this field, the main guidelines were to develop a TV-Conference facility which provided an environment which, as closely as possible, resembled that of a conventional "board room". The presence of the television medium should have no effect on the free interaction of all participants, regardless of their location, i.e., whether they were in the same room or separated by the telecommunication medium. In other words, the medium was to be sufficiently inconspicuous for the "illusion of direct face-to-face contact" to be preserved.

At that time experimental studies of TV-Conference techniques were already pursued in Britain by the United Kingdom Post Office, which had progressed furthest towards an operational service under the designation "Confravision" (Ref. 1). Apart from the British work it was known that the Bell Telephone Laboratories in the U.S.A. and the N.T.T.P.C. in Japan were experimenting with TV-Conference techniques (Ref. 2, 3).

In this paper we report on the Australian developments which differ in important aspects from those found overseas. After a series of laboratory studies (Ref. 4), first two experimental conference terminals were established in Melbourne, one located in the Headquarters Engineering Division's offices at Bourke Street (Parkade) and the other in the administrative H.Q. Building "Communications House" at 199 William Street. Although the distance between the two locations was only about one mile, the TV-Conference facility was used quite frequently and routinely for actual meetings. User assessment was solicited by questionnaire being completed after each conference and minor technical improvements were made in consequence of user response.

Since September 1972, a third terminal has been taken into operation at Sydney, located in the GPO and intra-Departmental trials are in progress between this and the Melbourne terminal at William Street. Also, the first invited external customers are participating in these interstate trials in order to establish their response to this new service before commencing commercial operations.

## VIDEO FACILITIES

### General Considerations

The role played by the video installation in any TV conference facility design is not confined merely to the display of the far-end conferencees. The nature of the video installation is, to a greater extent, the determining factor in the choice of an optimum terminal layout. This is exemplified by the completely diverse terminal arrangements adopted by the BPO in their "Confravision" facility and by Bell Telephone Laboratories in their own experimental facility as well as in several Japanese installations.

In the former case, a simple single-camera, single monitor (which displays all of the five far-end conferencees) system requires an in-line seating arrangement of conferencees. In the latter case a more sophisticated, voice-switched (i.e., displaying speaking parties only) video system has resulted in a totally different layout. Here, six active participants are accommodated in pairs at three conference tables located at the vertices of an equilateral triangle with a monitor display of two of the far-end participants facing each table. The transmitted video signal is selected by a voice-switched operation from one of three cameras. This operation may have had its conceptual origin in the TV-studio, where the producer may switch between a number of operator-controlled cameras.

In both of these systems a single broadcast standard broadband TV link is employed each way.

Careful consideration to the advantages and shortcomings of the above schemes was given prior to the establishment of a TV conference facility within the APO. For reasons of operational economy it was decided at an early stage that the required transmission facilities should not be more than a two-way broadcast standard TV channel and a two-way (mono or stereo) audio channel and, furthermore, that a total of six active participants would be accommodated at each terminal.

The two most serious shortcomings of a voice-switched TV-conference system are considered to be:

- The inability to have continuous visual contact with all participants and thus to retain the freedom of choice to "look at" whomever one wishes to see, and
- The likelihood of confusion arising due to ill-timed display transitions and the irritation of frequent display changes in a lively discussion involving many speakers.

In view of these disadvantages we were, from the onset, conceptually inclined to prefer a configuration similar to that of the BPO. At the same time we were not prepared to accept the shortcomings of an in-line grouping of conferencees in conjunction with a single monitor - single camera video installation having the standard TV picture format. In such a display large picture areas are ineffectively used by displaying irrelevant material, viz., backdrop and foreground material above and below the row of conferencees. At the same time, the head-and-shoulders display of the individual conferencees becomes unduly small and difficult to resolve when their number exceeds three across the width of the picture.

The problem then was to find a way of utilising the picture area more effectively by ensuring that as much area as possible was used for the display of people.

Initial attempts to find a suitable alternative studio layout using only one camera and display screen failed to yield a satisfactory result. In these trials it was found difficult to simultaneously satisfy all of the following criteria:

- Comfortable seating for every participant;
- Equal size and optimum focussing for the display of every participant;
- A seating arrangement which would allow a discussion between all distant and local participants without unduly straining them (e.g., turning about to face another person was unacceptable).

Arrangements using a single camera and single monitor were therefore abandoned. From these studies a novel approach evolved which was to divide the total display into two half-height displays on closely adjacent picture monitors each showing three participants. This may be considered tantamount to changing the TV display format from a 4 : 3 aspect ratio to a 8 : $1\frac{1}{2}$ aspect ratio — the latter being considered more appropriate for a TV conference.

## Implementation

More explicitly, this technique may be better understood in terms of its implementation (see Fig. 1).

Two conference-mode cameras at each terminal scan a group of three conferencees such that the upper half-field (video A) of one and the lower half-field (video B) of the other contain the relevant material. The composite video signals from both cameras are then time-division multiplexed in a video switching unit (Transmit VSU) to produce a single composite video signal whose content is a stacked arrangement of the two groups of conferencees (this multiplexing operation requires that both cameras be driven from a common synchronising source). The signal is transmitted in this form.

At the remote terminal the received signal is processed in a complementary video switching unit (Receive VSU) to separate the two component half-fields. Fresh vertical synchronising information is added to each of the resulting signals (video D and video E) in order to locate them in the vertical centre of the two adjacent display monitors.

In addition to this conference mode of operation, a "graphics" mode was required for the presentation of documents, slides, transparencies and other visual aids material. For the transmission of graphics material the split picture operation as used in the conference mode is replaced by the conventional 4 : 3 aspect ratio more suited to the display of typical graphics (see Fig. 1). A special graphics console incorporating all of the functional components of the graphics facility into a single utilitarian entity has been included in both Melbourne and Sydney terminals.

Particular attention was given to the positioning of monitors and cameras. The display of the remote conferences was put in such a vertical and horizontal position that they appeared to sit on the opposite side of a large table. Thereby the optical axes of the cameras had to be positioned so that the vertical angle of these axes relative to the horizontal plane of the display arrangement was kept as small as possible; this way the impression of eye-to-eye contact was maintained.

Contrary to the installation of the BPO and others no continuous display of the local conference participants has been included. This kind of display, perhaps again adopted from TV-studio practice and which is equivalent to having a mirror in a conventional conference room, has the effect on some people to become self-conscious and "camera shy", leading to inhibited behaviour, being all the time reminded of the presence of the television medium. Instead, a "self-view" switch position has been included in the desk-mounted switching console (which is duplicated on a secretary's side table).

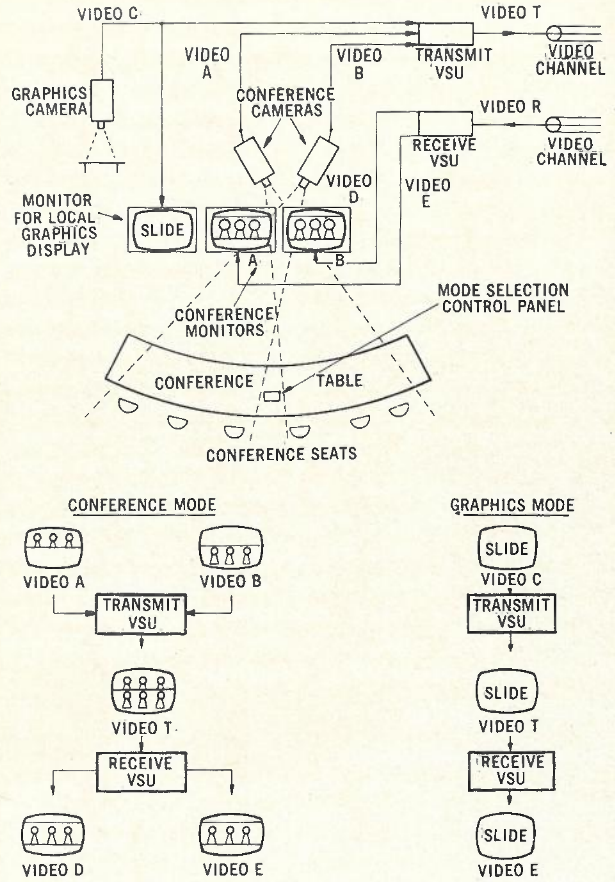


**Fig. 1—Operating Modes for TV Conference Facility.**

In this way, before the switching through to the remote location the proper seating of the participants can be readily checked and any adjustments can be made as required. Equally, should at any time during the conference, changes occur in the seating of the participants a brief self-view can be made without the opposite party being aware of this.

Another interesting point was found in the operation of the graphics facility. When a person is standing at the blackboard or in front of the display screen, where he can be seen by the conference participants through the graphics camera, it is necessary for him to look at the camera, that is, the people receiving the picture. In order to assist in this action two small display screens, showing the distant parties (in the stacked transmitting configuration), are placed close to the graphics camera.

As far as the video equipment used at each terminal is concerned it suffices to say that all components are commercially available off-the-shelf items except the video switching unit, which was designed, constructed and tested in the APO Research Laboratories (Ref. 5). Although vidicon TV cameras have been used throughout for reasons of economy and easy maintenance it is conceivable that terminals of the future will be equipped with higher quality units. The choice of camera for such a facility must, however, take into account the requirement of unattended operation during conferences.

Another aspect of the TV conference facility deserving brief comment in relation to the video installation is the lighting problem. It was considered of paramount importance to create an environment similar to that of a normal conference room. Trials showed that a direct frontal illumination of conferencees produced a good TV picture but also an intolerable eyestrain over longer periods. On the other hand, a conventional subdued fluorescent lighting from above, while providing a comfortable conferencing environment produced inferior television pictures by casting excessive shadows under eyes and chins, etc. A pleasing compromise found was a combination of overhead fluorescent lighting and a supplementary illumination of the conference table-top by a row of fluorescent tubes along the forward edge of the table. (This supplementary lighting must be designed so that the light source itself is not visible to the persons seated at the table, otherwise total reflection will occur on spectacles worn by some participants.)

In summing up, the following important aspects of the video installation of the APO facility deserve comment:

- Optimum use of monitor screen area for the display of conferencees has been made by dividing the total display into two half-frames of three conferencees each. This feature is believed to be unique to the APO facility.
- The choice of equipment used obviates the need for a technical attendant during conferences and minimises maintenance effort. In-conference operations such as the conference-graphics mode-changes are under the control of conferencees. For this purpose an easy-to-operate push-button console has been incorporated on the conference table.
- An effort has been made to create a natural conference environment by using a strain-free conventional lighting and by isolating the users from the hardware of the medium. All equipment is housed in a specially provided room adjacent to the conference area. The field of view of the

**Fig. 2—TV Conference Terminal, Melbourne.**

cameras is provided through a small slot in the partition between these two rooms.

An overall impression of the facility is given by the photograph, Fig. 2.

## AUDIO FACILITIES

### General Considerations

The requirement of a board-room atmosphere, into which the equipment did not intrude, imposed a number of constraints upon the audio design as well.

- The audio channels must be continuously open both ways; no form of manual or voice switching was acceptable;
- The microphones must be placed so as not to impede the participants' view of the display screens, nor hide their faces from the cameras;
- The participants must be able to speak at a voice level appropriate to a conference of twelve people;
- They should not be required to wear, hold or sit up close to the microphones;
- The received sound must be natural with respect to quality and loudness and acoustic feedback must not occur under any conditions of use;
- The acoustics must not be so dead that people unused to such an environment would feel uncomfortable, or have difficulty in pitching their voices comfortably;
- To ensure privacy the system must be stable and not require monitoring by an operator;
- The microphone placement must not restrict the use of the desk top for papers, etc.

### Control of Acoustic Feedback

If the microphone output was to be reasonably independent of how the participants sat in their chairs, it was evident that a reasonably long working distance would be required. Fig. 3 illustrates how, following an inverse square law, the sound pressure generated by a speaker varies with distance. If a nominal distance of 20 cm were used, a variation of plus or minus 10 cm would give a range of 9 dB in output, whereas at 60 cm it would give only 3 dB.

Placing two microphones to cover three participants, each at a distance of 60 cm from the second and fifth position, will give an overall output within 1.5 dB for all positions. This is a negligible variation compared with that between people and their manner of speaking. The microphones were suspended about 70 cm above the front edge of the desk, out of camera range.

This microphone arrangement, whilst giving the participants the required freedom, caused a critical problem with regard to acoustic feedback, as the microphone outputs required considerable amplification to give an adequate loudspeaker output. In addition, the intrinsic noise of the microphone amplifier input stages became significant. Fortunately, compared with the ambient noise levels in the rooms, due to people, air conditioning, etc., amplifier noise is barely detectable at the listening positions.

Fig. 4 shows a few of the paths involved in the acoustic feedback loop. The loudspeaker position is determined by its necessity to be close to the visual image for naturalness. To control feedback, loss must be introduced in each of these paths. Path A is controlled entirely by the directional properties of the microphone and path B by the absorption coefficient of the rear wall. All the other paths depend upon both the directionality of the microphone and the absorption of the reflecting surfaces involved. In practice, numerous other more complex paths exist and care must be taken not to deliberately introduce large reflective areas of material, e.g., blackboards, table tops, and the like.

If the overall frequency response of the feedback loop contains a prominent peak, this will determine the frequency and gain at which feedback will occur. To control the feedback, it will in such a case be necessary to reduce the overall gain, which in turn undesirably decreases the loudness at other frequencies. It is therefore desirable to use microphones and loudspeakers free from sharp resonances and design the acoustic environment similarly. This involves not only the acoustic properties of the room itself, but also the possible resonant vibration of objects within it. Offenders in this regard were found to be fluorescent lighting tubes, the steel legs of the table, the air-conditioning registers and the tightly stretched acoustically hard fabric of the six chairs at the desk.

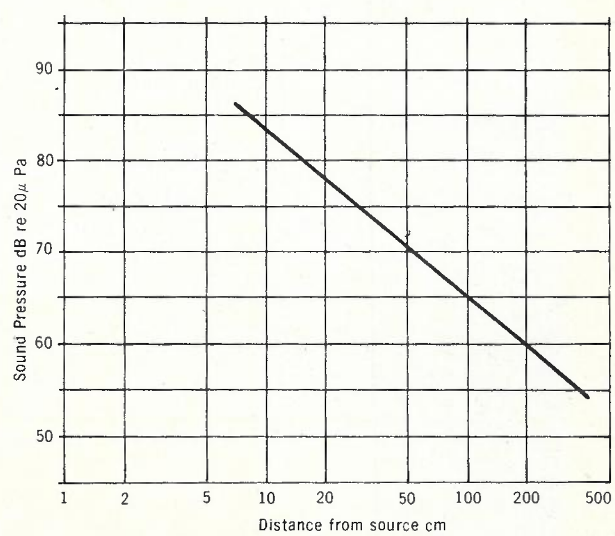


**Fig. 3—Sound Pressure v. Distance for Normal Speech.**

Further improvement in the feedback margin could have been obtained, to the extent of about 5 dB, by frequency shifting. Although this is acceptable for speech, it is generally not so for music, as it would destroy the harmonic relationships and therefore would sound discordant. It was felt that to impose such a limitation on the system might prove disadvantageous in some applications.

**Choice of Microphone and Loudspeaker**

With the requirements of directionality and smooth response in mind, a study was made of the published directional characteristics of a large number of good quality cardioid microphones. A minimum of loss at angles up to 45° from the axis, with a maximum loss at all greater angles and at all usable frequencies was desired.

It soon became apparent that many otherwise good microphones suffered from poor directionality between 45° and 135°. Fig. 5 depicts the comparative performance of a typical public address microphone with the studio microphone eventually used. In the region of 2500 Hz the public address microphone has hardly any directionality, even at 180°.

A column loudspeaker was used to direct the sound primarily in a horizontal plane to the listeners' ears, whilst avoiding the excitation of floor and ceiling reflections. A multicellular horn would have helped in controlling side wall reflections as well. However, to obtain an adequate low frequency response would have required a very large horn and this could not have been conveniently accommodated.

The driver units used in the column speaker were specially selected for their smooth frequency response.

A lavalier microphone was provided for the person operating the graphics unit, to give him mobility. This microphone, being mounted close to his mouth, may be operated with about 15 dB less gain than the desk microphones and may be taken close to the loudspeaker without causing feedback.

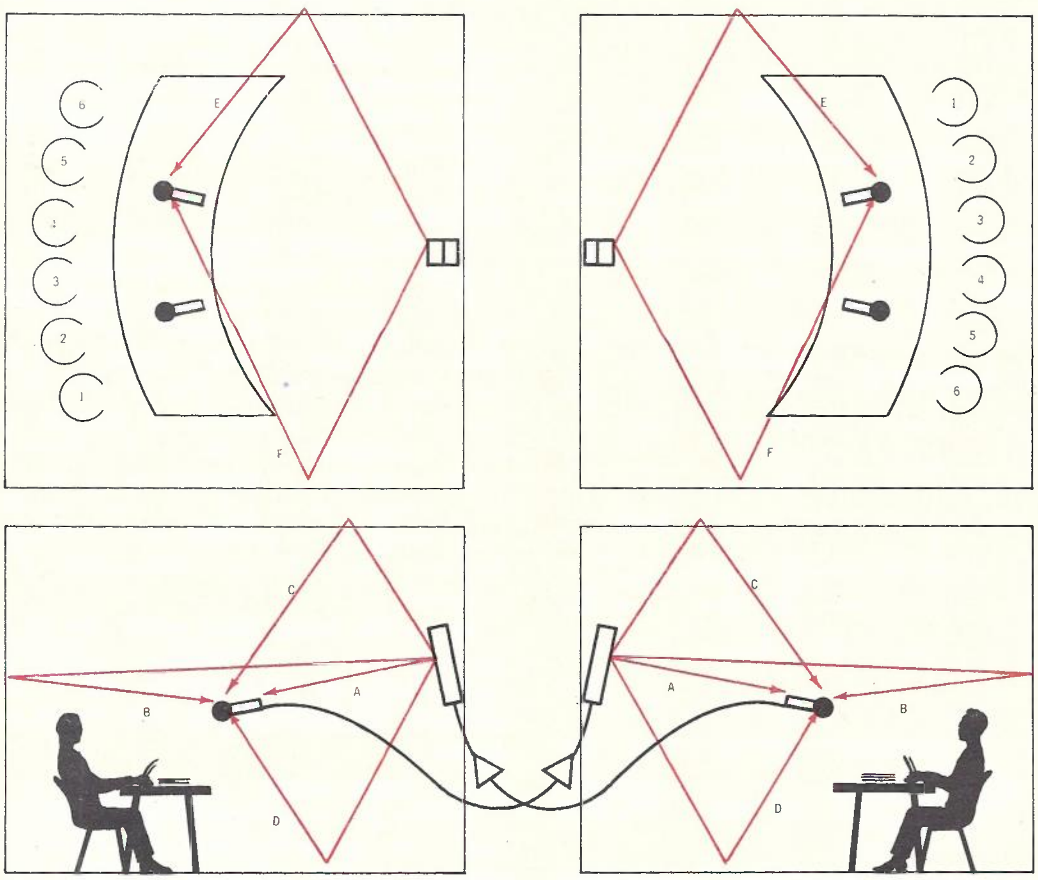


**Fig. 4—Acoustic Feedback Paths.**

## Acoustic treatment

Referring again to Fig 4, it will be seen that having obtained 20 dB loss in path A by means of a directional microphone, a similar loss must be introduced in the other paths. Paths C and D incur useful loss through the directionality of both microphones and loudspeaker and the side wall reflections E and F are partly reduced by the microphone. Path B is therefore the most critical and can only be controlled by absorption at the rear wall.

To be comparable with the 20 dB loss in path A requires that the rear wall have a reflection coefficient of the order of 0.1 over the usable frequency range. The services of Mr. G. Riley, an acoustical consultant, were secured to design the acoustic treatment.

He recommended, amongst other things, that the rear and side walls should be treated to give a reflection coefficient of 0.4 at 80 Hz to 0.1 over most of the range to 10,000 Hz. It is always difficult to obtain good absorption at low frequencies from a carpeted floor and achievable values of 0.4 above 500 Hz and 0.9 below were set for this surface.

To complement the wide band absorption so far stipulated, he recommended that the ceiling and control room wall should give an average reflection coefficient of 0.25 at low frequencies and 0.75 at high frequencies. It is desirable that these less critical areas provide some high frequency reflection, to enable participants to hear other persons in the room easily and to assist in pitching their own voices without strain. The reverberation time is therefore higher at these frequencies. A mid-range reverberation time of the order of 100 to 200 ms was aimed for.

To provide good listening conditions and reduce the need for high amplifier gain, air-conditioning and external noises were to be reduced to 30 dBA.

The desk was designed to provide a firm writing surface, whilst at the same time being acoustically transparent. As this would be the largest single piece of furniture in the room, it was felt highly desirable to avoid the use of large hard reflective surfaces.

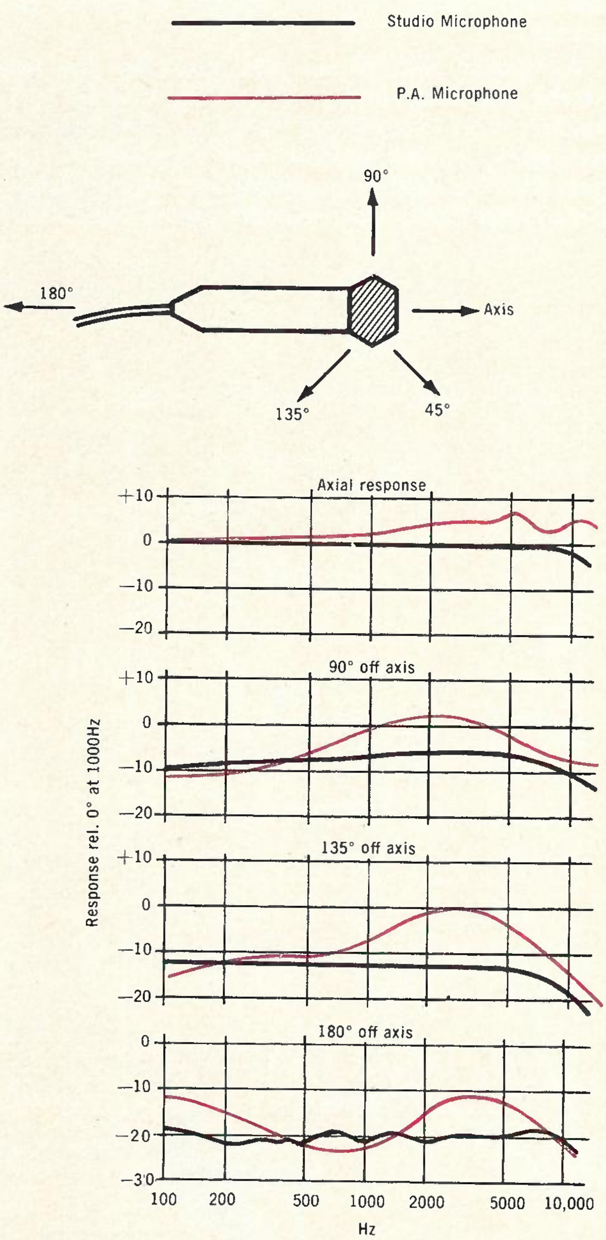


**Fig. 5—Comparison of Directional Characteristics of Microphones.**

## Equalisation.

In high quality sound systems, it is usual to emphasise the frequency range 2000 to 5000 Hz. The ear's maximum sensitivity occurs at 3500 Hz at low levels, but at higher levels, its response gradually becomes more uniform. If speech is reproduced at a level higher than it is normally heard, it lacks "presence" or naturalness unless such equalisation is used. In this installation, the reproduced level is comparable to normal speech in a meeting room and the room acoustics have been designed to provide some emphasis in this frequency range. Presence equalisation is therefore not used.

To reduce background noise and to overcome the slight rise in reverberation at low frequencies, some degree of roll-off below 100 Hz and above 5000 Hz has been used for the overall audio response.

## Use of Stereo Sound

During the experimental stage, an experiment was made, connecting each of the two desk microphones through individual amplifiers to separate loudspeakers beside the appropriate monitor screens at the distant terminal. A number of advantages quickly became apparent. Noises and side conversations could now be spatially located by the distant listeners and discriminated against. Also when a person started to speak, it was no longer necessary to visually scan six faces on the monitors; one naturally turned in the right direction. It was generally felt by users that stereo reproduction made the conference situation more natural and thus relaxed and it has therefore been adopted.

A difficulty however arises in interstate connections due to small slow phase shifts which may occur between the two transmission channels. These would be quite acceptable normally, but tend to shift the acoustic image, particularly of speakers in the middle seats. Therefore the sound channels must at all times be carried by the same transmission medium. A "sound-in-video" system is currently being developed and this technique should overcome any need for special operational conditions.

**Echo**

On very long connections, the time of transmission may reach a significant value. It is impossible to reduce the acoustic coupling at the distant studio by more than about 20 dB, and a person may thus hear an echo of his own voice. When this echo delay is of the order of 60 to 150 ms the effect on his co-ordination can be quite severe and he may not be able to speak coherently. For round-trip delays of about 500 ms, which occur in satellite circuits, 20 dB echo return loss would be considered objectionable but not necessarily leading to lack of coherence.

As a temporary expedient for use under such conditions, headphones may be used to replace the loudspeakers, thus breaking the acoustic return paths. In due course it is hoped that echo-cancellation techniques may render headphones unnecessary.

Between Melbourne and Sydney the echo has proved not to be noticeable, and it may be possible to operate throughout Australia without echo becoming objectionable. However, in overseas operations this will not be so and experiments are being planned in collaboration with the United Kingdom Post Office to study the associated problems and possible solutions.

**Additional Facilities**

Provision has been made to play previously recorded material into the system in both directions from either terminal. A splitting amplifier is used to avoid linking the two directions of travel. The local microphone is turned off in this mode, to break the secondary transmission path through the local loudspeaker causing unwanted reverberation. The proceedings may also be recorded at either terminal, the recorder being fed through high loss pads, again to avoid linking the two directions of transmission.

For the benefit of persons with impaired hearing, the headphones, which are of a lightweight design, may be replugged to provide an amplified combined transmit and receive signal. The user may control his own volume. Headphone outlets are provided at each of the six desk positions and at the graphics console.

To enable a local discussion to be held privately, if so desired, the chairman's control unit provides for switching off the outgoing audio signal.

**Amplifiers**

Plug-in modular broadcasting studio amplifiers have been used for ease of maintenance, especially in the case of a fault occurring during a conference. A mono output at the correct transmitting level is continuously available, so that should one of the stereo transmitting channels between terminals fail, the good channel can be quickly patched to carry a mono signal.

## OPERATIONAL AND COMMERCIAL ASPECTS

From an operational marketing point of view it is intended that the Sydney-Melbourne service should be used as a test facility by which to gauge the potential of TV-Conference services. This potential will, of course, be strongly dependent on the reaction of the business community and other users towards the concept of groups of people in voice and visual contact with each other, but being in widely separated locations, and conferring in an atmosphere which should closely resemble that of a normal boardroom environment.

Additionally, the APO is attempting to assess the number of hours, say, per week, that a service of this kind is likely to be used under differing charging rates on routes where video and audio links are readily available (even if unprotected) and on routes for which such links would have to be supplemented or specially provided. The requirement for simultaneous multipoint conferences will also be examined as a long term possibility.

To determine likely usage it was considered necessary to first establish interest in the facility and provide an opportunity for the business community to assess for themselves the general scope for conferring in this way. With this intention the Sydney-Melbourne service is offered to interested organisations at a nominal fee per hour, well below the charging rate that would need to be applied under actual commercial operation. This approach is seen, too, as a means for potential users to decide on the circumstances under which the facility would be the right medium for meaningful discussion between separately located groups.

The APO will also have the opportunity to evaluate the suitability of servicing procedures such as operating techniques, booking arrangements, receptionist service, accessibility of the terminals, parking requirements and the like and to gain an idea of how far user needs are met by the arrangements and facilities that are, or can be, made available at the conference terminals, e.g.:

- The number of participants on camera;
- The number of additional participants that can be accommodated outside the viewing area to support delegates;
- Display of diagrams, charts and other visual aids;
- Recording of proceedings;
- Telephone, telex, computer access and facsimile facilities.

The validity of the conceptual design approach and the sufficiency of the kind and range of facilities provided, can only be verified by using the service in actual conference situations, and not by demonstrations or artificially contrived experimental sessions. Only that way will the users be able to determine the circumstances under which a TV-Conference is a valid alternative to and offers advantages over the face-to-face conference.

The following benefits may be foreseen in that regard:

- Economics in travel/subsistence cost;
- Savings in executive time;
- Ability to call conferences at short notice;
- Attendance by otherwise heavily committed personnel;
- Eliminating effects of travel hazards, delay, late arrivals;
- Ability to conduct discussion with groups in several centres by sequential calls, or by simultaneous multipoint calls, within a short space of time.

Overseas reports of TV-Conference utilization indicate that the enumerable benefits, notwithstanding, customer response to the service offered is rather variable. For example, despite initial favourable marketing reaction in Britain, the demand for the BPO's public Confravision service which is operated between five cities, is still at a somewhat disappointing level.

On the other hand, in Japan, a private three-location installation on the island of Kiushu within a major steel works complex, is claimed to be used four hours a day on the average, although the distance between terminals is only between 8 and 13 km.

Factors operating against the use of the service are difficult to assess and may be of a subjective human nature or may be related to the choice of service parameters. Some likely factors that have emerged are:

- Preference for personal face-to-face contact;
- Preference for travel because of the opportunities for unforeseen social and business contacts;
- Convenient and pleasant travel facilities;
- Inherent conservatism of senior business executives;
- Insufficient publicity and inconvenience of booking arrangements;
- Need for security and confidentiality of communications;
- Wrong studio locations.

Apart from these factors the straightforward economical balance between value and cost of service to the customer is seen as being the factor which could most influence usage. The setting of tariffs is rather complex in that these will need to be related to the usage rate as well as taking into consideration capital cost of establishing the terminal studios, running charges for operating these, including arrangements for bookings, receptionist, parking, etc., and charges for the video and audio circuits interconnecting the terminals.

Our own observations so far are still not sufficiently extensive to permit a reliable assessment of the future development of this service in Australia. It should be reasonable to assume that there is great potential in this country, because of the long distances between the main business centres.

However, regardless of progress in the usage rate of the facility in the short term, it is desirable that the APO continue as it is in studying the human, technical and commercial implications, so that it will be properly prepared to meet demand as it develops to a commercially viable service.

It would be unrealistic to envisage, of course, that this means of conference making would do away with the need for face-to-face discussion; rather it should be seen as a desirable additional facility for use in the right circumstances. For example the TV-conference could prove advantageous when costly and time-consuming travel would otherwise be involved for a number of people to attend a rather short routine management conference or when the urgency of business requires an immediate and effective discussion between widely separated people.

In the longer term, once the concept is generally acknowledged as an acceptable medium of conference making in the right circumstances, one would envisage the possibility of large companies having their own TV-conference terminal, say at Head Office, through which access can be gained to Post Office transmission facilities and thus to other TV-conference terminals of their own or on Post Office premises.

With the increasing emphasis on the need for decentralization of industry and government operations, it should be expected that the provision of advanced telecommunication services, such as the TV-Conference, will become a significant factor contributing to the success of effective decentralization in the private as well as the public sector of the community.

## CONCLUSION

In the approach to the design of a TV-Conference facility the APO endeavoured to match, as far as was technically and economically feasible, the technical-environmental configuration to the needs of people. These needs can be stated in the most general fundamental terms, for facilities of telecommunication between people to be designed so that at all times the illusion of direct face-to-face communication should be preserved. Other than accepting McLuhan's "The Medium is the Message", it should be that the medium does not interfere with the message.

These were the guidelines which lead to the choice of the configurations of video and audio facilities and of the room architecture which are described in this paper. As for every engineering problem the eventual solution must always contain a compromise between what is feasible and what is ideally desirable in matching technology to human needs. In the end it will, however, be the acceptance of a new telecommunication service by the customer, which will decide whether this service is viable, and the final criterion for this acceptance will be the balance between the value and the cost of the service to the customer.

In order to determine the human validity of the design approach and the value/cost balance of the service, it was necessary to establish a service facility which provided a trial situation under realistic operational conditions.

That is why the trial installations had to be sufficiently well engineered, taking into account the human factors, and had to be in locations sufficiently far apart (Sydney-Melbourne) to represent an operationally realistic need.

We are aware that the technical implementation has been limited by the current state of the art in suitable hardware, especially on the display side. We are also aware that in the future, with the introduction of colour television, monochrome presentation might become unacceptable. Security of information in transmission will have to be further developed, not only of the audio, but also of the video signal, to obtain a higher degree of confidentiality. Transmission cost will have to be reduced by signal bandwidth compression (which would also significantly increase security) and the specific problem of acoustic echo on international satellite links will have to be solved. Simultaneous multi-location conference operations will have to be implemented and are expected to enhance the value of the service to some customers significantly (Ref. 6).

However, it is felt that the current implementatior is providing the APO with a national trial facility from which to take-off and by which, with customer co-operation, to develop a new service which must be expected to become more relevant as business, industry and government become more decentralized.

Moreover, it is hoped that the techniques and practices developed for the APO's facility will also serve as a model for private installations in large industrial and commercial organisations.


## ACKNOWLEDGEMENTS

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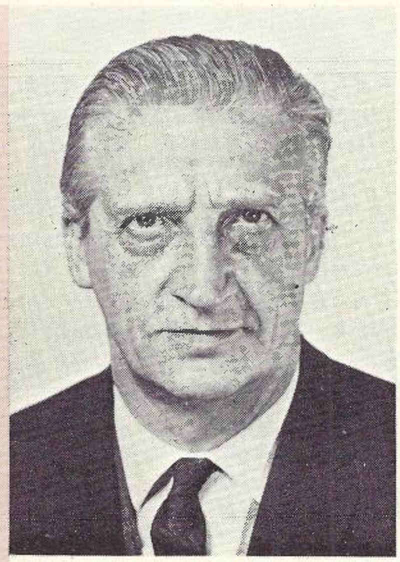

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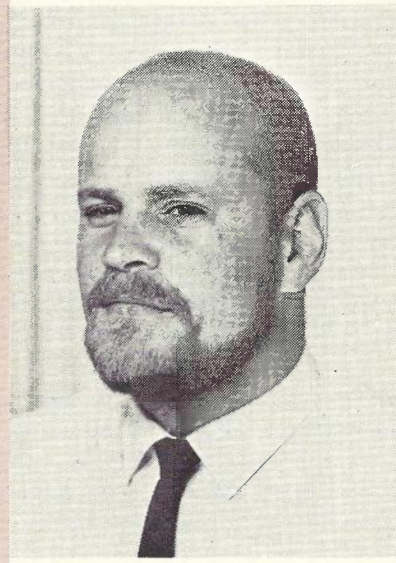

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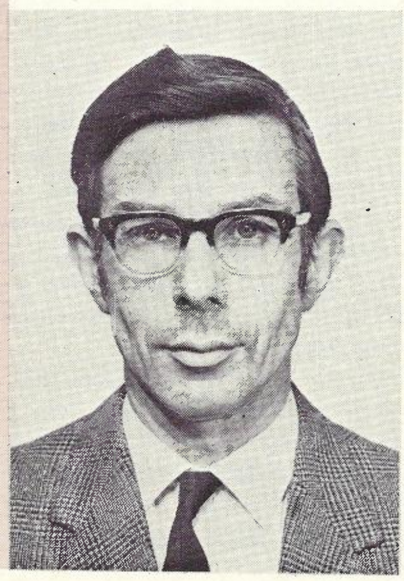

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# Technical News Item.

## ARMOURED TELEPHONE CABLES FOR HARBOUR CROSSINGS

It took precisely 5 minutes to lay two 466.3 metre-long heavy-wire-armoured Post Office cables across the bed of the Parramatta River. Two similar cables of 578.8 metres took 6 minutes to lay across Sydney Harbour—almost under the Harbour Bridge. In each case, when the project was completed, 1,200 new telephone channels had been provided.

Manufactured by Austral Standard Cables Pty. Ltd. at Liverpool, N.S.W., the 600 pair/0.64 mm (0.64 mm indicates the diameter of each conductor) cables were laid across the Harbour from Dawes Point to Milsons Point and across the Parramatta River from Drummoyne to Gladesville.

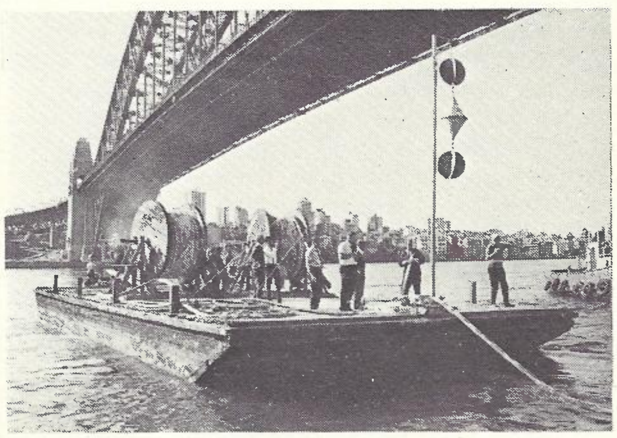
These submarine cables were waterproofed and armoured with 5.7 mm galvanised steel wire, each Harbour cable tipped the scales at 12 tons and the Parramatta River cables at 9 tons. The weight of the cables was sufficient to make them sink to the bottom and anchor within the narrow corridor set out by the Maritime Services Board. In both cases the cables were laid two at a time and each pair of cables jointed to a single 1,200/pair/0.64 mm PIUT Moisture Barrier cable at the crossing ends.

Low tide was chosen for the laying so that maximum access to each cable end was given, also with minimum current running the tendency to drag the cables from their surveyed path was reduced. Low tide was determined in a very scientific manner—the leading tugboat captain threw a stick into the water and watched its progress or lack of same.

The cables were anchored securely to one side of the crossing and laid off large drums or reels fastened to a barge which was towed by a tug. At the far side, the cable left on the drums was laid out on the deck of the barge, one at a time, to give access to the inner end, which was then winched into position.

To check the accuracy of the laying a diver actually walked across the Parramatta River and found that the two new cables were on top of previously laid cables. The cables across the Harbour were in water too deep for the diver to check, but measurement of the excess length at the completion of the job verified that these cables had been laid in a dead straight line.

Three more submarine crossings are required, these are, Iron Cove Bridge, Glebe Island and Pyrmont. These latter crossings are scheduled to be carried out in late August and early September and the whole project completed by October 1973.



**Beneath the Harbour Bridge; Payout of the Cable from the Barge Crossing the Harbour.**

# Microstrip Techniques for Microwave Radio

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*Current design philosophies appropriate to microwave and millimetre wave integrated-circuit network functions are outlined, illuminating the advantages to be gained in using a medium such as microstrip in preference to the conventional co-axial or hollow waveguide counterparts.*

*Some examples of typical applications are presented, and photographs of sub-system assemblies highlight the compact, miniaturised neatness which such a medium affords.*

## INTRODUCTION

The twentieth century will undoubtedly be heralded as a century of technological awakening, absorbing the energy and intrigue of enquiring minds of countless disciplines, all colligated with the one aim of understanding and utilising the forces of nature around us. A typical example of the fortitude and tenacity with which scientists and engineers have responded to this challenge has been in the harnessing of the electromagnetic spectrum, by which the slow but steady uphill climb of the frequency scale has availed and continues to release virgin channel-space to a communication-hungry world. The present day sees us on the brink of bridging the gap between microwave and the infrared frequencies, whilst tomorrow will probably see the development of coherent sources in the ultra-violet and X-ray regions.

Motivations for the exploration of higher and higher practicable user frequencies stem from the ever-increasing demand evident in the trend of world communication needs for increased bandwidth of video and data transmission, along with the imminent volume markets associated with automobile braking systems, surveillance, warning, detection systems, and so on. Even in the concept of the "wired city", and community antenna relay services, space transmission may have a part to play.

The past decade or so has seen some phenomenal strides in the development of active devices such as Gunn, Impatt and varactor diodes in anticipation of the predicted demand at millimetre wavelengths, whilst transistors have been produced to operate up to 10 GHz. At microwave and millimetre wave frequencies the present state-of-the-art is to fabricate passive circuitry on dielectric substrates by thin-film techniques controlled to almost integrated circuit requirements, which is a necessity imposed by the very critical geometrical tolerances at such high frequencies. Active devices, in chip form, are then bonded into these passive circuits to create the now familiar hybrid or microwave integrated circuit (MIC). The logical allusion is, of course, to the next step of complete integration of MICs, fabricating an entity of passive and active circuitry on the single semiconductor substrate, and thereby creating all the advantages associated with integrated circuits at lower frequencies. However, it is within the context of hybrid circuitry that this article is intended, and for this reason it is proposed to introduce the design philosophy and practices in current vogue, restricting attention mainly to passive circuitry, which provides an excellent insight into the understanding of such network techniques, which rely heavily on conceptions of guided waves and fields, and their distributed or lumped electrical equivalences.

## MICROSTRIP — THE BASIC BUILDING BLOCK

### Fabrication

Most microwave integrated circuits are fabricated on either plastic-based or ceramic substrates. The dielectric constants of plastic-based substrate materials are in the range 2-3 while those of the ceramic substrates are from 9-12.

There are a variety of different strip transmission line structures that are available to the microwave circuit designer. Fig. 1(a) illustrates the symmetrical balanced stripline which was the first form of microwave stripline to receive general acceptance. The plastic-based substrates are most often used with this type of line. The advantages of balanced stripline include ease of design, a high degree of mode purity, and high circuit isolation. The major disadvantage of balanced stripline is the difficulty involved in integrating semiconductor devices and chip resistors and capacitors within the structure. Therefore, the balanced stripline has been employed mainly in the field of passive components, particularly filters and directional couplers.

In Fig. 1(b), the microstrip transmission line is shown. A major advantage of microstrip is its small size, due to the use of high dielectric constant ceramic substrates, which reduce line dimensioning by a factor of about three from the equivalent construction in air. This results in a component which has a small volume compared with the coaxial or waveguide equivalent. Substrates which have received widespread acceptance by the microwave engineering community are those of alumina with a dielectric constant, $\epsilon_r$, of 9.7 and standard thicknesses of 0.64 mm (.025") and 0.25 mm (.010"). Alumina can be obtained to a high degree of purity and isotropy in 2.5 cm square samples ground to a surface finish of 50 nanometre rms. Other materials have also been exploited to advantage. See, for example, Ref. 2. Another important advantage of microstrip is that its open-sided planar structure permits the mounting of semiconductors and lumped elements with little difficulty and also enables the designer to tune and adjust the circuit after fabrication.

A third type of MIC transmission line is shown in Fig. 1(c). This type is called the inverted microstrip line and is one of a class of inverted and suspended microstrip lines. The main advantage of this structure is that shunt mounting of solid state devices is facilitated. The air gap also has the effect of reducing the effective dielectric constant.

The practical advantages of the microstrip line have resulted in it being the most popular transmission line structure for MICs. Consequently, the remainder of this paper will deal solely with microstrip circuitry.

**Propagation Modes**

Unlike the balanced stripline, the fundamental mode of propagation along a microstrip line is not a pure transverse electromagnetic (TEM) wave. Although this mode exhibits TEM behaviour at the lower microwave frequencies, it is actually a hybrid mode consisting of field components in all coordinate directions, a result directly attributable to the inhomogeneity of the medium.

At frequencies up to a few GHz, the assumption of pure TEM propagation leads to little error. The exact analytic derivation of the transmission line parameters is not possible. However, Wheeler (Ref. 1) has used an approximate conformal mapping technique to derive approximate formulae for the impedance and guide wavelength in terms of the line dimensions (W/H) and dielectric constant ($\epsilon_r$). Wheeler's formulae are accurate to within one or

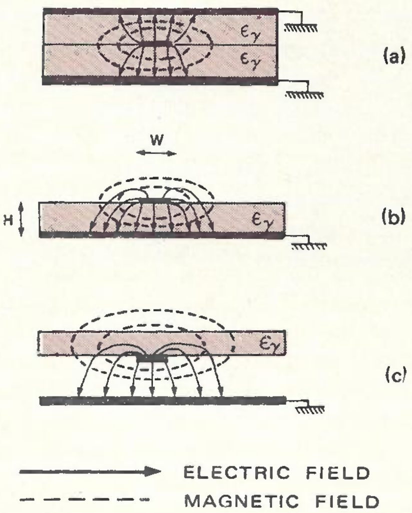


**Fig. 1 — Cross-Section of Some Types of Strip Transmission Lines.**

**(a) Strip Line.**

**(b) Microstrip Line.**

**(c) Inverted Microstrip Line.**

two percent at low microwave frequencies, and have been widely used.

At higher microwave frequencies, the hybrid fundamental mode causes the phase velocity to decrease with frequency, whereby an increasing portion of the total field becomes confined to the dielectric region. This departure from TEM behaviour, or dispersion, is of the order of a few percent at 10 GHz for alumina substrates and thus must be accounted for in the design of network elements that are critically dependent on electrical length. The phenomenon of dispersion is insoluble as an analytical problem. However, modern computing facilities have enabled numerical solutions of this problem to be obtained within requisite engineering tolerances and samples of this approach are given in Refs. 3, 4 and 5.

**Coupled Microstrip Lines**

The pair of coupled microstrip lines, a cross-section of which is illustrated in Fig. 2, serves to transfer a prescribed fraction of the forward propagating wave from one microstrip line to the other, via the electromagnetic coupling between the strips, and has its applications in such devices as power splitters, feedback circuits, monitors of propagated power, side-coupled filters, etc. The fraction of coupled power is

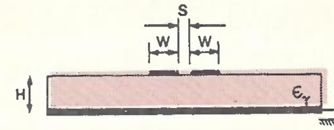


**Fig. 2 — Pair of Coupled Microstrip Lines.**

dependent on the gap spacing, S, and the length of coupled section employed for a particular substrate material over any given frequency range. The fundamental propagating mode of a single microstrip line, upon entering a coupled region, splits into two orthogonal modes, necessary to comply with symmetry requirements, designated the even- and odd-modes. This behaviour is demonstrated simply in Figs. 3(a) and (b) in which the signal incident on line 1, of amplitude 2A, decomposes into odd and even components in the coupled region. The amplitudes of the waves emerging from the region when lines 1 and 2 diverge from each other can be obtained from a knowledge of the odd- and even-mode impedance and phase velocities (Refs. 6, 7), and each of these emergent waves becomes once again the single-line microstrip mode.

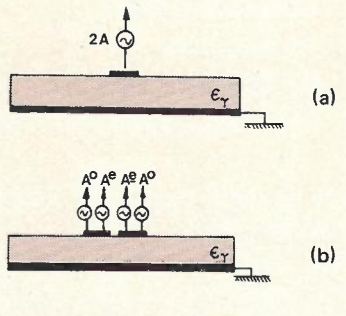


**Fig. 3 — (a) Incident Signal on Single Line.**
**(b) Component Signals in Coupled Region.**

The attenuation suffered by the guided waves in a microstrip medium are of the order of .04 dB/cm for a single 50 Ω line (Ref. 8), and in the case of a pair of coupled lines the even mode is about the same, whilst the odd-mode can be as high as 1dB/cm (Ref. 9). The attenuation is due mainly to copper losses encountered in the conducting strips and ground planes, and represents the most detracting feature of a microstrip medium. This inconvenience is to some extent alleviated by the vast reduction in circuit size over conventional hollow waveguide counterparts, although the barrier to highly stable cavity sources still remains.

## CIRCUIT DESIGN

The wealth of information already available on the analysis and synthesis of transmission line networks can be used directly in the design of microstrip circuits such as directional couplers, mixers, filters, equalisers and impedance matching networks.

Some simple examples of the conductor configurations applicable to particular network functions are shown in Figs. 4, which depict the upper conductor patterns only. Figs. 4(a) and (b) represent 3 dB couplers of the rat-race and branch-line type, respectively, and have applications in balanced mixers, frequency discriminators, and phase shifters. In operation, a signal incident at port 1 of the rat-race coupler produces outputs 180° out of phase at ports 2 and 4, whilst those incident at port 3 produce in-phase outputs. These outputs of ports 2 and 4 are then presented to diode mixing stages, or

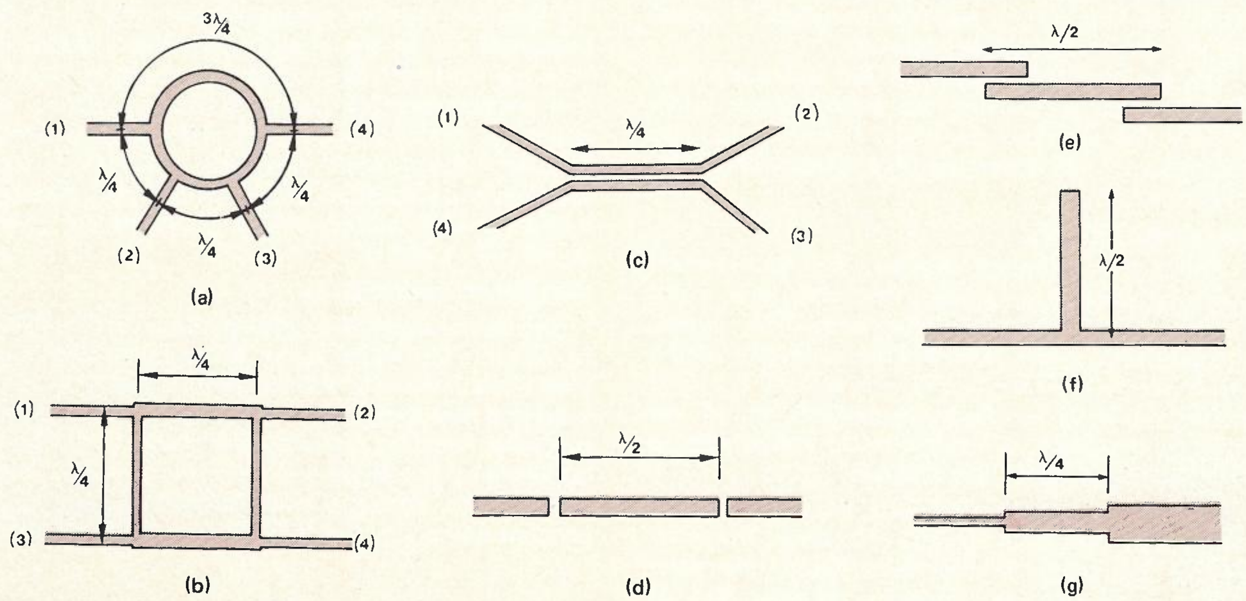


**Fig. 4 — (a) 3 dB Rat-Race Coupler.**
**(b) 3 dB Branch-Line Coupler.**
**(c) Parallel-Coupled Coupler.**
**(d) End-Coupled Filter.**
**(e) Side-Coupled Filter.**
**(f) Stub-Line Filter.**
**(g) Impedance Transformer.**

whatever the next signal processing requirement is. In the branch line coupler, a signal incident at port 1 produces outputs at terminals 2 and 4 which are equal in amplitude but differ in phase by 90°. The widths (and hence impedances) of the constituent lines are adjusted to comply with these properties and the suitability of either coupler, the number of branches, etc., depends on the requirements of VSWR, isolation, and insertion loss.

Fig. 4(c) shows a directional coupler providing D.C. isolation between output ports. This is of the coupled section type, and the length of coupled region is made $\lambda/4$ to minimise the interaction of reflections caused by discontinuities. Here again the even- and odd-mode impedance levels, and the number of cascaded coupled sections are dictated by the design prescription.

Fig. 4(d) demonstrates the basic filtering action of an end-coupled filter, in which a maximum of transmission occurs when the isolated resonator is $\lambda/2$ long. Coupling to and from this resonator is capacitative and is achieved by the gaps shown. Any number of sections may be used, of varying impedances, each coupled to the other by similar designed lengths of gaps, and particular responses can be tailored by means of standard filter design formulae such as those given in Ref. 10. The side-coupled version of the filter, of Fig. 4(e), not only relieves the tolerances on coupling gaps, but also serves to compress the physical length of such filters. Stub-line filters, the basic component of which is shown in Fig. 4(f) rely, for their rejection, on the reactance slope looking into an open-circuited stub and have thus found applications in broad-band filter design. A succession of open-circuited stubs, usually spaced $\lambda/4$ apart along the propagating line are normally fabricated to the desired response, although some efforts have produced filters of non-commensurate stub lengths and separations, designed by numerical optimal search routines.

The microstrip version of the $\lambda/4$ impedance transformer is depicted in Fig. 4(g), and this can be broadbanded by using a succession of impedance steps, using $\lambda/4$ sections of intermediate widths.

For a successful accomplishment of the above circuit functions the peculiarities in design relevant to a microstrip medium must be pointed out at this stage, and these can be summed up by the terms discontinuities and dispersion. Discontinuities in the path of the forward propagating wave are evident in all of the above circuits, and serve to create a local excitation of higher-order non-propagating modes other than the fundamental. This reactive condition of effective energy storage can be accounted for in the design by introducing the lumped energy storage elements of inductance and capacitance into the distributed transmission-line equivalent networks relevant to such configurations as Figs. 4. In practical terms, the example of the open-circuited end of the stub of Fig 4(f) can be visualised as comprising a shunt discontinuity capacitance associated with a fringing of electric field lines extending beyond the physical end of the stub. The impedance steps in the transformer of Fig. 4(g) cause a local distortion of current path, and hence magnetic field and an inductive effect, with the additional superposition of a capacitative effect associated with electrical fringing. Similar considerations are due for 'T' junctions and any other form of discontinuity occurring, such as right-angled bends which profuse in the interconnection of individual circuits. Translating discontinuity effects into distributed circuit nomenclature causes a displacement between electrical and physical reference planes, for which drastic consequences of ignorance would result, as will be demonstrated shortly.

Dispersion has been mentioned previously, and must also be accommodated in the design, particularly in cases where electrical length is critical, if the correct centre frequency of operation of any of the devices, say, in Fig. 4, is to ensue.

As a typical case study of the effects of discontinuities and dispersion at microwave frequencies, a five-stub band-pass filter was designed and fabricated in microstrip from standard design data available in Ref. 10. The final form of the upper conductor circuitry is shown in Fig. 5 where the stubs are arranged alternately along the centre strip to avoid coupling effects. The outcome of analyses of insertion loss both without and with account of dispersion and the 'T' junction and end-effect discontinuities is shown in Fig. 6, and can be seen to clearly indicate the importance of these effects, by the evidence of some 10% difference in the centre frequency of operation. Measured response of the filter is also shown in Fig. 6, and further demonstrates the effects of conductor losses in the pass band.

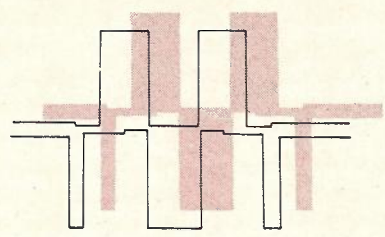


**Fig. 5 — Five-Stub Bandpass Filter.**

## PRACTICAL EXAMPLES

To illustrate the practical realization of some of the microstrip configurations mentioned in the previous section, two MICs designed and fabricated

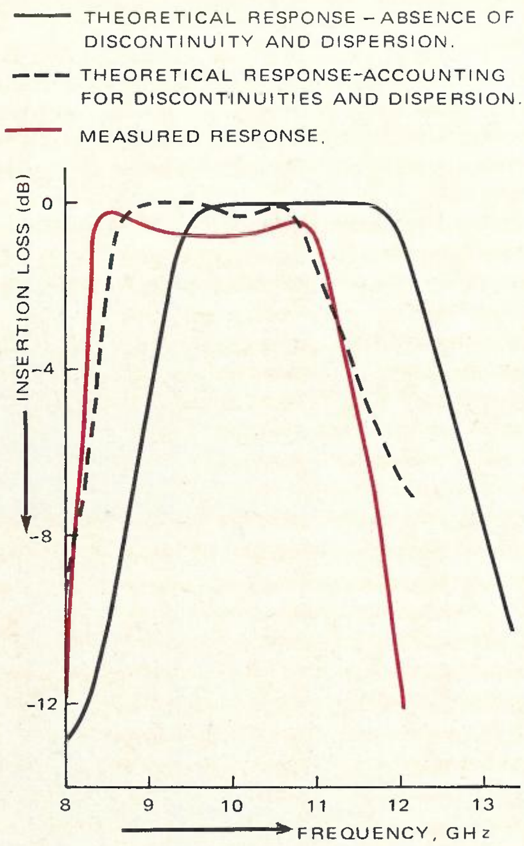


**Fig. 6 — Response of the Filter.**

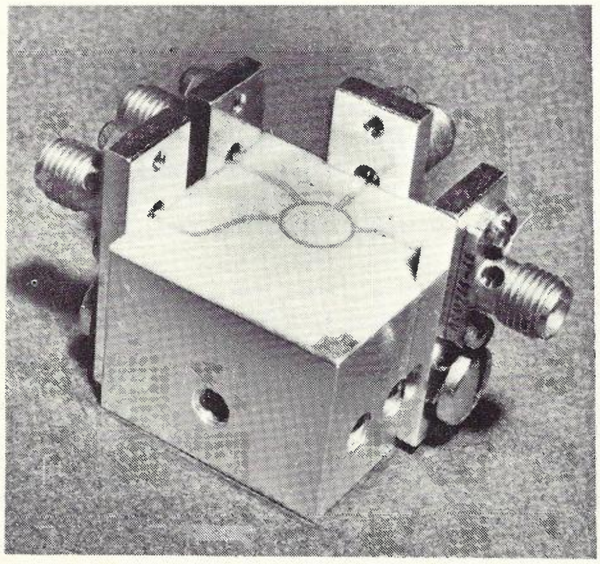

**Fig. 7 — Hybrid Ring.**

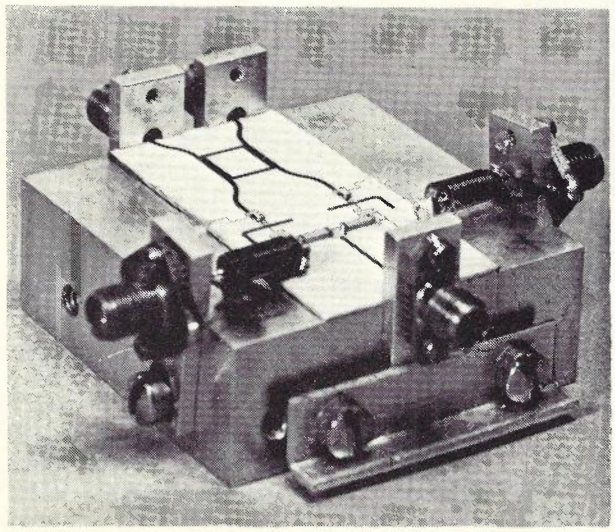

**Fig. 8 — Balanced Mixer.**

at the APO Research Laboratories will now be discussed.

Fig. 7 shows a hybrid ring or rat-race fabricated on a 2.5 cm square alumina substrate. This device finds application as an isolator or power splitter. The centre frequency is 8 GHz, the isolation is 40 dB and the input VSWR over a 5 percent bandwidth is less than 1.1.

A good example of the miniaturization that can be achieved with microstrip is the broad-band balanced mixer shown in Fig. 8. This 4 GHz mixer has an insertion loss of 7 dB and a VSWR less than 1.4 over a 500 MHz bandwidth. The 3 dB branch line coupler at the input can be clearly seen.. Beam lead Schottky barrier diodes are series mounted on the output arms of the coupler. The whole circuit was fabricated on a 5 cm by 2.5 cm alumina substrate.

## CONCLUSION

In conclusion, an introduction to design philosophy of networks of current research interest in the communications field has been disseminated with the aid of simple, practical examples. References have been furnished for a deeper involvement, although these only represent a selected small fraction of what has now become an extensive volume of literature available to the designer of MICs.

The peculiarities in design using the microstrip medium have been pointed out, and the typical effects of discontinuities and dispersion highlighted in the synthesis of a multistub filter.

Finally, examples of the end product have been photographed to animate the description of previous sections, and provide the reader with a first-hand observation of microstrip circuitry.

## ACKNOWLEDGEMENTS

The synthesis and analysis of the five-stub filter described were performed by Mr. Him Leung and

Mr. Peng Kwan Loke, respectively. The hybrid ring was designed and fabricated by Mr. J. Hubregtse, and the 4 GHz balanced mixer was designed by Mr. A. J. Bundrock.

The authors are grateful to Dr. A. Seyler and Dr. W. J. Williamson for their encouragement of this field of study.

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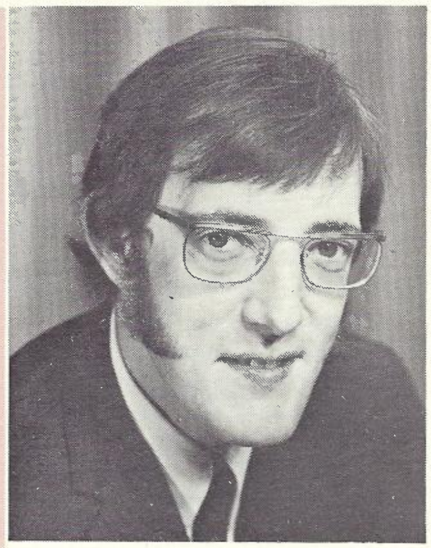


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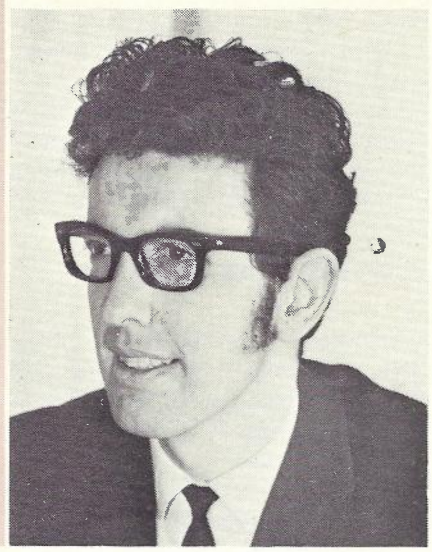
From 1968 to 1970, he undertook research in the field of computer-aided design and piecewise–linear and nonlinear networks for which he received the degree of Doctor of Philosophy from the University of Melbourne.

In 1971 he was employed at the APO Research Laboratories on the design of solid state microwave sources. During the past year he has been involved in research in the area of high speed detectors for optical communications.

# Development of Nylon Jacketed Telephone Cable Resistant to Insect Attack

R. A. CLARK, B.E. and G. FLATAU

*The field and laboratory testing of the protection against insect attack offered by cables jacketed with nylon are discussed. These tests led to the use of NYLON 11 and NYLON 12. Production problems cable diameter restrictions, and results of widespread field usage of nylon jacketed cable in Australia over more than five years are described.*

**Editorial Note: This article was delivered as a paper by the authors to the 21st International Wire and Cable Symposium 1972.**

## INTRODUCTION

Insect attack on underground telephone cable, in particular plastic sheathed cable, has been of sufficient economic importance in the Australian Post Office (A.P.O.) network, for a solution to the problem to promise worthwhile savings, and as a consequence of an investigational program dating back to the early 1950's nylon jacketing has been developed and shown to give complete protection. The special problems faced by the A.P.O. due to the vast range of climatic conditions traversed by its telephone network, and the aggressiveness of its termite and ant fauna, have been described in a previous paper to this symposium (Ref. 1). At that time (1966) it was concluded that adequate protection of plastic sheathed cable, the sheathing material for underground use in the A.P.O. being polyethylene, could only be provided by a metallic barrier, although some polymeric materials such as nylon and acetal showed sufficient promise to warrant more detailed investigation.

This paper will discuss the test program which led to the adoption of Nylon 11 and 12 as acceptable jacketing materials, and describe the problems encountered in the development of a range of insect resistant cables.

## EVALUATION OF INSECT RESISTANCE

### Earlier Work

As already mentioned, by 1966 the A.P.O. had established that immunity from termite and ant attack, to the degree considered essential, could be provided by metal tapes or barriers and that some plastic materials used as jackets over the conventional polythene sheath warranted further study. In addition soil treatment with Dieldrin was meeting with good success in some areas of the country and offered an alternative means of protection. On further consideration, the use of metal tapes was rejected not only on economic grounds, but also because there was concern regarding the possibility of corrosion damage which could still provide the insects with an eventual entry point. There was also some doubt whether soil treatment would give protection over the required 20-40 years of cable life in all climatic environments, particularly in the tropical rainfall areas, but an even more powerful objection was the possible ecological damage which could be caused by treated soils in cultivated or grazing areas and the possible health hazard, mostly due to careless handling, to operating staff.

### Nylon 11

Some early tests (Ref. 2) had shown that Nylon 6 and 6.6 applied as a 0.25 mm jacket, whilst promising, were liable to blister and/or delaminate and that insects could thus gain access to the underlying polythene sheath via cracks in the jacket. It seemed evident that the delamination process was largely due to moisture absorption, and consequently a nylon with much lower moisture absorption properties was required. The optimum material then available was Nylon 11, and hence trial quantities of polythene sheathed cable, with a 0.75 mm thick outer jacket of Nylon 11 were ordered from Australian cable manufacturers. Samples of this cable, together with various other experimental cable constructions, were installed in test plots in the Darwin area from 1964 onwards. In common with most of our previous tests, this program was designed to evaluate the resistance to termite attack, as controlled testing with ants had not met anywhere with much success. However the assumption that any material able to withstand the depredation of the giant termite MASTOTERMES DARWINIENSIS would be able to resist attack by ants, is considered reasonable.

In these tests samples were buried vertically, to a depth of 30-35 cm, in two different types of test plot lay-outs. One was similar to the type used successfully in previous work where the samples, attached to wooden pegs, are arranged in an array of horizontal rows and columns joined by timber laths whose purpose is to lure the termites into the test area. The second type of plot used in the 1964 trials, still retained the pegs and laths arrangement, but these were now arranged in a rough circle around the mound of a termite species known to attack cables, the theory being that the termites on their normal food gathering excursions would have to pass through, and possibly attack, the sample perimeter (see Fig. 1). Sufficient samples were installed to permit the withdrawal of replicates at roughly yearly intervals for 3 or 4 years. At a later stage of the field trials, some samples of nylon 610 and acetal co-polymer jacketed cables were introduced into some of the test plots.

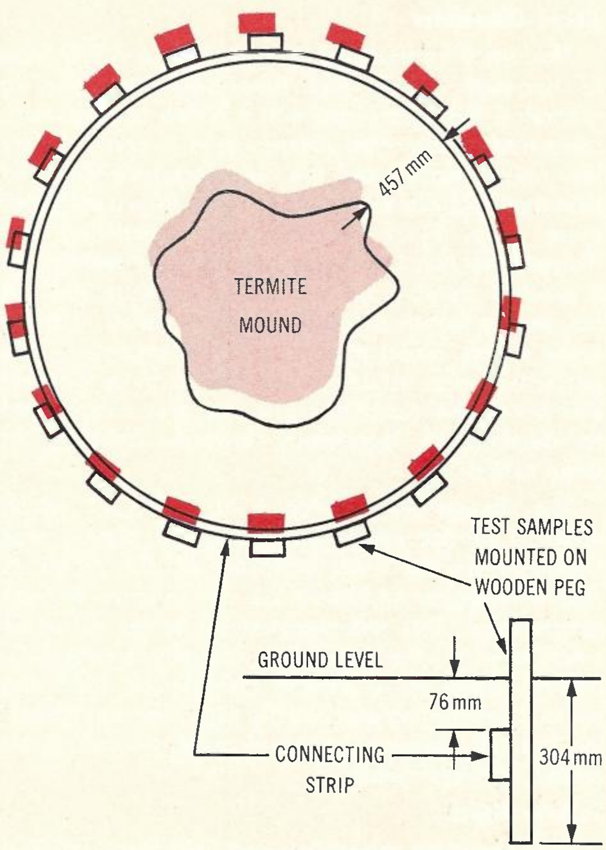



**Fig. 1 — Test Plot, Type 2.**

**Laboratory Evaluations**

All sample materials were also submitted to the Commonwealth Scientific and Industrial Research Organisation's (C.S.I.R.O.) Division of Entomology, for Laboratory evaluation. This organisation has perfected methods which enable the resistance and/or toxicity of materials to be tested against various species of termites under controlled experimental conditions (Ref. 3) in the laboratory, and in addition they maintain extensive field testing facilities in Northern Queensland where Mastotermes Darwiniensis termites, which are not amenable to laboratory conditions, are prevalent.

**Test Results**

The test program terminated in 1968, and the results (Ref. 4) made it evident that Nylon 11 provided excellent protection from termite attack, and in fact no damage was recorded with any of the specimens exposed for up to 36 months. The results with acetal co-polymer, though only limited in scale, were also quite promising as were those with Nylon 610, although in the latter case, possibly due to the surface roughness of the experimental samples, there had been some minor, shallow attack. It is interesting to note that the laboratory tests demonstrated that all these materials were liable to damage at the cut ends, where the termites were able to use their manibles in scissor fashion, but samples where the ends were capped with a metal ferrule did generally escape all attack. This tends to confirm our belief that smoothly extruded sheathing, free of scratches, etc. will always be more difficult for the insects to grip with their mandibles, and that if the material in addition is of reasonable hardness and good resilience, attack is most unlikely. Results obtained with high density polythene, polypropylene, rigid PVC and polyurethane whilst not as good as those for nylon, are far superior to those for low density polythene, plasticised PVC, natural and synthetic rubbers, etc., as would be expected if our theory (Ref. 5) is valid. At the same time it clearly stresses the importance of proper extrusion conditions, if the advantages gained by the choice of a highly resistant material, are not to be partly sacrificed.

Another field trial was conducted from 1965-1970 on various experimental cable constructions at more than 20 test sites all over the Commonwealth. In these trials lengths of approximately 50 m were buried at depths of 25 to 50 cm, with one end sealed and the other connected to above ground terminals. Periodic measurements of insulation resistance between conductor and earth were carried out to give indication of damage, and at the end of approximately five years the cables were recovered for detailed examination. It was shown that whilst none of the Nylon 11 jacketed samples had been attacked, there had been several instances of penetration of Nylon 6 jackets. Various other types of plastic materials, with or without additives such as silica, gave poor to moderate results. In the case of brass barriered cables, there was considerable evidence of corrosion even though the insects had not been able to do any damage to the inner plastic sheath. Some cable types performed reasonably well, such as those equipped with greasy barriers or "Tanalith" treated wrappings, but because of their poor physical properties, large size, and the difficulties in handling, they cannot be considered as practical solutions. Our results agree with the findings by other investigators in Australia, in particular the C.S.I.R.O. Divison of Entomology, and Nylon 11 has now also been successfully utilised by other authorities in areas where the hazard due to termite or ant attack is high, and steel wire or tape armouring had to be employed previously. Some of this experience now extends over 10 years, without any recorded failure.*

## NYLON 12 AS AN ALTERNATIVE

Nylon 11 is available from only one manufacturer, and in 1969, a worldwide shortage of castor oil, the basic raw material, created a difficult supply position for our ever increasing demand for nylon jacketed, insect proof cable. It therefore became necessary to look for an alternative material and after surveying available materials it was decided to further evaluate Nylon 12. The latter was available from two manufacturers (soon after two further manufacturers entered the market), was made from a readily available petro-chemical, butadiene, and offered a price advantage. Its chemical and physical properties were similar, and with regards to water absorption slightly superior, to Nylon 11. Field and laboratory tests confirmed that Nylon 12 conferred insect resistance equal to Nylon 11, and as a result of several years of testing, two manufacturers' materials have been type approved.

## THE EFFECTS OF FORMIC ACID

It is well known that a large proportion of the ant family possess venom-producing glands by which they are able to secrete formic acid, as an approximately 50% aqueous solution. For some species it has been calculated that an individual contains up to 2 mg, that is 20% of its total body weight, of formic acid. As formic acid is known to cause some degradation in nylons, experiments were conducted to study the effects of 5% and 50% formic acid solutions on various grades of nylons. It was shown that Nylons 11 and 12 whilst suffering some decrease in surface hardness, after immersion for up to 28 days at temperatures between 20 and 50°C, were still satisfactory (Ref. 6). However, various other grades such as Nylon 6, 6.6, and 6.10 and also acetal co-polymer were found to suffer severe degradation, and whilst the danger from prolonged exposure to formic acid in service may not be very great, our preference for Nylons 11 or 12 over other nylon materials has been reinforced by these findings.

## MANUFACTURING PROBLEMS

### General

The problems of placing a thin coating of nylon over a cable sheath take on different aspects depending on whether one is a user interested primarily in the end result or a manufacturer trying to meet the reasonable (or unreasonable?) requirements of a user. The A.P.O. is, as far as cable is concerned, solely a user and therefore the authors of this paper can only give the user's view on the problems and their solutions. It is a pity perhaps that we cannot give an adequate coverage of the other side of the story.

### Cable Diameters

The initial application of nylon by the A.P.O. was to two-pair cables, less than one centimetre in diameter. The nylon used was a Nylon 6 which had, compared to the other plastics used in cable, a very low melt viscosity and the manufacturers indicated that they did not expect to be able to jacket cables more than $1\frac{1}{2}$ cm in diameter. Restricting the diameter to this low figure would have resulted in a product suitable for use on only about 30% of the sheath length of plastic cable installed in those areas where insect attack could be expected. This percentage was adjudged too low to be acceptable and hence the Australian industry was encouraged to develop its technology towards jacketing of large cables.

The change from Nylon 6 to Nylon 11 which arose from the early trials discussed above, was fortunate as the melt viscosity of the latter is markedly higher and has a low dependence on melt temperature. This led, assisted by better extrusion machinery, to the Australian industry successfully coating cables up to 2 cm in diameter by 1967 and up to 4 cm in diameter shortly after, thereby covering the full diameter range of underground plastic cables for rural areas.

### Surface Finish

The laboratory evaluation and field tests included samples that had a surface finish in which small bubble-like imperfections, lumpiness and absence of surface gloss were evident. It was these samples that showed the greatest propensity for being attacked by insects.

* Editorial Note: Subsequent to the preparation of this paper, a few related failures have been reported. The cases are still under investigation.

The reasons for poor surface finish were investigated, and it was found that the moisture content of the granules entering the extruder was a major factor. A high moisture content lowers the melt viscosity and increases the rate at which the nylon deteriorates (by hydrolysis) at high extruder temperatures.

From the user point of view the problem can be controlled by the inclusion of a specification requirement demanding that the jacket have a smooth glossy surface, free of imperfections, and the A.P.O. specification does include such a requirement. Provision of agreed acceptable and unacceptable samples is useful in determining compliance with this requirement.

This surface finish requirement should provide adequate assurance to the user that jacket defects existing at manufacture will not result in points of weakness which can be attacked by insects. However the A.P.O.'s specification also limits the moisture content of granules entering the extruder (samples are taken for laboratory evaluation) to a maximum of 0.1 %, and limits the time/temperature of the material within the extruder. These requirements are set primarily to guard against other forms of jacket degradation, but they give added security against manufacture of cable with defective jacket.

The aim must be to provide a cable with a "smooth gloss surface" ex factory, but for maximum protection against surface damage during installation by cable ploughing equipment, attention should also be paid to the surface finish and cleanliness of the cable chutes of that equipment. This is desirable but not always achievable. However, no case where minor abrasion of a good "ex factory" jacket has allowed insects to complete the penetration of the jacket has come to our attention.

**Cracking of the Jacket**

During experimental use of Nylon 12, problems of severe cracking of the jacket during, and even before installation were reported from a few operating areas. Investigation revealed that all the material involved came from one raw material supplier and from one cable manufacturer. It was found that those samples not yet exhibiting cracks deteriorated rapidly, (within days) on exposure to sunlight. The nylon was said to include some carbon black and an unknown amount of heat stabiliser.

Laboratory investigation of the problem showed:—

- The nylon used contained only an insignificant percentage of carbon black.
- Test specimens taken from cable immediately after manufacture exhibited normal tensile strength and elongation properties.
- Immediately following manufacture the cables were able to pass a bending test.
- Cable aged naturally on cable drums over about three months during an Australian summer, but protected from direct sunlight, sometimes exhibited cracks.
- Test specimens taken from cables immediately after manufacture, and artificially aged in a Weatherometer, exhibited embrittlement after periods ranging from 119 to 236 hours.

These results suggested dual causes:—

- The nylon had only minimal amounts of heat and light stabilisers incorporated in it.
- The temperature and/or time that nylon spent in the extruder during cable manufacture varied and, in some circumstances, e.g., when changing cable size, became excessive so that the stabiliser was largely consumed during the extrusion process.

Concurrent tests by the A.P.O., the cable manufacturers and nylon suppliers confirmed that nylon could be adequately heat and light stabilised, that up to 2 % carbon black did not degrade any physical properties of the nylon and aided the stabilisation process, and that factory processing need not exceed certain acceptable temperature/time profiles. Consequently, the A.P.O.'s specification for Nylon 11 and Nylon 12 for cable jacketing requires the use of heat and light stabilised grades, and carbon black when used as a stabiliser is to comprise 2 % by weight. The temperature of the molten resin during extrusion is not permitted to exceed 260°C and the time at that temperature is not to exceed 15 minutes. The time is permitted to double for every 10°C reduction in extrusion temperature. Type approval tests and periodic check tests include tensile stress at yield (median of five tests, to exceed 4,500 lbs/sq. in (3.10 x $10^7$ Pa)), elongation at break (median of five tests to exceed 230 per cent) and require that the median observations do not vary by more than 20 % after exposure in a Weatherometer to ultraviolet radiation in the range 275-440 nm for 300 hours. The most critical parameter is the elongation. The 20 % variation permitted may seem excessive but the thermal environment of the Weatherometer, (temperature 45°-50°C) leads to changes in the crystallinity of the specimens and accounts for much of the permitted variation.

The several grades of Nylon 11 and 12 approved for use and complying with the requirements now specified, provide complete immunity from cracking problems. It should be noted that the standard installation practices of the A.P.O. do not require, nor permit, nylon jacketed cables to be installed in situations where they are subjected to sunlight.

**Wrinkling of Jacket**

Nylon jacketed cable must withstand the bending associated with factory processes, culminating in winding on to a despatch drum, and then after a variable period of storage, sometimes in a hot dry climate, it has to withstand unwinding from the drum and passage into and through cable laying equipment. Finally the cable ends are coiled up in the small "pits" used for housing joints. It must withstand these operations without significant degradation of the "smooth gloss surface", which has been shown to be important in maximising the protection the jacket offers against insect attack. Also the jacket must not become wrinkled, as it could then catch in the cable laying plant, and be severely torn.

Initially A.P.O. specifications required the nylon to be at least 0.25 mm thick and to withstand a bending test on a mandrel with a diameter twenty times the cable diameter. After two forward and reverse 360° cycles of bending the jacket had to "remain continuous and undamaged".

Some problems occurred in the field while this specification was operative. The worst of these were found to arise from cable laying machinery where bends sharper than 20 diameters could occur.

Bending a cable around a curve of diameter twenty times that of the cable results in a strain of 5% and this strain is, with Australian laying machinery, imposed in the opposite direction to the strain on the cable during prolonged storage. When allowance is made for some stress relaxation during storage the effective strain during laying may exceed 7%. For Nylon 11 or 12 a 7% strain in a specimen conditioned at 20°C and 65% R.H. leads to a stress level very close to the yield strength. In a cable, where the average R.H. over the days preceding installation may have been well below 65%, and yet the temperature on a cool morning could be as low as 10°C, local yielding of the jacket is likely, particularly at points where the jacket thickness is below average. As the cable straightens as it leaves the cable laying machinery, wrinkles can occur which at best are a point of weakness, and at worst can be torn by the machinery and leave a section of cable unprotected. Unfortunately once these adverse laying conditions are encountered a considerable segment of the sheath along the whole length of the cable will be subject to the same conditions.

The solution to this problem has been to modify laying equipment by increasing the diameter of any surfaces, wheels, etc., which the cable passes over, to increase the minimum acceptable thickness of the jacket by 50% to 0.37 mm, and to require samples subjected to the bending test to exhibit no wrinkling. The minimum barrel diameter of drums has remained at 20 times the cable diameter. The cost increase occasioned by the thicker jacket has not been excessive, since manufacturers are now able to control the thickness and set their operating point closer to the minimum acceptable thickness.

Some work still remains to be done in defining a conditioning treatment for the bending test that will adequately simulate adverse field conditions. Immediately after extrusion the nylon has extremely low moisture content (well below 0.1%) and performs badly in this test, but after being left with its surface wet for some days and then conditioned in a standard 65% R.H. test environment the cable is able to pass the bending test.

Perhaps a complete solution to the problem of wrinkles under severe bending will not be available until manufacturing methods or materials are developed that provide a high strength bond between the underlying polythene and the nylon jacket. This aspect is under investigation.

## FIELD EXPERIENCE

### Fault Reporting Systems

The A.P.O., like most telephone administrations, has a general fault reporting system whereby field staff attending a fault are required to provide a coded fault docket giving details of the fault, the type of construction involved and their opinions of the cause of the fault. In parallel with this system, facility exists for the field supervisory staff to report plant deficiencies.

The general fault reporting system has never indicated a high incidence of faults attributable to insect attack, but in the early years of polyethylene sheathed cable usage, many reports of large scale damage were received from field supervisory staff, even though plastic cable was not used in areas where termites were known to be a major hazard.

The reason for this apparent contradiction provides an interesting sideline to the main theme of this paper. In brief it arises because, in Australia, field staff are permitted to restore an isolated faulty service in buried cable plant by transfering the service to any good spare pair in the cable, and no attempt is made to locate the actual fault. In such cases the cause of failure is not recorded by the reporting system. With our policy of no party-line service, and the expectation that the demand for services will continue to increase over the life of the cable, most newly installed cables are only 20% to 50% occupied. The transfer procedure may be used repeatedly until cable occupancy surveillance shows that most pairs are either occupied or faulty, whereupon a maintenance group, which is largely independent of the local service restoration group, locates the faults and effects restoration. It was reports from the maintenance organisation that drew attention to the alarming incidence of ant attack in the early 1960's. This incidence was sufficient to cause a reversion to high cost lead sheathed cables in many rural areas of Australia.

### Acceptance of Nylon Jacketing

The acceptance in the field of nylon jacketed cable as adequate protection against insect attack, has resulted in low cost plastic cable now being considered suitable for subscribers cables for all rural environments in Australia. Reports from field supervisory staff indicate that ant or termite attack on nylon jacketed cable is non-existent*, and all faults attributed to insect attack have been found to occur only on the older unprotected cables. The following figures show the trend:—

| Year | 1966 | 1969 | 1971 |
|---|---|---|---|
| Faults attributed to Insect Attack | 2,058 | 2,483 | 3,078 |
| Sheath Mileage of Plastic Cable | 30,671 | 57,436 | 72,203 |
| Faults per 100 Sheath Miles | 6.7 | 4.3 | 4.3 |

### Jointing

An attractive feature of nylon jacketing has been its complete compatibility with our standard methods of jointing plastic cable. These methods were developed with insect protection in mind and are based on the use of two rigid P.V.C. mouldings, with field poured epoxide resins providing a mechanical bond between the cable sheath/jacket and one of the mouldings. Rigid P.V.C. is termite resistant and the epoxide resin whilst not immune is in the form of a thick casting so that total penetration is most improbable. The joints are placed underground in small jointing pits.

Some above-ground joints are used in steel posts and whilst not constructed from recognised insect proof materials, attack within the posts has not occurred, probably because the insects tend to prefer underground locations.

## EXTENSION TO OTHER CABLE TYPES

### Carrier Cables

Single quad, plastic insulated, plastic sheathed, copper tape screened, nylon jacketed cable is already in extensive use in rural areas as a bearer for two 12-channel FDM carrier systems or one 120-channel FDM system. This cable uses 1.27 mm copper conductors and has proved extremely popular and versatile. It has largely replaced multi-pair, paper insulated, lead sheathed carrier cables.

### Voice Frequency Minor Trunk (Toll) and Coaxial Cables

These are usually polythene jacketed, lead sheathed cables and provide satisfactory insect resistance in all but the more hazardous areas, where steel tape armouring is used. In these latter areas it is expected that a nylon jacketed, lead sheathed cable will be a satisfactory and cheaper substitute. To date, fully satisfactory bonding (or flooding) compounds to protect against corrosion of the lead under the nylon have not been developed, and as an interim solution a thin polythene jacket followed by a second jacket of nylon is being used. Cables up to 4 cm outside diameter have now been successfully jacketed, and this is not regarded as the upper attainable limit.

It is expected that the lead sheathed, voice frequency cables, which usually are in the size range 20 to 100 pairs and have about 10% of their pairs allocated as future carrier bearers, will ultimately be replaced by plastic insulated, jelly filled, plastic sheathed, nylon jacketed cables. An extensive development programme for this form of cable is in progress.

## COSTS, BENEFITS

### General Costs

Overall the cables used by the A.P.O. now consume some 300 tonne of nylon per year. The new material and processing cost for the nylon component in completed cable amounts to around $A1,000,000 per annum. This large expenditure must be set against the derived benefits and compared with the costs of alternative solutions.

For individual cables the cost of jacketing ranges from 10-50% of the total cable cost. Currently about 45% of all plastic cable purchases are nylon jacketed, and due to the cost of jacketing and the large conductor size of many rural cables this portion requires about $A7 million of the $A10 million spent annually by the A.P.O. on small size plastic cable.

### Benefits

The major benefit achieved by the use of nylon jacketing is not in the elimination of faults. This statement may surprise but it is true.

Before the adoption of nylon jacketing, the fault incidence in plastic cables in some rural areas was so high that required service standards could not be met. Therefore operating districts had to adopt othe forms of cable, typically lead sheathed with plastic jacket or steel tape armour. Hence to achieve a real benefit it is necessary that nylon jacketed cables cost less than these lead sheathed cables and yet give comparable, or better, service performance. In fact the purchase of equivalent quantities of lead sheathed cable would cost at least $A2 million more annually than nylon jacketed cables. In addition there are substantial installation cost advantages with nylon jacketed cables.

This analysis could still lead to an incorrect assessment of the benefit if nylon jacketed cables were to be used in areas where the performance of standard plastic cable is adequate. However this would only become a significant factor if over half the nylon jacketed cable were used incorrectly.

* Except for isolated occurrences in 1972/73 (Editor).

### Alternative Solutions

To spend $A1 million per year on nylon protection of cables could still not be justified if cheaper solutions were available. One other possible solution subjected to extensive field trial in Australia was brass tape protection. This cable had brass tapes helically applied over the polythene sheath, and held in place by a thin extrusion of polyethylene. The corrosion liability of such a cable, as demonstrated by our field trials, has been already mentioned in an earlier section of this paper. Its cost was much more than nylon but less than cables with lead sheath. Even when allowance is made for some advantages conferred by the metal tape such as protection against a proportion of lightning strikes, the nylon is a preferable solution.

The use of steel tapes over plastic cables is another possible solution as also would be the Western Electric "Stalpeth" sheath but, in Austalia, this would not be cheaper than nylon and has therefore not been investigated.

The incorporation of insecticides in the plastic sheath as part of the extrusion process, has been advocated by various manufacturers and designers. In our experience, which covers a substantial number of such compounds in both polythene and P.V.C., none of the insecticides available have given the required degree of protection. The difficulty appears to be that if the insecticide "blooms" rapidly to the sheath surface, it will repel the insects more effectively but its life will be too short, whilst if the blooming rate is slow enough to allow for a 20-40 year life, there is probably insufficient material available at the outer periphery to give adequate protection. In addition the presence of insecticides is an undesirable health hazard to installation and repair staff.

## CONCLUSION

Our experience with Nylon 11 and 12 extends over almost 10 years, and there is no doubt that this form of protection against insect attack has been outstandingly successful. In fact there has not been a single recorded failure, due to penetration by an insect, of cable jacketed with Nylon 11 or 12 and the only faults recorded have been clearly shown as being due to installation damage, manufacturing defects or incorrect choice of the grade of nylon. Having also surmounted the original limitations with regard to cable size and ease of handling, the A.P.O. has now reached the stage where the probability of insect attack on newly installed cable has been reduced to a negligible magnitude, and the faults now recorded as being due to insect attack almost certainly refer only to the older style, unprotected cables still in the ground*.

* See previous note (Editor).

### Prospects for Cost Reductions

As with many semi-automated processes, the major cost component in the cost of nylon jacketing cable is the raw material cost of the nylon. It accounts for 60-70% of the jacketing cost and is therefore the area in which the greatest scope exists for cost reductions. However the residual 30-40% could be reduced by the successful operation of tandem extrusion or "piggy-back" extrusion. The Australian cable industry is being encouraged to pursue developments in these areas.

### Alternatives to Nylon

Whilst we are therefore in the happy situation of having reached a solution to our problem, we are continuing to search for cheaper alternative jacketing materials. This work has not advanced to a stage where is it possible to reach any firm conclusions, even though there are a number of promising materials in the course of investigation. The major objective of our studies will be to determine what factors make a polymer insect resistant, and it is hoped to achieve this by conducting a large scale factorial experiment, with termites under laboratory conditions. If these experiments are successful, it should then be possible to accurately predict the magnitudes of physical parameters and the concentration of polymer components and additives, required to confer insect resistance on to a chosen polymeric material, and accordingly "tailor" jacket or sheath materials to our economic and technological needs.

## ACKNOWLEDGEMENT

The assistance of the A.P.O. field staff at the test sites, of the C.S.I.R.O. Division of Entomology in conducting laboratory tests and of our fellow engineers and scientists in the AP.O. is gratefully acknowledged.

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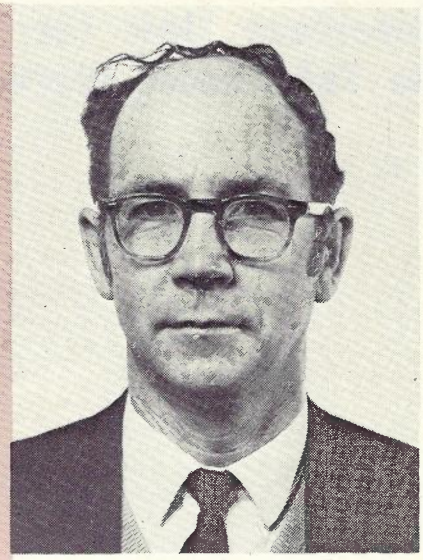

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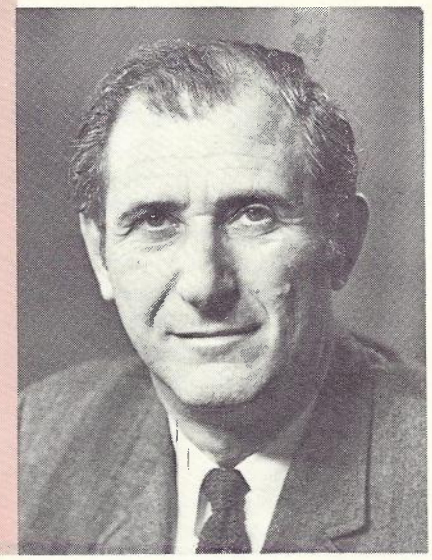

# An Interface Unit for Transmission Measuring Sets Used in the Telephone Network.

J. P. SALTER

*Transmission measurements in the telephone switching equipment environment pose some problems in protection of test instruments from the effects of D.C., and in control of the switched connections established for the purposes of measurement. This article outlines the features of an instrument developed to overcome these problems and simplify transmission measuring procedures in telephone exchanges.*

## INTRODUCTION

Instruments for transmission measurements on telephone circuits traditionally, have been designed primarily for the transmission equipment environment, with little thought being given to electrical potentials, other than that of the signal to be measured, which may be present at the point of measurement. When we have the need to make transmission measurements in the telephone switching equipment field, potentials necessary for signalling and control of that equipment, far in excess of the voice frequency signal being measured may be present at the measuring point. Typically, D.C. potentials of up to 50 volts, from which the "loop holding" current for maintaining established connections is derived, will be encountered.

A transmission measuring instrument's input transformer, which is designed to pass alternating currents of small amplitude and wide frequency range, can be permanently damaged by direct current passed through its windings for even a brief period. This D.C. leaves the transformer core permanently magnetised, reducing its incremental permeability, changing the transformer's A.C. loss and affecting the calibration of the instrument. Also when making transmission measurements in the switching section of the telephone system it is frequently convenient to be able to establish and hold a connection for test purposes through the switched network from the point of measurement.

The Interface Unit described here evolved from these dual needs to protect the transmission measuring apparatus and to control switched connections while transmission measurements are being performed.

It was developed by Amalgamated Wireless (Australasia) Ltd., to Australian Post Office specifications, especially for use with the A.P.O. standard transmission measuring set type A215-2.

## FACILITIES

The L216 Interface Unit provides the following:

- Isolation of D.C. potentials from the transmission measuring set.
- Loop-holding of both the circuit under measurement and an auxiliary voice communication line.
- Dialling by means of standard loop-disconnect pulses on 2-wire lines.
- Voice communication on the 2-wire or 4-wire line under measurement or on an auxiliary 2-wire line.
- Access from both sending and receiving sections of the transmission measuring set to 2-wire or 4-wire lines.
- A choice of either 600 or 1200 ohms for the value of the impedance presented to the line terminals.
- Answering of incoming calls on 2W or 4W lines by either loop or reversal of line potential.
- Transfer of control of the test calls to an Automatic Exchange Tester when M.F.C. signalling is necessary for establishing these calls.
- Monitoring, without looping, the line under test.
- An attenuator for controlling the send signal level from the transmission measuring set in 0.5 dB steps for the purpose of testing with a Test Call Answer Relay Set (Ref. 2) at the far end.
- A Send Level Check key by means of which the output of the generator section of the transmission measuring set, can be connected to the level meter section.

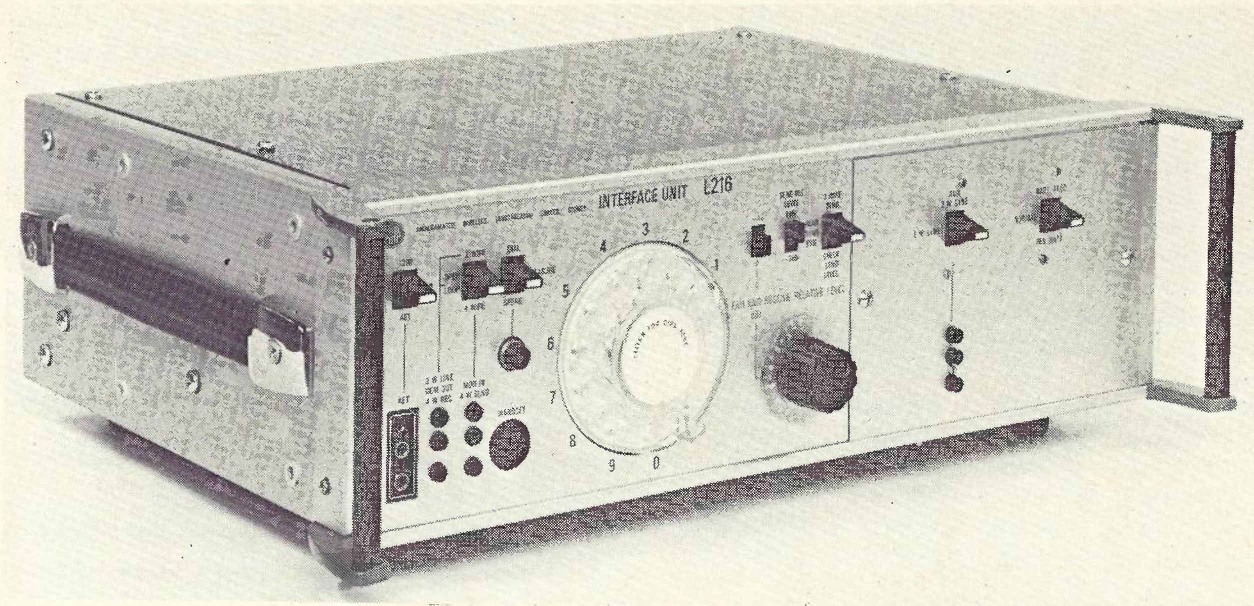


Fig. 1 — Interface Unit.

## FEATURES OF THE INTERFACE UNIT L216

### Physical Size

It is a requirement that the Interface Unit fit into the same size case as the T.M.S. type A 215-2. This is so that both units can be mounted in the extension frame fitted to the ARF (2 wire exchange) type Automatic Exchange Tester. Otherwise a trolley to hold the instruments would need to be provided and located in the aisle space when carrying out transmission tests.

The overall dimensions of the I.F.U. are:

Width — 495 mm
Height — 133 mm
Depth — 305 mm

### Circuit Testing Impedance

The unit has been developed to carry out tests with 600 or 1200 ohm sending and receiving terminal impedances. For insertion loss measurements from the test points in a telephone exchange switching stage the circuit is terminated in 600 ohms and a check is made that a pre-determined insertion loss is achieved between impedances of this value. The 1200 ohm terminating impedance was added to allow tests on loaded cables to be carried out where 600 ohm instruments only are available. The Interface Unit provides the termination across which measurements of received signal levels are made. Consequently the associated transmission measuring set must be in the 600 ohm bridging condition to read correctly.

### Attenuator

The attenuator connects, via an interconnecting cord, into the internal circuitry of the transmission measuring set A215-2 to enable precise control of

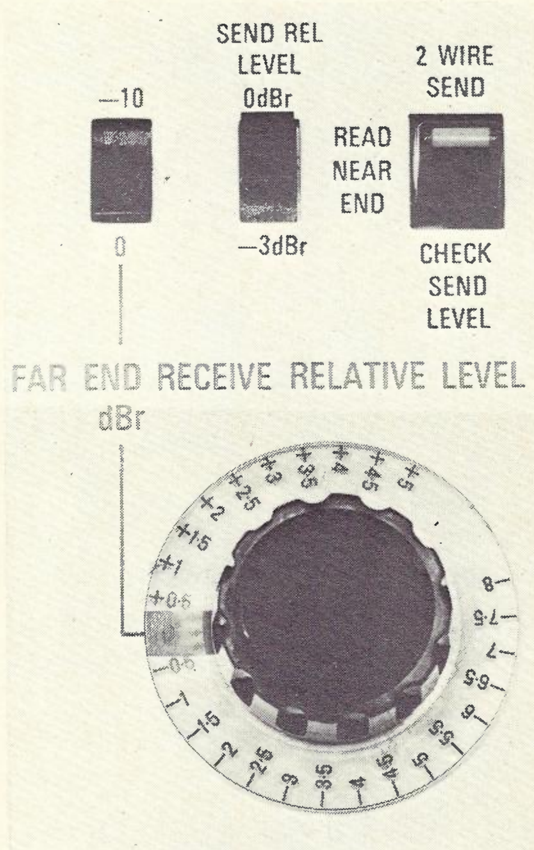


Fig. 2 — Enlarged View of the External Attenuator Controls. Standard send relative level pre-sets for Terminal (0 dBr) and Transit (—3 dBr) are clearly shown.

its sending level in 0.5 dB steps. The attenuator is illustrated in Fig. 2. Its scale gives a direct reading of the Far End Receive Relative Level with respect to a reference level or 0 dBr point of the network when a transmission test is being conducted in co-operation with a Test Call Answer Relay Set at the far end. This direct far end level reading is possible because the T.C.A.R.S. receiver responds to a known absolute power level (—20 dBm) and the Attenuator and line losses together make up the total insertion loss of the path between the T.M.S. oscillator at the near end and T.C.A.R.S. receiver at the far end.

At the 0 dBr setting of the attenuator and its two associated switches the power set to line from the T.M.S. is —20 dBm. If, for example, the line loss is 6dB, clockwise rotation of the attenuator knob to the —6 dBr point, which raises the send level to —14 dBm, will be necessary to make the T.C.A.R.S. respond.

The Send Relative Level switch presets the send level to match the send reference level of the (near end) exchange at which the Interface Unit is located; that is 0 dBr for a Terminal Exchange, —3 dBr for a Minor Switching Centre.

This switch must be correctly set to suit the Interface Unit's particular location but then ignored in reading Far End Receive Relative Level, which is indicated directly by the main attenuator scale.

A further switch permits extension of the main attenuator's range by 10 dB for cases where excessive line loss is encountered. Switching to the —10 position raises the send level by 10 dB, and the Far End Receive Relative Level is then the algebraic sum of this —10 and the main attenuator's reading.

**Power Supply**

Power for the internal amplifier associated with the attenuator is derived from the A215-2 transmission measuring set. The handset transmitter and the receiver amplifier are supplied from internal dry cells.

**Compensation for Insertion Loss**

When an Interface Unit is connected between the transmission measuring set and the testing points the loss of the Interface Unit must be allowed for. This loss can be compensated for by the adjustment of two preset potentiometers internally fitted to the A215-2 T.M.S. Interconnection between the Interface Unit and the T.M.S. is then made to rear panel "METER IN" and "GEN OUT" sockets. Adjustment of these potentiometers does not have any effect on the front panel sockets of the transmission measuring set.

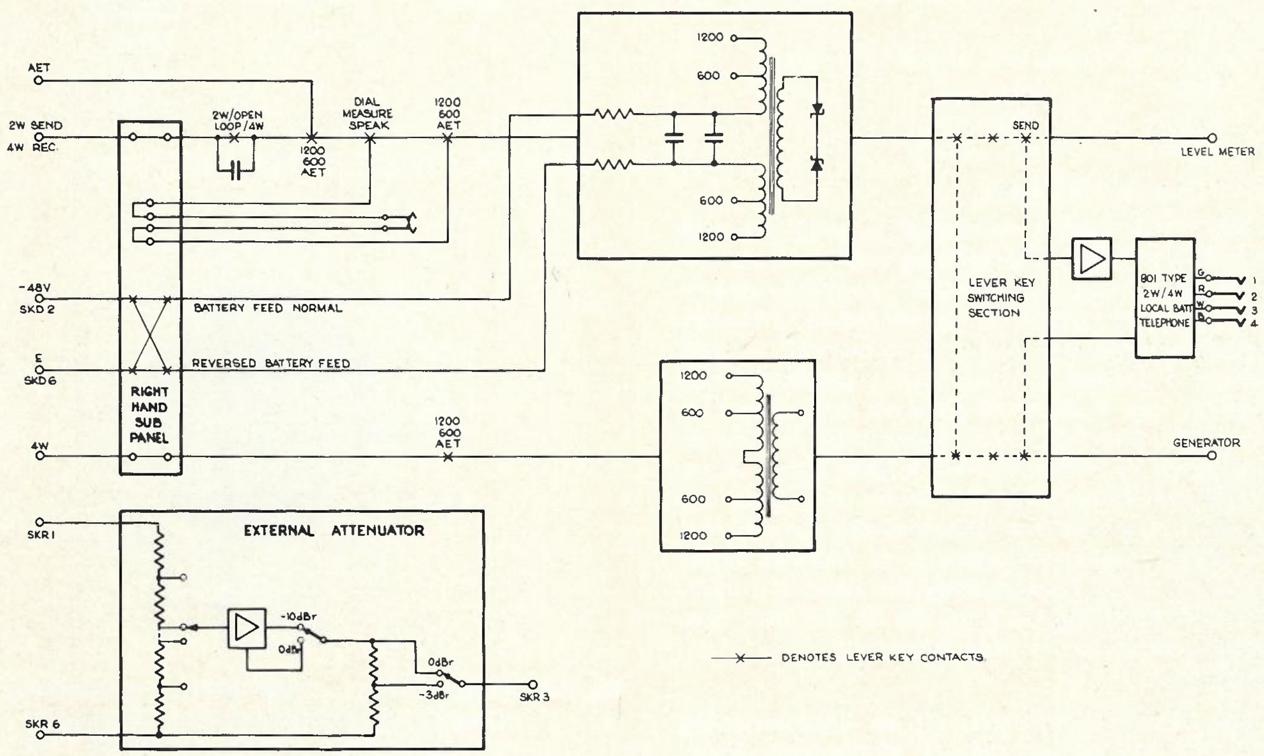


**Fig. 3 — Interface Unit Functional Diagram.**

**Uses of the Interface Unit L216**

- Primarily the Interface Unit enables existing testing instruments to be used to carry out transmission tests, where it is necessary to prevent the "loop hold currents" from flowing in the testing instrument input and output transformers.
- Fitted into the framework attached to the ARF type AET, the Interface Unit allows transmission testing to T.C.A.R.S., test console, or to a similar unit at the exchange transmission measuring point.
- Coupled to the A215-2, the unit provides a composite test set for use in small country exchanges for both circuit insertion loss space and carrier systems level measurements.
- In carrier stations the unit provides a means for 4W sending and receiving, monitoring or speaking on a channel or 4-wire amplified circuit.
- The unit caters for transmission tests on "loaded cables" (1200 ohm) from the exchange MDF, when D.C. may be present. Here also the facility to talk over a 4 wire circuit may be useful.
- With its attenuator the Interface Unit allows the A215-2 to be used by inexperienced staff to carry out transmission tests to T.C.A.R.S. making it unnecessary to perform calculations for determining the relative receive levels, hence the circuit insertion loss. The L216/A215-2 arrangement, does in fact, allow the "near" and "far" end relative levels to be determined directly.

**Conclusion**

It is expected that the use of the Interface Unit will give greater utilization of measuring sets and will allow a wider range of measurements to be made by the telephone exchange staff without the need to develop specialised testing instruments. This will allow economical provision of testing plant, since additional specialised instruments will not need to be developed.

The need for transmission measurements to be made from the exchange switching equipment is becoming greater as data and M.F.C. signalling facilities, and circuits provided by means of carrier equipment are employed to an increasing extent in the telephone switched network.

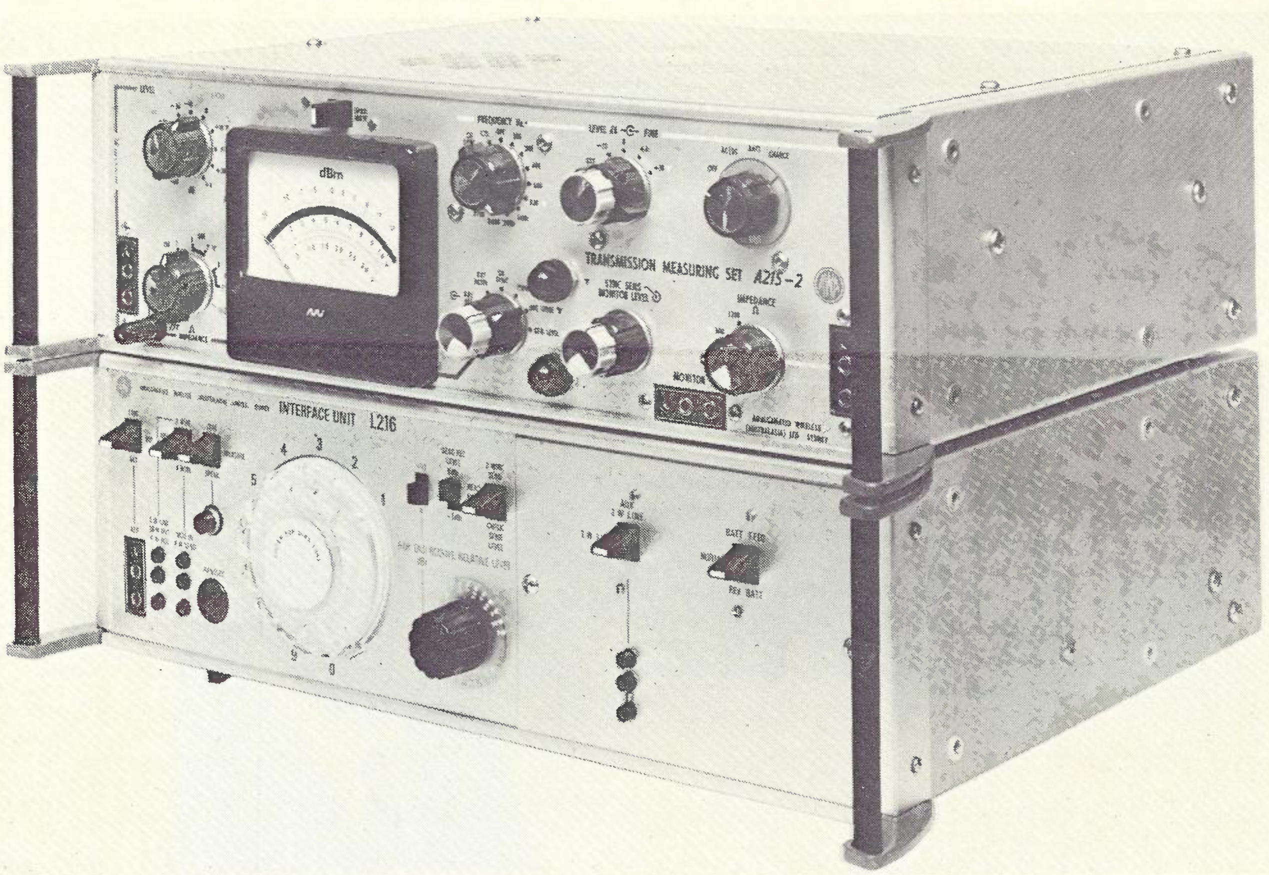


**Fig. 4 — Mounting Arrangements for TMS (A215) and IFU (L216) to give Functional Test Unit to establish a Testing Position; e.g. ETMP. (The bottom cover is removed from the A215-2).**

It is not necessary to confine the concept an Interface Unit to transmission testing. The technique could be developed to provide a function or facility to enable two non-compatible items of plant (two faces of plant) to be interconnected so that special conditions for operational tests can be set up when a particular set of circumstances have to be investigated. Such an approach means that neither item of plant need be modified to allow interworking.

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## APPENDIX

**Performance of the Interface Unit**

| | |
|---|---|
| Instrument impedance at 2 wire and 4 wire socket (terminal) input/output. | 600 ohm or 1200 ohm |
| Loop hold current (DC flowing in transformer windings) | 0 mA to 80 mA DC |
| Return loss at the input/output | At least 25 dB at 820 Hz and 835 Hz<br>At least 20 dB over the range 150 Hz to 4KHz |
| Insertion loss | From 2 wire line or either 4 wire socket (terminals) through to the A215-2 meter input or generator output is less than 1.0 dB (This loss is compensated for within the A215-2). |
| Frequency response | For the abovementioned signal paths:<br>+0 dB to —0.4 dB at 150 Hz ref. 820 Hz<br>—0 dB to —0.3 dB at 4 KHz ref. 820 Hz<br>(When referred to level read at 820 Hz). |
| Maximum level input. | +5 dBm. |

J. P. SALTER joined the APO as a Technician's Assistant in 1948. He was appointed a Cadet Draftsman in 1951 and after completing a Diploma of Electrical Engineering at Sydney Technical College in 1959, was transferred as engineer in the Trunk Service Section. He is appointed as Engineer Class 3 in the Network Performance Division of Trunk Service Section and is currently acting Supervising Engineer, Trunk Service Section, New South Wales.

# Line Signalling

A. H. FREEMAN

*This article outlines the basic principles of line signalling in a telephone switching network, with particular reference to the techniques employed in Australian networks. Loop signalling is described, and this is followed by a description of line signalling techniques used on carrier systems, and within a telephone exchange. The article concludes with an outline of how the line signalling functions are implemented in some standard ARF line relay sets.*

**Editorial Note: This article is a further chapter from a monograph of the principles of telephony to be published by the Telecommunications Society of Australia. Previous issues of this Journal contained the chapters dealing with principles of trunking and switching, and the principles of common control in telephone exchanges. The article will be of interest to practically all the readers of the Journal.**

## INTRODUCTION

In a large telephone network a few comparatively simple signals from a telephone may result in the execution of complex switching operations in several widely spaced telephone exchanges in order to set up the desired connection, and all of these actions must subsequently be cancelled at the end of a call. This requires a signalling (i.e. data transmission) network covering the full extent of the switching system, and in all but the most recent developments, this takes the form of a signalling path associated with each transmission path and switching device so that, simultaneously with the building up of a speech path from the originating point, a signalling path is built up linking every component of the speech path.

For the reasons given in the previous article (Ref. 1) on control system design, the signalling in the crossbar system is divided into two components known as line signalling and information signalling. The line signalling component requires a relatively low signalling speed and the facilities are usually provided as a by-product of the speech path, in one of the three following forms:

- A speech path in the form of a pair of wires, either for a subscriber's line or for a junction is capable of carrying signals down to zero frequency, and the band below about 200 Hz which is not required for speech transmission is available for signalling. In addition, the whole bandwidth is available (subject to some constraints) during part of the setting up process.
- Within an exchange a supplementary wire or wires for signalling may be provided in parallel with the speech wires. There is usually at least one such extra wire used for holding the connection through the exchange, and ARF crossbar has two signalling wires, to provide for a variety of internal signalling needs.
- Junctions provided by carrier systems are usually unable to transmit low frequencies but a separate signalling path is provided in all modern systems. In Frequency Division Multiplex (F.D.M.) systems use is made of frequencies between channels, which are combined with the speech path at the first modulation point, and remain associated with it until the final demodulation.

In order that this signalling network can perform its functions, every exchange in the telephone network must be provided with the facilities to:

- Recognise and act on signals received over lines (either subscribers or junctions) connected to it;
- Transmit or repeat signals over these lines for action at the exchange, or telephone connected at the other end;
- Interchange signals between parts of the exchange.

This is usually done by providing a 'line relay set' at the exchange termination of every line, with facilities for sending and receiving signals on both the exchange and line side of the relay set, and to perform, or control the performance of switching actions needed in the exchange as a response to the signals. Fig. 1 shows a connection set up in an exchange using this line signalling configuration, and a number of important terms can be defined on the basis of this diagram.

Any telephone call is set up from one end, so that in the completed connection one subscriber is the calling party and the other the called party. By a long established convention these are known respectively as the 'A' party and the 'B' party and Fig. 1 has been drawn with the calling or 'A' party on the left and the called or 'B' party on the right. Therefore the line shown on the left hand side is either the 'A' party's telephone line, or a junction to which the 'A' party's line has been connected via another exchange (or exchanges). Likewise, the line on the right hand side is either the 'B' party's telephone line, or a junction that is, or will be in due course, connected to the 'B' party's telephone line.

The side of the exchange nearest to the 'A' party is called the incoming side, and the relay set at that point is called an 'incoming' relay set, while the other side of the exchange is the outgoing side, and the relay set is called an 'outgoing' relay set.

It will be realised that the designations 'A' and 'B' party are appropriate for the duration of a particular call only, because a normal telephone can both originate and receive calls, and can therefore be the 'A' party for one call and the 'B' party for the next. A subscriber's line must therefore be terminated on both the incoming and outgoing sides of its exchange, with a line relay set capable of handling calls both incoming and outgoing from the exchange. Such a relay set is called a 'bothway line relay set', but for any one call will be in use as either incoming (to the exchange), if the telephone is the 'A' party, or outgoing if the telephone is the 'B' party. Bothway trunks and junctions also exist, and some exchanges are so designed that the one line termination can be used both for incoming and outgoing traffic. In any of these cases, the designation incoming and outgoing can still be applied for the duration of a particular call.

In Fig. 1 both relay sets are required to receive line signals from either side and repeat them, and the two relay sets between them must arrange for the line signals to be acted on in the exchange. This latter function is usually vested in one only of the two relay sets, which then becomes the more complex of the two. If a relay set is required to repeat line signals either with or without changing the form of the signals the relay set is often called a repeater or a signalling repeater.

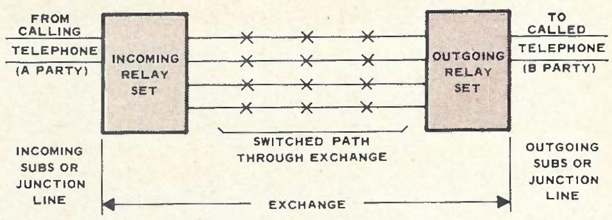



**Fig. 1 — Line Relay Sets.**

**Automatic Telephones**

The signalling facilities of an automatic telephone have been standardised for over fifty years, and have exercised a dominant influence on the design of automatic equipment and the associated signalling facilities. Fig. 2 is a simplified representation of the signalling facilities of a subscriber's telephone.

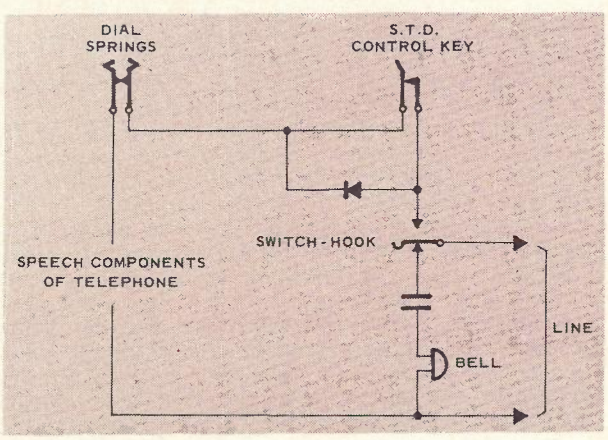



**Fig. 2 — Signalling Elements of Automatic Telephone.**

There are four separate devices, each providing a different signal as follows:

- A bell, responding to 16 Hz AC power from the exchange to indicate an incoming call.
- Switchhook contacts, which are controlled by the handpiece, giving two conditions known as 'on hook' and 'off hook'. The on hook condition applies when the handpiece is in place, and the contacts place the bell in series with a capacitor across the line. In this condition the bell can be rung by AC power from the exchange but no direct current can flow through the telephone. The off hook condition applies when the handpiece is removed and the contacts place the telephone in the speaking condition. In this condition the DC resistance of the instrument is about 100 ohms. Equipment at the exchange determines the state of the switchhook by observing the change in DC resistance.
- Dial interrupter springs in series with the line which, when the dial is returning to normal, open the circuit in a series of short breaks, the number of which is equal to the digit dialled. The standard timing is 66ms breaks, with 34ms intervals, giving 10 impulses per second, as shown in Fig. 3.
- A recent addition is a series diode, which can be shorted out by a control key. When the exchange equipment detects the presence of a diode it will not permit certain types of call (STD for example) and such calls can therefore only be made by persons in possession of a key. This control lock and key is provided only as an optional extra.

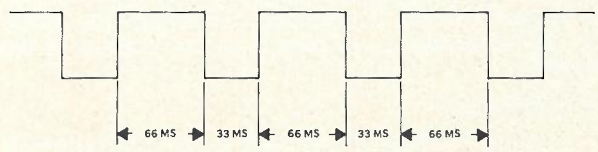



**Fig. 3 — Detail of Dial Pulses.**

It will be noted that in the speaking condition, the speech components of the telephone are in series with the line. The exchange equipment is so designed that a current of about 50mA is present on the line at these times and this current is used both as an indication of the state of the switchhook and also to provide the power needed by the telephone transmitter.

The two states of the switchhook are known as 'switchhook signals', but the word 'signal' in this context carries three overlapping meanings.

- Firstly there is what may be called the 'message' contained in the signal. When the subscriber lifts off the handset it means 'I want to make a call', or 'I am answering this call', depending on whether or not the bells are ringing. Thus the same action has a different 'message' depending on the context.
- Secondly there is the circuit change arising from removing or replacing the handset, or at least that part of the circuit change which is related to signalling. In this case it is the change from an open circuit between the wires of the line in the on hook condition to a low resistance path in the off hook condition.
- Thirdly there is the change which is detected at the exchange end of the line, from which it is inferred that the telephone is in the 'on hook' or 'off hook' condition. In this case it is the absence, or presence, respectively of current in the line.

The use of the one word 'signal' for all three of the above meanings is deeply ingrained in the technical literature, and usually the context in which it is used is relied on to avoid ambiguity. This practice will be followed here, except that where it is desirable to emphasise that the second or third meaning applies, the term 'electrical condition' will be used.

The switchhook and bell are used respectively to generate and receive line signals, while the dial, and the diode, where fitted, generate information signals. in the subscriber's line these two types of signal use the one signalling path, and in step-by-step automatic switching systems they continue to share the same path in virtually the same form right through the network. This type of information signalling is known variously as 'loop', 'loop disconnect', 'dial pulse' and 'decadic' signalling.

In most crossbar systems the register separates line signals and information signals and transmits the two categories by different techniques. However, because of the need for interworking between crossbar and step by step exchanges, many crossbar line relay sets are required to transmit decadic information signals.

The line signals which are transmitted from the subscriber's telephone and the electrical conditions used for them are listed in Table 1.

**TABLE 1 — LINE SIGNALS AND ELECTRICAL CONDITIONS**

| When Used to Call (i.e. A Party) | | When Used to Answer (i.e. B Party) | |
|---|---|---|---|
| **Signal** | **Electrical Condition** | **Signal** | **Electrical Condition** |
| Call | DC Loop | Answer | DC Loop |
| Release | DC Open Circuit | Clear | DC Open Circuit |
| | | Reanswer | DC Loop |

The functions of these signals have already been described, except for 'B' party 'clear' and 're-answer'. In the telephone network release of the call normally takes places when the 'A' party restores his telephone and therefore the 'B' party switchhook condition subsequent to answering is unimportant. This allows the 'B' party to temporarily restore the handset, or leave the DC loop temporarily open circuit to transfer the call to another telephone and this is sometimes a very useful facility. The 'clear' and 're-answer' signals correspond to 'on hook' and 'off hook' conditions subsequent to answer, and may be repeated without limit. This system where the establishment and release of a call is controlled by the calling party only is called 'calling party release'.

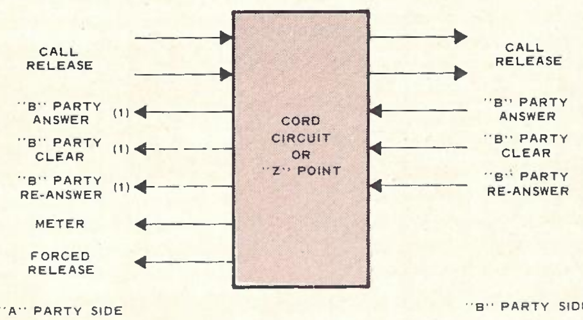
In most modern systems this method of controlling the release of a call is modified to provide that release will also occur if the 'B' party has cleared for a specified period — typically 90 to 180 seconds — even if the 'A' party has not released. This system, known as 'modified calling party release' prevents the 'B' party's telephone being kept out of service if the 'A' party fails to release, due, for example, to incorrectly replacing the handset. It also releases any junctions which would otherwise be held on such calls.

One further release condition which has advantages in special cases is 'last party release', where the call is not released until both parties clear. This is necessary on certain types of test calls and in crossbar exchanges a facility exists for temporarily marking a particular subscriber's line for last party release on incoming calls, so that malicious calls can be held and their origin traced.

### Cord Circuit Point

In order to provide these more complex release conditions the control of release must be performed by a decision circuit which is provided with information about the state of both switchhooks. This decision circuit forms part of a relay set located somewhere in the completed connection, most frequently in the terminal exchange to which the 'A' party is connected, but sometimes at a tandem exchange through which the call is switched. By analogy with manual switchboards this point is often called the cord circuit point.

There should be only one such point in a call, and it must transmit the release instruction towards both the 'A' party and the 'B' party (but only as far as the subscribers line circuit, since no electrical signal can replace the handset). The release signal towards the 'B' party need not be distinguishable from 'A' party release but a new signal is needed in the direction of the 'A' party and is called 'forced release'. These signals are illustrated in Fig. 4.



NOTE (1) THESE ARE OPTIONAL SIGNALS

**Fig. 4 — Signals at Cord Circuit Point.**

### Metering

One further signal is required to allow the charges for a subscriber to be recorded. The charge for any call dialled by a subscriber is a multiple of a 'unit fee charge'. For calls to a defined 'local area', usually about 20 miles radius, a charge of one unit fee is made, regardless of the call duration while calls outside this area are classified as trunk calls and the charge depends on the distance, and on the duration of the call. (For further details see Ref. 1.)

Call charges are recorded on an electro mechanical counter (subscribers meter) associated with each subscriber's line, and the method employed by the APO for trunk calls requires that the meter be stepped at regular intervals during the call. The cord circuit point is the most logical location for determining the timing of these charges, and a signal is therefore required from the cord circuit point to operate the subscriber's meter. This signal, unlike the preceding ones, is transmitted while conversation is proceeding.

When a cord circuit point is able to apply metering signals for trunk calls it is usually called a 'Z' point.

The signals so far described have to be transmitted over all, or a substantial part of a complete connection and requires responses at various points along the connection. These two requirements of end to end transmission and action at intermediate points are fully satisfied by the exchange configuration of Fig. 1 in which line signalling relay sets are provided at the exchange termination of each internal circuit.

A line signal from the 'A' party side will be identified at the incoming relay set, which will then retransmit or repeat it over the exchange path to the outgoing relay set, which in turn identifies and repeats it to the outgoing line. Either or both relay sets, as well as repeating the signal can cause action within the exchange in response. Line signals in the B to A direction are handled in a similar manner. As signalling repeaters these relay sets can use different types of electrical conditions for signalling on their two sides, so that there is a considerable degree of freedom in types of line signalling.

In addition to the above signals, there is a wide variety of line signals needed within a single exchange, or from end to end of a particular junction, and even within a single switching stage of an exchange. Every part of the telephone system therefore has its own particular requirements of line signalling, and its own schedule of electrical conditions to represent the signals needed at that stage.

There is, of course, a large degree of standardisation, particularly of the end to end signals and nearly all line signalling conditions used on trunks and junctions in Australia can be regarded as variations and extensions of four basic schemes, as follows:

- Loop Signalling.
- Separate Path Pulse Signalling.
- Separate Path Continuous Signalling.
- Rural Carrier.

In addition there is a signalling scheme developed for use with PCM carrier systems, and which will become important if PCM systems are used more extensively. A number of older systems are in use but they are all obsolescent, and are being replaced fairly rapidly.

## LOOP DISCONNECT SIGNALLING

### Transmission Bridges

Loop signalling is undoubtedly the dominant form of line signalling (and will retain this dominance for many years) being used on subscribers' lines, and nearly all junctions provided by physical conductors, as well as being the basis of signalling within most types of exchanges. The principles and techniques of loop signalling are best illustrated by examination of a specific case, and the configuration of Fig. 5 in which there are three signalling relay sets, two subscribers lines (A and B) and two junctions will be used.

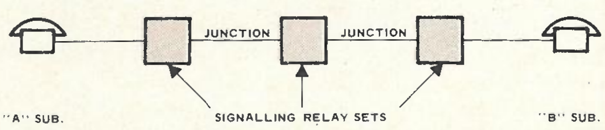



**Fig. 5 — Typical Connection.**

Because loop signalling uses the speech path for signalling it is necessary to separate signalling and speech at the relay sets and prevent signalling currents from passing through the relay sets. This is done by using one of the two types of circuit shown in Fig. 6.

In Fig. 6(a) there is a series capacitor in each conductor of the line, and the signalling relays and contacts are connected across the line on either side. Since the relay coils appear as a large inductance at speech frequencies, the relay coils and the capacitors form a rudimentary high and low pass filter set, allowing speech to be transmitted with little attenuation, while confining the signalling currents to their own side of the relay set. If the relay impedance is too low for satisfactory speech transmission, series inductors, as shown on the left hand side may be included to increase the shunt impedance.

In Fig. 6(b) a transformer is used to isolate the two sides of the relay set for signalling, and the signalling conditions are applied and recognised across capacitors in the centre points of the primary and secondary. In this case, the transformer inductances and the centre point capacitors form the necessary filters to separate speech and signalling.

Either combination of circuit elements is known as a 'signalling bridge', 'transmission bridge' or 'supervisory bridge'. Fig. 6(a) is known as a condenser bridge or a 'Stone bridge' while Fig. 6(b) is known as a transformer bridge or 'Hayes bridge', in each case recalling the name of the inventor.

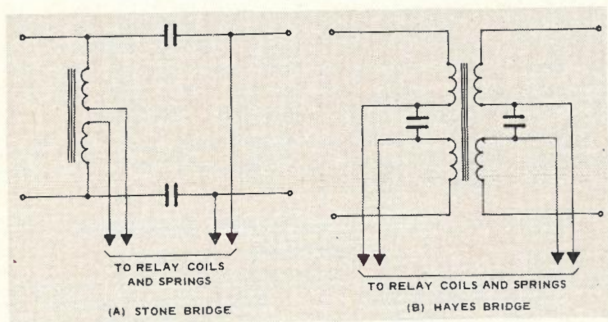



**Fig. 6 — Transmission Bridges.**

### Electrical States

By means of transmission bridges at the two ends of a junction, the two wires of the junction are made available for signalling. These two wires are used to connect signalling equipment at each end in the form of a single series path (or loop), usually containing the elements shown in Fig. 7. At one end of the junction, sometimes called the battery feed end, DC potentials are fed in series with a relay while at the other end relays and rectifiers are connected between the two wires. At each end relay contacts can alter the magnitude and/or direction of the current in order to transmit signals.

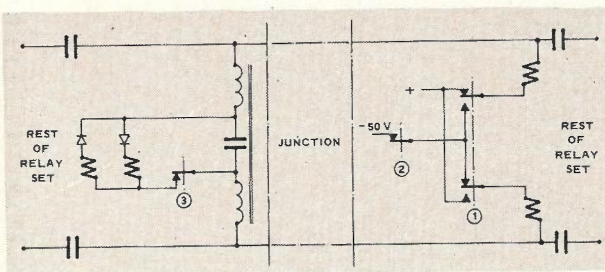



**Fig. 7 — Loop Signalling Principles.**

There are three possible conditions which can represent signals:

- Current in normal direction
- Current in reverse direction
- No current.

Because the signalling relay contacts at each end of the junction are in series, there is considerable interference between the two signalling directions. This is illustrated by Table 2, which shows that there is considerable ambiguity in the zero current state.

TABLE 2

| Relay States | | | Line Current | Ability to Identify State at Opposite End | |
|---|---|---|---|---|---|
| Battery Feed End | | Other End Relay 3 | | Battery Feed End | Other End |
| Relay 1 | Relay 2 | | | | |
| Released | Released | Operated | Normal | Yes | Yes |
| Operated | Released | Operated | Reversed | Yes | Yes |
| Either (1) | Operated | Operated | Zero | No | Yes (2) |
| Released | Released | Released | Zero | Yes (2) | No |
| Operated | Released | Released | Zero | Yes (2) | No |
| Either (1) | Operated | Released | Zero | No | No |

**Notes:** (1) Since relay 2 is operated to give zero current, the state of relay 1 is important.
(2) If zero current is not caused by local relay it must be due to relay at distant end.

The meanings given to these states must be such that the interference does not affect the performance of the system, and this is not unduly difficult. However, in some cases the interference is minimised by adding two new states of 'low current normal polarity' and 'low current reversed polarity', and using the circuit of Fig. 8, at the end remote from the battery feed. At the battery feed end the relays are designed so as not to operate on 'low current', which at that end is therefore interpreted as 'zero current'. At the other end, a more sensitive relay is switched into circuit, which operates on the low current. There are now five electrical states of live current, and the only interference remaining is that with zero current (due to relay 2 operating), the battery feed end cannot determine the signalling condition at the other end.

This circuit can often be simplified if some signalling combinations are not used, and in particular, in the high resistance case it is usually only necessary to detect the presence or absence of battery and not its polarity, so that one relay can be used without diodes.

**Signalling Schedules Without Multimetering**

In a simple network such as the APO step-by-step system prior to about 1955 the only signals needed were seize and release, originating at the A party's telephone and requiring to be transmitted progressively to every relay set in turn, and B party answer requiring to be transmitted backwards as far as the point where metering is determined. Design of a line signalling system to provide these facilities can be considered as a matter of defining an electrical state to specify each of these signals.

In doing so there are already some constraints in respect of the subscribers line sections of the connection, since the signalling facilities of the telephone are defined and there is a further requirement that the exchange supplies a source of DC power to the transmitter. Consequently, for the A party's line the relay set must be at the telephone battery feed end of the signalling circuit, and loop and open circuit at the telephone as previously specified will correspond to call and release. Again, for the B party's line the relay set must be at the battery feed end of the signalling circuit. Provision must also be made to transmit a 16Hz ringing current for the call signal.

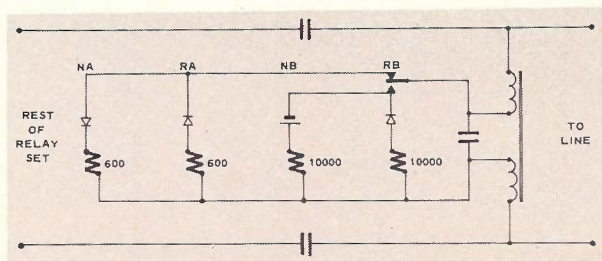



**Fig. 8 — Additional Signals with High Resistance Relays.**

For the other two links there is no inherent reason for the battery feed end to be at one position or the other, but the most satisfactory signalling schedule is obtained by placing it always at the B party, or incoming end of the junction. The call and release conditions are then loop and open circuit as for the A party's telephone. In the B to A direction normal polarity is made to correspond to the 'on hook' condition of the B party and reverse polarity to 'off hook.' These signalling schedules are listed in Table 3.

**TABLE 3 — SIGNALLING IN S x S NETWORK**

| Signal | Electrical Condition | | |
|---|---|---|---|
| | A Party's Line | Junction | B Party's Line |
| Battery at | Exchange End | B Party (Incoming) End | Exchange End |
| A-B Signals | | | |
| Call | Loop | Loop | 16Hz Ring |
| Release | Open Circuit | Open Circuit | No Signal |
| B-A Signals | | | |
| B Party on Hook | Normal Polarity | Normal Polarity | Open Circuit |
| B Party off Hook | Reverse Polarity | Reverse Polarity | Loop |

This signalling schedule allows for B party switch-hook conditions to be repeated right to the A party telephone, and this makes signalling identical on junctions and on the A party's line, and allows some simplification of exchange circuits. The only use made of them, on the A party's line, is that the B party's first answer is used in Public telephones to collect the coins.

**Signalling Schedules with Multimetering**

With the introduction of STD and of more complex release conditions, as described earlier, a greater number of signals are needed in the B to A direction, and the simple signalling system used for step-by-step needs to be expanded. As discussed earlier, the B to A signals needed are:

- B party answer
- B party clear
- B party re-answer
- Forced release
- Meter

As there are only three electrical conditions available to represent all these signals, the effective capacity of the signalling system must be expanded in some way. This has been done by adopting two different schedules, for junctions on the A party and the B party side of the cord circuit point.

On the B party side the signals needed are the same as the simple step-by-step network and the same signalling schedule is used. On the A party side, it has been decided that B party switch-hook signals subsequent to the first answer will not be transmitted, as they are not used. This limits the signals needed to B party answer, metering, and forced release. Metering is signalled by a 150 ms transition from reversed polarity to normal and reversed again, while forced release uses the remaining condition of open circuit at the battery end.

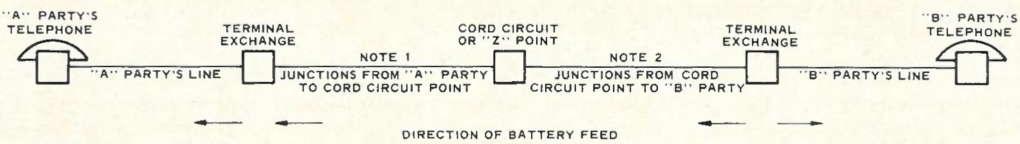
The signals used on junctions on the A party side of the cord circuit point cannot be used on subscribers' lines, because the loop current is used to power the carbon microphone and the polarity changes used for metering would cause audible interference as the current passed through zero. Moreover, the use of diodes in the telephone for access barring prohibits the use of polarity reversal even as an answer signal. Therefore it is now APO standard practice to normally provide no B-A direction signalling on the A subscriber's line. On public telephones, where B party answer is needed, and diode access barring is not required, a special signalling unit (called an MR relay set) repeats B party answer as a polarity reversal. On STD public telephones, and some other lines there is also a requirement for the transmission of metering signals to the subscriber's instrument. These are transmitted as 50Hz pulses over an earth return (cailho) circuit which does not interfere with speech. As with the answer signal, a special signalling unit is fitted to each line requiring this facility.

This method of providing for multimetering requires the use of four different signalling schedules all designated by the general title 'loop signalling.' When it is essential to distinguish between them the following designations are often used:

- A party subscriber signals — on the calling subscriber's line.
- Karlsson signals — on junctions on the A party side of the cord circuit point.
- B party switch-hook signals — on junctions on the B party side of the cord circuit point.
- B party subscribers' signals — on the called subscriber's line.

The signalling schedule for each of these segments is given in Table 4.

**TABLE 4**




| SIGNAL | ELECTRICAL CONDITION FOR SECTIONS ABOVE | | | |
|---|---|---|---|---|
| "A" TO "B" DIRECTION | | | | |
| CALL | LOOP | LOOP | LOOP | 16 Hz POWER (RING) |
| RELEASE | O/C | O/C | O/C | NO SIGNAL |
| "B" TO "A" DIRECTION | | | | |
| CALL NOT YET ANSWERED | NORMAL POLARITY | NORMAL POLARITY | NORMAL POLARITY | O/C |
| "B" PARTY ANSWER | NOTE 3 & 4 | REVERSAL POLARITY | REVERSAL POLARITY | LOOP |
| "B" PARTY CLEAR | NOT USUALLY PROVIDED (NOTE 4) | NOT USUALLY PROVIDED (NOTE 4) | NORMAL POLARITY | O/C |
| "B" PARTY REANSWER | NOT USUALLY PROVIDED (NOTE 2) | NOT USUALLY PROVIDED (NOTE 4) | REVERSAL POLARITY | LOOP |
| FORCED RELEASE | NOT POSSIBLE | O/C BATTERY FEED | NOT NEEDED | NOT NEEDED |
| METERING | NOTE 5 | NORMAL POLARITY FOR 150 M.S. | NOT NEEDED | NOT NEEDED |

NOTE 1 THE CORD CIRCUIT POINT IS FREQUENTLY IN THE TERMINAL EXCHANGE ESPECIALLY FOR UNIT FEE TRAFFIC IN WHICH CASE THIS SECTION IS NOT PRESENT. SOMETIMES THIS SECTION INCLUDES AN INTERMEDIATE EXCHANGE.

NOTE 2 THIS SECTION IS NOT PRESENT IN ALL CASES. WHEN IT IS, IT MAY INCLUDE ONE OR MORE INTERMEDIATE EXCHANGES.

NOTE 3 "B" PARTY ANSWER MAY BE SIGNALLED BY REVERSE POLARITY IN CERTAIN CASES.

NOTE 4 FOR UNIT FEE CALLS FROM STEP BY STEP EXCHANGES, ALL "B" PARTY SWITCHHOOK CONDITIONS ARE REPEATED TO THE "A" PARTY TELEPHONE. IN THIS CASE, THE CORD CIRCUIT POINT IS IN THE "A" PARTY'S TERMINAL EXCHANGE.

NOTE 5 WHEN THE SUBSCRIBER'S EQUIPMENT REQUIRES THIS (IN PARTICULAR S.T.D. COIN TELEPHONES) A 50 Hz SIGNAL OVER THE CAILHO IS PROVIDED BY A SPECIAL RELAY SET.

One disadvantage of the above system of signalling is that a variety of signalling relay sets is needed, depending on the particular signalling schedules on the A and B sides of the relay sets.

Another system which was investigated at the time multimetering was being developed involved adding a new signal for metering, (in fact the 50Hz cailho signal used on subscribers' lines in the present system) so that polarity reversals invariably represented B party switch-hook signals. The result would have been some reduction of relay set varieties, but the savings were judged to be less than the extra cost of the additional signalling facilities required to provide the 50Hz cailho signals.

With the exception of metering, line signals occur at times when conversation is not possible and therefore some incidental noises in the speech path associated with their transmission can be tolerated. Therefore, the filtering provided to separate speech and line signals need not be of a very high standard, provided it prevents line signals in one section of the complete speech path from spilling over into adjacent sections and has a sufficiently low attenuation to speech frequencies. In the design of these elements signalling requirements are more stringent than speech transmission, and the relays are designed with emphasis on their signalling performance rather than transmission efficiency.

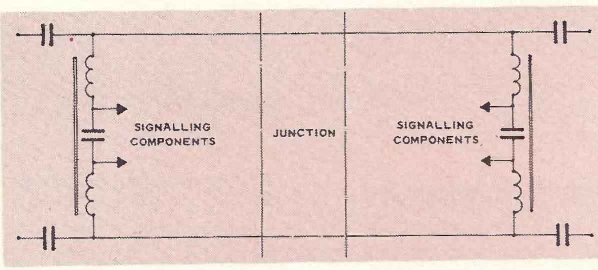



**Fig. 9 — Filtering for Metering Signals.**

Metering signals differ from other line signals in that they are present during conversation and must be inaudible. Where they are transmitted by polarity reversals the signals are filtered by networks of inductance and capacitance and no reliance is placed on relay coils to provide inductance. Fig. 9 shows the circuit elements normally used at each end. At the battery feed end, where the polarity reversals are generated, the filter made up of the inductor Dr and C1 reduces the amplitude of high frequency components associated with the signals until they are inaudible. A filter is also needed at the receiving end, because noise is generated in the relay coils as a result of changes of inductance with current and induction effects from relay armature movement.

### Decadic Information Signals

If decadic information signals are transmitted over the same line, it is necessary to distinguish them from the line signal for release. Both are generated by interrupting the line current at the end remote from the battery feed but each interruption forming part of a decadic signal is approximately 66 ms, whereas the release signal continues for much longer, so that time duration can be and is used as a distinguishing criterion. There is no clearly defined duration of open circuit which a relay set must identify as release, and as it usually depends on the design of slow releasing relays which are not always easily controlled, it ranges from 200 ms to nearly 1 second for different situations. This can be a source of some operational difficulties and is being given more attention now than in the past.

The requirements to be met for transmission of line signals are considerably different from those to be met for transmission of decadic information, the latter having timing tolerances one or two orders more stringent. High speed of response brings with it a greater sensitivity to operation from transient interference, so that a system optimised for line signals only would have different timing to one optimised for transmission of decadic information signals. The first would have response times of about 50 ms, while the second would have response times of 1 or 2 ms.

The need for these compromises makes relay set design difficult, and in a large heterogeneous network, with equipment designed at different times, and to different specifications there are some extremely difficult maintenance problems caused by these variations. Network changes made possible by the introduction of cross bar systems should eventually minimise the importance of these problems, but at the present stage (1973) the introduction of crossbar into metropolitan networks has made the situation more, rather than less, complex and there is a need for very careful oversight.

One aspect of the use of decadic signalling is that the filters used for multimetering signals cause intolerable impulse distortion and must be switched in and out of circuit, depending on whether decadic information signalling is needed at the particular time.

### Intermediate Signals

In addition to the basic line signals, from end to end, there are numerous intermediate signals required between the two ends of a junction or within a telephone exchange, or even a specific switching stage of an exchange. These signals are superimposed on the basic pattern already developed. There is an almost unlimited range of such special signalling, both for lines and exchanges, and they need to be studied in detail for each specific application. Exchanges in particular have a very large number of special variations. For junctions and trunks, there is only one extra signal in extensive use, known under the names of 'back busy', 'blocking' and 'release guard.' It is a signal which indicates that, due to some condition existing at the incoming end, the junction is unavailable. The reason may be, for example, that the line has been taken out of service manually (Blocking or Back Busy), or has not yet completed its release sequence (Release Guard). The condition is usually indicated by the same electrical condition as is used for forced release, the signal being distinguished by its context since one signal can only be present if the junction is idle and the other is only present if it is busy. (Actually, forced release and release guard can be consecutive, without any interval between them, or any definite point which can be called the end of the forced release and start of the back busy.)

The 'Blocking' signal must be recognised in the idle state, and the use of a sensitive, high resistance relay whose current is not sufficient to be interpreted as a loop condition is necessary, as shown in Fig. 8.

Some trunks and junctions are designed for both way operation and these must transmit all the necessary line signals in either direction. To do this, each end is equipped with the elements of both an outgoing and an incoming relay set, with provision for switching from one to the other. A problem with both way circuits is that they may be seized at both ends simultaneously, and 'call collisions' must be suitably dealt with in the circuit design. Since it must take a finite time for a seizure at one end to be transmitted and recognised at the other, there is always a 'risk time' during which collisions are possible. The only way of completely overcoming problems arising from this is to make the seizure a sequential process; in which the initial action is a 'seizure request', which may be responded to by 'seizure accepted', or 'seizure refused'. In the latter case either the call is allowed to fail, and the subscriber receives busy tone, or a second trunk or junction selected. The choice depends on the probability of the 'seizure refused' condition and the ability of the equipment to make a re-selection.

To fully implement this technique, electrical conditions are needed from both ends to signal:

- Seizure request to other end.
- Seizure from other end accepted.
- Seizure from other end refused.
- Circuit blocked at this end.
- Circuit available for seizure.

Furthermore, the completion of the seizure sequence must see the two relay sets in the correct condition for the direction of the call, i.e. normal battery at the incoming end and loop at the outgoing end, and the sequence must be completed before the next digit is dialled, if decadic information signalling is used.

No really trouble-free both way relay set for loop conditions has yet been developed, and it is obvious that it would be rather complex and the seizure release sequences would take a fairly long time. Fortunately, the cases where both way signalling on loop circuits are most important are low traffic cases such as from a small exchange and the probability of call collisions is low and can be reduced by various tricks. Quite a big improvement for example can be made simply by sequential searching over a group of junctions in opposite directions from each end, so that as long as two trunks are idle no collision can occur. On a group of 7 trunks this gives nearly 100 : 1 reduction in call collisions.

## SIGNALLING OVER CARRIER CHANNELS

### Early Method

Modern carrier systems are provided with signalling facilities, which allow a two-state signal to be transmitted in each direction as shown in Fig. 10.

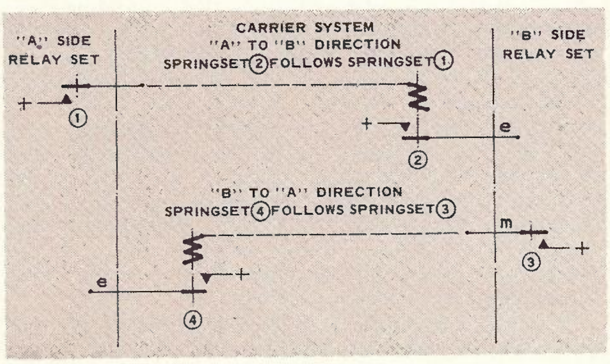



**Fig. 10 — Signalling on Carrier Channels.**

It was originally intended that these two conditions would correspond to loop and open circuit in one direction and normal and reverse polarity in the other. This left no condition to correspond to open circuit battery feed — i.e. forced release and blocking. A system of compelled sequence signalling was therefore developed in which the seizure and release required a sequence of signals in both directions, and provided blocking and release guard facilities. The signalling schedule for this type of signalling is shown in Fig. 11.

An unforseen problem with the above system and with any system which involved the presence of signalling tone on a large number of channels simultaneously was that the various signalling tones are coherent, and add in an unfavourable way to cause severe over-loading of the carrier system line amplifiers. Because of this, systems using short pulses in place of continuous tones are now standard.

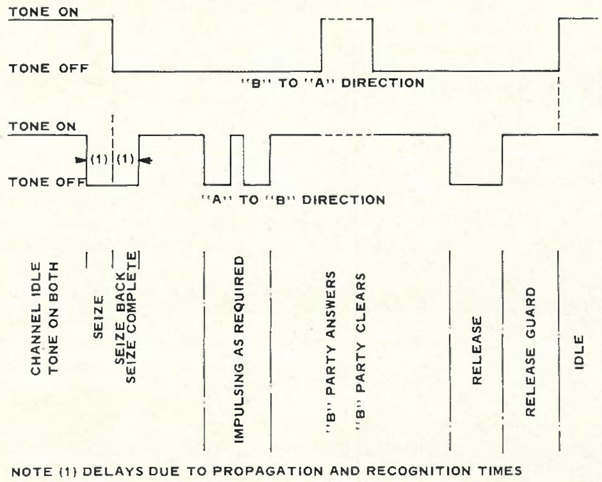



**Fig. 11 — Compelled Sequence Signalling.**

### LME Pulse Signalling

With pulse signalling, the only way to provide a variety of signals is to control the pulse duration. The APO has adopted, with some variations, the L. M. Ericsson pulse system which uses two pulse lengths; a short pulse of 150 ms nominal, and a long pulse of 600 ms nominal. The short pulse is the shortest which can be reliably transmitted over the carrier signalling path, while the ratio of 4 : 1 is adopted to allow relay timing circuits to be used to distinguish between them.

With only two electrical signals available, some additional coding is needed to provide for the full range of line signals needed. The method used relies on the fact that line signals must of necessity follow a known sequence, and the schedule of main signals is given in Table 5.

**TABLE 5 — SIGNAL SCHEDULE**

| Signal | Electrical Condition | |
|---|---|---|
| **Call** | **Short Pulse** | |
| **Release** | **Long Pulse** | |
| Answer | Short Pulse | From 'B' party to Cord Circuit Point |
| Clear | Long Pulse | |
| Re-answer | Short Pulse | |
| Answer | First Short Pulse | From Cord Circuit Point to 'A' party |
| Meter | Subsequent Short Pulses | |
| Forced Release | Long Pulse | |

Bothway use of trunks is rather easier with this type of signalling because the two signalling paths are symmetrical and independent. The usual arrangement to guard against call collisions is that if signalling is received from the opposite end while the seize pulse is being transmitted, the seize pulse is extended to become a release signal, and busy tone is returned to the caller.

This signalling system is designated T type and was developed by L. M. Ericsson for a register controlled system. It is not suitable for step-by-step networks, because the pick-up is too long to be accommodated in the interval between dialled digits. A modified system has therefore, been developed in which the decadic information signals are stored at the originating end until the incoming circuit at the far end has been seized and is ready to receive digits. This is indicated by a 'proceed to dial' signal which is a short pulse. This means that the first short pulse is proceed to dial, the second is 'B' party answer, and the third and subsequent ones are metering. This kind of sequential coding is the only one possible with carrier signalling and has definite limitations, and with the essential differences in technique between carrier and loop signalling techniques, each imposing constraints, it seems to be impossible to add new major line signals within the established format. Indeed, one of the most recent line signalling requirements is for control of echo suppressors on calls used for data transmission and the signal will use a voice frequency tone, transmitted over the speech path in order to avoid the complexity of adding it to existing line signalling circuitry.

**Rural Carrier Signalling**

A special type of carrier system, known as rural carrier has been developed to provide junctions to small terminal exchanges using existing aerial wires. This application called for a low cost design and uses transmitted carrier, so that a simple signalling facility was provided by switching the carrier on and off. This was adequate for signalling in unit fee networks, but because the carrier cannot be interrupted during conversation it cannot be used for transmission of multimetering signals. Therefore, a subsidiary signalling channel, of a very limited signalling speed is added when this is needed. This channel is also used to improve the protection against call collisions. The signalling schedule used for these systems is designated T1.

**Pulse Code Modulation Signalling**

Pulse code modulation (PCM) carrier systems are a comparatively new development, which by coding speech signals into trains of pulses allows carrier systems to be provided economically over distances of 15 to 50 km without the need for special carrier cables. The nature of the design makes it relatively easy to provide more elaborate signalling and it is usual to have two signalling channels in each direction instead of the one channel provided on standard carrier. Moreover, the restriction on system loading which applies on standard carrier and requires the use of pulsed signals does not apply to PCM. Consequently, a signalling schedule has been developed and designated T5, which makes use of the PCM signalling facilities and allows great simplification of the signalling relay sets.

Very little PCM carrier is in use in the APO mainly because the development in the largest cities of an extensive co-axial cable network, with standard carrier systems, has pre-empted the field of its greatest advantage. However, the future extensive use of PCM is highly probable.

**Intra Exchange Signalling**

Within an exchange, at least three, and usually four wires are available for line signalling, two of these wires being the speech transmission path, and the other wire(s) being used purely for internal signalling. The arrangements vary from one type of exchange to another, but in most exchanges the two speech wires carry line signals corresponding to the external circuits connected to the exchange as this allows a great simplification of either the incoming or outgoing relay set. The two possible situations are shown in Figs. 12(a) and 12(b).

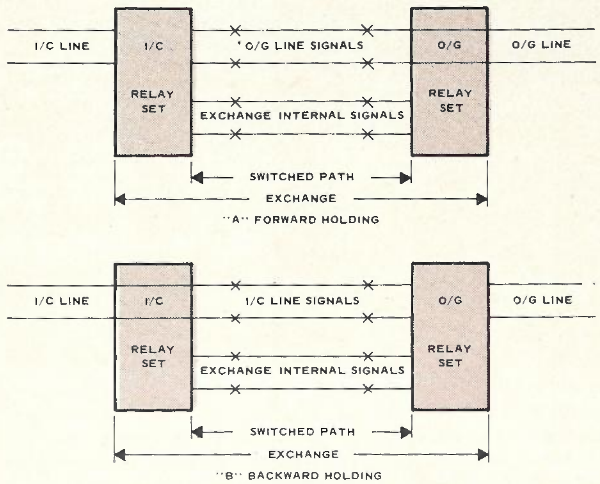



**Fig. 12 — Intra-Exchange Signalling.**

In Fig. 12(a) the line signals on the speech pair within the exchange are those needed by an outgoing line, with all line signalling within the exchange controlled from the incoming relay set over other wires. Consequently the speech path wires can be connected straight through the outgoing relay set, as indicated. That is, the outgoing relay set does not have a transmission bridge, and signalling to it is carried over the other exchange wires. The incoming relay set provides a transmission bridge and has the functions of sending, receiving and acting on line signals across three interfaces, one on the 'A' side to the incoming line, one on the 'B' side to the outgoing line, and a further one on the 'B' side to the exchange equipment. The outgoing relay set is considerably reduced in complexity and indeed in some cases is non-existent.

There is, however, one line signal over the outgoing circuit which cannot conveniently be recognised by the incoming relay set over the exchange switching path. This is 'back busy', and if this facility is needed, the outgoing relay set must provide it. This facility can be provided without a transmission bridge, so that even if it is needed, there are still substantial cost savings possible because of the simplicity of the design.

This configuration is known as 'Forward Holding' since one of the more important internal signals is the one which holds the switched path in service and it is sent from the incoming relay set.

In Fig. 12(b), the speech pair carries the line signals needed by an incoming line, and the outgoing relay set is the one with a transmission bridge and from which all control is exercised. In this case the only line signal which the incoming relay set must recognise is the pick-up or seizing signal. This configuration is known as 'backward holding'.

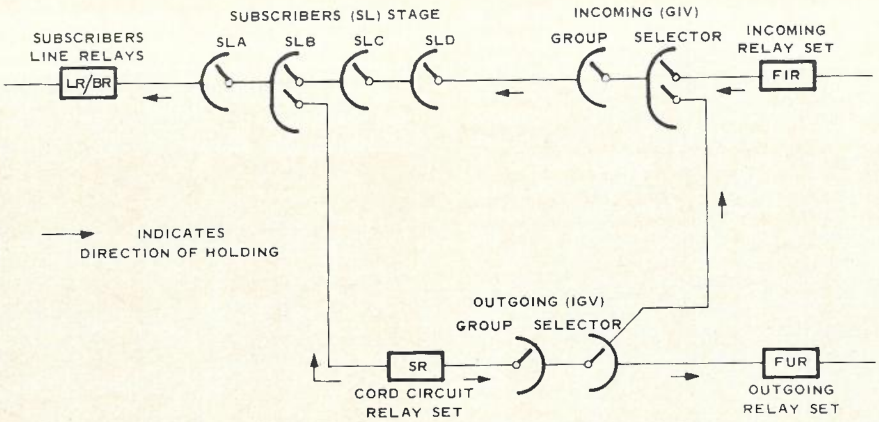



**Fig. 13 — Holding Conditions in ARF Exchanges.**

All ARF exchanges are designed as forward holding systems, except for the portion of the call from the calling subscriber to the cord circuit relay set, which is backward holding. The direction of holding is shown in detail in Fig. 13, which shows the main classes of line relay set which are required. These are the subscribers line relays usually designated as the LR/BR relays, the cord circuit relay set (SR), which is used on all calls outgoing from subscribers in the exchange, outgoing relay sets (FUR) for calls to other exchanges, and incoming relay sets (FIR) for calls from other exchanges.

On a local call, the 'A' side of the cord circuit provides the line conditions needed by the calling subscriber, and the 'B' side provides the conditions needed by the called subscriber, so that, once a connection has been established the subscribers' line relays do not have to recognise any signals over the subscribers' line. The SR holds both backwards to the 'A' party and forwards to the 'B' party.

On outgoing calls, the conditions from the 'A' party to the SR relay set are the same, while on the 'B' side, the SR relay set provides the line signals needed by the outgoing junction. The outgoing relay set (FUR) is therefore a simple relay set without a transmission bridge.

On incoming calls, control and holding are performed in the incoming relay set (FIR) which provides the signalling needed by the 'B' party, as well as holding forward, and includes a transmission bridge.

**'d' Wire Signals**

The signalling within the exchange is carried on two wires designated 'c' and 'd', which extend through all switching stages, and a third wire designated 'r' which is only provided between the subscribers line relays and the 'A' side of the SR relay sets.

The 'd' wire carries a fairly simple and limited series of signals needed to set up the switching stages which are listed in Table 6.

The significance, and the method of using these signals is shown in Fig. 14, which is part of the circuit of a crossbar selector (GV or SL stage). In the idle state, the incoming 'd' wire is connected to a call detector circuit, in the portion of the marker known as the code receiver (abbreviated to KMR). The selector is seized by applying ground potential to the 'd' wire at the preceding switch,

**TABLE 6 — 'd' WIRE SIGNALS**

| Signal | Direction | Electrical Condition |
|---|---|---|
| Seize, call, callmarker call KMR* | Forward | Ground from Preceding Equipment |
| Hold | Forward | Ground from Preceding Equipment |
| Release | Forward | Removal of Ground |
| Idle | Back | -50V potential in series with 1000 ohms |
| Busy | Back | Earth Potential |

* Different names used for the one signal

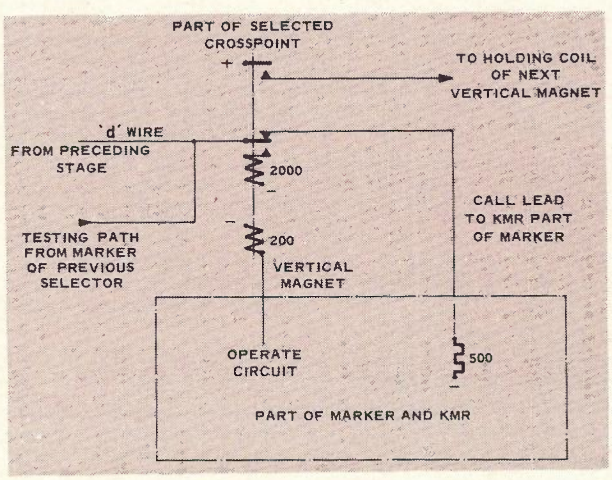



**Fig. 14 — Use of 'd' Wire.**

which initiates action in the marker, as a result of which an outlet is selected, and the necessary horizontal magnets and vertical magnets in the selector rack are operated. Operation of the vertical magnet (GVA or SLD) associated with the selector inlet causes the 'd' wire to be switched, so that the ground from the preceding device is holding the vertical magnet. Another contact operated by the vertical magnet causes earth potential to be extended to the other vertical magnets of the selector stage and to the 'd' wire of the next selected switch, when the same sequence is followed. At the end of the call, the ground is removed by the first device in the connection, usually an FIR or SR relay set causing the vertical magnets to release in succession. The only other function of the 'd' wire is to provide a busy test for a marker in a preceding stage when it is selecting an idle inlet in this stage. Examination of Fig. 14 will show that the conditions on the 'd' wire are as shown in the last two entries in Table VI for the two states of an idle and a busy inlet.

**'c' and 'r' Wire Signals**

It will be noted that the 'd' wire is not continuous through the exchange, but that the signals are repeated at every switching stage. The 'c' wire, on the other hand, is continuous between any two line relay sets and carries a variety of signals between them. In a local call, the 'c' wire is used to seize and hold the subs line LR/BR relay set, and to provide a busy test for the subs line. The seize and hold signal is earth potential from the SR relay set, as in the case of the 'd' wire. The busy test is rather more complex, for reasons which will be obvious later.

Between the 'A' party's line and the SR relay set there are five wires, a, b, c, d, and r, as shown in Fig. 15, and of these, a, b, c and d have the same functions and signalling as on the 'B' side of the SR relay set, while the 'r' wire is connected to the subscriber's meter (formerly called 'register', hence 'r') and provides metering signals and an answer signal, the latter being needed only for public telephones.

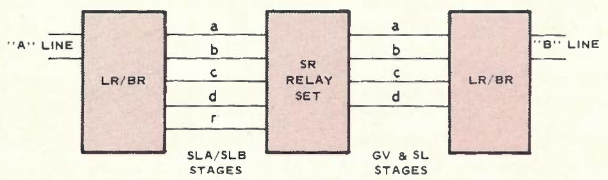



**Fig. 15 — Signalling Wires in Local ARF Call.**

## ARF RELAY SETS

The significance of these signalling schedules and the method employed can best be appreciated by a more detailed examination of the circuits of some ARF crossbar relay sets in typical switching configurations.

In a local call there are three line signalling relay sets: two LR/BR relay sets, one for the incoming ('A') side of the connection and one for the outgoing ('B') side, and an SR relay set. The two LR/BR relay sets are, of course, identical, as every subscriber's line is a bothway circuit, and used for incoming and outgoing calls.

**LR/BR Circuit Operation**

On an incoming call, the LR/BR relay set must:

- Recognise a call signal from the telephone and initiate marker operation to connect the line to an SR relay set.
- When switching to the SR relay set is completed, change to a state in which the speech pair is carried through the LR/BR relay set without any series or shunt impedances, to allow battery feed from and signalling to and from the SR relay set.
- Return to normal on a signal from the SR relay set at the end of the call.
- Accept metering signals.
- Protect the line from intrusion by attempted calls incoming to the line.

On an outgoing call, the LR/BR must:

- On a signal from the SR relay set switch to the same state as (2) above.
- Return to normal at the end of the call.
- Protect the line from intrusion by further attempted calls incoming to the line.

In addition, these relays provide an extra function whereby busy tone can be returned to the subscriber's line from the line relay set without requiring any other equipment to be held. This state is generally called 'line lockout'.

Fig. 16(a) is a circuit of the LR/BR relays, with both relays shown in the idle condition, which is the state when no call is in progress. It will be noted that relay LR has one winding connected to line to detect calls, outgoing from the subscriber.

When the line is seized for a call incoming to the subscriber, earth is applied to the 'c' wire from the SR relay set, operating the two relays LR and BR in series, giving the situation in Fig. 16(b), and it will be seen that there is now no equipment across the line wires 'a' and 'b', which pass straight through. In this direction of switching there is no connection to the 'r' wire.

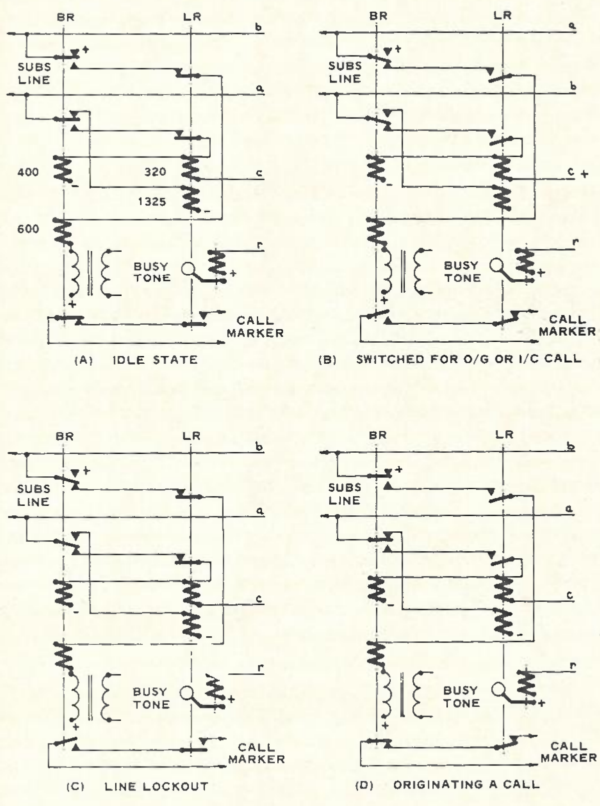



**Fig. 16 — LR/BR Relay Set.**

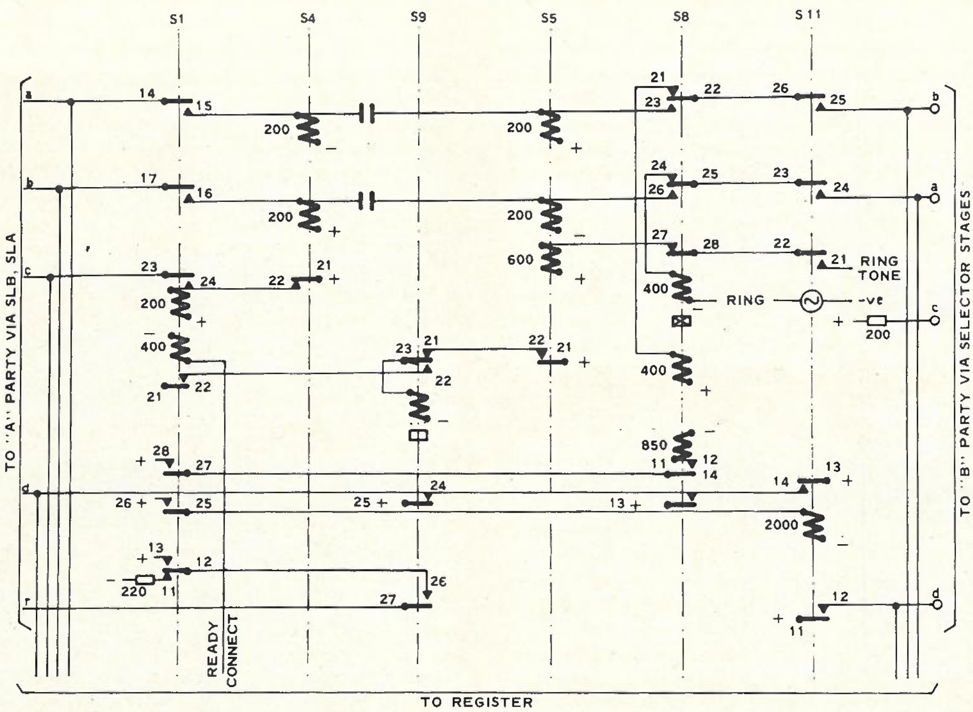



**Fig. 17 — Simplified SR Relay Set.**

At the end of the call, the earth is removed from the 'c' wire, and relays LR and BR are no longer held over this path. The relays are so designed that LR releases first, so that if the telephone has not been restored, relay BR remains operated over the line, giving the circuit condition of Fig. 16(c). It will be noted that busy tone is fed in series with the BR relay to the subscriber's line. This situation, known as line lockout, continues until the subscriber hangs up.

If the subscriber originates a call, placing a loop across wires 'a' and 'b', the relay LR operates, giving the condition of Fig. 16(d), in which there is a circuit between the two 'call marker' wires. This causes the marker to establish a connection to the 'A' side of an idle SR relay set, from which a ground on the 'c' wire operates relay BR and holds relay LR, giving again the condition of Fig. 12(b). At this stage the 'r' wire is extended to the SR relay set but is open circuit there. If this call is ultimately successful, the 'r' wire will be earthed in the SR relay set when the called number answers and at the end of the call the wire will be connected for a short period to -ve 50V to operate the meter. The 'r' wire thus provides an answer signal (which is only used if the line is a public telephone, in which case there is a different relay set (MR relay set) which repeats this answer signal to the telephone for control of coin collection and metering.

The release of the call, including if necessary a 'line lockout' sequence, is precisely as for a call outgoing to the subscriber.

The line lockout condition performs another useful function in regard to line faults. The most common line fault is a permanent loop (or call) condition and the exchange is designed so that if a call is present for more than about 45 seconds without dialling, the line is placed on line lockout, so that no exchange equipment other than the LR/BR relays of the faulty subscriber's line is held up. This is the function from which the facility derives its name.

The busy test for a subscriber's line uses the 'c' wire, and it is possible to distinguish between 'sub idle', 'sub busy normal' and 'sub busy line lockout'. This allows some special facilities to be provided, the most useful being to allow test positions to get access to lines on lockout.

**SR Circuit Operation — Local Call**

The SR relay set, which provides signalling over the external lines to the two subscribers, and controls the call is a much more complex device. Fig. 17 shows a considerably simplified circuit, in which some features have been omitted. This relay set is associated with a register until the call is set up, and during the setting-up period the register performs any necessary line signalling functions. For this reason the 'a', 'b', 'c' and 'd' wires on the 'A' party side, and the 'a', 'b' and 'd' wires on the 'B' party side are extended to the register via the register finder stage, as indicated in the diagram. When the 'A' party calls as described, the call marker signal causes the common control equipment to set up a call to an idle SR and connect it to an idle register which holds the switching stages on the 'd' wire and switches the LR/BR relays into the through condition over the 'c' wire. The register also sets up the call towards the 'B' party, using the 'a', 'b' and 'd' wires for this purpose.

When the connection is established to the 'B' party's line the +ve potential on the 'c' wire via a 200 ohm resistor operates the LR and BR relays, so switching them into the speaking condition. At about the same instant the register operates relay S1 in the SR relay set over the wire designated 'ready connect'. Relay S1 operates relay S11 and the contacts of the two relays connect both sides of the SR relay set to the exchange equipment. Relay S4 also operates from the calling subscriber's line.

With S1, S11 and S4 all operated, the following conditions are applied to the relay terminals:

- Speaking battery is fed to the 'A' subscriber via relay S4.
- Earth (+ve) potential via the 200 ohm winding of S1 is applied to the 'c' wire on the 'A' side. This holds S1 in series with LR and BR in the line circuit.
- The 'A' side 'd' wire is connected to earth (+ve) via a contact of relay S11, holding the 'A' side switches.
- The 'B' side 'd' wire is earthed by a contact of S4, holding the 'B' side switches.
- Ring current (about 75V, 16Hz), in series with the exchange battery, and the windings of relay S8 is applied to the 'B' subscriber's line, ringing his telephone bells.
- Ring tone, i.e., a signal suggesting the sound of the telephone bell, is applied to the 600 ohm winding of relay S5. This relay is acting at this stage as a transformer to transmit ring tone to the 'A' party.

At this stage the signalling conditions previously applied to the SR terminals by the register have been duplicated by the same conditions applied by the SR relay set. The register is no longer required and is released by a circuit which is not shown.

When the 'B' party answers the call, a DC path is completed over the line, operating relay S8 (ring trip relay) which then locks on the 850 ohm winding. Contacts of S8 disconnect ring tone and transfer the 'B' party speech path wires from relay S8 to relay S5, completing the speech connection.

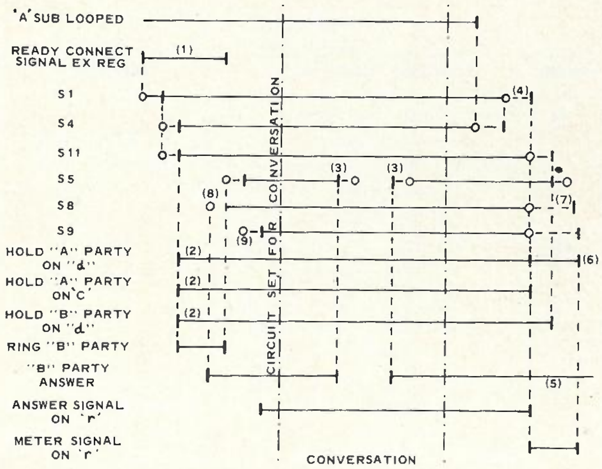
Relay S5 operates to the 'B' party's line loop, and its contact operates S9. S9 disconnects its operating circuit, and changes to a holding circuit dependent on relay S1. A contact of S9 applies earth potential to the 'r' wire to repeat 'B' party answer to the line relay sets of public telephone lines.

The circuit is now in the speaking condition and remains so until the calling party clears.

The 'B' party may clear and re-answer with no effect, as the release and re-operation of S5 now causes no change.

When the calling party restores his telephone, relay S4 releases, and commences a sequence which clears the connection. The winding of relay S1 is short-circuited by the contact S4 21-22, and releases slowly. This ensures that a brief interruption to the loop is ignored, as some subscribers equipment can generate short breaks. Once S1 has released, the disconnection of the call proceeds irrevocably, since S1 contacts have now disconnected relay S4 from the 'A' party's line. The release sequence is:

- S1 releases S11, which releases promptly, and S8 and S9, which release slowly.
- When S11 releases, S5 is disconnected from the 'B' party's speech wires, and if it still operated, it now releases. The release of S11 also removes the hold condition from the 'd' wire on the 'B' side, releasing the selectors.
- The release of the 'B' side selectors opens the 'c' wire, and the 'B' party LR/BR relays either release, or change to line lockout.
- When S1 releases it also changes the condition on the 'r' wire from ground potential (answer) to -ve via 220 ohms, which operates the subscriber's meter.
- This latter state continues for the release time of relay S9, which is a slow releasing relay.
- The release of S9 removes holding ground from the




NOTES:
(1) REGISTER READY CONNECT SIGNAL GIVEN WHEN "B" PARTY IS CONNECTED.
(2) THESE HOLD CONDITIONS TAKE OVER FROM HOLD APPLIED BY REGISTER.
(3) DURING CONVERSATION "B" PARTY MAY (BUT NEED NOT) CLEAR AND REANSWER WITH NO EFFECT ON SR CIRCUIT.
(4) S1 IS SLOW RELEASING DUE TO S/C WINDING. DELAY PREVENTS SHORT BREAKS FROM RELEASING CALL.
(5) RELEASE OF SELECTORS TO "B" PARTY CAUSES LINE TO BE SET IN LINE LOCKOUT. THIS WILL CONTINUE, REGARDLESS OF THIS CIRCUIT TILL "B" PARTY CLEARS.
(6) CLEARING OF CONNECTION TAKES PLACE ONLY AFTER ALL RELAYS NORMAL.
(7) DELAY ON RELEASE OF S8 IS INCIDENTAL TO CIRCUIT OPERATION AND UNAVOIDABLE CHARACTERISTIC OF RING TRIP RELAY.
(8) CONTACTS 11-12 OF S8 MUST MAKE BEFORE 21-22 OR 24-25 BREAK, SO THAT HOLDING CIRCUIT IS MAINTAINED.
(9) CONTACTS 21-22-23 ARE MAKE BEFORE BREAK SPRINGS SO THAT DURING OPERATION S9 IS CONTINUALLY HELD ON S5 OR S1.

**Fig. 18 — Sequence Chart for SR Relay Set.**

'd' wire on the 'A' side, completing the release of the connection. (Note: This release could not be permitted until the call was metered.)

Table 7 is a chart showing the combination of relays in the SR relay set needed to achieve certain conditions, and Fig. 18 is a time sequence chart of the relay operations. These two charts present a more compact representation of the operation of the circuit than the preceding description. Sequence charts in one form or another are widely used as a means of describing the operation of a relay circuit, and Fig. 18 is one of the standard types of representation with considerably more explanatory detail than is usually provided.

### SR Circuit — Junction Calls

The SR relay set is also used for outgoing calls, in which case the 'B' side is signalling to a junction instead of to a subscriber, and for unit fee calls the signals required are those in the second column of Table 3. This requires the relay configuration similar to that shown earlier in Fig. 7 and means of switching from the previous circuit (Fig. 17) to this. These extra segments are shown in Fig. 19. On junction calls relay S10 is operated from the register before S1 (Fig. 17) and changes the circuit elements associated with the 'B' party side of the speech path to a circuit involving a retard Dr and two relays, S6 and S7, with rectifiers so that S6 operates on reverse polarity and S7 on normal polarity. S6 has contacts which duplicate the function of S5, and contacts

### TABLE 7

| Relay | Operate Condition | Remarks |
|---|---|---|
| S1 | (1) Ground on Ready Connect Lead.<br>(2) S1 Op + S4 Op + —ve from LR/BR on C wire. | When S4 releases, S1 releases with a delay. |
| S4 | S1 Op + A party calling (Looped). | |
| S5 | S8 Op + S11 Op + B sub answering (Looped). | |
| S8 | (1) S11 Op + B sub answer + S8 not operated.<br>(2) S8 Op + S1 Op. | Springsets of S8 adjusted so that these two states overlap. |
| S9 | (1) S5 Op + S9 non Op.<br>(2) S1 Op + S9 Op. | S9 21-22-23 is made before break to ensure that these states overlap. |
| S11 | S1 Op | |

| Signal | Condition for Signal | Remarks | |
|---|---|---|---|
| Hold to 'A' party on 'd' wire | S9 Op or S11 Op or S8 Op | Holds Switches | All these signals can also be provided from Register during set up of call. |
| Hold to 'A' party on 'c' wire | S1 operated | Holds LR/BR | |
| Hold to 'B' party on 'd' wire | S11 operated | Holds Switches | |
| Hold to 'B' party on 'c' wire | Signal present permanently | Only effective when call is connected. | |
| Ring 'B' party | S8 Op and S11 Op | | |
| Answer on 'r' wire | S1 Op and S9 Op | | |
| Meter on 'r' wire | S1 not Op and S9 Op | | |

of S10 ensure that the appropriate relay, either S5 or S6, is effective.

In this state the SR must work with the outgoing (FUR) relay set, which is required to prevent the junction being seized if a back busy condition is applied at the distant end and switch the speech path through when seized. Towards the exchange the FUR signals on one lead only, the 'd' lead, and the signals are as shown in Table 8.

### TABLE 8

| | |
|---|---|
| (1) back busy — O/C 'd' wire<br>(2) idle — batt via 1000 ohms | signalling to the exchange |
| (3) seize and hold — ground on 'd' wire<br>(4) release — O/C 'd' wire | signalling from the exchange |

Only FUR signals (3) and (4) involve the SR relay set.

### FIR Circuit Operation

For incoming traffic, an incoming (FIR) relay set controls the connection within the exchange and holds forward. A simplified circuit is shown in Fig. 20. In the idle condition, all relays are released, including the vertical magnet of the associated selector inlet, and battery and ground is fed to line via relay F1, which is the call detecting relay.

A call operates F1, from a loop applied at the distant exchange, and F1 operates F2 after a short delay which in turn applies ground to the 'd' wire to call the incoming selector. Signalling and selecting take place using MFC information signalling until the circuit is extended to a subscriber's line relays. Relay F6 then operates over the 'c' wire, in series with the LR/BR relays in the subscriber's line circuit, and connects the relays F3 and F4, which ring the 'B' party's telephone, detect the answer condition and repeat it back to the calling end as a polarity reversal. These circuit elements are almost identical to the corresponding part of the SR relay set.

At the end of the call F1 releases, followed after a delay by F2, and all the remaining relays, the last being F4, which is slow to release. Only when this relay and the crossbar selector vertical magnet are restored is battery re-applied to the line to indicate to the far end that the circuit is again available. Note also that the key BK can be operated to 'back busy' the junction. If this is done while a call is in progress the key is ineffective until that call is released.

In the circuits so far described, the 'c' wire is used as a means of signalling between SR or FIR relay sets, and the subscriber's LR/BR relays, and the signals used can be described as:

- Seize and/or hold subscriber's line.
- Busy test for subscriber's line.
- An indication that connection has been extended to a subscriber's line (and therefore ringing should commence).

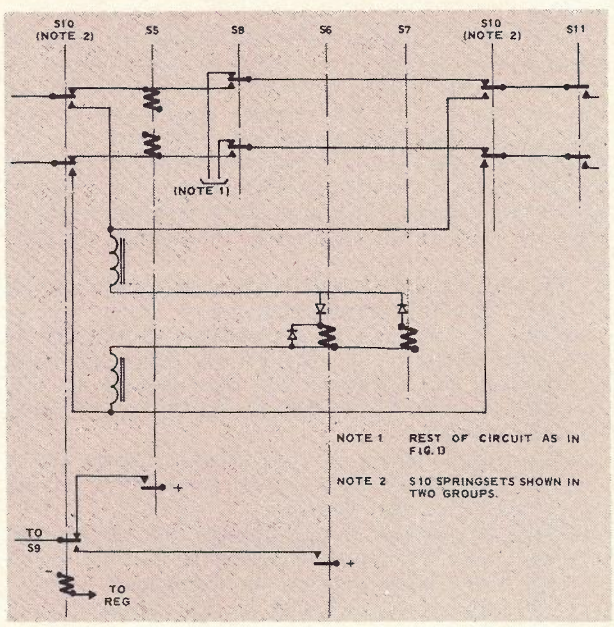



**Fig. 19 — SR Circuit Elements for Junction Traffic.**

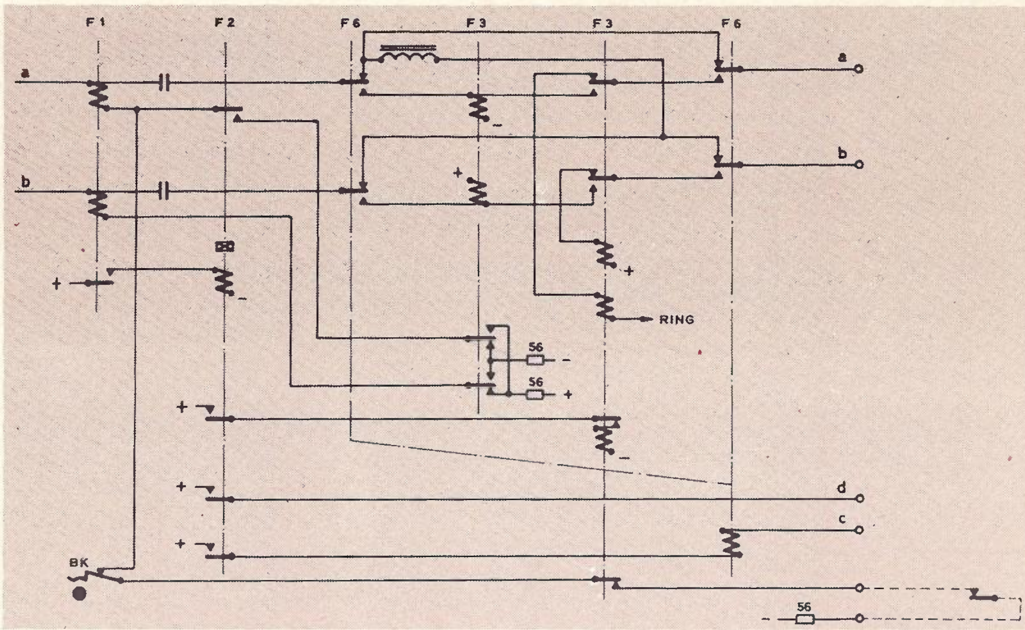



**Fig. 20 — Simplified FIR Relay Set.**

### Other Signalling Needs

The 'c' wire is also used for signals needed between other types of relay sets, these signals being necessary because of the design concept of ARF. From the description of the 'd' wire signalling it should be apparent that the ARF switching stages are inherently forward holding and that it is desirable that the incoming relay set (or SR) should provide the signalling and transmission bridge. However, this requires the 'B' side to be capable of signalling to all types of outgoing lines from the exchange, and as this is not always possible one of the following methods is used to overcome the problem:

- A limited number of signalling options can be provided on the 'B' side of the incoming relay set. The SR as described has two, and in the complete circuit a third is provided for Karlsson signals.
- Outgoing relay sets with transmission bridges and acting as signalling converters can be used on outgoing lines for which the incoming relay sets do not provide the necessary signalling conditions.
- Outgoing relay sets with transmission bridges can be provided, with 'A' side signalling to suit the most common form of 'A' side signalling, and for a call from this kind of incoming circuit the outgoing relay set can assume control, switching the transmission bridge out of circuit on the incoming relay set.

All three methods are used in the ARF system, the choice depending on the particular circumstances, and each has requirements for inter-relay set signalling for which the 'c' wire is used. Within a local network, serving a town and its surrounding rural area, or a large city, the two most common signalling conditions are those for subscribers lines, and for 2 wire junctions with 'B' party switch-hook conditions. These two options will often cope with 90% or more of signalling needs and solution (1) is the most suitable. However, there are also requirements for a limited number of external circuits with other signalling such as carrier channels with E and M lead signalling, and 2 wire junctions with Karlsson signalling.

Furthermore, the ARF exchange described so far is a 'pure' crossbar exchange in which all junction circuits are 2 wire lines, with MFC information signalling, and no interworking with step-by-step equipment. In most cases, however, an ARF exchange is installed as an extension to an existing network, with a large step-by-step component, and is often an extension of an existing step-by-step exchange. It may also have a PABX connected with facilities for direct in-dialling using decadic pulses. Allowing for all these possibilities, as well as the possibility of lines with special signalling (such as carrier channels), an ARF terminal exchange may have all the types of relay set connected that are shown in Fig. 22.

It is convenient in discussing this exchange to deal with the originating and terminating portions separately. The originating section is comprised of the 1GV stage and the devices connected to it, and the inlets to this stage may be switched to any outgoing circuits connected to the exchange. All the 1GV inlets come directly from subscribers (via a concentrating stage) and require register access. There are two possible groups, crossbar subscribers switched to an SR relay set as previously described, and sometimes step subscribers connected to a similar relay set known as SR (B). This is done when for some reason it is desired to give the subscribers the calling facilities of crossbar without replacing the uniselectors and final selectors.

Both relay sets are identical in their B side facilities and can interwork with 'B' party subscriber condition, 2 wire junctions with 'B' party switch-hook signalling and 2 wire junctions with Karlsson signalling. The choice between the three is made by signals from the register which decides by analysing the dialled code, and sometimes as a result of backward MFC signals.

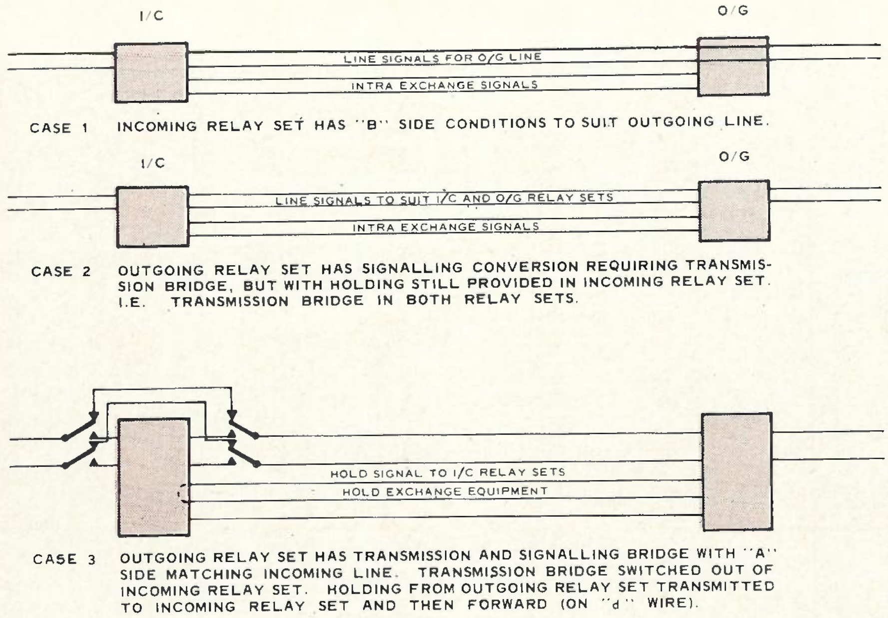



**Fig. 21 — FUR-FIR Interworking.**

Of the outgoing junctions connected to the 1GV stage, those which are 2 wire circuits need no signalling repeater as the SR relay set provides the necessary line signals for all types of junctions. This means that the speech wires pass through the outgoing relay set, and line signals, decadic information and MFC information can all be transmitted freely. The two categories (C) and (D) representing MFC and decadic signalling cases thus have the one type of relay set.

Outgoing junctions other than those with loop signalling (i.e. categories (E) and (F) have relay sets which include a signalling bridge, but use it for signal conversion and repetition only, and do not provide any holding signals. Because provision for decadic signalling increases the cost, different relay sets are available in some cases for circuits which do and those which do not need this facility. The SR and SR(B) relay sets must always have a transmission bridge because the exchange internal signals are different on the A and B side of the relay sets. At the same time its intimate association with a register makes it possible and economical to provide the three main types of 2 wire loop signals on the 'B' side without needing 'c' wire signals. The incoming (GIV) stage has a variety of incoming junctions from other exchanges, as well as internal trunks from the 1GV stage, and must connect all of these to three types of lines:

- Crossbar subscribers (M)
- Step-by-step selectors switching to SxS subs (N)
- Indialling PABX's (P)

None of these present any new condition to the SR relay sets, but for incoming traffic there are several new requirements. Firstly, the incoming relay sets may not have register access and need some other way than a signal from the register to indicate the types of line signalling needed. There are here only two types needed, 'B' party subscriber conditions on calls to crossbar subs and 'B' party switch-hook junction conditions on calls to the step section or to indialling PABX's. There are also some opportunities to switch out the incoming signalling bridge on calls to SxS. This arises because SxS is inherently backward holding and a call to a SxS subscriber will always have a signalling bridge in circuit in the final selector.

For this reason, the relay set for loop signalling junctions from crossbar (G in Fig. 22) provides the options of 'B' party subscriber signals and a through metallic path, with provision for holding from the step equipment, which is essentially Case 3 of Fig. 21. This requires:

- A relay in the incoming relay set which switches out the signalling bridge.
- A signal from the SxS inlet (actually from the GIV when it selected the SxS inlet) to operate this relay.
- An extension of the holding signal from the SxS equipment.
- The signals between the FIR and the LR/BR relay set as in Fig. 20 are still needed.

The switching signal (2) is a pulse of +ve battery on the 'c' wire, followed by the holding signal which is earth potential on the 'c' wire.

Fig. 23 shows part of the relay set, and should be read in conjunction with Fig. 21. The 'c' wire connects via diodes to relays F6 and F7, so connected that on a call to crossbar F7 does not operate and the circuit is in fact identical in operation to Fig. 21, and battery on the 'c' wire operates relay F6 to start 'B' party ring.

On a call to a step-by-step number, the positive battery pulse on the 'c' wire operates relay F7, which switches the speech pair to a through metallic path, and applies a holding ground to the 'd' wire. F7 then connects its other winding to the 'c' wire and this winding holds to the ground potential returned from the step-by-step equipment. This holding signal is repeated from the private wire of the step equipment via a simple relay set, which has no connection to the speech path.

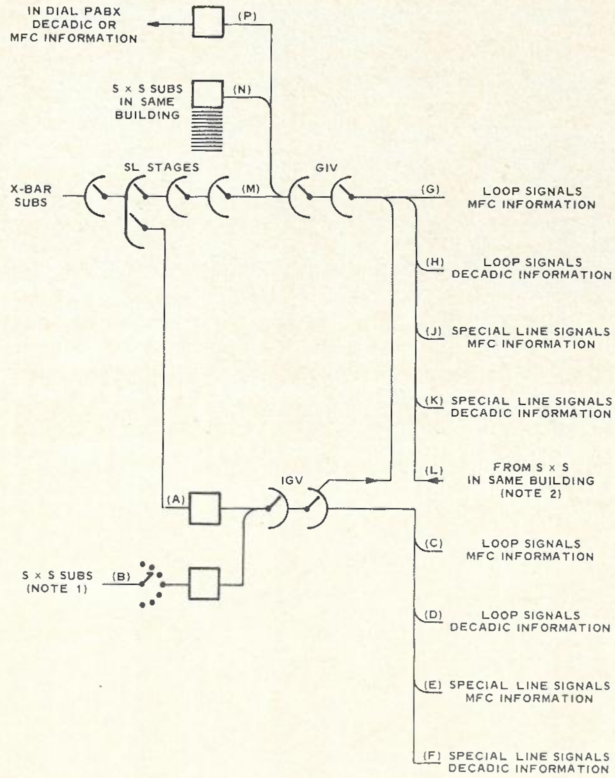
The other type of circuit requiring junction signalling conditions is the indialling PABX line (P). These are provided with outgoing relay sets which include a signalling bridge and hold over the 'c' wire precisely as the step-by-step circuits. The number of this kind of circuit is never large and in many exchanges none at all are needed, so this is a more economic solution than providing the facility to interwork with 'B' party junction signals in all incoming relay sets.

For loop signalling circuits incoming from step-by-step (i.e. (H) and (L)), it is necessary to provide a register, but the same line signalling conditions are needed, and on calls to SxS or indialling PABX's the incoming relay set switches to a metallic path precisely as for group (G) except that the decision on switching is made in the register. In group (L), there is an additional requirement for metering signal to be transmitted from calls which switch metallic to step-by-step selectors or indialling PABX's. This signal is a +ve battery pulse on the 'c' wire.

The remaining types of relay set (J) and (K) have signalling other than loop on the junction side. These, of course, cannot switch through on calls to (N) and (P), and must have facilities on the exchange side to signal either to 'B' party lines or junctions with 'B' party switch-hook signals. The change over is made either in response to 'c' wire signals, or by decisions in the register if one is associated.

A full schedule of the signalling on the 'c' wire in an ARF crossbar **Terminal** exchange is given in Table 9.

Other types of crossbar exchange, including the various ARF tandem configurations, ARK terminal exchanges, and ARM trunk exchanges have similar means of internal signalling, with a schedule specifically designed for each of the different cases. Detailed information is available in relevant APO Engineering Instructions.




NOTE 1 STEP SUBSCRIBER'S GIVEN ACCESS TO CROSSBAR 1ST SWITCHING STAGE.

NOTE 2 ROUTE FOR STEP TRAFFIC FROM OWN EXCHANGE TO THE CROSS-BAR PORTION MAY ALSO CARRY TRAFFIC TO THE S x S PORTION OF EXCHANGE.

**Fig. 22**

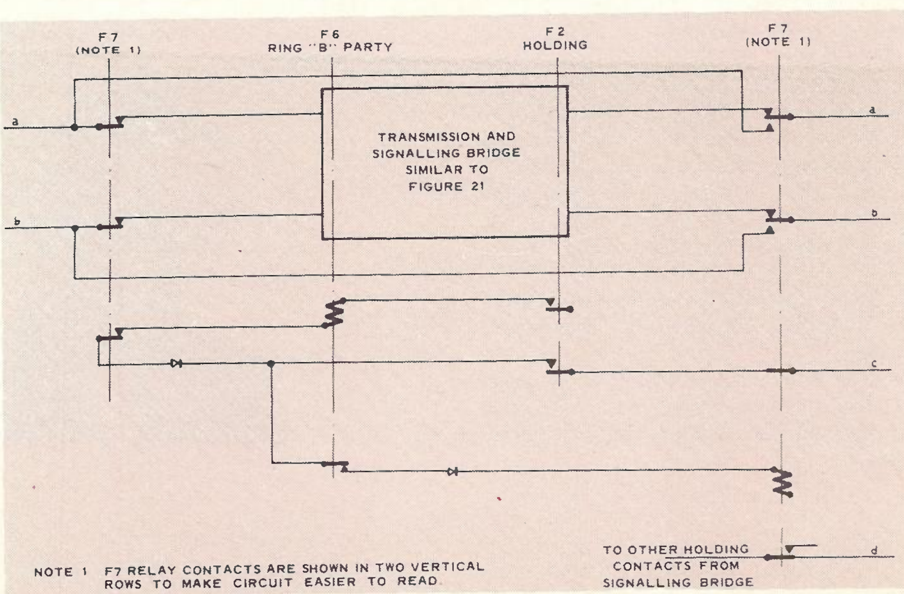



**Fig. 23**

**TABLE 9 — C WIRE SIGNALS IN ARF TERMINAL EXCHANGES**

| Signal | From | To | Electrical Condition |
|---|---|---|---|
| Switch to Junction Type Signals | FUR | FIR | Pulse of +ve50V |
| SR Connected | SR | FUR-L3F-C | +ve via 1000 ohms (must not precede signal "switch to junction conditions.") |
| Backward Hold | Some FUR'S | Some FIR's | +ve on 'c' wire |
| Metering | Some FUR'S | Some FIR's | +ve50V pulse on 'c' wire |

**REFERENCES**

A. H. Freeman, 'Principles of Common Control in Crossbar Exchanges'; Telecomm. Journal of Aust., June 1973, Vol. 23, No. 2, page 150.

A. H. FREEMAN is Supervising Engineer, Fundamental Planning, New South Wales. See Vol. 18, No. 3, page 287 of this Journal.

# New Assistant Director (Engineering), New South Wales

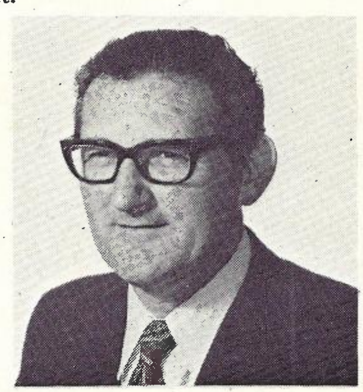
Mr M. J. Power, M.I.E. (Aust.), has been appointed Assistant Director (Engineering), New South Wales to replace Mr G. A. Simpson.

Mr Power joined the Australian Post Office as a cadet engineer in 1937. After completing his training he served as engineer in Sydney Metropolitan Exchange Installation, and was responsible over the course of some 18 years for the development of three main areas of the Sydney telephone network. During 1959 Mr Power was appointed Supervising Engineer, Metropolitan Installation. In 1962 he transferred to the Planning Branch as Supervising Engineer, and in January 1971, was appointed Executive Engineer, Planning and Programming Branch, where he remained until his present promotion to Assistant Director (Engineering) N.S.W.

Mr Power has been engaged in Australian Postal Institute activities, including Chairman of Committees for an extensive period.

A highlight of his career has been his 36 years membership of the Telecommunication Society, including 13 years as Chairman of the New South Wales Division. He was the Foundation Chairman of the Division and has continued in this office to the current year. Under his guidance the New South Wales Division has grown in numbers, funds and activities. He was appointed a Life Member of the Society in 1969.

The Society takes this opportunity to express its appreciation of his service and wish him well in his new appointment.



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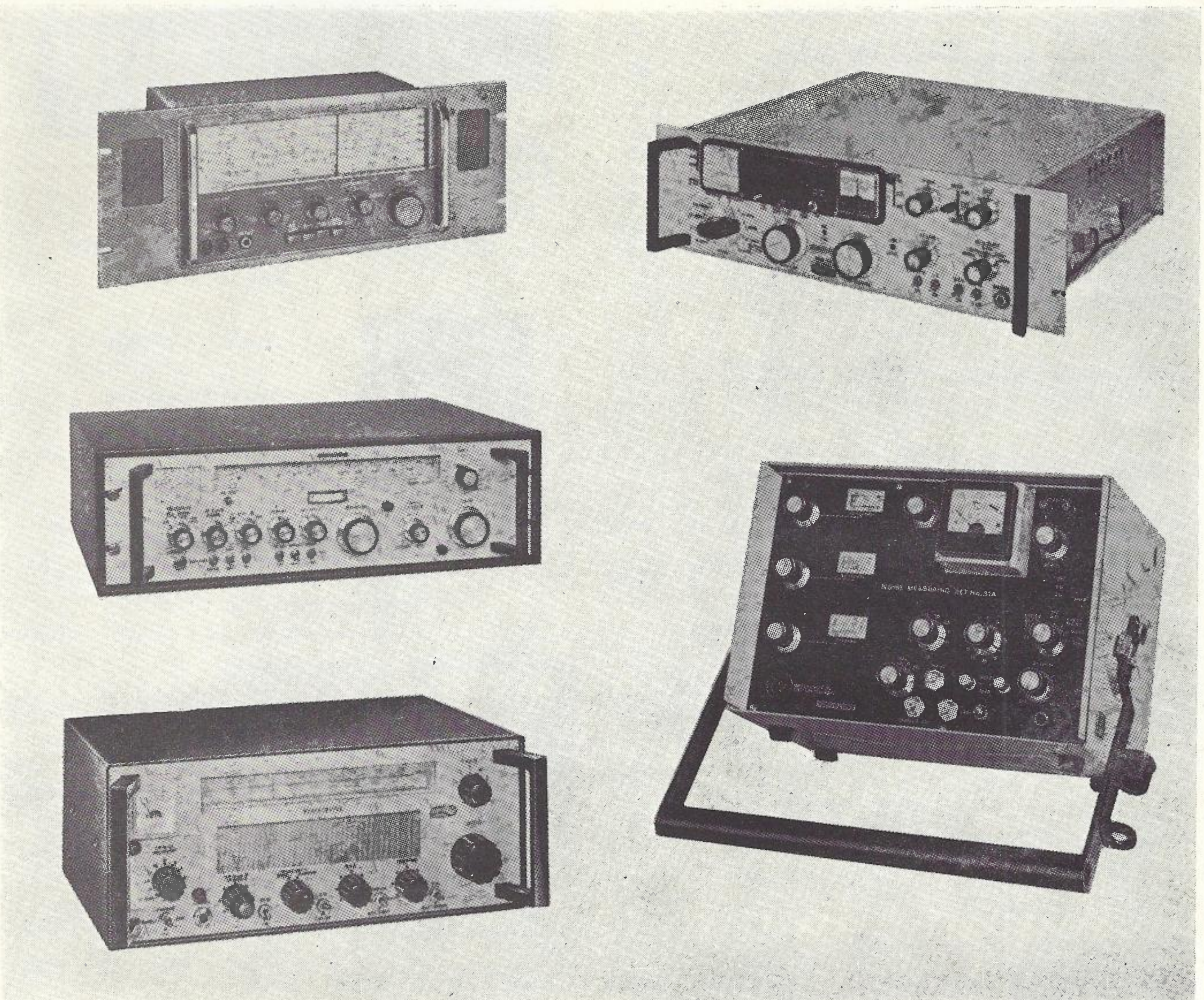

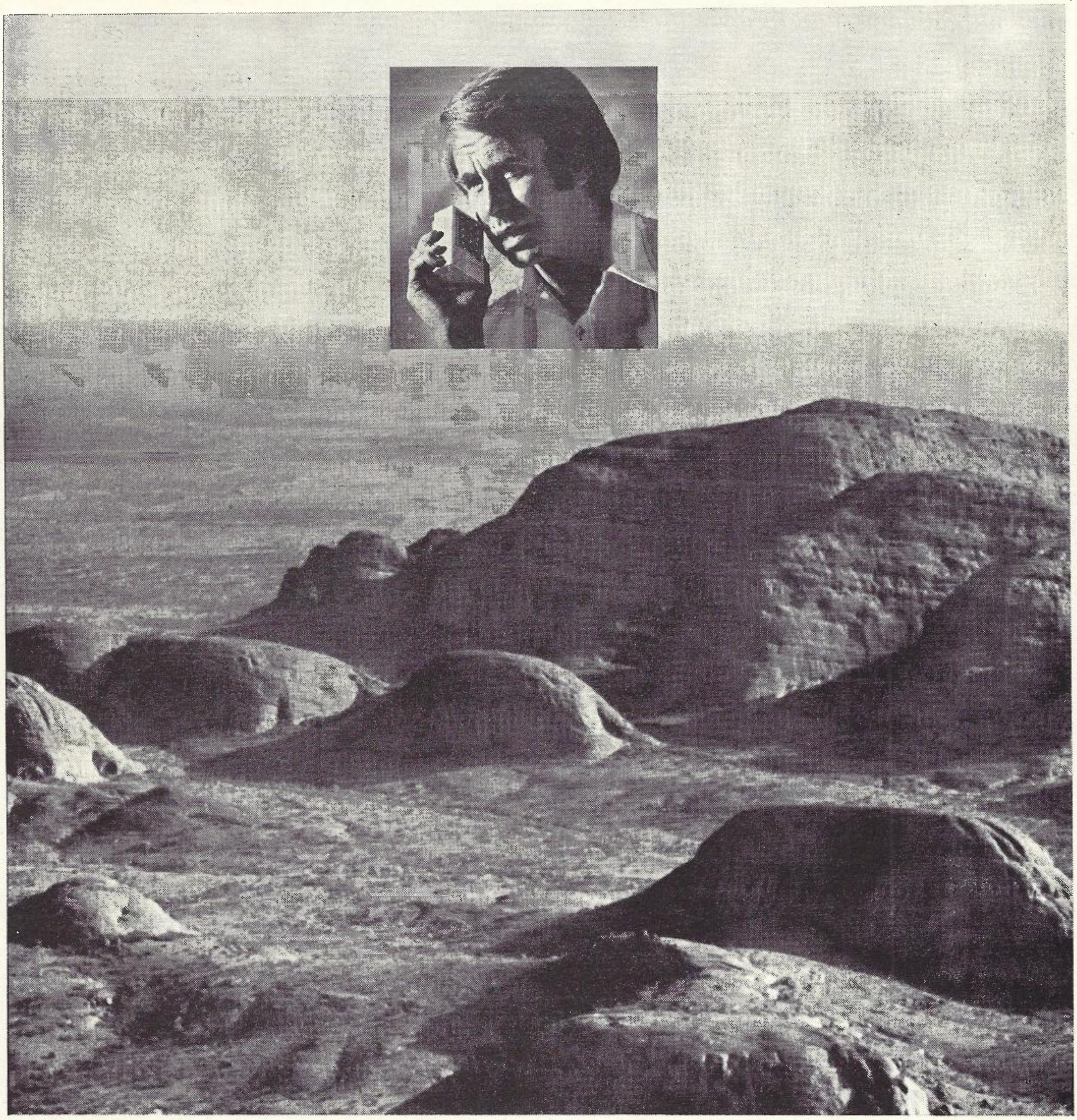

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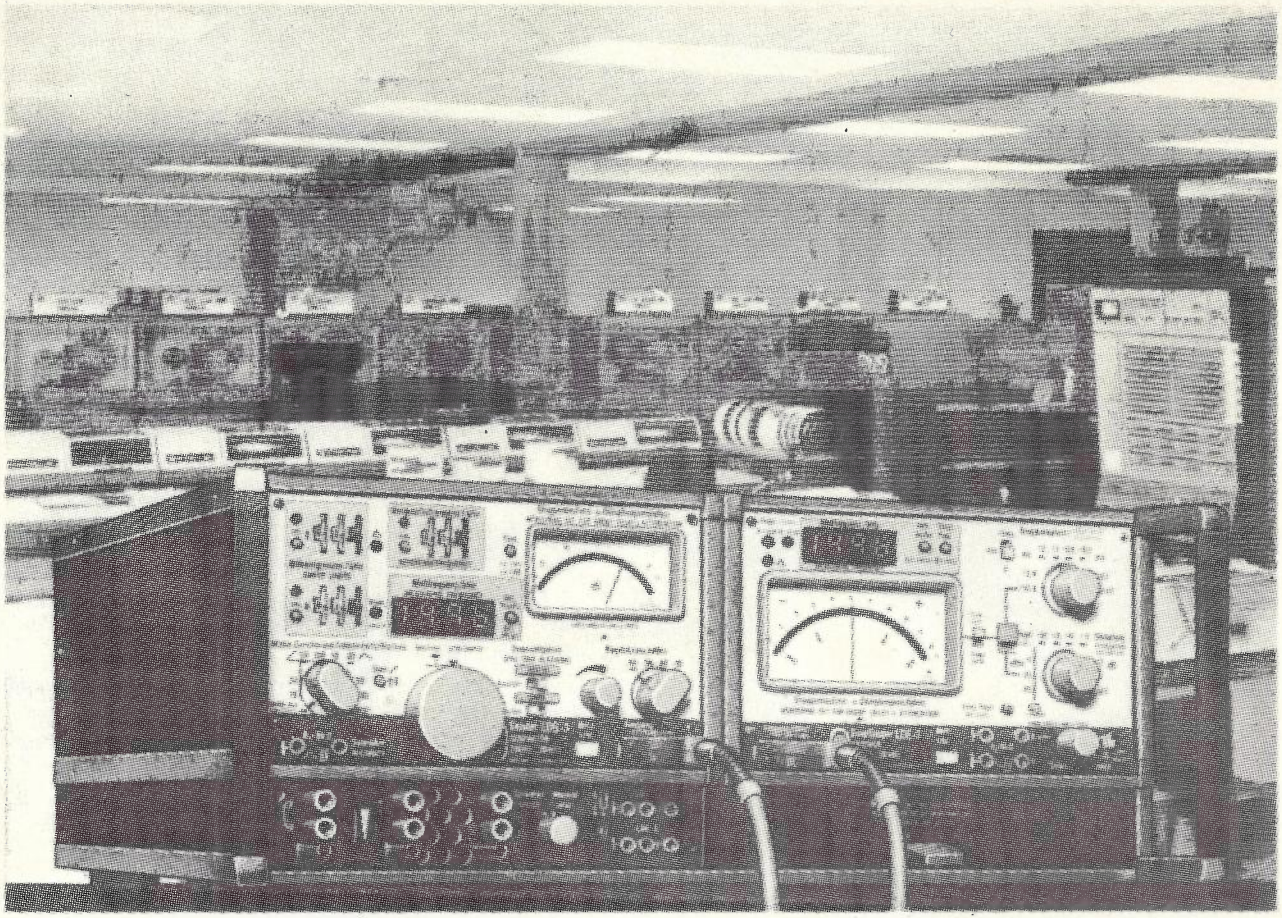

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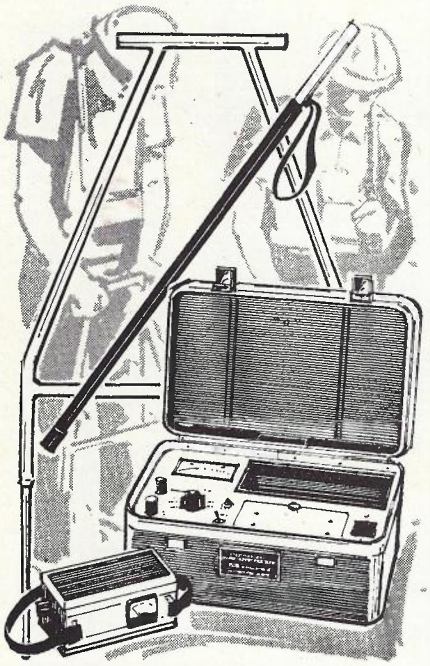

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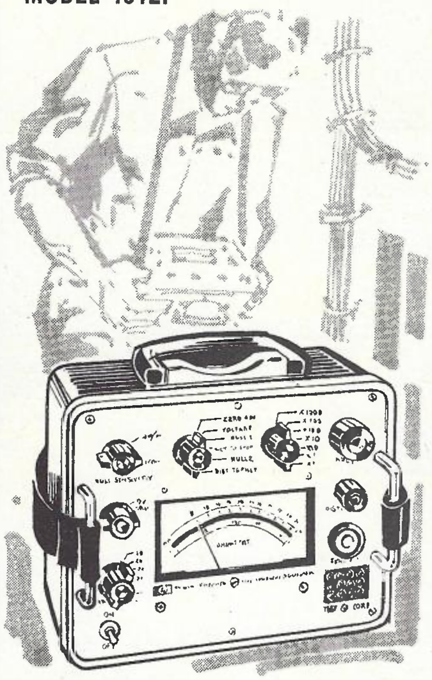

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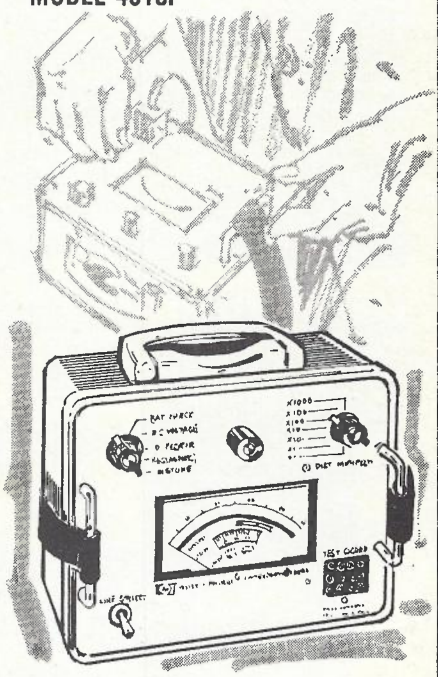

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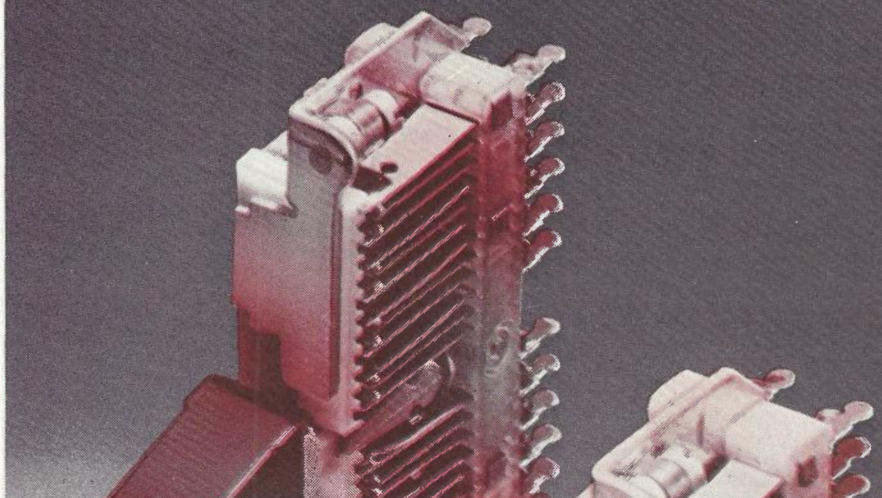

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# The Telecommunications Journal of Australia

## ABSTRACTS: Vol. 23, No. 3.

**CLARK, R. A., and FLATAU, G.: 'Development of Nylon Jacketed Telephone Cable Resistant to Insect Attack'; Telecomm. Journal of Aust., October 1973, page 234.**

The field and laboratory testing of the protection against insect attack offered by cables jacketed with nylon are discussed. These tests led to the use of NYLON 11 and NYLON 12. Production problems, cable diameter restrictions, and results of wide-spread field usage of nylon jacketed cable in Australia over more than five years are described.

**FREEMAN, A. H.: 'Line Signalling'; Telecomm. Journal of Aust., October 1973, page 247.**

This article outlines the basic principles of line signalling in a telephone switching network, with particular reference to the techniques employed in Australian networks. The article concludes with an outline of how the line signalling functions are implemented in some standard ARF line relay sets.

**HORTON, R., and CAHILL, L. W.: 'Microstrip Techniques for Microwave Radio'; Telecomm. Journal of Aust., October 1973, page 228.**

Current design philosophies appropriate to microwave and millimetre wave integrated-circuit network functions are outlined, illuminating the advantages to be gained in using a medium such as microstrip in preference to the conventional coaxial or hollow waveguide counterparts.

Some examples of typical applications are presented, and photographs of sub-system assemblies highlight the compact, miniaturised neatness which such a medium affords.

**KELLOCK, A.: 'The Wired City'; Telecomm. Journal of Aust., October 1973, page 185.**

The APO has just commenced a complex operation to plan the course of telecommunications in Australia beyond the year 2000 A.D. This article indicates the national significance of the undertaking and the complexities of the issues involved. The potential facilities which may be offered to subscribers are outlined, some of which call for a network of markedly different capabilities to the existing telephone networks.

**PETERS, N. W.: 'Connector Jointing of Telephone Cables'; Telecomm. Journal of Aust., October 1973, page 192.**

A review of the development of pressure crimped wire connectors and their application to, and compatibility with, the range of cable conductors in use in the APO are discussed. The related cable jointing machines and hand tools are described, together with the methods to provide for quality assurance of field joints. A brief look at future developments in the connector jointing area is included.

**PRATT, C. W.: 'Development and Application of Telephone Traffic Measuring Equipment (Part 1)'; Telecomm. Journal of Aust., October 1973, page 205.**

Part 1 of this article discusses the data requirements for planning and supervision of the telephone network. Data of two basic categories are required: occupancy (traffic load) and dispersion (origin-destination). Equipment developed within the APO is planned to be used at key exchanges within the network to provide computer legible data of both categories. Part 2 will deal in more detail with the design philosophy of the equipment.

**SALTER, J. P.: 'An Interface Unit for Transmission Measuring Sets used in the Telephone Network'; Telecomm. Journal of Aust., October 1973, page 242.**

Transmission measurements in the telephone switching equipment environment pose some problems in protection of test instruments from the effects of D.C., and in control of the switched connections established for the purposes of measurement. This article outlines the features of an instrument developed to overcome these problems and simplify transmission measuring procedures in telephone exchanges.

**SEYLER, A. J.; BRUEGGEMANN, H.; KETT, W., and DICKSON, J.: 'The APO TV-Conferencing Facility'; Telecomm. Journal of Aust., page 216.**

In 1969 APO management decided that experimental studies should be undertaken to determine the human, technological and economic factors pertaining to the establishment of TV-conference facilities in the Australian telecommunication environment. This paper presents the philosophy of approach, the technical implementation and the early operational experiences associated with the development of these facilities.

**WALKER, A. P.: 'The Evolution of Radio Frequency Spectrum Management'; Telecomm. Journal of Aust., October 1973, page 210.**

The article surveys the development of the use of the radio frequency spectrum and the evolution of international management in this field to date, and concludes with a discussion of some of the problems of the future.

# THE TELECOMMUNICATION JOURNAL OF AUSTRALIA

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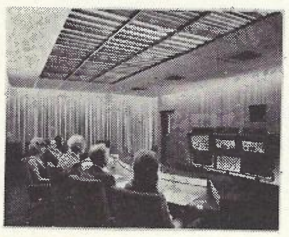

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