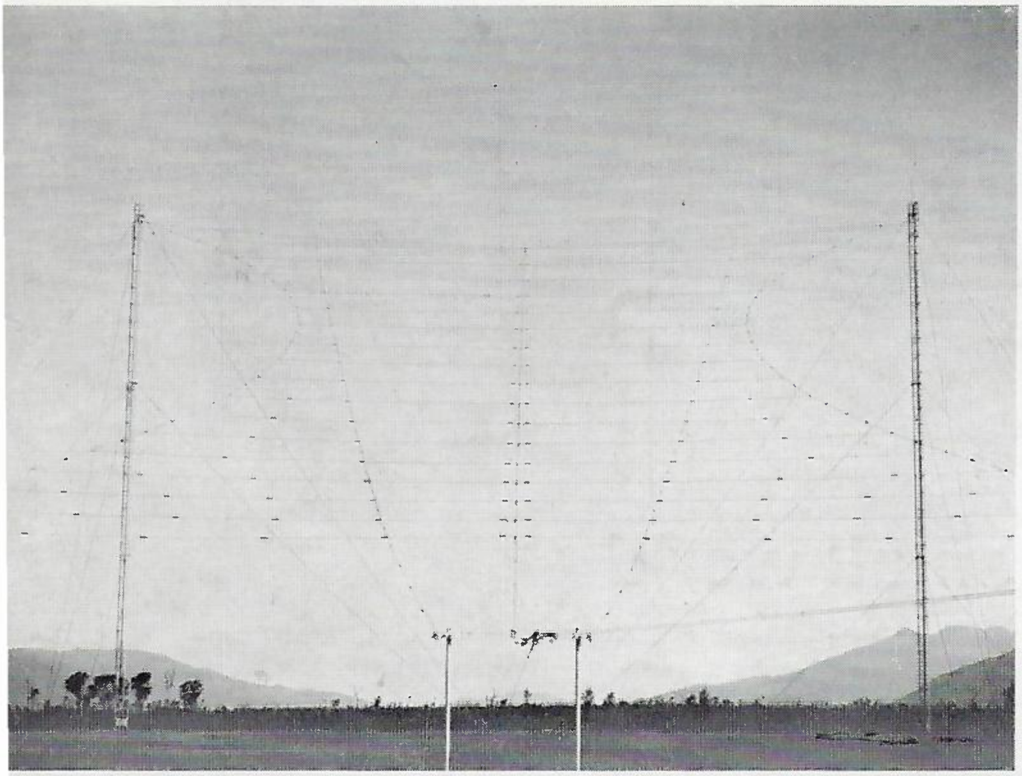
THE
Telecommunication Journal OF AUSTRALIA



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IN THIS ISSUE

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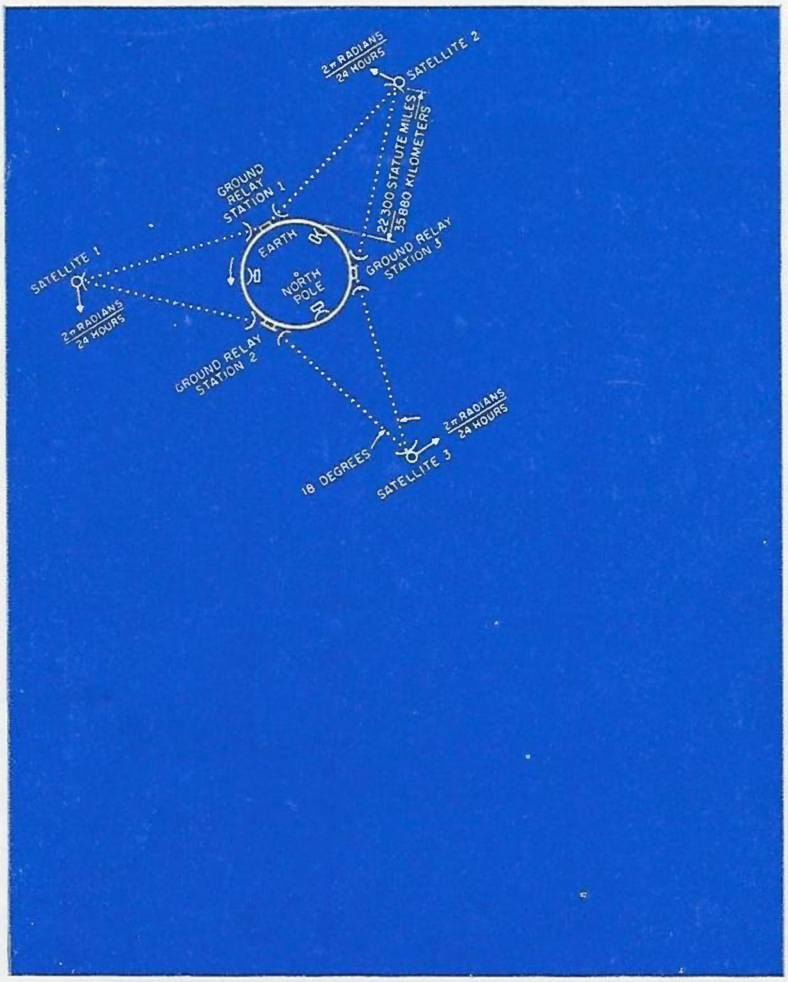

small world

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*For addresses see page 73

THE CHALLENGE TO MANAGEMENT OF ELECTRONIC DATA PROCESSING

Editorial Note. — The Postmaster-General, the Hon. Alan S. Hulme, M.P., presented this address to the Australian Institute of Management, Brisbane Division, on 21st April, 1966.

INTRODUCTION.

I suppose trying to look ahead seeking to find guide lines on which to base to-day's decisions is a favourite, and indeed a most rewarding occupation of managers generally. It is certainly a most necessary and important part of the Post Office way of life.

One of the classic ways of looking ahead is to look around at contemporary business and society in Australia or in the world at large, where the phase that your organisation is passing through now, was experienced years ago by some other generally comparable enterprise. What are they doing and how are they doing it can be a most rewarding subject of analysis in more clearly defining what you will be doing and how you will be doing it when you reach their size or their sophistication, or whatever is the significant basis of reference.

I was reminded of this classic exercise when I came to think about the subject of your conference: The Challenge to Management of Electronic Data Processing. Our country is still relatively new to E.D.P., but other places, in particular the United States, have come a long way since they passed through this stage. Present E.D.P. practice in such countries can be highly illuminating for us in trying to see our way ahead.

One of the very significant developments that one can define in this manner is the growing use of data transmission facilities in association with computers to permit both centralised processing of information and decentralised control and operation of enterprises. I feel that in this country, with its great distances and extremes, whose enormous potential in mineral and fuel resources, as well as in agricultural and pastoral development only, is now becoming understood, the combination of computer and data transmission can achieve most significant fulfilment.

The Post Office, as the National common carrier for telecommunications, is swiftly moving into very high capacity backbone and supporting systems around Australia, and is very well placed to play whatever part it is called upon to play in this modern computer - network concept. I would like to talk about this again later, but at this point I will address myself more generally to the subject of this conference.

ON LEARNING ABOUT E.D.P.

For the past ten years, electronic data processing, conspicuous by its centrepiece, the computer, has been claiming an increasing amount of our notice and attention. We hear on the radio and read in the press of the computer's exploits. It guides the objects hurled into space. It forecasts the results of elections. It plays chess and composes music. As usual, we hear mainly of the off-beat successes and the more abject failures. But we hear of only a few of the hundreds of computers in Australia and the thousands overseas.

For most of us, contact with the computer has been only superficial. Obviously in the near future this situation will change radically. The computer has left the scientist's backroom and come into the market place. Soon it will occupy a major place in the lives of most managers and businessmen, scientists and other researchers. Soon it will be just about in our front rooms.

As with any other technology, before we can use it properly we must learn about it. This, therefore, is an important conference. As the Minister responsible for the country's largest enterprise, and as the Minister responsible for the communications that will have such an important role to play in these developments, it gives me great pleasure to come along and speak to you.

We all acknowledge the need for innovation and progress, but sometimes find ourselves working against it, while we are talking for it. I am convinced that to avoid this risk with E.D.P., much study and rethinking is required. This learning about E.D.P. is not just learning about a new gadget that will help us improve on the way we have always been doing things; although in the beginning this will probably be our first type of association with E.D.P. Ultimately and more importantly it is learning about a new way of life for managers; the knowledge and skills and attitudes that are needed to make computers work for us to real advantage.

Some of the elementary rules of this new way of life have already revealed themselves, but much has still to be learnt. E.D.P. is an exciting new frontier in management and the business leader has as much to learn about it as any beginner. Willingness and ability to go on learning afresh is the management need of the times, and I commend the Institute for its outstanding educational programmes and on its choice of the subject for this conference.

COMPUTERS IN GOVERNMENT.

The Commonwealth Government has played a leading role in introducing computers and E.D.P. to Australia, and computers have been in use at the Weapons Research Establishment in South Australia for over ten years. Their use has related mainly to missile work, in connection with pre-flight simulations and calculations, during-flight processing and control, and post-flight processing and analyses. In the simulations the computer completes theoretical experiments merely by using a mathematical model that simulates the real missile. Each simulation takes only a few seconds, allowing many to be carried out in a short time. But, of course, expenditure of an actual missile is not involved. Thus wide experience has been gained in a short time at small expense. During flight the computers are used to provide control information on the course and other characteristics of the missile; obviously the time factor here is all important, and only computers can provide the answers in an adequate time-scale. In the post-flight processing, the various recordings can be processed to obtain finer details of the experiments, so as to allow the ironing-out of major or minor aberrations.

The use of these computers for weapons work has had important side benefits for E.D.P. in Australia—the availability of relatively high-powered computing facilities for other work and the development of a body of trained man-power able to branch out into other applications of computing. For instance, W.R.E. provided the first head of the computer unit at the University of Queensland.

Gaining from its experience with these earlier computers, the Commonwealth in more recent years has introduced a number of major computer facilities in other departments and authorities. The first of these was for the Department of Defence. The Defence Headquarters in Canberra is linked by data lines to various Defence establishments in Australia and there are overseas links. In 1963 the Commonwealth ordered equipment for two notable networks of computers, one for C.S.I.R.O., the other for the Commonwealth Statistician. Each of these is centred on a larger computer and includes smaller computers in a number of States.

The C.S.I.R.O. network exists primarily to meet the needs of the various research establishments of that wide-ranging organisation, but also aids the work of universities and other research groups. Its work includes computations, sometimes of massive scale, and the processing of data recorded during practical experiments at its laboratories and field stations scattered throughout the country.

The Commonwealth Statistician's network meets the needs of the Bureau of Census and Statistics, and also some needs of other Commonwealth bodies, notably the Departments of Treasury and of Health. Its prime purpose is the improvement of data available for the management of the nation. All management, including the Government, needs data on production, sales, outstanding debts and credits, employment, etc. Good management and good Government depend on accurate data promptly to hand. With its dynamic internal growth and development, and its sensitivity to fluctuations in external trade, particularly in basic commodities, Australia probably needs this promptness more than most countries.

In my own department, the Post Office, computers have been used since their first availability. We have made extensive use, in particular, of those installed at universities, including the University of Queensland. In recent years, to keep pace with demands in the Department, it has been necessary to obtain our own computers for full-time departmental use. The uses cover a huge range—analysis of reports of plant faults and maintenance work, analysis of traffic and projections thereof to facilitate planning, account processing and computations, network simulations, allocation of orders and allocation of facilities, analyses of contracts, computations associated with research, development and design. In all of these the aim is to provide a better service to our millions of customers at as low a price as possible.

In planning the growth of network plant, we aim to have the right facilities in the right place at the right time. Because they may take years to introduce, we must rely on long-term forecasts, which cannot always be right in themselves. But the computer allows these forecasts to be made more quickly and more soundly. It thus allows us to be right more often.

The analysis af faults and maintenance save money by giving a better appreciation of the quality and performance of the various types and makes of plant in use, and by giving better direction to maintenance work. In this application the report dockets completed by the field staffs throughout Australia are sent weekly to the national centre for transcription into the computer. The management reports produced by the computer analysis are then mailed directly to the managers in the field. With over two million telephone services, an average of one fault per service every two years still means 10,000 overall per week.

The research and design computations provide better solutions to problems, solutions that can mean a higher grade of service and a lower cost of providing the service.

By computer analysis of tenders and allocation of orders we can reduce the actual purchase cost of many types of equipment and services, particularly where a wide range of items and number of sources are involved. The Post Office is spending $24,000,000 annually on underground cable, most of which is made in Australia. This cable comes in a wide range of sizes and types, and computers are being used to allocate the bi-monthly orders between manufacturers in the most economic distribution, taking into account price differences for individual cable types and sizes and ordering levels, transport distances, factory capacity and so on.

Some hundreds of "programs" have been written for Post Office projects over recent years and we believe that we are only as yet scratching the surface of computer usage. Whilst we have a team of specialists in computer work, my Department has tried to develop an appreciation of computer programming and computer potential through the organisation.

With annual capital expenditure in the Post Office approaching $200 million, and ordinary services expenditure approaching $300 million, even small percentage saving can be of great public interest and value.

As elsewhere, developments with E.D.P. in the Post Office have to date been on a somewhat isolated basis. However, these developments are being directed toward a nation-wide management information system based on an integral network of computers and telecommunication links, and dealing with the processing problems of the Department on a total basis. We have a long way to go; the real potential is yet to be understood.

Today, Commonwealth and State Government and industry and capital are in partnership in a great upsurge of national economic development that covers the length and breadth of the land. Opportunity knocks loudly on the door. Let us open the door with a determination to make wise and full use of the facilities that this electronic age is offering to us.

MANAGEMENT AND THE COMPUTER.

At this point I would like to contribute some further comments on the theme of your conference. It seems very clear that such is the nature of the computer and such is the wide range of possibilities arising from its expanding use, and, indeed, such is its cost, that most careful thinking and planning ahead must precede the gradual, but what will eventually become the complete assimilation of E.D.P. by management. If the maximum benefits are to be gained from computers and E.D.P., it is essential that we study their attributes, so that the computers can be given the right work to do and receive the right support.

Clearly, movement into E.D.P. must involve rethinking by many people, not just a few. This is not a job for a small group of experts. Everybody in management will be drawn in and the sooner the better. The growth of professionalism in business is an important fact of life, with or without computers, and is bound to be even more so. Side by side with professional men, we need participation by experienced men of the line who know the traditional attitudes, so that we have, not a tug-of-war, but a reasoned and constructive dialogue. This must resolve itself, perhaps not without stress and strain, into a new and mutual understanding of the goals and the way of achieving them.

It is so necessary for management to define clearly what it wants from computers, because the computer is helpless and aimless until we teach it to work the way we want it to. What we want from computers must not be confined by established procedures, organisation and objectives. Such will be the impact of E.D.P. on business management, that it will be the uninhibited approach, the overall integrated approach, that will produce the resonant peak in efficiency during the years ahead.

The information system of an enterprise crosses all boundaries and the computer must be thought of in terms of that total system. Because of the power and cost of each individual computer, there must be a tendency towards concentration of processing, perhaps at one centre for the whole enterprise. Such centralisation will doubtless require changes in established administrative patterns, transgressing somewhat on local responsibilities. On the other hand, it leaves greater opportunity for decentralisation of management responsibility through the use of suitable communication links between the various managers and the data-storing computer.

In making a decision as to the correct place of a computer in an organisation, management must also be certain as to the place of the staff in the organisation—those who will work with the computer and those whose work will be changed by the computer. While I do not minimise the impact of computers in changing the pattern of employment, I am sure the greatest impact will be in forcing us to think. Mankind has created many tools designed to ease his load, but none has ever before so peremptorily required him to use his head. This is true not only during the process of movement into the use of E.D.P., but also when it becomes available to management.

Properly used, the new techniques will give management the information it needs on which to base its decisions. Too often it has been necessary to make decisions in some areas on approximate and imprecise information. Cost factors and the need for quick action have made this inevitable. The computer, properly used, will enable the manager to have the information processed fully and quickly, so that he may investigate a wider range of alternatives in assessing and evaluating the best course of action.

Furthermore, computerised systems ought to be able to reduce or even eliminate problems that often keep managers preoccupied with overseeing people instead of helping and inspiring them. As the range of information available to computers extends, and the scope and complexity of decisions by management increases, there will doubtless be a mounting realisation by the manager of the political, economic and social forces, which will bear increasingly upon his decisions. There must be acceptance of these outside forces as part of the environment in which he operates.

It seems possible that to achieve the maximum gain from E.D.P., there will be, in the distant years ahead, an integrated approach by business, the Government and public undertakings, and by the community generally, whereby necessary and proper cross-flow of information between computers may take place to the mutual advantage of all parties. There is great merit in sharing this revolutionary aid between as many as possible, for costly resources can work hard for many users at low cost to each.

However, as complexity grows, the greater the need becomes for managers to keep their feet well and truly on the ground. Managers will require more working face to face with people and problems. Every influence and situation the manager exposes himself to can help him sense developing situations and help him towards wisdom in plans and decisions.

It would seem that the future will bring a stronger demand for basic qualities of character and vision, not just for management skills and techniques. One cannot foresee what the lasting effects of E.D.P. will be upon us, but the perturbations and tension of finding out will doubtless be very healthy. People will try harder and grow bigger, the flow and exchange of ideas will be stimulated, and there will be great opportunities for giving talent problems to grow on.

TRENDS IN THE USE OF COMPUTERS.

In looking at E.D.P., our thinking must not rest only on to-day's practices and equipment, but must be projected into the future. The introduction of a complete E.D.P. system is a major investment and a job that will take considerable time. We must relate it then to our needs of 5, 10, and even 20 years' time. In a fast-moving field like E.D.P., working ahead to this extent is very difficult. Forecasting the future of E.D.P. to-day is probably as hard as forecasting the future of the automobile was 60 years ago. With E.D.P. we are still in the horseless carriage days; we are employing the engine, but only to power a system that is unchanged from manual days.

But if we look around at bigger organisations here and overseas, we can see the trends towards the sleeker systems of the future, and gain some guide towards our own futures. Looking and learning does not mean blind copying. Each country and each enterprise has its own particular problems that demand particular solutions. We each must take an individual approach to our own problems guided by the approach of others. We must also endeavour to progress from the point reached by others. A classical advantage in starting to do things later than others is that of being able to do them better.

What are the trends? In the United States so-called information utilities are being created to provide processing facilities similar to the way in which gas and electricity utilities provide their services. Research is continuing toward the storing of major libraries on computers so that requests for information can be met promptly by teleprinter message after searching and extracting of the computer files. Other research is dealing with the problem of translation between languages, so that at first books can be translated and subsequently the spoken word, allowing us to envisage the day when international telephone calls can link speakers of different tongues through a translating computer.

One of the features of modern science is the surprising way in which things that appear to be quite different can be handled in the same way, and this is true of speech and data. Thanks to recent advances in solid state electronics, it is now possible to represent speech as data impulses and to transmit these impulses as data to a distant point and there reconstruct them to a form that is indistinguishable from the original speech. Already digital transmission systems, as they are known, are in use in some overseas administrations and are being considered for trial use in our network in the near future.

It is clear to our scientists that speech data between persons and information data between machines is essentially the same thing electrically, and one can imagine that when the engineering problems are solved it will be possible to develop a universal information transmission system in which data from whatever source is handled by the one transmission and switching network. Engineering technology is supporting this information technology by developing faster, smaller, more powerful, cheaper, more reliable and more rugged computers. Already computers are in use in ships, aeroplanes, missiles, satellites, and space probes. One day they might be as ubiquitous as the transistor radio.

Looking closer to the present day and the particular area of general management, we can see the computer progressing from the circumscribed coverage of one or two applications to the all-embracing management information system, in which the computer holds most of the information required for management. So as to take full advantage of the speed of the computer, such an advanced system will include direct links by telecommunications between the computer and the various work points, where changes that affect the records take place or where the information is required. The clerical operative taking orders or issuing goods will record his transaction on a counter-top device connected to the computer. The manager will have an interrogation unit on his desk whereby at the pressing of a few keys the computer will provide a television-like display of the information required; for instance, the status of an account or an order. Some overseas companies are already planning this sort of development, including the "record-less office," that is, an office relying solely on computer - held records rather than local paper records.

In the specialised area of seat reservations, systems of this nature are already in use. With a number of airlines in North America and Western Europe, booking a seat is handled through a computer, while you wait briefly at the agent's counter. And the computer might well be at the other end of the continent or the other side of the Atlantic. Some of these systems handle not only the booking of seats, but the construction of an itinerary as well, all within very few minutes. Already some Australian airline companies have announced plans along these lines.

In all of these trends and developments, the computer is intimately linked with communications—communications to allow the various data to reach the computer for storage and processing; communications to let the managers and other users have the information they need. And if the speed and accuracy of the computer is to be fully exploited, these communications need to be good and fast; that is, they need to be telecommunications. It has been estimated that within ten years over half of the telephone traffic in U.S.A. will be data travelling to and from computers rather than normal speech, and this does not mean that there is likely to be any decline in the rate of growth of talking over telphones. Similar trends may be expected in Australia.

WHAT THE POST OFFICE CAN DO TO HELP.

Telecommunications thus have a vital role in the E.D.P. developments of the future. In Australia this means a vital role for the Post Office. When you process data you make it usable, but you need communications to make it available. The Post Office is mobilising to fill this role, to meet the challenges of this new era of information handling. It is already providing some services of this nature. It is planning and installing extra line capacity to meet the extra traffic that will eventuate. It is carrying out research and development work necessary to ensure that the special demands of data transmission for computers will be met. It is investigating what additional facilities will be of benefit in the computer area.

Australia, in common with other developed countries, has an extensive automatic telephone and telegraph network, spreading to virtually every settlement in the country. By the use of relatively simple attachments, this network can be used to provide for data transmission over the length and breadth of the land. Since the network was developed essentially for ordinary telegraphy and telephony, this wider use poses some technical problems, particularly over the older parts of the network. However, the Post Office is keeping abreast of world developments in this regard.

Our network is being extended and expanded continuously—to connect with new outposts of development, such as Weipa, as they are created—and to cope with the continuing increase in demand and traffic. The 11 per cent. per annum growth rate of trunk traffic shows up the force of our advance.

A major feature of the expansion is the development of the broad-band part of the network. Broad-band links use either co-axial cable or microwave radio for the transmission of a very high frequency signal. Each link is able to deal with television relays or direct computer-to-computer transfers, or alternatively to carry over a thousand simultaneous conversations. Much of this broadband system has been in use for some time. The major section between Brisbane and Cairns, linking the various centres in between, is about to enter service. By 1971 it will extend around the eastern, southern and western coasts as far as Carnarvon and Port Hedland, and across to Tasmania, providing a backbone of numerous very high quality circuits. Further extensions are planned for subsequent years.

Ten years ago the laying of the first trans-Atlantic submarine telephone cable ushered in a new era of international communications and the installation of the trans-Pacific cable in 1963 gave Australia the same high quality and abundant means of communication with the rest of the world. The satellite era is now commencing, and a tremendous expansion in communication facilities is envisaged between Australia and overseas countries in the next few years. Much of this expansion will involve data links between Australian industry and counterparts overseas.

Some of our broadband links contribute, together with other parts of the network, to a number of data transmission facilities already in use. The most notable of these are those of the American National Aeronautics and Space Administration. Ever since the first satellites went aloft in the late fifties, special telegraph links have been provided between South Australia and the United States. As the space missions have grown more complicated the number of ground stations in Australia has grown and the importance of their data has also grown. Particularly on manned missions that data is vital, and it must be communicated directly and immediately to the space flight centre in the U.S., where it is analysed by computer. In many cases this analysis may result in data being passed out to the ground stations for transmission to the satellite. The recent drama with the Gemini capsule highlighted the role such communications play; life and death being dependent on accurate and prompt communications over tens of thousands of miles. I am pleased to say that the Post Office communications in Australia have played a major and successful part in these various missions, linking such far distant places as Carnarvon, Muchea, Woomera and Tidbinbilla through a special switching centre to the Overseas Telecommunications Commission terminal at Sydney and thence to America.

The Post Office is meeting the needs of others whose projects might be less exciting to the public, but for whom the accurate rapid transmission of data is no less important. The extensive network for the Defence Department is one such example, with links extending to a number of remote points. The Bureau of Meteorology is another major user, and one for which the speed requirement is obvious to us all. The Post Office has been taking part in tests in preparation for the recently-announced computer network for this Bureau. Direct links will be required between a number of computers, and to various country centres, such as Mt. Isa, Cairns, Townsville, Rockhampton and Charleville.

Not all existing and forthcoming data transmission links are for Government use. An increasing number of private and public companies, both small and large, are using the ordinary telephone circuits successfully for transmission of urgent data. The Post Office will be facilitating such developments soon by offering as a standard telephone attachment, the interconnecting equipment required to allow data to travel on speech circuits. Such equipments are already available to subscribers as "approved" attachments.

In anticipation of a developing demand for large time-sharing computers, where joint access is given to a number of users over telephone and telegraph lines, experiments are currently under way, using our Telex network with the interrogation of the computer and the receipt of the answer being performed by the standard teleprinter machines operating in the normal way. It is believed that computer time-sharing techniques will be used extensively as the smaller companies come within the area of computer utilisation. Consideration is also being given to entirely automatic calling and answering as between computers using data transmission links.

The Post Office is investigating for possible longer term introduction the production of a special telephone on which the keys can be used for data transmission after connection of the call. It might not be long before, instead of complaining about the hours our families spend on the telephone to their friends, we are complaining about the time being spent placing orders with the computers of supermarkets, department stores, and other retailers. That is, those of you not concerned with boosting Post Office revenue.

As the demand grows for data links to and from computers and between computers and data equipment becomes more sophisticated, we may need to give consideration to the setting up of special networks for data transmission designed specifically for the purpose and preliminary studies are already in hand. The emergence of data communication as a more and more popular service, however, does not mean a decline in business communications as we know it to-day. The information transmitted by voice and data are generally quite different. Data is essentially impersonal machine-to-machine communication, yet many business transactions require the personal touch which only people can supply. Therefore, data will not replace voice communication, but will substantially supplement it.

CONCLUSION.

I am sure that there will be general agreement with me when I say that the circumstances and technological sophistication of to-day's world, and certainly of to-morrow's world, are making heavier and heavier demands upon the manager; upon the scope and depth of his knowledge, on his judgment, on his versatility, on his enterprise and foresight, and so on. It is timely and fortunate indeed that E.D.P. has become available to aid him.

Herein lies the opportunity for the manager to have available at great speed, from a wide range of factual and statistical sources, exactly the sort of material that he needs for his decision making. Herein lies the opportunity to step up the level and range of his own thinking, and bring to play the imaginative and wide-ranging approach and social consciousness that seems so necessary to-day and in the future.

E.D.P. will enable the efficient manager to function even more effectively, but will increasingly expose the weaknesses of an inefficient man. The manager may be sure, in this highly competitive and in this demanding world, and the Post Office is just as much a part of this as any enterprise, that if he does not take this opportunity to raise his sights and standards, higher management will or his competitors will.

With its vastness and with its tremendous potential only now being revealed to us in its full depth, but yet with only a relatively small population to finance and promote it from within, our country must not fail to take unto itself and widely exploit every modern aid that will assist its growth and progress.

Gentlemen, again I commend the Australian Institute of Management, Queensland Division, on the choice of its Conference subject, and sincerely hope that all who participate have taken benefit and inspiration from it.

SUBSCRIBER TRUNK DIALLING IN AUSTRALIA

R. T. O'DONNELL, A.M.I.E.Aust. and K. J. SIMPSON, A.M.I.E.Aust.***

Editorial Note: This article is reprinted from the Journal of Institution of Engineers, Australia, Vol. 38, No. 6, June 1966, with the kind permission of the Institution. The paper was presented at the 1966 Conference of the Institution at Newcastle, N.S.W.

INTRODUCTION

For some time now the Australian Post Office has been planning and developing the telephone system for Australia within the framework of the telephone policy described in a White Paper entitled "Progress—Policy—Plans" issued in August, 1959. Included in the Policy is a long term objective of complete subscriber trunk dialling (S.T.D.) throughout the Commonwealth, i.e., all subscribers will be provided with automatic service and each subscriber will be able to dial any other subscriber in Australia without the intervention of a manual operator.

The purpose of this paper is to discuss the current position on the mechanisation of the trunk telephone service and the likely rate of progress in the future, together with those aspects to which special attention must be given. There will be a brief survey of the past development in the trunk system which has led to S.T.D. being a natural extension of the trunk service and some views will be expressed on the established target for expanding S.T.D., including the need for an appropriate programme of automatic trunk exchange installations. The special technical requirements for S.T.D. in the trunk network generally and trunk switching in particular will be examined and the close association required under S.T.D. conditions between switching, numbering and charging will be discussed to show the preparations which have been made for the expansion of S.T.D. throughout Australia. This will be followed by a general description of the equipment used in Australia for S.T.D., including the new trunk switching equipment currently being installed.

The second part of the paper will deal with the progress of S.T.D. in New South Wales and discuss the background against which the early installations were made. Some details will be given of the problems of planning and designing the installations, particularly the problem of estimating the traffic which will occur under S.T.D. conditions. Finally, there will be some comment on the present plans for the New South Wales trunk network.

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A NEW PHASE IN AUTOMATIC TELEPHONY

The prospect of telephone subscribers dialling their own trunk calls throughout the Commonwealth of Australia is a far cry from the day in 1888 when Australia's first telephone trunk line was opened between Hobart and New Norfolk in Tasmania. However, this event and the installation of Australia's first automatic telephone exchange in 1912, at Geelong in Victoria, were the first application in Australia of two techniques which are now inevitably being united into the facility of S.T.D. At first, the expansion of the trunk system was restricted by the difficulties of conversing over long physical circuits without the benefits of amplification but long distance telephony was given great impetus in the nineteen-twenties with the development of carrier systems which enabled a number of good quality circuits to be readily provided. Trunk line service commenced between Sydney and Melbourne in 1907, and it was on this link that Australia's first telephone carrier system was installed in 1925.

In the early years of the trunk service, the trunk line was the most valuable component of the trunk system as the cost of manual exchanges and their operation was low by comparison. Under these economic conditions, every effort was made to make full use of the trunk lines which existed by virtually placing the calling subscribers in a queue to await their turn to speak on the available circuits. This was achieved by the telephonist booking the call and reverting it to the calling subscriber when a trunk circuit became available. A telephonist was used at each end of the circuit with intermediate telephonists being required on those calls which were connected through other switching centres. With the introduction of carrier telephony, the cost of trunk circuits began to decrease, and through the years trunk circuit costs have continued to decrease relative to the switching and operating costs. While these relative cost changes were occurring, the number of automatic subscribers was increasing with the result that direct dialling techniques aimed at employing only one telephonist on each call were introduced. The use of carrier equipment also enabled the number of circuits on a link to be more readily increased so that, as well as providing direct dialling by telephonists, the manual trunk system has progressed toward a demand type service with calls being connected on request and this has been achieved on most of the main trunk links. Inter-capital city dialling by telephonists was introduced in 1945 and automatic trunk switching techniques have since been continually applied to the trunk system so that by 1960 the trunk service was highly mechanised under operator control.

Automatic telephone service has always been preferred by the community because compared with a manually operated service it provides speedier connection and greater secrecy. In addition, from the point of view of the operating authority, automatic service reduces operating costs and leads to overall economies in providing service to subscribers who also gain from the more economic operation even though they may be unaware of the savings. The conversion of manual exchanges to automatic, the use of nation-wide trunk dialling by operators and the introduction of Extended Local Service Areas (ELSA) have all been aimed at providing improved service to subscribers whilst at the same time reducing Post Office operating costs. However, all these methods have succeeded only in maintaining the number of manual operators at a reasonably constant level and, with a continuing penetration of local automatic exchanges into country areas, it is a natural progression to permit subscribers access to the trunk system so that they may dial their own trunk calls.

The Post Office has striven continuously to improve service offered to subscribers who naturally are only amenable to new services if the charges are not increased. As a result it is the economic pressures within the Post Office which set the timing for the introduction of new facilities or techniques. Within the trunk network single operator dialling reduced Post Office costs and provided subscribers with a speedier service, the introduction of ELSA converted to local calls and subsequently to automatic operation short haul trunk traffic which was proving too expensive to handle manually, and the same kind of pressures are now forcing the expansion of S.T.D. Operating costs are still increasing, there is a virile growth in trunk traffic and the capital costs of providing a modern demand manual service are becoming comparable with the costs of automatic switching. Far from being a luxury, S.T.D. is essential for economic operation of the trunk service, and the expansion of this facility throughout Australia will be in the best interests of both the community and the Post Office.

S.T.D. TARGET

The objective of nationwide subscriber dialling, as stated in the White Paper, does not include any timetable for its progress or ultimate achievement. As discussed earlier, the basis of the S.T.D. objective is not only that it provides a better service to the subscriber but that it is also the most economical means of providing trunk service, which means that early expansion of S.T.D. facilities will be profitable. However, even though there may be strong reasons for actively pursuing the implementation of a programme of S.T.D. installations, there are many constraints in forming a long term or even short term target for the extension of S.T.D. throughout the trunk network. Any target set must be achievable within these constraints which include all the other commitments of the Post Office which, together with any S.T.D. programme, must be met within the capital resources available. An S.T.D. programme must take account of the overall economic operation of the Post Office and, at the same time, relieve points of saturation and raise the appropriate sections of the trunk network to the required dimensions. Furthermore, the level of the gains from S.T.D. will vary considerably at different points in the trunk system depending upon the quantities of traffic involved together with the type of existing plant, and these gains could be adversely affected if the S.T.D. target relied too heavily on an accelerated programme of converting manual exchanges to automatic or on too great a penetration into outback areas with their inherent communication difficulties.

In spite of these constraints, the scope of the S.T.D. operation together with the size of the Post Office organisation demands that there be a stated rate of anticipated progress. A target is needed by all those concerned in planning and providing all components of the trunk system including buildings, switching centres and trunk line circuits. As a result, a comprehensive study was made to determine a suitable short term target for the S.T.D. programme. This study indicated that at least 66 per cent of all trunk calls should be subscriber dialled by 1975 and that this target could be achieved without placing undue pressures on the manual to automatic conversion or trunk provisioning programmes and by introducing the facility in only profitable situations.

In evaluating the 66 per cent S.T.D. target in terms of the magnitude of the task within the framework of other Post Office commitments, it is worth noting that it is now approximately ten years since the first S.T.D. link was opened from St. Marys to Sydney, and it is estimated that less than 10 per cent of Australia's trunk calls are currently being subscriber dialled. Furthermore, consideration must be given to the following two factors which when combined will represent a formidable barrier and necessitate strong efforts by all concerned to maintain an appropriate trunk network programme —

(i) Wherever S.T.D. facilities are provided, something less than the total traffic will be dialled by the subscribers, the remainder being offered to manual assistance centres for connection by an operator. The achievement of 66 per cent S.T.D. overall is therefore dependent on the effectiveness of S.T.D. where provided. There are various estimates of the likely effectiveness in Australia ranging from 80 per cent to 95 per cent, but on present indications, it appears that we can reasonably anticipate 90 per cent S.T.D. effectiveness by 1975. With S.T.D. 90 per cent effective, the 66 per cent target means that 73 per cent of trunk calls must be offered to subscribers to dial their own. Experience to date is discussed further in the section dealing with progress of S.T.D. in New South Wales.

(ii) The distribution of trunk traffic throughout the Commonwealth is such that the target cannot be achieved by concentrating on comparatively few sectors of the network. The nature of the trunk traffic distribution between metropolitan and country areas is demonstrated in Fig. 1 which shows the categories of trunk traffic as a percentage of the Commonwealth total. With such a distribution of trunk traffic, where a high component is spread throughout the country areas of Australia, it follows that if the 66 per cent target is to be achieved the trunk system developed from now on must be designed to enable the maximum degree of trunk traffic to be subscriber dialled.

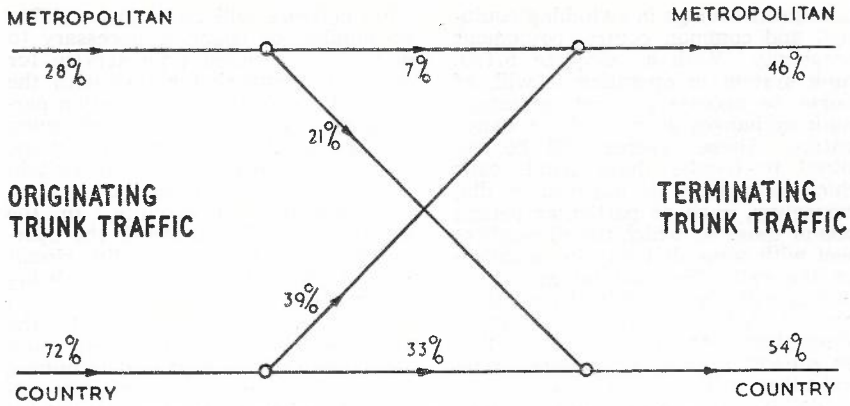

Fig. 1 — Percentage Distribution of Trunk Traffic between Metropolitan and Country Areas in Australia.

However, these two factors opposing the achievement of the target may well be offset by the virile growth of the trunk traffic. This growth may well be high enough during the next ten years to ensure that the target of 66 per cent by 1975 is achieved so long as S.T.D. is used to meet the overall growth of the trunk system and is aided by the additional S.T.D. which will result from the conversion of manual exchanges to automatic. Using S.T.D. techniques to meet the incremental growth of the trunk network is attractive as the estimated cost of switching a given amount of trunk traffic over the next ten years using manual techniques is of the order of twice the cost of switching the same amount of traffic automatically. With the cost advantages of S.T.D. over manual operation so marked, it follows that S.T.D. must inevitably be the only acceptable means of meeting the future growth of the trunk system, and it is essential that all aspects of the trunk network be prepared for the rapid expansion of S.T.D. needed to meet the 1975 target.

SPECIAL TECHNICAL REQUIREMENTS OF S.T.D.

A telecommunication network consists of three elements — the switching centres, the interconnecting circuits and the signalling system. An S.T.D. trunk network makes special technical demands on each of these elements as compared with those made by a trunk system operated by trained telephonists. The special requirements will be discussed generally for each of the trunk system elements mentioned.

Switching Centres

Automatic switching centres for the S.T.D. traffic must be provided and, in replacing an operator, they must also provide automatic charging and call routing facilities in addition to a capacity capable of handling virtually all calls on demand. In achieving this, the automatic equipment must be able to collect calls from a number of originating points and apply the correct charge to the call which may be to any part of the Commonwealth. In Australia, the method of automatically recording trunk charges is to operate the subscriber's call meter at the appropriate rate for the trunk call concerned. As the call charges will be determined at the automatic trunk centre, it follows that the equipment must be capable of transmitting periodic metering pulses during conversation to the originating exchange over the connecting circuits in the network. The switching equipment must also provide for a national numbering scheme which is essential under complete S.T.D. conditions to avoid complicated calling procedures for subscribers. In contrast, a manual or semi-automatic trunk system manipulated by trained operators can more readily use open type access codes for trunk switching purposes with consequent savings in switching equipment and common control equipment complexity. With a complete S.T.D. trunk system in operation it will, of course, be necessary to retain manual trunk exchanges as manual assistance centres. These centres will be required to handle those trunk calls which subscribers do not wish to dial themselves, such as particular person calls or those on which the subscribers meet with some difficulty in establishing the call. The manual assistance centres will also provide the network services such as enquiries, directory information, etc. It is expected that the present number of manual trunk exchanges will be reduced with a decided trend towards greater centralisation at the larger switching centres.

There are many automatic switching centres already in operation which enable operators to dial throughout the trunk system without calling on the services of other operators. These switching centres are not suitable, as they stand, for S.T.D. operation as they have been designed for the operator-controlled network. For example, the type of signalling used is not compatible with S.T.D. and any attempt to convert the equipment would be unwarranted as the quantity existing in our network is no more than will be required to serve the operator-controlled element in the trunk system. In addition, there are no automatic charging facilities as the call charging methods currently in use are manually controlled being based on a handwritten docket on which particulars of the calling and called parties are entered together with the duration of the call. However, it will be essential for the operator and S.T.D. networks to interwork with each other although they will be developed as separate networks as much as possible. It is not intended to allow the subscribers access to the operator's 2VF signalling network but there will be a need to provide the manual operators with access both into and out of the S.T.D. network. Some new manual assistance centres will be established in conjunction with new automatic trunk switching exchanges and the normal access to the trunk network for the telephonists will be via the automatic trunk exchange and S.T.D. network. On the other hand, retaining separate operator and S.T.D. networks at the extremities of the system such as within a secondary switching area will be unattractive, so that the automatic trunk exchange will be the normal point of entry from the operator-controlled network into the secondary area.

Interconnecting Circuits

Major changes in the methods of providing the interconnecting trunk channels have occurred in recent years with the advent of broadband systems, both coaxial cable and radio. Most of the larger subscribers' networks are now served with one or more of these large capacity trunk systems and their increasing penetration throughout the trunk network will assist in providing the number of channels necessary to maintain a demand type service for the S.T.D. network together with the required standard of transmission performance. The S.T.D. network must have a high degree of stability in the quality of transmission under switching conditions resulting in random interconnection of circuits. In the operator-controlled network the operator may reject a poor quality circuit without the calling subscriber being disconnected.

There is a current trend in the S.T.D. network towards even more centralising of the charge determining equipment than was previously envisaged and there is also a trend towards carrier channels being used in local networks. With the combination of these two trends, there will be many cases where the passing of repeated metering signals during conversation over carrier circuits will be essential and this is one of the compelling reasons why the trend in the Australian trunk network is toward the outband carrier signalling system.

Signalling

The trunk signalling scheme must allow the most inexperienced subscriber to dial a trunk call and not require him to use any special operating procedures over and above those he normally experiences on calls within his own local network. It must also allow for centralised trunk charging and the transmitting of the appropriate charging information to the calling exchange via the trunk or junction during conversation. In the S.T.D. trunk system the combination of subscriber dialling and register operation demands that there be no intermediate listening or waiting points during dialling.

The signalling schemes which have been used in the past have been exclusively decadic pulsing systems and as they were designed for a trunk network employing trained telephonists, they sometimes included a quite elaborate interchange of supervisory signals between the ends of the circuit. The main signalling system used has been the Siemens 2VF signalling system which has the facility of being able to signal on any channel on which speech is possible and which was conceived for manual operators to give them a number of supervisory facilities. In the interests of overall network flexibility the register-controlled system examines a number of digits before determining the optimum routing of the call and this delayed operation introduces the need for a high speed transfer of information, much faster than decadic pulsing, in order to minimise the post dialling delays which result. In the trunk network there will be the possibility that an S.T.D. call will switch through up to eight trunk centres (see Fig. 2) which means that there will be a higher potential for long post dialling delays in the trunk system than in the local networks. However, it must be recognised that only a very small percentage of the trunk traffic will traverse the maximum number of links possible from one terminal exchange to another, whereas a high proportion of the calls will pass through one, two or three switching centres.

In addition to the comparatively slow speed of operation, voice frequency pulse signalling suffers from the disadvantage that it is unacceptable on those circuits over which charging information must be passed during conversation without interference to the speaking parties. As mentioned above, repeated metering signals will normally be transmitted outside the speech band in the case of carrier circuits. For physical circuits the signals will be transmitted by reversing the polarities of the circuit and these metering signals are referred to as "silent reversals".

Local Networks

As well as its effects on the trunk system, S.T.D. also has an influence on the local networks. Resulting from S.T.D. there is a need for a public telephone with S.T.D. facilities and for subscribers' private meters to be available for installation at those subscribers' premises where there is a need to collect trunk charges, for example, hotels, clubs, etc. In addition, S.T.D. from metropolitan areas has a number of inherent difficulties because of the type of switching equipment or method of operating the subscribers' meters in a number of the older exchanges. It is not proposed to enlarge on the local network aspects in this paper.

Association of Switching, Numbering and Charging

In conjunction with the telephone policy announced in 1959 the Post Office has prepared switching, numbering and charging plans covering the whole of Australia and all have been closely co-ordinated to assist in implementing the policy of nationwide S.T.D. The trunk switching plans are based on the principles shown in outline in Fig. 2. The full lines in Fig. 2 are the inter-connecting links which are the final choice routes and each switching centre is classified by its status in the hierarchial type structure formed by the network of final routes. There are five main switching centres in the Commonwealth located at Sydney, Melbourne, Brisbane, Adelaide and Perth, with Tasmania switching via Melbourne. The area served by each main switching centre is divided sequentially into a number of smaller components — mains into primaries, primaries into secondaries, secondaries into minors and, finally minors into terminal exchange areas. In a similar way the whole of Australia is divided into telephone districts and each district into a number of zones to enable call charges to be determined. For the purpose of switching and charging calls throughout the Commonwealth each of the above categories in the switching and charging plans must be identifiable in the national numbering plan.

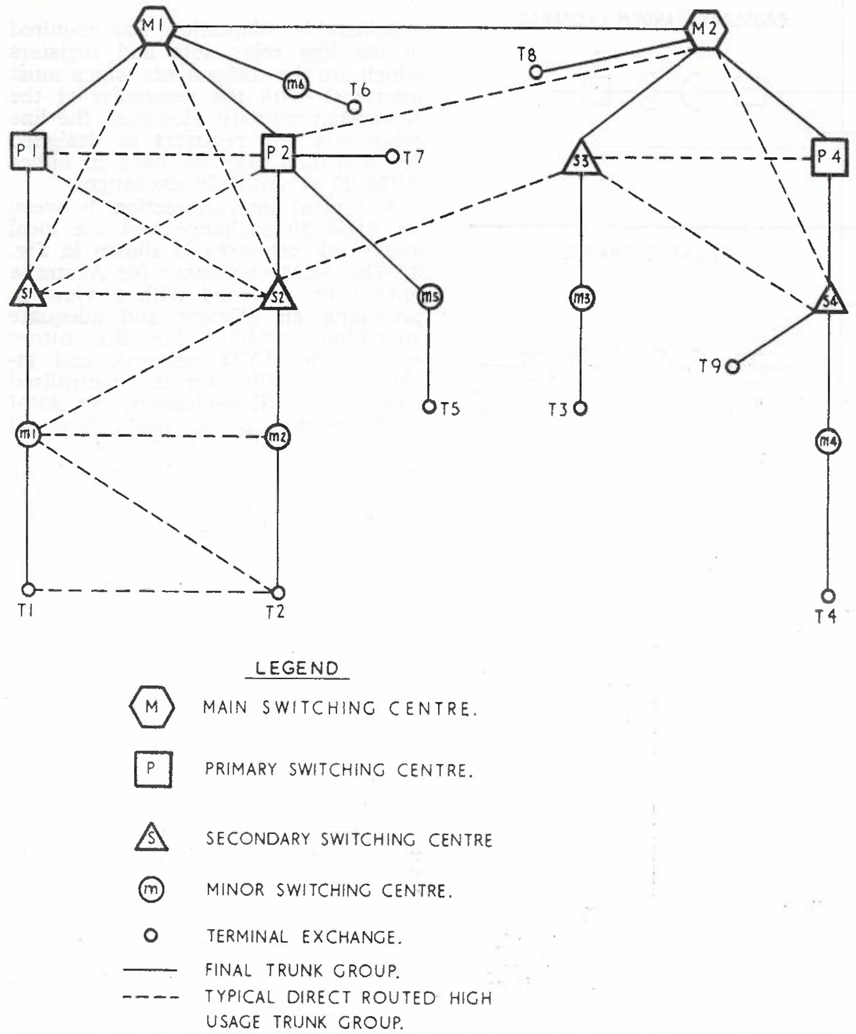

Fig. 2. — Trunk Switching Plan Showing Classification of Trunk Switching Centres and Typical Routing Pattern.

The automatic switching equipment for the S.T.D. trunk network must route the call to its destination efficiently and apply the correct charge. The indiscriminate allocation of exchange codes independent of traffic routing or charging considerations is theoretically possible with register-controlled switching equipment but the degree to which it may be permitted in practice is governed by the ability of the switching equipment to perform the necessary analysis of the dialled number. The amount of analysis equipment to be provided in the automatic trunk exchanges is a compromise between the costs of providing the analysis, the resultant equipment complexities and the need to maintain a fair degree of flexibility in the allocation of national numbers; for example, the main restrictions are that all switching centres of main, primary or secondary classification and all charging districts must be recognised by, at the most, four digits, including the national access digit "O". In addition, all charge zones must be identified within six digits, including the access digit.

The development of integrated plans for switching, numbering and charging on a national scale for the Australian telephone system ensures a sound foundation for nationwide subscriber dialling and has set a firm framework for the design of the automatic trunk switching exchanges.

DEVELOPMENT OF EQUIPMENT FOR S.T.D.

The S.T.D. equipment developed originally was known as multi-metering equipment and this term is still used to describe S.T.D. equipment designed for step-by-step exchanges. The multi-metering equipment used in Australia to date is fundamentally a single link system carrying S.T.D. traffic between two centres or networks but having limited ability to distribute the traffic efficiently over wide areas. The first multi-metering technique used was to determine the charge at each individual exchange where S.T.D. was provided. The locations requiring S.T.D. at that time were those exchanges near large networks having a high proportion of their total traffic manually switched at trunk rates to the nearby network. Furthermore, the high proportion of trunk traffic normally led to saturation of the manual trunk exchange and its continued expansion in new premises was unattractive.

With the advent of crossbar exchanges to local networks and the anticipated introduction of crossbar trunk exchanges, it became necessary to develop a centralised form of multi-metering equipment to enable the step-by-step and crossbar systems to interwork. This interworking is achieved in the step-by-step design by using the same techniques for transferring charging information from the trunk exchange to the originating exchange as will be used with a crossbar automatic trunk exchange, which means that both ends of the circuit, either terminal or trunk exchange, may vary between step-by-step and crossbar without effecting the operation of the equipment.

However, if the Post Office is to make any real progress towards the approved objective of nationwide subscriber dialling, the trunk system and particularly the switching equipment must not place any restrictions on the generation of S.T.D. traffic. The limitations of the earlier multi-metering equipment, which are mentioned in the later sections of the paper describing practical applications of its use, mean that any attempt to provide widespread S.T.D. by current Australian practices of charging on individual links will be inadequate. Improved techniques are required to enable S.T.D. traffic to be collected from a number of sources, the calling subscriber to be charged according to his location and the destination of his call, the call to be switched efficiently to its destination, possibly through other switching centres and supervision of the call to be maintained.

Crossbar Automatic Trunk Exchanges — ARM

The automatic switching equipment which has been developed for the Australian trunk network is an adaptation of the ARM crossbar equipment designed by L. M. Ericsson as a part of a complete telecommunication switching system which also includes crossbar terminal exchanges, types ARF and ARK, already being used by the Australian Post Office.

The ARM equipment is available in two types, ARM 20 and ARM 50. The ARM 20 is designed for the larger installations and may be extended in 200 line units up to 4,000 lines while the ARM 50 is designed for the smaller trunk switching centres and is extendable in units of 38 lines. In developing the ARM system for Australia, the basic objective was to maintain the fundamental L. M. Ericsson design in order to facilitate design, manufacture and installation of the equipment. This was generally achieved, as far as the fundamental switching equipment is concerned, but

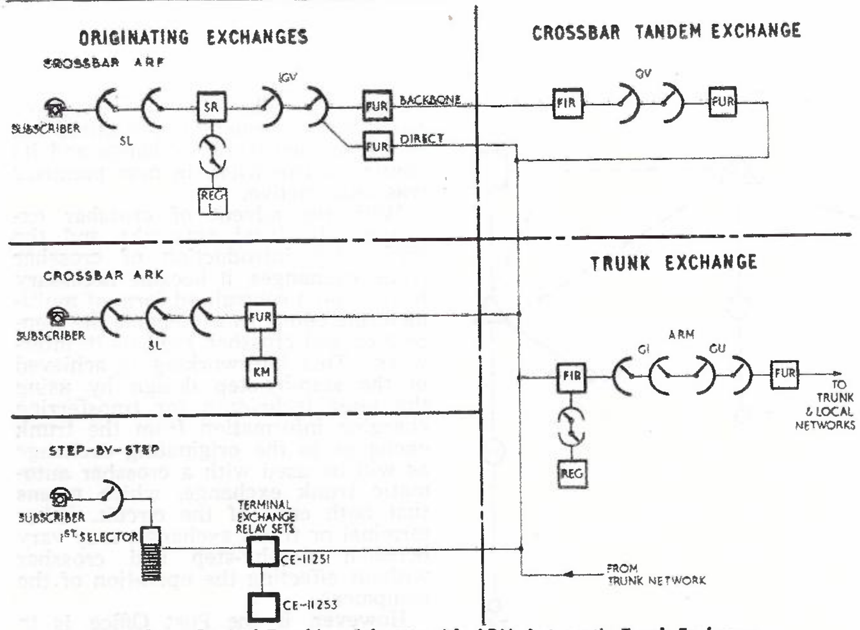

Fig. 3. — Typical Trunking Scheme with ARM Automatic Trunk Exchange.

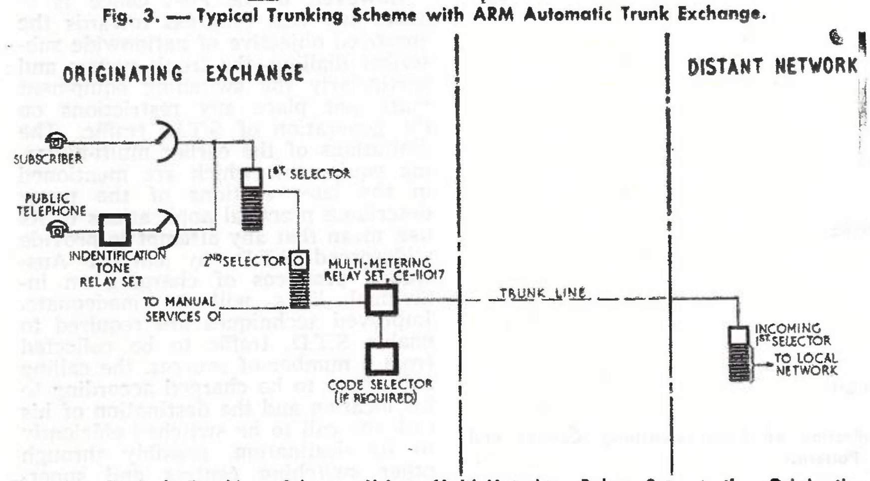

Fig. 4 — Typical Trunking Scheme Using Multi-Metering Relay Set at the Originating Exchange.

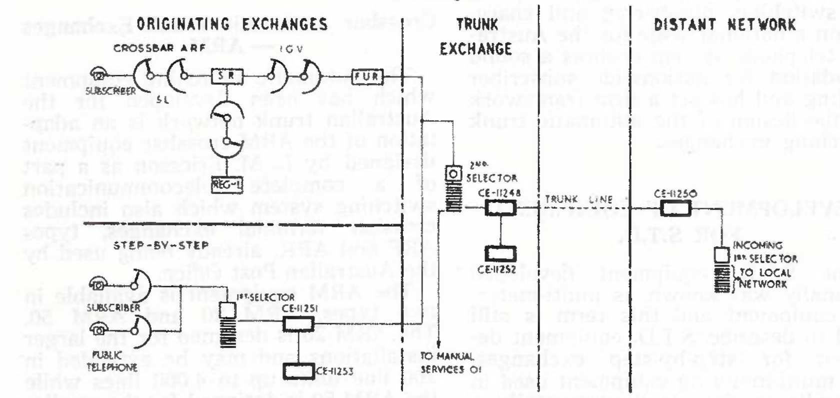

Fig. 5. — Typical Trunking Scheme Using Centralised Multi-Metering Equipment.

Notes:

1. **CE-11251. Terminal exchange relay set. Receives repeated metering pulses transmitted over junction from Trunk Exchange.**
2. **CE-11253. Terminal exchange relay set associated with relay set CE-11251. Provides discriminating facilities for handling calls from public telephones.**
3. **CE-11248. Outgoing trunk relay set. Applies appropriate meter rate and transmits pulses to originating exchange.**
4. **CE-11252. Tariff selector relay set. Determines correct charge to be applied from CE-11248, not required when single charge rate only is required.**
5. **CE-11250. Incoming trunk relay set associated with distant end of trunk channel. Includes provision for impulse regenerator.**

considerable adaptation was required in the line relay sets and registers which are the components which must interwork with the remainder of the Australian network. However, the line relay sets and registers as designed for Australia may be used in either ARM 20 or ARM 50 exchanges.

A typical interconnection between an ARM 20 exchange and the local and trunk networks is shown in Fig. 3. The ARM exchanges for Australia have been designed with a view to providing an efficient and adequate switching machine for the future nation-wide S.T.D. network and include the facility for the centralised control of ARK exchanges. An ARM exchange may collect traffic from all types of exchanges, both step-by-step and crossbar, over a wide area as up to 24 different originating charge zones may be identified. The originating zone and the called number are then utilised to estimate the correct charge which is returned to the originating exchange by the incoming line relay set by transmitting metering signals at the appropriate rate. In addition to switching and charging S.T.D. traffic from the local network, ARM exchanges may also switch traffic within the local network, trunk traffic terminating into the local network and transit trunk traffic from one switching centre to another. Four-wire switching of all traffic is provided and there are facilities available to provide for a great deal of flexibility in the alternate routing of switched traffic.

Multi-Metering Equipment

Initially, the S.T.D. or multi-metering equipment was designed for the step-by-step system and the call charges were determined at each terminal exchange provided with S.T.D. Fig. 4 shows the trunking of a typical installation using this type of equipment. The code selector would be associated with the multi-metering relay set only in those cases where the traffic on the route may cause different rates to be charged to the calling subscriber. In these cases the code selector analyses enough digits of the called number to determine the correct charging rate to be applied. Some details of early installations are given in the section headed Progress of S.T.D. Installations in New South Wales.

Typical trunking arrangements of the centralised multi-metering equipment are shown in Fig. 5, including a short description of the functions of the relay sets which make up the multi-metering equipment. The appropriate charge is determined at the trunk exchange and multi-metering pulses at the required rate are returned to the originating exchange during the progress of the call. As shown in Fig. 5, crossbar terminal exchanges may be connected to the multi-metering equipment as the crossbar exchanges are designed to receive the multi-metering signals from the centralised equipment as silent reversals. In the same way, the multi-metering equipment installed at the step-by-step terminal exchange will enable the exchange to be connected to an ARM exchange as indicated in Fig. 3, as the latter is also designed to transmit multi-metering pulses as silent reversals. Thus the terminal exchange relay sets of the centralised multi-metering equipment are an essential requirement to enable step-by-step terminal exchanges to be included in the long term S.T.D. objective.

The multi-metering relay set provided at the originating exchange (Fig. 4) recognises public telephones which are barred from access to the S.T.D. link. The public telephone line circuits are equipped in the same way as they are in step-by-step exchanges without S.T.D., with an identification tone relay set to alert the trunk operator to collect the appropriate charges. However, with centralised multi-metering equipment (Fig. 5), an identification tone relay set is not required in the public telephone line circuit as the terminal exchange equipment recognises public telephones and provides the identification tone on calls to trunk operators. This has the advantage that the identification tone is applied only on those calls for which it is required. Normally the public telephone is barred to any S.T.D. route but if desired the public telephone may be permitted access to S.T.D. routes for a unit fee period, the public telephone being disconnected on receipt of the second meter pulse.

Whereas the ARM exchange is designed to recognise the charge zone of the originating exchange, the centralised multi-metering equipment at the trunk exchange does not identify the originating zone. Therefore, the multi-metering rate applied is independent of the location of the originating exchange and it follows that either the S.T.D. originating exchanges must be restricted to those in the same charge zone as the trunk exchange or the S.T.D. routes must be restricted to those on which district to district charging applies.

TRUNK SWITCHING EQUIPMENT PROGRAMME

The combination of the target of 66 per cent S.T.D. by 1975, and the nature of the trunk traffic distribution, makes it imperative that S.T.D. facilities be given to as many subscribers as possible and that these subscribers must not be restricted in the destinations they can dial for themselves. This means that fairly quickly there must be a high penetration of ARM exchanges into the Australian trunk system.

There are, at present, some 650 switching centres in the Commonwealth, but this figure is likely to be reduced to 400-500 as the result of a review currently in progress. Approximately 150 of these will be of secondary switching status or higher and a high proportion of the 150 will need to be equipped with ARM equipment within the next ten years in order to gather and distribute S.T.D. trunk calls in sufficient quantities to achieve the target.

The S.T.D. programme will be assisted by the current development of transit switching facilities for ARF equipment which will enable them to operate as minor switching centres. The two-wire switching inherent in ARF equipment is acceptable at minor switching centres where there is no demand for the connection of nominally zero loss circuits to each other. Some S.T.D. traffic can be switched direct from the ARF exchange via line relay sets which inject metering pulses at a fixed rate to charge the calling subscriber. The trunk traffic pattern is generally such that the remainder of the traffic requiring automatic charging to be applied can economically be routed to the ARM exchange at the secondary switching centre.

In programming ARM exchange installations it will generally follow that the larger automatic networks will demand the higher priorities as they will provide more substantial gains than the smaller areas. This is clearly demonstrated in the early ARM programmes for New South Wales where the first installations are in Sydney, Canberra and Newcastle to be followed by such centres as Goulburn, Albury, Orange and Griffith. As the provision of broadband systems generally follows the same pattern, the demands for ARM will usually coincide with the availability of adequate circuits. The development of such a pattern has the added advantage that the ARM network will tend to grow out from the main switching centres, to primaries to secondaries and to minors, ensuring that from the beginning we build an integrated system to provide the advantages of direct and alternate routing together with multi-frequency code signalling.

The progress to date in providing S.T.D. in New South Wales is discussed in the remaining sections of the paper and indicates the interim methods used in meeting demands in the trunk system whilst awaiting the availability of the ARM trunk exchange equipment with which to build the framework for the nationwide S.T.D. network.

PROGRESS WITH S.T.D. IN NEW SOUTH WALES

The Environment Immediately Prior to First Installation

The description of progress in the introduction of S.T.D. in N.S.W. should be prefaced by a brief description of the situation as it existed at the time, about ten years ago, when S.T.D. was first proposed. A committee was formed to study the feasibility of introducing S.T.D. in Australia as a means of reducing the amount of trunk traffic handled manually, because great difficulty was being experienced, particularly in N.S.W., in meeting the demand for trunk service. It was clear that continuation of manual handling of the shorter distance traffic was making a heavy demand on the total funds available to meet total growth, on the available material and labour, on the recruitment of telephonists, on the facilities for training them and on building accommodation. The Committee found that the introduction of S.T.D. on a limited scale initially was feasible and designed the initial circuitry for use with the then step-by-step network. At the same time there were other factors, enumerated below, which did not encourage rushing into S.T.D. with complete confidence that this was the solution on a long term basis. These remarks together with the following list serve as a useful backdrop against which to study the decisions that were then made so that the reasons for them may be better appreciated.

(i) There was a marked deficiency in trunk circuit provision as compared to the number required to provide "on demand" service on all routes.

(ii) A number of trunk routes were nearing the limit of their capacity so far as meeting future development was concerned and major replacements were necessary to meet these expanding demands.

(iii) Broadband (large capacity) installations had not yet commenced and were not envisaged on the scale that we know them now.

(iv) The existing manual trunk exchanges were reaching the limit of their traffic handling capacity.

(v) Large initial capital expenditures were required to change from the open wire or pair cable to broadband routes.

(vi) The acceptance of S.T.D. by subscribers was not known with any certainty.

(vii) It was not known whether there was a limiting distance (meter pulse repetition rate) beyond which subscribers would regard S.T.D. as unacceptable because of the rate at which the cost of the call accumulated with time.

(viii) It was not known how much traffic would be generated on the S.T.D. routes and only relatively sketchy information could be obtained readily about manually handled traffic.

(ix) The way ahead to meet continuing growth on the S.T.D. routes proposed could not be guaranteed within a limited future period because the trunk routes had not been converted to broadband.

(x) Only a minority of trunk channels were provided with "out of band" signalling facilities and these were less than 50 miles in length.

(xi) Both line and information signalling methods in use in the manually controlled trunk network (mainly 2VF) were regarded as unacceptable for S.T.D. and signalling methods for use "in band" on S.T.D. had not been developed to the point where all safeguards against malfunctioning due to varied operating methods by the subscribers could be guaranteed.

(xii) The effects of possible traffic congestion and plant failure in the large networks on the performance of S.T.D. routes and on subscriber reactions were not known adequately.

(xiii) Charges for trunk calls were based on radial distance between originating and terminating exchanges and were not necessarily a multiple of unit fee charges.

(xiv) There were 22 different charge rates as against the seven (7) trunk charge rates at present.

The First S.T.D. Installations

A good example of the environment just described is the route chosen for the introduction of S.T.D. to N.S.W.; from the industrial area at St. Marys to the Sydney Metropolitan Unit Fee Area (S.M.U.F.A.). Before S.T.D. was introduced, the manual handling of the calls to Sydney was severely taxing the limited resources available. The automatic exchange then serving the industrial portion of the St. Marys exchange area was originally part of a Private Automatic Branch Exchange (P.A.B.X.) for the Ministry of Munitions shell filling factory at St. Marys (Dunheved) which was erected during the 1939-45 war. The conversion of part of the P.A.B.X. and the subsequent introduction of S.T.D., although separated in time by several years were very interesting exercises in adaption, particularly as the conversion from a P.A.B.X. to a public exchange was carried out early in 1947, when extreme shortages of equipment and manufacturing capacity were the order of the day, and the S.T.D. installation was the first off in Australia. This exercise in adaptation, although not recognised as such at the time, is the forerunner of fairly large scale adaptation necessary to introduce initial S.T.D. into the N.S.W. network and indeed also in other States. The S.T.D. installation was completed in 1956 and consisted of fixed fee multi-metering relay sets trunked via two switching stages to level 01 and thence to first selectors at City South exchange in Sydney. The channels used were provided by N1 type carrier on cable systems using E and M lead signalling. This installation is mentioned because, in addition to being the first application of S.T.D. in N.S.W., it used circuitry for fee determining, class of service, barred caller detection and impulse repetition functions which was untried under actual service conditions. Although the need for S.T.D. on calls to Sydney lapsed in 1960 with the inclusion St. Marys in the Sydney Extended Local Service Area (ELSA), the installation had made a worthwhile contribution to service for automatic subscribers in the area and had enabled the then existing manual assistance exchange to hold the traffic load. The manual assistance installation at St. Marys already had reached nine trunk operating positions in two separated rooms at the St. Marys Post Office and was at the limit of its capacity for the 550 subscribers served. The containing of the manual traffic load was in itself sufficient justification for the S.T.D. installation. It is also to be noted that there was a need for one trunk telephonist per 61 subscribers. The experience with this installation from the design, operating and subscriber reaction viewpoints was very valuable and set the pattern to a considerable measure for future installations.

The St. Marys-Sydney route was followed within about a year by further installations using circuitry which was developed after the St. Marys project. The installations were at Palm Beach, Avalon, Austral, Ingleburn and Blacktown, all of which are exchanges situated between fifteen and twenty-five miles from the Sydney G.P.O. These exchanges together with St. Marys were later included in Sydney ELSA and the multi-metering of calls to Sydney was therefore no longer required.

During the period between the first installation at St. Marys in 1956 and the introduction of ELSA, S.T.D. was provided at several country centres which have remained at trunk fee distance from Sydney. These installations were at Penrith, Windsor, Campbelltown and Dungog (into Newcastle). S.T.D. was also introduced from Hamilton exchange in the Newcastle network to Sydney and this was, up to that time, the longest S.T.D. route and consequently had the highest metering repetition rate (shortest interval between metering pulses) by a considerable margin. S.T.D. was later introduced from Canberra to Sydney, then from Canberra to Melbourne and more recently from selected Sydney inner city exchanges to Melbourne.

Traffic Studies

It is worthy of mention that at the time of the early S.T.D. installations trunk traffic had been growing at rates as high as 15 per cent per annum and that on the major routes, e.g. Newcastle to Sydney, each increment in trunk provision was quickly absorbed by the traffic demand, because the traffic received a stimulus from the improvement in service that the trunk channel increment produced. To a large measure this is still occurring but, at the time when S.T.D. was being introduced, some disquiet was felt at the possible demand which may arise from the improvement in service that S.T.D. was likely to provide. This in turn could produce a build-up in traffic to the point where extreme difficulty could be met in providing sufficient channels on the S.T.D. route to carry the increased traffic, which clearly had to be met "on demand" or the whole situation would become chaotic. Accordingly it was decided that the estimated traffic should be increased by 25 per cent to cater for this possible stimulus.

It is true that when it was proposed to extend S.T.D. to exchanges beyond the immediate (50 mile radius) vicinity of Sydney, information was available regarding the traffic characteristics of routes already established. Nevertheless, as is mentioned previously, it was not known whether there was a distance factor which would change the pattern significantly and the approach to S.T.D. from the more distant centres was made with some caution and provision of channels tended to be liberal, although when the estimates were made this was not known with any degree of certainty.

It may now be of interest to see what traffic patterns emerged and how the estimates lined up with the actual traffic read immediately after the route was placed in service and in various periods since. These details are shown in Table I for a number of routes ranging from short distances to distances at the maximum charging rate. Before discussing these estimates, the subsequently measured results and the conclusions, if any, that may be drawn from them, it is necessary to point out that the figures depicting read traffic may include some which was generated by telephonists in the manual assistance centre who have access to a proportion of the channels on the S.T.D. route. Telephonists inject traffic to the route when the channels allocated for manual assistance and telephonist generated transit traffic are congested and the S.T.D. route is clearly not congested at that time.

The traffics shown in Table I were measured in some cases at the busy season (Easter and Christmas), but it is not certain even then that the readings are truly representative of peak traffic. It is mentioned here that the inadequacy of present traffic measuring methods and frequency are well recognised and steps towards overcoming these deficiencies are being taken both within the State and by Headquarters. Nevertheless, it is likely that several years will pass before traffic measuring and result processing are fully automated.

Estimating S.T.D. Traffic: The basic problem in making the initial estimate of traffic on a particular S.T.D. route lies in the difference in the nature of the traffic when under telephonist control and the difficulty of collecting the data and converting these into hardware in the form of switching equipment, trunks, junctions, etc.

The methods used to arrive at the initial trunk channel requirements on a new S.T.D. route vary to some extent depending on the availability of and feasibility of procuring the desirable data. A study of trunk call dockets is made to produce a form of traffic estimate. This has to be done manually and, to produce results with a high confidence rating, a large number of dockets would need to studied. The effort involved is usually beyond the capacity of the available staff and therefore the results from a relatively small sample are accepted in most cases. As was mentioned earlier, quantitative traffic details will become available in the future as a product of the automation of traffic data collection processing methods now being developed. The information gleaned from the docket is compared with traffic readings made on the trunks carrying the telephonist-originated traffic. The difficulty with these latter data is that the trunks also carry traffic originated in centres other than the subject one, to destinations other than the subject one and it is not easy to isolate the traffic which requires study. There is also the problem of interpreting the readings because the nature of read traffic (trunk occupancy) differs as between telephonist-handled calls and subscriber-dialled calls because the former tends to be smoother than pure chance traffic. In addition, the holding times tend to be longer with telephonist traffic because of the cumulative effect of delays in starting to dial after seizure and delays in clearing after the subscriber has completed the call. At the best, the data must be regarded as a guide rather than a true replica of the traffic likely to be generated. These matters are mentioned as background information and are intended to make the backdrop more complete. At the same time the information also touches on the problems of making the initial traffic estimate with a good confidence rating. The estimates have included an allowance for the possible stimulus that S.T.D. will generate and with the expectation that up to 90 per cent of the originated calls will be dialled by the subscribers themselves.

TABLE I(A): ESTIMATED AND MEASURED TRAFFIC S.T.D. ROUTES IN N.S.W.

Exchange to Sydney	Original estimate (Erlangs)	Estimated subscribers at originating exchanges	Date placed in service	Initial traffic measurement (Erlangs (E) Date Subscribers)	2nd traffic measurement (Erlangs (E) Date Subscribers)	Subsequent traffic measurements (Range of Erlangs (E) and Subscribers) (Note 1)	Average holding time (measured values)	Remarks
Penrith	31	1,331	14. 3.59	18.2E 4/59 1,278	19E 10/59 1,366	19.8-28E (9) 1,417-2,014	2' 28"	38 channels initially, increased to 52 in 1965.
Hamilton	17.8	3,800	21. 3.59	13E 4/59 3,719	18E 10/60 4,090	18.5-22E (13) 4,180-4,415	2' 38"	24 channels initially, increased to 30 in 1962, and 36 in 1965.
Windsor	18.3	833	7. 5.60	10E 6/60 567	10.1E 4/61 691	9.6-12.5E (6) 780-840	2' 23"	No increase in channels from initial provision of 26.
Campbell-town	21	2,142	20. 4.61	15E 6/61 1,595	16E 12/61 1,687	21.3-24.2E (7) 1,897-2,216	2' 13"	29 channels initially, increased to 32 in 1963, and 39 in 1965.
Canberra	33.7	12,400	17. 3.62	25E 4/62 10,783	31.8E 10/62 11,670	31.8-41.2E (16) 12,180-17,050	3' 5"	43 channels initially, increased to 47 in 1962, 52 in 1964, 63 in 1965.
Gosford	18.5	1,800	26.11.62	11.7E 12/62 1,731	18.9E 12/63 1,910	18.9-19.8E(10) 1,910-2,108	4' 6"	No increase in channels from initial provision of 29.
Wollon-gong	42	6,430	23.10.63	27.5E 11/63 6,164	32.4 12/63 6,179	32.4-35E (6) 6,237-6,597	2' 22"	No increase in channels from initial provision of 55.
Goulburn	8.2	3,298	17. 6.64	6.1E 7/64 2,991	6.5E 12/64 3,017	6.1-6.5E (4) 2,991-3,017	2' 2"	No increase in channels from initial provision of 17.
Wolfe	34	4,496	30. 6.64	21.8E 7/64 3,850	26E 12/64 3,869	21.8-26E (5) 3,850-3,869	—	No increase in channels from initial provision of 52.
Wyong	4.4	570	15.12.64	2.4E 12/64 500	4.4E 1/65 514	2.4-4.4E 500-514	1' 54"	No increase in channels from initial provision of 12.
Springwood	4.8	1,121	9. 6.65	—	—	—	—	Measurements not completed at time of writing.
Maitland	8.5	2,562	30. 6.65	—	—	—	—	Measurements not completed at time of writing.
Wollon-gong Area	23.5	7,126	9. 7.65	—	—	—	—	Measurements not completed at time of writing.

Note 1: Figures in brackets are numbers of measurements.

TABLE I(B): OTHER S.T.D. ROUTES IN N.S.W.

Route	Original estimate (Erlangs)	Estimated subscribers at originating exchanges	Date placed in service	Initial traffic measurement (Erlangs (E) Date Subscribers)	2nd traffic measurement (Erlangs (E) Date Subscribers)	Subsequent traffic measurements (Range of Erlangs (E) and Subscribers) (Note 1)	Average holding time (measured values)	Remarks
Dungog-Hamilton	6.1	488	4. 2.61	5.9E 3/61 393	5.0E 5/61 397	5.0-4.9E (4) 397-429	—	No increase in channels from initial provision of 12.
Dungog-Maitland	1.1	488	4. 2.61	1.2E 3/61 393	1.6E 5/61 397	1.5-1.3E (3) 397-429	—	No increase in channels from initial provision of 4.
Gosford-Newcastle	3.8	1,800	26.11.62	2.3E 12/62 1,731	4.2E 12/63 1,910	4.2-3.5E (3) 1,910-1,954	—	No increase in channels from initial provision of 8.
Canberra-Melbourne	19.3	1[illegible],262	20. 8.63	9.0E 3/63 13,593	13.3E 3/64 14,447	16-17.2E (3) 15,323-17,050		36 channels initially reduced to 28 in 1964, increased to 40 in 1965.
Wyong-Newcastle	6.9	1,007	15.12.64	1.2E 1/65 514	—	—	1' 41"	No increase in channels from initial provision of 13.
Albury-Melbourne	8.5	3,788	26. 6.65	—	—	—	—	Not measured at date of writing.

Note 1: Figures in brackets are numbers of measurements.

TABLE I(C): FROM SYDNEY INNER CITY EXCHANGES TO:

Distant End Exchange or Network	Original estimate (Erlangs)	Estimated subscribers at originating exchanges	Date placed in service	Initial traffic measurement (Erlangs (E) Date Subscribers)	2nd traffic measurement (Erlangs (E) Date Subscribers)	Subsequent measurements (Range of Erlangs (E) and Subscribers) (Note 1)	Average holding time (measured values)	Remarks
Melbourne	45	21,000	5.12.64	23E 12/64 18,544	25E 6/65 19,564	24-28E (2) 19,723-20,057	3'	
Canberra	17	21,000	29. 5.65	8E 6/65 20,057	—	—	2' 29"	Only one reading taken at date of writing.
Wollongong	18	21,000	29. 5.65	6E 6/65 20,057	—	—	2' 41"	Only one reading taken at date of writing.
Newcastle	21	21,000	—	—	—	—	—	Placed in service after date of writing.
Brisbane	13	21,000	—	—	—	—	—	Placed in service after date of writing.

Note 1: Figures in brackets are numbers of measurements.

The Traffic Actually Observed: Turning again to Table I it is seen that some fairly wide variations between the estimated and read traffic can be observed on nearly all routes. The estimates are consistently higher than the actual. A number of opinions have been expressed as to the cause of these variations, including views that in fact there is no stimulus and/or that the calls increase, but the holding times diminish on S.T.D. as compared with the three minute paid for time intervals on manual assistance traffic. It is difficult to prove or disprove these opinions because of the paucity of detailed data prior to the introduction of the facility. The view of the writers leans towards generous initial provision of channels on the basis that if the users encounter good service from the outset they are likely to increase their use of it and, from economic and engineering viewpoints, it is almost certain that the traffic will follow the usual growth pattern observed on trunk traffic so that, at the worst, the initial over-provision will meet development for rather longer than the usual two years, and in any case the route is also available for some telephonist traffic. The traffic after introduction of S.T.D. usually follows a pattern which suggests that the subscribers, after in some cases a short burst of curiosity calls, treat S.T.D. with some caution at the outset. However, within six months the traffic builds up to a value which suggests that about 80-90 per cent of originated calls are made via S.T.D.

The Trunking Arrangements

The initial S.T.D. installations used simple trunking and access codes mainly because this was the least costly way of adding S.T.D. to an existing installation. The inherent inflexibility of step-by-step trunking precluded and still precludes the economic introduction of full national codes to more than the few destinations which can be identified on the first national digit (A digit), and even then requires some form of digit absorption on codes other than Sydney which has a full A digit (2) allocated to it. The methods which were employed on later installations are shown in Figs. 7, 8 and 9, while Fig. 6 illustrates the simpler form of access used initially at Hamilton.

It is possible to trace the evolution that ideas went through by a study of the methods used. The initial cases were quite straight-forward, being stripped of any complications in order that the circuitry be similarly

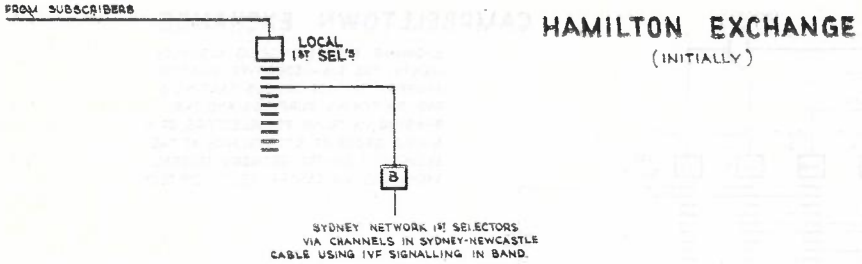

Fig. 6. — Note: B denotes a relay set to Drg. CE-11017 (Mod) — APO type multimetering repeaters providing for S.T.D. metering pulses to be returned to the caller, and signals forward on a loop disconnect basis.

simplified. In particular, it should be noted that the choices of the number of fee rates were limited, and as the fee determining equipment was associated directly with the trunk in the same building on the calling subscriber's primary equipment, there was no need for metering signals to be passed over a trunk or junction. Emphasis is given to this when it is recalled that there were 22 trunk charge rates in operation when Hamilton was first given S.T.D. to Sydney and not all of these were an exact multiple of a unit fee.

When S.T.D. was first provided from Hamilton, trunking was simplified to the point where a single digit (8) was used as the prefix for calls to Sydney, the prefix being followed by the Sydney subscriber's number. This is shown diagrammatically in Fig. 6. The only complication was that local and incoming first selectors were mixed on the same racks and consequently shared the same outlets including the S.T.D. circuits. At Hamilton this difficulty was overcome by using the same access barring method as is used for the public telephone line circuit. This consists of permanently connecting a resistor of about 500 ohms from —48 volts battery to the private (P) wire of the public telephone line circuit or incoming group selector. This allows sufficient current to flow in the P wire to trigger off the throw-out circuit if a multi-metering relay set is encountered. Later, when the national access code (02) for Sydney calls was introduced at Hamilton simultaneously with the introduction of standard three digit "0" codes for manual assistance (011, 012, etc.) considerable rearrangement and the addition of "0" level second selectors at Hamilton were necessary. These "0" level second selectors were additional to the existing installation of "0" second selectors at the "2" exchange (Wolfe) and through which, up to that time, all manual assistance traffic from the Newcastle network was routed. The introduction of the second group of "0" second selectors in the network required separate groups of circuits to the "01" third selectors with consequent reduction in traffic efficiency. These factors are mentioned to illustrate the difficulties even in this relatively simple installation, of introducing national numbering in step-by-step-type exchanges, as compared to the situation in a register controlled network.

Referring again to the trunking methods and circuitry indicated in Figs. 6 to 9, it will be noted that following the simple trunking arrangements used in the initial installation at Hamilton (Fig. 6) it was soon found necessary to introduce more complex trunking and circuit arrangements as the need for S.T.D. arose in the other areas mentioned in the figures. This culminated in the installation, in stages, of the multiplicity of different trunking and circuitry needed at Canberra to provide S.T.D. from all Canberra network subscribers to Sydney and Melbourne. This clearly points to the need for a sophisticated automatic trunk switching machine such as the ARM type as has been mentioned earlier in this paper.

Some Features of the Trunking and Circuitry

It may be of interest to describe some of the features of the trunking and circuit arrangements because they may not always be self evident. Fig. 6 requires no comment except to say that the fixed rate multi-metering relay set is in fact a variable rate type modified to operate without a code selector. The arrangements shown in Fig. 7 are those which were installed at Windsor in 1960. The trunking arrangements are not provided, in the form shown, solely because of the introduction of S.T.D. but are included in this paper because they may be of general interest. It is necessary to accept the traffic efficiency penalty and divide the first selectors into a number of separate groups in order to provide for:

(i) National numbering from those selectors available to the local automatic subscribers (Group 1—Fig. 7).

(ii) Access via standard dialling codes from dependent terminal automatic exchanges to the manual assistance positions without traversing a 3 db. stabilising pad (Group 2—Fig. 7).

(iii) Correct usage of 3 db. stablising pads on calls from local subscribers to amplified (nominal zero loss) trunks (Group 1—Fig. 7).

(iv) A form of "open" numbering with access codes for use by distant telephonists to obtain access to the manual assistance positions via level 1 of the first selectors (Group 2 and Group 3—Fig. 7).

(v) The switching in of a 3 db. stability pad on calls mentioned in (iv) when the Windsor telephonist is coupled to the connection.

(vi) Correct positioning of 3 db. stabilising pads on calls terminating on local subscribers from amplified (nominal zero loss) trunks.

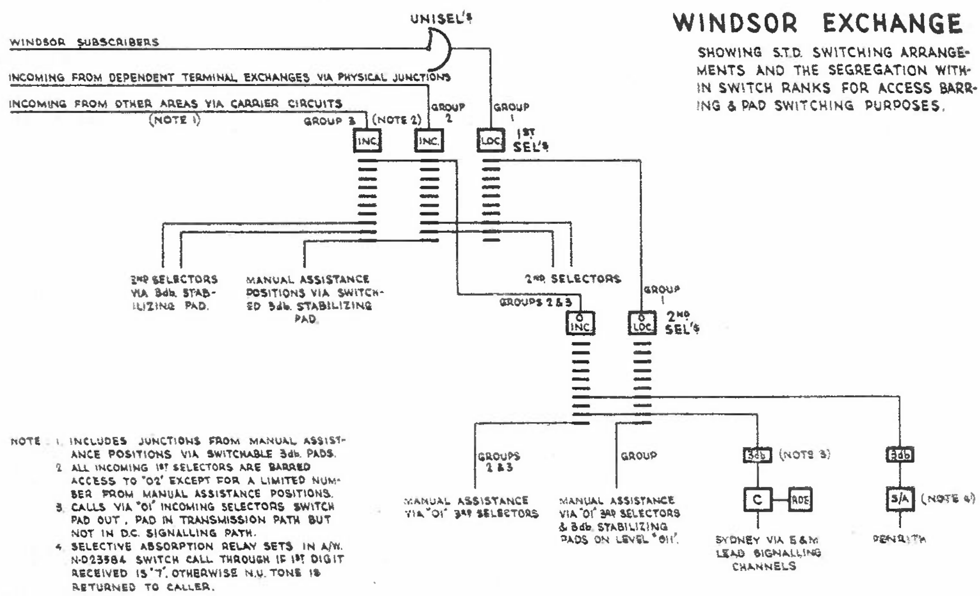

Fig. 7 — Note: C denotes a relay set to Drg. CE-11017 with code selector to Drg. CE-11018.

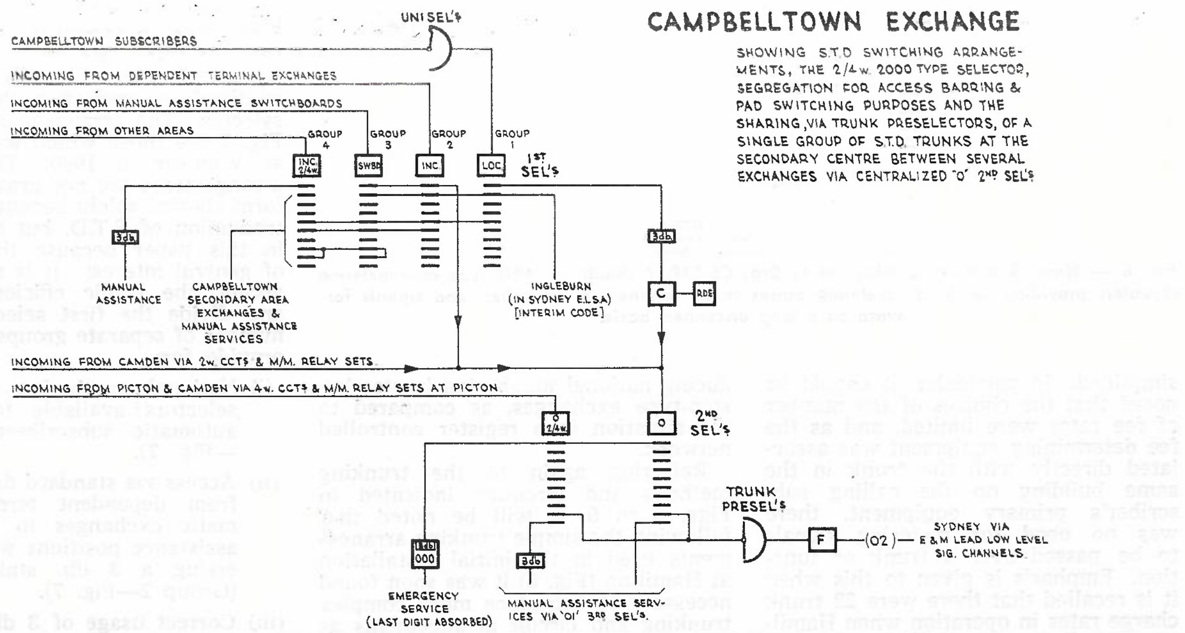

Fig. 8. — Note: C denotes a relay set to Drg. CE 11017 with a code selector to Drg. CE 11018 for variable rate charging. F denotes a relay set to Dr. CE 11248 (Mod.) — Outgoing loop sequential trunk signalling relay set to convert incoming loop disconnect junction signalling to outgoing loop sequential trunk signalling.

If reference is now made to Fig. 8, it will be noticed that there are four groups of first selectors at Campbelltown. In addition to providing for the same conditions as are mentioned in (i) to (vi) above, the four-group arrangement at Campbelltown caters for true four-wire switching of connections between four-wire circuits.

In going from the one exchange arrangement at Windsor to the multi-exchange requirements of the Campbelltown secondary area, a further complication is introduced in order to minimise the number of trunk channels. The complication is the necessity to centralise the "0" second selectors and then divide them into two groups, one of which allows for four-wire switching. This necessitated the installation of more multi-metering and fee determining equipments at each of the other exchanges in the secondary area (Camden and Picton) from which multi-metering is available because all of the "0" level calls originating in these exchanges had to pass through these relay sets. The multi-metering relay sets and their attachments are markedly more costly than the relay sets normally used in the unit fee network (an auto. to auto. repeater) and as the "0" level traffic contains a fair percentage requiring manual handling of the call, the cost of the multi-metering equipment in a situation such as has been described tends to be maximised in order that the trunk channel provision should be minimised. It will also be noted that a further trunk channel reducing process was used at Campbelltown by medium of the trunk pre-selector which theoretically produced conditions approaching full availability to be introduced on the S.T.D. route to Sydney. On this aspect current thought is that with the gradual downward trend in the cost of trunk channels the desire to minimise trunk channel provision for economic reasons will not be nearly as strong as it was when Campbelltown was installed. While it is not the purpose to enter into a full scale discussion on the economic balance between the number of trunks, the number of switching stages and the number of switches in each stage, it could be said that the arrangements at Campbelltown are not necessarily regarded as optimum with present channel and switching costs.

The arrangements shown in Fig. 9 for the Canberra network have evolved through a number of stages and have become more complicated at each stage. The first installation was to Sydney (02) from Civic, Barton and Manuka exchanges and access to the trunk group was obtained through decentralised "0" second selectors to a single group of trunks via trunk pre-selectors at the Central trunk exchange. The arrangements adopted avoided the installation of a centralised group of "0" second selectors at Central where accommodation problems existed. The "0" second selectors used for two-digit trunk assistance access codes, already installed at Central, were converted to "01" level third selectors with the introduction of three digit "0" level service codes. The use of trunk pre-selectors as a concentration point for the S.T.D. traffic to Sydney introduced a considerable amount of circuit design complexity, particularly as they were being used in an environment markedly different from that intended when they were designed. The switches are Siemens' high speed motor uniselectors adapted for the purpose. While some of the basic Siemens' circuitry was retained, the new requirements necessitated fairly extensive modifications, and the fact that these circuits were able to perform satisfactorily is a credit to the adaptability of the Siemens' high speed motor uniselectors and operating circuitry. However, because these trunk pre-selectors have to stand on a free circuit while a free circuit exists, there is frequent movement of the free trunk pre-selectors as they take up a new position after the position on which they previously stood is seized by another trunk pre-selector. During this movement the inlets to all of the trunk pre-selectors which are moving are busied and consequently the more frequent the movement, the greater is the generation of artificial traffic. This tends to create some lost traffic even though free trunk channels exist at that instant. It was therefore necessary to introduce a number of modifications which were a compromise between a high traffic efficiency per channel and a minimising of artificial traffic. A number of further stages including the introduction of S.T.D. to Melbourne and the inclusion of crossbar installations at Deakin, Russell and Civic produced the rather complex arrangements shown in Fig. 9. The complexity of the trunking points to the need for the ARM installation which is currently being provided at Canberra. It is not difficult to envisage the complications which would be introduced if traffic destinations additional to Sydney and Melbourne were included in the Canberra S.T.D. arrangements without having such a centralised switching, routing and charging machine as the ARM automatic trunk exchange previously discussed.

Types of Trunk Channels Used for S.T.D.

The general requirements that S.T.D. trunk channels have to meet as far as signalling is concerned have been outlined in the preceding sections of this paper. It is proposed now to discuss briefly the variety of trunk channel types used in New South Wales for the S.T.D. so far installed. Although a high percentage of the installations are now using "in-channel out of band" (shortened to the term out band) low level continuous tone signalling channels with loop sequential type (compelled sequence) relay set terminations, the signalling being built into the channel unit, some "in band" signalling methods are used, as well as other older types of signalling.

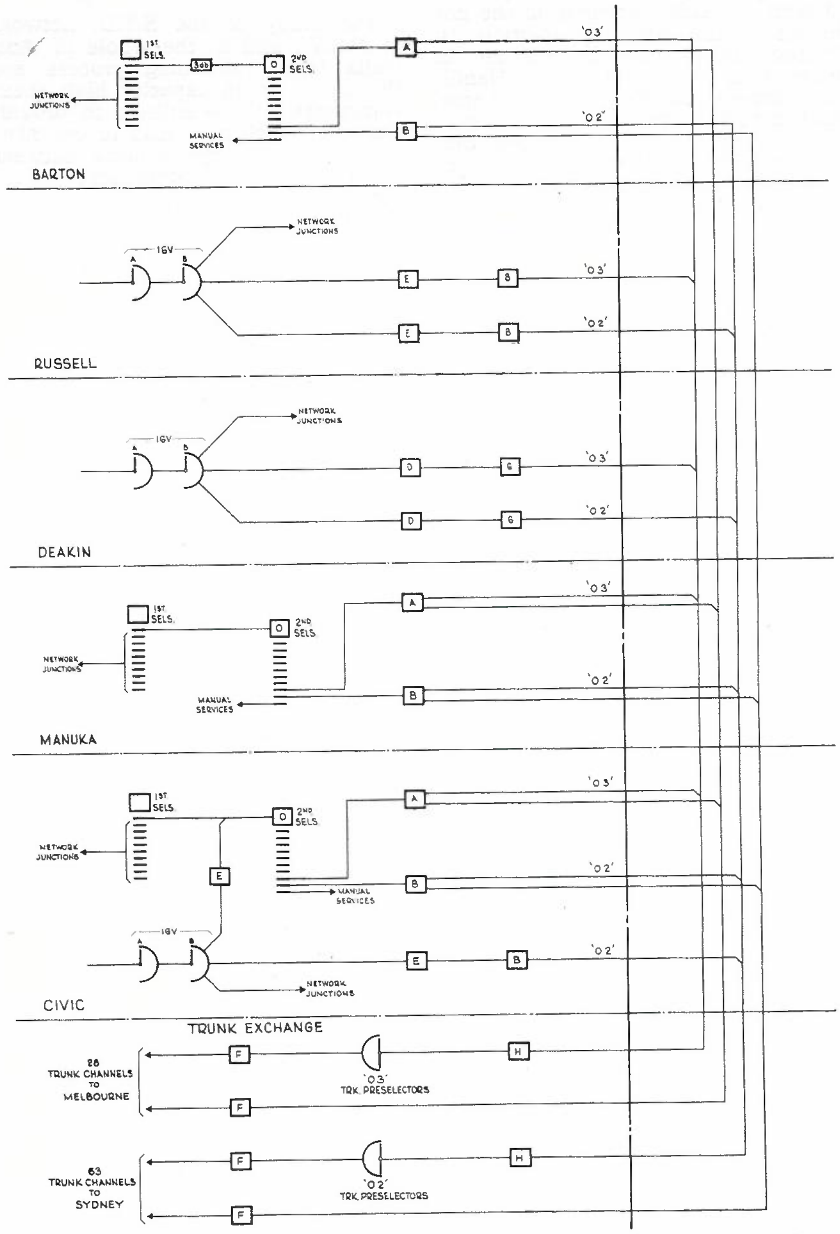

Fig. 9. — Canberra Network—"O" Level Trunking at Fune, 1965, showing S.T.D. Relay Set Arrangement. Note: A denotes a relay set to Drg. CE 11017 and B, a relay set to Drg. CE 11017 (Mod.)—APO type multimetering repeaters providing for S.T.D. metering pulses to be returned to the caller, and signals forward on a loop disconnect basis. D denotes a relay set to CSK 12436 — This is an early design of CE 11248 (CC48) relay set which provides for fixed rate S.T.D. silent reversals to be returned to the caller, and works directly into a carrier channel on a loop sequential signalling basis. E denotes a relay set to N-SK 10321 — Locally designed relay set to convert meter pulses returned from A.P.O. type multi-metering repeaters to silent reversals for the operation of meters of subscribers served by crossbar equipment. G denotes a relay set to CE-11249 (Mod) — Incoming loop sequential trunk signalling relay set to convert incoming loop sequential trunk signalling to outgoing loop disconnect junction signalling. H denotes a relay set to ND 29237 — Junction connect relay set to permit connection of trunk preselector to an incoming two wire junction.

Some of the earlier installations used channels with signalling contained within the nominal 300-4000 c/s channel bandwidth. The signalling frequencies are restricted to a bandwidth of about 100 c/s and the signal current is transmitted at a frequency of 3,825c/s. The signalling tone (current) is transmitted in both directions when the channel is idle. Cessation of tone in the "go" direction of a uni-directional traffic channel, say an "out" trunk from a selector level, is an indication that the channel has been seized by a selector. Cessation of tone in the "return" direction indicates that the called party has answered (reversal). Dialling is performed by bursts of tone in the "go" direction, each burst representing a break period of the dial impulsing springs. The shortcomings of this method of signalling are fairly obvious when it is remembered that the automatic switches rely on the opening of the holding loop for their release. The loop is opened when channel tone is restored at the end of call, that is, when the caller or called party "hangs up". The failure of a channel during conversation is the same to the automatic switches as the continuation of the call and the switches at the incoming end are therefore "held up" until released by restoration of the tone, the restoration of the caller's handset, or other means such as maintenance attention. This shortcoming is not more serious from a user's viewpoint than being cut off during conversation because a failure of a speech channel is usually followed by restoration of the caller's handset to the telephone resulting in release of the local exchange switch train. Nevertheless, it is an undesirable condition even though its occurrence is infrequent. The signalling channel just described is referred to as a "high level tone on idle" channel, the significance of this being that the signalling tone is transmitted at a relatively high power level allowing the use of fairly insensitive receivers. The high signalling tone level, if used during the same period that speech is being transmitted, would tend to overload the common amplifiers (repeaters, etc.).

The disadvantages of the signalling channels and associated circuitry outlined in the preceding paragraph are overcome by the circuitry designed for use on the later type signalling channels which are similar in concept to the earlier out band channels, but use low power levels for tone transmission with the advantage that the tone can be applied in bursts or continuously during speech without causing overloading. This requires a more sensitive signal receiver but the overall advantages warrant the additional cost.

Both the high level and low level signalling channels are frequently referred to as E and M lead signalling, the letters E and M referring to the signal wires of the input and output of the carrier channel. Thus E and M lead signalling is frequently meant to refer to any system using separate signal wires. This is mentioned merely to introduce readers to the different terms used to describe substantially the same thing, the signalling channels being considered as an extension of the signalling wires.

The other types of channels used for S.T.D. in N.S.W. are of an older type in which signalling must be done within the speech band (in band signalling) or on an exclusive signalling path outside the speech band by means of carrier frequency signalling. The latter is a form of out band signal requiring bursts of current of different durations and, in a particular order (impulsive signalling), to indicate what function has to be performed. The in band signalling used is also necessarily an impulsive form using a tone in the voice frequency range, is heard by the caller to a limited extent and requires a high degree of immunity from interference from speech currents. The actual signalling equipment used is basically the Siemens' 1VF system which was originally designed for use in the telephonist's network and has been successfully modified for use with S.T.D. This method has now replaced the carrier signalling originally used from Hamilton to Sydney.

The importance of providing for a reliable signalling system which may be used on any type of voice frequency channel is perhaps, illustrated in the foregoing remarks. The ARM automatic trunk exchanges will cater for these requirements, particularly when interworking with other ARM or other type crossbar exchanges is concerned.

The Present Plans for N.S.W.

The trunk switching network envisaged for N.S.W. as part of a national trunk switching scheme is based on a hierarchical structure (see Fig. 2) with Sydney as the main switching centre with direct routes to all other main centres in Australia. The next lower order switching centre is called a primary centre. At the moment there is some further thought being given to whether primary centres do in fact contribute to optimisation of overall costs. Nevertheless, until quite extensive economic studies have been made, it is difficult to be conclusive on this point and consequently, it is proposed for the purposes of this paper to include primary centres in the description of the trunk switching network. There are at present seven centres (excluding Sydney which, being a main centre, is necessarily also a primary centre) which are designated as primary switching points out one of these, Lithgow, is not likely to retain its present nominal status. The other centres are Newcastle, Canberra, Orange, Wagga, Tamworth and Lismore. Each primary centre will severe a number of secondary trunk switching centres located in the general geographical area of the primary centre, with the secondary centres in their turn serving a number of minor centres which service the terminal exchanges.

Each primary centre will be provided with an ARM exchange in the not distant future and in addition to Sydney, installations are already in progress at Newcastle (in the Hamilton exchange building) and Canberra. Subject to the availability of the necessary resources it is planned that further ARM installations proceed at the secondary centres and also at some minor centres.

The automatic trunk switching exchanges must be served by adequate trunk channels both initially and on a continuing basis. Fig. 10 shows where broadband bearers are installed and are immediately proposed, these large capacity bearers following the heavy traffic routes where the greatest gains can be made by the introduction of S.T.D.

The study of the S.T.D. network in N.S.W. and in the whole of Australia is a continuing process and the aid of large capacity high speed computers will be enlisted to provide answers which may lead to optimisation. The economic balance between costs of the main components in the network, the switching equipment, the connecting links and the signalling equipment has to be found and main-

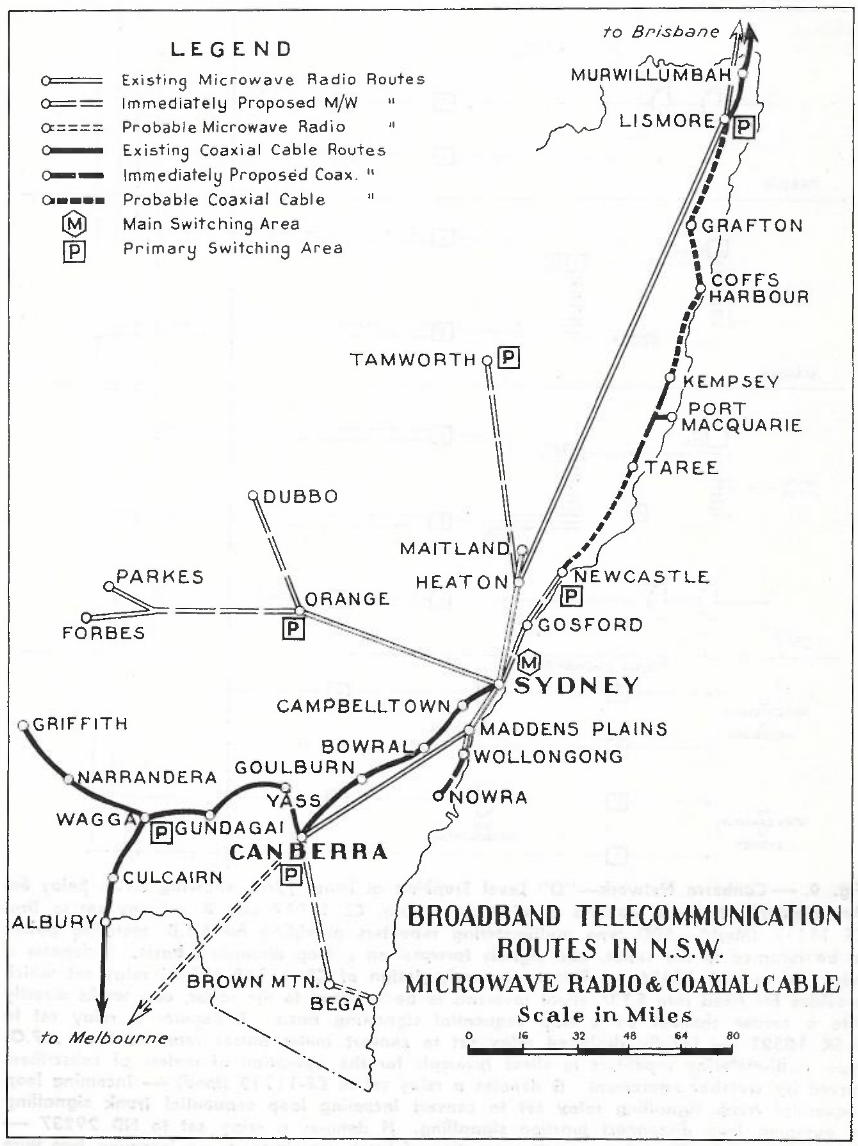

Fig. 10.

tained as conditions change.. Any subsequent variation in the relative costs of these components can produce a requirement for a change in the network. The study of the S.T.D. network cannot be done without a concurrent study of the whole trunk network and the major local networks such as the capital cities and other large centres of population and telephone density.

CONCLUSION

The authors of this paper are both engaged on planning activities which require the making of predictions for the future and both have learned to accept the hazards of such an occupation. Nevertheless, although the future may prove the predictions to be wrong, it is felt that this paper would not be complete without some forecast of the likely shape of the future trunk network. It is expected that the general shape, which is dependent upon the calling habits and communications needs of the community, will alter gradually and, even then, only in degree. However, as in the past, there is continuous change in the various components of the trunk system under such influences as the variation in relative costs, the magnitude of the traffic to be carried and the interests of service security.

It is anticipated that both the ARM automatic trunk switching exchanges and the broadband carrier links will continue to penetrate further into the trunk system. It is expected that this dual penetration will result in the number of trunk switching centres being markedly reduced by the elimination of many current minor switching centres which would become terminal exchanges switching only traffic generated by and for the local subscribers. In addition, some current secondary centres will be reduced to minors and, possibly, the primary centres will be reduced to secondary status. It is considered that the manual assistance centres will continue to be centralised as more areas are converted to automatic, and that the number of service areas are converted to a utomatic, and that the number of service centres wil be considerably less than the number of switching centres. The balance between costs of switching equipment and trunk channels will be the predominant determining influence and there still appears to be a downward trend in the overall cost of providing trunk channels. A similar downward movement in switching costs has not been observed. As far as the trunk circuits are concerned, it is expected that when the trunk traffic increases to much higher proportions than we now experience, a new network of trunk channels, well separated from the existing links, will be established. This will reduce the risk of losing all circuits in any one section of the country at any time.

It is interesting to note that the pattern of development which has taken place in Australian network is gradually extending into the international network. With the development in postwar years of reliable submerged repeaters, the use of long distance submarine telephone cables, designed on the coaxial principle, has enabled the provision of large numbers of high quality telephone channels between countries, over which international subscriber dialling will be a feature of the future. Already Australian operators are dialling direct into the networks of New Zealand, Canada, United States and Britain.

Given the resources required it is confidently expected that the Australian Post Office will continue to provide improved service in the connection of trunk calls. The important requirement is to meet the demands that subscribers make on the service, both local and trunk, and this task is occupying the full attention of planning and plant people alike.

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I.T.U. MEETINGS — MELBOURNE, SEPTEMBER/OCTOBER, 1966

Between the 7th of September and the 26th of October, 1966, the Australian Administration acted as host to three separate series of meetings of the International Telecommunications Union. This was the second occasion on which the Australian Administration had welcomed delegates to I.T.U. meetings held in Australia.

In October, 1963, meetings of certain Telephone Study Groups were held in Melbourne, and this year, the meetings held were the Plan Committee for Asia and Oceania, C.C.I.T.T. Telegraph Study Groups I and X and associated joint working parties. A seminar on the Development of a Telephone Network, was also arranged.

Brief reports of the proceedings of each of these three meetings are given below.

I.T.U. PLAN COMMITTEE FOR ASIA AND OCEANIA

Seventy-eight delegates from 33 countries attended a meeting of the I.T.U. Plan Committee for Asia and Oceania which was held in Melbourne from 7-19th September, 1966, under the Chairmanship of Mr. C. P. Vasudevan (India). The Australian delegation included members from Post Office Headquarters, the Overseas Telecommunications Commission and the Papua and New Guinea Posts and Telegraphs Administration.

The Work of the Plan Committees

The I.T.U. Plan Committees operate under the joint auspices of the C.C.I.T.T. and C.C.I.R. — the international consultative committees on telephony and radio. The Plan Committees are responsible for establishing broad plans for the development of the international network, to help administrations and recognised private operating agencies in negotiating agreements to organise and improve the international services between their countries. They also examine technical, operating and tariff questions raised by countries in applying the plans and refer them for study by appropriate I.T.U. bodies.

There are four Regional Plan Committees, covering the areas of Europe and the Mediterranean Basin, Africa, Latin America, and Asia and Oceania. The World Plan Committee co-ordinates the work of the Regional Committees and plans the development of the network interconnecting them. The Committees normally meet every three years.

Growth of International Traffic

Plans for the development of international telecommunication services were significantly advanced during the Melbourne meeting. The conference produced new and reconciled estimates of traffic and circuits for telephone, telegraph, Telex and miscellaneous services at the years 1965, 1970 and 1975 for connections within the Region and to other Plan Regions. These figures reveal a "communications explosion" over the next decade, with forecast traffic increases of up to tenfold on many major traffic streams. Various discrepancies between the forecasts of Australian traffic and the corresponding estimates of the reciprocal countries were revealed and reconciled.

New Submarine Cables Planned

Progress in planning and constructing new international arteries to provide a high capacity network within and out of the Region was reviewed and documented. Details of revised routing for the SEACOM cable, with the Guam landfall, were supplied by Australia, and Japan again recorded proposals for the South Asian/Far East Cable (SAFE) shown to be routed from Tokyo, via Taipei, Manilla and Bangkok to Singapore. An Indian Ocean cable (IOCOM), from Madras to Penang and a submarine cable linking East and West Pakistan were amongst new facilities proposed.

Satellite Communications

Details were recorded of satellite earth stations scheduled for construction during the period to 1970. Fifteen earth stations were listed, with up to seven giving access to the Pacific Satellite and eleven to the Indian Ocean Satellite.

Planning of routing and switching arrangements for the Region was advanced by recording the existing and proposed international switching centres. Limitations of the present routing plan principles were demonstrated by the fact that no attempt was made to assign to centres a classification in terms of the current switching hierarchy. However, countries nominated their choice of switching centre for transit and overflow routing of major traffic streams.

Minor changes were made in the allocation of country codes for the world telephone and Telex numbering plans by substitution of two-digit codes for Singapore in lieu of the three-digit codes formerly allocated.

Technical Assistance

The conference reviewed progress in obtaining answers to technical questions raised at the previous Plan Asia meeting in 1963. The C.C.I.T.T. and C.C.I.R. have supplied answers to most of these and the remainder are expected to be available within the next six months. No further questions were raised at the present meeting. The chairman surveyed the various avenues for technical assistance available through the I.T.U. and referred to a current proposal to appoint four experts to assist developing countries in planning their networks.

With countries in possession of the latest information concerning traffic and circuit forecasts, new arterial and satellite proposals and routing information, they should be able to proceed towards engineering concrete proposals for further developing the international network. — I.A.N.

C.C.I.T.T.-TELEGRAPH STUDY GROUP MEETINGS

The following Telegraph Study Groups, and Working Parties, met in

Fig. 1. — The Australian Delegation to the Plan Asia Committee Meeting. Left to Right: Mr. R. E. Butler, Mr. R. T. Pearson, Mr. R. J. Christoffersen, Mr. R. R. Long, Mr. I. A. Newstead, Mr. B. J. Nolan and Mr. P. S. Bethell.

Fig. 2 — From Left to Right: Delegates Mr. C. A. Figueiras (Brazil), Mr. D. S. Robertson (Canada), Mr. M. H. Woodward (U.S.A.), chat with the Postmaster-General, the Hon. A. S. Hulme, and the Director-General, Mr. T. A. Housley.

Melbourne from 7th September to 26th October, 1966:—

Study Group I — Telegraph Operation and Tariffs 28.9.66-4.10.66 (Chairman: Mr. R. Vargues, France).

Study Group X — Telegraph Switching 3.10.66-7.10.66 (Chairman: Mr. A. Jansen, Netherlands).

Study Groups I and X — Joint Meeting 3.10.66-4.10.66.

Working Party GM-MRT — Re-transmission of Messages—8.9.66-14.9.66 (Chairman: Mr. R. K. Andres, United States).

Working Party GM-TGX—Worldwide Telex and Gentex Routing Plan — 15.9.66-21.9.66 (Chairman: Mr. W. G. Gosewinckel, Australia).

Working Party GM-EFF — Efficiency Factor — 22.9.66-26.9.66 (Chairman: Mr. M. L. Benko, Hungary).

Mr. Andres (Vice-Chairman) acted as Chairman of GM-MRT because of the absence, due to illness, of Mr. M. Bonacci (Italy) and Mr. Benko (Vice-Chairman) became Chairman of GM-EFF due to the death of Mr. Wilcockson (United Kingdom).

Study Groups

Some of the important subjects discussed were:—

Study Group I: Collect-transfer account service in the telegram, telex and photo-telegraph systems.

Revision of telex regulations covering the administrative arrangements for the international telex service.

Amendments to the rules governing page reception of telegrams so as to bring these into line with page reception in international message switching.

Amendments to Recommendation F.31 concerning international message switching in respect of switching format, page format, and with particular reference to the co-operation of gentex and message re-transmission systems.

Amendments to F.31 in respect of service correspondence in the message re-transmission network.

Counting of words, with a view to simplifying the rules such that automatic equipment might make, or check the count.

Examination, from the telegraph operational point of view, of a new data inter-change alphabet, prepared by Working Party GM-ALP and containing an agreed C.C.I.T.T./I.S.O. (International Standards Organisation) code allocation.

Study Group X: Characteristics of the re-test signal to be used in automatic telex operation over types of circuit normally used in internal systems and throughout Europe.

Technical aspects of the start of chargeable duration in fully automatic international telex calls.

Proposed additional service codes, and the format of these in systems using printed service code supervision.

Telex signalling over radio circuits dealing particularly with automatic testing of circuits on seizure, both-way working, and the disposition of stored traffic on ARQ circuits when call failure is experienced.

Use of circuit efficiency control on ARQ radio channels in the telex service.

Proposed amendments to Recommendation U.11 (Intercontinental Signalling System).

Transmission considerations in the intercontinental telex network.

Possibility of the establishment of telegraph-type switching networks operating at 200 bauds.

The Working Parties

The joint working parties referred to, reported to their controlling Study Group on the particular topics included in their terms of reference. For example, GM-MRT, Joint Working Party of Study Groups I, VIII and X, reporting to Study Group I, dealt principally with the re-transmission of message questions such as amendments to Recommendation F.31, with particular reference to switching format, page format, gentex and message re-transmission system inter-operation, and service correspondence in the message re-transmission network. The report of this working party to Study Group I was then considered in Study Group I and, similarly, the Joint Working Party, GM-TGX, reported to Study Group X, as did GM-EFF. The working party system enables specialists in the particular area of the working party to work in a smaller environment than the full Study Group, producing reports proposing particular lines of action, thus assisting the work of the full Study Groups — R.D.K.

THE SEMINAR "DEVELOPMENT OF A TELEPHONE NETWORK"

General

The I.T.U. meetings and in particular the meetings of the Plan Asia Subcommittee brought together in Melbourne many telecommunications experts from developing countries. The Post Office took the opportunity to arrange a seminar on telephone network development as a contribution in the field of technical co-operation.

The Seminar took place at the Southern Cross Hotel, the venue for the I.T.U. meetings and ran for a period of two weeks. It was opened on the 21st September by Mr. C. J. Griffiths, First Assistant Director-General, Engineering Works.

Attendance

Twenty-five delegates from Brazil, China, Fiji, India, Kenya, Kuwait, Malaysia, Nigeria, Pakistan, Papua, New Guinea, Saudi Arabia, Singapore and Thailand attended. Delegates from Japan and the U.S.S.R. also attended some sessions of particular interest to them and many other I.T.U. delegates sought copies of the Seminar papers.

The Seminar

The Seminar took the form of a series of lecture and discussion sessions supplemented by field inspections. The aim in each session was to promote discussion and interchange of views between participating countries. Printed papers describing Australian methods and practices in telephone network development were provided before the start of the Seminar and each session opened with presentation of the appropriate paper by its authors. The set of 18 papers, many of which were in more than one part, gave a review of the approach to telephone network development which had been adopted in Australia to suit its own particular environment. The subject matter covered was, broadly:

— General Organisation of the Australian Administration

— Establishment of Policies and Objectives

— The Nature of the National Networks

— Plant Planning and Procurement

— Associated Aspects of Installation

— Preparing for the Future

The papers bound in two books were presented to the delegates and have since been distributed to all Departmental Engineering Administrative Libraries throughout the Commonwealth. A quantity has been made available to the I.T.U.

Fig. 3 — Delegates to the Seminar on Development of a Telephone Network Discuss an Exhibit at the Close of a Session.

A different chairman presided at each session. Each was widely experienced in the particular subject and was able to guide and stimulate the discussion. Points raised where further discussion was considered desirable but which could not be completed through lack of time or because further research was required were deferred to an "open forum" or weekly review sessions.

Five inspection visits were arranged to supplement and illustrate preceding papers and to provide a change from the formal discussion sessions. The P.M.G. Research Laboratories were visited in the early part of the Seminar and field inspections followed the "National Network" Sessions on Exchange Equipment, External Plant and Radio and Long Line Equipment. An inspection also followed the "Associated Aspects of Installation" Sessions on Buildings and Air Treatment. Places visited were North Melbourne, Brighton and City West exchanges, the Surrey Hills radio relay terminal, the Oakleigh line depot, the City cable tunnel system and various external plant installations.

Conclusion

The Seminar was well received. Throughout a very active interest was displayed by both overseas and local participants. Provisions had been made for a limited number of visitors to attend the discussion sessions and the available seats were seldom vacant.

In all sessions the discussion time was fully utilised and the carryover of topics to the "open forum" sessions confirmed that these periods were more than justified and as fruitful in their exchange of views as the planned sessions.

The A.P.O. participants found the Seminar a stimulating and informative experience. — G.E.H. and A.W.S.

LINE SIGNALLING IN THE AUSTRALIAN POST OFFICE

*G. L. CREW, B.E.(Hons.), A.M.I.E.Aust., Grad.I.E.E.**

INTRODUCTION.

In the last five years, with the introduction of crossbar equipment and subscriber trunk dialling facilities into the Australian Post Office exchange network, the line signalling schemes needed on trunks and junctions interconnecting exchanges in the network have changed. This article describes the new line signals and discusses the reasons for their introduction.

By "line signals" is meant supervision signals used to convey information relating to the state of relay sets at each end of a trunk or junction. The term is not meant to include "information signalling," which takes the form of decadic dial pulses or multi-frequency codes.

Typical line signals include:

Seize forward—the controlling relay set, usually an outgoing repeater (FUR), signals to the controlled relay set, usually a step-by-step group selector or an incoming repeater (FIR), that a connection is being established. FIR and associated common equipment are prepared to accept information signals.

Clear forward—the controlling relay set signals to the controlled relay set that the connection is to be released, usually when the calling party clears.

Answer—the controlling relav set is informed that the called party has answered.

Clear back—the controlling relay set is informed that the called party has cleared.

Meter—a signal used to record one unit fee charge (one registration) on the calling party's meter.

Force release—a signal used to release a connection other than by the calling party clearing. This signal allows an FIR to "force" the corresponding FUR to release the connection by generating a clear forward signal.

Blocking—a signal used to back-busy a trunk or junction, By this means an FIR can prevent its corresponding FUR being seized for a call.

The line signals will first be described as used on physical circuits. The description will then be extended to the various forms of signalling on carrier derived circuits. The automatic exchange network only is being considered, and particular signalling schemes used on the manual and semi-automatic networks are not discussed.

THE STEP BY STEP NETWORK.

In a purely step network without crossbar or S.T.D. facilities line signalling systems are required to convey a minimum of information and thus are relatively simple. On a junction between two step exchanges, the outgoing repeater, FUR, is required to place a loop on the junction as an indication of "seize forward," and to remove the loop to indicate "clear forward." In turn the equipment to tial to indicate "B—party answer," and which the junction may be connected at the incoming end (which may be an FIR, a final selector or another outgoing repeater) is only required to reverse the polarity of the line poten-to restore it to normal to indicate "B—party clear." In some cases blocking or back-busying is possible by removing the battery potential placed on the junction by the FIR in the idle condition. Such a scheme is shown in Fig. 1. Because the junction conditions during a call are a direct representation of the A and B-parties' switch hook conditions, we may call this type of signalling "Switch-hook" signalling (S/H for short).

On local calls in the step network the A-party's meter registers one call when the B-party answers, that is, on receipt of a reversal of junction polarity. If subsequently the B-party replaces his receiver and re-answers, the resulting line reversal is not recorded on the A-party's meter. If the called number is a non-metering service, a reversal is not returned to the A-party's exchange at answer.

THE CROSSBAR NETWORK.

The advent of crossbar equipment into the A.P.O. network introduced the concept of common control and its guard facility—time supervision. The use of time supervision to prevent subscribers or faulty line conditions holding equipment for excessive periods is incorporated in FUR and FIR relay sets. Time supervision before answer is stopped on receipt of the line reversal indicating B-party answer, and restarts on receipt of normal line polarity when the B-party clears. It is thus seen that whereas in a step network "answer" is only used to meter the A-party, and in general the clear back signal has no purpose, in a crossbar network both these line signals control time supervision functions.

By means of m.f.c. information signals, the classification of the called subscriber can be returned to the originating register. Such a signal can be used to identify a non-metering number, and at the originating end the subscriber's meter lead is open circuited. When the non-metering party answers a reversal is generated in the normal way and stops time supervision on the link without metering the calling subscriber.

It is thus seen that the introduction of crossbar, while still using the S/H signalling scheme of Fig. 1, has introduced a subtle change to the effect of the line signals.

THE S.T.D. NETWORK.

When subscribers are allowed access to an automatic trunk network, arrangements must be made to debit the calling subscriber for the appropriate trunk charge. The A.P.O. achieves this by recording registrations at regular intervals on the subscriber's meter, which is also used to record local calls. Because the calculation of the correct charging rate requires expensive equipment to perform code analysis, this is done at a common point in a network, usually the automatic trunk exchange. Thus information relating to the correct charge must be transmitted over the network junctions in some suitable manner—it must be possible to return successive meter pulses from the trunk exchange to the originating exchange. This is called "multi-metering." (Fig. 2.) The line signalling scheme must provide for additional polarity changes to convey this metering information, and the relay set receiving them must be able to interpret them correctly.

The philisophy for multi-metering developed by S. Karlsson, of the Helsinki Telephone Company, modified slightly, has been adopted by the A.P.O. At the automatic trunk exchange a number of leads are available for connection to the charging equipment, each of which has pulses applied at one of the possible metering rates. The

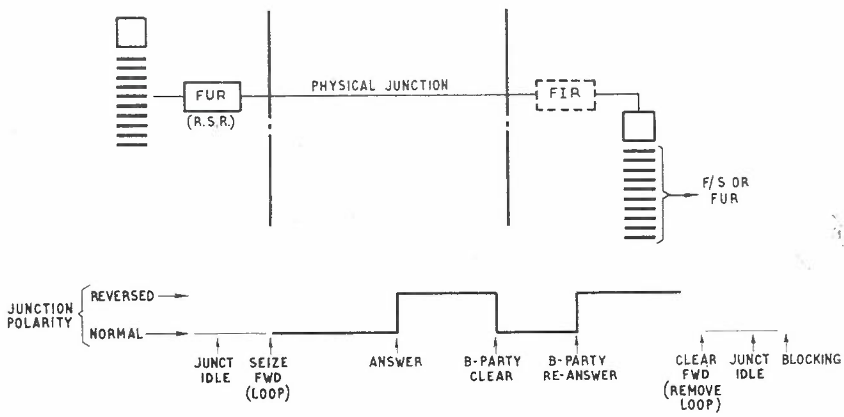

Fig. 1. — Switch-hook Signalling.

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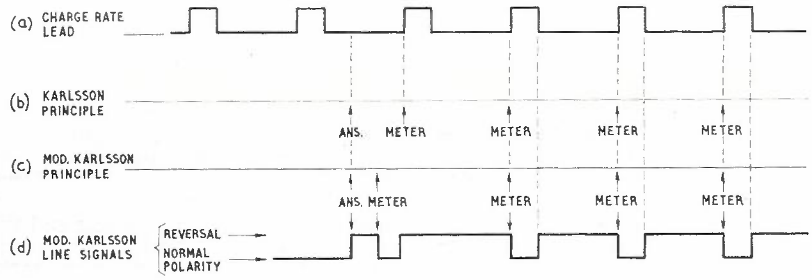


Fig. 2. — Multi-metering Principles.

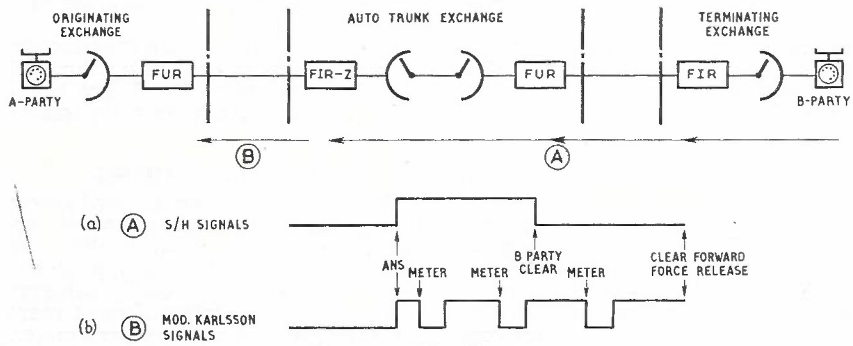


Fig. 3. — S.T.D. Signalling.

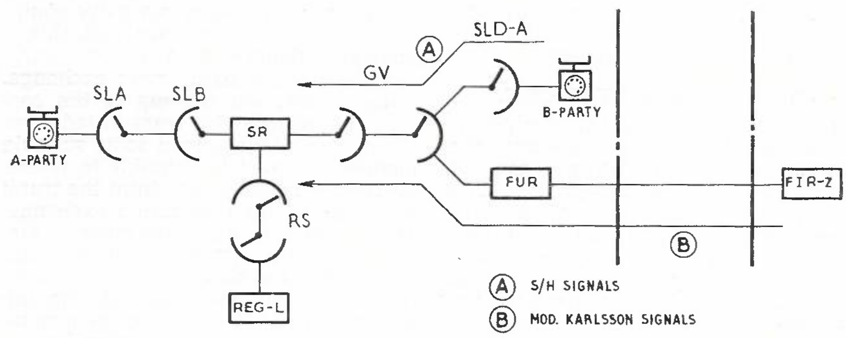


Fig. 4.

charging equipment, called the "Z repeater," is a convenient FIR or FUR in the connection. Until it receives B-party answer condition, the selected charging lead is open-circuited. In the Karlsson system an answer signal is returned to the originating exchange when the B-party answers, and the charging-lead is connected to the Z-repeater. Thus after answer, meter pulses are returned to the A-party as they occur on the charging lead, Fig. 2 (b).

It can be seen under this scheme that it is possible on the cheaper trunk rates for the calling subscriber to have some reasonable period of conversation before he receives his first meter pulse, thus allowing the possibility of short "free calls." A modification to Karlsson's scheme is used by the A.P.O. to prevent this possibility. A meter pulse is generated immediately after the answer signal by the Z-repeater, and the first meter pulse occurring on the charging lead after answer is not repeated to the junction. This is shown on Fig. 2 (c).

Both the Karlsson and modified Karlsson schemes generate an answer signal that is distinct from a meter signal. This allows the return of a signal on answer of non-metering numbers which may be used to stop time-supervision or for other purposes such as, for an operator to cut-off P.T. tone or as a supervision signal to a manual operator.

It remains to return the "answer" and "meter" conditions from the Z-repeater to the originating exchange in some suitable way. The signalling scheme used is shown in Fig. 2 (d). A reversal is returned to the caller at answer, and metering information is conveyed by a return to "normal" or pre-answer polarity. Under this scheme it is obvious that B-party switch-hook conditions must not be returned through the Z-repeater to the A-party, as return to normal polarity would cause metering (Fig. 1). The Z-repeater in fact receives S/H line signals, from the B-party's side, which tell it when to start metering, and generates Modified Karlsson signals on the A-party's side. (Fig. 3.) The Z-repeater must now allow the S/H signals on its B-side to be repeated to its A-side.

When the Z-repeater detects B-party clear condition it starts a time-supervision period, but continues to meter the A-party if a clear forward signal is not received. This is reasonable, as the A-party is holding an expensive circuit, and the B-party may be moving a portable service or looking for information. If the B-party has not re-answered within the time supervision period the Z-repeater clears forward on its B-side and sends a force-release signal on its A-side. The force release signal consists of an open circuit (removal of line polarity) and causes the FUR at the originating exchange to clear forward (remove the holding loop) and return busy tone to the caller (in crossbar exchanges this is done by placing the A-party to line lock-out condition).

It should be noted that if the relay set which ultimately converts the line signals into operations of the subscriber's meter can obtain access to circuits having both S/H and Modified Karlsson signalling, it must know which signalling scheme is being used to enable it to correctly meter the calling party. Such a case is shown in Fig. 4—the SR in an ARF exchange must be set by Reg-L for the correct signalling condition in each case.

MISCELLANEOUS SIGNALS.

In addition to the signals discussed above—seize forward, answer, meter, clear forward, B-party clear, force release—there are two further line signals that will be commonly encountered —fleeting test reversal (F.T.R.) and "call KM" signal.

An F.T.R. may be generated by an analysing relay set such as a register, and is used to test the condition of the calling subscriber's line. A diode placed in the calling subscriber's telephone loop will appear as an open circuit under this line reversal conditions, and this can be used to modify a subscriber's classification or to detect a public telephone or other restricted service. F.T.R. occurs in the inter-digital pause and must be completed within 400 mS. of the end of the last received dial break (Fig. 5).

The second signal, "call KM," is only used on circuits between a dependent m.f.c. type ARK exchange and its parent exchange. This is a short reversal sent from the parent to the ARK exchange, and is used to couple the code receiver at the ARK exchange to the junction. The parent exchange then uses m.f.c. information signals to test the dialled number for internal

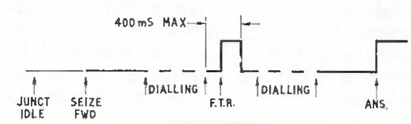


Fig. 5. — Fleeting Test Reversal.

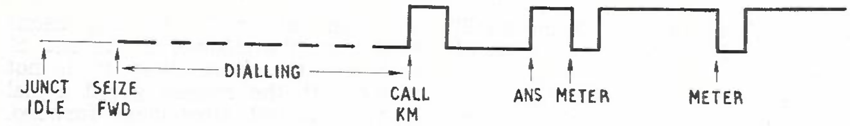
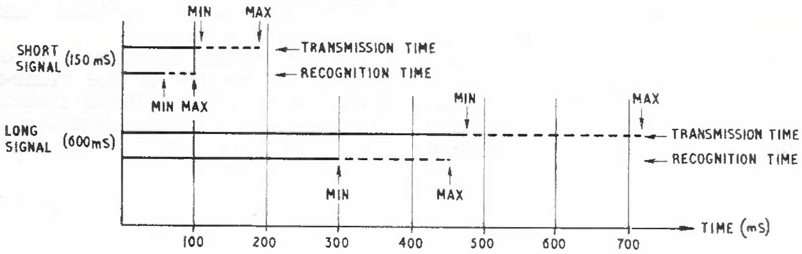


Fig. 6. — M.F.C. Type ARK Line Signals.



SIGNAL TIMING

Fig. 7. — Signal Timing.

connection or direct route connection at the ARK. The "call KM" signal cannot be used until the calling subscriber has dialled all the digits of the wanted number. Apart from this signal, normal Modified Karlsson signalling is used on the link between a dependent ARK and its parent exchange (Fig. 6).

SIGNAL TIMING.

Many of the signals described above are of indefinite duration, depending upon the conditions causing them. Among these are seize forward, clear forward, answer in the S/H mode, and B-party clear. However, Modified Karlsson answer, meter, and force release are timed signals.

We now consider what is involved in the timing of a line signal. The A.P.O. line repeaters use relays for timing purposes—usually by a slow releasing feature. Due to normal manufacturing tolerances, a number of relays designed to have a specific release delay will exhibit a variation of 50 per cent. between the minimum and maximum delays actually obtained from individual relays. It is therefore necessary to allow for this variation when specifying a signal duration.

If a 600 mS nominal interval is required, the actual interval obtained rrom a relay set may be anywhere in the range 480-720 mS. If this is the duration of a signal generated by a relay set, the receiving equipment must be designed to recognise the signal within its minimum period. The tolerance on the recognition time of a signal is the same as that on its generated period, and the maximum allowable recognition time must not be greater than the minimum generation time—in fact, it should be less, to provide a margin for error. Thus if a signal persists for 480-720 mS (600 mS nominal), it must be recognised within 300-450 mS (375 mS nominal). This allows a safety margin of 30mS between generation and recognition of the signal. The principle is illustrated in Fig. 7.

With reference to Fig. 3, in Modified Karlsson signalling the time between answer and the start of metering is not critical and need only be long enough for the FUR to record the fact that answer has occurred. This period is 200 - 300 mS as generated by ARM Z-type relay sets. The duration of the meter signal also is not critical—it must be long enough to be recognised by FUR and shorter than the minimum period between meter signals, which is at present 4 seconds. The meter signal is usually of 150 mS duration (nominal value). Force-release, however, has a definite duration with specified limits for its generation and its reception. Its nominal duration is 600 mS, which means its range is 480 - 720 mS. The FUR receiving it must recognise it as force release in an absolute maximum time of 480 mS. As described in the preceding paragraph to provide a safety margin the recognition time is 300-450 mS.

LOOP SEQUENTIAL SIGNALLING.

In the preceding paragraphs the effect of the introduction of crossbar and S.T.D. on line signals has been discussed, with illustrations of signalling over physical junctions. S.T.D. in particular has also influenced signalling on carrier derived circuits in Australia, and we now discuss the schemes in use and proposed, with some reasons for their adoption.

The A.P.O. has established S.T.D. services in the step network, using a multi-metering trunk repeater (A.P.O. Drawing CE. 11248). This relay set is a "Z" type relay set—it generates Modified Karlsson metering and transmits this via physical circuits to the calling subscriber. On its outgoing side it signals over trunk lines into distant exchange networks using the loop sequential E and M lead signalling scheme shown in Fig. 8 (a). This signalling scheme was designed for use on out-of-band carrier systems.

The M-lead is a connection into the signalling modulator fitted in the channelling equipment. Earth is applied to the M-lead by the relay set generating the signal to turn tone on. Tone received by the channelling equipment operates the receive relay and places earth potential on the E-lead into the receiving relay set. The loop sequential signalling scheme was developed by G. A. M. Hyde, formerly

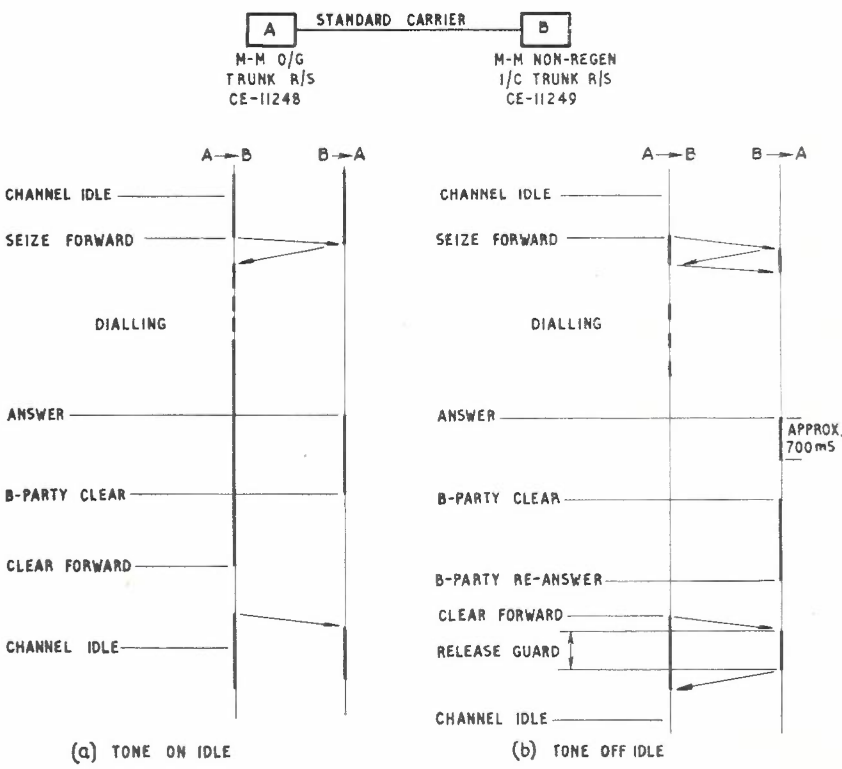


Fig. 8. — Loop Sequential Carrier Signalling.

Sectional Engineer of the A.P.O. Circuit Laboratory. It is a "tone-on-idle" system; i.e., the forward and backward signals are applied while the channel is not in use, to provide a constant check that the channel is in working order. In the event of channel failure the relay set at the outgoing end can detect the fact and busy itself out of traffic, thus preventing lost calls. It will be noted from Fig. 8 that this signalling scheme is only used to transmit S/H signals; it is not designed to carry multi-metering signals.

This signalling scheme may suffer from a disadvantage when used on broadband systems. Because a signal is applied to the M-leads for a large proportion of the time on all channels, and because a common oscillator source is used to supply the tone over all channels, this can result in periodic overloading of amplifiers common to a large group of channels, due to all the signals coming into phase. The effect is that the noise level on the channels will rise, although the quantitative effect of this on channel quality has not been determined.

To eliminate this effect, the A.P.O. is proposing to modify the multi-metering trunk repeater and corresponding FIR (A.P.O. Drawing CE 11249) to convert their signalling scheme to a "tone-off-idle" system (see Fig. 8 (b)). The advantage of loop sequential (immediate detection of channel faults) is thus lost. A call must be attempted on a faulty channel before the fault is detected by failure of the compelled seize forward sequence. In this event busy tone is returned to the calling party and the FUR is busied out of traffic until the channel fault is cleared. This signalling scheme is still only intended for the transmission of S/H signals.

We will now examine signalling schemes used to convey multi-metering signals on carrier derived circuits.

PULSE SIGNALLING.

The pulse signalling scheme is an out-of-band tone-off-idle system, using two pulses of different duration to convey information in both directions. The two pulse periods are nominally 150 mS and 600 mS, with a specified range on their transmission and recognition times based on normal relay timing tolerances. The scheme, known as the "T" pulse signalling scheme, is shown in Fig. 9, and the pulse times are shown in Fig. 7. Fig. 7 illustrates the need for a separation of 450 mS in nominal times between the short and long pulse, to ensure a reasonable safety margin between the maximum transmit time of the short pulse and the minimum recognition time of the long pulse. There is also a minimum recognition time for "seize-forward" signals, which ensures that FIR is not seized by spurious E-lead signals.

It will be noted from Fig. 9 that the "T" system can be used to convey S/H and Modified Karlsson signals, depending upon how FUR interprets the signals. In the Modified Karlsson mode, the first short backward signal is "answer" and subsequent short backward signals are "meter." The long backward signal represents "force release" in the Modified Karlsson mode and "B-party clear" in the S/H mode. It should be noted that "release-guard," a long backwards signal, is always returned from FIR to FUR on receipt of "clear forward." By this means FUR tests the channel at the end of each call to ensure that it is not faulty. If the release guard signal is not received after clear forward, FUR busies itself out of traffic and periodically tests the channel by re-transmitting clear forward until release guard is received.

The "T" system overcomes the objections to the use of the "tone-on idle" system on broadband systems, but it still has a defect when used on calls to or from "step" exchanges.

On calls between crossbar exchanges if a faulty channel is seized the absence of a backward m.f.c. signal in response to the forward signal causes time-out of the code sender and busy tone will be returned to the caller, thus preventing no-progress calls.

On calls from or to step exchanges no such guard feature is available and in the event of a faulty channel being seized a no-progress call will result. It should be noted that only the first call attempted over the channel will fail in this way, as on clear forward the absence of the release guard signal will cause the FUR to busy itself out of traffic.

To eliminate no-progress calls due to faulty channels a modification to the "T" scheme, known as the "T3" system, was developed for use on standard carrier links having a step exchange at one end of the channel. The modification adds one signal to the "T" system—a "seizure acknowledge" signal, which is returned from FIR when it receives the seize forward signal. This is a short pulse designated "proceed-to-send" as shown in Fig. 10. If it is not received before FUR is required to repeat the first dial pulse, busy tone is returned to the calling subscriber.

If the dial pulses are being generated by a crossbar register, a period of 800 mS is available between seizure of the FUR and register out-pulsing, which is quite adequate to allow transmission and recognition of the "seize forward" and transmission and receipt of the "proceed-to-send" signals. However, if the dialling is under the control of a subscriber as in the step system, the inter-digital pause in a significant percentage of cases will not allow the transmission and receipt of these signals in time for the call to be successful—dialling will be received by FUR before the "proceed to send" signal. To overcome this problem all FUR's used for this signalling scheme from step exchanges will contain a Siemens and Halske Dial Pulse repeater, which stores digits as they are dialled and repeats them to the channel after the "proceed to send" signal has been received.

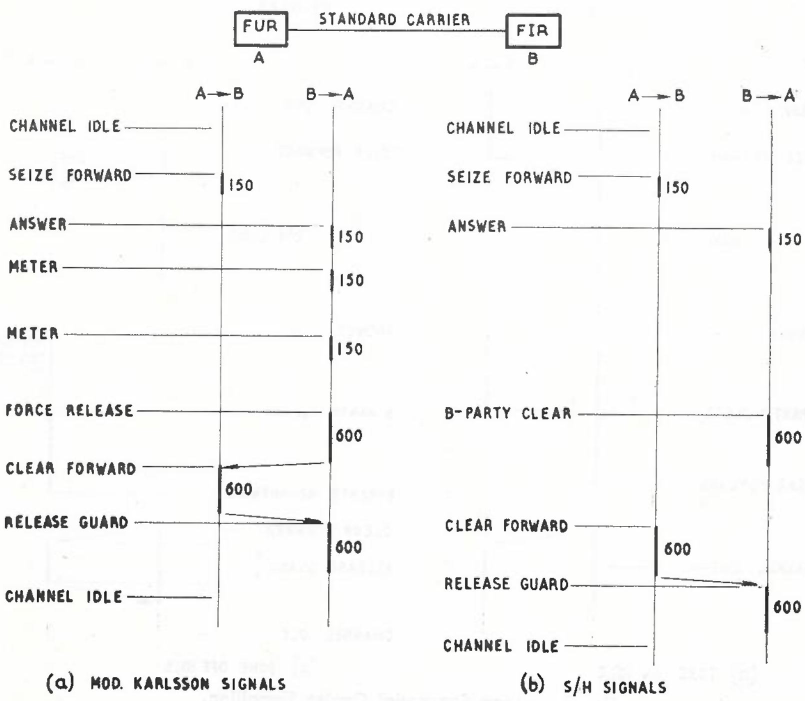


Fig. 9. — "T" Pulse Carrier Signalling.

RURAL CARRIER SIGNALLING.

Rural carrier systems have been in use in Australian country areas for some years. They use the channel carrier as a signalling medium. This means that, in the terminology used

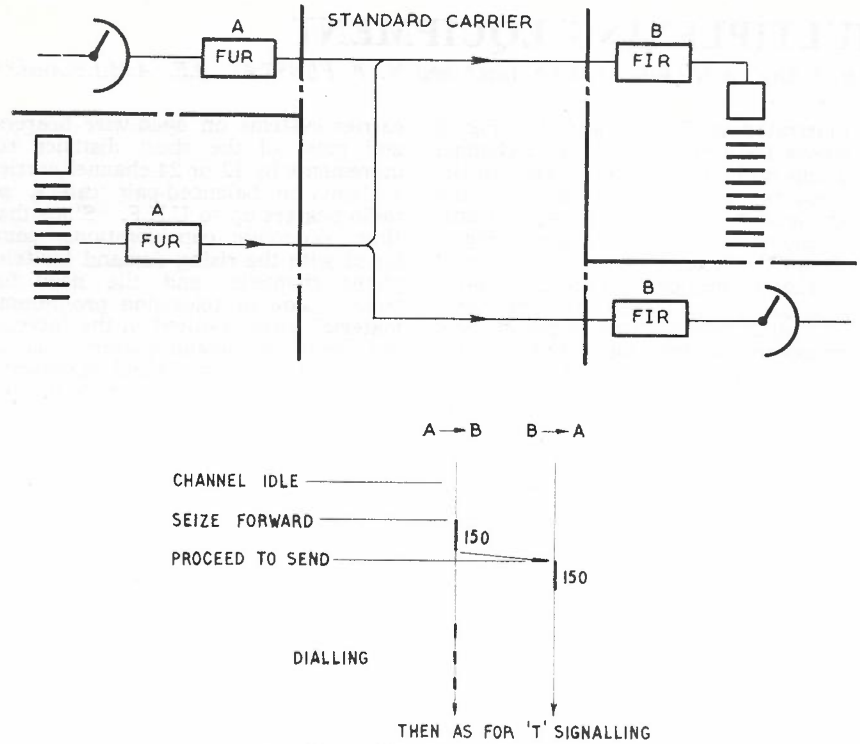


Fig. 10. — "T3" Carrier Signalling.

above, "tone" must be on while conversation is proceeding. It is not possible to transmit multi-metering information over such a system because of the resultant interruption to the conversation. To provide an out-of-band signalling path and allow Rural Carrier systems to be used on links carrying multi-metering, a low frequency (83 c/s out-of-band signal has been provided in one direction only—from the parent exchange to the terminal.

The signalling scheme is shown in Fig. 11. The following points are of interest:—

(i) The parent end of the system has two M-leads (M1—carrier, M283 c/s) and one E-lead. The terminal end has two E-leads and one M-lead.

(ii) The 83 c/s signal is used for one purpose only on calls from the parent to the terminal—to seize forward. On calls from the terminal to the parent it is used in much the same way as the E and M-lead signals in the "T" pulse system.

(iii) On a terminal to parent call, seize forward is a compelled sequence signal to reduce the possibility of false seizure by spurious carrier breaks.

(iv) On parent-to-terminal calls, the answer signal is a compelled sequence signal to reduce the possibility of spurious carrier breaks, causing false answer.

(v) On both-way circuits the terminal end can readily detect dual seizure conditions, as the normal response to its seize-forward signal is both carrier and 83 c/s off, whereas an incoming call is identified by the 83 c/s signal only being removed.

(vi) When the carrier from the parent is turned off the 83 c/s signal is also automatically removed.

This signalling scheme, known as the "T1" scheme, has been designed specifically for use in both-way circuits, and uses a comprehensive system of guards and tests to prevent circuit lock-ups. These are given in detail on A.P.O. Drawing CE 11329, sheet 3.

Rural Carrier systems are being developed which will have an out-of-band signal provided in both directions and so will use the standard pulse carrier signalling scheme, but systems equipped with the 83 c/s tone will continue to use the "T1" scheme.

CONCLUSION.

The A.P.O. has recently embarked on a programme to provide nation-wide subscriber trunk dialling facilities, which will ultimately be made available to all subscribers in the Commonwealth. This has necessitated a critical examination of line signalling schemes, made more important by the requirement for compatibility with the different types of exchange equipment used in the network. In some cases the choice of a signalling scheme has been influenced by the requirements of plant already in use; in others the experience of overseas administrations has been drawn upon. The line signalling schemes described in this article are expected to meet the requirements of the A.P.O. electro-mechanical switching systems for the foreseeable future.

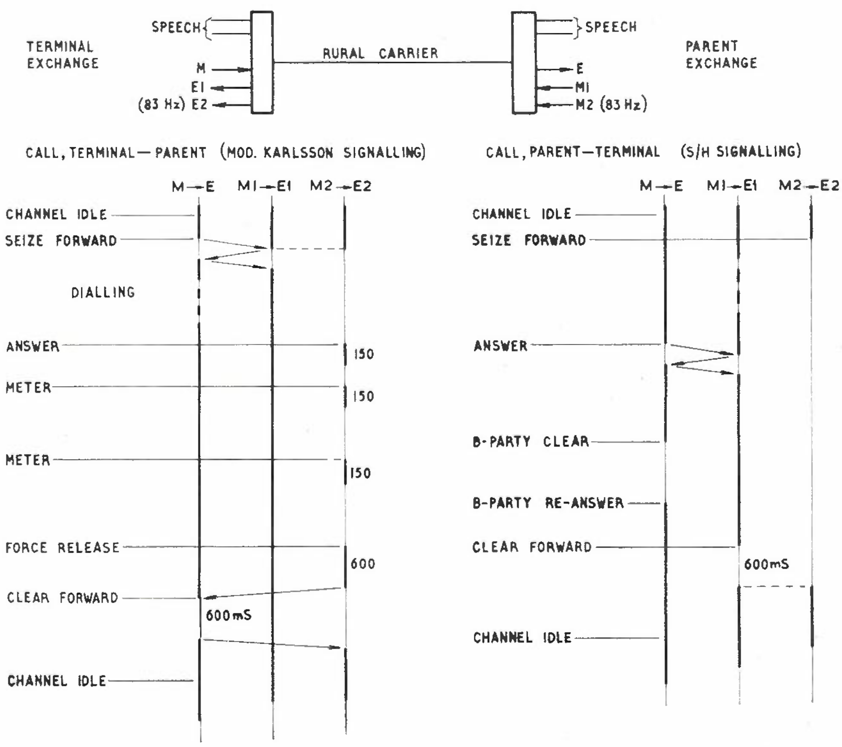


Fig. 11. — Rural Carrier Signalling.

NEW 12-CHANNEL MULTIPLEXING EQUIPMENT

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INTRODUCTION.

Telephonic speech is generally carried by circuits having a frequency range of approximately 300 - 3400 c/s, and most circuits exceeding about 25 miles in length use channels of carrier telephone systems, which combine multiples of 12 channels to form single systems. In most types of these systems 12-voice frequency circuits are translated into a "12-channel group," in the frequency range of 60 - 108 kc/s, in which the information in each circuit is obtained within a bandwidth of 4 kc/s. The translations are carried out by "12-channel Multiplexing Equipment," which also retranslates incoming information from the 60-108 kc/s frequency range into 12 voice frequency circuits. The frequency translating process uses amplitude modulation and single sideband suppressed carrier transmission. Similar processes are used for the translation of 12-channel groups into bands suitable for transmission on a line or radio bearer, and also when numbers of 12-channel groups are combined into larger blocks to form broadband systems. With the rapid increase in long distance telephone traffic throughout the world, telephone administrations invest heavily in new carrier telephone equipment each year, and the provision of the necessary 12-channel multiplexing equipment accounts for an appreciable proportion of this investment. In the case of the Australian Post Office the proportion is about one-quarter.

12-channel multiplexing equipment, which contains many identical circuit elements, is well suited to quantity production, and so any unnecessary costs incurred by poor design will be multiplied many times. The equipment, therefore, justifies great care in design and development.

It is the purpose of this paper to discuss recent technical developments in the 12-channel multiplexing equipment being purchased by the A.P.O.

FUNCTION.

The function of 12-channel multiplexing equipment is illustrated in Fig. 1 (left), which shows direct modulation of 12 voice frequency bands to the 60 to 108 kc/s carrier frequency range. Two-stage modulation, as illustrated in Figs. 1 (centre) and (right), was developed mainly for reasons of economy, because the number of filter types is reduced.

Two typical applications of the 12-channel multiplexing equipment are illustrated in Figs. 2 and 3. Fig. 2 shows the translation of a 12-channel group in the 60 - 108 kc/s band to the frequency range 6 - 54 kc/s, and the application of both directions of transmission to a single cable pair. Fig. 3 shows the translation of a number of 12-channel groups, first into 60-channel supergroups and then into the range 60 - 4028 kc/s to form a 960-channel broadband system for a radio or coaxial cable bearer having a separate transmission path for each direction. Since this paper is concerned only with the 12-Channel Multiplexing Equipment, no further reference will be made to these or other types of carrier system in detail.

HISTORY.

Carrier telephone systems of 12 channels and upwards have been in use in Australia for more than 25 years. They are used:

(i) For the long distances between State capitals and between each State capital and the major centres in its own State;

(ii) For short distances (about 20-100 miles) around State capitals, and, in recent years, also around the larger provincial centres.

Until about 1960 the long distance requirements were met by 12-channel carrier systems on open-wire bearers, and most of the short distance requirements by 12 or 24-channel carrier systems on balanced-pair cables, or radio bearers up to U.H.F. Since that time, economic considerations, combined with the rising demand for telephone channels, and the need for transmission of television programme material, have resulted in the increasing use of broadband bearers (coaxial cable pairs or wideband microwave or S.H.F. radio bearers), for both long and short distance requirements.

Until the present time it has been normal practice for the Australian Post Office to purchase carrier telephone equipment as complete systems, so that in each case one manufacturer has provided the channel multiplexing equipment, all other modulation and line equipment, and the carrier frequency supply equipment for the terminals. In the case of line systems the manufacturer would also supply the repeaters, but in the case of radio systems it would be quite usual for the radio bearer equipment to be obtained separately.

The advantages of this method of purchase are as follows:—

(i) The complete carrier system is obtained in a single purchase, minimising the purchase negotiations and delivery supervision.

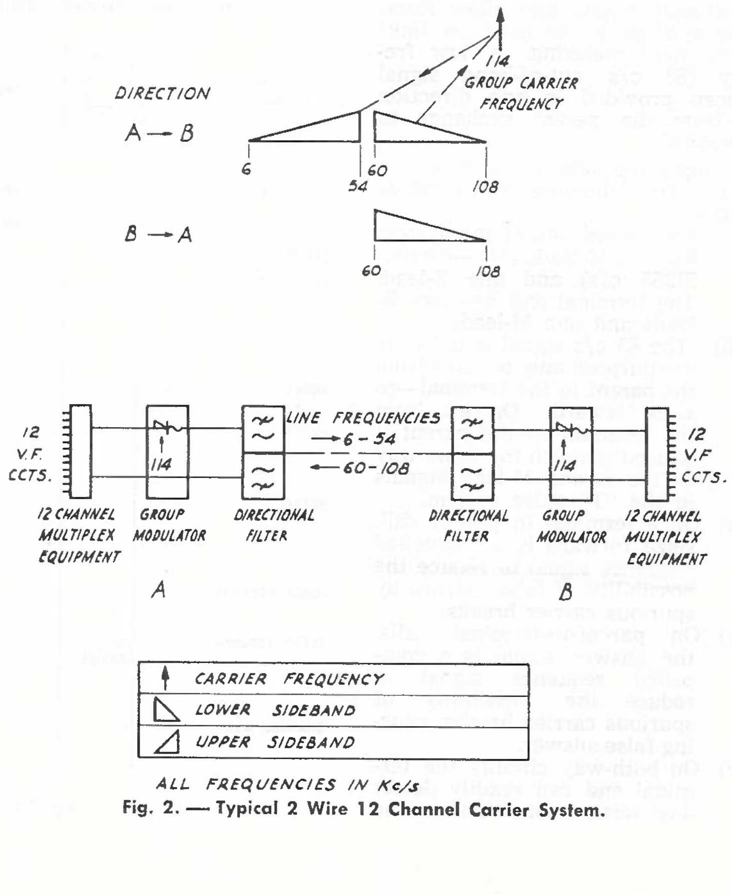

Fig. 2. — Typical 2 Wire 12 Channel Carrier System.

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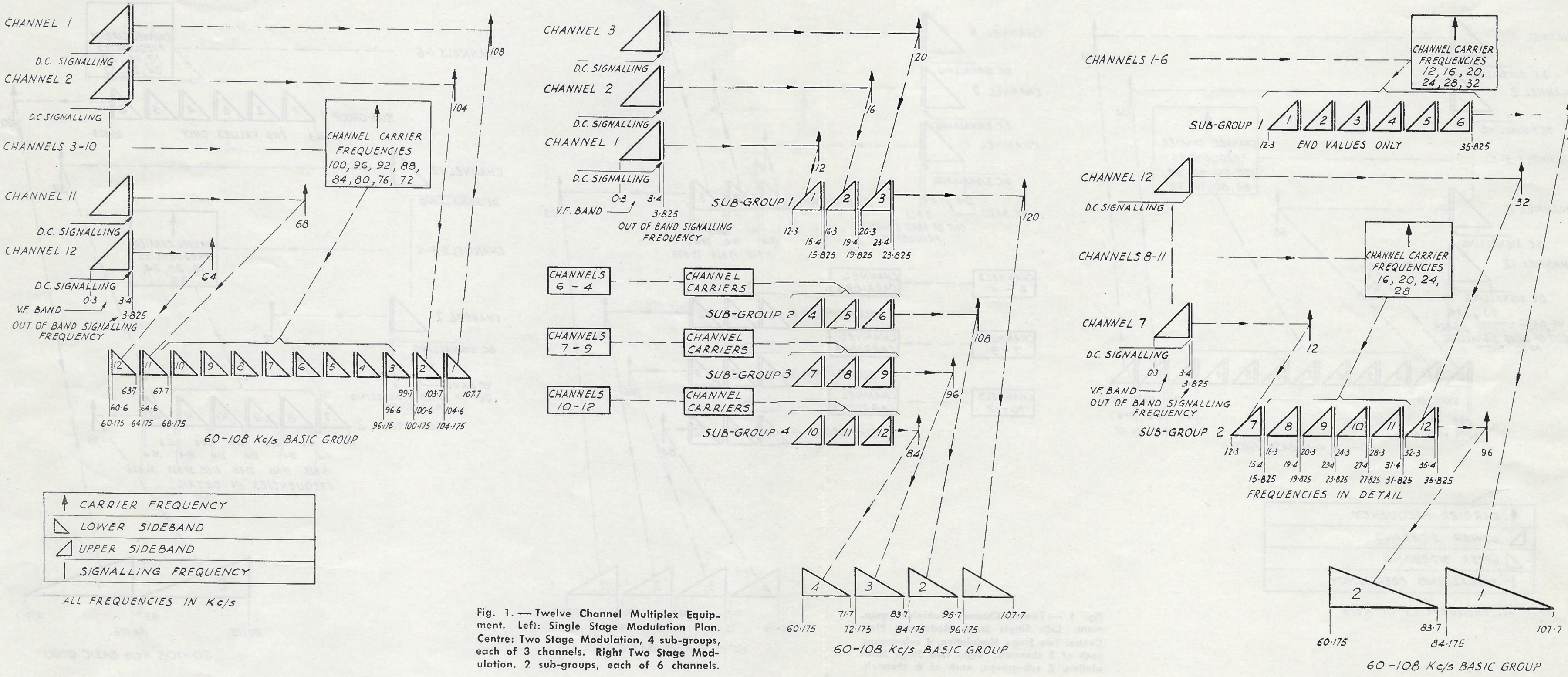


Fig. 1. — Twelve Channel Multiplex Equipment. Left: Single Stage Modulation Plan. Centre: Two Stage Modulation, 4 sub-groups, each of 3 channels. Right Two Stage Modulation, 2 sub-groups, each of 6 channels.

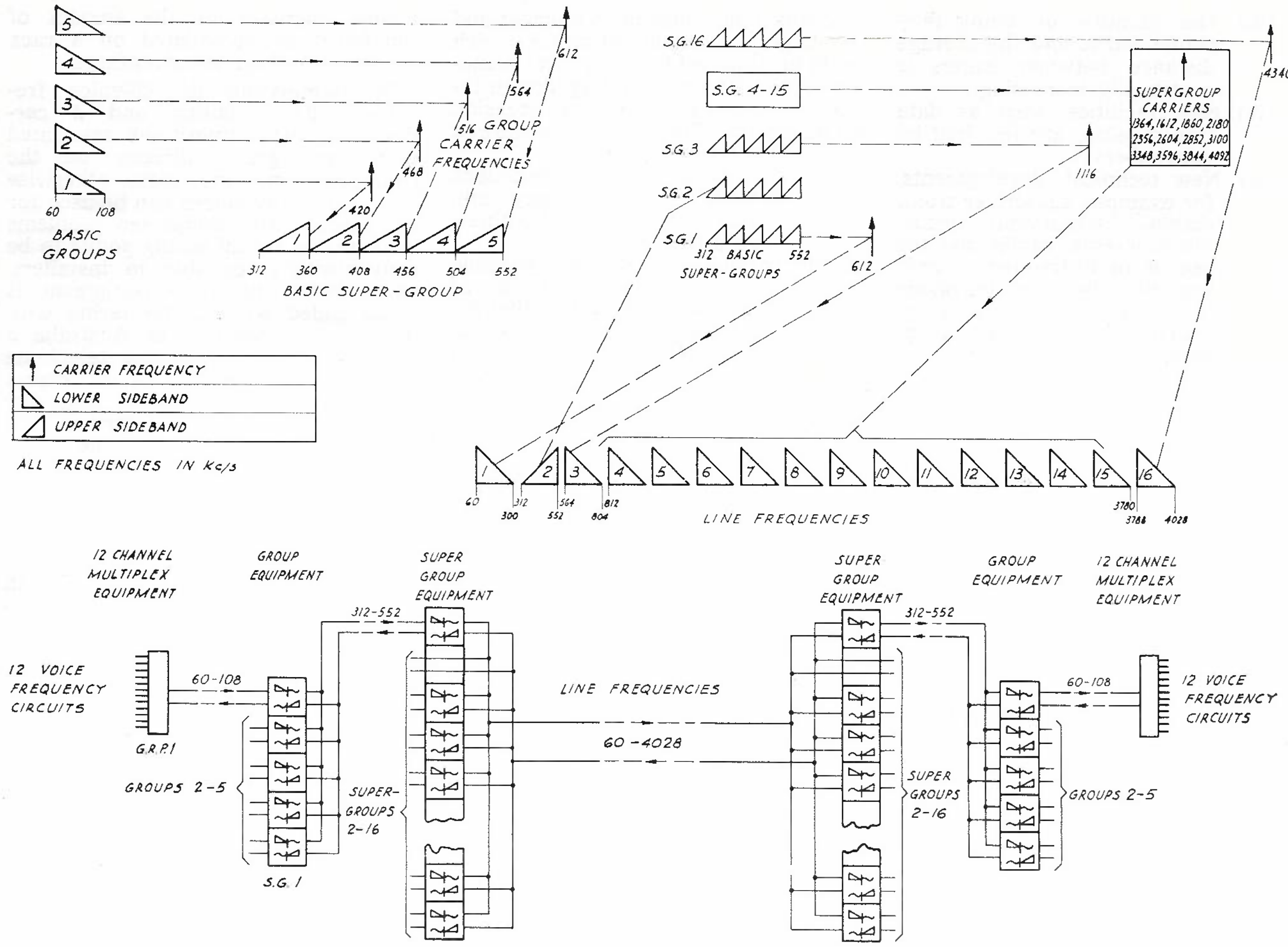


Fig. 3. — Typical Broadband Multichannel Carrier System.

(ii) There are no problems in ensuring electrical or mechanical compatibility between different equipment designs, as the manufacturer has all parameters under his own control, and equipment may in some cases be obtainable in a self-contained unit.

The disadvantages are:—

(i) Because different systems were ordered from different manufacturers, the larger long line equipment centres acquired a great variety of types. This resulted in the wasteful use of floor space, carrier frequency supplies, maintenance effort and spare parts.

(ii) As traffic has increased it has become increasingly necessary to "through group connect" blocks of 12 channels without demodulation to voice frequencies. These connections are made in the 60 - 108 kc/s frequency band at the Group Distribution Frame (G.D.F.) point. As different impedances and transmission levels may be used by different manufacturers, direct "through group connections" cannot always be made between different types of equipment.

(iii) The 12-channel multiplexing equipment was purchased in smaller quantities from each manufacturer, with consequently higher prices than could have been obtained for purchases in greater quantities.

(iv) Different manufacturers' equipments could not readily be combined because of their differing physical dimensions and carrier frequency supply requirements. This caused flexibility to be lost because equipment could not always be re-allocated after the date of ordering. Similar difficulties occurred in arranging for the re-use of recovered equipment.

(v) The choice between the equipments offered by different tenderers had to be made on the basis of the quality and economics of the system as a whole rather than of any particular part of it.

As the Australian telecommunication network grows in size and extent, the disadvantages increasingly outweigh the advantages, and in 1964 it was decided to purchase all 12-channel multiplexing equipment in bulk.

BACKGROUND TO RECENT DEVELOPMENTS.

There is a natural tendency for manufacturers to offer, and for customers to accept, the latest proven developments available at the time an order is placed. This is a desirable state of affairs provided that either full interchangeability between the newer and the older equipment is assured, or the advantages of the change outweigh this consideration. Any restriction on full interchangeability reduces the flexibility of the equipment for installation and all design changes increase the number of maintenance instructions required.

The Department's technical requirements change from time to time because:

(i) Development of materials and electronic components permits better performance.

(ii) Construction techniques improve.

(iii) The quantity of trunk telephone traffic and the average distance between callers is continually increasing.
(iv) New facilities, such as data transmission, are required by subscribers.
(v) New technical developments, for example, subscriber trunk dialling, international working via submarine cables and the use of multi-frequency code signalling between telephone exchanges, make different demands on long line equipment.

It was obvious that the installation and operating costs of long line equipment could be reduced by the use of fewer new equipment types, thus reducing the amount of special staff training and spare parts required. 12-channel multiplexing equipment appeared to offer considerable scope for achieving economy through standardisation, but it seemed desirable for the introduction of the new standard to coincide with a major development in carrier telephone equipment.

In the 1950's permanently wired equipment panels mounted on heavy channel iron racks, accommodating 12 channels on each side, gave place to slide-in or plug-in units on light weight, single-sided pressed steel racks holding 36 or 48 channels, including built-in, out-of-band, signalling. In the early 1960's there was a general change, first to transistor designs, and later to printed circuits without any great change in the equipment density. More recently there have been considerable reductions in component sizes and advances in the use of miniature assembly techniques, and in 1962 it was expected that by the late 1960's it would be possible to accommodate something between 60 and 300 channels per rack.

For some years most of the 12-channel multiplexing equipment purchased by the Australian Post Office has been made by overseas-owned Australian firms. The large amount of detailed design and development work required in the rapidly developing carrier telephone equipment field often forces these companies to use design information obtained under licence from their overseas associates rather than to carry out their own design and development. It is usual to find that design information obtained from overseas cannot be exchanged between these Australian companies, because their parent companies are competitors. Consequently it has not been possible for the A.P.O. to follow the example of some European administrations and to select a particular manufacturer's equipment as a standard and to arrange for the manufacture of interchangeable equipment by other suppliers.

Conferences were held in 1962 and 1963 between engineering representatives of the A.P.O. and the major suppliers, to discuss new designs of 12-channel multiplexing equipment and the degree of standardisation which could be obtained between local manufacturers without inhibiting design initiative and contravening their licensing arrangements. These meetings showed that at that time:

(i) Standard electrical conditions at the voice frequency and carrier frequency terminals could be obtained.
(ii) Although it was not possible to select a standard set of dimensions for all equipment racks, two sets of dimensions, one in metres and one in feet and inches, could be agreed to.
(iii) Test access facilities could be standardised with only minor variations in layout.
(iv) A standard modulation plan could not be adopted by all manufacturers.
(v) The multiplexing equipment of one manufacturer could not be guaranteed to operate satisfactorily from the carrier supply equipment of another manufacturer, even where the same modulation plan was used.
(vi) Equipment layout on racks could not be standardised.
(vii) Interchangeability of equipment panels or assemblies of different manufacture could not be obtained.

THE NEW A.P.O. SPECIFICATION.

In the light of this information A.P.O. Specification 972, dealing with "12-channel Modem and Carrier Supply Equipment," was prepared so that equipment for delivery in about 1966 or 1967 would follow new design principles, and prospective tenderers against the forthcoming schedule would be able to consider their new equipment designs in relation to A.P.O. requirements. It was intended that this specification would not be altered until another definite stage in equipment development had occurred. It was expected that more than one manufacturer's design would be accepted, but that further development of any design would only be permitted if full interchangeability with earlier versions of that particular design was maintained.

Mechanical.

Equipment purchased recently has generally taken the form of units plugged into a rack which was fully wired in the factory, and external cabling has been terminated on tag-blocks at the top of the rack occupying approximately 10 per cent. of the space.

This form of construction has two disadvantages:

(i) The tag-blocks occupy appreciable space;
(ii) The capital investment in the unused wiring on a partly equipped rack is not revenue producing.

Any increase in the amount of equipment accommodated on a rack accentuates these disadvantages.

By terminating the 48-voice frequency, 24 signalling and 4 carrier frequency connections associated with each group directly on the equipment unit the space otherwise occupied by tag-blocks can be used for equipment. This brings new problems in arranging for all wiring points to be conveniently accessible to installers, particularly when new equipment is to be added without interfering with working equipment. In Australia a large proportion of carrier telephone equipment is installed in remote places by technicians working at long distances from their headquarters, and any increase in installation time would increase costs considerably.

It is the practice of the A.P.O. to install long line equipment racks back-to-back and access to the wiring points must therefore be obtained from the front. Furthermore, test facilities in every voice frequency channel are required at a convenient working height between 3 ft. 6 in. and 5 ft. 6 in. from floor level. It is possible to save installation time by locating the connection points for external cabling at a similar height above floor level, thus avoiding the work on ladders or platforms involved in terminating cables on the tag-blocks of factory wired racks.

Since no agreement had been reached with the various Australian manufacturers on the subject of a standard layout and wiring, it was not possible for the A.P.O. to demand any particular arrangement. A capacity of at least 120 channels per rack was specified, and this accorded with two desirable principles:

(i) New equipment types should not be introduced for a small increase in channels per rack.
(ii) Overseas designs of 120 channels or more per rack were known to be available, or in course of development, and the use of this capacity by the A.P.O. would be convenient for Australian manufacturers and would assist them to compete in export markets.

It was specified that the design of the equipment racks should facilitate quick and efficient installation. There were at least two practicable methods of achieving this objective:

(i) The external cabling could be terminated on connectors at a wiring table, and provided that the connectors could pass through the rack structure, the cables, complete with connectors, could then be fed through the normal wiring spaces.
(ii) The connectors to which external cables were to be attached could be so mounted that they could be moved to a position for convenient and rapid wiring.

Electrical.

The performance requirements are based on the C.C.I.T.T. recommendations for equipment to be used in forming international connections. The C.C.I.T.T. defines the performance required in terms of frequency allocation, frequency response, distortion, noise, etc., and member countries are expected to design their networks accordingly. In Australia, trunk connections are often longer than international connections in Europe, and, apart from international considerations, it is necessary from the national point of view to provide a performance equal to that recommended by the C.C.I.T.T. The detailed electrical performance requirements, dealt with in Specification 972, are:

(i) Impedance and test level at the voice frequency and carrier frequency terminals.
(ii) Carrier leak and production of unwanted modulation.
(iii) Channel frequency response, linearity, intermodulation, crosstalk, noise level and harmonic distortion.
(iv) Volume limiting.
(v) The permissible distortion of the signalling system and the interference permissible between speech and signalling paths.
(vi) Pilot frequency insertion.
(vii.) Facilities for testing.
(viii) Stability and purity of carrier generating equipment together with standby carrier supply arrangements.
(ix) Voltage limits and noise levels of power supply under which equipment should function normally.

No attempt is made to detail all these requirements in this paper, since they are adequately covered in the specification and associated drawings but the following paragraphs contain comments on the clauses where the requirements differ appreciably from those specified in the past.

Frequency Response: Previously the A.P.O. has required the frequency response of the transmitting and receiving direction of a channel of a 12-channel multiplex equipment to be within one-fifth of the tolerance permitted under C.C.I.T.T. recommendations for a 2500 kilometre international circuit. The new specification is in accordance with recent recommendations made by Study Group XV. of the C.C.I.T.T., in which the tolerance for each transmit or receive channel equipment was relaxed to between one-third and one-quarter of that for the reference circuit, and in which additional tolerances were stipulated for the sum of the responses of the transmit and receive direction taken together and for the average response of all channels in a 12-channel group. These changes should have the effect of widening the acceptable tolerance of individual equipment units, and at the same time of improving the average frequency response of telephone channels.

Unwanted Products of Modulation: Unwanted sidebands in the 60 - 108 kc/s band produce noise in the speech circuits after demodulation and must be controlled by specification requirements for inter-channel interference. It is also necessary to specify that products of modulation outside the 60 - 108 kc/s band shall not interfere with channels of adjacent groups in broadband systems. The previous requirement that no product outside the band 60-108 kc/s should exceed—70 dBmo was difficult to achieve at frequencies just above 108 kc/s. The new specification requires that interference between channels of adjacent groups shall be no worse than that between channels of the same group. The performance cannot be checked easily by direct measurements, but it can be calculated from filter characteristics.

G.D.F. Impedance and Level: Two different sets of impedance and levels are in general use in Australia, and it is required that either should be available, for the immediate future,. by a simple wiring change or similar means. It is expected that a 150 ohm impedance with a transmitting level of —36.5 dBr and a receiving level of —30.5 dBr will eventually become the standard for all new equipment.

Limiting: Overloading an individual channel can cause intermodulation affecting the transmission path of hundreds of telephone channels in a multi-channel system. Although the effect of momentary overloads is trivial on speech transmission, it can be serious where data, telegraph signals and routing information is concerned. This risk is minimised by providing a limiting device in each channel modulator having an operating level low enough to prevent overloading, but not so low as to cause noticeable distortion of normally loud speech. The limiting characteristic demanded in the past is difficult to meet with a simple limiting device, and it has now been modified to express only the maximum voltage output permissible and the range of input levels through which the equipment shall be linear.

Noise Measurements: It was previously required that noise levels should be measured with a psophometer, using the weighting factor curve recommended by the C.C.I.T.T. (then known as C.C.I.F.) in 1951. This curve, while allowing for the sum of the average responses of human ears and typical telephone receivers, does not specify a suitable weighting factor at frequencies below 150 c/s and above 4700 c/s and a new network has been designed having the same characteristic in the range 150 c/s - 4700 c/s and flat weighting factors above and below this range. Pending availability of this network, noise measurements will be estimated as the power sum of separate measurements in the three ranges.

Speech Simulation: Crosstalk is measured using random noise, weighted to simulate the frequency spectrum and level of the louder passages of typical speech, as the disturbing signal. A network recently proposed by the French delegation to the C.C.I.T.T. is to be used by the A.P.O.

Two-tone Harmonic Distortion: Signalling systems, V.F.T. systems, etc., are liable to be affected by third order intermodulation ($2f_1 - f_2$ etc,) at relatively low levels. Maximum permissible third order products are therefore specified over the frequency range 540 c/s - 1980 c/s, which is that used by multi-frequency code signalling systems in Australia. It is probable that this range will be extended in the near future to cover voice frequency telegraph and data transmission systems in the 420-3280 c/s range.

Signalling: Two-State d.c. signalling conditions from a telephone exchange are translated by the channel equipment into an a.c. on-off signal at a frequency of 3825 c/s relative to the channel carrier frequency and the signal frequency is then modulated and demodulated in the transmission path in exactly the same way as the speech signal. The requirements for the signalling path are largely unchanged except that a preference for a solid state device instead of a relay in the signalling receiver has been stated. Recent designs of reed relays have such excellent performance, however, that this preference is no longer very strong.

Group Regulation: The equipment is required to provide for the injection of a pilot frequency at 84.08 kc/s, but, where automatic regulation to compensate for variations in the transmission path is required (i.e., on the longer groups), the regulating amplifier will be a separate equipment. Whether automatic regulation is provided or not, selective measurements of the pilot will permit the performance of a group to be checked while it is carrying traffic. A change in pilot frequency to 104.08 kc/s is being considered by the C.C.I.T.T. in order to leave a greater portion of the 60 - 108 kc/s band clear for wideband data transmission when required. However, it is understood that this change is at present favoured by few member countries other than the U.S.A. With the arrangement for pilot injection and automatic group regulation specified by the A.P.O., the 84.08 kc/s pilot will not be transmitted when a complete group path is used for data transmission because the associated channel modem equipment and group regulating equipment will be disconnected.

Carrier Frequency Supplies: A carrier frequency supply unit is required to produce all carriers for 20 groups of channel multiplex equipment (i.e., two racks). The unit is to be driven by an external 4 kc/s supply, which will be of high stability and will have a high stability standby source. An additional internal standby oscillator of lower stability is to be arranged to drive the channel multiplexing equipment if the external 4 kc/s feed is interrupted. This arrangement is preferred to the alternative of having a common carrier supply equipment for all the channel multiplexing equipment in a station because:

(i) It reduces the amount of carrier distribution wiring.
(ii) It permits the use of channel multiplexing equipments of different manufacture, in blocks of 20 group ends, without waste of carrier supply equipment.
(iii) It permits the synchronisation of different makes of channel multiplex equipment to a 4 kc/s supply derived from group and line carrier generation equipment. It will also simplify the problem of synchronising and phase locking all carrier supplies throughout Australia to a reference frequency which will be necessary for error free operation of large scale, high speed data transmission systems.
(iv) The inbuilt standby 4 kc/s supply may be of lower accuracy because it will be used infrequently and for short periods only. The frequency error will be small and can only affect 20 groups.

Test Access: Access is required to six wires on every channel, namely, V.F. input pair, V.F. output pair, and signalling input and output wires. A 12-point socket and connector designed by Siemens Halske has been found, after environmental tests, to be a suitable connector for the purpose. It has high pressure contacts, the pressure being provided by a small steel spring, but gold-plating of the contact metal will be required as protection against corrosion. Because of the high contact pressure, a high withdrawal force is required and an extractor tool may be required.

Sub-Rack Equipment.

In Australia there are many carrier stations where the development foreseen in the next 10 to 20 years does not exceed one or two 12-channel groups. In such stations, even with the non-wired rack, the use of equipment holding 120 channels per rack would waste floor space. Some manufacturers have submitted alternative designs, in which the 12-channel multiplexing equipment, the carrier supply equipment, power unit, etc., are available as sub-racks, suitable for installation on standard A.P.O. racks, leaving the remaining rack space available for other long line equipment.

MANUFACTURERS' DEVELOPMENTS.

With the kind permission of the manufacturers concerned, the main constructional features of four designs which are to be made in Australia will be described. No comments on the performance of the equipment will be made except that the equipment is not accepted for delivery to the A.P.O. unless it satisfies the performance requirements in all significant respects.

The four designs, three of which will be available in sub-rack as well as in rack-mounted construction, will not be interchangeable, but a 12-channel group, which has been modulated by any of the equipments may be demodulated by any of the equipments. In the interests of simplifying installation and maintenance it will be desirable for the equipment supplied to a State to come from only one, or at the most two, manufacturers. Where one manufacturer supplies both rack-mounted and sub-rack mounted equipment, the plug-in assemblies used in

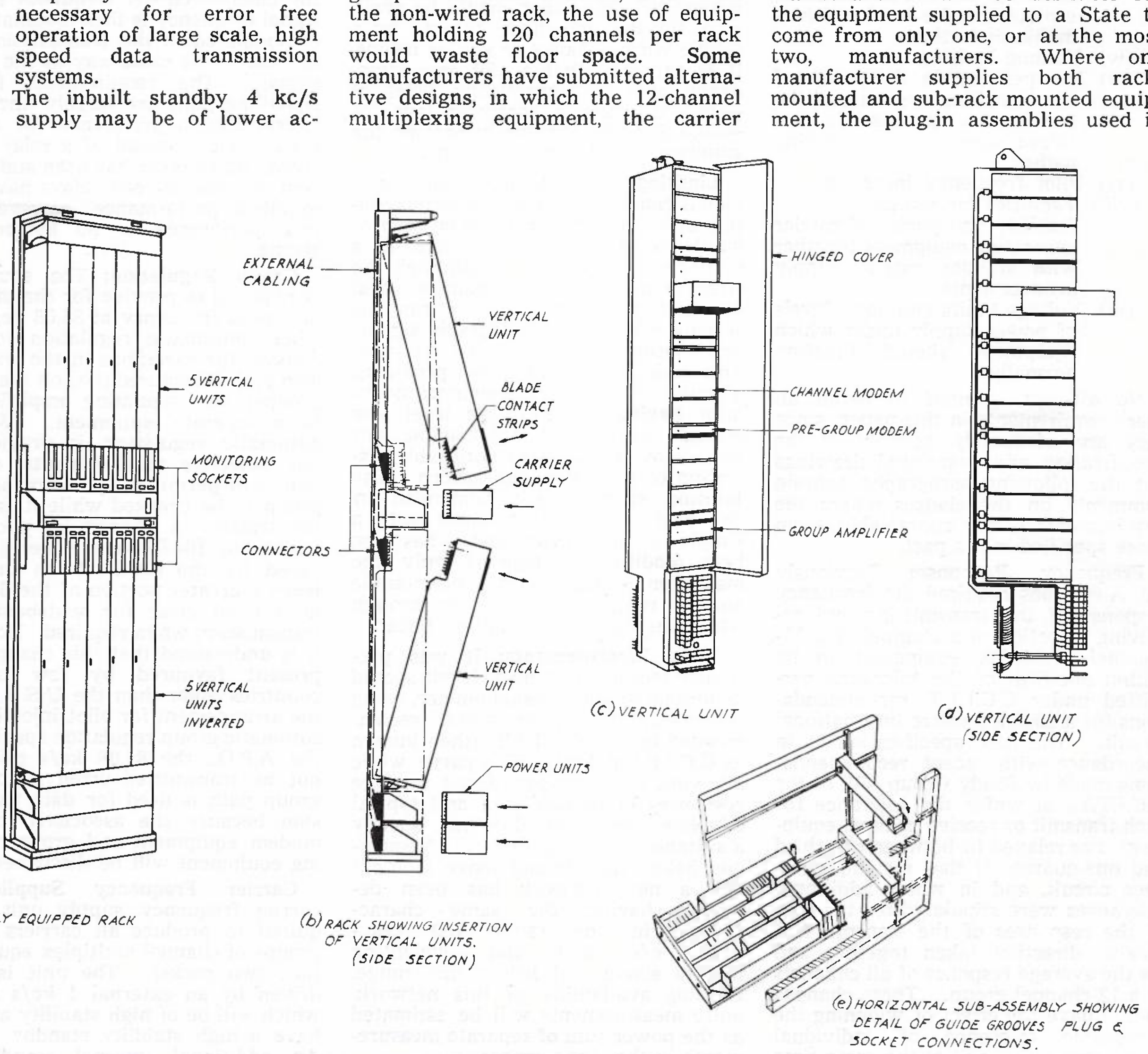


Fig. 4. — Siemens Halske Vertical Construction.

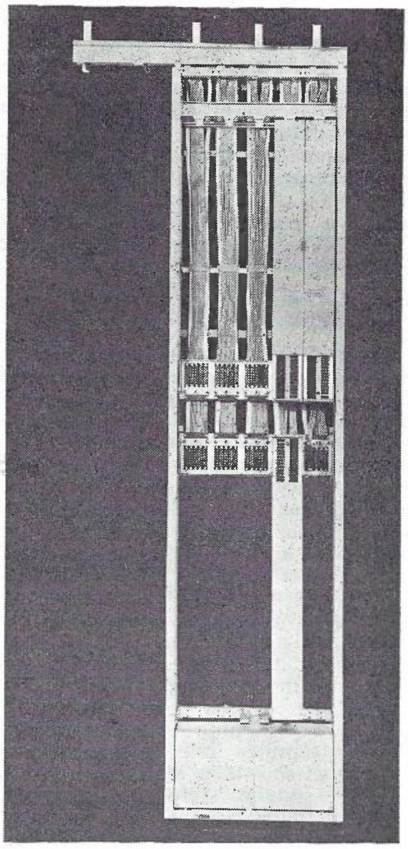


Fig. 5. — Partially Equipped Siemens Halske Rack.

each form are generally interchangeable. The principal exception to this is mentioned below in the section describing equipment manufactured by Standard Telephones and Cables Pty. Ltd.

Siemens Halske - Siemens Schuckert (A'asia) Pty. Ltd.

The design is known as "Vertical Construction" (Ref. 1) and has been developed to accommodate 120 channels on a rack, and is expected to be available from Australian manufacture by July, 1967. Each rack carries ten narrow vertical units, arranged in two rows each of five units side by side. (See Fig. 4.) Each unit contains a complete 12-channel multiplex equipment and in the lower row the units are inverted. (See Fig. 4 (a).) Monitoring and test facilities are provided on each vertical unit and appear at the bottom of the upper row of units and hence at the top of the lower row. All test access is thus at a convenient height. A partially equipped rack showing the external cabling is seen in Fig. 5 and a comparison with earlier designs of Siemens Halske equipment is seen in Fig. 6.

The rack has dimensions of 8 ft. 6⅜ in. high, 1 ft. 11⅝ in. wide, and 8⅞ in. deep. This is the standard size used in West Germany and is also widely used in Australia. The rack framework consists of a head frame, a base plate, two side rails, a central terminal frame, and rails for supporting the plug-in assemblies. The rack can be transported in pieces and assembled on site, thereby simplifying movement and installation and avoiding the cost of handling and storing large assemblies.

All fixed rack wiring has been eliminated by using detachable connectors fixed to the rack in the space behind the monitoring panel on the vertical unit. (See Figs. 4 (a) and (b).) A space for all external cabling is provided across the full width of the rack behind the vertical units.

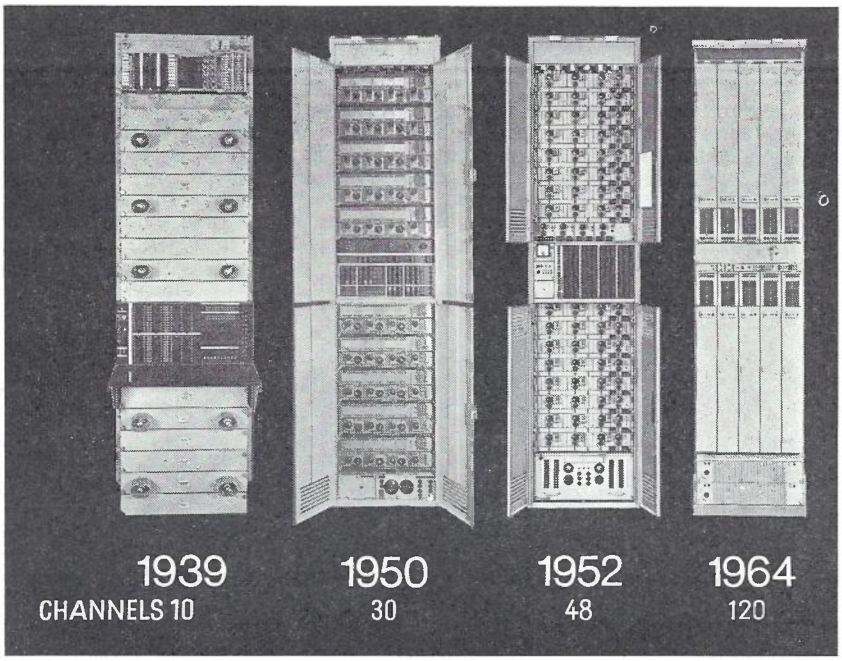


Fig. 6. — Comparison of Siemens Halske Designs.

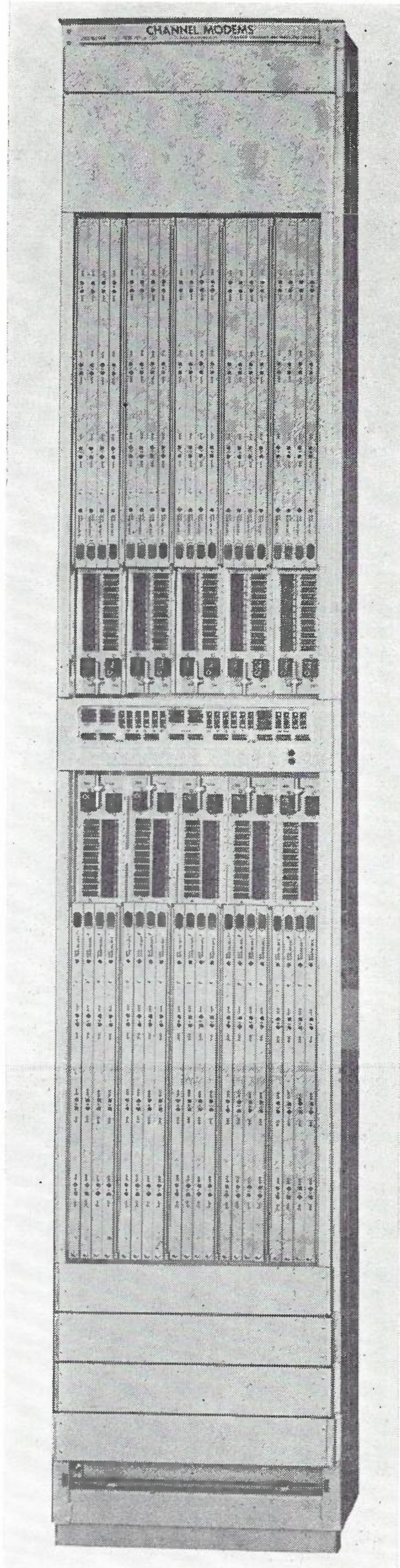


Fig. 7. — Fully Equipped S.T.C. Rack.

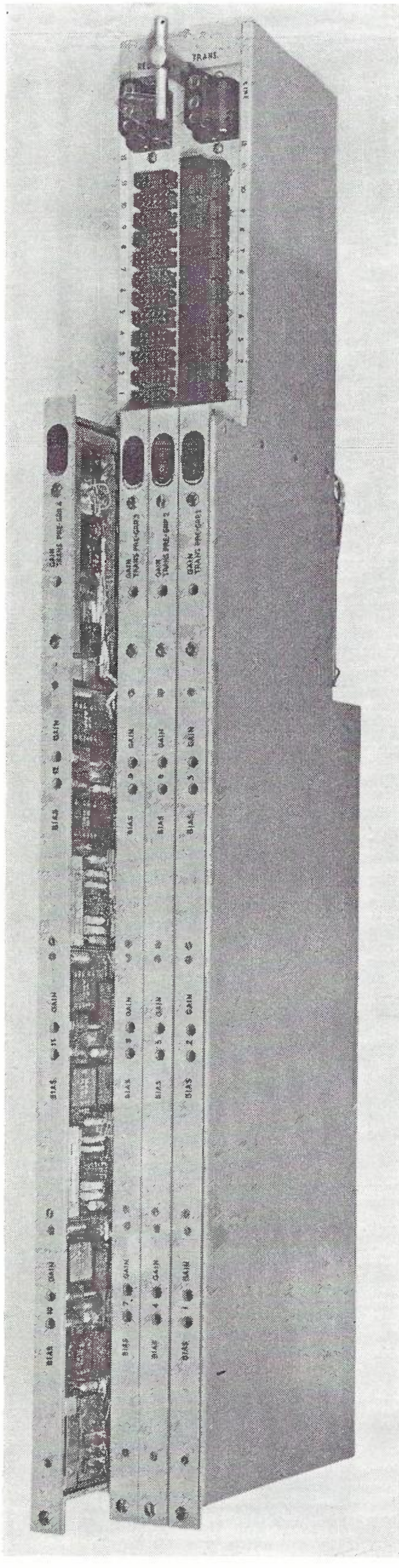


Fig. 8. — S.T.C. Vertical Sub-frame with one Tray Partly Withdrawn.

Space is also provided at the foot of the rack for horizontal units containing the necessary one or two power supply assemblies, and, in the centre of the rack, for carrier supply, protective and supervisory devices. (See Figs. 4 (a) and (b).)

Each 12-channel multiplex equipment is contained in a unit approx. $38\frac{1}{2}$ in. high, $4\frac{1}{2}$ in. wide and $7\frac{1}{2}$ in. deep, covered in front by a hinged lid, and carrying knife blade connectors, mating with those on the rack wiring. (See Fig. 4 (c) and (d).) A unit is inserted in the rack by engaging a pin at the end remote from the connectors, with a matching slot on the rack and then pivoting the unit until the connectors engage. (See Fig. 4 (b).) Guide pins ensure correct engagement of the connectors.

As the equipment uses double modulation with the plan shown in Fig. 1 (b) each vertical unit carries twelve channel modem (modulator and demodulator) assemblies, four subgroup modem assemblies, one group amplifier assembly and the test access panel. This, in turn, carries sockets for testing each of the 12-voice frequency channels and the 60 - 108 kc/s signals.

Each assembly consists of a component card, which slides into horizontal guides on the side walls of the vertical unit. Plug-in connectors on the assembly make connection to the wiring of the unit as shown in Fig. 4 (e). Some components are individually mounted, but most are in small modular blocks, each containing a subcircuit. Space is conserved by maintaining a uniform height in a particular assembly. The coil and condenser filters are carefully dried during manufacture, and before final adjustment, after which the filter cans are filled with dry gas and closed by welding. They cannot be reopened for repair and will be discarded if they become faulty.

The connectors between the vertical units and the external wiring have high pressure silver-plated contacts and are the same type used by Siemens Halske on their earlier "type 52" equipment. The connectors between the equipment assemblies and the vertical unit wiring have low pressure contacts and are gold-plated.

It is understood that the performance of the filter is such that the frequency response of individual channels will be within 1/10th of the C.C.I.T.T. requirement for a 2500 kilometre reference circuit, thus more than meeting the A.P.O. specification. This anticipates a recommendation of Study Group XVI. (Telephone Circuits) of the C.C.I.T.T.

Standard Telephones and Cables Pty. Ltd.

In the S.T.C. equipment (see Figs. 7, 8 and 9), which is now being delivered from their Sydney factory, each 12-channel multiplex equipment is mounted on a narrow "sub-frame," which plugs into the rack as shown in Figs. 10 (a) and (b). Mounting space is provided for five sub-frames, side by side, in the upper part of the rack, and five similar sub-frames inverted, in the lower part.

The rack consists of a light-weight, sheet-steel framework, with a full-width cabling space at the rear, and carrying detachable sockets for terminating the external wiring. The rack also carries horizontal sub-frames containing carrier supply, power supply, and interconnection panels, as shown in Fig. 10 (a). The carrier supply sub-frame occupies space at the top of the rack, the interconnection panel for use with test equipment is located at the centre of the rack between the upper and lower 12-channel sub-frames, and the power supply units are at the bottom of the rack.

The multiplex equipment uses double modulation with the plan shown in Fig. 1 (b). The sub-frame shown in Fig. 10 (c) is approximately 33 in. high, $3\frac{1}{2}$ in. wide, and 8 in. deep, and carries the test access panel and four plug-in vertical trays. Each tray carries equipment cards for three channel modems and a sub-group modem wired together within the tray, as shown in Fig. 10 (d).

The equipment layout within the trays has been so arranged that all components, including relays, transformers, filter inductors, and modules containing groups of components, are accommodated in a width of approxi-

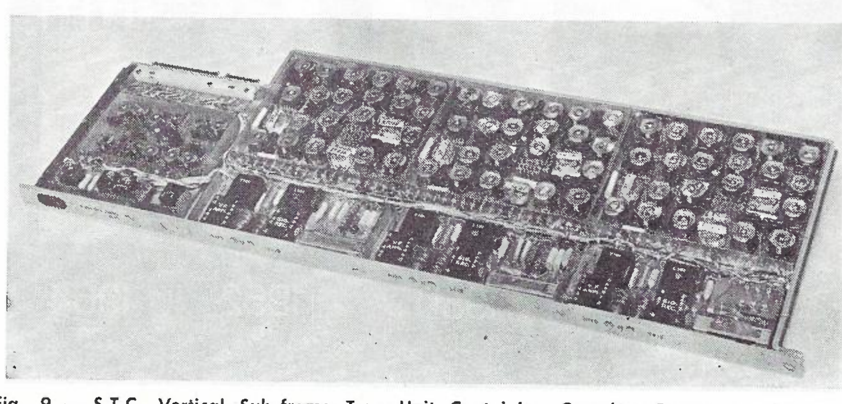
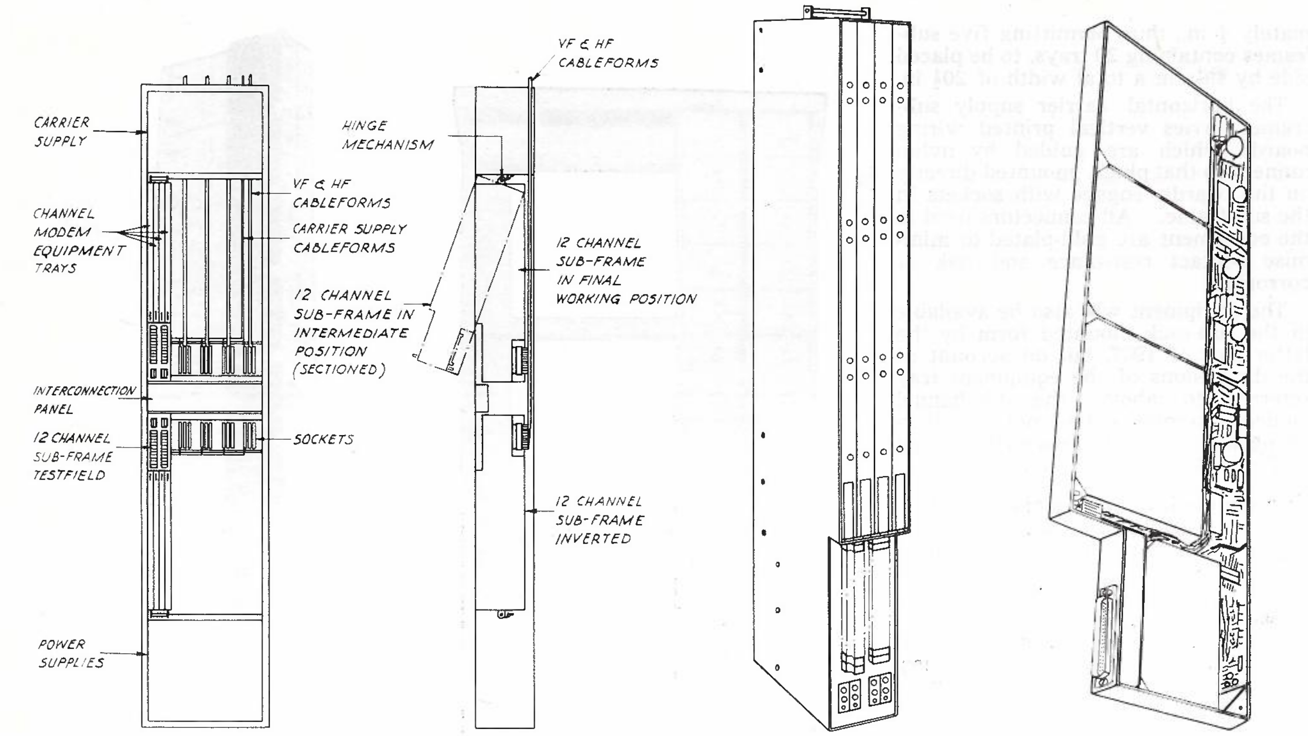


Fig. 9. — S.T.C. Vertical Sub-frame Tray Unit Containing Complete Pre-group Equipment.



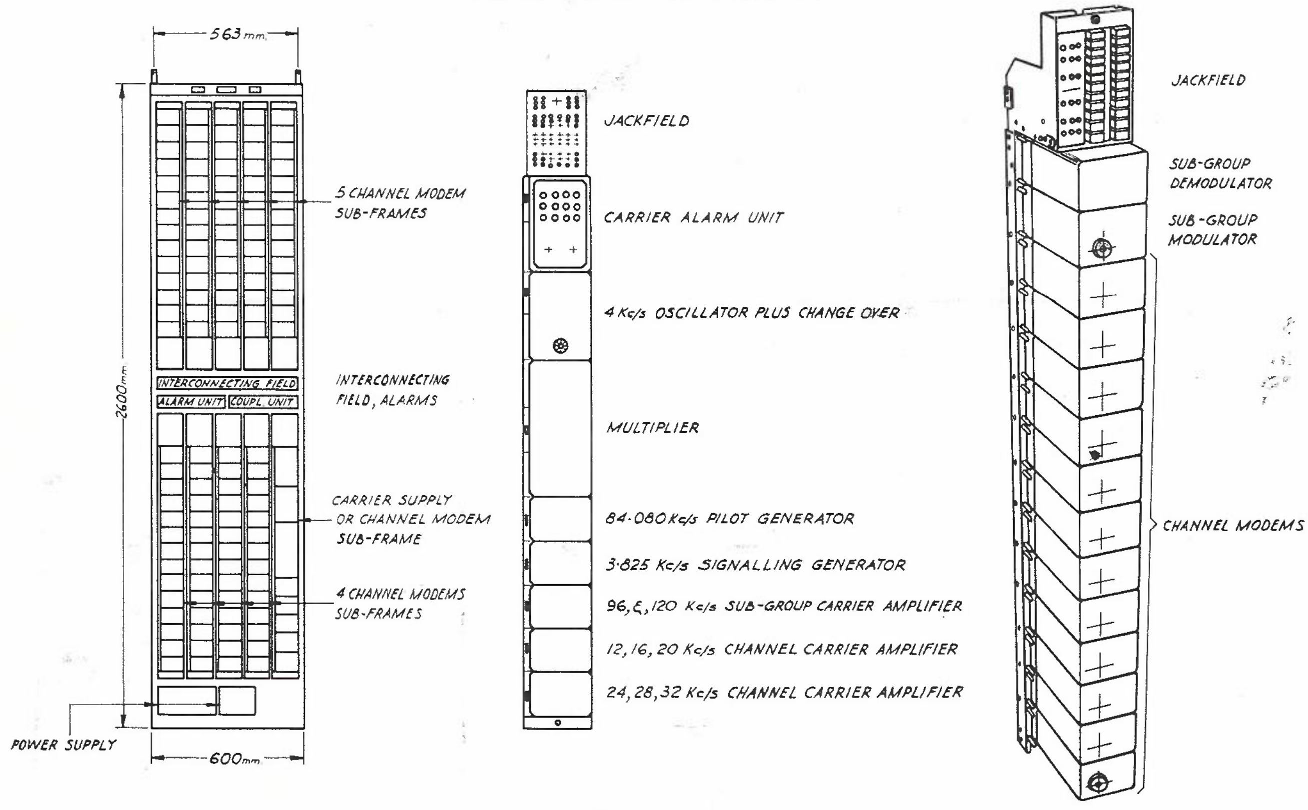
(a) RACK EQUIPPED WITH ONE UPPER & ONE LOWER SUB-FRAME. (FRONT ELEVATION)

(b) RACK SHOWING INSERTION OF VERTICAL SUB-FRAME (SECTION)

(c) VERTICAL SUB-FRAME EQUIPPED WITH FOUR TRAYS.

(d) TRAY EQUIPPED WITH 3 CHAN. MODEMS & ONE SUB-GROUP MODEMS.

Fig. 10. — S.T.C. Channel Equipment



(a) CHANNEL MODEM RACK FULLY EQUIPPED. (FRONT ELEVATION)

(b) CARRIER SUPPLY SUB-FRAME (FRONT VIEW)

(c) CHANNEL MODEM SUB-FRAME (INVERTED)

Fig. 11. — T.C.A. Channel Equipment.

mately ¾ in., thus permitting five sub-frames containing 20 trays, to be placed side by side in a total width of 20½ in.

The horizontal carrier supply sub-frame carries vertical printed wiring boards, which are guided by nylon runners so that plugs, ,mounted directly on the boards, engage with sockets in the sub-frame. All connectors used in the equipment are gold-plated to minimise contact resistance and risk of corrosion.

The equipment will also be available in the sub-rack mounted form by the latter part of 1967, but on account of the dimensions of the equipment tray referred to above, the 12-channel modem assemblies will not be interchangeable with the assemblies used in the rack-mounted form.

Telecommunication Company of Australia Pty. Ltd.

T.C.A. have been supplying high density rack-mounted equipment to the A.P.O. since October, 1966, from their Adelaide factory. The mechanical design is again on the basis of vertical sub-frame construction. Sub-frames, each containing a 12-channel multiplex equipment, are mounted side by side in a rack framework, as shown in Fig. 11 (a), there being five sub-frames in the upper part and five, inverted, in the lower part. Connections to external cables are made by multipoint plugs on the sub-frame, which engage with sockets on the rack. To facilitate insertion and withdrawal of the sub-frame, the plugs are individually pivoted and may be engaged and disengaged with the sub-frame held securely on its mounting. (See also 12 and 13).

Modulation is according to the plan shown in Fig. 1 (right). The sub-frame carries 14 "conclave" units containing 12 channel modems, a sub-group modulator and a sub-group demodulator, as shown in Fig. 11 (c). The "conclave" is the plug-in assembly used in most Philips transmission equipment, and contains components on printed wiring boards carried by a light framework. It has a metal cover sealed with a rubber "O" ring and contains a dessicator.

A power supply equipment, also in conclave units, is mounted below the lower set of sub-frames and the interconnection circuits for test access are mounted between the upper and lower sets of sub-frames. A special sub-frame, shown in Fig. 11 (b), is available, which contains carrier generating equipment, and can be mounted in the lower right-hand position on the alternate racks. A rack containing a carrier supply, therefore, holds equipment for nine groups instead of ten. Alternatively, the full rack of ten groups may take its carrier supply from a central supply of the 2 x 6 modulation type, or, with duplicate supplementary carrier supply units mounted at the base of the rack, from a central supply of the 4 x 3 modulation type. In A.P.O. stations the carrier generating

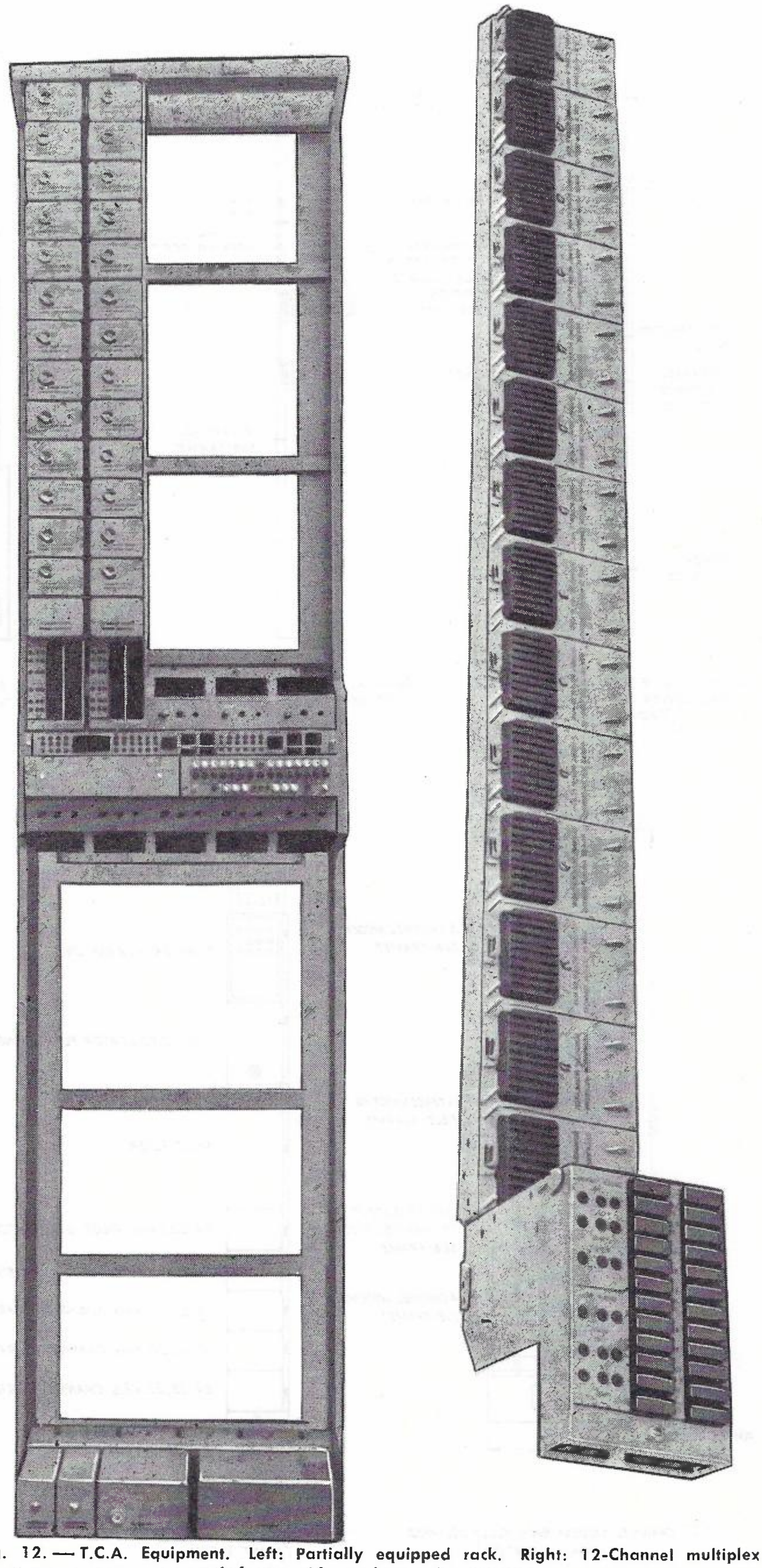


Fig. 12. — T.C.A. Equipment. Left: Partially equipped rack. Right: 12-Channel multiplex sub-frame with conclave units removed.

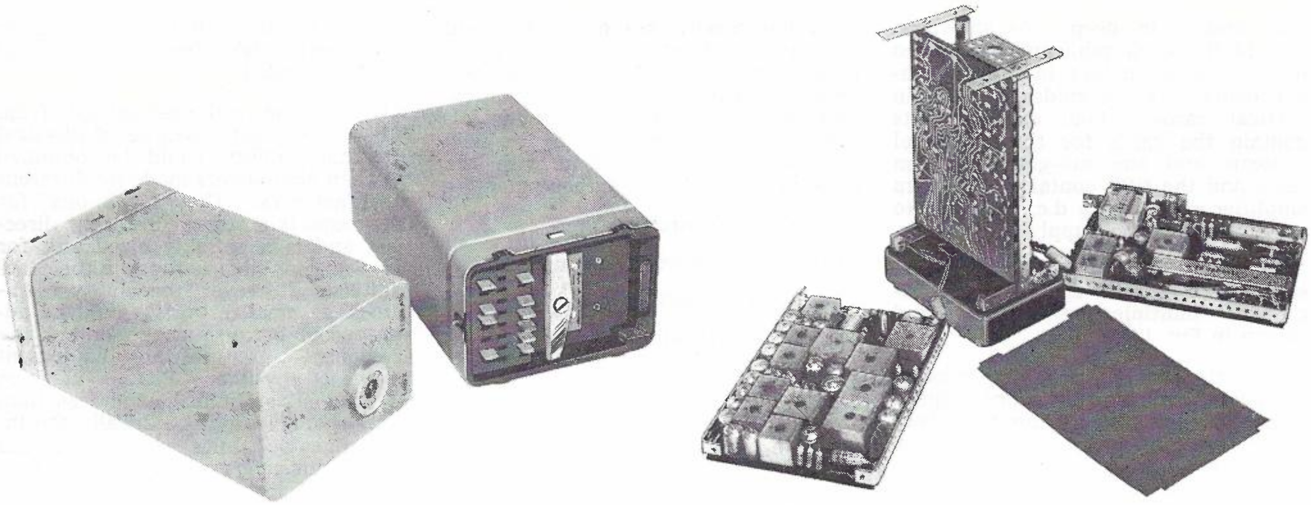


Fig. 13. — T.C.A. Conclave Unit. Left: Closed. Right: Open.

equipment sub-frame is preferred, but the supplementary carrier supply units may be used where suitable central carrier supplies are available.

The connectors between the conclave units and the sub-frames, and between the sub-frames and the external wiring, have gold-plated contacts.

A sub-rack mounted version of the equipment will be available in the latter part of 1967.

Telephone and Electrical Industries Pty. Ltd.

In the T.E.I. equipment, which is expected to be available late in 1967 or early 1968, a sub-frame contains a 12-channel multiplex equipment, and a rack holds five sub-frames in the upper part and five inverted sub-frames in the lower part, as shown in Fig. 14 (a). The connections between the external cabling and the sub-frames are made directly at the test and monitoring access sockets by the link plug. In order that the sub-frame can be withdrawn from the rack, two-part test and monitor sockets are used, one part of each socket being attached to the rack and the other to the sub-frame.

The modulation plan shown in Fig. 1 (b) is used and the 12-channel multiplexing equipment is contained in a sub-frame measuring 34 in. high, 4¾ in.

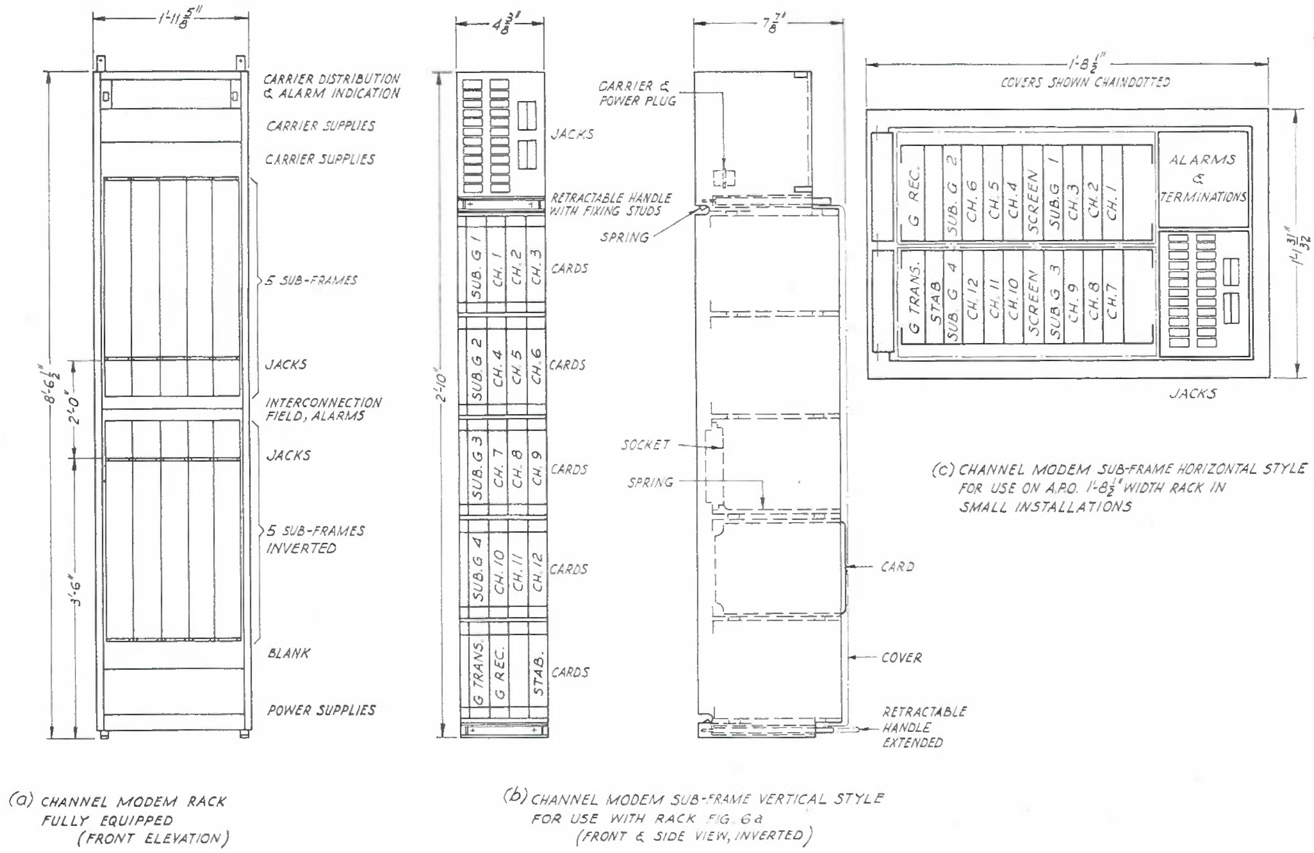


Fig. 14. — T.E.I. Channel Equipment.

wide and 7⅞ in. deep. As shown in Fig. 14 (b), each sub-frame is divided by horizontal shelves into five compartments carrying guides for plug-in vertical cards. Four compartments contain the cards for three channel modems and one sub-group modem each, and the fifth contains the group amplifier cards and a d.c. stabiliser to regulate the power supply to all cards.

Identical cards can be mounted in a sub-rack designed to hold one 12-channel multiplex equipment and shown in Fig. 14 (c)

On the 12-channel multiplexing equipment rack carrier supply equipment is mounted on horizontal shelves above the upper set of sub-frames. Power units are mounted below the lower set of sub-frames and alarm equipment and interconnection circuits for test access are mounted between the two sets of sub-frames. All of these units will be available as sub-racks for use with the sub-rack mounted 12-channel multiplexing equipment on standard A.P.O. racks.

On the printed wiring boards gold-plated contacts are attached directly to the board and use is made of wired-in secondary printed boards for assembling modules of miniature components.

FUTURE DEVELOPMENTS.

Although developments have proceeded separately for each type of equipment described, it has been found that there are a number of similarities of mechanical construction. For reasons stated previously, although all the equipments will be electrically interchangeable at the voice frequency, signalling and 60-108 kc/s G.D.F. connections, it has not been possible to achieve physical or carrier supply inter-changeability. In other words, equipment has now been designed as a "black box" occupying the space of two racks. The black box will translate 240 (or 228 in the case of T.C.A.) voice frequency circuits into 12-channel groups in the 60 - 108 kc/s band and vice versa, provided it is supplied with a.c. or d.c. power of specified voltage, stability, source impedance and noise content, and with a 4 kc/s supply of specified stability, voltage and source impedance.

Design and development is a continuous process, which sometimes proceeds rapidly and sometimes slowly. Certain changes are fundamental and affect the whole telecommunication network (for example, the introduction of inbuilt out-of-band signalling), but the majority of design changes involve small improvements in performance, decrease in size, weight and power consumption, increase in reliability, decrease in cost, etc. In the opinion of the writers the carrier telephone equipment produced for the A.P.O. should not attempt to follow every improvement in design and development too closely, but changes should be made in definite stages at fairly long intervals (say 5 to 6 years), and then only when economically justified. This involves consideration of the following factors in relation to the new equipment and comparison with the same factors for existing equipment:—

(i) Cost of purchase.

(ii) Cost of power consumed.

(iii) Cost of additional test gear.

(iv) Cost of additional spares.

(v) Cost of installation.

(vi) Cost of additional staff training.

(vii) Cost of maintenance.

(viii) Value of improved performance.

(ix) Cost of faults because of loss of use of the equipment.

(x) Space occupied.

(xi) Delivery obtainable.

The items (i) to (ix) are listed in order of increasing difficulty in making accurate assessments rather than in order of importance. Because of the pressure to provide new equipment to cope with increasing traffic, purchases are often decided on the basis of cost of purchase, together with consideration of space occupied and delivery dates. Sometimes factors (ii) to (iv) are taken into account, but if (v) to (ix) are considered at all, reliance is usually placed on opinion rather than facts, because the collection and analysis of factual information on these subjects is very difficult, time consuming and expensive.

The preference, expressed in the previous paragraph for changes of equipment design in definite stages has a number of advantages, which are as follows:—

(i) The expenses of training and spares can be reduced because of the smaller number of types of equipment in use at any time.

(ii) A longer period can be spent on "de-bugging" new designs before they are taken into general use.

(iii) The economic justification for a new design can be more accurately studied.

(iv) A greater run of production of a design can be obtained by the manufacturer, and, with competition this can be reflected in lower prices.

At the same time there is the disadvantage that there is a greater lag in the adoption of the latest techniques than would be the case if designs were changed at frequent intervals. However, the essence of the matter is the economic consideration; there is no advantage in changing designs unless the end result is either to reduce, or to get better value for, the money and effort expended.

It would be to the advantage of the A.P.O. if a greater degree of physical interchangeability could be obtained between equipments made by different manufacturers. The "black box" for 20 groups is a step in the right direction, and is a suitably sized unit for large stations such as those in the State capitals. However, the ability to interchange smaller units would be advantageous because more than half the 12-channel multiplexing equipment purchased by the A.P.O. is used in fairly small stations having less than 20 12-channel groups. Ideally the interchangeable units should be the printed wiring boards and certain sub-frames, such as the carrier supply equipment and the power supply unit. The advantages to the A.P.O. would be:—

(i) When equipment is required for an extension to an existing installation, the requirements could be obtained from any one of several sources.

(ii) Stocks of spare assemblies would be reduced in variety.

(iii) Training would be simplified.

(iv) Planning and ordering would be simplified.

At present simple repairs to long line equipment are normally carried out on site and more difficult repairs are made in A.P.O. workshops or are sent to the manufacturer. Equipment is guaranteed for one year, so that repairs in that period are made by manufacturers free of charge. The tendency to smaller and smaller components, sealed and encapsulated modules, and printed wiring will make repairs on site more difficult. Even A.P.O. workshop repairs will involve the holding of quite large stocks of spare parts, together with special tools for opening sealed modules and unsoldering printed wiring. Investigations are now being made into the economic and other considerations involved in limiting the work on site to exchanging assemblies and replacing items such as lamps and fuses, and despatching all faulty assemblies to the manufacturer. It is proposed that the arrangement should be in the nature of an extended guarantee or a service contract, payment being made in fixed amounts irrespective of the number of repairs. Provision will need to be made for stocks of vital spare assemblies to be held at strategic points and for rapid return of repaired work.

The advantages claimed for this are that:

(i) The necessity for training A.P.O. staff in repairs to numerous different manufacturers' equipment would be eliminated.

(ii) The real cost of maintenance should be reduced.

(iii.) The A.P.O. holding of spares would be reduced.

(iv) Manufacturers would retain an increased profit for supplying reliable equipment and suffer a reduced profit for supplying unreliable equipment.

(v) Since all faults would be repaired at one centre, the collection of accurate statistics for use by both the manufacturer and the A.P.O. would be simple.

(vi) Repairs on site would be eliminated and risks of incorrect parts being fitted, or damage being done by A.P.O. staff working from general knowledge, but lacking special training on the particular assembly should be avoided.

FUTURE DESIGN TRENDS.

It can be fairly safely forecast that by 1972, when a new design of equipment should be in course of manufacture, a 12-channel multiplex unit should be much smaller than the designs described in this paper. It may consist of one or more sealed or encapsulated modules built up from miniature components, or it could be built from integrated or thin film circuits. The problem of wiring to such modules and providing test access to channels without doubling or trebling the volume occupied by the equipment may not be capable of solution by conventional means. It may, at that stage, be found attractive to combine 12-channel multiplex equipment with the relay sets associated with the switching centre, or with a distribution frame carrying the wiring to those relay sets. At some later period, pulse code or some other form of modulation may be found more convenient than amplitude modulation, in which case it may be no longer expedient for the "basic group" to occupy the band 60 - 108 kc/s and 12-channel multiplex equipment as described in this paper may then disappear.

CONCLUSION.

The new equipment has been described with some of the reasons leading to its adoption. Equipment manufacturers' designs have been discussed and the advantages of a standard design of 12-channel multiplex equipment, to be produced by all suppliers to the A.P.O. have been stressed. These are considered to be so great that it appears desirable in the future that manufacturers should be invited to compete for design contracts for a 12-channel multiplex equipment, to be adopted by the A.P.O., on the condition that the accepted design will be made available to other firms for manufacture and supply to the A.P.O.

ACKNOWLEDGEMENTS.

Assistance from Siemens Halske - Siemens Schuckert (A'asia) Pty. Ltd., Standard Telephones and Cables (Aust.) Pty Ltd., Telecommunication Company of Australia Pty. Ltd., Telephone and Electrical Industries Pty. Ltd., and colleagues in the A.P.O., is acknowledged with grateful thanks, as is also the permission of the managements of the firms mentioned to publish the information in this paper.

REFERENCE.

1. F. Haas and E. Mehr: "The Vertical Style—a New Construction Design for Communications Transmission Equipment"; Siemens Review, Vol. 33, No. 2, Feb. 1966, page 66.

TECHNICAL NEWS ITEMS

PERTH - CARNARVON COAXIAL CABLE SYSTEM.

The Postmaster - General's Depart ment intends to lay a 4-tube coaxial cable from Perth to Carnarvon (W.A.), via Geraldton, a distance of 612 miles. The cable will provide telecommunication circuits to places along the route and to places beyond, such as the U.S. Navy establishment at Exmouth, and the Carnarvon satellite tracking station. It may later be extended by means of a broadband system to Port Hedland, to cater for development in the Pilbara area. A television relay will also be provided and the cable will be capable of transmitting television relays to or from Carnarvon if required.

One pair of tubes will be equipped with repeaters having a bandwidth of 12 Mc/s, enabling the television programme to be superimposed above 1200 telephone channels. The other pair of tubes will be equipped with 4 Mc/s repeaters and will provide standby facilities for up to 960 telephone channels. All repeaters will be buried with the cable. Although the idea of doing so is not new, it appears likely that Australia will be the first country to actually transmit a television relay simultaneously with telephone channels over the same bearer. Line transmission equipment is being supplied by Siemens Industries Pty. Ltd., Melbourne, a proportion being of West German manufacture.

Laying of the cable is expected to commence in August, 1967, and the first circuits should be ready for commissioning by June, 1969. To enable this date to be met the cable must be placed at a rate exceeding ten miles per week, much the fastest laying rate yet attempted for coaxial cable in Australia.

RADIO AUSTRALIA BOOSTER STATION — DARWIN, N.T.

During October the Postmaster-General's Department placed a $1.465 million order with R.C.A. of Australia Pty. Ltd., Sydney, for the design, supply and installation of aerial systems and radio receiving equipment for the Radio Australia booster station being established on Cox Peninsula, near Darwin.

In this scheme, programmes from Radio Australia, Shepparton, Victoria, will be received at the Cox Peninsula station and boosted to give improved programme transmissions into South-East Asia and other Asian areas. Initially, the station will provide up to three simultaneous transmissions (various languages), with transmitter power of 250 kW each.

Nine organisations from various parts of the world submitted proposals. The aerial systems will be designed and manufactured in Italy, radio links will come from the U.S.A., the receiving equipment from the United Kingdom and Australia, whilst the design and manufacture of the aerial support masts, together with other civil engineering works will be carried out in Australia.

An interesting aspect of the project is that a system of broad-band vertically polarised logarithmically - periodic transmitting aerials will be used, each of which is suitable for operation at any frequency between 7 and 26 Mc/s. This system will simplify the necessary switching operations when frequency bands are changed in accordance with transmission schedules.

Work on the prototype antenna will commence immediately and the station is scheduled for operation by mid-1968.

CAIRNS - WEIPA RADIO LINK WITH H.F. LOG PERIODIC AERIALS

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INTRODUCTION

In some remote areas of Australia, where the provision of telephone communications by landline, V.H.F. radio or microwave link is economically unattractive, it is necessary to utilise high frequency radio communication. The problems of fading, noise and interference inherent in the use of ionospheric transmission generally result in a secondary grade of service and may restrict the hours of use of such a link.

In the design and installation of a high frequency link to carry simultaneous telephone and telegraph channels between Cairns and Weipa, in North Queensland, a departure was made from the usual S.S.B. modulation methods, resulting in an improved grade of service. Also, the opportunity was taken to develop and use aerials of the log periodic type, for which this application is particularly suited.

The radio link, with a path distance of 400 miles, as shown in Fig. 1, was established for the Commonwealth Aluminium Corporation Ltd., in 1965, and provides one telephone subscriber service from the Weipa P.A.B.X. into the Cairns telephone network and a point-to-point machine telegraph circuit from the Company's office at Weipa to their office in Cairns. The reliable operation of both these circuits is essential for the efficient operation of the town of Weipa and the bauxite mining activities.

Aspects of the installation which use new techniques, such as the aerials, the signalling method, the modulation system, and the correction of telegraph frequency drift, will be discussed in detail, and standard equipment, such as transmitters and receivers, will be described briefly.

BASIC SYSTEM DESIGN

In the initial planning of a high frequency link, certain broad selections may be made regarding the overall system design. These are described in the following sections.

Frequency Range

For propagation over 400 miles, the high frequency band is the only economic choice, and frequencies in the range of 3 Mc/s to 12 Mc/s should be suitable, based on ionospheric considerations. Four frequencies placed at nominally 3 Mc/s, 5 Mc/s, 8 Mc/s and 11 Mc/s should allow one suitable frequency, to be selected under all conditions.

Method of Modulation

Single sideband modulation provides advantages in terms of:

(i) Minimum spectrum occupancy.
(ii) Maximum radiated power in information - carrying sideband.
(iii) Secrecy.
(iv) Elimination of distortion due to selective sideband fading.
(v) Minimum received interference and noise due to narrow bandwidth.

Transmitter Power.

With heavy noise in the North of Australia from electrical storm activity and heavy interference from foreign short-wave transmissions, the radiated power should be as high as possible. Considering the cost, space and power requirements, related to performance, a 500 watt transmitter was selected. To obtain a further improvement of 10 db a 5 Kw transmitter would be required and the system would assume the proportions of a major broadcasting station. A standby transmitter can be provided with 50 watt power at an attractive cost, allowing a degradation of 10 db in signal noise ratio under standby conditions.

Transmitting Aerial System.

Two general types of aerial system are considered:—

(i) Four separate resonant aerials for the four operating frequencies.
(ii) One frequency - independent aerial system.

In class (i), the basic aerial is the dipole, which is defined as having zero relative gain. Four dipoles could be supported by one pair of masts, and fed with four transmission lines. To obtain gain from resonant aerials, additional driven or parasitic elements

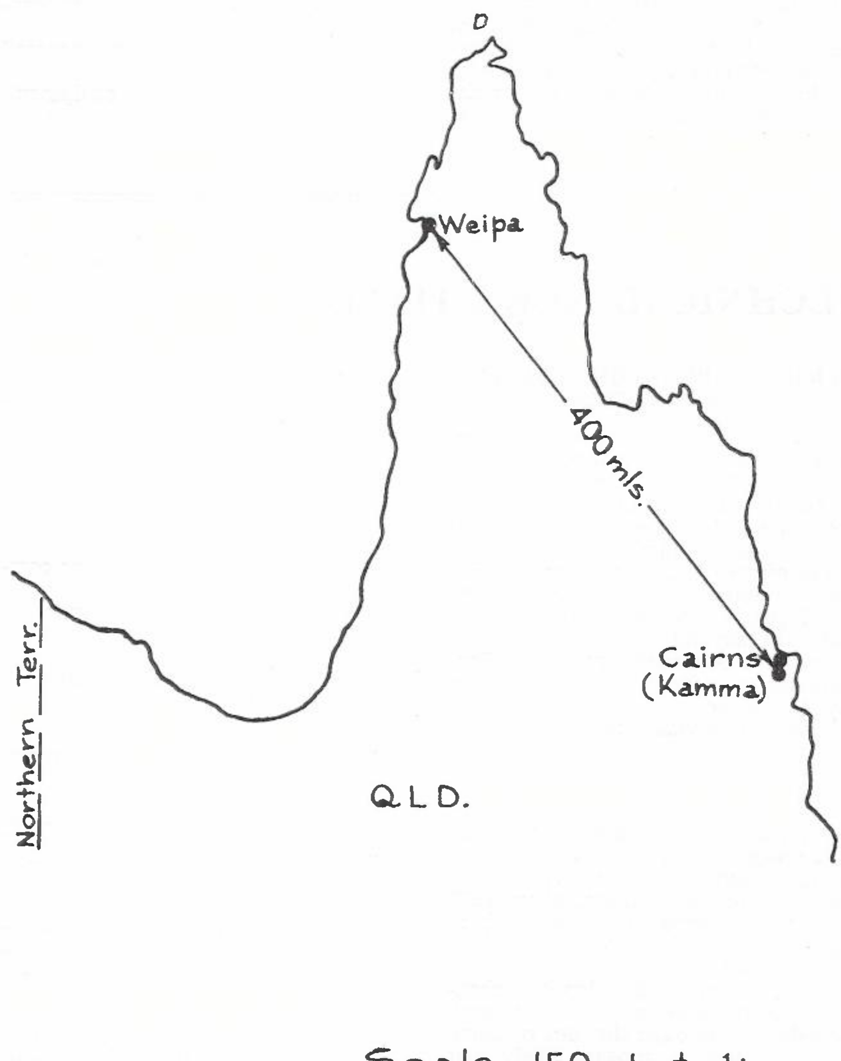

Fig. 1 — Cairns-Weipa Radio Link.

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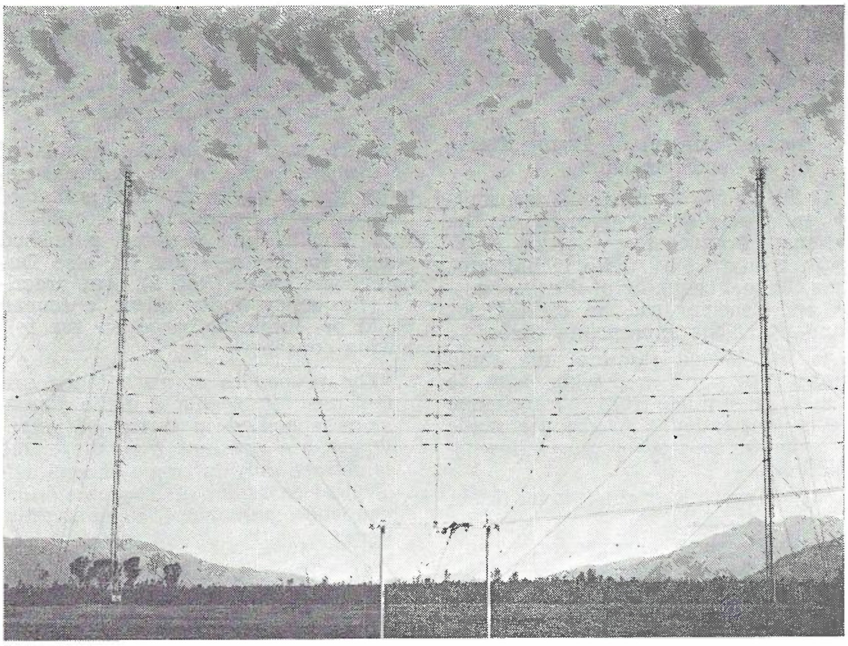


Fig. 2 — Log Periodic Aerial — Cairns.

would be required, and these would have different horizontal spacing for the four aerials, thus necessitating at least two additional masts, and a complex suspension and feed system. Also, the proximity of the three idle arrays to the active array could be expected to distort the radiation pattern, thus reducing or eliminating any gain advantage expected.

In class (ii), the two possible aerials would be the rhombic and the log periodic. In the case of the rhombic, four masts and a considerable land area are required. Also, for a path of 400 miles, the elevation angle of fire of 40 deg. average would be rather too high to use a rhombic to advantage and the resultant small aerial gain would not justify the masts and land area. Furthermore, the frequency range proposed is two octaves, and even a two-tier rhombic would not operate well over this range.

The log periodic aerial, however, is very well suited to a path length of 400 miles and has inherent constancy of impedance and radiation pattern over a wide frequency range. This aerial requires only two supporting masts and a much smaller land area than the rhombic. Also, a single transmission line is used for all operating frequencies. The gain is 3 db above that of a dipole at optimum height. Despite the apparent complexity of this aerial, with its numerous elements, fabrication is simple, and it may be raised or lowered in minutes for maintenance. The log periodic transmitting aerial at Cairns is shown in Fig. 2.

Receiving Aerial System

To permit the receiver automatic gain control to minimise the effects of fading, the maximum possible signal should be supplied to the receiver input. Thus a directional receiving aerial is desirable. Also, a good "Front to Back" directional characteristic of the aerial is a considerable advantage where interfering signals are received from bearings other than that of the desired signal.

The same considerations apply as for the transmitting aerial, and the log periodic aerial was again selected.

In further support of this selection, it is advantageous to have identical elevation field patterns for the transmitting and receiving aerials to achieve the maximum gain of both at the same angle of fire.

Transmission of Telephone and Telegraph Channels

Assuming that the telephone and telegraph signals are radiated at similar signal strength, a comparison may be made of two alternative methods, viz.:

(i) Two separate transmitters, on different frequencies.
(ii) Transmission of the telegraph signal on a sub-carrier mixed with the telephony signal on a single transmitter.

The use of separate transmitters is unacceptable due to cost, space and power requirements, and the need to allocate twice the number of frequency channels in the already overcrowded H.F. spectrum. Also, to mix the outputs of two transmitters into a single aerial would involve the additional expense and complexity of bandpass resonators to block the flow of power from one transmitter to the other, with the resultant intermodulation problems.

The sharing of the available 500 watts of transmitter power between two separate channels of information obviously results in a decrease in modulation depth for each channel, but this is still economically more attractive than provision of separate transmitters.

It will be demonstrated later that the telegraph signal can be used to advantage as a pilot signal to control the gain of the telephony system, and this factor alone would justify the transmission of the combined signal.

Telegraph Modulation System.

The bandwidth of the S.S.B. radio transmitter and receiver is 300 c/s to 3000 c/s. This may be reduced to 300 c/s to 2600 c/s with only small loss in performance to the telephony signal, leaving a band from 2600 c/s to 3000 c/s for insertion of the telegraph signal.

Frequency shift keying of a 2800 c/s sub-carrier with a deviation of $\pm$ 40 c/s is employed and the 400 c/s telegraph bandwidth available is more than adequate to contain the significant sidebands produced by this modulation without introducing telegraph distortion.

Telegraph equipment is selected to produce the FSK signal when connected to a standard teleprinter and to decode the received FSK signal at the distant machine.

Frequency Stability

The frequencies of the suppressed carrier in the S.S.B. transmitter are derived from crystals which are subject to a small frequency drift with temperature variations. A total relative drift of 20 c/s would affect telephony only to the extent of changing the voice character somewhat and introducing noticeable distortion, but would cause severe distortion to the telegraph signal due to displacement of the sub-carrier frequency.

To maintain the telegraph sub-carrier within 1 c/s of its original frequency, it is necessary to transmit a frequency reference pilot signal at 3000 c/s, which will experience the same frequency drift as the 2800 c/s sub-carrier and to use this frequency reference at the receiving terminal to correct the sub-carrier and restore it to its original frequency.

A telegraph correction circuit, with the above function, is specified as necessary, and design details will be shown later.

Signalling System

Dialling over the telephony system is considered as an unnecessary and undesirable objective for the following reasons:—

(i) The probability of an incorrect digit to radio interference, particularly during electrical storms.
(ii) The lack of available bandwidth in the system to permit signalling outside the speech band.

(iii) The need for additional equipment to code and decode tone signals with adequate guard circuits to avoid triggering by speech signal components and sufficiently fast response to avoid dial impulse distortion.

For a radio telephone circuit, which is the only traffic channel to a remote town, it is considered that manual switching is justified. This arrangement permits some supervision to ensure that the channel is working and allows the possibility of limiting the length of calls in periods of very heavy traffic, to minimise the number of lost calls. Accordingly, magneto signalling, using "in-band" tones can be used, and this results in a simple and effective system.

A signalling frequency of 2200 c/s is selected instead of 1000 c/s for the following reasons:—

(i) Speech power is considerably less at 2200 c/s than at 1000 c/s.

(ii) The third harmonic of a 1000 c/s tone would interfere with the telegraph sub-carrier and pilot near 3000 c/s.

(iii) The second and higher harmonics of a 2200 c/s tone are outside the system bandwidth and will be attenuated by the system filters.

(iv) The 2220 c/s tone is 200 c/s removed from the second harmonic of a 1000 c/s test tone which may be used over the telephony system.

To "guard" against false operation by voice or a heterodyne signal,, the 2200 c/s signal is modulated by a 20 c/s signal and the detector circuit is arranged so that it will not operate unless the 20 c/s modulation is present.

.A voice frequency ringer oscillator-detector to satisfy the above requirements will be described in detail later.

Voice Terminating Unit

Since the radio telephone link from transmitter to receiver is a unidirectional device, four wire operation is necessary. The conversion to two wire operation is carried out by a conventional hybrid coil. To minimise the difference between send and receive levels at the exchange, the voice terminating unit is located at the exchange and four wire circuits are used between the exchange and the transmitting and receiving site.

Conventional practice with operation of S.S.B. radio telephone systems makes use of compression amplifiers to ensure a high level of transmitter modulation and the consequent variable gain of the overall system introduces hybrid stability problems which are usually controlled by special "anti-singing" circuits.

In this application, a linear system has been considered necessary to avoid intermodulation between telephony and telegraph signals and the resultant system has been proved superior to the compression system. This aspect will be discussed in detail later.

Remote Control of Transmitters and Receivers

At the Cairns terminal the transmitter and receiver are located at the National Broadcasting Station 4QY, which is staffed by radio technicians. Thus channel changing of the transmitter and receiver can be carried out manually at the appropriate times.

At the Weipa terminal the radio transmitting and receiving site is located three miles from the exchange and is unattended. Provision is made for remote control of the following functions:—

(i) Transmitter changeover (Main Standby).

(ii) Receiver changeover.

(iii) Channel selection (four channels) on transmitters and receivers.

D.C. signalling over the lines is used to operate the remote control relays.

LOG PERIODIC AERIALS

In 1964, the available published information regarding log periodic aerials was to a large extent theoretical, and full practical design information was not available, despite the fact that high frequency log periodic aerials were manufactured by a number of companies.

To establish a design method, a study of the various published papers was made by the author to correlate the theories and empirical results where possible, to advance reasonable hypotheses where information was lacking, and to draw practical conclusions which could be used with confidence.

The results of this study, including a typical design example, were published in June, 1965, within the P.M.G. Department as Queensland Engineering Report No. QB.209, entitled "Practical Design of H.F. Log Periodic Receiving Aerials"

The more important parts of this report are included below, and then supplemented by details of the further theoretical and experimental extensions of this study, which culminated in the successful installation and operation of the transmitting and receiving log periodic aerials at Cairns and Weipa.

THEORY OF OPERATION

The desirable performance objectives for a high frequency aerial used in "point-to-point" operation are as follows:—

(i) Constant efficiency, field pattern and impedance and low V.S.W.R. over a wide range of operating frequencies.

(ii) High gain, good "front-to-back" ratio and suppression of minor lobes.

(iii) Economical support structure and small land areas.

Apart from the specific details of performance, the most essential requirement of any such aerial is that of "frequency independence". In 1957 it was shown in various published papers by Ramsey (Ref. 1), also Duhamel and Isbell (Ref. 2), that practical frequency independent antennae could be obtained, based on the following concept:—

"The properties of an antenna are frequency independent if the dimensions specified in terms of wavelength are constant (i.e., the shape is defined only in terms of angles)." Typical examples of frequency independent antennae demonstrated were:

(i) The equi-angular spiral (two dimensional) and

(ii) The conical screw (three dimensional), both of which would be infinite in size.

However, Duhamel (Fig. 2) investigated the effect of finite size and the effect of replacing the continuous shape (which has constant electrical dimensions for all frequencies) with a repeating shape (which has the same electrical dimensions for any two frequencies related by a particular scale factor "k").

The conclusion was reached that, with suitable values of scale factor "k," the variation of parameters such as radiated field pattern and feed impedance in the frequency interval between "f" and "kf" generally could be made small so that the antenna performance approximated that of a continuous antenna. Also, the "end effect" due to the finite size was found to be significant only outside a certain calculated frequency range, which depended on the dimensions at which truncation of the small and large ends occurred.

It did not, of course, follow that all frequency independent antenna shapes would have desirable field patterns, but many successful antennae were derived using this principle to suit applications ranging from the high frequency to the microwave region.

In the high frequency range (3 to 30 Mc/s), the large physical size necessitated the use of wire rather than solid structures for antennae, and various arrays of straight wires were derived, featuring a repeating structure dimensioned by geometric progressions.

THE LOG PERIODIC DIPOLE ANTENNA

The array with which this study is concerned is the log periodic dipole shown in Figi. 3, and the important physical parameters are indicated.

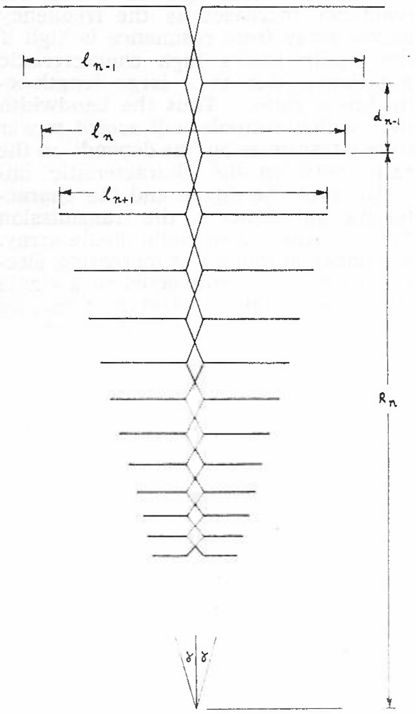


Fig. 3 — Log Periodic Dipole Array.

This antenna comprises an array of simple dipoles fed by a central balanced feeder, which is transposed for alternate dipoles. The feed point is the small end or high frequency end of the array.

The dipole element lengths l are related by the parameter τ such that—

$$\tau = \frac{l_n}{l_{n-1}} = \frac{R_n}{R_{n-1}} \quad \ldots\ldots (1)$$

since, by similar triangles, τ also relates the distances, R, of elements from the apex.

The spacing of the dipoles, d, is related to the lengths of the dipoles by the parameter σ such that—

$$\sigma = \frac{d_n}{2l_n} \quad \ldots\ldots\ldots\ldots (2)$$

The angle included by the antenna envelope, which is triangular, is 2α.

The parameters τ, σ and α are related by the equation—

$$\sigma = 0.25\ (1 - \tau)\ \cot \alpha \quad \ldots\ldots (3)$$

At any frequency in the operating band, one element will be a resonant half-wave dipole or close to resonance and radiation will occur mainly from this dipole. With careful selection of antenna parameters, the radiation from adjacent elements will reinforce that of the resonant element in the direction of the apex. Elements further removed will be fed relatively little power due to the large reactive feed impedances in the "off resonance" condition and will contribute little to the radiated field. This leads to the concept of an "active-region," from which most of the radiation emanates at a particular frequency. The "phase centre" of the antenna is located within this region.

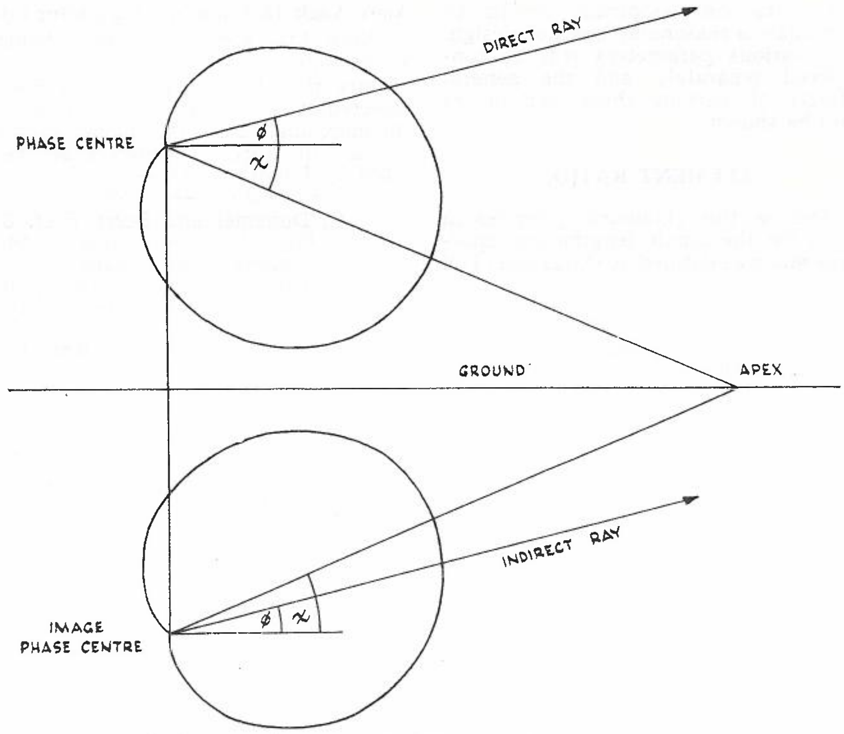


Fig. 4 — Vertical Plane Radiation from Array and Image.

If the frequency is increased, then a shorter element becomes the predominant radiator and the active region and the phase centre move towards the apex. The phase centre is thus located a fixed number of wavelengths from the apex regardless of frequency.

When the antenna is inclined with the dipoles horizontal and the apex at ground level, the phase centre is thus a constant electrical height above ground, and the radiation pattern (including reflected wave) is independent of frequency.

This is illustrated in Fig. 4, which gives a side-elevation of the array and indicates the shape and direction of the vertical plane field pattern and its image. The radiation pattern depends on the selection of the parameters τ, σ and α and this aspect will be considered later in more detail.

The radiation fields of the array and image combine to produce the resultant radiation pattern of the inclined array above ground, as shown in Fig. 5. This pattern is dependent on the array pattern, the location of the phase centre and the inclination angle of the array. The actual derivation of the optimum angle of fire will be described in the design details.

SELECTION OF ARRAY PARAMETERS

From a study of various published papers, it is possible to correlate the

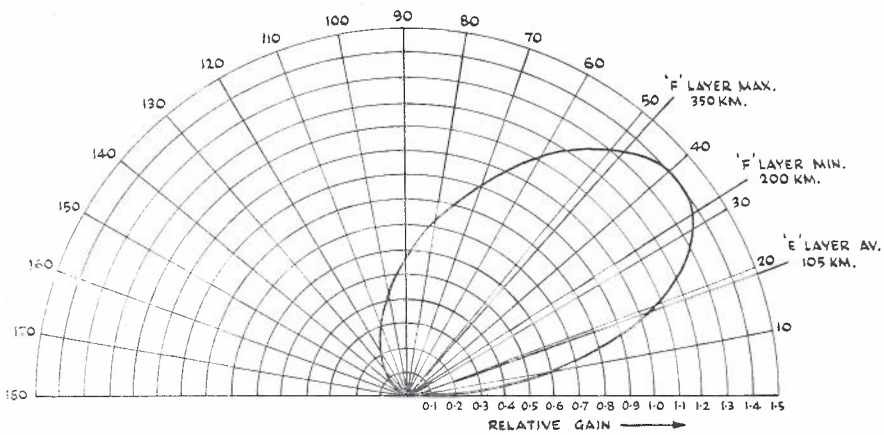


Fig. 5 — Vertical Elevation Pattern.

theoretical and empirical results to formulate a reasonable basis of design. The various parameters will be considered separately and the general effects of varying these parameters will be shown.

ELEMENT RATIO.

This is the geometric progression ratio for the dipole lengths and spacings and was defined as (Equation (1)):

$$\tau = \frac{l_n}{l_{n-1}} = \frac{R_n}{R_{n-1}}$$

(1) τ must be less than 1.

(2) τ should be large so that the change in length from one dipole to the next will be small. Hence there will be a large number of dipoles near resonance and the power carried up the central feeder will be shared by an effectively large end-fire array of dipoles, resulting in high gain. Conversely, if τ is too small, only one or two dipoles may be sufficiently close to resonance to accept the power from the feeder, and the gain will be low.

(3) τ should be large, since the resulting small frequency ratio interval of the repeating structure minimises the variation of the electrical characteristics over the interval.

(4) According to Duhamel and Deschamps (In Ref. 9, Figs. 18-14) and Thomas (Ref. 8), the E-plane (horizontal) beamwidth is virtually unaffected by variation of τ, for practical values of the apex angle.

(5) According to Thomas (Ref. 8), for reasonable values of τ, the H-plane (vertical) beamwidth increases slightly with decreasing τ.

(6) Duhamel and Deschamps (In Ref. 9, Figs. 18-14) show graphically the minimum permissible value of τ for any given apex angle and the E-plane and H-plane beamwidth obtained under these conditions. For smaller values of τ, the pattern is adversely affected.

(7) If τ is too large, the number of elements required for a selected apex angle may be excessive and impractical from structural considerations. Also the increased material cost may not be justified by the improvement in performance.

Most authors select a value of τ of 0.89 as an optimum value. This is an empirical result, which provides a satisfactory compromise for all factors. Since no nett advantage can be envisaged by using a higher or lower value of τ, the value of 0.89 is adopted and should only be altered if design restrictions necessitate some other value.

Apex Angle (2α) and Spacing Factor (σ).

(Note that some references define apex angle $= \alpha$).

Once the element ratio τ has been selected, it is necessary to select either the apex angle 2α or the spacing factor σ since the three parameters are related by Equation (3):—

$$\sigma = 0.25\ (1 - \tau) \cot \alpha$$

(i) Duhamel and Berry (Ref. 3, Fig. 4) show graphs of the H-plane and E-plane beamwidth of a trapezoidal tooth log periodic antenna for various values of 2α and it is noted that for $\tau = 0.89$, the directivity in both planes improves as the apex angle is reduced to about 10°. According to Duhamel and Deschamps (Ref. 9.) the polar patterns of trapezoidal tooth and log periodic dipole antennae are similar.

(ii) Carrel (Ref. 5, Fig. 11) shows graphically for a log periodic dipole antenna, the theoretical relationship between τ, σ and directivity. For $\tau = 0.89$, an optimum value of σ of 0.165 is indicated, which corresponds to an apex angle 2α of about 20°. For σ greater than the optimum value, side lobes appear. For an apex angle 2α of 30.8°, $\sigma = 0.1$ and the directivity would be within 1 db of optimum. For σ less than 0.05, the directivity falls off rapidly and the input impedance varies with frequency.

(iii) Duhamel and Deschamps (In Ref. 9, Fig 18-21) indicate graphically that for $\tau = 0.89$, the measured V.S.W.R. of a typical log periodic antenna is a broad minimum for an apex angle 2α of about 30°.

(iv) The length of the antenna increases very rapidly as 2α is reduced below about 30°.

An apex angle 2α of approximately 30° is considered to be optimum, based on experimental results and the practical consideration of size. The theoretical predictions of Carrel, while not in exact agreement, indicate that the 30° angle would be very satisfactory. A 30.8° angle is adopted, giving the convenient value $\sigma = 0.1$.

Feeder Impedance

Since the radiation pattern from the log periodic dipole array is dependent on the relative magnitude and phase of the dipole currents and on the dipole spacing, it follows that the total feeder power must be correctly distributed to the dipoles.

When a dipole is tuned to half-wave resonance, its feed point impedance is resistive and of the order of 73 ohms. As the frequency moves away from resonance, the series reactive component of its feed impedance increases (capacitive for lower frequencies and inductive for higher frequencies), and this increased impedance results in a decreased dipole current and consequently reduced power radiation from the dipole. The rate at which the reactance increases as the frequency moves away from resonance is high if the dipole has a high characteristic impedance, due to a large length-to-thickness ratio. Thus the bandwidth over which a dipole will accept power from a transmission line depends on the ratio between the characteristic impedance of the dipole and the characteristic impedance of the transmission line. In the log periodic dipole array, a number of dipoles of increasing electrical length are connected to a single transmission line (feeder) at increasing distances from the feed point of the transmission line. At each dipole connection point on the feeder, the current will distribute between that dipole and the remainder of the array in the inverse ratio of the dipole feed impedance and the impedance looking into the remainder of the feeder, loaded by later dipoles, respectively.

If the feeder characteristic impedance is too high, power will be accepted by electrically short elements, and much of the power may be radiated by the smaller part of the array, leaving inadequate power for radiation by the half-wave resonant dipole, thus reducing the effective size of the array.

To further add to the complexity of any analysis of the power distribution between the dipoles, the feed impedance of each dipole is modified by the effect of mutual impedance with adjacent dipoles, and the effective load impedance at any point on the feeder is dependent on the electrical distances to all later dipoles. The optimum power distribution, in exciting a significant number of dipoles to form an effective array, would be expected to give a relatively smooth impedance response and low V.S.W.R. over a wide frequency range because of the smooth transfer of real power from the feeder.

According to Carrel (Ref. 5), who provides an extensive mathematical analysis of the array, the directivity is independent of the characteristic impedance of the feeder for practical value of feeder characteristic impedance. This is encouraging and suggests that the effects outlined above may be compensated to some extent by the complex interaction of currents and voltages in the array. However, he also noted that the directivity is reduced by about 0.2 db for each doubling of the length to radius ratio, h/a, of the dipoles, which would tend to confirm the concentration of power in a smaller number of dipoles as their characteristic impedance is increased. Also, he found experimentally that the V.S.W.R. was a minimum when a feeder of 100 ohms was used, in a particular aerial with dipoles for which h/a = 125.

It is considered that in the case where very thin dipoles are used, a higher feeder characteristic impedance could tend to offset the reduction in directivity at the expense of a slightly higher V.S.W.R. However, the feeder impedance should not be raised to too large a value in the absence of more detailed knowledge of the possible effects.

The impedance of dipole elements significantly larger electrically than the half-wave resonant element will be reactive, but will have little effect on the feed impedance of the array, since nearly all the power will have been radiated by the lower elements.

However, the electrically short elements are connected to the feeder before the power has reached the radiating elements and the capacitive reactance must be considered as a distributed load on the transmission line.

Carrel (Ref. 5) indicates that for these short elements, the effective capacitance is approximately proportional to their length. Since their spacing on the feeder is also proportional to their length, the feeder is effectively loaded by a constant capitance per unit length, resulting in a decrease in characteristic impedance of the feeder. The transition from the region of short elements to the region of radiating elements is a smooth function and since an array of low V.S.W.R. will absorb all the forward wave on the feeder with small reflected power, the array must effectively terminate this modified characteristic impedance. Thus the aerial feed point impedance is the impedance of the feeder, reduced by the capacitive loading due to the short elements.

Carrel (Ref. 5) derives the following equation relating the feeder characteristic impedance Z_0 and the array mean input resistance R_0:—

$$Z_0 = R_0 \left[\frac{1}{\frac{8\sigma' Za}{R_0}} + \sqrt{\frac{1}{\frac{(8\sigma' Za)^2}{R_0^2}} + 1} \right] \quad \ldots\ldots\ldots\ldots (4)$$

Where:—

$\frac{h}{a}$ = dipole length to radius ratio.

Za = dipole characteristic impedance.

σ = spacing factor.

τ = element ratio.

R_0 = mean input resistance

Z_0 = feeder characteristic impedance

and $$\sigma' = \frac{\sigma}{\sqrt{\tau}} \quad \ldots\ldots\ldots\ldots (5)$$

and $$Za = 120 \ (l_n h/a - 2.25) \quad \ldots (6)$$

Lengths of Longest and Shortest Elements

Since the "active region" of the array includes some elements both shorter and longer than half-wave resonance, the ratio of the lengths of the longest and shortest elements will be somewhat greater than the ratio of the highest to the lowest frequency limits of the array.

The width of the active region depends on the distribution of current in the various elements.

By experiment, both Thomas (Ref. 8), and Carrel (Ref. 5, Fig. 7), found that the current distribution was asymmetric with a maximum displaced from the location of the half-wave dipole in the direction of the shorter elements. They noted that the current drop-off beyond the maximum was quite rapid, thus allowing a practical antenna to be truncated at the low frequency end without serious effects. Carrel (Ref. 5) improved the low frequency performance by terminating the feeder with a short-circuited stub of length 1/8 wave-length at the resonant frequency of the largest element.

Isbell (Ref. 4, Fig. 7) shows a graph of radiation efficiency versus antenna length and indicates that by the time the half-wave element is reached, nearly 80 per cent. of the power is being radiated and hence there is little advantage in adding further elements.

Both Thomas (Ref. 8) and Carrel (Ref. 5) recommend that the longest dipole should be 0.5 wavelength at the lowest required frequency, while Isbell (Ref. 4) uses a dipole of 0.47 wavelength.

At the high frequency end of the array, the effect of truncation is not so easily defined, since the power distribution into the shorter elements is dependent on their impedance and on the element ratio τ and the spacing factor σ.

Isbell (Ref. 4) recommends a shortest element of 0.38 wavelength at the highest operating frequency. Thomas (Ref. 8) suggests a lower value of 3/16 wavelength. Carrel (Ref. 5) defines the active region by the points at which dipole currents are 10 db below the maximum value and finds by experiment the width of the active region as a function of τ and α. He shows that elements become active well below their resonant frequencies. For τ = 0.89 and α = 15.4°, the shortest element is given as 0.31 wavelengths.

From the physical lengths of the longest and shortest elements, the number of elements may be derived for any value of element ratio τ.

Carrel (Ref. 5) defines:

$$B_s = B \times B_{ar} \quad \ldots\ldots\ldots (7)$$

where B_s = structure bandwidth = ratio of longest to shortest element.

B = operating bandwidth

and B_{ar} = bandwidth of active region.

The number of elements (N) is then given by—

$$N = 1 + \frac{\text{Log } B_s}{\text{Log}\left(\frac{1}{\tau}\right)} \quad \ldots\ldots (8)$$

Free Space Field Pattern

According to Duhamel and Deschamps (In Ref. 9), the polar patterns of trapezoidal tooth and log periodic dipole antennae are similar.

The H-plane pattern of the trapezoidal tooth antenna is described very closely by the equation—

$$E = \left(\text{Cos}\frac{\phi}{2}\right)^n \quad \ldots\ldots\ldots (9)$$

and is cardioid in shape, the beamwidth depending on the value of "n". The direction of fire is towards the apex.

This general type of pattern would be expected for the following reason. If two elements in the centre of the active region have approximately equal currents, the current in the larger element will lag 180° due to transposition, an additional angle θ, due to time delay in the feeder, and another angle θ_2 due to its inductive reactance relative to the shorter element's capacitive reactance, the total lag thus exceeding 180°, but unlikely to exceed 360°.

Thus the larger element may be said to lead in phase relative to the shorter element. In this case, allowing for relative time delay in the radiated waves, the radiation in the direction of the apex will reinforce by adding with decreased phase shift and radiation away from the apex will tend to cancel by adding with an increased phase shift tending towards 180°. The resultant H-plane pattern would thus have a cardioid shape.

Assuming the above expression for H-plane beamwidth to be approximately correct in form, it is possible to calculate a suitable value of the index "n" from the half-power angles of experimentally measured patterns. Duhamel and Deschamps (In Ref. 9, Figs. 18-17), provide a graph to facilitate this step.

Duhamel and Berry (Ref. 3, Fig. 4), show graphically the H-plane and E-plane beamwidth for given values of 2α and τ.

For example, in this design, if τ = 0.89, and 2α = 30.8°, then σ = 0.1 and the H-plane beamwidth is 93°. This results in a value of n = 4.

Construction of the cardioid free space pattern according to equation 9 gives the shape of the field but not its magnitude.

The "directivity" of the array, which is the free-space gain above isotropic in the direction of the apex, is presented graphically as a function of τ and σ by Carrel (Ref. 5, Fig. 11.) (This graph applies to a specific element length-to-thickness ratio and the earlier remarks regarding the effect on gain of this parameter should be noted.)

Field Pattern Including Ground Reflection

To obtain the elevation field pattern when the array is above a reflecting ground and at an angle to it, it is necessary to add the fields of the array and its image, taking into account both phase differences and time delays due to path length differences. This process may be simplified by assuming that all the radiation from the array emanates from the "phase centre", the location of which may be defined.

Duhamel and Deschamps (In Ref. 9, Fig. 18-15), show graphically the distance in wavelengths from apex to phase centre as a function of apex angle 2α. It should be noted that the phase centre location is essentially independent of the element ratio τ. Also, while the physical location may change with frequency, the electrical location (in wavelengths) is constant.

The free-space fields of the equivalent antenna at the phase centre and its image (shown in Fig. 3) are combined to obtain the vertical plane pattern (shown in Fig. 4). The combined pattern is given by—

$$F(\phi,\psi) = f(\phi+\psi) - f(\phi-\psi)\,e^{-j2\beta H \sin\phi} \quad \ldots\ldots\ldots\ldots\ldots (10)$$

where $F(\phi, \psi)$ = combined field
ϕ = elevation angle
ψ = inclination of antenna to horizontal
$\beta = \frac{2\pi}{\lambda}$
H = height of phase centre above ground
and $f(\phi)$ = free space field.

The gain enhancement due to the reflected wave is indicated by the ratio of the maximum magnitude of the combined field to the maximum magnitude of the free-space field.

It is desirable that the maximum of the combined field should occur at the "angle of fire" which is the optimum for the radio path. This may be achieved by selecting the appropriate inclination angle of the array to the horizontal. (In the Cairns-Weipa design, the combined field was evaluated by computer calculations to obtain the optimum inclination angle of 23° for an angle of fire of 40°).

Design Calculations

The principal steps in the design procedure are set out below, to illustrate the application of the above theory.

Path length — 400 miles
Angle of fire ("F" layer propagation)
Max. 48° (350 Km virtual height)
Av. 40°
Min. 32° (200 Km virtual height)
Frequency range — 2.332 Mc/s — 12.000 Mc/s

(1) Select τ = 0.89 (as recommended).
(2) Select σ = 0.1 (as recommended).
(3) Then $2\alpha = 30.8°$.
(4) Find H-plane beamwidth = 93° (from Ref. 3, Fig. 4).
(5) Find cardioid index "n" = 4 (from Ref. 9, Fig. 18-17).
(6) Find distance from apex to phase centre = 0.77 λ (from Ref. 9, Fig. 18-15).
(7) Find height of phase centre above ground for various trial values of inclination angle ψ.
$H = 0.77\,\lambda \sin\psi$.
e.g. for the selected value of $\psi = 23°$.
$\sin\psi = 0.3907$
thus $H = 0.3909\,\lambda$.
(8) Find radiation pattern above ground for the various trial values of angle ψ.

$$F(\phi,\psi) = \cos^4\left(\frac{\phi+\psi}{2}\right) - \cos^4\left(\frac{\phi-\psi}{2}\right)e^{-j2\beta H\sin\phi}$$

e.g. For the selected value of $\psi = 23°$.

$$F(\phi) = \cos^4\left(\frac{\phi+23°}{2}\right) - \cos^4\left(\frac{\phi-23°}{2}\right)e^{-j4\pi\times 0.3909\sin\phi}$$

This pattern is shown in Fig. 4.

(9) Note gain enhancement due to ground reflection at angle of fire.
e.g. For $\psi = 23°$, the maximum radiation occurs at 40° and the gain enhancement is 1.395 representing 2.9 db.
(10) Find directivity
For $\tau = 0.89$ and $\sigma = 0.1$.
Directivity = 8.6 db (from Ref. 5, Fig. 11).
(11) Find gain above isotropic
= Directivity + gain enhancement
= 8.6 + 2.9 db
= 11.5 db.
(12) Find gain above dipole at optimum height. (Gain of dipole is 2.15 db above isotropic and gain enhancement is 6 db).
Gain above dipole
= 11.5 — 2.15 — 6.0
= 3.35 db.
(13) Find longest element. (Half wavelength at lowest frequency, allowing also 5% for end effect).

$$l_1 = \frac{468}{2.332}\text{ ft.} = 200.6\text{ ft.}$$

(14) Find distance from apex to longest element.

$$R_1 = \frac{l_1}{2\tan\alpha} \quad \text{where } \alpha = 15.4°$$

$$= \frac{200.6}{2 \times 0.2754} = 364.2\text{ ft.}$$

(15) Find height of longest element.
$h_1 = R_1 \sin\psi$
= 364.2 sin 23°
= 142.3 ft.
Thus 150 ft. masts will be required.
(16) Find the bandwidth of the Active Region (B_{ar})
For $\tau = 0.89$ and $2\alpha = 30.8°$.
B_{ar} = 1.6. (from Ref. 5, Fig. 8).
Length of shortest dipole at highest frequency

$$= \frac{0.5\lambda}{B_{ar}} = \frac{0.5\lambda}{1.6} = 0.31\lambda$$

(17) Calculate operating bandwidth (B)

$$B = \frac{12000}{2332} = 5.145$$

(18) Calculate Structure Bandwidth B_s.
$B_s = B \times B_{ar}$
= 5.145 × 1.6
= 8.23 ....(7)
(19) Calculate Number of Elements N.

$$N = 1 + \frac{\log B_s}{\log\left(\frac{1}{\tau}\right)} = 19.09.$$

Note: In the actual design, 18 elements were considered adequate.
This corresponds to—
B_s = 7.25
B_{ar} = 1.41
and the length of the shortest dipole at the highest frequency = 0.355λ which is acceptable.
(20) Calculate the distances from the apex to all elements
$R_n = \tau R_{n-1}$
(21) Calculate the lengths of all elements.
$l_n = \tau l_{n-1}$
(22) Note the length of the smallest element.
In the above example,
l_{18} = 27.68 ft.
(23) Calculate the half-length to radius ratio $\frac{h}{a}$ for both the longest and shortest dipoles, for the selected wire size.
e.g. 7/0.036 copper
radius "a" = 0.054 in.

$$\text{Max}\ \frac{h}{a} = \frac{200.6 \times 12}{2 \times 0.054} = 22{,}289$$

$$\text{Min}\ \frac{h}{a} = \frac{27.68 \times 12}{2 \times 0.054} = 3{,}076$$

(24) Calculate the characteristic impedance of the longest and shortest dipole elements.

$$Z_a = 120\left(l_n \frac{h}{a} - 2.25\right)$$

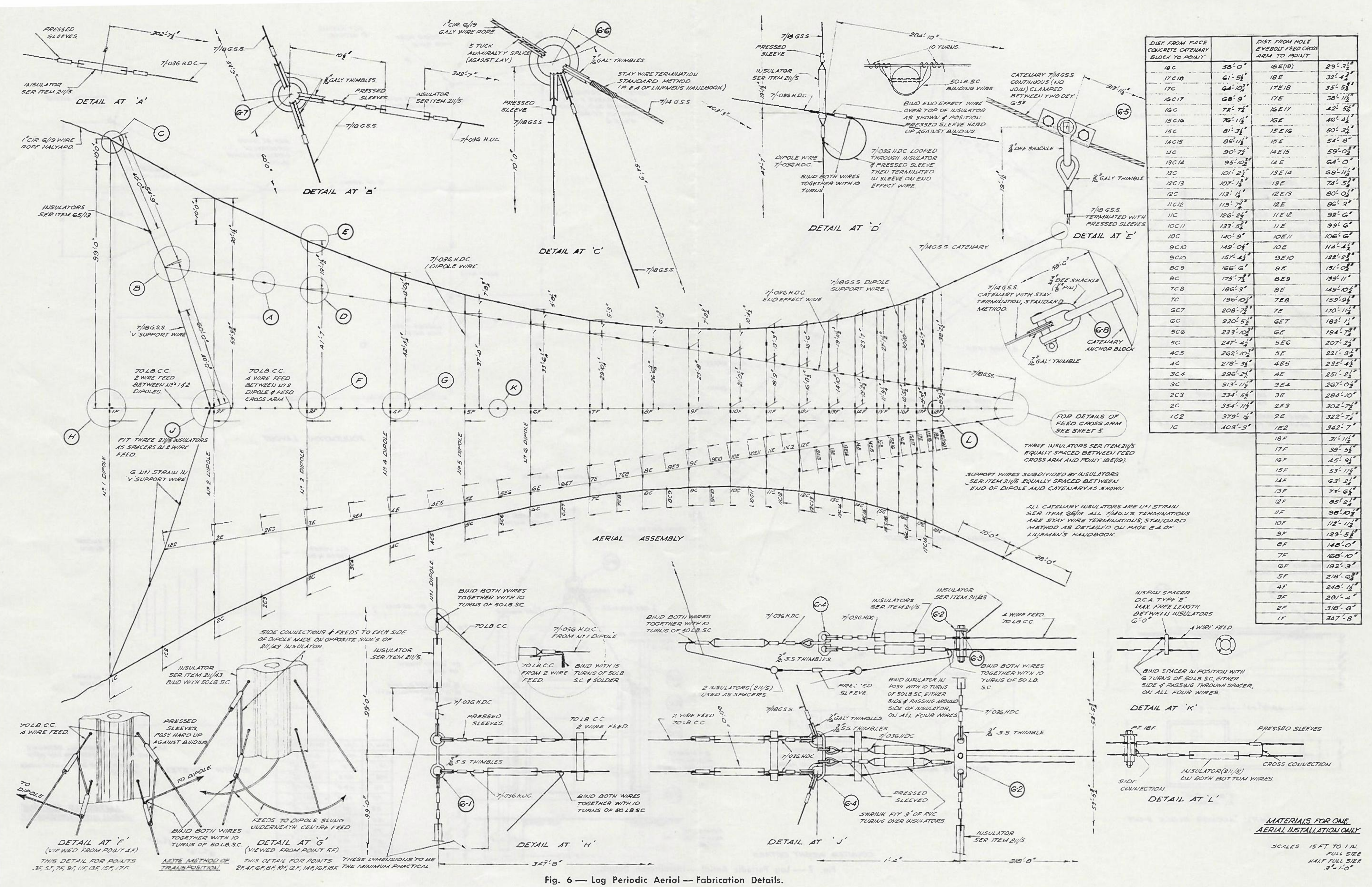
(from Ref. 5, Fig. 15).
$Z_{a\,max}$ = 930 ohms.
$Z_{a\,min}$ = 694 ohms.
(25) Select a desired input impedance R_0 to the antenna, to match an available transmission line.
e.g. 200 ohms to match a 4-wire cross-connected line.
(26) Calculate the maximum and minimum values of $\frac{Z_a}{R_0}$.

$$\text{Max}\ \frac{Z_a}{R_0} = 4.65$$

$$\text{Min}\ \frac{Z_a}{R_0} = 3.47$$

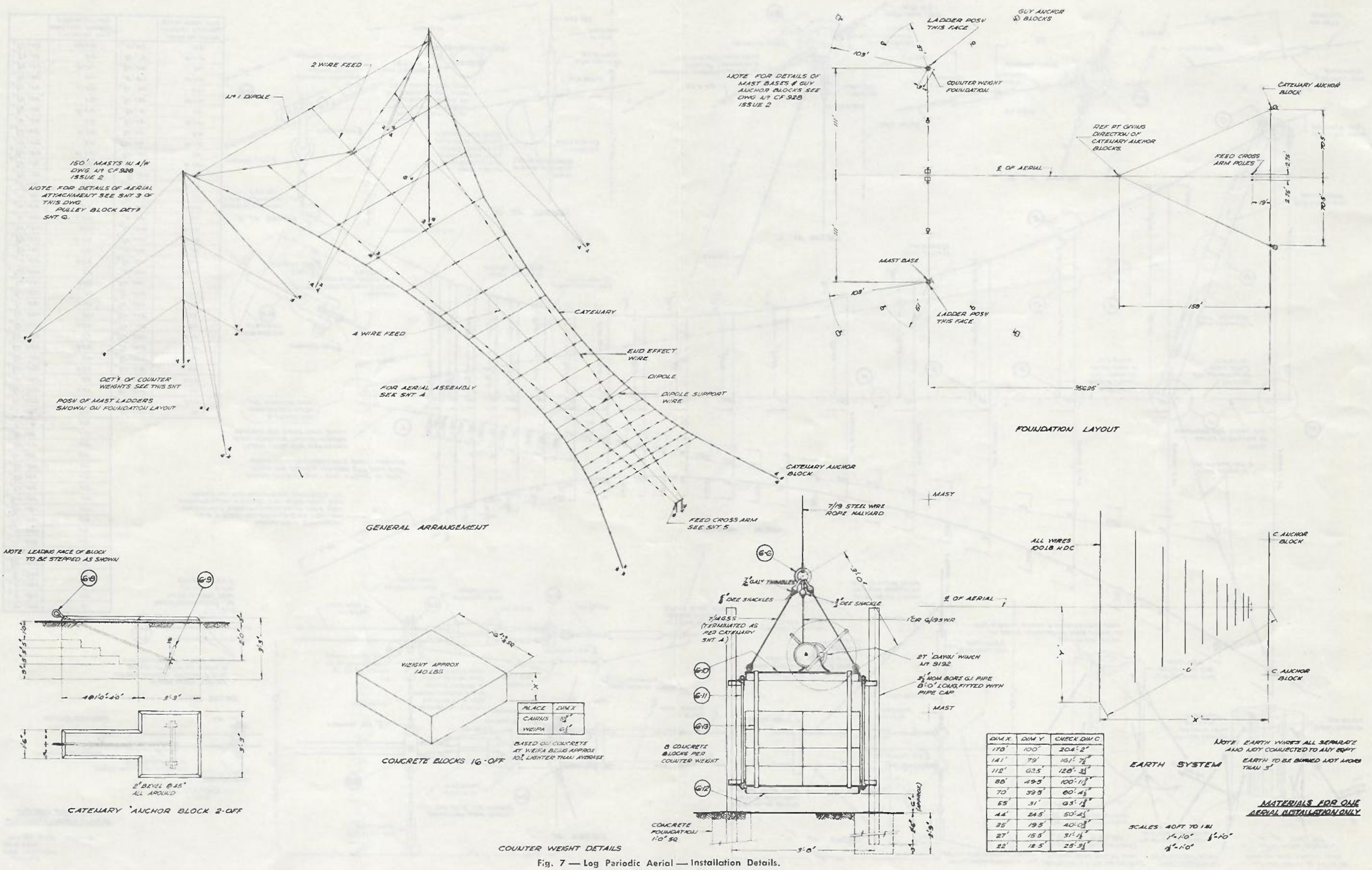
(27) Calculate $\sigma' = \frac{\sigma}{\sqrt{\tau}}$
In this case

$$\sigma' = \frac{0.1}{\sqrt{0.89}} = 0.106.$$



DIST. FROM FACE CONCRETE CATENARY BLOCK TO POINT		DIST. FROM HOLE EYEBOLT FEED CROSS ARM TO POINT	
18C	58'-0"	18E(19)	29'-3½"
17C18	61'-5½"	18E	32'-4¾"
17C	64'-10¾"	17E18	35'-5¾"
16C17	68'-9"	17E	38'-11½"
16C	72'-7½"	16E17	42'-5¼"
15C16	76'-11½"	16E	46'-4¼"
15C	81'-3½"	15E16	50'-3¼"
14C15	85-11½"	15E	54'-8"
14C	90'-7¼"	14E15	59'-0¾"
13C14	95'-10¾"	14E	64'-0"
13C	101'-2½"	13E14	68'-11¼"
12C13	107'-1¾"	13E	74'-5¾"
12C	113'-1¼"	12E13	80'-0¼"
11C12	119'-7¾"	12E	86'-3"
11C	126'-2½"	11E12	92'-6"
10C11	133'-5¾"	11E	99'-6"
10C	140'-9"	10E11	106'-6"
9C10	149'-0½"	10E	114'-4½"
9C10	157'-4¼"	9E10	122'-2¾"
8C9	166'-6"	9E	131'-0¾"
8C	175'-7½"	8E9	139'-11"
7C8	186'-3"	8E	149'-10¼"
7C	196'-10¼"	7E8	159'-9½"
6C7	208'-7¾"	7E	170'-11¼"
6C	220'-5½"	6E7	182'-1¼"
5C6	233'-10¾"	6E	194'-7¾"
5C	247'-4¼"	5E6	207'-2¼"
4C5	262'-10¾"	5E	221'-3¼"
4C	278'-5½"	4E5	235'-4½"
3C4	296'-2½"	4E	251'-2½"
3C	313'-11½"	3E4	267'-0½"
2C3	334'-5½"	3E	284'-10"
2C	354'-11½"	2E3	302'-7½"
1C2	379'-1¼"	2E	322'-7¼"
1C	403'-3"	1E2	342'-7"
		18F	31'-11½"
		17F	38'-5½"
		16F	45'-9¼"
		15F	53'-11½"
		14F	63'-2¼"
		13F	75'-6½"
		12F	85'-2¼"
		11F	98'-10½"
		10F	112'-11½"
		9F	129'-5½"
		8F	148'-0"
		7F	168'-10"
		6F	192'-3"
		5F	218'-6¾"
		4F	248'-1½"
		3F	281'-4"
		2F	318'-8"
		1F	347'-8"

Fig. 6 — Log Periodic Aerial — Fabrication Details.



PLACE	DIM X
CAIRNS	5¾"
WEIPA	6½"

DIM X	DIM Y	CHECK DIM C
178'	100'	204'-2"
141'	79'	161'-7½"
112'	63.5'	128'-3½"
88'	49.5'	100'-11½"
70'	39.5'	80'-4½"
55'	31'	63'-1½"
44'	24.5'	50'-4½"
35'	19.5'	40'-0½"
27'	15.5'	31'-1½"
22'	12.5'	25'-3½"

Fig. 7 — Log Periodic Aerial — Installation Details.

(28) Find the required relative characteristic impedance of the feeder $\frac{Z_0}{R_0}$ from $\frac{Z_a}{R_0}$ and σ' (Ref. 5, Fig. 16). Ascertain the maximum and minimum values of $\frac{Z_0}{R_0}$ and Z_0.

$$\text{Max } \frac{Z_0}{R_0} = 1.4$$
$$\text{Max } Z_0 = 280 \text{ ohms.}$$
$$\text{Min } \frac{Z_0}{R_0} = 1.3$$
$$\text{Min } Z_0 = 260 \text{ ohms.}$$

(29) Calculate mean feeder characteristic impedance.
Z_0 (av.) = 270 ohms.

PRACTICAL DESIGN

At this stage, the electrical design of the log periodic antenna is virtually complete and it is now necessary to consider the structural aspects of the design.

In the interests of economy, it is important to assess the extent to which the antenna and its supporting structure may be simplified without significant departure from the designed electrical performance.

Detailed plans of the log periodic antenna are shown in Fig. 6 and Fig. 7 and the practical considerations which led to the more important features of this design are discussed below.

Weight, Sag and Wind Deflection

Since a wire structure is used, sag is unavoidable, and all dipoles will not be co-planar. The variation, however, is a gradual and continuous function and since only part of the system is active at any one frequency, the aerial will be satisfactory if the extreme values of inclination are both acceptable. The normal sag at the centre of each dipole has an insignificant effect electrically on both pattern and impedance. Deflection by wind should not exceed the order of magnitude of sag.

However, the design should minimise sag and deflection by making all wires as **light** and as **short** as possible. This is also consistent with economy.

Catenary Structure

The dipole elements, of 7/0.036 hard drawn copper wire lightly tensioned, are supported inside an insulated catenary envelope comprising a pair of 7/14 galvanised steel strand wires, heavily tensioned. Each catenary, which sweeps in a smooth curve from its mast to its catenary anchor block in the ground, distributes the required horizontal tension to each lateral dipole element, through a catenary clamp as

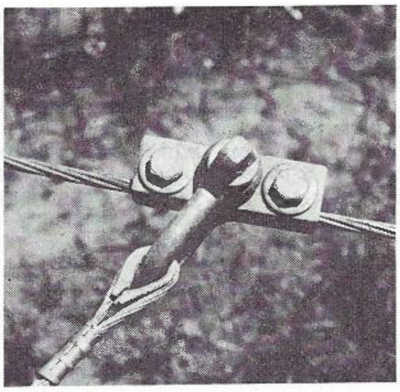


Fig. 8 — Catenary Clamp.

shown in Fig. 8. To maintain constant catenary tension, the top end of the catenary passes through a pulley at the top of the mast and drops vertically to a counterweight at the base of the mast. Fig. 9 shows a counterweight for one of the Weipa aerials. Small hand winches are fitted to the counterweight tops to raise and lower the array, a process which requires only a few minutes.

End-loading of Dipole Elements

The curve of the catenary, in satisfying the "resolution of forces" at each

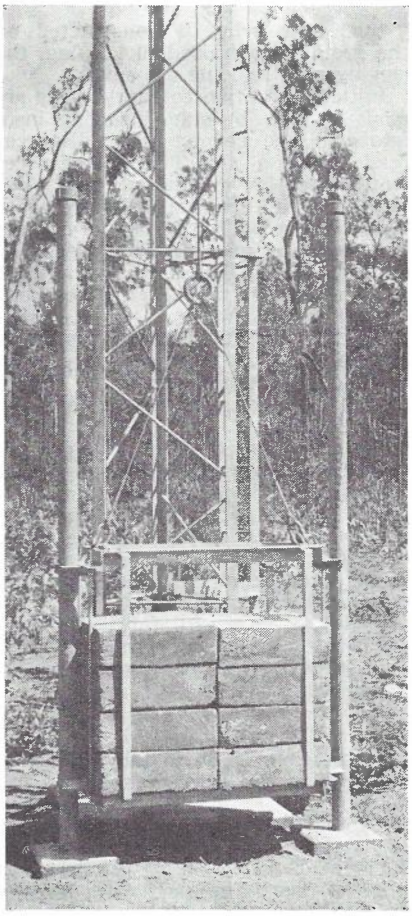


Fig. 9 — Counterweight — Weipa.

dipole attachment point, would move sideways away from the array at the mast top and at the ground and would be close to the array in the middle region. However, since the array is already diverging at an angle of 30.8 deg. as it moves upwards, the catenary would curve away rapidly to the side at the top, and it would be necessary to locate the masts much further apart than the half wave-length at the lowest frequency. This situation is undesirable, since, apart from the unreasonable demands made on site area, the additional wire length supporting the larger dipoles increases cost, sag and wind deflection and may necessitate heavier gauge wire and greater tensions, thus aggravating the problem.

A simple solution, which has proved effective, is to shorten the dipoles and restore the electrical length by balanced end loading. "End Effect" wires of 7/0.036 hard drawn copper are run from the top of the array to the ground in the plane of the array and are broken by insulators almost midway between dipoles. The dipoles connect to the centre points of these sections, forming a "T" shape. The "end effect" wire assists somewhat in supporting the array and strengthens and stabilises the array against changes in shape, due to wind disturbances.

In each side of the end loaded dipole, the 90 deg. electrical length is made up of 54 deg. straight section (radiating) and two 20 deg. half-T sections in opposite directions (radiation cancelling). This is based on the assumption of sinusoidal current and voltage distribution and the fact that 2 tan 20 deg. = tan 36 deg.

The effect of the "end-loading" on the electrical performance is considered below:—

(i) The far-field radiation from the two halves of the T will cancel in their broadside and end fire directions and almost fully cancel in all other directions due to their close proximity to one another. In any case, the current in each half is small.

(ii) Near field disturbance to the mutual coupling of aerial elements should be of a smaller magnitude than the variations in mutual coupling effects as the frequency passes through one interval τ.

(iii) Reduction in the feed-point radiation resistance of the resonant dipole is not very significant, since the individual dipoles are not matched to the feeder in any case. Hence the effect will be no different than a change in dipole characteristic impedance or feeder characteristic impedance, both of which have reasonable latitude in the original design. There would be no difference in the total power radiated.

(iv) The effect on the directivity of the dipole is smaller than might be expected. A half-wave dipole has a gain of 2.15 db above isotropic; a very short dipole has a gain of 1.76 db above isotropic, a reduction of 0.39 db. However, the end-loaded dipole cannot be classed as a "very short" dipole, so the reduction in directivity should not exceed about 0.2 db, which is insignificant.

Support of Centre Feeder

To maintain tension in the centre feeder, it is supported by insulated galvanised steel wires from the masts. Since dipole No. 1 is in the same vertical plane as the masts, the feeder support and tension is applied at the centre of dipole No. 2. The support wires are also used to terminate and tension the end effect wires; hence dipole No. 1 cannot be end-loaded. However, there is adequate space between the masts for the full length of dipole No. 1, so end loading is not required.

The feeder between dipole No. 1 and dipole No. 2 is of two-wire construction, with spreader insulators, since only small tension is available. The increase in feeder characteristic impedance in this section would have some effect at the low frequencies, but the truncation effects due to the necessary reflection of all energy not radiated by dipole No. 1 would probably be more serious. The terminating S/C stub recommended in the literature (Ref. 5) would improve the impedance at the low frequencies; however, the practical difficulties of supporting such a stub were considered to be greater than the advantages to be gained and no stub was fitted. It is also an advantage to have no metallic connection between the two sides of the feeder, as d.c. checks can then be made for short circuits on the feeder when required.

For simplicity, dipole No. 1 should be the highest and last part of the array. It therefore becomes the terminating element and could be tuned for optimum impedance performance at the low frequency extreme.

Transmission Line and Feeder Design

A 4-wire cross-connected (200 ohm) square transmission line using 70 lb. c.c. wire at $1\frac{1}{4}$ in. spacing was selected since the lowest practical impedance of a 2-wire line was rather high for this type of aerial.

The line was supported simply using insulators type 211/43 and suitable porcelain in-span spacers were also used.

The transmission line was carried up the array to the lowest dipole. At this point a transposition to side-connected line was made, which increased the nominal impedance to 240 ohms for the continuing feeder. This is somewhat less than the 270 ohms calculated for the feeder, but the impedance could not be controlled readily with the available insulators. Test results indicating the importance of this impedance transition will be discussed.

Both the array transmission line and the end-effect wires terminate on a "feed cross-arm," which is supported by two 8 ft. steel pipes. This cross-arm also acts as a point for change of direction of the transmission line to the transmitter building.

Insulation of Support Wires

As a general rule, support wires were broken by insulators, so that the largest electrical length was significantly smaller than the electrical length of any active conductors which radiated a field in that direction. It was found necessary to break the lateral support wires at the high frequency end of the array into small sections, and in particular, the insulators in the supports for dipoles 11, 12 and 13 were added after initial impedance measurements indicated a break from the usual cyclic behaviour due to parasitic resonances. Insulators were required less at the low frequency end of the array as the relatively large sections of support wires were not in the forward radiation of the high frequency active elements. The mast guys were not broken with insulators.

Assembly Method

Since the array is constructed on the ground and raised like a flag, the rigging requirements are small.

Initially, the two catenary wires are made up side by side, inserting insulators at the correct total distances read from a tape, with the wires strained to 1500 lb. several times prior to use. With the insulated wire again strained to 1500 lb. the catenary clamp positions are marked with pieces of adhesive tape. The catenary wires are then moved into their correct positions in plan, and fastened to the catenary anchors. Catenary clamps are fitted and dipoles and support wires are fabricated, commencing with dipole No. 18, and making rapid joints, using press-sleeves.

The end effect wires, which are initially fabricated separately, are fastened to the feed crossarm and then connected to the dipoles. The vee-support wire at the top of the array is fitted. The transmission line and feeder are assembled from the feed cross arm upwards.

Although successful fabrication depends on careful measurements, the work is simple and repetitive and rapid progress is possible.

Earth Mat

To ensure a good ground reflection, ten earth wires are buried just below the surface. The wires are provided on the basis of one earth wire for each two aerial wires and are located at the point of reflection for the designed angle of fire. The earth wire lengths also decrease logarithmically. The wires are not connected together or as an equipment earth, but merely serve to ensure the flow of some ground current, even if the ground has high resistivity.

Test Results

In general tests, the impedance of the log periodic aerial was measured at every quarter interval ($\tau = 0.89$) over the frequency range of all dipoles, using a General Radio Signal Generator, a Wayne-Kerr RF Bridge and a Racal RA17 Receiver.

While it was possible to plot the resultant values on a Smith Chart, the 18 cycles and about 70 points limited interpretation of the performance to a general impression of the V.S.W.R. limit. However, the susceptance values were relatively low and it was found to be more useful to plot conductance against a log frequency scale (which resulted in a linear scale of frequency intervals). These graphs are shown in Fig. 10.

The transmitter and receiver both operate at 75 ohms impedance. A building entry coaxial cable (75 ohms) connects the equipment to the terminal pole, where wideband transformers match the cable to the balanced open-wire line. The transformers were selected as 50 ohm to 150 ohm, this being the closest available to the desired ratio at the time. The correct secondary impedance for a 75 ohm primary would be 225 ohms. Accordingly, this impedance has been used as a reference on the graphs to assess the probable V.S.W.R. on the coaxial cable section. The Cairns and Weipa transmitting frequencies are marked (C) and (W) respectively.

The first graph indicates the impedance seen at the feed crossarm, when the original aerial used a cross-connected feeder throughout its length. This test was to ascertain the general order of performance at a time when no experience was available. The following observations were made:—

(i) The low frequency truncation resulted in large variation of impedance.

(ii) Dipole No. 1 was too long. This was partially corrected.

(iii) The cyclic variation was broken at a frequency corresponding to dipole No. 13. This was corrected by additional insulators in the support wires for dipoles 11, 12 and 13.

(iv) A slow variation of the curve indicated a dip at about 5 Mc/s, a return to the original value at 10 Mc/s and a large dip at about 15 Mc/s. This was recognised as the action of a short length of transmission line as respectively a quarter-wave, half-wave, and three-quarter wave transformer. The line length corresponded closely with the distance to the lowest dipole element, thus verifying the impedance change at the high frequency truncation.

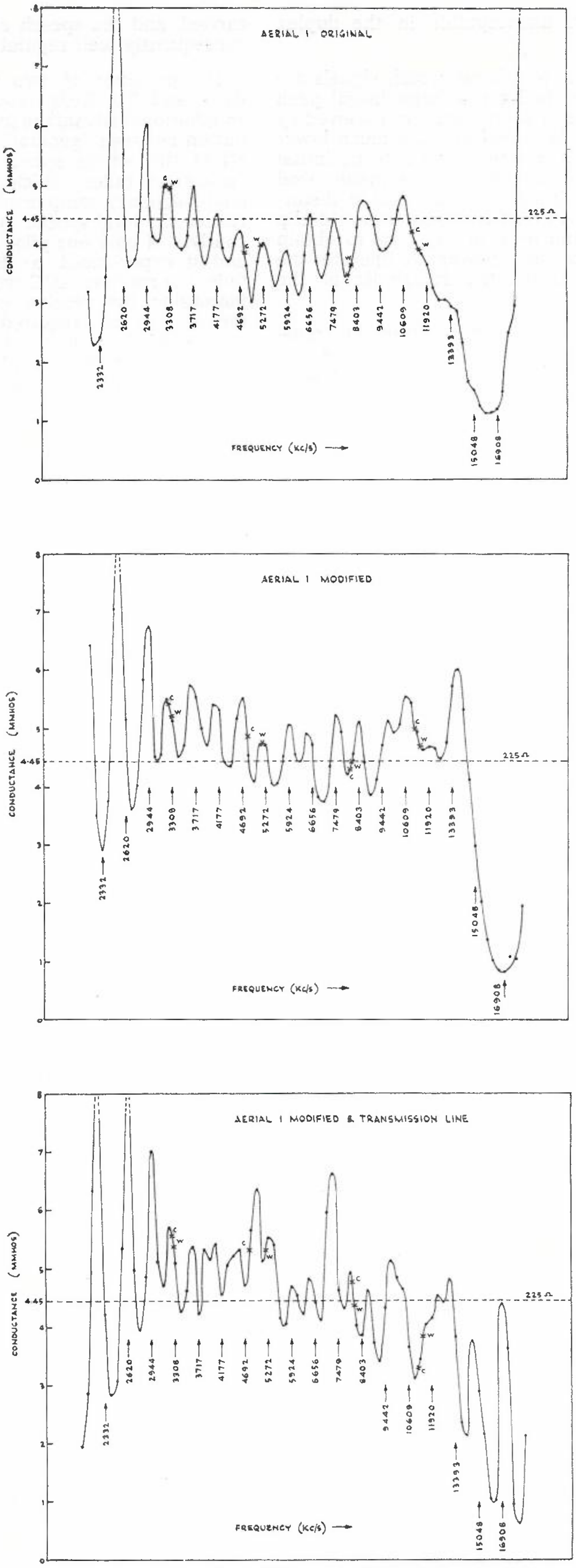


Fig. 10 — Aerial Frequency Response.

(v) The usable frequency range was 2.7 Mc/s to 12 Mc/s.

The feeder was transposed to the side-connected configuration at the lowest dipole, and the results are shown in the second graph. The following observations were made:—

(i) Dipole No. 1 was now closer to its correct length, but the region showing the effect of the truncation had moved slightly higher in frequency.

(ii) Good cyclic behaviour was noted generally.

(iii) The dip at 5 Mc/s had been reduced significantly, but not fully corrected. This agrees with the calculation of 270 ohms as the desirable feeder impedance.

(iv) The performance in the frequency range 11 Mc/s to 15 Mc/s was much improved.

(v) The usable frequency range was 2.7 Mc/s to 14 Mc/s.

The impedance response was then measured at the terminal pole, to include the whole open wire transmission line. The results are shown in the third graph:

(i) The curve exhibits more pronounced peaks due to the longer line performing alternately the quarter and half-wave transformations at more closely spaced frequencies, with the consequently greater probability of a peak in the aerial impedance being accentuated by a peak in the impedance transformation of the line.

(ii) The usable frequency range was 2.7 Mc/s to 14 Mc/s.

(iii) All Cairns and Weipa frequencies are well situated relative to the reference 225 ohms, thus providing low V.S.W.R. lines and relatively simple transmitter output tuning.

EQUIPMENT DESIGN AND OPERATION

The requirements of the overall system were outlined earlier. In the following descriptions of the main equipment items, some detail will be given of the methods used to satisfy these requirements.

Modulation System

When an audio signal is transmitted using amplitude modulation, the magnitude of the carrier is available as a reference level. Hence, an automatic gain control system at the receiver, sensitive to the variations in the carrier level due to fading, can correct the overall gain and recover the audio modulation at its correct level.

In single sideband modulation, the carrier is removed before transmission and any automatic gain control action at the receiver can only operate on the average level of received modulation and would require a fast attack time constant and a slow recovery. In the absence of received modulation, the receiver gain is at its maximum value, and the audio output consists entirely of exaggerated noise. Also, due to the AGC action, the gain of the system is high for small audio signals and low for large audio signals.

In many applications, the above features would not be undesirable. The noise during absences of modulation can be suppressed by muting or "squelch" circuits. Also, the compression action would tend to improve the uniformity of received audio levels from perhaps different transmitters. However, where a duplex telephone circuit is involved, incorporating hybrid coils, the essential requirement is constant gain and not constant received volume. Also, if noise can be suppressed by the AGC action, when audio modulation is being received, then it must be possible to suppress it for the remainder of the time, with a very noticeable improvement in apparent transmission quality to the subscriber.

Constant gain and suppressed noise can be achieved by the transmission of a "pilot tone" at the top end of the voice band (about 3 Kc/s). This tone, which controls the AGC of the receiver and maintains essentially constant overall gain despite fading of the RF signal, can be removed by a filter at the receiver audio output. While the instantaneous peaks of audio signal can equal or exceed such a pilot, the average power level in the audio will be considerably less and consequently the gain will not be affected by the audio level. Furthermore, the fast attack feature of the receiver will no longer be required and can, with advantage, be disconnected.

The SSB transmitter is designed to include a compression amplifier of high initial gain which is reduced suddenly when the modulation signal is sufficiently large to fully drive the transmitter. This "automatic level control," ALC, which may be desirable in other applications to ensure the transmission of full power at all times, is again unacceptable in the duplex circuit.

Typical telephone speech signals are observed to have a large initial peak envelope of short duration, followed by a decaying waveform at a much lower level. It is possible to clip the initial peak and limit it to a reasonable level without introducing noticeable distortion. (An SSB transmitter would clip this initial peak in any case to obtain the necessary power to operate the ALC bias for the remainder of the word.)

If the audio sensitivity of the transmitter is now adjusted so that the sum of an audio signal at this clipping level and the pilot at its desired relative level has an instantaneous maximum value which modulates the transmitter to just less than 100 per cent. and just fails to initiate the ALC compression action, then the transmitter will be a linear device and typical telephone signals will still modulate well.

The choice of the pilot level relative to the "clipping level" has some conflicting aspects and a compromise is necessary. If the pilot is too large, then there will be a reduction in the transmitted level of the audio modulation and this will reduce the signal to noise ratio at the receiver. On the other hand, the larger the pilot, the more constant the system gain and the greater the immunity to fades and hybrid ringing.

In the Cairns-Weipa system, there are additional considerations, since the pilot is used as a sub-carrier for the FSK machine telegraph system and an excessive relative speech clipping level would overload the telegraph system, resulting in errors. Experimentally, the ideal sharing of modulation depth was found to be:

Clipped speech peak, 50 per cent.

Telegraph 2.8 Kc/s FSK sub-carrier peak, 25 per cent.

Telegraph 3.0 Kc/s frequency reference peak, 25 per cent.

The total effective pilot is thus allocated a larger share of the modulation than if telegraph were not being carried, and the speech circuit gain is consequently well regulated.

The presence of two pilots at 2.8 Kc/s and 3.0 Kc/s respectively has an additional advantage in the differentiation between "general" fades, which affect the whole speech band, and "selective" fades, which affect individual frequency components, but do not reduce the total speech power signigicantly. If only one pilot were present and it experienced a deep selective fade, the receiver AGC would respond, increasing the receive gain when in fact it was not required. A second pilot 200 c/s removed is unlikely to experience a selective fade at the same time, so the pilot can only be affected a maximum of 3 db by the selective fading action.

Transmitter

A detailed description of the transmitter is outside the scope of this discussion, but a block schematic is shown in Fig. 11. The transmitter is a 500 watt Racal Type TA83C, with four switched channels and selection of either upper or lower sideband.

Lower sideband operation is used and the allocated frequencies of the four channels are in the region of 3, 5, 8 and 11 Mc/s for the four channels.

The SSB modulation is carried out at an Intermediate Frequency of 1.4 Mc/s regardless of channel and then translated to the channel frequency by modulation with the channel oscillator frequency. The Automatic Level Control (ALC) responds when an excessive grid signal appears at either the 50 watt power amplifier or the 500 watt power amplifier, and controls the gain at the 1.4 Mc/s I.F. amplifier.

At Weipa, a 50 watt standby transmitter. (Racal Type TA104C) is also provided.

The RF output is carried by a single 75 ohm coaxial cable to the terminal pole, where a Hatfield balun transformer is used to match to the open wire transmission line.

Receiver

The Racal RA222 transistorised receiver block schematic is shown in

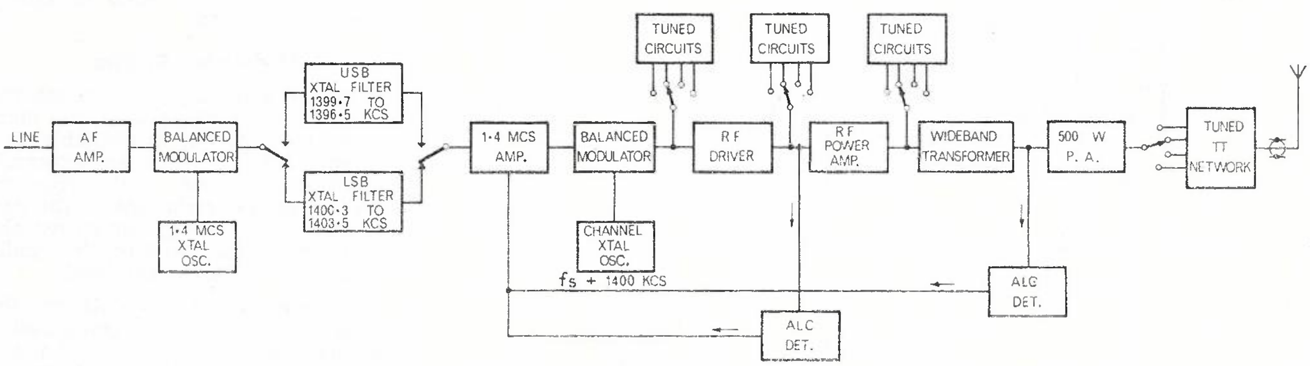


Fig. 11 — S.S.B. Transmitter — Block Diagram.

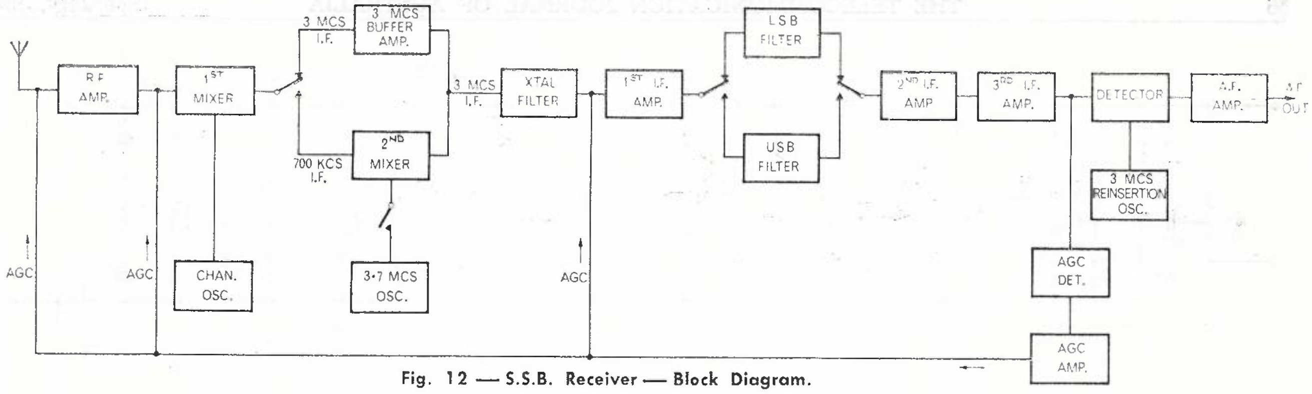


Fig. 12 — S.S.B. Receiver — Block Diagram.

Fig. 12. Switched channel selection is used with double conversion for frequencies below 7 Mc/s.

An amplified AGC signal controls the RF amplifier, the 1st mixer and the 1st IF Amplifier .

The receiver is fed by 75 ohm coaxial cable, using a Hatfield balun as for the transmitting line.

Telegraph Adaptor

One channel of a T.M.C. type T3B Telegraph Terminal Equipment is used. This unit is self-contained and connects direct to the teleprinter. It sends and receives the FSK tone at 2800 c/s ± 40 c/s, and contains the necessary filters to separate the telegraph tone from the speech. The Telegraph Correction Circuit and 3Kc/s Pilot Oscillator, which work in conjunction with the telegraph signals, are mounted adjacent to this unit and are connected to its 21 volt D.C. power supply .

Voice Terminating Equipment

The block schematic of the V.F. terminating unit is shown in Fig. 13. The operation of each function is considered below.

Speech from the exchange line or local rack telephone passes through the hybrid coil via a 3 db pad, which improves the hybrid balance. After mixing with Ring Tone, the signal is amplified in the Clipping Amplifier, which clips at + 12 dbm output.

The speech then passes through the telegraph filters where the two pilots are added before the composite signal is amplified and sent by line to the transmitter.

The signals from the receive line are separated by the telegraph filters. Speech passes through the low pass filter and continues through the hybrid to the exchange line.

Ring: When 17 c/s Ring is received on the line, the A relay operates and switches on the Ring oscillator, generating a 2200 c/s tone switched at 20 c/s.

Received Ring tone triggers the Ring Detector, which operates the B relay and connects the sub-cycle ringer to the exchange line for the duration of the received ring tone.

Telegraph Tones: The 2.8 Kc/s ± 40 c/s FSK tone and the 3.0 Kc/s frequency reference pilot are mixed and sent to line through the high pass filter.

The received pilot tones may have experienced frequency translation. Both pass to the Telegraph Correction Unit, where their difference frequency is extracted and re-modulated with the local 3.0 Kc/s oscillator thus producing new tones, both carrying the FSK information, at 2.8 Kc/s and 3.2 Kc/s respectively. The 2.8 Kc/s tone is decoded by the Telegraph Adaptor, while the 3.2 Kc/s tone is filtered out.

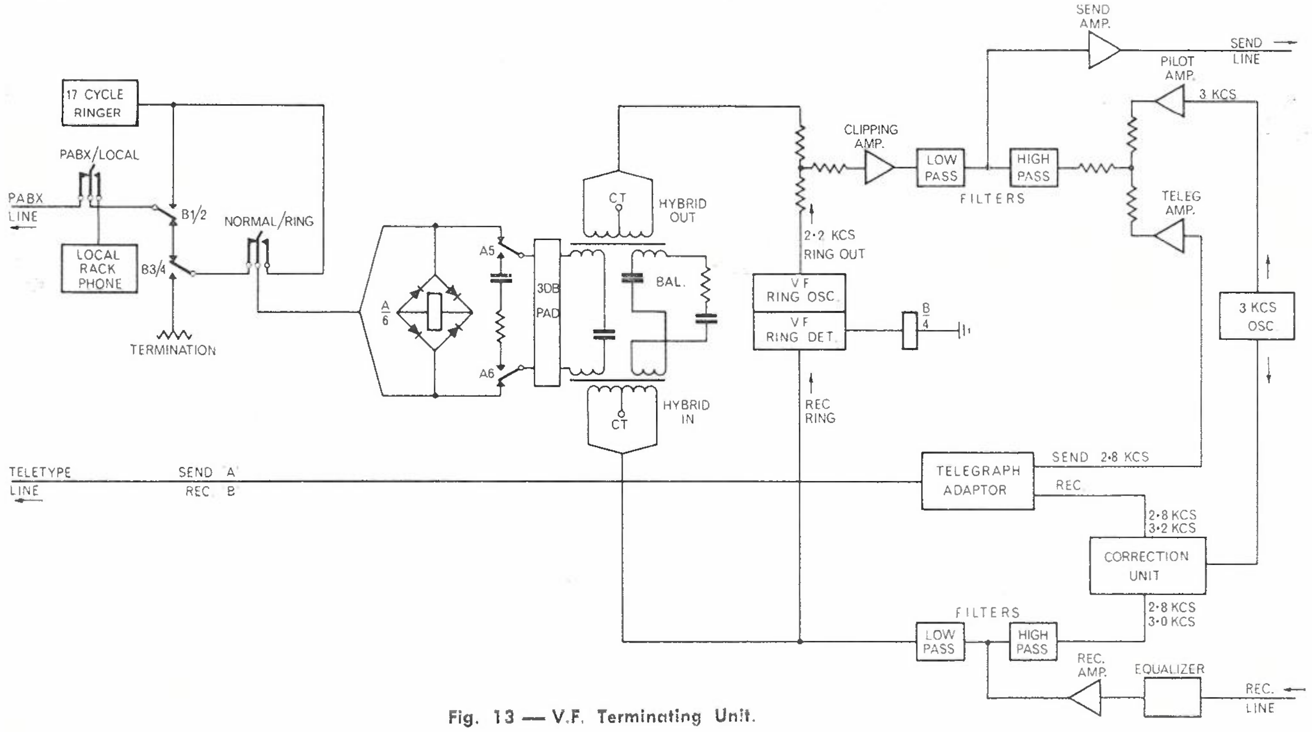


Fig. 13 — V.F. Terminating Unit.

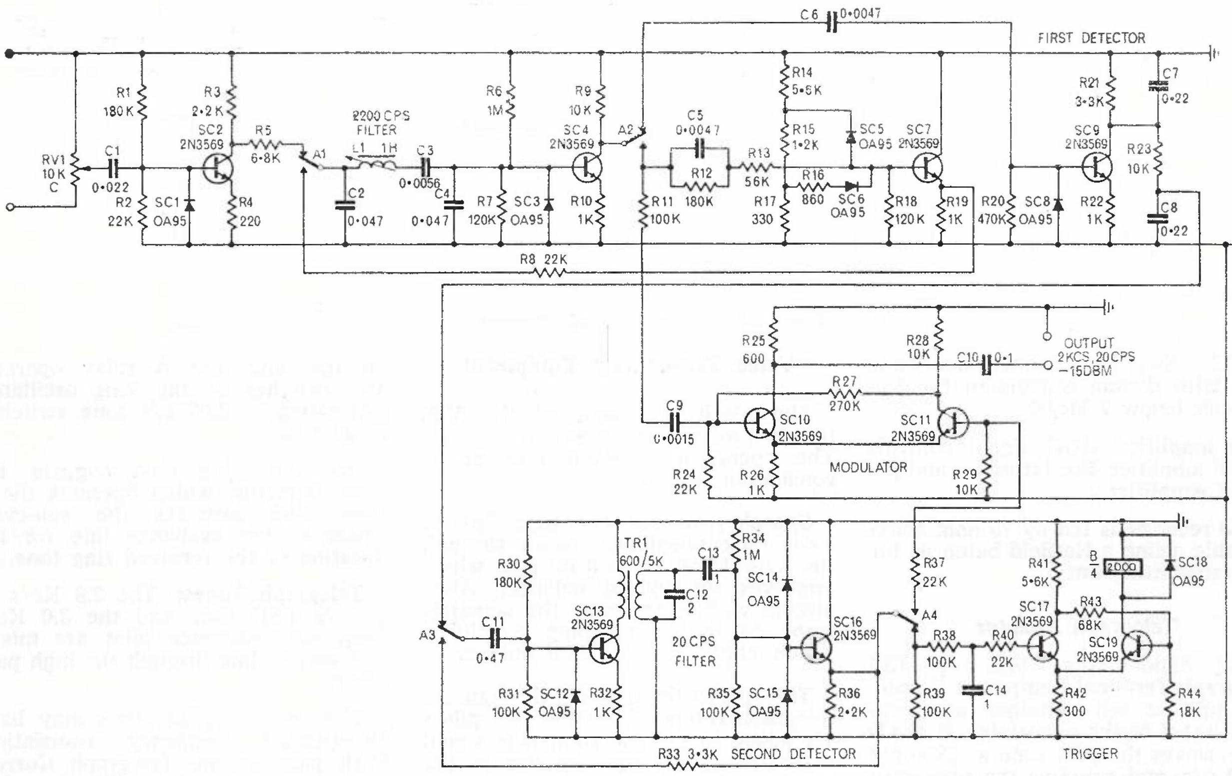


Fig. 14 — V.F. Ringer Oscillator Detector.

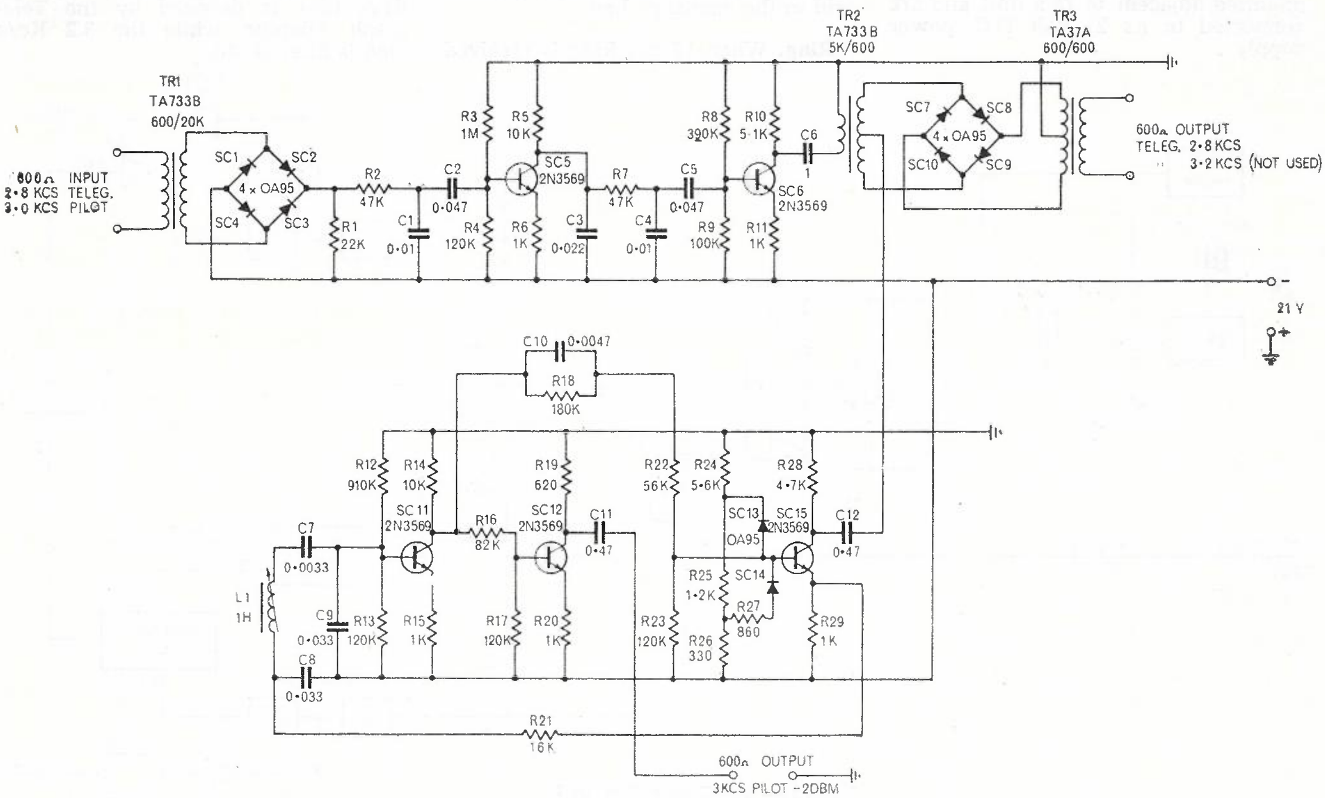


Fig. 15 — Telegraph Correction Circuit.

V.F. Signalling Unit

The V.F. Ringer Oscillator Detector incorporates guard circuits with greater immunity to false operation than usual in view of the severe radio interference experienced at times in the short-wave band.

The circuit, shown in Fig. 14, is fully transistorised, using the 2N3569 exclusively, for ease of maintenance.

Normally the circuit rests in the Detector condition. The sensitivity of the detector is adjusted by RV1 to give reliable operation.

After the buffer amplifier SC2, the signal passes through a narrow band filter tuned to 2200 c/s and a second buffer amplifier SC4. Diode SC8 functions as the 1st Detector and provides a bias for ampifier SC9 proportional to the 2200 c/s amplitude. The carrier frequency is removed by a two-stage RC low pass filter, leaving the 20 c/s component, which passes through the tuned amplifier SC12 to the 2nd detector comprising diodes SC14 and SC15 and transistor SC16. When the base signal passes a threshold voltage, the d.c. emitter voltage of SC16 increases linearly until it saturates at 11 volts. The 20 c/s component is removed by a low pass filter and the d.c. signal is used to operate a Schmitt trigger, which releases the B relay and applies ringing current to the exchange line.

When the A relay is operated by incoming ringing current, relay contacts rearrange the circuit to convert the 2200 c/s and 20 c/s filters to oscillators at their respective frequencies and to gate the 2200 c/s with the 20 c/s in the Schmitt trigger modulator, comprising SC10 and SC11.

Telegraph Correction Circuit

The Telegraph Correction circuit, which also uses the 2N3569 transistor, is shown in Fig. 15.

The received 2.8 Kc/s ± 40 c/s and 3.0 Kc/s tones are mixed in a bridge rectifier giving an output of 200 c/s ± 40 c/s after smoothing. This 160 c/s or ; 40 c/s signal is amplified and fed to a ring modulator gated by the local 3 Kc/s oscillator.

The 2.8 Kc/s ± 40 c/s component in the output signal is accurately matched to the local telegraph discriminator. During the development of the correction circuit, it was found experimentally that the circuit could correct varying frequency translations up to about 1000 c/s without error on a teleprinter.

The telegraph system is accurately synchronised when the transmitted beat frequency equals the received beat frequency. This can be simply checked and adjusted at either terminal by displaying the received 200 c/s ± 40 c/s on the X plates of a CRO and the outgoing mixed pilots on the Y plates. The resultant pattern is an obliquely truncated rotating vertical cylinder, which stops rotating when the local 3 Kc/s oscillator is adjusted to produce the synchronous condition.

The 3 Kc/s oscillator is designed to have good frequency stability and constant level. The frequency-determining circuit is loosely coupled to the transistor circuits preceding and following. SC11 is a buffer amplifier which provides signal and bias for both the output stage SC12 and the limiter stage SC15.

The signal is symmetrically clipped by diodes SC13 and SC14, which act also with capacitor C10 to ensure accurate centring of the waveform between the clipping diodes. Amplifier SC15 provides the constant level signal for return through the tuned circuit and also the gating signal for the correction circuit ring modulator.

CONCLUSION

The successful transmission of telephony and machine telegraphy on a single high frequency link between Cairns and Weipa was achieved using some departures from the conventional methods.

The linear system, the gain-regulating pilot, the frequency reference pilot, the V.F. signalling circuit and the telegraph correction circuit combined to overcome some of the problems of conventional high frequency links. The log periodic aerial, developed for this project, proved to be successful and well suited to this application.

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AUTOMATIC DISTURBANCE RECORDING (A.D.R.) EQUIPMENT FOR CROSSBAR EXCHANGES

A. D. PETTERSSON, A.M.I.E.Aust.*

INTRODUCTION.

This article describes a novel supervisory system, known as Automatic Disturbance Recording (A.D.R.) Equipment, developed by the Australian Post Office for the control and supervision of crossbar exchanges. A.D.R. equipment converts the comprehensive supervisory information generated in crossbar exchanges to a form suitable for telemetering, and transmits this information to any desired location. The first exchange completely equipped with A.D.R. equipment was brought into service at Ingleburn, N.S.W., in December, 1965. Ingleburn, a non-staffed 1600 line ARF 102 crossbar exchange, is situated on the periphery of the Sydney ELSA area and the supervisory information is telemetered to control and analysis centres in Sydney, some 27 miles distant. Telemetering and exchange control is performed, using a standard 50 baud telegraph channel.

PRESENT SUPERVISORY EQUIPMENT.

ARF10 crossbar exchange equipment has now been in service in Australia for about six years and the present supervisory equipment and maintenance practices are described in the June, 1964, issue of the *Journal* (Refs. 1, 2). These maintenance practices are governed largely by the inherent characteristics of the crossbar equipment and by the supervisory equipment provided. The ARF supervisory equipment is designed to record and indicate fairly comprehensively the performance of the exchange equipment. This information is made available to a central point in the exchange, normally the maintenance control room, where it is recorded or indicated by means of audible and visual alarms and meters. Additional supervisory devices are available for connection to units of the exchange equipment to facilitate fault localisation activities, and more sophisticated items such as multi-pen recorders may be used for locating the more obscure faults. Very satisfactory equipment performance level, and low maintenance costs, can be achieved, using the present standard supervisory equipment.

In recent years various manufacturers and administrations have introduced printed or punched card records for recording equipment defects or disturbances in common control switching equipment. The Pentaconta exchange installed at Kew, Victoria, employs a punched card disturbance recording supervisory system, and a "Centralograph" printed record system. is employed in L. M. Ericsson's ARM exchanges, which are now being installed in Australia. Both of these systems represent significant advances in the supervisory field. The Pentaconta supervisory system is attractive as standard cards, suitable for machine processing, are employed. The cost of these processing machines, however, is such that they must be centralised and hence the cards have to be physically transferred from the exchange to a processing centre. The Centralograph system does not permit machine processing of the supervisory system.

THE CONCEPT OF AN IMPROVED SUPERVISORY SYSTEM.

The Australian telephone network contains a large number of small crossbar exchanges up to about 3000 or 4000 lines, as well as a few larger exchanges. Many of these smaller installations are extensions of existing step by step exchanges. Maintenance of small crossbar installations presents some difficulties due to the small work loads involved, and the complexity of the equipment. This equipment can be maintained either by staffing each installation or alternatively by using centralised staff to maintain a group of exchanges. The first alternative was adopted initially and necessitated the training of large numbers of men in crossbar switching techniques. The alternative solution, that of providing a centralised group of adequately trained men to whom all the available crossbar maintenance experience is given, is much more attractive due to the substantially smaller number of men required, reduced training costs, and centralisation of expensive test equipment. This smaller group of men would be expected to become specialists in the crossbar maintenance field due to the extensive experience they would acquire.

Operating experience has shown that the main costs in maintaining crossbar equipment are those incurred in supervising the performance of the equipment and determining the location of the fault when a defect occurs. Actual repair costs, that is, the labour and material costs involved in repairing or replacing the component that has failed, are insignificant, representing only a few cents compared to each dollar spent on supervisory and fault localisation work. Under these conditions it is obvious that substantially lower maintenance costs will be attainable only if both the cost of supervising the performance of the switching equipment, and the difficulty (and hence the cost) of fault localisation work be materially reduced.

Crossbar supervisory information may be classified into two broad categories:

(i) Urgent supervisory information that requires immediate or early attention by exchange maintenance staff;

(ii) Non urgent supervisory information which indicates minor equipment defects. By definition this class of information need not be handled speedily and in many instances is of little or no practical value unless accumulated over a period of time.

Urgent supervisory information comprises certain power fault alarm conditions, alarm indications of the malfunctioning of particular elements or components, and detections of the abnormal number of "time-outs" that occur in the common control equipment when a major fault occurs. Time-out is the forced release of an item of common control equipment due to its inability to handle a connection within the permitted time interval. This facility is essential in any common control system to ensure that a connection failure does not permanently hold up the common equipment.

The non-urgent supervising information includes such items as the occupancy of various units of equipment, minor blocking conditions, and the quite small number of time outs that occur in the common control equipment when only minor defects exist.

The two types of supervisory information should preferably be handled differently. The first category must be promptly reported to the maintenance staff so that remedial action may be initiated quickly. It would be desirable for the second category of supervisory information to be extracted without any effort by the maintenance staff, and then accumulated for future analysis as required.

In view of the above considerations, it appears that an improved supervisory system should provide the following possibilities:—

(i) Automatic extraction of supervisory information;

(ii) Sorting of the information into urgent and non-urgent categories and direction of the sorted information to different destinations;

(iii) Permit the supervisory information to be telemetered to any desired locations, either within the exchange or to centralised outside locations;

(iv) Sensitivity, in order to quickly detect minor equipment failures;

(v) Provide comprehensive information to facilitate the location of faults;

(vi) Present the supervisory information in a form suitable for machine processing.

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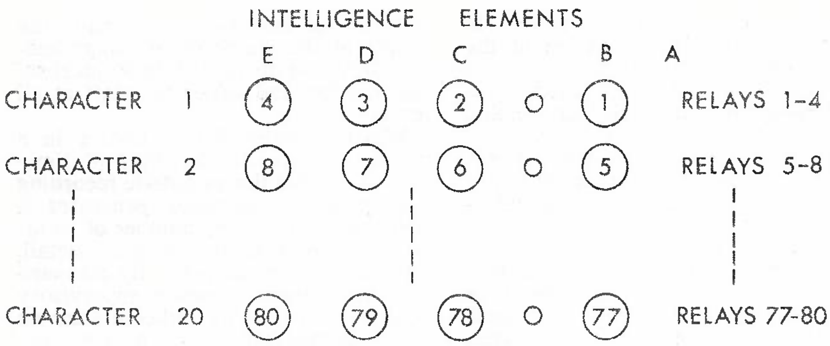

Fig. 1. — Allocation of 80 Relays to 20 Telegraph Characters.

THE HAYMARKET EXPERIMENT.

Towards the end of 1964 an experiment was conducted at the large Haymarket (Sydney), ARF102 m = 10 installation to ascertain the reason for each time-out that occurred in the various types of markers employed. At the time it was not known whether these time-outs were due to the existence of faulty components, inherent in the system due to subscriber action, or caused by some other factors, such as design weaknesses, or inter-working problems. It was also desired to ascertain the feasibility of locating faults by performing a detailed analysis of the state of the common control equipment at the instant of time-out. Some experience in this latter field had already been obtained from the use of L. M. Ericsson's 10 lamp lampset equipment and the A.P.O. developed 30 lamp lampset. The lampset is a maintenance aid comprising a series of relays actuated as slaves of significant relays in the marker to which it is connected. If the connection being handled by the marker is completed satisfactorily, the slave relays are released, but if the connection attempt fails these relays hold and a lamp display indicates which relays in the marker had been operated prior to the instant that time-out occurred.

An equivalent of an automatic lamp set with the capacity for recording the state of up to 80 relays in a marker was developed for the Haymarket experiment, utilising high-speed tape perforating equipment. Each time a time-out occurred, the recording equipment was called in, and a series of holes punched on the recording tape to record which of the 80 relays being monitored in the marker was, at that instant, operated. The recording took the form of twenty machine telegraph characters, each character representing the state of four of the relays. The allocation of the 80 relays over the twenty telegraph characters is shown in Fig. 1, where it will be seen that only the intelligence elements B to E are employed for recording purposes.

As there are sixteen different combinations of four, two condition elements, the four relays can generate 16 of the possible 32 telegraph characters. Three of the possible combinations, namely, mark on intelligence element 2, 3 or 4 only, with spaces on all other intelligence elements represent the functional telegraph characters, line feed, space and carriage return respectively. As the recording of these characters in the text of a message would prevent intelligent print-outs on page printing equipment, these unwanted characters were suppressed by using the first intelligence element in the telegraph signal as a "parity" element which was inserted whenever the particular combination of relays which existed would otherwise result in the formation of a functional character. In A.D.R. equipment this is done by electronically reading the character prior to its transmission and inserting the parity element if a mark is read on less than two of the intelligence elements two to five. The character combinations for line feed, space, carriage return, letter T and blank are then translated to letters A, S, D, Z and E respectively. The state of 80 relays can thus be recorded in the form of twenty alphabetical telegraph characters. To facilitate interpretation these twenty letters are recorded as five, four-letter words.

An example of the allocation of the relay recording contacts in a GIV (incoming group selector stage) marker is shown in Fig. 2. It will be seen that the allocation has been made in the following order:—

(i) Inlet identity—first word.
(ii) Overall state of the code receiver—6th letter.
(iii) Received digits—7th to 10th letters.
(iv) Overall state of the marker—3rd word.
(v) Outlets selected—4th word.

Analysis of the data collected during the Haymarket experiment revealed that obvious patterns existed within the print-outs. Repetitive identical or similar print-outs occur because development of a fault in a marker causes connection attempts to fail at a particular stage of its sequence of operation. Each resultant print-out must therefore display this common factor. For example, if time-out only occurs when a particular inlet is used, every print-out will have an identical first word. If time-out occurs only on calls to a particular route, the 7th to 10th letters, which record the digits received, will be identical in every print-out. The preliminary analysis of this information, therefore, involves recognition of the similarities (or pattern) that exist in a group of print-outs.

Once a pattern is detected, further analysis is performed by converting the coded information into the relay designations for the particular marker, using the type of table shown in Fig. 2. An analysis of this information will show at what stage failure is occurring. For example, consider the following print-outs received from KMR1 (Code Receiver 1) when working to GVM1 (GV Marker 1). No print-outs were received from KMR2, or when GVM2 is being used. The relay allocations shown in Fig. 2 refer. The letters E, representing the condition where none of the group of four relays were in the operated condition, have been replaced by a stop symbol to facilitate pattern recognition.

.AA. .	LI. . Z	C.SI.	. . . . .
D.S. .	LN. . Z	C.SI.	. . . . .
Z. . .Z	LZA.Z	C.SI.	. . . . .

The pattern, C.SI., is obvious. We now have the following information:—

(i) Only calls from KMR1 to GVM1 are subject to failure.
(ii) The differing first words show that calls from different inlets fail.
(iii) The sixth letter, L, which is repeated in all the print-outs, shows that failure is occurring with significant relays BB and WK3 only operated.

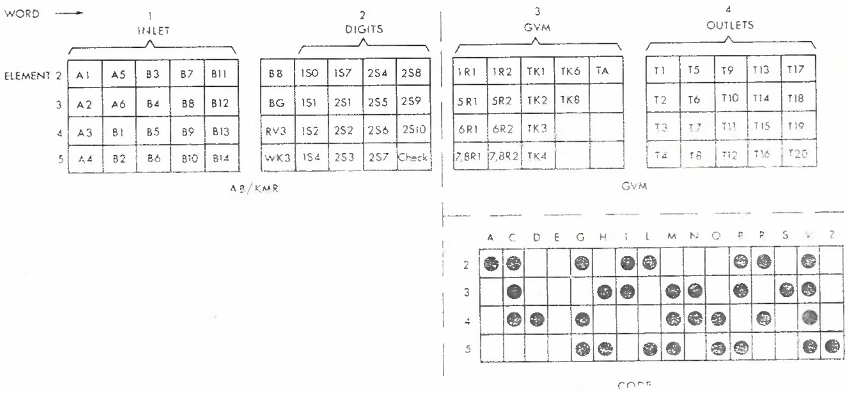

Fig. 2. — Allocation of Recording Contacts 1/80 GVM.

(iv) The seventh to tenth letters vary in each print-out, showing that the fault is not restricted to calls to any particular route.

(v) The third word, C.SI., shows that at time-out, relays 1R1, 5R1, 6R1, TK2, TK6, and TK8 only are operated. It is noted, from knowledge of the circuit operation, that relay TK1 should have been operated.

We may therefore conclude that as relay TK1 in GVM1 operates normally to KMR2, and that as both KMR's function normally into GVM2 that the fault must lie in the section of the operate path of relay TK1 in GVM1 that is peculiar to KMR1. Inspection showed the presence of a dry joint on spring tag 23 of relay 2R1.

The exactness of fault locating using this approach depends to some extent upon the type of fault that exists. In many cases the exact location of the fault, even down to particular wires or relay contacts, can be deduced. In other cases only the faulty sub-section can be determined. In some cases of time-outs, the marker itself is not faulty, but is being disturbed by faulty equipment which is required to inter-work with it, e.g., registers, code senders, etc. These cases can be recognised from the type of failures that occur and their distribution over all or groups of the inlets. The exactness of fault localisation is also, of course, dependent upon the skill and experience of the person performing the analysis. It is desirable therefore that this work should be highly centralised and performed by experienced crossbar staff possessing good circuit knowledge. This specialisation, however, is not essential, as basically the supply of this much more comprehensive information makes fault localisation quicker and easier for staff at all levels.

When a major defect occurs in a marker, substantial numbers of time-outs occur and the automatic recording system being described generates a correspondingly large number of print-outs, which describe, in great detail, the state of the marker. By comparison, the present standard supervisory equipment will only indicate that an abnormal number of time-outs has occurred.

When only minor defects or intermittent faults exist, only comparatively small numbers of time-outs occur. The present standard supervisory equipment records, on a meter, only the occurrence of each time-out. These

TABLE 1: HAYMARKET EXCHANGE TIME-OUTS

SLM/S 3000 GP TIME-OUTS

Unit	Week	Without ADR Supervision August 1964 SLM1 O/G	SLM1 I/C	SLM2 O/G	SLM2 I/C	With ADR Supervision SLM1 Only September 1965 SLM1 O/G	SLM1 I/C	SLM2 O/G	SLM2 I/C
SLM/S 3000 GP	1	218	31	252	30	316	0	423	12
	2	321	24	362	25	330	0	345	41
	3	362	46	388	30	334	8	503	10
	4	388	36	395	40	514	0	630	15
	Mth	1289	137	1397	125	1494	8	1901	78

2/160 AND 1/80 GROUP SELECTOR TIME-OUTS

Unit	Week	Without ADR Supervision August 1964 XY	KMR1	KMR2	With ADR Supervision September 1965 XY	KMR1	KMR2
2/160 1 GV	1	32	41	47	25	10	5
	2	20	67	95	24	44	45
	3	33	37	34	26	11	7
	4	41	41	53	28	6	6
	Mth	126	186	229	103	71	63
2/160	1	18	44	*	27	7	*
	2	33	47		27	4	
	3	27	90		30	5	
	4	42	107		36	9	
	Mth	120	288		120	25	
1/80	1		46	86		10	10
	2		158	254		19	12
	3		30	47		17	8
	4		42	80		11	9
	Mth		276	467		57	39

* Not Installed

minor disturbances are normally tolerated, as the effect on traffic is small, and the cost of locating the defects is normally prohibitive. With automatic recording equipment a detailed history of each disturbance that occurs can be accumulated, until such time that sufficient information is available to enable the cause of the defect to be located. This method is a particularly valuable one, and in fact the only practical method, of localising intermittent defects before they deteriorate into major defects. Time-outs can be virtually eliminated from crossbar exchanges using this method of supervision and fault localisation.

The efficacy of this more sophisticated method of supervision can be seen from Table 1, which shows the number of time-outs recorded in various markers at Haymarket prior to and some time after, the provision of automatic recording equipment.

The marked reduction in the number of time-outs represents a substantial improvement in the performance of the units. This improved performance arises from the fact that when faults occur, they are detected more quickly, and rectified with less effort and delay, than is possible with the present type of supervisory equipment.

The time-out information shown for the SLM/S stage is of added interest as automatic recording equipment was installed on one only of the two markers in the 1000 group, the second marker being supervised by standard equipment. The performance of the two identical markers can therefore be compared, one with the other, both before and after the provision of the automatic recording equipment to SLM1. It will be seen that in August, 1964, both markers had very similar performances. In September, 1965, outgoing time-outs in both markers had increased, but SLM2 substantially more than SLM1. The majority of these time-outs were due to register congestion and there was a substantial traffic increase in the period. Time-outs on incoming traffic have been virtually eliminated from the unit supervised with automatic recording equipment and there has been a marked reduction in the time-outs of the other unit. This latter reduction can be mainly attributed to the detection, and removal from service, of faulty equipment ahead of the SL markers, which affect the operation of both the markers. Provision of automatic recording equipment on one only of each type of marker at Haymarket has enabled many faults that affect other markers in the exchange to be removed and consequently there has been a marked reduction in the total number of time-outs recorded in the whole exchange.

The following conclusions were reached from the Haymarket experiment:—

(i) With the exception of some of the SL outgoing time-outs, every time-out in a crossbar exchange appears to be due to an assignable fault condition.

(ii) Fault location work is made substantially easier if more comprehensive supervisory information is available.

(iii) The "background" level of time-outs can be reduced to such an extent that even minor disturbances can be readily detected.

(iv) Faults, including design defects, which are not detectable with the present supervisory equipment or service indicators, are readily evident and may be located with automatic disturbance recording equipment.

(v) The performance of the plant could be improved, and maintenance costs substantially reduced, by the provision of a more sophisticated supervisory system. The cost of the improved supervisory system would be only marginally greater than that of the present system.

(vi) It is desirable to automatise and centralise the supervision of crossbar exchanges. If this is done, maintenance costs would be drastically reduced.

(vii) Non-urgent and urgent supervisory information should be segregated. Urgent supervisory information must be directed to ensure that early remedial action may be initiated. On the other hand, as the time spent recording and analysing supervisory information that does not warrant corrective action is wasted,

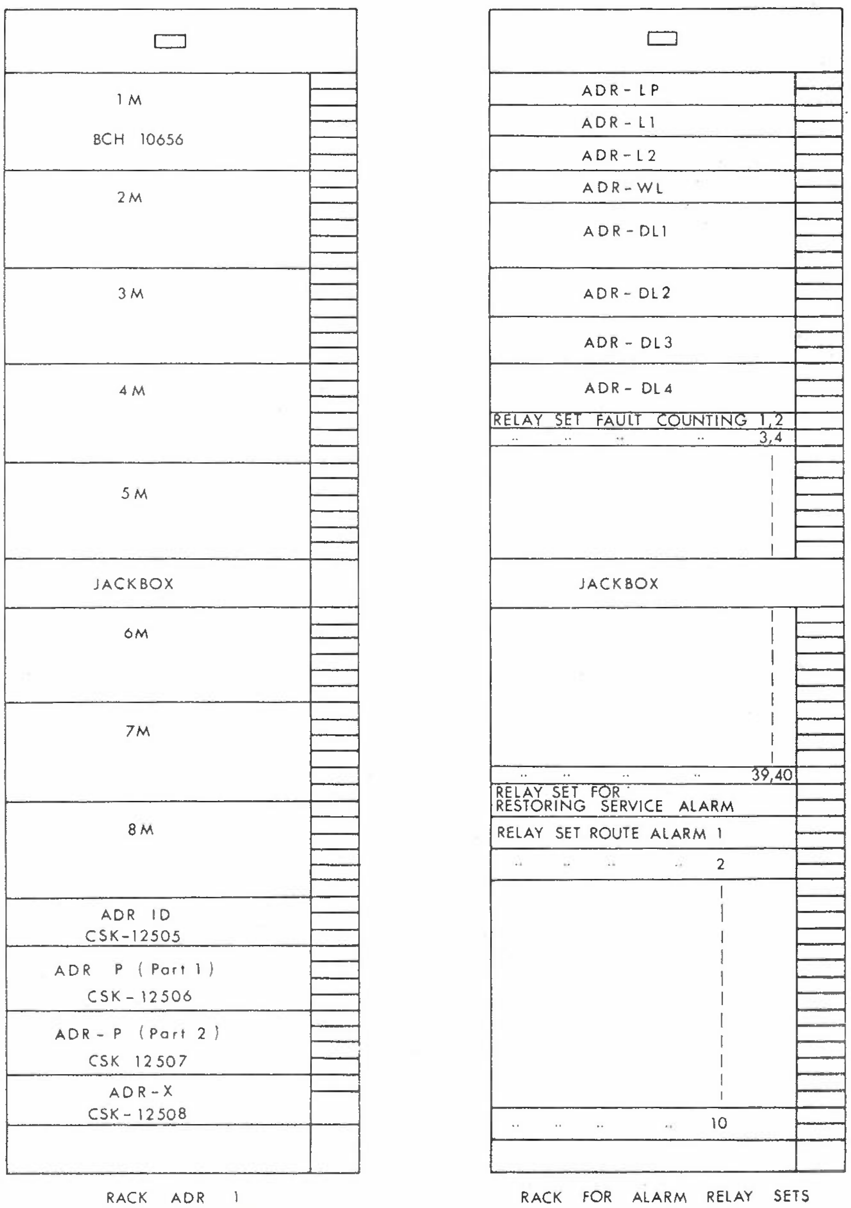

Fig. 3. — ADR Racks.

this information should not be made available to maintenance staff. It should be accumulated and processed automatically until sufficient information is available to permit economic removal of the fault conditions.

A.D.R. EQUIPMENT.

ADR equipment is a supervisory system developed to provide the special facilities proved desirable by previous operational experience, and the conclusions reached from the Haymarket experiment. This supervisory system has been designed as an "add on" system, utilising the comprehensive supervisory information already generated within the ARF102 equipment. Being an add-on system, ADR equipment may be readily applied to the supervision of other types of common control systems.

ADR equipment provides the following facilities:—

(i) Interface equipment for conversion of the supervisory information to a form suitable for telemetering.

(ii) Storage and control units to handle the transmission of the information.

(iii) The ability to decide the degree of urgency of the supervisory information, and consequently the routing destination for each supervisory message.

(iv) Telemetry transmission and reception equipment for transmitting supervisory information from the exchange equipment to any desired locations, and for the reception of operational commands which may be used for control functions.

(v) Supervisory messages are transmitted in a form suitable for machine, including computer, processing.

Telemetry takes place over a standard 50-baud double-current telegraph channel. An electronic telegraph transmitter / receiver is employed at the crossbar exchange end of the circuit and standard page printing and tape perforating equipment is used for message reception and storage. Networks of ADR supervised exchanges may be established reporting to, and controlled by, one or more maintenance control and analysis centres. An auxiliary auto telex exchange, system ADX, is employed for the switching and concentration of this supervisory traffic.

The ADR equipment is mounted on two standard racks, type BCH161. Rack ADR 1 contains the mandatory common equipment comprising an identifier, control relay sets and electronic telegraph transmitter / receiver, and up to eight connecting relay sets for the automatic "80 lamp lampset" facility. In very large installations an auxiliary rack, Rack ADR2, may be required to connect the lampset facility to the large number of markers involved. The second rack, Rack for Alarm Relay Sets, houses the interfaces required to convert the form of the present alarm supervisory information to a form suitable for telemetering. This rack also houses the normal service alarm, route alarm and restoring service alarm relay sets, and replaces the miscellaneous rack normally used for this purpose. The layout of the two basic racks is shown in Fig. 3; Figs. 4 and 5 are surveys of the system, showing the exchange end equipment and a typical supervisory network layout.

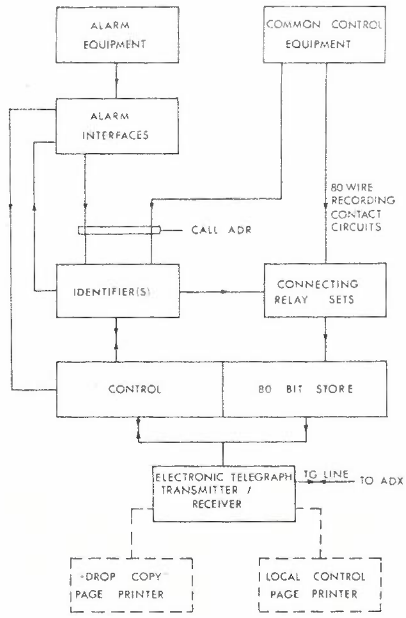

Fig. 4. — ADR Equipment—Exchange Equipment Survey.

Equipment Operation.

The operation of the equipment is best described by considering the function of the various relay sets.

Relay Set ADR-ID comprises a 100 line, storage type, one wire identifier. When called by a supervisory unit it identifies the calling unit and then calls the control relay set ADR-P. ADR-P can handle calls from two identifiers, thus providing a maximum capacity for telemetering information from 200 supervisory units. Each supervisory unit is allocated a unique identification number and relay set ADR-ID stores, for future transmission, the hundreds, tens and units digits of the calling supervisory unit. ADR-ID also directs the control relay set as to the type of print-out that is required, and the routing information for switching the message to the required destination. In addition ADR-ID couples the calling supervisory unit to the control relay set for information storage and/or transmission.

Relay Set ADR-P is divided into two sections. Part 2 contains the 80 bit relay store. which, on calls from markers. records the state of the recording contacts: a twelve unit stepping chain and a diode matrix for the development of various telegraph characters. Part 1 contains the remaining control functions. When the control relay set is seized the identifier transfers to it the routing information for establishing the call, and an instruction specifying the type of print-out required. On calls from marker supervisory units the connecting relays are operated for about 50 milliseconds and the state of the recording contacts is registered in the 80 bit store.

The control relay set then proceeds to establish a connection to the required destination in accordance with the routing instructions supplied by the identifier. ADR-P contains register facilities for the transmission of up to two routing characters. Where only one switching centre, ADX, is involved, only the "B" route character is transmitted to set this stage to the desired level. This B route character may comprise any of the 32 possible telegraph characters. Where two tandem switching centres, ADX, are involved, the B route character is preceded by the transmission of a fixed, pre-strapped, "A" route character. Alternatively, if desired, both routing characters may be omitted.

When the machine at the destination has been connected and its motor run up, the motor start signal is received and ADR-P commences message transmission. All messages are commenced by the transmission of the preamble:

Carriage return;
Line feed;
Figure shift;

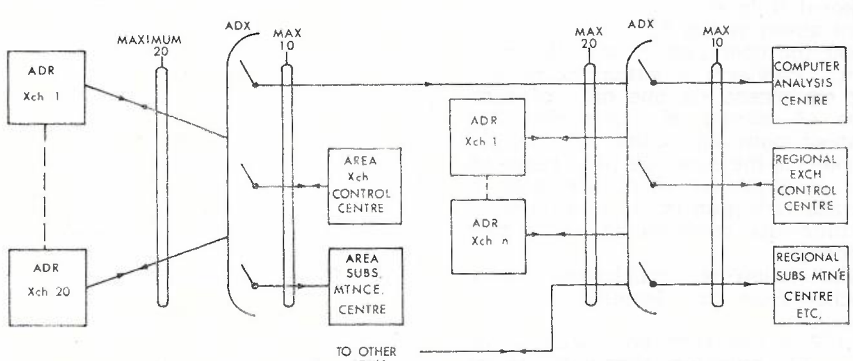

Fig. 5. — ADR Equipment Supervisory Network — System Survey.

Three figure exchange prefix, or exchange identification number.

The text of the message, representing the supervisory condition, is then transmitted. At the end of the text a signal is sent forward to the ADX to call in a timer that adds date and time of message to the transmission.

Immediately the text has been transmitted, the identifier, and store, are released in preparation for handling a follow on message. The established connection via the ADX is, however, maintained for a period of six seconds after the time and date information has been added. If another call, to be routed to the same destination, is received during this holding period, it is transmitted with the routing information omitted. A succession of follow on calls is likely to occur when a major defect occurs in the exchange, and this holding period eliminates the need to clear down and then re-establish the same connection for each call. If the follow on call is for a different destination, it is not transmitted until the established ADX connection is cleared down at the end of the holding period, and a connection to the new destination is established.

Message transmission takes from 11 to 15 seconds, depending upon the occupancy of the time and date service. Time-outs that occur during about the first 8 seconds of this interval cannot be recorded as the store is already occupied. This limitation is inconsequential in practice as the probability of two time-outs occurring within 8 seconds is very limited except under major fault conditions. If a major fault does occur, so many similar time-outs occur that a surfeit of information is obtained even if only a small percentage of the time-out messages are transmitted. Alarm messages are always transmitted, as these messages are stored until such time as message transmission occurs.

The destination of each message is determined primarily by the type of equipment to which the message refers. Basically all alarm messages are regarded as urgent, whilst time-out messages are normally non-urgent. If desired, the urgency classification and hence the destination of messages can be changed. This may be done at any time by a remote control centre, or automatically when service alarm conditions occur in the exchange or when the volume of outgoing supervisory traffic exceeds a predetermined figure. With these arrangements, non-urgent supervisory traffic is normally routed clear of the exchange maintenance staff. When some major equipment disturbance occurs the maintenance staff are immediately provided with all the available, and quite comprehensive, supervisory information, so that they may best make the necessary decisions as to the corrective action that should be taken. This means that, whilst an exchange is free of detectable faults, no supervisory information is forwarded to the maintenance centre, but that as soon as a fault condition is detected, the maintenance staff will commence to receive information.

When a major fault occurs, a large volume of supervisory traffic is generated and passed to the maintenance control centre. To avoid the possibility of the equipment at this centre being monopolised by one exchange, which could prevent the reception of urgent supervisory information from another exchange, facilities exist for the control centre to block all supervisory transmissions from an exchange, except those signalling exchange and extended alarm conditions.

Operational commands may be directed from a control centre to a supervised exchange. When the connection from the control centre via the ADX to the ADR equipment is established, the identity of the called exchange is transmitted, together with a service signal to show that the equipment is ready to receive an operational character.

A typical message is as follows:—

605 RX GA 23 JUN 1966 1021

which signifies that the command receiving equipment at the 605 exchange is attached and ready to receive a command at the date and time shown.

The control centre may then transmit any one of the 32 telegraph characters which will be received in the electronic telegraph transmitter/receiver and stored in a five element relay store in ADR-P. When the established connection is cleared down, the selected operational command pulses are generated. The pulse may be used for any desired operational function, such as control of the ADR equipment, alarm query, resetting alarms, blocking equipment, controling the Traffic Route Tester, etc.

Normally all traffic to and from the ADR equipment passes over the external telegraph channel to an ADX switching centre. Alternatively some or all of this traffic may be routed to another telegraph circuit outlet from the ADR equipment, referred to as the "Local Control" line. This circuit is used in applications such as small country exchanges where an ADX is not provided. Messages that do not pass through an ADX do not have time and date information added, as the timer facilities are incorporated in the ADX equipment. Operational commands may be generated over the Local Control line.

The control relay set also supervises the continuity of the receive leg of the telegraph channel to the ADX. Current failure in the receive leg is repeated as current failure in the send leg to the ADX, where alarm is given.

Relay Set ADR-X is the electronic telegraph transmitter / receiver and basically consists of five ROA component boards. Mercury wetted Clare polarised relays are employed as send and receive line relays to act as a buffer between the line and the transistorised equipment. A third Clare relay is employed as a "monit" relay, to provide a drop copy of all send transmissions if required. This transmitter/receiver develops telegraph characters by generating eight consecutive 20 millisecond pulses, which are combined in gates for transmission via the send relay to line. Transmission of each of the five intelligence elements only occurs if the corresponding signal wire from the control relay set is placed at earth potential. Completion of transmission of each character is signalled to step the control relay set. When stepping is completed, a "set" signal is fed from the control relay set to the transmitter, which then generates the next character. ADR-X contains a 50-volt inverter to generate the +50 volts required for double current telegraph working.

The reception of a telegraph character is very similar to the transmission process. The unit is triggered by the receipt of a start element and generates the five intelligence elements, which are directed to five reed relays. The state of the receive relay is sampled at intervals corresponding to the mid point of the transmitted telegraph elements and the generated element pulses are suppressed if the line sampling shows that a spacing signal is present.

ADR-X also contains circuitry for insertion of the parity element described previously. This is done by an inverter that changes state when two or more of the inputs controlling the transmission of intelligence elements two to five, are at earth potential. This change of state removes the earth potential from the element one input, thereby suppressing the parity element. Parity insertion is only performed during the transmission of print-outs of the 80 lampset facility.

Connecting Relay Sets: The standard crossbar relay set "Relay Set for Fault Counters," containing four multiple connection relays is used for connection of the various recording contacts in the markers to the control relay set store. Each connecting relay set provides ten 40-wire circuits, and the relay sets are used in pairs to develop groups of ten 80-wire circuits. The vertical strips connect to the store relays 1-80, whilst the ten levels of 80 contacts wire via the IDF to the recording contacts. The number of connecting relay sets provided depends upon the number of 40 or 80-wire circuits required to serve the markers installed. The capacity of Rack ADR 1 is 3200 recording contacts in 40 groups of 80, 80 groups of 40, or combinations of both. Should this capacity be inadequate for the size of the installation, the auxiliary rack, Rack ADR2, is required and provides for the connection of an additional 4000 recording contacts. Rack ADR2 may also be equipped with the second relay set ADR-ID, if additional identification capacity is required.

Alarm Interfaces: Interface relay sets have been developed for converting the normal exchange supervisory information to a form acceptable to the ADR telemetering system. The interface relay sets, together with the normal supervisory equipment relay sets, mount on one rack, "Rack for Alarm Relay Sets." This rack caters for 40 service alarm circuits, 100 route alarms, and 60 exchange or extended alarms. Transmissions from this supervisory rack are controlled by the alarm control relay set ADR-LP, which occupies one inlet of the main identifier ADR-ID. Any number of these supervisory racks may be employed, providing virtually unlimited alarm telemetering possibilities.

Relay Set ADR-L: All alarm transmissions are very similar and only those emanating from the exchange or extended alarms will be described. Relay set ADR-L provides facilities for the telemetering of 30 exchange or extended alarms, and uses three of the twelve ADR-LP inlets. These 30 alarms are divided into three groups of ten, and an alarm transmission consists of a scan of the condition of the ten alarm relays in the ten group, e.g.:

605 001 2 139 ⍾ 23 JUNE 1966 0925

where 605 is the exchange prefix or identity number

001 signifies an alarm transmission

2 The second group of ten exchange/extended alarms. (The 60 alarms of this type are divided into six groups of ten, numbered 1 through 6.)

139 The alarm relays 1, 3 and 9 are operated.

⍾ Bell symbol — End of alarm transmission.

An alarm transmission normally takes place when an alarm occurs and when an alarm clears, and is repeated at one of two predetermined time intervals (say every 30 minutes for urgent alarms, and three hours for non-urgent alarms). If desired, however, by removing a strap in any alarm circuit, that circuit will not initiate the transmission of alarm messages. This facility is used for line lock out and blocking alarms, etc. A control centre may interrogate the alarms by using one of the operational commands.

Where 30 exchange/extended alarms are insufficient, a second relay set ADR-L may be provided to extend the capacity to 60.

Relay Set ADR-SM: An auxiliary relay set, ADR-SM, is used as a store and interface for the telemetering of control register information. Each time a control register is seized, the identity of the calling subscriber and the equipment used to establish the connection is transferred to, and stored in, ADR-SM. If the control register detects a fault condition the ADR equipment is called and the stored information is transmitted as follows:—

605 004 3 2345 1 3 24 23 JUNE 1966 1227 where:

004 (or 005) is the identification number of the control register

3 Type of fault (open circuit meter). Provision is made for ten types of faults, numbered 1 through 0.

2345 Calling subscriber's number.

1 SLM 1 used.

3 Number 3 Register Finder used.

24 A, B identity of the SR used.

This information details the complete connection from the subscriber's line circuit to the 1GV inlet. Transmissions from control registers referring to line faults may be routed to a different destination to those referring to exchange equipment defects.

CONCLUSION.

The preliminary results obtained from the first exchange completely fitted with ADR supervisory equipment indicates that the exchange equipment maintenance effort required has been substantially reduced to about 0.1 man-hours per line per annum, and that a very satisfactory plant performance can be attained for this effort. Additional sets of ADR supervisory equipment are now being manufactured for initial installations in all the States. ADR equipment promises to be another valuable tool in the A.P.O.'s continuing efforts to improve productivity in the exchange maintenance field.

The fundamental philosophy of automating plant supervision, and simultaneously facilitating fault localisation work appears to have been validated by the results being obtained from the initial installation of this supervisory system. It might be expected that future developments in this field will be along similar lines, culminating in a supervisory system which automatically removes defective equipment from service and then informs the maintenance staff which component or circuit block requires replacement.

ACKNOWLEDGMENT.

The author desires to acknowledge the valued assistance of the many Engineering, Drafting and Technical staff at Headquarters and from the New South Wales and Queensland Administrations who contributed towards the development of this system. The assistance of Telephone and Electrical Industries Pty. Ltd., in the manufacture and installation of the prototype installation at Ingleburn, is also acknowledged.

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TECHNICAL NEWS ITEM

HIGH SPEED NEWSPAPER FACSIMILE.

In addition to the traditional uses for long-distance communication systems, namely, telephony and telegraphy, Australian Post Office circuits are provided for various other uses, such as transmission of broadcasting and television programmes, weather maps and pictures. More recently requirements for data transmission between office machines and computers have arisen. A new requirement which was fulfilled recently was providing a channel for the high speed transmission of the full contents of a daily newspaper. This is required so that printing plates can be set up to print the newspaper in more than one locality at the same time. Equipment is available to transmit a newspaper page approximately 16 in. x 24 in. with extremely high quality definition in about three minutes. This equipment must be connected together by a communication channel, which normally serves to provide 60 telephone channels.

For newspaper facsimile, however, it is necessary to specially treat the channel to reduce delay distortion. While this distortion has no noticeable effect on telephony, it would cause so much blurring of a newspaper page transmitted at this speed as to render it useless.

Over the frequency band of interest the distortion is normally about 80 micro-sec., and this is reduced by a special equaliser to less than 5 micro-secs. This equaliser, designed by the A.P.O., enables the channel to operate with a binary signal capacity of about 400,000 bits/second.

A TEST CALL DIRECTOR (T.C.D.) FOR ARK EXCHANGES

*J. R. ALCORN, A.M.I.E.Aust., B.Econ.**

INTRODUCTION.

People involved with the installation and maintenance of ARK exchanges have a need for some form of test equipment which will allow access to any desired device or combination of devices for test traffic. A portable set has been designed to achieve this, and this article describes its facilities and operation. Although it could be applied to ARK511, this is probably not warranted, and the descriptive material refers to ARK521 exchanges only. The unit will be the basis of standard equipment provided by the Australian Post Office in its ARK exchanges.

In essence, the Test Call Director (T.C.D.) provides a three-position key per device, i.e., FUR, FDR, REG-D, SNR. When normal, the key has no effect on the device; when operated to the block position, it permanently blocks it; and when operated to the test position the device is selected for "test" calls.

SCOPE FOR USE.

The facility to select a particular FUR, FDR, REG-D or SNR for test traffic is of use both to the installer and to the maintainer of ARK exchanges. The main fields of use include:

- (i) In the pre-cutover testing period, it is of advantage to have full blocking facilities for all devices concentrated on one panel. The circuit of the T.C.D. is arranged so that if more than one key is operated to the "test" position, then all these devices will be offered. Load testing can thus be conveniently controlled, using these facilities.
- (ii) As faults tend to develop soon after cutover, the T.C.D. is a valuable fault-finding aid during the commissioning period.
- (iii) When extending an exchange, new devices may be fully installed and tested before releasing them to normal subscriber traffic. In addition, there will possibly be a major scope of use when changing an exchange from manual to automatic parent working, and from REG-D to M.F.C.
- (iv) Facilities are provided to allow testing of every function of each device. It is therefore a simple matter to introduce a routine which tests these facilities at regular intervals.
- (v) On the more difficult faults, particularly faults in the link connections, the T.C.D. is of major assistance in fault localisation.
- (vi) When modifications are made to relay sets, it is convenient to be able to test each facility of the relay set in the actual exchange before releasing the device to live traffic.

PRINCIPLES OF OPERATION.

Fig. 1 indicates the basic design principles. Selected test numbers are class marked in the AX relay set. Providing the T.C.D. is switched on, a call originating from or directed to one of these test numbers will cause a positive to be connected from the class marking relay to operate relay AX in the T.C.D.

If a device key (KD on the right of Fig. 1) is operated to the "Test" position, a positive from KD will operate relay T via the operated AX relay contact. Note that this will only occur while the Marker is engaging its AX relay set.

The break contact of relay T had previously blocked the device via the changeover springset of KD and thence to a blocking relay in the device. This blocking relay is fitted with a break contact in the "e" and "i" wire, which of course blocks the device.

The operation of T will now:

- (i) Release the blocking relay associated with KD's device and therefore free the device for traffic.
- (ii) From the positive on each make contact of T, block each device of that type via the unoperated changeover springsets of all unoperated KD keys of that type.

Hence for this particular test call, the Marker will find all "e" and "i" wires open except those for the device pre-selected by a KD.

Note that for an originating call, FUR's and FDR-L-N will be blocked. Where a call is directed to an SNR, or FDR-LM or VM this equipment will only be blocked when the marker is setting up that section of the call. Also the incoming side of FDR's will not be blocked by the T.C.D. at all and incoming traffic will proceed as normal.

Because REG-D's are also required for incoming calls it is unsound to block all these devices for one second (say) every time a test call is in progress. The circuitry of the T.C.D. has, therefore, been arranged to block REG-D's for about 200 millisecond only. Blocking of REG-D's can only occur after the desired FUR or FDR-L-N is selected. The method used is to tap the "f" wire to the repeater at the IDF, and not until the repeater is called on this "f" wire will a potential be available to operate the T relays associated with REG-D's. Furthermore, where more than one group of REG-D's is installed only that group associated with the pre-selected FUR will be blocked by the T.C.D.

These T relays can accommodate 16 devices of similar type. Consider, for example, a REG-D exchange with an automatic parent and fitted with FUR-L-N's, FDR-L-N's, SNR's and FDR-L-

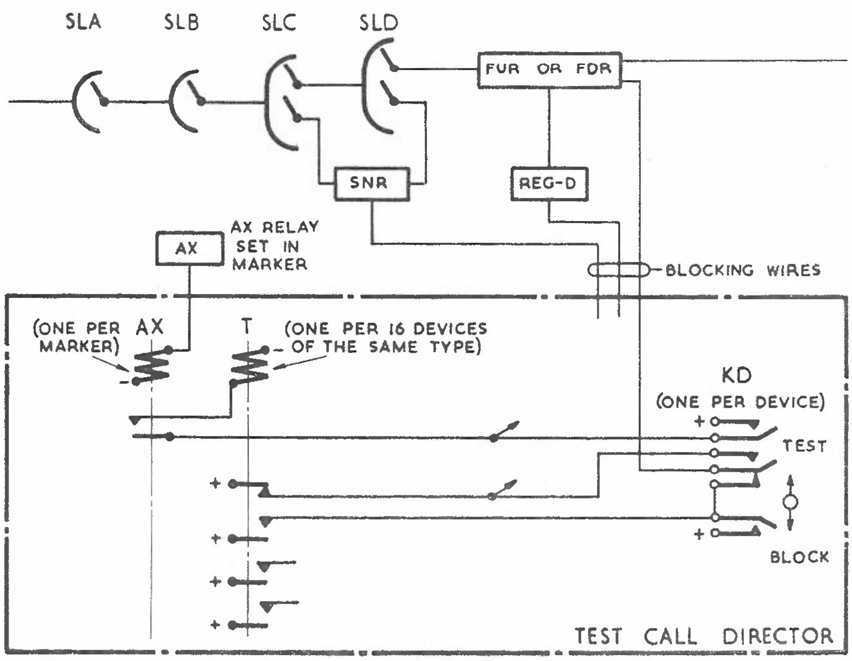

Fig. 1 — Design Principles of Test Call Director (T.C.D.)

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M's. We would need one T relay for each group of REG-D's. On the one T relay we could accommodate both FUR's and FDR-L-N's and we could also accommodate SNR's and FDR-L-M's on a particular T relay. Other combinations apply for different types of exchange.

COMPOSITION OF THE TESTER.

Fig. 2 shows the various units of the prototype manufactured for field trial at the 400 line SLC last stage exchange at Wellington Point, Brisbane. Some minor changes have been made since, but the composition of units is unaltered. It can be seen that the T.C.D. consists of three different types of units, which will be described in reference to their physical positions in Fig. 2.

The Upper Relay Set: This 3-bar relay set consists of a start relay (S), which operates when the tester is switched on, two AX relays under the control of the exchange's two AX relay sets, a group of six control relays, which are needed to account for the complication of two Marker working, and a total of ten T (Test) relays.

These T relays each accommodate 16 devices of the same general type and therefore the T.C.D. can handle an absolute maximum of 160 devices. An extension relay set can be provided if necessary to accommodate more devices, but it is most unlikely that this will occur, even in a 2000 line exchange.

The Control Unit: This unit is mounted on a 2-bar relay set base situated below the upper relay set. The functions of the control switches keys, etc., are described in the following paragraphs, in order of their location from left to right on the unit.

The two rotary switches on the left are used to select test numbers for the "calling" and the "called" subscribers' numbers respectively. On the basis of one test number per hundreds group there are thus 20 test number positions. Operation of the switch merely connects the test telephones (not shown in the photograph) to the "a," "b," and "c" wires of the selected numbers.

The third rotary switch from the left selects the subscriber's class. This allows the operator to convert his test number to any class of subscriber he wishes for test calls. Wiring has been arranged for a maximum of ten different classes, which is considered adequate to meet the originating and terminating classes required in ARK exchanges.

The jacks are used to plug in telephones or a 1 to 1 TRT calling and called subscribers. The jacks are multipled in pairs, which allows the connection of a 1 to 1 TRT in the top ones (for example) and amplifier-speakers in the bottom ones to assist in hearing the various tones.

The next four keys have been modified in a later design to become five push buttons, each equipped with a lamp to indicate their condition of operation. The five conditions are:

Test Diode in Loop: This button inserts a diode in the loop of the test number and allows this "class" to be tested on FUR's and FDR's.

Leakage: This button puts a 15K resistor in the loop of the selected test number.

Line Resistance: This button puts a 200-300-500 ohm resistor in each leg of the selected test number.

Marker 1 - Marker 2 Key: This selects the desired Marker for the originating call. The circuitry requires one Marker to be pre-selected for the originating call, but for all other uses of the Marker during a test call, this is of no consequence. Thus, when the line is looped by the test number, the call will be delayed until one Marker is blocked, and the selected Marker will then receive the test call. Both Markers are freed for traffic after the call is handled. Thus we have one Marker blocked for about two seconds during the progress of each test call.

Test Overflow Register D: If the parent is automatic, REG-D's are normally selected via RS and connected to an FUR or FDR. If we desire to test a REG-D on overflow we need to block the overflow REG-D's we don't want, and press the "Test O/F Reg." key. This will cause all FUR's and FDR's to be busied during the progress of originating a test call and the Marker will test in the normal way to select the desired REG-D.

Fig. 2. shows eleven **resettable meters,** but the production model will have twelve. Ten of these parallel the fault and congestion meter readings, five for each Marker. When the tester is switched off, these meters are directly in parallel with the non-resettable fault and congestion meters fitted in the exchange. They are thus useful to make snap checks of the condition of the exchange between visits, without calculating the difference from the non-resettable meters. When the T.C.D. is turned on, however, these meters only record faults and congestion on traffic involving test numbers.

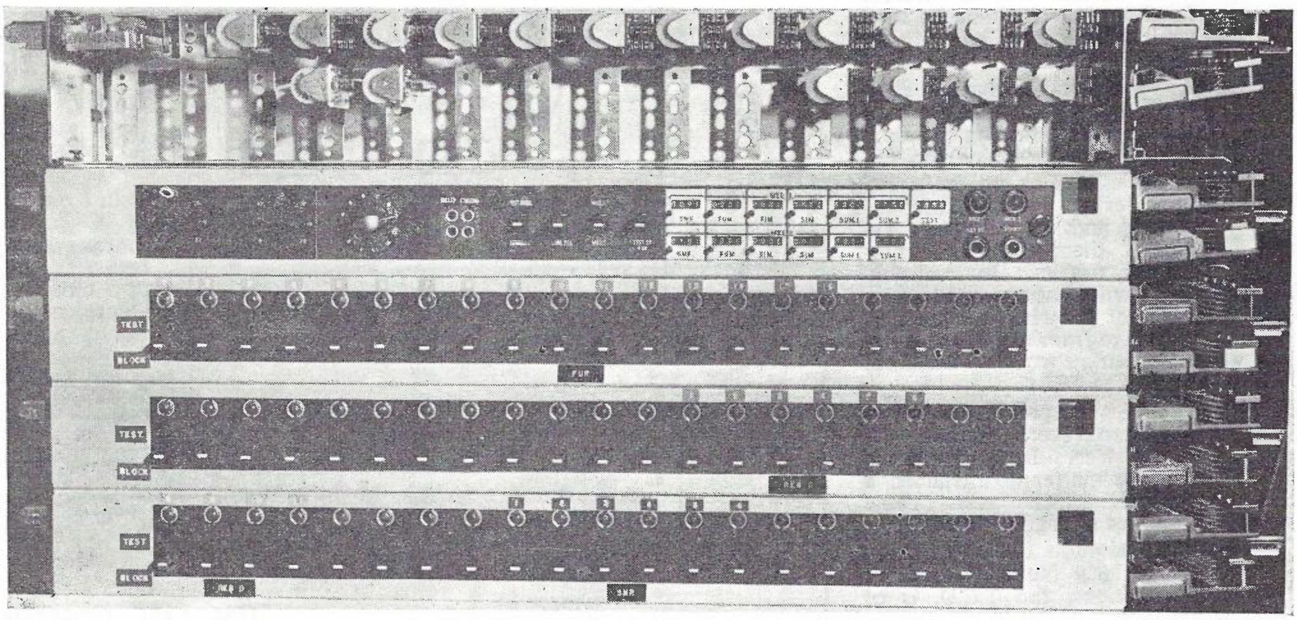

Fig. 2. — The T.C.D. used in the Field Trial at the 400 Line ARK Exchange at Wellington Point, Queensland. (Note: Additional relays have since been added and the proposed mechanical construction is somewhat different from that illustrated.)

One of the remaining meters measures the number of test calls, and the other one indicates that metering has occurred. This meter is designed to operate on a marginal basis from the discharge of the metering capacitor. Thus, if this capacitor is in the process of breaking down, the T.C.D. will indicate this, even though some, or all, subscribers' meters are still registering.

The Four Lamps to the right of the meters have been superseded by the push buttons with lights attached, referred to above.

The Start Switch on the extreme right of the unit switches the T.C.D. on. Except for the ten re-settable meters referred to above, the T.C.D. is completely disconnected, unless this switch is operated.

The Three Lower 2-Bar Units: Each of these units consists of twenty keys and lamps, each key and lamp being associated with a particular device. These units are identical and may be interchanged within the exchange, or between exchanges. The association of each key with a device is achieved by straps on the I.D.F. Thus, the designation strips for each unit need to be interchangeable.

CABLING.

The cabling is identical in each exchange for the relay set and control unit, and I.D.F. strips have been allocated for this cabling for each ARK grouping plan. The key units also have identical cabling to the I.D.F. and can be built up in units as the exchange increases in size. There is no strapping required within any relay set, this being provided for by straps on the I.D.F. Rack space must be allotted to handle ultimate growth of each exchange, but in smaller exchanges where this space is at a premium, a wall frame may be used. Additional cabling is also required to some relay sets and cabling drawings have been or are being modified accordingly.

PORTABILITY.

As mentioned previously, the units are portable between exchanges and can be interchanged at will, irrespective of whether the exchanges are MFC or REG-D, working to manual or automatic parent, or SLB, C or D last stage exchanges. The recommended basis of provision at this stage is one set per 5 or 6 exchanges in a district, but maintenance practice will clarify this issue when more experience has been obtained.

OTHER POSSIBLE SOLUTIONS.

There are, of course, several other approaches that could have achieved similar results. The three approaches originally considered were as follows:

1. To arrange additional cabling from each device, to allow a tester to be plugged into any device which required testing. The plug-in unit would need to contain a skeleton exchange consisting of the facilities normally provided by the exchange before the relay set under test is brought into use.

An elementary tester to do this with FUR's and FDR's was designed and used in one installation, but needed considerable additional facilities to handle class analysis, especially for MFC exchanges.

The testing of SNR's and REG-D's would have required a most complicated unit under this arrangement. The problem is difficult in ARK because of the "jump" and this method floundered accordingly. It might be noted that this is the approach used in ARF exchanges currently installed in Australia.

Apart from these complications, this method of approach has a basic weakness in that it only tests the relay set and does not necessarily test the wiring by which the device is connected in a normal call. Thus, even though the device might test perfectly, it could occur that it could never be brought into use due to some fault in the wiring used to select it.

2. A second method is to arrange to preset call distributors. We can visualise a number of keys which would set call distributors to selected positions for calls from test numbers. This method would result in less keys than the method chosen, because keys could be thrown in various combinations to select particular devices. However, this method has the following disadvantages:—

(i) A separate field of keys would need to be mounted permanently in each exchange, and the advantage of portability would be lost.

(ii) A chart would need to be referred to each time a device was required. This would complicate the usage of the tester as compared with a separate designated key for each device.

(iii) A 1 to 1 TRT run via several devices would be complicated by the need to re-arrange keys during the progress of connecting the call.

(iv) Load testing would not be possible through several devices of the same type as the method depends on pre-setting for one device only.

This method was considered early in the development of a suitable tester, but was discarded before any prototype was developed. It became clear that a formidable array of keys and relay contacts would be involved to achieve the necessary combinations. Further, preliminary design considerations indicated that it would not be possible to select the required device via the normal exchange circuitry and this was accepted as an unsatisfactory technique.

CONCLUSION.

The T.C.D. described above should prove a valuable maintenance aid in ARK exchanges by providing the following facilities:—

(a) It permits the testing of every device in the exchange, incoming relay set (FIR's) are tested manually.

(b) The test calls are set up under the same conditions as normal calls.

(c) It is a simple matter to include the facility on future extensions to the exchange.

ACKNOWLEDGMENTS.

The successful development of this maintenance aid was due largely to the practical assistance of staff at the Department's office at Maryborough (Queensland), the Brisbane Workshops, the Brisbane Metropolitan Equipment Section, and at Headquarters in Melbourne. The author records his appreciation of this assistance.

THE OPERATIONAL SWITCHING SYSTEM OF THE ELECTRICITY COMMISSION OF N.S.W.

*J. WARTH**

INTRODUCTION

To cater for its own internal operating purposes, the N.S.W. Electricity Commission has installed an extensive automatic exchange network. At each major centre, an automatic switching unit (known as an O.S.U., Operational Switching Unit) has been installed, and this articles describes one of these units manufactured by Telephone Manufacturing Company Ltd. of England.

Basically, the unit is a 50-volt operated, step-by-step automatic exchange, using a Crossbar Bridge in place of uniselectors and bi-motional switches. Fig. 1 shows a complete unit.

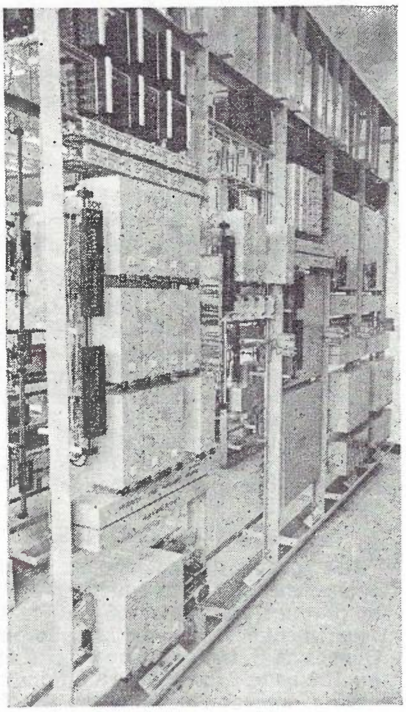

Fig. 1. — Full View of Suite of Racks for a Complete Unit.

Being designed specifically to meet the needs of the Commission, it provides for several functions not normally found in exchanges used by public authorities. These are, namely:

(i) A priority tone intrusion system.
(ii) A redialler unit.
(iii) A vocal annunciator (verbal announcement) in place of dial tone, which repeats the name of the location, e.g., Vales PT.

The equipment will cater for the interconnection of three different types of circuits:

(i) Local extensions (2 wire).
(ii) D.C. Junctions, loop dialling (2 wire).
(iii) Carrier trunks (4 wire with out-of-band signalling).

THE T.M.C. CROSSBAR BRIDGE.

The T.M.C. crossbar bridge is a multiple contact device in which the main armature can operate any one set of selected contacts, leaving the remainder unoperated. Figs. 2 and 3 illustrate the construction and mounting of the crossbar bridge.

The bridge has five banks of eight make contacts, and any one of these five banks may be selected for operation. The selection is accomplished by means of small electro-magnets, called "finger magnets," one of which is provided for each of the five banks of contacts. Off normal springs are also provided and are operated by the main armature.

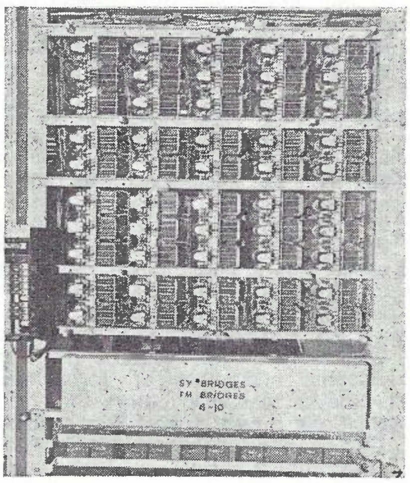

Fig. 3. — Front View of Rack, Showing a Group of Bridges with Dust Cover Removed.

The whole unit is mounted on a modified 3000 type relay yoke, the main armature assembly closely resembling that of a 3000 type relay. The overall dimensions of each bridge are: $4\frac{1}{4}$ in. high, $2\frac{1}{4}$ in. wide, and 4 in. deep.

Once the main armature has operated, the finger magnet can be released, the main armature holding the selected bank operated. The finger magnet does not operate any of the contacts, but simply selects its group of contacts for later operation by the main armature.

SERVICE TONES.

Six different service tones are used to indicate to a user what stage his call has reached and how to proceed with the call.

Dial Tone: Normally a magnetic tape annunciator is used and a verbal announcement of the name of the exchange is given in place of dial tone. A standard "low pitched burr" dial tone is available in the event of a failure of the verbal announcement.

Ringing Tone: When a wanted party is being called, ringing tone is returned to the caller. This is a 400 c/s tone super-imposed by 17 c/s ring frequency, and interrupted in the same manner as the ringing signal, i.e., 0.4 secs. ON, 0.2 secs. OFF, 0.4 secs. ON, 2.2 secs. OFF.

Busy Tone: If the wanted party or junction is being used, a high-pitched note is returned to the caller. This tone is of 400 c/s interrupted 0.8 secs. ON, 0.8 secs. OFF.

N.U. Tone: If the number called is a spare line, an N.U. Tone is returned. This is a continuous 400 c/s tone.

Priority Intrusion Tone: This tone is used to indicate to persons using the system, that there is a priority call waiting to speak to one or other of the parties using the system,

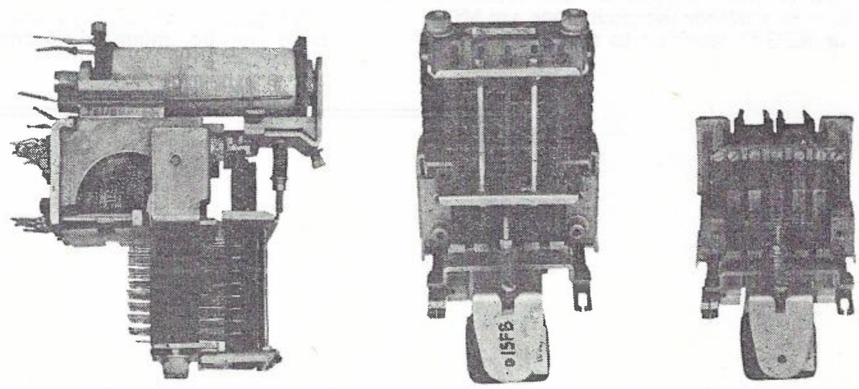

Fig. 2. — The Crossbar Bridge. Left: Side view (The finger magnets can be seen towards the rear of the switch, behind the frame). Centre: Front view of single bridge. Right: Front view of bridge without contact pile to show mounting of finger on yoke.

* Mr. Warth is Communications Foreman, Waratah, Electricity Commission of N.S.W.

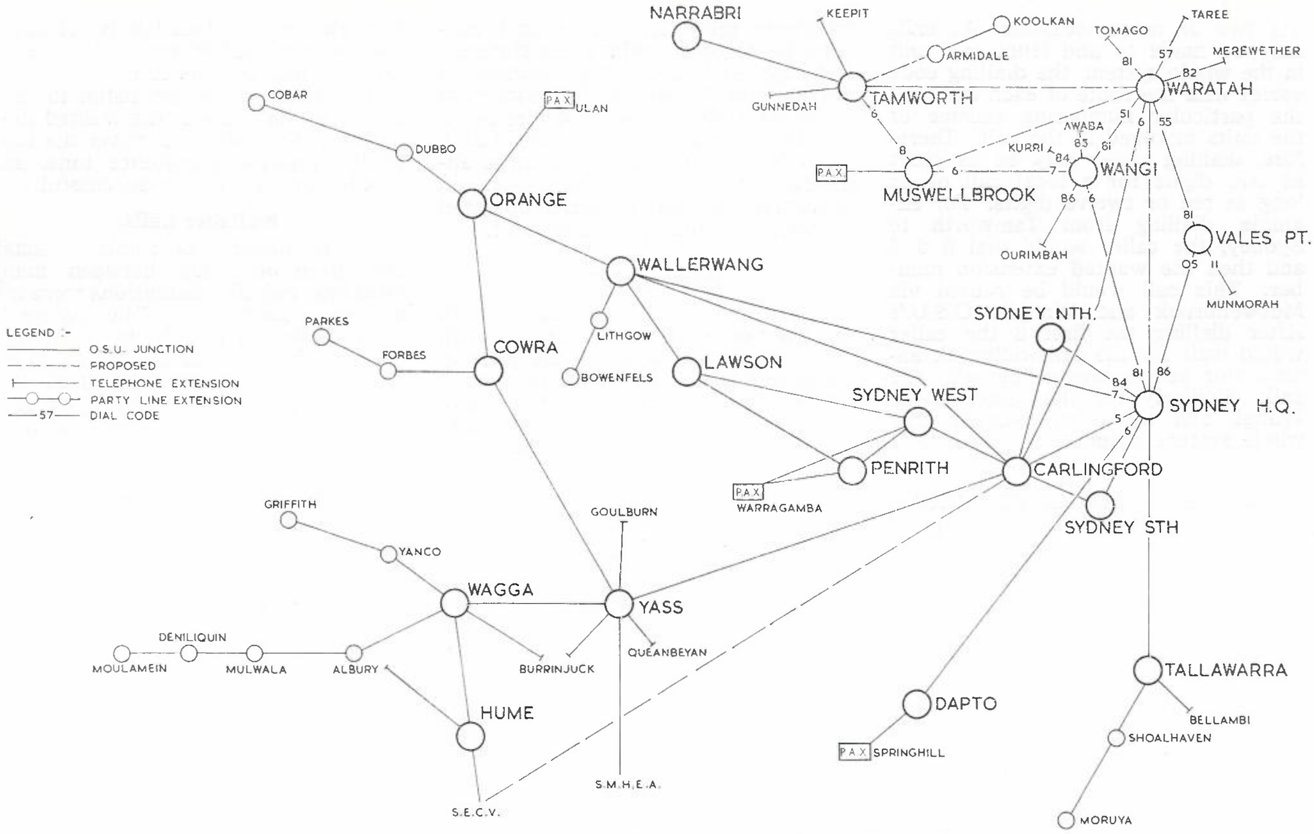

Fig. 4. — General Plan of O.S.U. Network. (Only some numbering shown).

or wishes to use one of the junctions they may be using at the time.

The tone is a 1000 c/s tone superimposed by 20 c/s and interrupted at four times the frequency of busy tone.

Priority Acceptance Signal: This tone is used to indicate to a priority caller that the equipment has responded to his use of his priority button and that the priority intrusion tone has been injected into the wanted lines. It has the same pitch as busy tone, but is interrupted at four times the frequency.

MAKING CALLS ON THE O.S.U.

The O.S.U. network is shown in Fig. 4. A mixed dialling code of single and two digit numbers is generally used. Discrimination for a particular type of call takes place on the first digit, therefore it is not possible to mix the various types of lines with the same digit.

Local extensions have a two digit number and calls to and from local extensions are straightforward. The count train remains under the control of the dial until the end of the second digit.

Most of the calls made on the O.S.U. are to and from a distant location, and quite frequently are routed

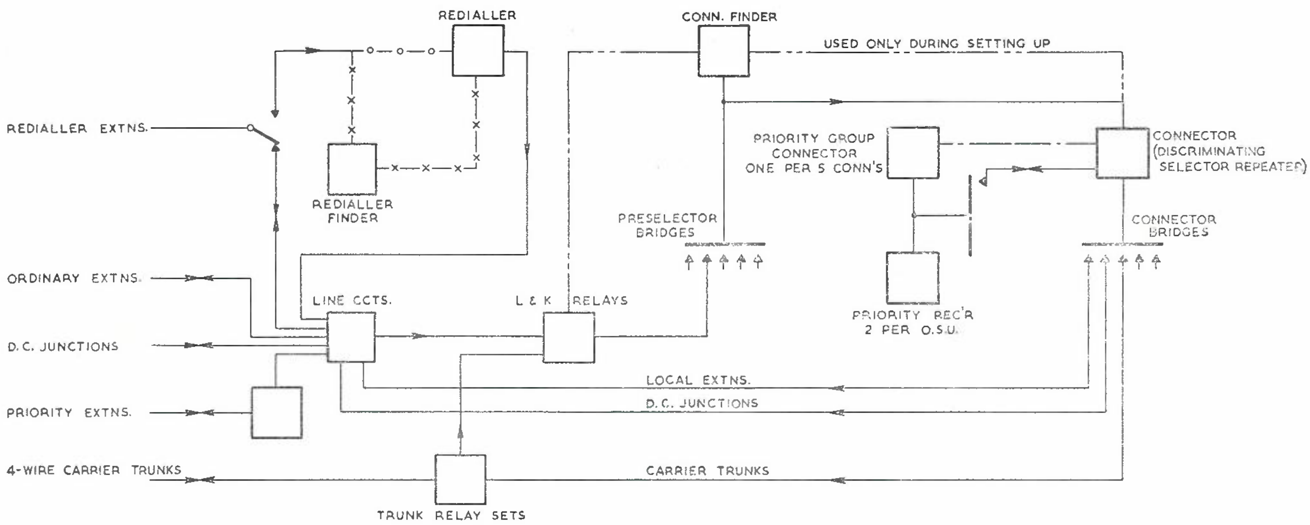

Fig. 5. — Trunking Diagram of an O.S.U.

via two or more locations. As calls may be made to and from any unit in the whole system, the dialling code varies with the route of each call, and the particular numbering scheme of the units involved in the call. Therefore, dialling codes may be as short as two digits for a local call or as long as ten or twelve digits. For example, dialling from Tamworth to Sydney, the caller would dial 6 6 6 and then the wanted extension number. This call would be routed via Muswellbrook and Wangi's O.S.U.'s After dialling the first 6 the caller would wait for the Muswellbrook annunciator before proceeding with the call. Similarly for the second 6 to Wangi, and the 6 to Sydney. The whole system is subscriber operated.

FACILITIES OF SINGLE TELEPHONE ENDED TRUNK RELAY SET.

The trunking of an O.S.U. unit is shown in Fig 5.

To provide O.S.U. facilities to unattended or wayside sub-stations which do not require a complete switching unit, service is given by carrier system to the nearest major location.

At the O.S.U. the connection is made in a similar manner to a carrier trunk, except that as soon as the carrier is seized, ringing tone is returned to the caller, and the bell is rung at the wanted location.

At the remote sub-station, the carrier system is terminated into a single telephone relay set. This unit contains the necessary relays, transformers and supplies to allow the telephone to operate into the carrier, the connection being made on a 2 wire to 4 wire basis. Lifting the handset at the sub-station loops into the O.S.U. and returns annunciator to the user. The sub-station is virtually a remote carrier operated extension of that particular unit.

Priority Calls.

Priority extensions are provided with an additional push button, which, when depressed, actuates the priority equipment in the O.S.U. This class of extension is severely restricted and generally provided to system operating staff only, for use in emergencies, such as system disturbances.

Whenever a caller receives busy tone, he may intrude into the busy circuit by using his priority button. The priority intrusion tone is generated in each O.S.U. and this tone is transmitted from the originating unit to wherever the call has stopped on busy. When a connector stops on busy, it automatically connects to a priority tone receiver, ready to receive a priority tone. If it does so, relays are actuated in the connector to switch the local 1000 + 20 c/s tone into the wanted line. At the same time a circuit is prepared so that when the busy line is freed, the priority caller will immediately seize the wanted line. If it is a local extension, ringing tone is returned, if a trunk, annunciator from the wanted location is returned. The priority caller would then continue to dial out his call.

A priority caller can listen to, and speak, to the users of the wanted line; however, he must do so "over the top" of the priority acceptance tone, and this feature is not over-successful.

Redialler Calls.

As the number of trunks is small and often only one between many locations, redialler extensions were not put into general use. The feature is there, however, and could be used if ever the Commission decided to do so.

Redialler extensions are fitted with a special telephone, which is virtually a two-line instrument, one line being used into the redialler equipment. Using the redialler, the extension can dial into the redialler up to seven digits. These are stored in the redialler, which "redials" the stored number once every minute for fifteen minutes, or until a connection is made, the redialler extension is rung back to indicate that the call has been made successfully. If after fifteen minutes no successful call has been made, the equipment restores to normal. The redialler extension can use his ordinary extension at any time whilst the redialler is trying for the wanted number.

GENERAL DESCRIPTION OF CIRCUIT OPERATION.

Line and Preselector Circuits.

When an extension lifts his handset or a d.c. junction is looped (see Fig.

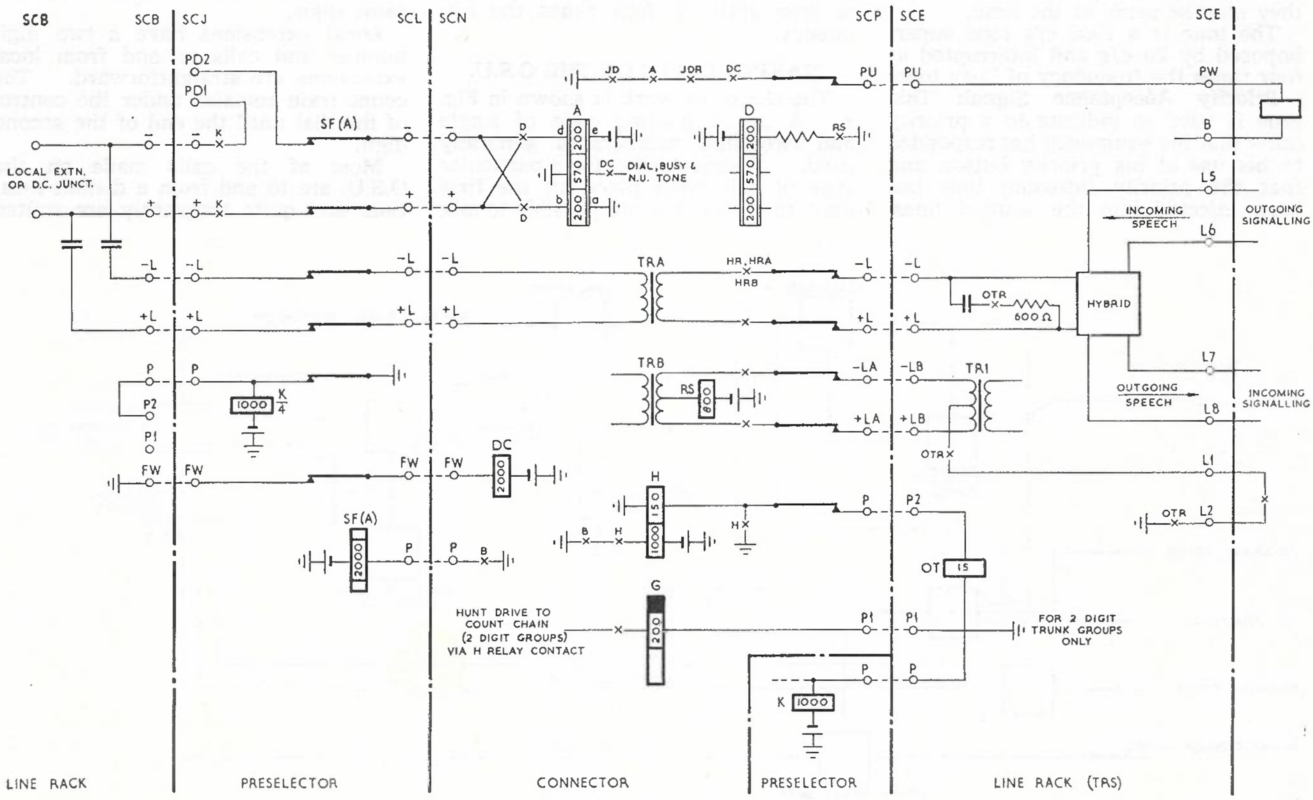

Fig. 6. — Circuit Conditions for a 2 Wire to 4 Wire Call.

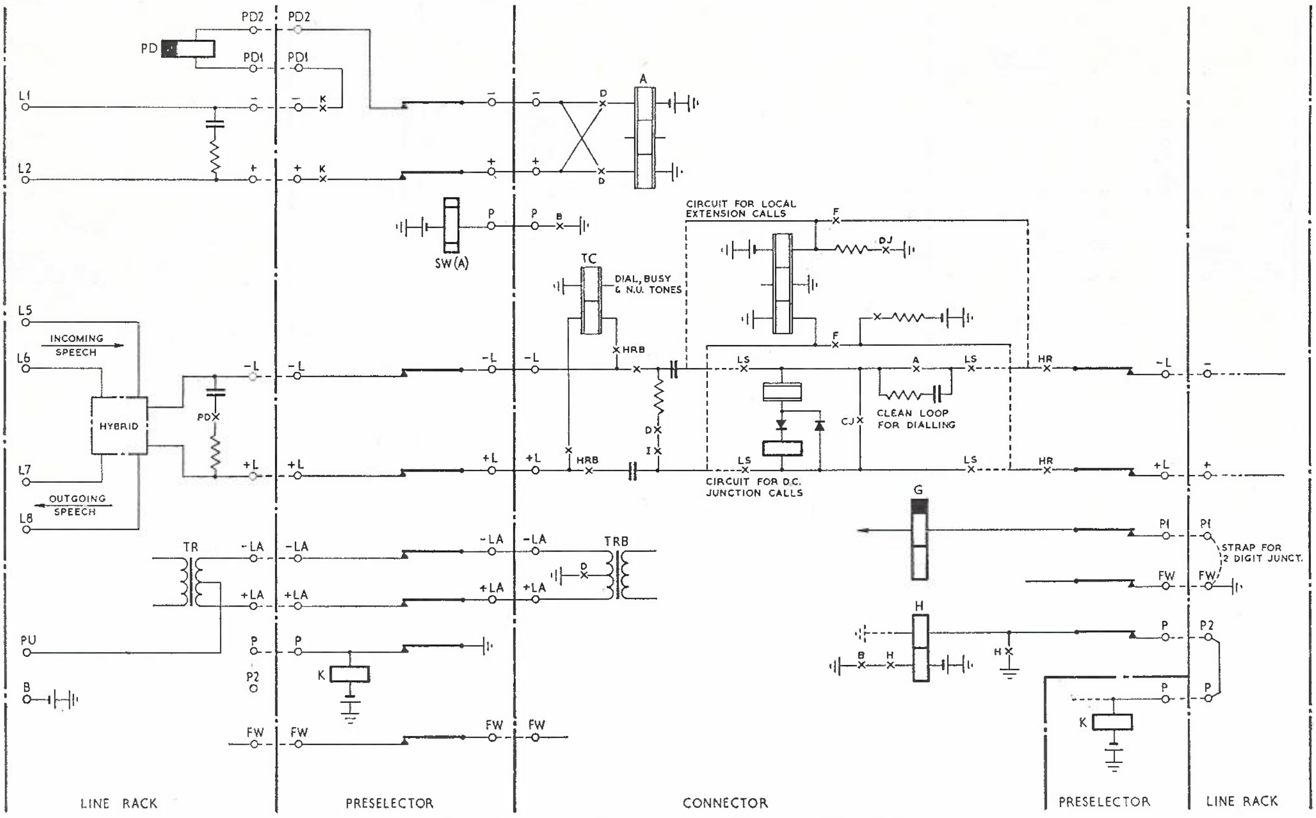

Fig. 7. — Circuit Conditions for a 4 Wire to 2 Wire Call.

6) or an incoming carrier trunk signalling relay is operated (see Fig. 7), the line relay operates to mark the appropriate finger magnet in the preselector bridge, which operates in series with a group start relay. This relay starts a self search circuit to search for a free connector. All connectors attempt to seize to the marked line, but only the earliest choice one does so. In so doing, the circuit for the crossbar bridge is completed and the marked line is switched through to the connector. The finger magnet is released and the self search chain restored.

Operating the crossbar bridge results in the following conditions:—

(i) The +, —, +L, —L, +LA, —LA, and FW, wires are extended to the connector. For a local extension or d.c. junction the +LA, and —LA, wires perform no function.

(ii) Earth is applied to the K relay of the calling line, which operates to disconnect the L relay and extend the + and — wires to the connector via the pre-selector crossbar bridge operated.

(iii) The release of the L relay allows another line to hunt for a connector. Only one line at a time can search for a free connector, eliminating the possibility of a double connection. Should a calling line of any type fail to find a free connector within 2 seconds, the line is locked out on its fault relay circuit, necessitating clearing down before another call can be attempted.

The + and — wires are used for control purposes, whilst the +L and —L wires are used for speech. This method is used to standardise the working with that of calls over carrier equipment.

Call to a Carrier Trunk.

When a free carrier trunk is seized, an H relay applies earth to the P2 wire to the trunk relay set (T.R.S.), which operates relay OT in series with its K relay. Relays OT and OTR convert the T.R.S. circuit conditions to ones suitable for an outgoing call. Earth is also applied to a PW wire, which operates the outgoing signalling relay, which in turn loops the distant O.S.U. to return annunciator to the caller to indicated that dialling may proceed.

If the call originated from a carrier trunk, the FW relays are also operated in each T.R.S. These relays convert the circuit to remove hybrids and connect the carriers together on a 4 wire basis via the +L, the —L, and the +LA, and the —LA wires. (See Fig. 8)

In the original circuits the 3060 c/s signalling tone from an incoming trunk line was passed through the O.S.U. to the outgoing trunk line, i.e., there was no translation of the signal tone to d.c. signals. The present arrangement differs from this and the forward signalling is now accomplished by repeating the dialling pulses via the connector A relay. This method was adopted to cater for different types of carrier channels, which used differing frequencies for their out-of-band signalling.

Connector Circuits.

The connector relay set can be described as a discriminating-selector-repeater, which also provides for 4 wire switching on certain classes of calls. The conditions set up in the connector are the result of the particular digit dialled, and depends upon strappings made on the first digit storage bridge cross connection field. (FM storage bridge). All the terminals of the five sets of eight contacts are brought out to this field. The allocations of which are given below.

Bank.	Use.
FM. 1	Functional discrimination for first digits 1 to 5.
FM. 2	Functional discrimination for first digits 6 to 0.
FM. 3	Selection of connecting bridge finger magnet for first digits 1 to 5.
FM. 4	Selection of connecting bridge finger magnet for first digits 6 to 0.
FM. 5	Sets up test circuit for junction hunting groups for single digit codes 1 to 5. (Also used for digit absorption.)
FM 6	Sets up test circuit for junction hunting groups for single digit codes 6 to 0.
FM. 7	Used for discrimination between single and two digit codes for first digits 1 to 5.
FM. 8	Used for discrimination between single and two digit codes for first digits 6 to 0.

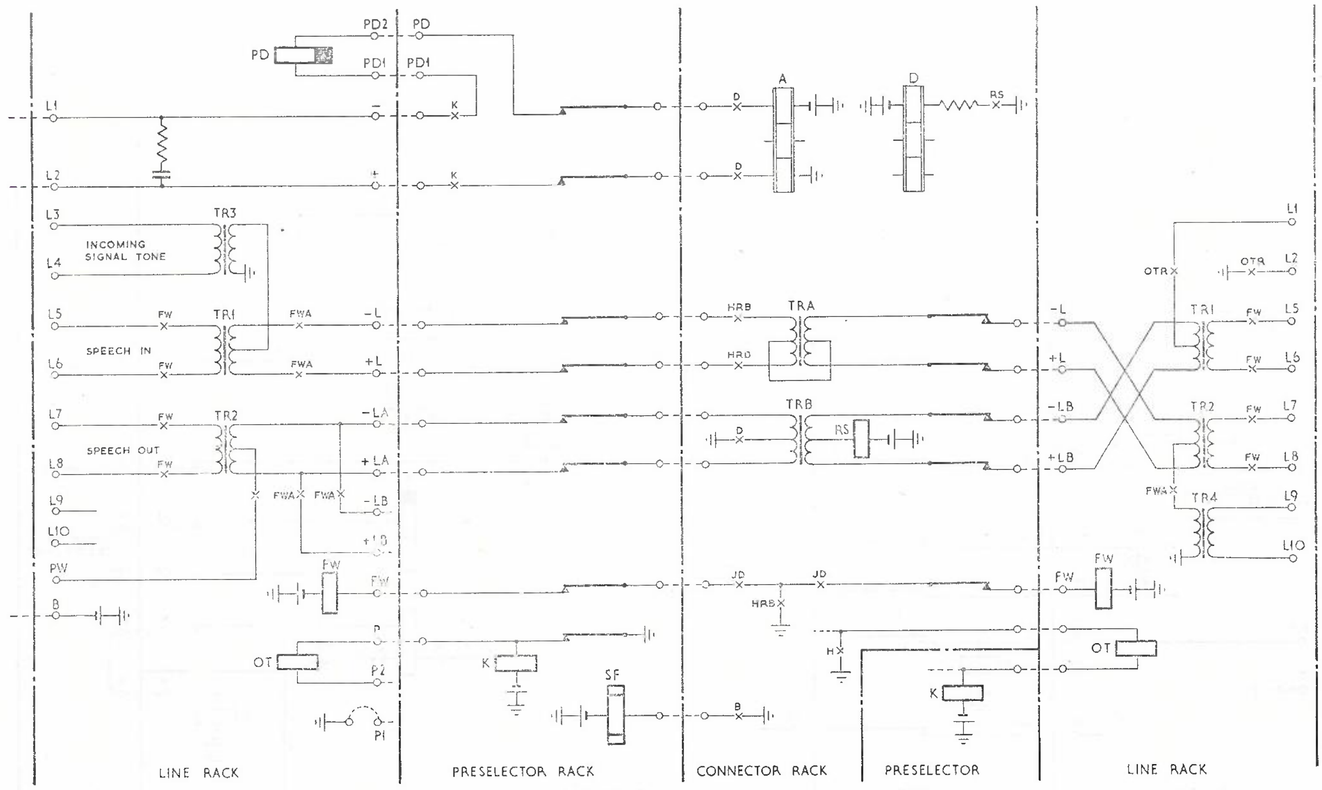

Fig. 8. — Circuit Conditions for a 4 Wire to 4 Wire Call.

Dialling the First Digit.

The dialling impulses pulse the connector A relay, which in turn steps the count chain. The count chain consists of five bridges only, even in units with more than five bridges in the connector. For first digits greater than five, the count chain is operated twice, a discriminating relay, SPR, operating on the sixth pulse.

At the end of the first digit, one of the five finger magnets in a storage bridge, FM will be operated. (SPR will also be operated if the first digit is more than 6.) The FM bridge is then operated and holds the first digit marked. All the finger magnets for the digit dialled will also be held operated in the connector bridges. When relay FM operates at the end of the first digit, one of three things will happen, depending upon the strappings made on the FM cross connection field:—

For local lines there are no strappings and no discrimination takes place.

For d.c. junctions strappings are made on the FM field, which will cause to operate the appropriate discriminating relay in the connector.

For carrier junctions different strappings are required to operate the discriminating relays used for this class of call.

Dialling the Second Digit.

The second digit dialled steps the count chain in a similar manner as the first digit. At the end of the second digit, one of the connecting bridges SR1, SR2, etc., will be operated, thus operating the marked bank of that particular bridge. The finger magnet operating circuit will be disconnected and the remainder of the finger magnets will restore to normal.

Depending on the type of call and the state of the wanted line, one of the following conditions will be completed in the connector. If the call was to a local extension, the called party will be rung and ringing tone returned to the caller, if a carrier trunk or d.c. junction, annunciator or dial tone from the wanted unit will be returned to the caller. If the wanted line is engaged, busy tone will be returned to the caller.

Single Digit Junctions or Carrier Trunks.

If the number dialled is a single digit code, at the end of the first digit a circuit is made which causes the count chain to re-operate in succession until a free line is found. The appropriate SR bridge is then operated and a connection established.

Because an outlet may be connected to any code dialled, full availability of connector outlets can be utilised, within the limits set by the first digit discrimination. The number of connector outlets depends upon the number of SR bridges provided. Units range in size from five lines to 50 lines.

Forced Release.

The connector is fitted with a forced release circuit, which operates after a period of 90 seconds under certain conditions. These are:—

(i) Connector seized but no digits dialled.
(ii) Calling party fails to clear at the end of a call.
(iii) Incomplete dialling on a junction or trunk call.
(iv) No reply on a junction or trunk call after ringing for 90 sec.
(v) Calling party fails to clear down on receipt of busy or N.U. tone.

Further to forced release circuit, after a second period of 90 seconds elapses and the caller has still not restored to normal, a PG alarm circuit is actuated to indicate this condition.

Ringing and Tone Supplies.

Ringing tones and voltages are generated in special relay sets, two of which are provided in each O.S.U., with automatic change-over in the event of a failure of the in service set. The 17 c/s ringing voltage is generated by a vibrating relay and transformer, whilst the 400 c/s tone is generated in a valve oscillator. Interruption times are achieved by a series of interacting relays designed to give the needed periods for interruption of the various tones and voltages.

Alarms.

The equipment is fitted with a full range of alarms, divided into urgent and non-urgent groups. Urgent alarms generally indicate the failure of some part of the unit which will prevent the successful use of the unit in establishing a call, while non-urgent alarms cover the rest, such as PG, annunciator failure, etc.

CONCLUSION.

In its application the equipment has proved to be most successful and extremely free from faults. It requires little or no maintenance; all that is necessary or recommended being an occasional cleaning of the group selecting relay contacts. The contact material used is sterling silver. The circuit is a "chain" and two contacts in parallel are used on each relay. If any one pair of contacts should "fail," no selection will take place, and no PG lockout function operates either, thus causing a complete failure of the unit. To overcome this, therefore, the manufacturer recommends contact cleaning with a smooth burnisher, washed in carbon-tetra-chloride.

Ringer relays require some attention after operating for long periods due to contact deterioration, though the fitting of spark quench circuits has improved this.

The most frequent failure in service has been the breaking or stretching of tapes on the vocal annunciator, but a newer design using a magnetic disc recording is to be used and should eliminate this shortcoming.

ACKNOWLEDGMENTS.

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MEASUREMENT OF TV AERIAL RADIATION PATTERNS

*D. GOSDEN, B.E.**

INTRODUCTION.

It is desirable in transmitting television signals to direct most of the energy towards the horizon. If much energy is directed upwards it may be reflected or refracted downwards again by the upper atmosphere. This happens particularly to signals in the low VHF range and can cause interference to other stations on the same frequency far over the horizon. Furthermore, it is not necessary to direct a strong signal at large angles of depression because these areas are close to the transmitter and consequently receive adequate signal.

One method of pattern measurement which has yielded good results is carried out by comparing the radiation from the transmitting aerial with the radiation from a reference aerial. (Ref. 1). The reference aerial whose pattern was known was mounted on the mast above the main aerial, and a known amount of power was fed to each aerial in turn. A vehicle equipped with a field strength meter was used to measure the strength of signals emanating from each aerial. The ratio of these signals, together with information regarding the characteristics of the reference aerial and the position of the vehicle, allowed the pattern of the main aerial to be determined. This method, however, is only successful when the vehicle can be driven to the required points around the mast. In mountainous country where many television transmitters are situated, this is not always possible.

This paper describes a method which has proved effective in measuring the vertical radiation pattern of transmitting aerials. It utilises the principle of reciprocity whereby an aerial exhibits the same radiation pattern whether it is receiving or transmitting provided non-linearities are absent. A small transmitter which operates on the required frequency is supported by a balloon. The balloon is manoeuvred so that it moves along a vertical line approximately 1000 feet from the mast. The main aerial intercepts the field produced by the balloon-borne transmitter and a field strength meter connected to the main aerial feeder indicates the response of the main aerial to signals arriving from different directions as the position of the balloon is varied.

BALLOON DISTANCE.

The distance from the mast at which the balloon is flown is governed by a number of requirements. The balloon must be far enough away so that the induction field is negligible compared with the radiation field. This is generally taken to be 16 wavelengths. Furthermore, the dimensions of the main aerial should be small compared with the distance between the balloon and the mast, so that the incident wave is almost uniform. The variations which are usually accepted across the aerial are $\pi/8$ radians in phase and $\frac{1}{4}$ dB in amplitude. (Ref. 2.)

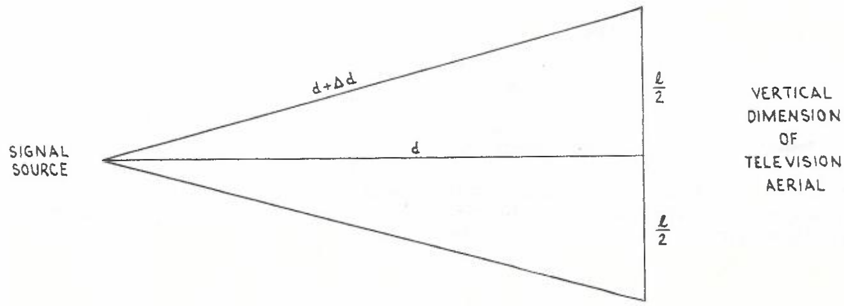

Fig. 1. — Diagram Showing Variation of Phase across Aperture of Aerial.

Referring to Fig. 1, l is the vertical dimension of the main aerial. This is usually of the order of 50-100 ft. From the figure, and neglecting the second order term $(\Delta d)^2$, it can be calculated that:

$$\Delta d = \frac{l^2}{8d}$$

The conditions which must be met in respect to the allowable phase and amplitude tolerances are:

$$\frac{2\pi}{\lambda}\Delta d \leqslant \frac{\pi}{8} \text{ for phase}$$

$$\text{and } \frac{\Delta d}{d} \leqslant 0.025 \text{ for amplitude.}$$

The requirement to meet the phase tolerance is therefore:

$$d \geqslant \frac{2l^2}{\lambda}$$

Usually if the phase tolerance is met, the amplitude tolerances will also be met.

The maximum distance is usually governed by the local topography. If the ground is fairly flat, the maximum vertical angle which can be obtained at ground level is restricted at large distances. In cases where the ground slopes away rapidly this will not be a limiting factor; however, the balloon would have to be flown at a high altitude to get above the level of the main aerial. Control of the balloon becomes difficult at heights greater than about 700 feet.

EQUIPMENT.

The Balloon.

The balloon used in this measurement was of the kite-balloon variety. This is an air-foil balloon, shaped like a zeppelin, which combines free lift with dynamic lift produced by the action of wind on the air-foils. The inflated volume of the balloon is approximately 40 cubic feet and when filled with hydrogen the static lift is about 1.5 lbs. The usual precautions when using hydrogen were taken and no difficulties were experienced.

Tethering Line.

Nylon cord was found to be the most successful material for tethering the balloon. A breaking strain of 85 lbs. was used to give a safety margin in strong wind gusts. Eight hundred ft. of this cord weighed only one pound, so the balloon was not loaded excessively. Care was necessary when tying knots in the cord on account of their tendency to slip.

The Transmitter.

The balloon-type transmitter was designed and manufactured by the P.M.G. Research Laboratories. It uses one transistor operating as a tuned collector oscillator. The circuitry enabled the operating frequency to be changed easily by replacement of the tuning coil. Fine frequency variations were made possible by the adjustment of a small variable capacitor across the output circuit.

The power supply consisted of three small 9V batteries connected in series, and a zener diode regulator to produce a fairly constant potential of 16V. The power delivered by the transmitter was about 20 mW and remained constart within 0.2 dB over a period of three hours of operation. The frequency variation over this period was of the order of 0.05 per cent.; however, the tuning of the receiver was checked every time a reading was taken, so this did not present a problem.

The aerial consisted of a pair of aluminium rods fixed to the sides of the transmitter to form a balanced dipole. (See Fig. 2.) The length of the aerial was made less than half a wavelength in order to reduce weight. The total weight of the transmitter with batteries was 1 lb.

The transmitter was supported by the end of one of the aerial rods, approximately 6 ft. below the balloon; accordingly the polarisation of the radiation was vertical and uniform in the horizontal plane. The vertical radiation pattern was considered uniform up to an angle of 18 deg. away from the perpendicular to the dipole.

Measuring Technique.

Using one tethering line, the balloon was allowed to rise until it was in the correct position at an angle of elevation of approximately 8 deg. above the tower. The balloon was then hauled down and field strength readings were taken at intervals of one degree of vertical angle until the balloon was at

* Mr. Gosden is Engineer Class 1, Radio Section, N.S.W. See Vol. 16, No. 1, Page 87.

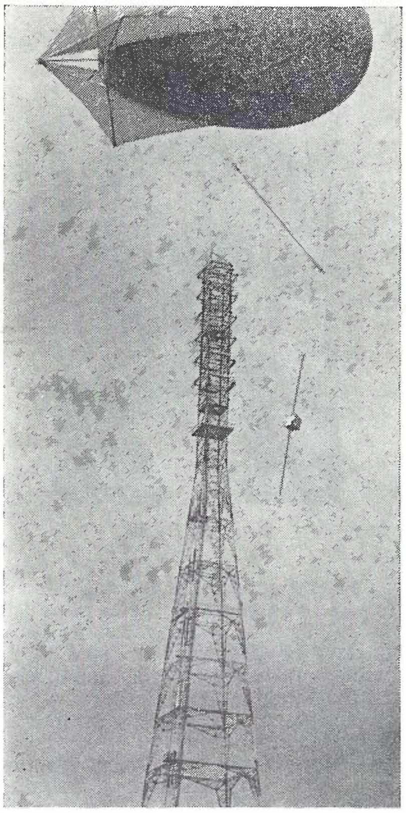

Fig. 2. — The Balloon-Borne Transmitter.

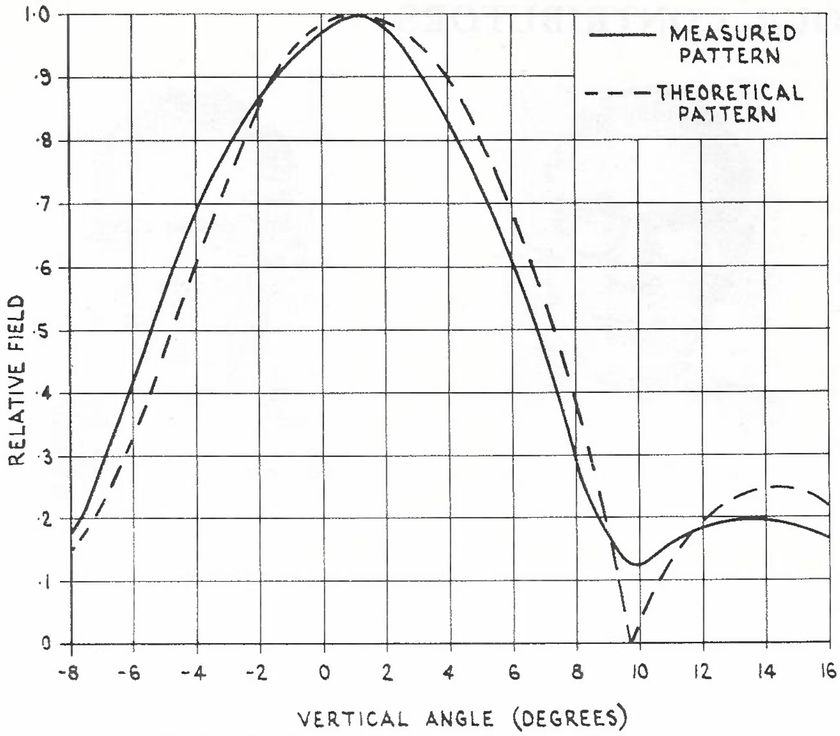

Fig. 4. — Vertical Radiation Patterns of Television Aerial.

ground level. It was found that only one tethering line was required to keep the balloon on the correct path. A number of tethering lines arranged in a triangular formation were tried on one occasion, but great difficulties were experienced in manoeuvring the balloon over the required range of altitudes.

A steady breeze of about 15 knots provided the best conditions for flying the balloon. This ensured a constant lift at all times and allowed the balloon to take up a position such that the angle between the tethering line and the horizontal was about 60 deg. In gusty winds the lift varied considerably, and caused the balloon to move in an arc, the centre of which was the tethering point. When flying at a height of 500 feet, this caused a variation in height of 100 ft. or so in a matter of seconds, thus making it impossible to position the balloon correctly.

The method of fixing the position of the balloon is shown in Fig. 3. An observer at point A on the mast sights the balloon with a clinometer. With this instrument he can determine the vertical angle of the balloon with respect to the aerial. He also sights the balloon with a compass to determine the horizontal angle. Any variations in the distance between the balloon on the mast is determined by an observer with a theodolite at point B Communication among the observers and operators was achieved using a number of portable transceivers tuned to the same frequency.

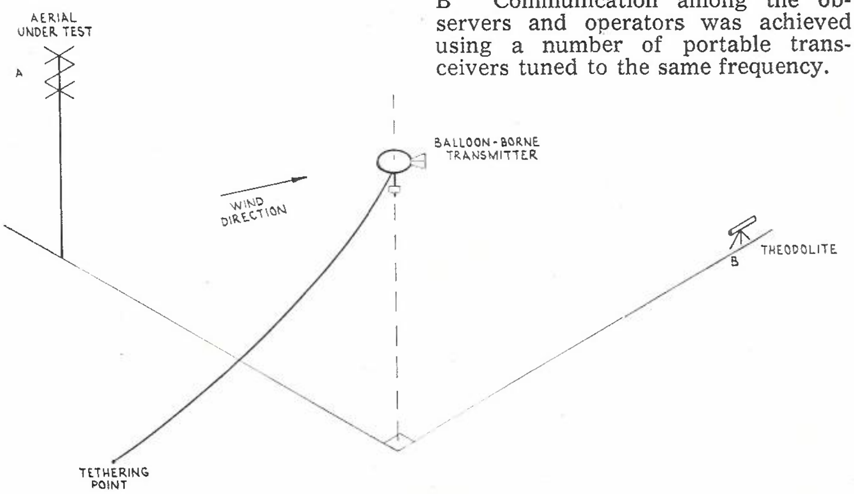

Fig. 3. — Physical Layout of Balloon and Position Fixing Apparatus.

RESULTS.

The results of the measurements taken are shown in Fig. 4. The measured pattern follows the predicted pattern very closely except for the region around and beyond the first null. The deviation from the predicted pattern is probably caused by ground reflections since in this region the balloon was fairly close to the ground. The measurements indicate that the beam tilt at approximately 1 deg. is correct, and this is probably the most useful information to be gained from a vertical pattern measurement.

CONCLUSION.

The use of a balloon represents a very simple and accurate method of measuring the patterns of television transmitting aerials after they have been installed and can provide results in a matter of an hour in most cases.

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R. T. O'DONNELL, co-author of the article, "Subscriber Trunk Dialling in Australia," entered the Postmaster-General's Department in 1925 as a Junior Mechanic-in-Training. He was successively a Mechanic and Senior Mechanic and in 1941 qualified at the Departmental "Open" Engineers Examination for promotion as Engineer. His experience as an engineer was mainly concerned with the installation of switching equipment in Sydney and in country areas in N.S.W. He was promoted as Divisional Engineer in 1948 and continued to be associated with manual and automatic switching equipment installation both subscribers and trunk, including the Siemens semi-automatic exchange at Lismore and the first S.T.D. installations in the State. In 1958 Mr. O'Donnell took up duty in the Internal Plant Planning Section of the Planning Branch as Supervising Engineer and was associated with the A.N.S.O. Committee and with the introduction of crossbar switching equipment into the Australian networks. He was promoted to the position of Superintending Engineer, Planning Branch, in 1962, a position which he currently occupies.

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N. P. FERSTAT, co-author of the article "New 12-Channel Multiplexing Equipment," joined the P.M.G.'s Department in Western Australia as a Cadet Engineer in 1950. After graduating from the University of Western Australia as Bachelor of Engineering (Electrical), he commenced duty in 1953 as a Grade 1 Engineer on Long Line Maintenance. In 1956 he became a Grade 2 Engineer on Long Line Installation, transferring in 1962 to Trunk Service. In 1964 he commenced a two-year period of temporary transfer to the Long Line Equipment Section, Central Office, where he occupied a Works Programme position dealing with specifications and provisioning of channel modem, cable carrier, carrier programme and through group filter equipment. He is an Associate Member of the Institution of Engineers, Australia.

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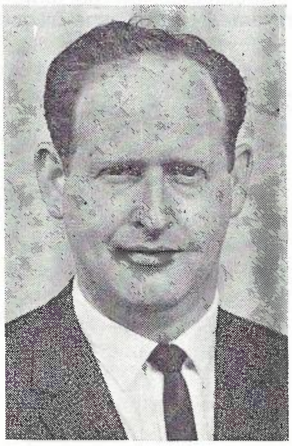
K. J. SIMPSON, co-author of the article, "Subscriber Trunk Dialling in Australia," joined the Postmaster-General's Department in 1938 as a Telegraph Messenger at Lismore, N.S.W., and commenced training as a Technician-in-Training in 1940. After four years' war service in the R.A.N., in which he received his commission, he completed his technical training in 1949. In 1950 he passed the Senior Technicians' Examination and also qualified as an engineer at the "Open" Engineers' Examination. He served in the Exchange Installation and Internal Planning Sections in N.S.W., gaining experience in both country and metropolitan areas before joining the Headquarters staff as Engineer, Class 4, Plan Development, Switching and Facilities Section, in 1962. His work in N.S.W. included the redesign of the numbering and switching plans for the Sydney network to cater for expansion to seven digit numbering, inclusion of the ELSA areas and recovery of the "O" digit from the network. At Headquarters he has been involved in the implementation of the National Plan, and the integration of crossbar switching equipment, particularly in the field of network planning and the implementation of the S.T.D. programme through the establishment of the automatic trunk network. In October and November, 1966, he spent six weeks overseas studying the development of automatic trunk networks in Europe, North America and Japan. Mr. Simpson is an Associate Member of the Institution of Engineers, Australia.



N. P. FERSTAT

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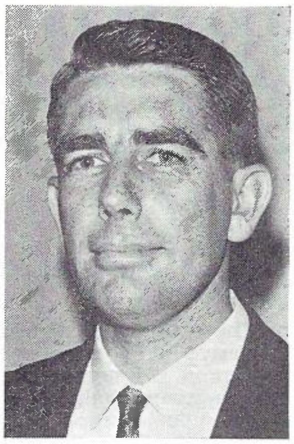
C. E. SMITH, co-author of the article, "New 12-channel Multiplexing Equipment," joined the British Post Office in 1938 as a Probationary Inspector. His training in the Post Office was interrupted in 1940, when he joined the Royal Signals, serving as a radio mechanic in an armoured regiment in North Africa and as a staff officer in Italy. He returned to the Post Office in 1946 and worked as a member of the group responsible for trunk service and transmission equipment maintenance first in the Home Counties Regional headquarters and then in the Engineer-in-Chief's office, Lines Branch. He also served in the Territorial Army during that period. He left the B.P.O. in 1957 to join the P. and T. Department, Sarawak, and was Assistant Controller of Telecommunications in Brunei for three years. He joined the Department in 1960 as Group Engineer in the L.L.E. Section Central Office, where he is responsible for programming and provisioning channelling equipment and carrier line equipment for balanced pair cables. He was promoted to Engineer Class 3 in 1962. He is an Associate Member of the Institution of Electrical Engineers and of the Institution of Engineers, Australia.

G. L. CREW



R. P. TOLMIE

J. R. ALCORN

G. L. CREW, author of the article, "Line Signalling," joined the Postmaster-General's Department as a Cadet Engineer at Hobart in 1955. After graduating from the University of Tasmania in 1959 he worked in the Planning Section, Tasmania, as Engineer Class 1, Traffic Studies, and Engineer Class 2, Internal Plant Planning. In 1963 he transferred to the Telephone Equipment Section, Central Office, where the major part of his work was related to the introduction of ARK equipment into the A.P.O. exchange network. For a short time he worked for the Switching and Facilities Section of the Planning Branch, and was recently promoted as Engineer Class 3, Crossbar Development, in the Research Laboratories.

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R. P. TOLMIE, author of the article, "Cairns-Weipa Radio Link with H.F. Log Periodic Aerials," joined the Postmaster-General's Department in 1952 as a Cadet Engineer. After graduating from the University of Queensland as Bachelor of Engineering in 1956, he was sent to the University of Adelaide for one year to carry out additional study in Electronics and obtained the degree of Bachelor of Engineering with Honours from that University. Following a period as Acting Group Engineer, Professional Training, Brisbane, Mr. Tolmie transferred to Radio Section in early 1959, and until early 1965 was Engineer Class 2, Radio Installation, including twelve months' relieving as Engineer Class 3. During this period he was occupied with the design and installation of numerous broadcasting studios and transmitters for the National Broadcasting Service in Queensland and Papua, New Guinea. For the last two years, as Engineer Class 2, Radio Telephone Installation, including four months relieving as Engineer Class 3, he has been occupied in the installation of various HF, V.H.F. and Microwave links in Queensland, particularly the high frequency links from Cairns to Weipa and from Mt. Isa to McArthur River.

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J. R. ALCORN, author of the article, "A Test Call Director for ARK Exchanges," joined the Postmaster-General's Department as a Technician-in-Training in 1946. After completing this course and a Departmental cadetship, he was appointed Engineer in 1955. Since then, except for a period of twelve months' association with Central Office on ARK Maintenance, he has been employed as a Country Engineer in Queensland. In this capacity he worked in Rockhampton, Townsville and Maryborough prior to his appointment as Divisional Engineer, Mackay, in 1965. Mr. Alcorn graduated Bachelor of Economics in 1964 and is an Associate Member of the Institution of Engineers, Australia.

BACK NUMBERS AND INDEXES

Some back numbers of the *Journal* are still in stock and are available on application to State Secretaries (for Australian residents), or the General Secretary (overseas residents). Prices for orders received during 1967 are as follows (post free Australian currency):—

	In Australia	Overseas
From Feb., 1964, (Vol. 14, No. 3)	$0.40	$0.52
Oct., 1963 (Vol. 14, No. 2) and earlier	$0.10	$0.20

A Volume Index is included in the last issue of each volume (No. 6 in Volumes 1-13, No. 5/6 in Volume 14, and No. 3 in Volume 15 onwards). A 12-year index is produced separately, and two have been published to date:

Index to Volumes 1-6 (1935-1948):

Price 15 cents (all addresses).

Index to Volumes 7-12 (1948-1961):

Price 30 cents (all addresses).

The following back numbers are **out of stock:—**

Vol. 1 (1935-1937), Nos. 1, 2.

Vol. 8 (1950-1952), No. 5.

Vol. 11 (1957-1959), Nos. 1, 3.

Vol. 12 (1959-1961), Nos. 1, 3.

Vol. 15 (1965), Nos. 2, 3.

Vol. 16 (1966), No. 3.

ANSWERS TO EXAMINATION QUESTIONS

Examination No. 5364, 3rd July, 1965, and subsequent dates to gain part of the qualifications for promotion or transfer as Senior Technician (Telecommunications), Telephone, Postmaster-General's Department.

SECTION 2.

LONG LINE EQUIPMENT.

QUESTION 1:

(a) A special meter is used for reading the programme level in circuits for broadcast transmission.
What is the name of this meter and in what main characteristic is it different from the various types of meters used for line-up purposes in telephone work?

(b) Assume a programme line when correctly lined up meets performance requirements with no margin. What would be the effect on the quality of the transmission if the level of the programme as fed into the line was:
(1) Too low?
(2) Too high?

ANSWER 1:

(a) A volume unit (v.u.) meter is used to measure programme power level. The main difference between a v.u. meter and meters used for line-up purposes in telephone work is in the dynamic characteristics. Meters used for line-up purposes may be sluggish in operation or overswing because of light damping, but accurate indications are obtained on constant level signals. A v.u. meter, however, is damped to reduce overswing, but, in movement must follow the main changes in programme volume, and to do this must conform with specified standards.

(b) (1) If the level of programme is too low, then an unsatisfactory signal to noise ratio margin would exist, resulting in the noise frequencies masking low-level passages of programme in the reproduced signal.

(2) If the level of programme is too high, overload of amplifying equipment would occur, resulting in non-linear distortion. New frequencies are produced (harmonics and intermodulation products), and these change the quality of the reproduced signal.

QUESTION 2:

The figure below is a block schematic of a repeater of a coaxial cable system with facilities to terminate circuits on supergroup 1 in each direction

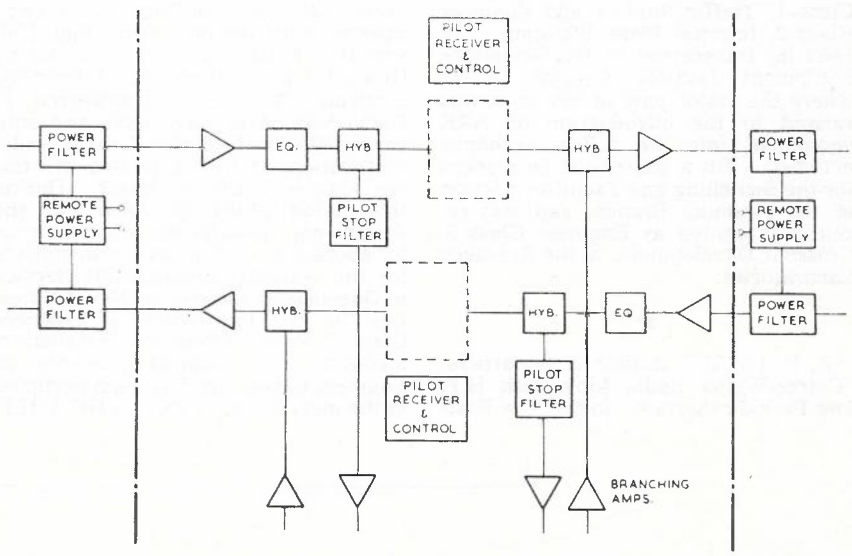
(a) What is the type and frequency range of the filter in the "dotted" block?

(b) Complete the diagram to show—

(1) The points of connection to the pilot receiver and control equipment.

(2) The main items necessary to derive V.F. circuits at the station. Equipment using a sub-group modulation stage, may be included or not as desired. Show the connection of carried supplies to modulators, but the actual frequencies are not required.

(c) Show on the diagram the frequency range at the output of the group and supergroup modulators.



ANSWER 2:

(a) A band stop filter with a blocking range from 60 - 300 kc/s.

(b) (1) A suitable answer can be found in the "Telecommunication Journal of Australia," Vol. 13, No. 4, page 194, Fig. 5.

(2) The basic information required is given in the "Telecommunication Journal of Australia," Vol. 13, No. 4, pages 293 and 294. The main elements of Fig. 4 (page 293) should be shown, but with carrier supply connected to the various modems. For terminal equipment, using a sub-group modulation stage, a channel modem, a sub-group modem, a group modem, and a supergroup modem should be shown. For terminal equipment, using a single stage of channel modulation, a channel modem, a group modem, and a super-group modem should be shown. **The transmitting and receiving terminal equipment should be connected to the repeater equipment (Fig. 5). (page 294), for both directions.**

(c) Frenquency range at the output of the group modulator 312-552 kc/s
Frequency range at the output of the supergroup modulator, 60-300 kc/s.

QUESTION 3:

Draw a block schematic circuit of a 2-wire voice frequency repeater. What is the purpose of the equipment in each of the blocks?

ANSWER 3:

A typical block schematic circuit and explanation can be found in the Course of Technical Instruction, Long Line Equipment 2, Paper 1, Fig. 17 (b) and Section 8.

QUESTION 4:

(a) What do you understand by the terms near-end and far-end crosstalk?

(b) Explain what is meant by "poling" of carrier systems and describe the effect that this has on near-end and far-end crosstalk.

(c) Two carrier systems operate over the same pole route between adjacent repeater stations. What will be the effect if these systems are lined up to different transmitting levels.

ANSWER 4:

(a) Crosstalk is defined with reference to the "disturbing source," so that near-end crosstalk is that appearing in the disturbed circuit at the end nearest the disturbing source; and far-end crosstalk is that appearing in the disturbed circuit at the end distant from the disturbing source.

(b) "Poling" of carrier systems is the arrangement of transmission directions to ensure that similar ranges of frequencies are transmitted in the same direction on adjacent pairs on the same route. In general in Australia, systems are installed to transmit A-B counter-clockwise, taking Perth as a starting point. Poling of systems avoids the possibility of near-end crosstalk, but the value of far-end crosstalk is dependent on normal crosstalk reduction methods, e.g., transpositions of open wire pairs, etc.

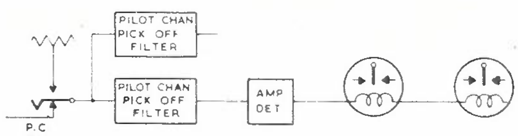
(c) The effect of different transmission levels for two similar types of carrier systems is, a high level of crosstalk with respect to signal level in the system transmitting at the lower level.

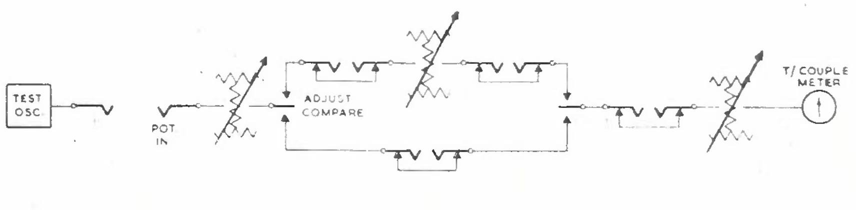
QUESTION 5:

(a) The schematic diagrams below represent part of the pilot control equipment of a 12-channel type J open wire carrier telephone system, a variable oscillator 0-150 kc/s, and a transmission measuring set (30A type)—
  (1) Draw in the connections you would make to carry out a pilot amplifier - rectifier sensitivity measurement.
  (2) Describe the method of carrying out the test. The procedures necessary to adjust the oscillator to the correct frequency and to calibrate the thermo-couple are not required.

(b) At what value of deviation of the sensitivity from the line-up value is adjustment required?

(c) At what value of deviation of the sensitivity from the line-up value is a more detailed equipment check required?





ANSWER 5:

The information necessary to complete the measuring circuit can be found in A.P.O., Engineering Instruction, LONG LINE EQUIPMENT, General, R2515, Fig. 17. The method of carrying out the test is described in Para. 6.2 of the same instruction.

QUESTION 6:

Draw a block schematic diagram of one channel of an A.M. V.F. telegraph system;. describe briefly the function of each block of apparatus.

ANSWER 6:

A block diagram and functions of components of a typical A.M. V.F. telegraph system are given in the Course of Technical Instruction, Long Line Equipment 2, Paper 7, Fig. 2 and Para. 2.2.

QUESTION 7:

You have just completed the installation of one terminal of a modern 3-channel carrier telephone system (not necessarily transistor type):

(a) List the tests which you would carry out to ensure that the terminal is in good working order so that line-up may proceed. You are not required to carry out the overall system line-up. Details of how the tests should be carried out are not required.

(b) List the test equipment which would be essential for the completion of your initial testing.

ANSWER 7:

The tests and test equipment are listed in the A.P.O. Engineering Instruction, Internal Plant, Installation General, R86510, pages 4 and 5. Tests up to No. 13, with appropriate test equipment, should have been listed. Suitable substitute test items could be given.

QUESTION 8:

(a) Name two applications in long line equipment installation for which quad cable is particularly suited.

(b) With the help of a diagram indicate the allocation of wires to pairs in a quad.

(c) What is the effect of incorrect use of wires in quad cables containing balanced circuits?

(d) Briefly describe the make-up of single pair shielded conductors used for long line equipment rack inter-connection.

(e) Where should the shields of single pair shielded conductors, used for long line equipment rack inter-connection, be earthed?

ANSWER 8:

(a) A suitable answer is contained in A.P.O. Engineering Instruction, INTERNAL PLANT INSTALLATION, Wires and Cables, C1510, para. 1.5.

(b) A suitable diagram is given in the Course of Technical Instruction, Long Line Equipment 3, Paper 5, Fig. 17.

(c) A relatively high degree of crosstalk would occur between the circuits concerned.

(d) The A.P.O. Engineering Instruction, INTERNAL PLANT INSTALLATION, Wires and Cables, A3510, contains illustrations of typical shielded pairs used for long line equipment rack interconnection. A description can be obtained from these illustrations.

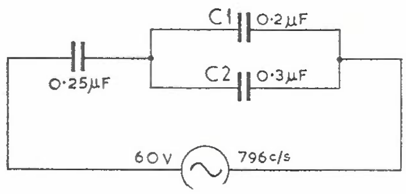
(e) A suitable answer is found in the A.P.O., Engineering Instruction, INTERNAL PLANT INSTALLATION, Wires and Cables, A3510, Para. 4.1.

Examination No. 5482, etc., July, 1966, to gain part of the qualifications for promotion or transfer as Senior Technician (Telecommunications), Postmaster General's Department.

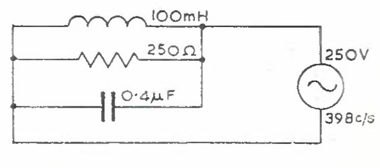
TELECOM PRINCIPLES.

QUESTION 3:

(a) A network of capacitors is connected to a 60-volt, 796 c/s supply as shown.
Calculate:
  (1) The current through C1.
  (2) The voltage across C2.



(b) The parallel network shown below is connected to a 250 volt, 398 c/s supply.
Calculate:
  (1) The LINE CURRENT.
  (2) The IMPEDANCE of the network.



ANSWER 3 (a)

$C1 + C2 = 0.2 + 0.3 = 0.5\mu F$

$\therefore$ one third of 60V = 20V across combination (and C2) (X_c would be half that of $0.25\mu F$ capacitor)

At 796c/s, $\omega = 5000$

$$\therefore X_{c1} = \frac{1}{\omega C} = \frac{10^6}{5000 \times 0.2} = \frac{10^6}{10^3} = 1000\Omega$$

$$I = \frac{E}{X} = \frac{20}{1000} = 20mA.$$

ANSWER 3 (b)

At 398c/s, $\omega = 2500$

$$\therefore X_L = \omega L = 2500 \times 100 \times 10^{-3} = 250\Omega$$

$$X_c = \frac{1}{\omega C} = \frac{10^6}{2500 \times 0.4} = \frac{10^6}{10^3} = 1000\Omega$$

$$I_R = \frac{E}{R} = \frac{250}{250} = 1A$$

$$I_L = \frac{E}{X_L} = \frac{250}{250} = 1A$$

$$I_c = \frac{E}{X_c} = \frac{250}{1000} = 250mA$$

$$I_L - X_c = 1A - 250mA = 750mA$$

$$I_{line} = \sqrt{I_R^2 + (I_L - I_c)^2} = \sqrt{1000^2 - 750^2} = 1250mA = 1.25A.$$

$$Z = \frac{E}{I} = \frac{250}{1.25} = 200\Omega$$

Answers—

(a) (i) 20mA (ii) 20V

(b) (i) 1.25A (ii) 200Ω.

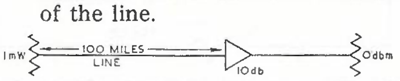
EXAMINER'S COMMENTS.

In part (b) (1) many candidates merely added the branch currents to find the line current, or used other incorrect methods. If these candidates had drawn a vector diagram they should have been able to deduce the correct method.

In (b) (2) many formulas were used to find impedance from the component values, including that for the series circuit. The method of using line current and voltage is the simplest.

QUESTION 12:

(a) From the information shown below calculate the attenuation constant of the line.



(b) A transmission measuring set, with a high input impedance, is calibrated to read power in decibels relative to 1mW in 600 ohms. In the absence of a suitable meter, it is terminated in 150 ohms and used to measure the power input of an amplifier designed to operate into a 150 ohm load.

A reading of +25dBm is obtained on the meter.

What is the actual power delivered to the 150 ohm terminating resistor?

ANSWER 12:

(a) 1mW = OdBm,.

So amplifier gain = line loss = 10dB.

$$\text{Atten. Constant} = \frac{\text{Line Loss}}{\text{Distance}} = \frac{10}{100} = 0.1\text{dB/mile}.$$

(b) Correction Factor $= 10 \log \frac{Z1}{Z2}$,

where

Z1 = Calibrated Z

Z2 = Termination Z

$$\therefore dB = 10 \log \frac{600}{150} = 10 \log 4. = 6dB$$

As termination Z is lower than calibrated Z, the correction factor is added.

dBm = 25 + 6 = + 31dBm.

Alternative Method.

If the above formula was not known, the problem could be solved by knowing that the T.M.S. responds to voltage and converting the indicated voltage to power in the 150Ω termination as below.

Power indicated

$$(mW) = \text{Antilog} \frac{dB}{10} = \text{Antilog } 2.5 = 316.2mW$$

Voltage to produce this is 600Ω =

$$\sqrt{P \times R} = \sqrt{\frac{316.2 \times 600}{1000}} = \sqrt{199.7} = 14.14V.$$

This is the voltage across 150Ω termination, so Power (150Ω)

$$= \frac{E^2}{R} = \frac{14.14^2}{150} = \frac{200}{150} \times 1000 = 1333.3mW.$$

$$dBm = 10 \log \frac{P1}{1} = 10 \log 1333.3 = + 31dBm$$

Answers:

(a) 0.1dB per mile

(b) +31dBm

EXAMINER'S COMMENT:

Part (a) was generally well answered.

Part (b) Many candidates who attempted this problem had wrong ideas about the operation of a T.M.S. and of the relationship between voltages and power of the T.M.S. when correctly and incorrectly terminated. The first method shown was seldom used. The other method, though longer, is well within the time available for the question.

Examination No. 5482, July, 1966, to gain part of the qualifications for promotion or transfer as Senior Technician (Telecommunication), Telephone, Postmaster-General's Department.

TELEPHONE EQUIPMENT.

QUESTION 4:

(a) The nation-wide subscriber dialling plan has a trunk access code and a maximum of eight numerical digits for subscribers' numbers:

(1) Which digit is allocated as the trunk access code?

(2) Give an example of a national number for a subscriber situated in a 7 digit local number scheme.

(3) Which is the "A" digit in your answer to question 4 (a) (3)?

ANSWER 4:

(a) (1) The digit "O" is the digit allocated as the trunk access code.

(2) 03-630 7744.

(3) The "A" digit in the number above is the first "3" which follows the trunk access digit "0."

QUESTION 4:

(b) Explain briefly the difference between early choice routes and final routes as used in the context of automatic alternate routing of telephone calls.

ANSWER 4:

(b) (1) An early choice route is one for which one or more alternative routes are provided. It provides a preferred direct link between any two centres, where it is able to carry a portion of the traffic offered more economically than the alternate routes.

(2) A final route is one for which no later choice alternate routes are provided. It is equipped with sufficient circuits to ensure that there is only a small probability of loss calls for the traffic offered during the busy hours. In this way it controls the overall system grade of service.

Traffic is first offered to the most direct route, but if all circuits are busy the call is routed by alternate paths.

QUESTION 4:

(c) In a numbering plan context what is the difference between a local number and a national number?

ANSWER 4:

(c) A subscribers' national number consists of an area code followed by the local directory number. In the example given in 4 (a), the digits 03 form the area code and the remaining digits 630 7744 form the local number. For a call within the same numbering plan area, only the local directory number is dialled. For a call beyond the same numbering plan area, the complete national number must be dialled.

QUESTION 4:

(d) Explain briefly the effect on 2VF signalling equipment if a break period was not provided in the N.U. tone from automatic exchanges.

ANSWER 4:

(d) The nominal frequency of the N.U. tone (400c/s) is received by the Amp. Limiter of the 2V.F. equipment. Harmonics are produced, and the 2nd harmonic of the N.U. tone (400c/s) is received by the the 750c/s tuned circuit, causing a locking up of the signalling circuit. The break in the N.U. tone allows the release of the trunk line relay set.

QUESTION 5:

(a) Explain briefly what is meant by the following terms when used in connection with trunking and switching aspects of telephone calls in automatic exchanges:
(1) "Pure chance" telephone traffic.
(2) "Smooth" telephone traffic.
(3) "Grading."

ANSWER 5:

(a) (1) Pure chance traffic is the type of traffic generated by a large number of subscribers who make their calls independently of each other. This is assumed to occur in primary groups with more than 200 calling sources which has random traffic peaks.

(2) After pure chance traffic has passed through a number of switching stages it loses its randomness, due to the combination of the various peaks, and is said to be smooth. This is assumed to occur at all switching stages in Step by Step other than the first stage.

(3) Grading is a system of interconnecting used on uniselectors or selectors which aways test the trunks in the same order of search. It is a method of connecting outlets together so that a group of switches is given access to individual trunks on the early choices, but in the latter choices shares access to trunks with other groups.

QUESTION 5:

(b) Explain briefly why, for a given amount of telephone traffic, more switches are required for "pure chance" traffic than "smooth" traffic.

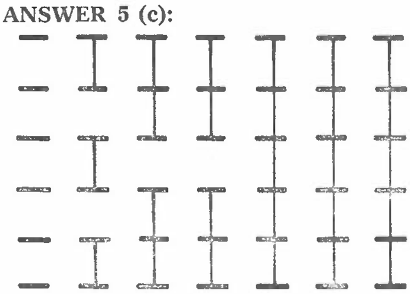
ANSWER 5:

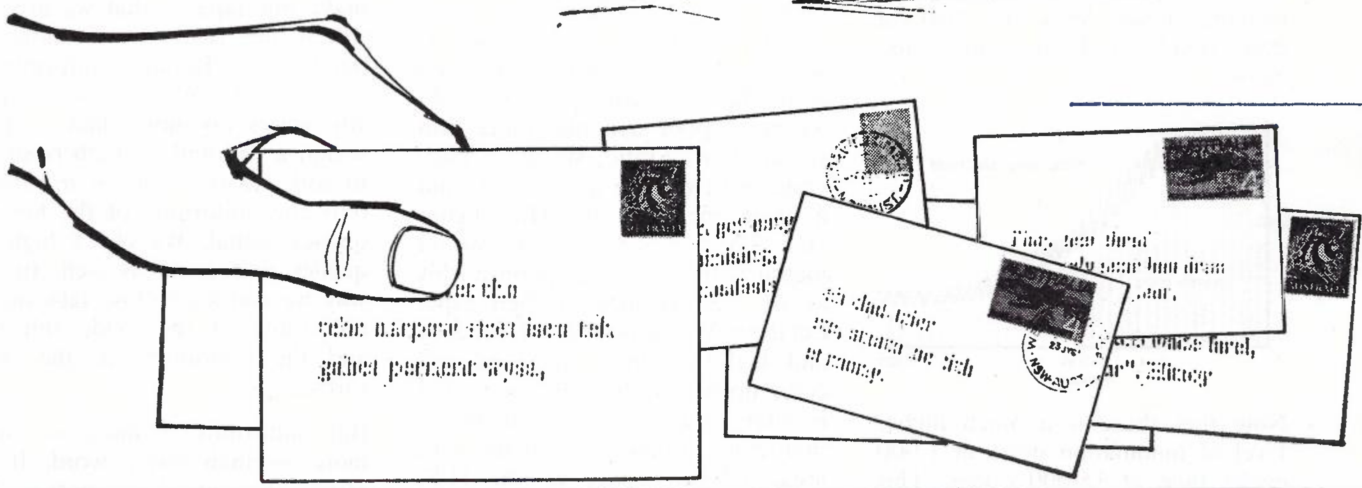
(b) With pure chance traffic, the number of switches provided is influenced largely by the traffic peaks, with many switches idle between peaks. With smooth traffick the peak traffic is much closer to the average traffic due to the combining effect of the peaks from various groups. The traffic provision for smooth traffic is therefore less.

QUESTION 5:

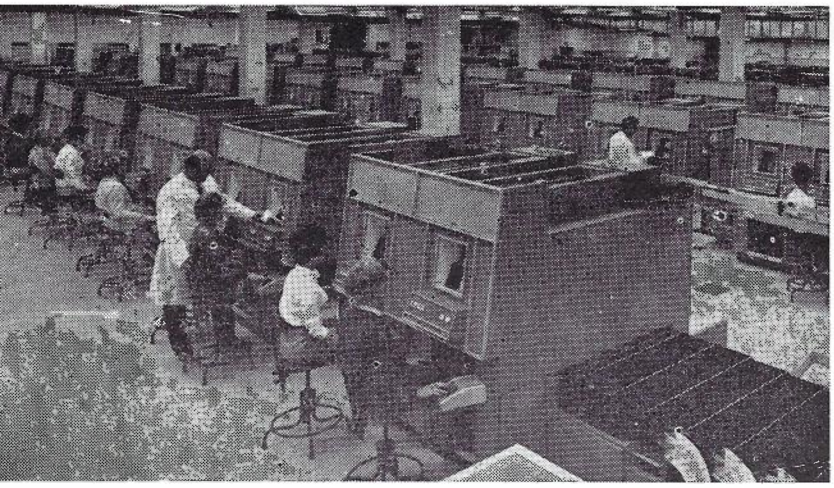
(c) The short dashes given below represent sets of multiple bank outlet contacts in an automatic exchange from a rank of switches. Show how you would common the outlets for a grading pattern in a 6-group grading with an availability of 7 for 16 trunks comprising 1 individual, 1 pair, 2 three and 3 common trunks per feed.

ANSWER 5 (c):

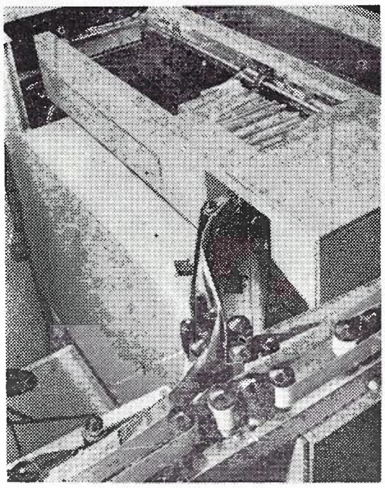


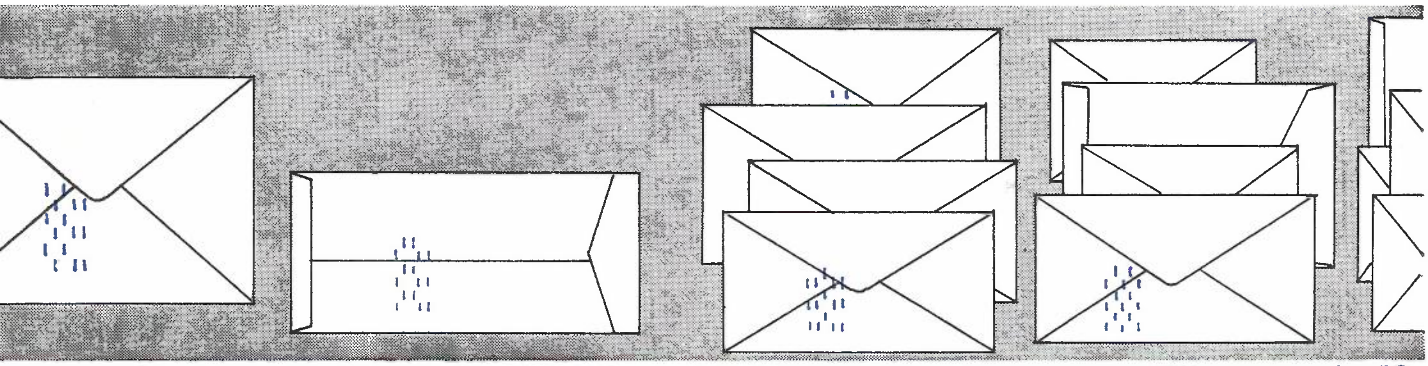


...ting the suites of coding ...chines prior to commission-



Unsorted mail is conveyed at 600 ft. per minute to the storage stackers located above each operator's position. The stackers are replenished automatically to ensure continuity of operation.

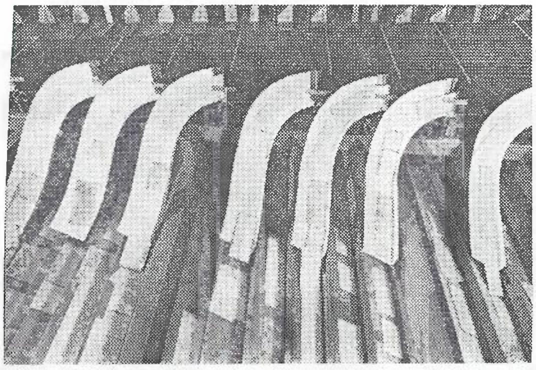


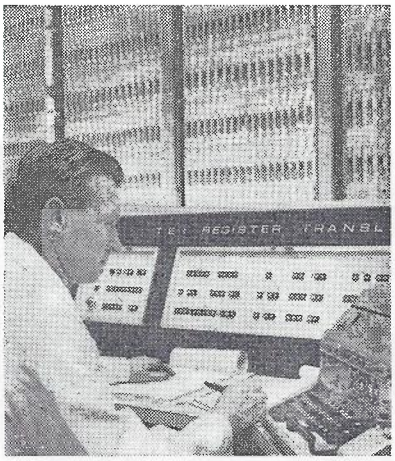


The first working model was tested in 1964 and the entire installation, comprising 150 operators' coding positions, 20 decoding machines and associated transfer conveyors, was completed for commissioning in 1966.

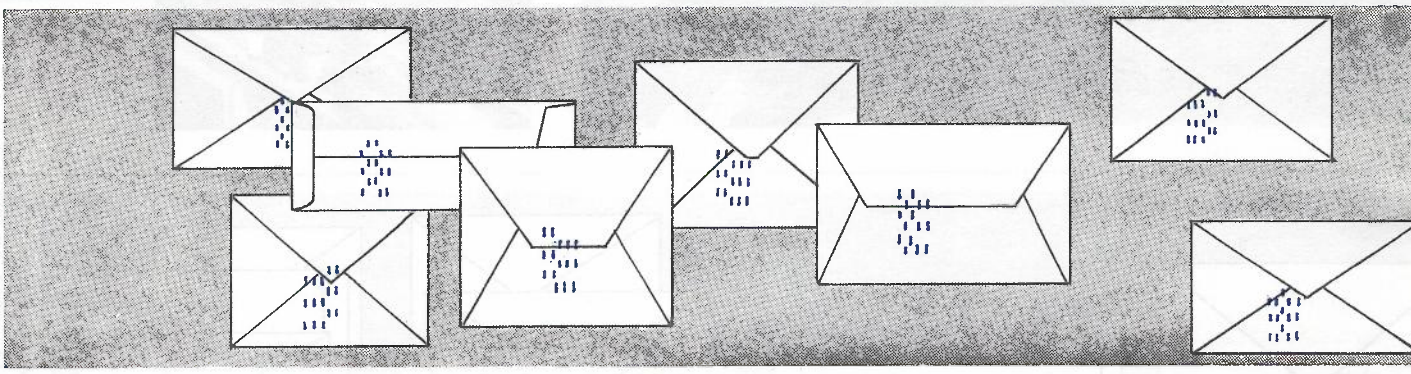
The simple step-by-step break-up in separate stages, each of 30 separations, gives maximum flexibility of equipment layout and greatly simplifies the mechanical problems associated with automatic letter-sorting to a large number of destinations.

After coding the letters are separated into 30 channels and discharged on to floor conveyors leading to the decoding machines.





The register translator equipment and control console.

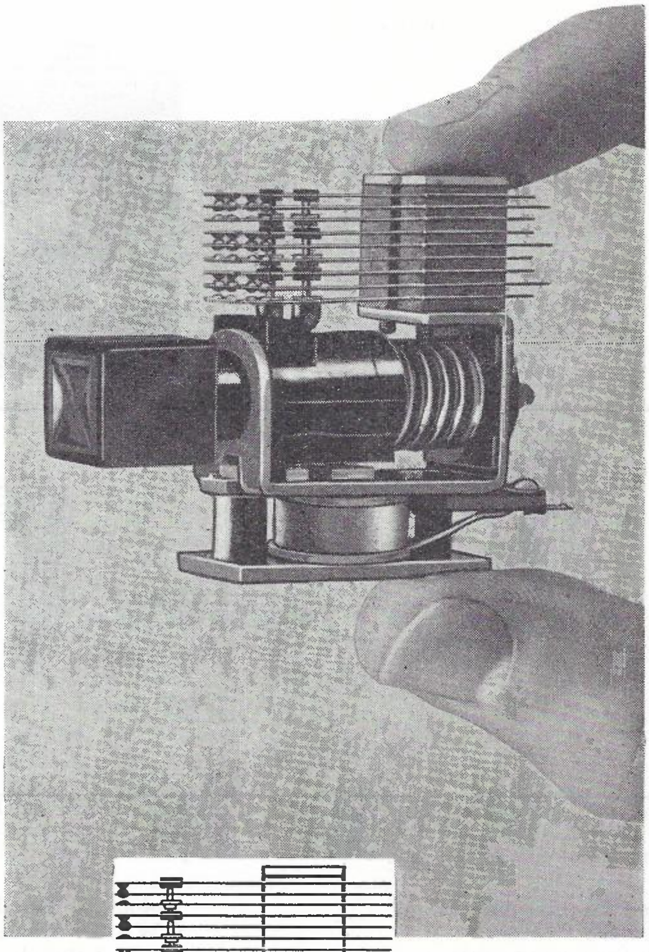


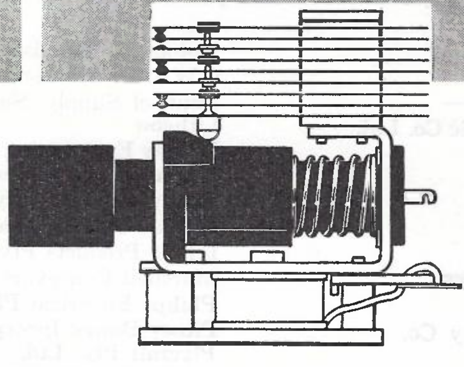
The heart of the coding system is the electronic register translator. TEI, as a member of the world-wide Plessey Group of companies, had access to the results of research and design work carried out by the Automatic Telephone & Electric Company of Liverpool, England, in the use of magnetic drums for information storage and translation.
These basic principles were developed by TEI for the particular purpose of receiving key-coded information from the operators' positions, its storage and recognition by the drum equipment, translation and final command instructions to the operators' code printers and primary sorting equipment.

the KEY to better switching

TMC AUSTRALIA

illuminated PUSH-BUTTON KEY-SWITCH





Actual size of a TMC Illuminated Push-Button Key-Switch. Available with magnetic hold or standard.

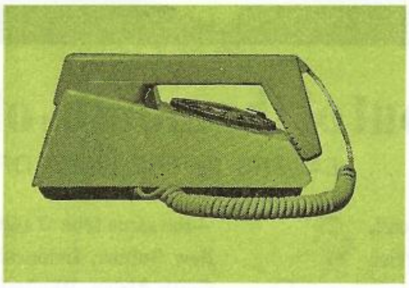
Fifty years of specialist experience is the reason why switches designed and manufactured by TMC Australia are specified by leading electrical and electronics manufacturers.

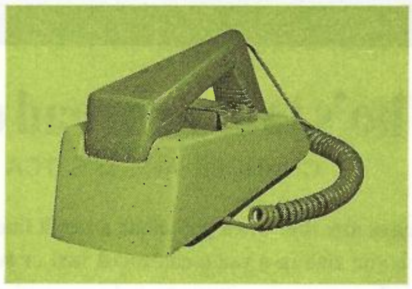
Other manufactures of TMC Australia are: 24-channel High-speed FM-VF Telegraph Equipment, Open-wire Telephone Carrier Systems, Transistorized Test Instruments.

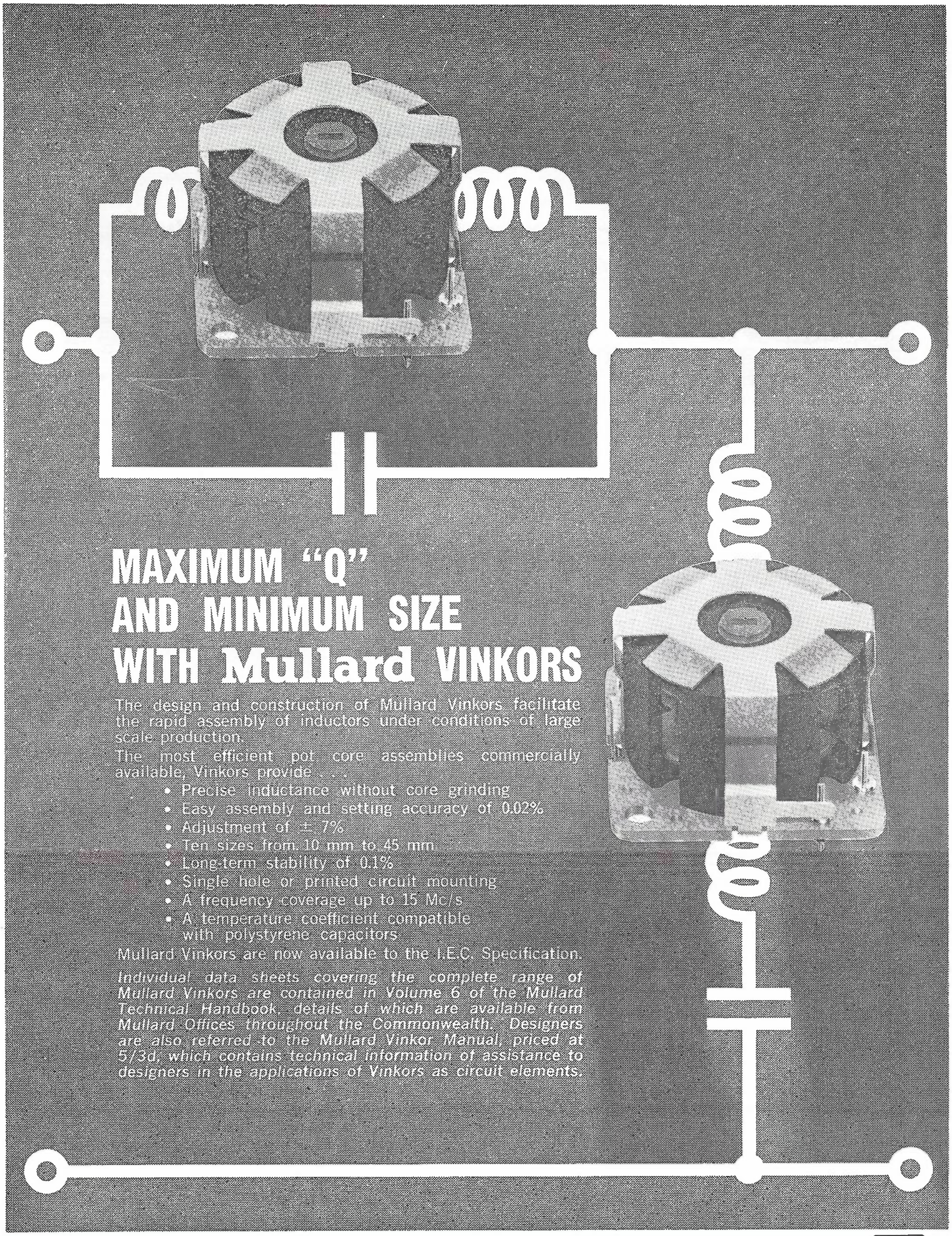
TMC Australia specialises in the design and manufacture of Filters used with Long Line Telecommunications.

TMC AUSTRALIA **Key Switches by the Key Switch Specialists**

TELEPHONE MANUFACTURING CO. [A'ASIA] PTY. LTD.



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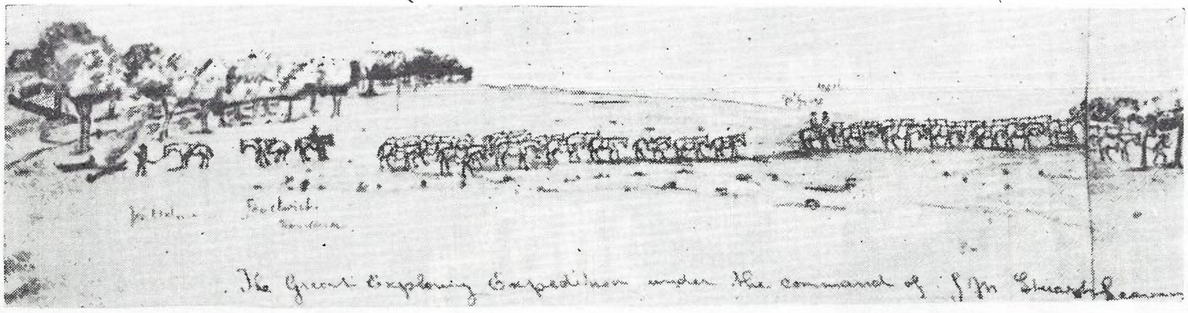

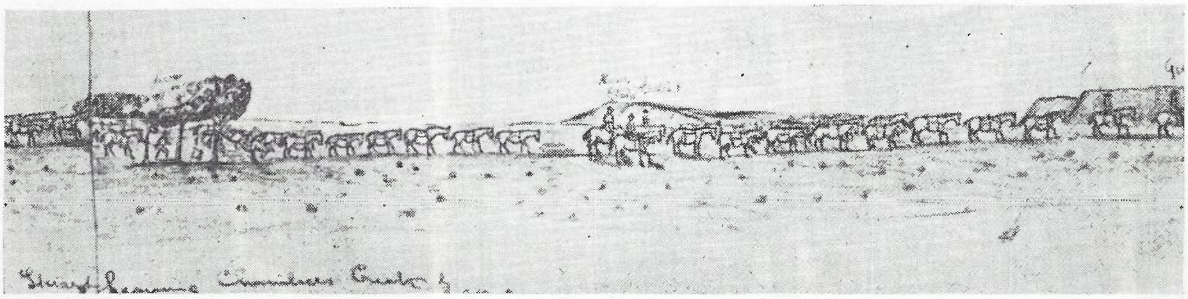

The expedition, under the command of John McDouall Stuart, leaving Chambers Creek on 8th January 1862.

From originals held in the Archives Department of the Public Library of South Australia.

Point Stuart, where the coast was first reached on 24th July 1862.

£2,000 REWARD

Over 100 years ago, the South Australian government offered £2,000 to the first person to cross to the Northern part of the continent. One of the main reasons for doing so was to bring about the proposed link with the cable and telegraph line to Europe.

The reward was eventually won by John McDouall Stuart, who succeeded in finding a route across the centre of Australia on his sixth and final expedition.

More than a century later, a new £3,200,000 transcontinental microwave communications system, linking eastern and western Australia, is to be supplied by G.E.C. (Telecommunications) Ltd., of Coventry, England. The system, one of the longest civil microwave links in the world, will be in service in 1969. By this date, telephone traffic over the 1500 mile route linking Perth and Adelaide—as far apart as London and Moscow—will amount to about one million calls a year.

Initially, the system will provide two bothway radio bearer circuits, one main and one standby, with a capacity of 600 telephone circuits. The standby circuit may also be used to provide a television link giving a nationwide T.V. network. In addition a separate T.V. link will be provided between Northam, near Perth, and Kalgoorlie.

Completely semiconductored equipment, operating in the 2000 Mc/s frequency band, will ensure maximum reliability and minimum maintenance of the equipment throughout the mainly virgin country which it will traverse. Over a hundred years after John McDouall Stuart's achievement, G.E.C. (Telecommunications) Ltd. will forge new links across the continent.

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Represented in Australia by
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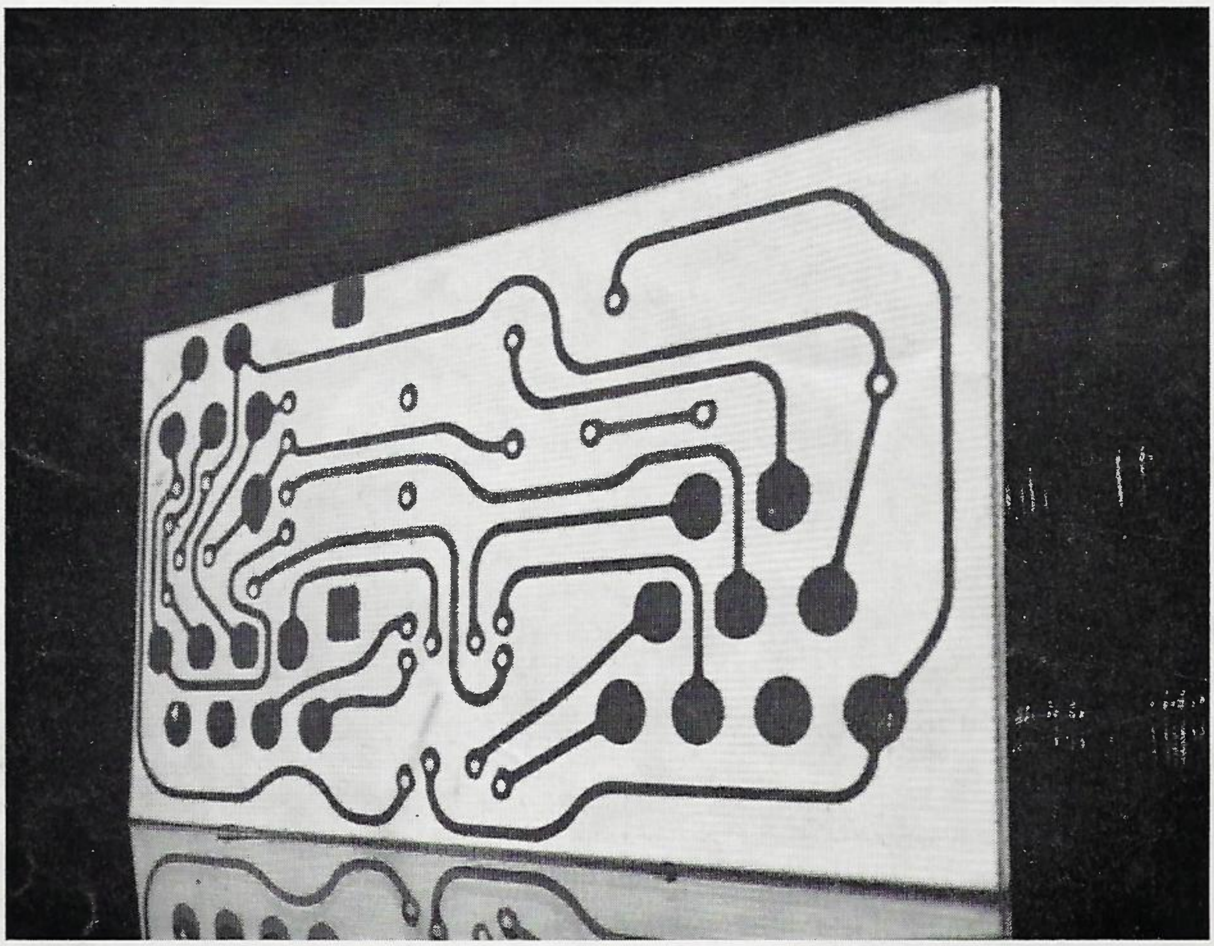

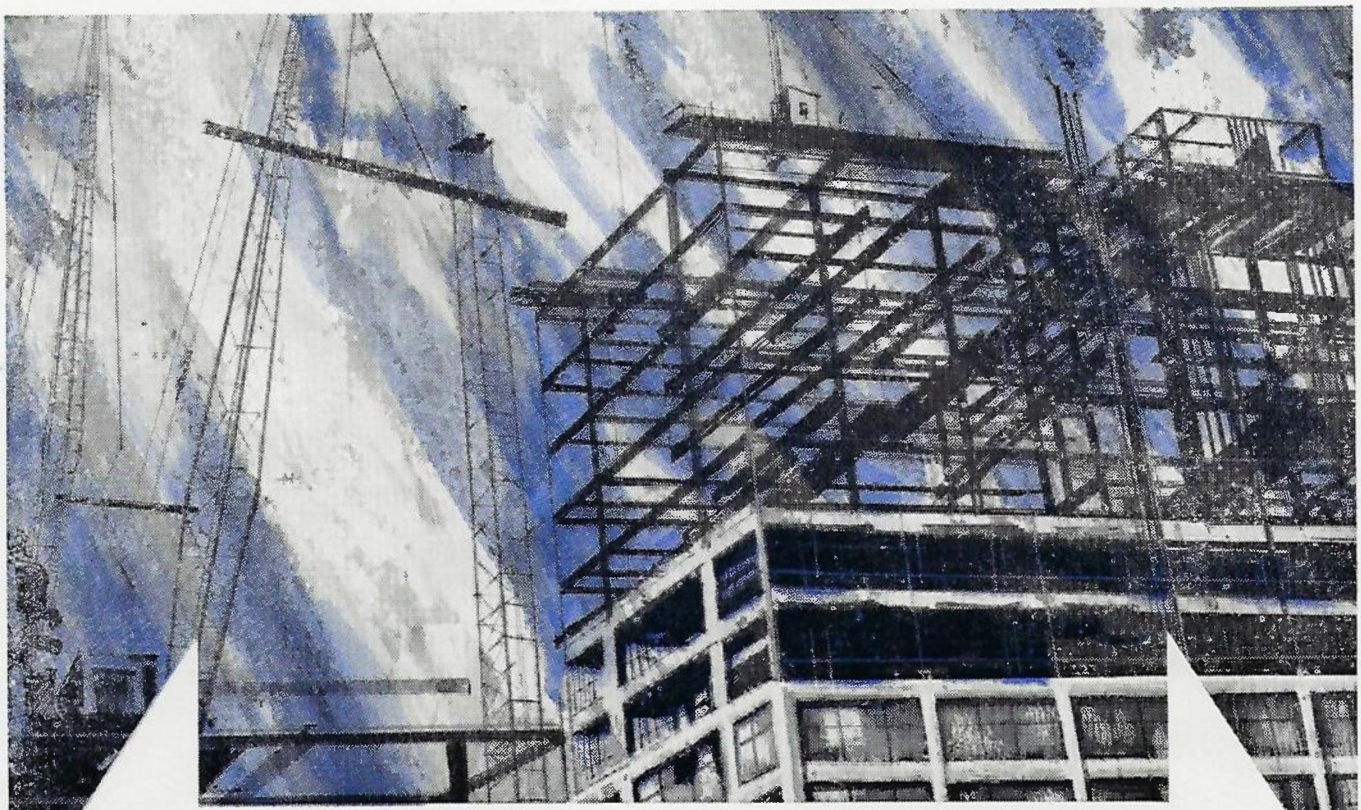

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