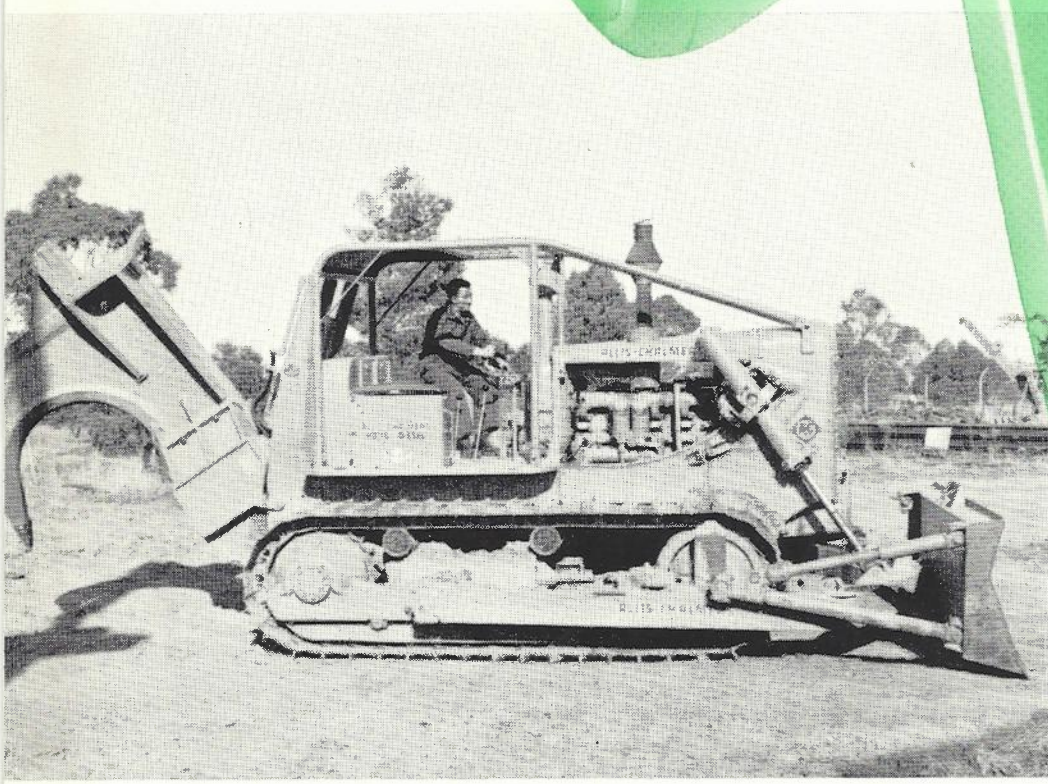
THE

Telecommunication Journal OF AUSTRALIA



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The

TELECOMMUNICATION JOURNAL

of Australia

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This Journal is available to members of the Postal Electrical Society of Victoria without charge. Non-members may obtain copies of all publications of the Society on the payment of 10/- p.a. Single copies of this Journal are available at 4/- each.

Remittances should be made payable to "The Postal Electrical Society" and should not include exchange. All communications should be addressed to the "Hon. Secretary, Postal Electrical Society, G.P.O. Box 4050, Melbourne".

MR. C. J. GRIFFITHS, M.E.E., A.M.I.E.E., A.M.I.E. Aust.

On February 19, 1959, Mr. C. J. Griffiths was appointed Assistant Engineer-in-Chief (Services). Mr. Griffiths joined the Department as an Engineer in 1927 and his first duties were in the Telephone Equipment Section of the Victorian Administration. Subsequently he worked in the Telegraphs, Lines and Transmission Sections of the Victorian Administration for a total period of 8 years.

In 1935 he transferred as an Engineer to the Lines Section in Central Office where he worked in various positions until 1957. He was promoted as Divisional Engineer in 1939, became an Assistant Supervising Engineer (Sectional Engineer) in 1947 and was promoted as Supervising Engineer (Lines) in 1955. During this period he was engaged on a wide variety of Lines Section activities including transposition design, cable protection, major trunk aerial and cable installations. He was closely associated with the Central Office work on many projects of national importance such as the Sydney-Maitland, Melbourne-Ballarat and Adelaide-Nuriootpa Trunk Cables, the Adelaide-Perth, Adelaide-Darwin and Townsville-Cape York Trunk Routes and the Bass Strait Submarine Cable. Mr. Griffiths was the Departmental representative for the development of telecommunication facilities at the Woomera and Maralinga Rocket Range projects.

Mr. Griffiths visited New Zealand on two occasions to discuss mutual problems with the New Zealand Post Office, and in 1958 whilst on leave overseas he spent two months on duty discussing latest developments with various communication authorities in Europe and the U.S.A.

Mr. Griffiths has been very active in Postal Electrical Society affairs and has over a long period enthusiastically supported the Journal. He was elected a Life Member of the Society in 1953. A tribute to his work as Editor of the Journal was included in the June 1956 issue. The Board of Editors and the Society generally are particularly pleased to congratulate Mr. Griffiths on his promotion and we offer him on behalf of all our readers best wishes for the future and full support in his new appointment.

MR. A. WILSON

Congratulations are extended to Mr. A. Wilson on his recent appointment as Assistant Engineer-in-Chief (Plant). Mr. Wilson has had an interesting career in the Engineering Division of the Post Office, having specialised mainly on equipment matters.

Following education to matriculation standard at the Fort Street Boys' High School, Sydney, he was successful at the open examination for Junior Assistant Engineer held in 1913, and indeed topped the Commonwealth results in that examination. Subsequently, he was appointed as Junior Assistant Engineer on March 10, 1914. He commenced almost immediately on telephone equipment work after a short period dealing with material testing, the telephone equipment work being concerned with the installation of some of the early automatic exchanges in the Sydney network.

He joined the A.I.F. and was on overseas service from 1916 to 1919; upon return he was engaged again in the telephone equipment field on installation and maintenance aspects. In 1926 Mr. Wilson was in charge of the installation of the largest exchange which, up to that date, had been wholly installed under the direction of an Engineer of his grade. Just previously he had designed circuits and installed equipment which was unique at that time in world practice, for automatic in-calling to a manual exchange in lieu of the usual practice at the time of handling such calls on manual positions. A particularly interesting job was undertaken in 1930 when Mr. Wilson was responsible for the installation and subsequent maintenance of equipment for the inauguration of the Radio Telephone Service between Australia and London. After installation of a number of automatic exchanges, large P.A.B.Xs and the complete replacement of the Sydney main trunk exchange, Mr. Wilson's installation interests changed mainly to country installation work and he became responsible for all country exchange and carrier installation work in New South Wales; this work carrying some maintenance responsibility as well.

He was appointed Divisional Engineer,

responsible for trunk exchange, country exchange and carrier installation and maintenance throughout N.S.W., in 1935, and transfer to Headquarters followed soon afterwards in 1938. Shortly after arriving at Central Office he was promoted as Assistant Supervising Engineer. From 1941 to 1959, first in an acting capacity and then as appointed Supervising Engineer, Telephone Equipment, Central Office, Mr. Wilson entered into a varied field of projects in telephone equipment matters which included the development of the manufacturing in Australia of practically all types of telephone equipment used in exchanges and subscribers' premises. It will be appreciated that, particularly as much of this work had to be initiated during the war years when many special problems of material and staff shortages were evident, much credit is due to Mr. Wilson for his energy and persistence to arrive at the present position of having so much good-quality locally-manufactured equipment available. In this regard he is Chairman of the Local Manufacture of Automatic Telephone Equipment Advisory Committee. During his time at Headquarters he helped to foster the development and expansion of two factories in Australia devoted almost exclusively to the manufacture of telephone equipment. It is confidently expected that Mr. Wilson's qualities of energy and leadership, with which he combines a very approachable and pleasing personality, will be of inestimable value to the Engineering Division in his new position as Assistant Engineer-in-Chief (Plant). His interest in the Telecommunication Journal has always been maintained and the assistance which he has freely given in the past will no doubt be continued in the future in this field.

THE NATIONAL TELEPHONE PLAN — NUMBERING

R. W. TURNBULL, A.S.T.C. (Elec. Eng.)
G. E. HAMS, B.Sc.
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INTRODUCTION

The article entitled "Nation-Wide Dialling System for Australia" in the October, 1958, issue of this Journal dealt with the principles for the long term development of the Australian telephone service. This article describes one of the basic elements in the design of the system—the national numbering plan.

TYPE OF NUMBERING

The numbering plan is the basis for the instructions given to subscribers so that they may dial their own calls over the national telephone system. As such, it should be simple to understand and capable of being used accurately. Incorrectly dialled calls result in wasteful use of costly trunk lines and switching equipment and inconvenience to subscribers.

From the technical viewpoint, each telephone number constitutes information which, when dialled into the automatic system enables it to establish connection to a particular subscriber's service and to apply the appropriate charge when the subscriber answers. The numbering plan chosen should facilitate the economic use of plant by allowing application of flexible switching equipment and should enable equitable charging to be performed automatically at reasonable costs.

These requirements are most satisfactorily met by a numbering scheme in which each subscriber's service is identified by a unique telephone number—the same number being dialled to reach a particular subscriber regardless of where the call is originated. This type of numbering is referred to as closed numbering. It has been adopted for the Australian national automatic telephone system, with some modification to provide shorter numbers on calls within networks covering local communities of interest.

Since the telephone numbers can be used regardless of the point of origin of calls, the same directory information may be given to all subscribers. Directories for any region may be prepared in bulk and distributed throughout the Commonwealth as required. Also, subscribers may include their national numbers on letter-heads and in advertisements, providing a useful supplement to Departmental directories and a valuable advertising feature for the public.

DIALLING PROCEDURES

Although a single closed numbering scheme for the Commonwealth would result in very simple directory instructions, it would require subscribers to dial a large number of digits on all calls.

Dispersion studies show that the bulk of the traffic originating from any exchange is confined to a relatively small surrounding area. The number of digits to be dialled is greatly reduced, giving lower equipment costs and reduced dialling effort by subscribers, if this traffic is treated separately. Accordingly, local closed numbering schemes will be established to serve these areas of high community of interest.

Each local number network is assigned a unique national area code. When a call is made beyond the local dialling range to a subscriber in another local numbering network the appropriate area code will be dialled followed by the wanted subscriber's directory number. A subscriber's individual national number thus consists of the area code plus the directory number.

There are two dialling procedures in the national plan. They are:—

(a) For calls within the local closed numbering network—dial only the directory number.

(b) For all other calls—dial the national number composed of an area code plus the directory number.

Investigations showed that the average number of digits to be dialled could not be appreciably reduced nor would any worthwhile equipment savings be obtained by the introduction of numbering schemes requiring more than two dialling procedures. Such schemes would have the serious disadvantage of much more complicated directory instructions and were therefore not favoured.

EXTENT OF LOCAL NUMBERING NETWORKS

Examination of traffic dispersion from country exchanges in Australia has shown that of the order of 80% of originated traffic remains within a typical secondary switching network. In the switching plan, a secondary network covers the secondary switching centre and its dependent minor switching centres and terminal exchanges. Local closed numbering schemes have been designed to cover these areas of high community of interest.

The allocation of area codes, however, has taken account of the fact that the community of interest of subscribers will extend as communications of all forms improve. The area codes have been allotted so that the local dialling range may be extended later, if necessary, with minimum changes.

THE TRUNK ACCESS CODE

When two dialling procedures are used, it is necessary to provide a code for moving from one procedure to the other. A code was therefore selected from the local number range to provide access to the national dialling system.

It is essential that the code should be the same at all locations to retain the advantages of national closed numbering. Also, it was desirable that the code should be short, preferably a single digit.

In Australia the most suitable local primary levels which could be considered were the level 1, which is not in use for subscriber's numbering, and the level 0, which is only lightly invested. Because of the incidence of false traffic the digit 1 could not be considered for trunk access unless accompanied by protective digits. Accordingly digit 0 was chosen as the trunk access code. This is consistent with present local policy and overseas trends.

The trunk access digit being uniform throughout the Commonwealth enables all area codes to be shown commencing with the digit 0 and this simplifies directory instructions.

Fig. 1.—"A" Digit Allocation.

CAPACITY OF NUMBERING SCHEME

Optimum capacity of the numbering scheme was determined after studying the likely order and distribution of future telephone demand. Fifty year estimates were used as a basis for an area code allocation designed to achieve the shortest local and national telephone numbers consistent with adequate capacity to avoid radical number changes over a long period.

The estimates of development were based on studies of future population and telephone density. A 50 year estimate was made for each region of the Commonwealth, weighted on the liberal side, to retain flexibility. Thus the aggregate of these individual studies, giving an overall Commonwealth figure of 33 million population and 15.3 million exchange services, ranks with the more optimistic estimates of Australian development. The individual State figures are shown in Table A.

TABLE A.

	Estimates for 2010 A.D.		
	Population	Subscriber Density	Exchange Services
New South Wales	11.0 Million	50 per 100 population	5.5 Million
Victoria	9.8 ,,	50 ,, ,, ,,	4.9 ,,
Queensland	4.6 ,,	40 ,, ,, ,,	1.8 ,,
South Australia	3.5 ,,	40 ,, ,, ,,	1.4 ,,
Western Australia	2.9 ,,	40 ,, ,, ,,	1.2 ,,
Tasmania	1.2 ,,	40 ,, ,, ,,	.5 ,,
Total	33.0		15.3

NUMBER OF DIGITS REQUIRED

National Numbers.

A national numbering plan using a trunk access code and a maximum of eight numerical digits with theoretical capacity of 100 million numbers has been adopted. The area code allocation and trial numbering within the areas has confirmed that this provides adequate capacity. A margin is available for increased requirements which could be imposed by extensive in-dialling to private branch automatic exchange extensions with numbers allotted from the normal spectrum.

Area codes have been reserved for allocation to areas where completely unforeseen development may occur due, for example, to the introduction of new irrigation techniques, development of mineral resources or establishment of new industries.

Local Numbers.

Development studies show that 5 digit numbering is required to serve the typical Secondary network. In some cases, where the Secondary network involves a large centre, e.g., Canberra (ACT), Morwell (Victoria) 6 digit numbering will be required. In other cases where the Secondary network is small or where the main community of interest is served by a network of lower order than Secondary, 4 digit or even 3 digit local numbering is used.

The Capital City networks, of course, contain the greatest numbers of subscribers. The numbering schemes for these serve the existing unit fee networks and some of the surrounding sub-metropolitan areas. 7 digit schemes are planned for Sydney and Melbourne and 6 digit schemes for the other Capitals.

Subscribers' numbers will be expressed in figures only. Typical numbers are shown in Table B.

TABLE B.

TYPICAL SUBSCRIBERS' NUMBERS

Location	Typical Local Number	Typical National Number
Sydney	542 6780	02-542 6780
Melbourne	746 2468	03-746 2468
Adelaide	31 4321	082-31 4321
Toowoomba	2 3467	0762-2 3467

SELECTION OF AREA CODES

Each local numbering network is designated by a unique area code to be dialled before the wanted subscriber's directory number, thus making up a national number, when a call is made between local numbering networks.

Equipment used when national numbers are dialled is simplified if the number of digits which need to be examined to determine the routing and charging is kept to a minimum. Reference to the trunk switching plans shows that generally satisfactory routing will be obtained if sufficient information is provided to identify Main, Primary and Secondary Switching Centres. An examination of this amount of information is also sufficient to determine charges for the longer distance calls.

The basis used for selecting area codes is as follows:—

(i) Switching centres of Main, Primary or Secondary classification are recognised by at the most 4 digits (including the trunk access digit 0).

(ii) The longest national number will consist of 9 digits (including the trunk access digit).

With 3, 4, 5, 6 or 7 digit local numbering schemes area codes vary in length to comply with this requirement, as shown in Table C.

TABLE C.

Local Closed Numbering	No. Capacity	Form of Area Code	Typical National No.
3 digits	1,000	OABCDE	053265-487
4 "	10,000	OABCD	05434-6326
5 "	100,000	OABC	0536-4 4418
6 "	1,000,000	OAB	062-33 4433
7 "	10,000,000	OA	03-630 7321

Note: The method of showing the general area codes used above, designating the first 5 digits following the trunk access code O as ABCDE, will be used throughout this article when the general treatment of area codes or of their individual digits is being discussed.

(iii) Although State boundaries are not strictly followed, the A digits have been allotted generally as follows:—

A = 1 Services
2 Sydney network
3 Melbourne network
4 Sydney Primary area
5 Victoria
6 New South Wales
7 Queensland
8 South Australia
9 Western Australia
0 Partially allotted to Tasmania. The remainder of the digit is spare.

They have been distributed in accordance with the 50 year development studies and so that the lower digits will be allotted generally where the incoming traffic is highest.

The A digit allocation is shown in Fig. 1. Allotting the A digits to particular regions allows some simplification in routing and charging equipment. As an example, the equipment handling calls originated in Perth for the Eastern States would obtain all the information necessary for routing and charging by examining the A digit of the national code.

(iv) Within a State, the B digits in the area codes are allocated to areas made up of a number of Secondary switching areas, representing the probable long-term community of interest. In many cases these areas correspond with Primary Switching areas since these reflect community of interest.

(v) The networks with the heaviest incoming traffic are allotted area codes composed of the lower numbers. For example Sydney is allotted the A digit 2.
This will result in faster setting up of the large number of calls to these networks with a consequent reduction in the amount of common equipment required and greater convenience to users.

(vi) Generally OABC codes are allotted to Secondary networks.
The distribution of the OABC codes is of considerable importance in the automatic charging of calls. Automatic charging equipment will examine the national number as far as the C digit to ascertain the charge for long distance calls or to determine whether further digits need be examined to provide more precise charging on the shorter distance calls. However, where convenient for charging and routing purposes an OABC code is allotted to a large Minor switching network.

SERVICE CODES

It is particularly important that subscribers be able to obtain assistance or access to any of the Department's services readily. The numbering provided for access to Services should allow:—

(i) the use of the same codes by all subscribers;

(ii) short codes to be used, with the more important Services, Emergency and Manual Assistance, having codes which would be easily remembered;

(iii) ample capacity to incorporate extra facilities which the Department may introduce in the future.

These requirements are met best by reserving the A digit 1 for Services.

The codes for access to the Services in the national telephone system will be:—

000—Emergency—for Fire, Police and Ambulance.
011—Manual assistance for trunk line calls.
012—Trunk Enquiry.
013—Directory information.
014—Time.
015—Phonograms.
016—Services provided by recorded announcements, e.g., 0164 — weather forecasts.
017—Miscellaneous Services requiring the attention of an Operator.
0171—Overseas calls.
0172—Mobile radio calls.
0173—Early morning and reminder calls.
0174—Phonogram enquiries.
018—To be used for Manual assistance for Inter-state trunk line calls at those centres at which Intra-state and Inter-state calls are connected on different suites Ultimately this code will become spare.
019)—Spare.
010)

The codes have been allotted so that the final digit corresponds where possible with the final digit of the existing service codes. This will assist subscribers, and may also reduce the trunking alterations required when the standard codes are introduced.

At large centres most of the codes will be used but in the smaller country automatic exchanges one code only—011—may be used to cover all calls requiring the attention of an operator.

DIRECTORY INSTRUCTIONS

In the ultimate scheme, standard directory instructions will apply throughout the Commonwealth. As each local numbering network is assigned its own area code, the national numbers of all subscribers, who may inter-dial by using the number listed in the directory only, will commence with the same national area code.

The instructions to allow the subscriber to select the correct one of the two dialling procedures, could be typically as follows:—

How to Make a Call

Each subscriber's telephone service has its own NATIONAL NUMBER consisting of two parts, a NATIONAL AREA CODE and a LOCAL NUMBER.

AREA CODE: The national area code for each exchange is shown in the directory, e.g., Toowoomba (0762-).

LOCAL NUMBER: The local number is shown against the subscriber's name, e.g., Smith J. B. Main Rd. 5 7521.

When the national number is written, these two parts are combined in the following form:

0762-5 7521

Dialling a Call

If the NATIONAL AREA CODE of the wanted subscriber's national number is the same as that of the telephone you are using, dial only the wanted subscriber's LOCAL NUMBER.

For all other calls, dial the full national number, i.e., the NATIONAL AREA CODE followed by the LOCAL NUMBER.

If the wanted subscriber's CODE or NUMBER is not known, dial 012 and enquire from the operator.

CONCLUSION

Summarised, the main features of the Australian National Numbering Plan are:—

- Local closed numbering schemes serving the subscribers' main community of interest. Generally, these will have 5 digit numbering covering secondary networks.
- Each local closed numbering network to be designated by an area code.
- The trunk access code 0 to be incorporated in the area codes.
- A national closed number scheme consisting of the area codes plus the local numbers.
- Maximum length of a national number, i.e., area code plus local number, of 9 digits.
- Standard service codes including an emergency code.

It provides the following advantages:—

Numbers as short as possible to save time and equipment and avoid errors.

Ample capacity to meet expansion over a long period without disruptive alterations.

Flexibility to permit alterations to meet unforeseen subscriber development.

Simple directory instructions for quick and accurate use by subscribers.

Bulk production of directories.

Introduction of the numbering in stages if necessary.

Economic use of plant.

Switching and charging functions to be performed automatically, with equipment as simple as possible, consistent with the need for flexibility.

AUSTRALIAN POST OFFICE ADOPTS CROSSBAR AUTOMATIC SWITCHING SYSTEM

*F. P. O'GRADY, M.I.E.Aust., S.M.I.R.E.Aust.**

The Department has recently made an exhaustive investigation of automatic exchange switching systems. These studies included not only the present methods of handling telephone traffic but also any likely new methods. The principal emphasis, of course, was on the new methods, especially those described in the article 'Nation-wide Dialling System for Australia' in the October, 1958, issue of this journal.

The present standard switching system is the Strowger bi-motional type. This was originally based on the equipment manufactured by Automatic Electric Company, Chicago. Similar switching equipment was later produced in United Kingdom factories. At a still later stage, modifications were made to the original American designs but the basic mechanical and electrical features were retained. In more recent years, the Department standardised the system introduced by Automatic Telephone and Electric Company, Liverpool, England, which was also standardised by the British Post Office under the name of 2000 type system. In quite recent times, a still further variant of this system was standardised involving the use of the S.E. 50 bi-motional switch produced by the General Electric Company at Coventry, England. The foregoing bi-motional systems have provided a very satisfactory service to the A.P.O. from 1913 onwards.

It has become obvious, however, that with the very large extension which has occurred in the number of telephone lines, particularly in the larger cities, some fundamental difficulties of the bi-motional system have become apparent. In these cities the principal weakness is the absence of the register or director equipment which is common in large cities overseas. It is possible, of course, to add director equipment to the existing bi-motional exchanges, but in view of the period which has elapsed since the original director systems were developed it was deemed advisable to make fresh studies of other systems now available. A second feature of importance was the relatively rapid increase in the cost of labour both for telephonists and technicians. These increases in relative values necessitated a fresh approach to:—

(a) Methods of operation, and
(b) Methods of maintenance.

The increased cost of operating charges favoured use of the single operator trunk handling method in the early stages and the use of subscriber dialling as a second stage to follow as quickly as possible. The use of these two innovations focused further attention on other weaknesses of bi-motional switching system notably in the speed of setting of the switches and in the introduction of noise at the various contact points. The single operator method and particularly the subscriber trunk dialling method necessitate the use of many more switches in tandem. Microphonic and similar noises, therefore, which can be ignored in local networks can become of great importance when the number of switching stages increases greatly.

The Department is satisfied that to meet the various new requirements in an economic fashion the use of the crossbar principle is necessary. The Department, therefore, announced in April, 1959, that it would adopt the crossbar switching principle as the future standard system. Summarised, the Department believes that the crossbar switching systems now available will—

(a) Meet the technical requirements for operation of Australia's telephone communication network at the highest possible standards better than any other system employing different principles.
(b) Cater, better and more economically than any other available different type of system, for the expansion of the numbering capacity of the large metropolitan networks and the creation of rural linked numbering areas.
(c) Be suitable for economic local manufacture.
(d) Be more adaptable than any other available system of a different type to foreseeable future developments, such as full electronic control and push-button telephones if these become commercially attractive.
(e) Be capable of complete integration with existing switching equipment.
(f) Be more conducive than any other available system of a different type to reductions in the size and cost of automatic exchange buildings.
(g) Permit of a worth while reduction in the overall cost of automatic telephone exchange equipment.
(h) Permit more readily than any other systems of the introduction of complete maintenance and service observation aids and of a substantial reduction in the cost of maintenance of telephone exchange plant generally, and
(i) Provide the most effective known available means of achieving greater value for a given expenditure on the network as a whole.

The Department is now engaged in consideration of the ways and means in which the crossbar system can be gradually manufactured in Australia and put into use. Naturally, the bi-motional switching system will continue in manufacture for a considerable time, if not indefinitely, for such use as extensions to existing exchanges and possibly for use in certain restricted fields.

*Mr. O'Grady is Deputy Director-General.

AUTOMATIC SWITCHING SYSTEMS—THE KEY TO ECONOMIC TELEPHONE NETWORKS

*N. A. S. WOOD**

INTRODUCTION

The aim of this article is to draw attention to the wide range of factors which must be considered when planning the economic development of the Australian telephone network so that a high standard of service is maintained. It is hoped that this overall survey, necessarily brief in parts, will be of value in furthering the understanding of the key importance of modern automatic switching systems in telephone network planning.

In a later article it is proposed to deal more particularly with the development of modern automatic switching.

CONCEPTION OF A SWITCHING SYSTEM

It is important to correct the all too common tendency to view automatic switching in terms of a particular type of switch. The modern conception is a switching system which includes the automatic switch as one of many components. It is quite impractical to design an automatic system without giving due regard to all the components of the system.

Basically a telephone system includes both local and trunk networks which are largely separate entities until subscriber trunk dialling is introduced when they begin to lose their separateness. This composite network consists of subscribers' telephones, subscribers' line plant, both automatic and manual switching equipment and connecting links between groups of switching equipment. There exists a close inter-relation between all of these items.

Telephone instrument transmission efficiency is being steadily improved with consequent reduction in the conductor weight of the subscribers' lines. The use of loading and amplification of selected subscribers' lines is also being investigated as a further means to this end.

Standard exchanges or specially designed equipments can be used to reduce quantities of lightly used subscribers' lines to smaller quantities of more efficient junctions. The switching equipment at these locations may also have an influence on the subscriber's line since equipment may be selected to permit higher signalling limits providing transmission limits are still met. For example, at present 1000 ohm loops excluding the telephone which may add up to 400 ohms, are the limit, but other exchange equipments will permit 1700, 1800 or more ohms including the telephone.

The quantity, length, and conductor weight, of junctions can also be influenced by the type of switching equipment which allows improved techniques of traffic routing. More direct routing and the segregation of traffic in intermediate links in accordance with the destination of the call can be achieved.

Improved efficiency may also be expected from the reduction of manually controlled switching by increased automatisation of telephone exchanges and the introduction of subscriber trunk dialling with automatic charging. Automatic switching equipment itself varies widely in efficiency and performance from one type to another, and it will be shown that the step-by-step bimotional equipment familiar in the existing A.P.O. networks, has very low efficiency and performance by modern standards.

With regard to transmission standards it is normal that an Administration offers as high a transmission performance as it can afford. Therefore, having in mind the rising costs of the expanding networks, it is reasonable to review transmission standards from time to time. In this respect it is of interest to observe that overseas trends are to accept higher transmission losses on a small percentage of calls thereby avoiding the necessity to up-grade large routes for a minority of calls.

Although it is proposed particularly to examine the automatic switching equipment component of the network, it should be quite clear that no one part may be treated separately from the remainder of the system. Network planning must take account of all the components of the network as a whole.

THE AUSTRALIAN TELEPHONE NETWORK PROBLEM

Primarily, the Australian problem is that of providing for a rapidly rising demand for service due partly to rapid immigration into this country, and partly due to the growing telephone consciousness of the general public. This rising demand has led to a doubling of the number of subscribers over the last 10 years, and developmental forecasts indicate that doubling every 10 years is likely to continue in the foreseeable future. In terms of equipment this means that new plant for a million subscribers must be provided in the next 10 years and an additional 2 million in the following 10 years. In this period also consideration must be given to the replacement with new equipment of much of the existing plant some of which has already been in service more than 40 years. The capital expenditure, required to meet this demand, will amount to several hundreds of millions of pounds, over the next 20 years. As the total number of subscribers and therefore the volume of traffic increases the average providing and operating costs per subscriber also increase. The cause for the rise in costs is the ever-increasing ratio of plant and operating staff to subscribers, which must be provided to ensure a reasonable grade of service in the busy hour.

The magnitude of the problem of meeting future development can be further illustrated by reference to the Department's Financial and Statistical Bulletin for the year ended 30/6/58 which shows that the total fixed asset net value of telephone and telegraph plant at that date was approximately £370 million including buildings. Of this total, the telephone network components amount to approximately £294 million excluding subscribers' instruments and buildings. The exchange equipment component represents approximately £70 million. Theoretically these assets must be increased by a factor of at least 4 to provide for the expected subscriber development up to 1980 assuming present methods are continued. These figures also indicate that the main area for large scale economies is that represented by the balance of £224 million which includes subscribers' line plant and connecting links.

However, since the population of Australia will be growing so rapidly, the need for vast development in many directions may be expected to place heavy demands on the available capital funds and resources. Therefore, in the telecommunication field there is a need to obtain the greatest value for capital expenditure as well as the greatest efficiency and the most effective use from plant. These aspects are of primary importance in deciding upon the equipment and techniques to be used.

It remains to mention two special features of the Australian telephone network and these are as follows:—

(a) The wide separation of the major population centres and the comparatively high volumes of traffic between them. Distances of several hundreds and even thousands of miles must be spanned within the continent by the Telecommunication system.

(b) The Sydney and Melbourne metropolitan networks have unit fee areas extending over approximately 500 square miles resulting in unusually long distances between terminal exchanges within these networks.

TECHNIQUES FOR INCREASING SYSTEM EFFICIENCY

The main means for achieving greater efficiency in the existing Australian telephone system are as follows:—

(a) A reduction in the amount of copper employed for a given volume of traffic by,

  (i) increasing the signalling limits for both subscribers and junction lines, so that transmission becomes the controlling factor,

  (ii) increasing the traffic loading of all connecting links between switching centres by development of direct and alternative routing techniques together with larger availabilities at switching stages,

*Mr. Wood is Acting Sectional Engineer Network Development and Design, Telephone Equipment Section at Headquarters.

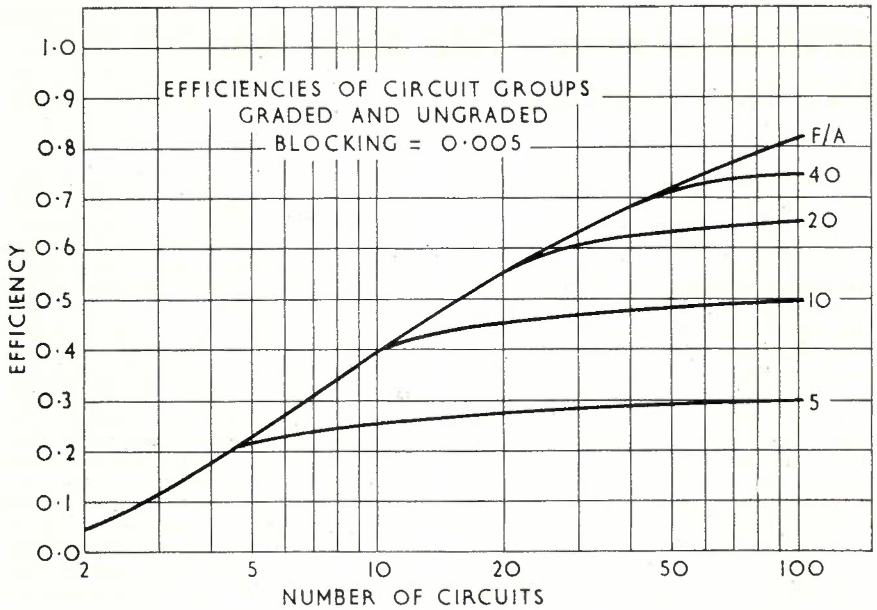

Fig. 1.—Traffic Efficiency Curves.

(iii) using the maximum allowable transmission equivalent for a higher proportion of calls,
(iv) using higher switching and signalling speeds to reduce setting up times,
(v) making use of pads between low loss circuits and subscribers' lines thereby permitting higher gains to be used in the former.

(b) The reduction of manual operating costs by,
(i) increasing automatisation,
(ii) employing equipment requiring lower maintenance.

(c) The use of switching plant which employs,
(i) register-translator control techniques,
(ii) more efficient internal trunking,
(iii) higher switching and signalling speeds,

The effective application of all of these means for achieving greater efficiency is dependent, in more or less degree, on the type of automatic switching system which is employed. Therefore it is worthwhile to examine at this stage the fundamentals of automatic switching. Automatic switching was originally developed with the express intention of replacing the manual exchange operator. This operator was, and is, able to receive information from a calling subscriber, store information with respect to the caller and calling party, process this information for routing and charging purposes, determine the route and actually make the connection and finally to supervise the call to completion.

In creating the Strowger system which is directly controlled by the calling subscriber's dial, the inventor built in a part of the operator to every automatic switch. Each group selector in this system receives a single digit by which its mechanism is positioned. It then selects a free trunk to another switching stage and makes the connection. Each final selector can receive two digits by which it is positioned on a particular circuit corresponding to the digits received. In addition the final selector supplies the operator's ability to make the connection, supervise the call and provide for a limited amount of charging. It is important to note that whereas the human operator was always available to deal with other calls, those portions of the operator built into the Strowger switches are tied, for the duration of the call, to the particular connection which has been made.

It became evident as large exchanges appeared, and these grew into networks that automatic systems needed more of the manual operator's abilities such as storage or memory, routing and charging discrimination, or more briefly, intelligence. The results of one effort to build more intelligence into the Strowger system are seen in the discriminating switches. No memory is provided but simultaneous seizure of main exchange equipment is used as a storage device until discrimination is complete. The real need is an automatic device which can be given the necessary intelligence but which will act faster and more reliably than a manual operator. This device should be as freely available to handle other calls, besides those already in progress, as the human operator. Such a device is the register-translator or, to use another description—the programmer.

Having given our system intelligence, a memory or store is available so that blind seizure of parent exchange junctions and equipment is no longer necessary. It can be arranged for busy tone to be supplied from the calling subscriber's line circuit or other appropriate source, without holding a connection through to the called line. Permanent loops may be detected and prevented from holding expensive switching plant. Automatic deletion of unwanted digits can be arranged thereby reducing the number of switching stages on a call. Discrimination, selection, and switch setting, can all be arranged independent of the speaking path, and the intelligence necessary for this is only required for the short time it takes to set up a call through an exchange. Therefore, by placing all the intelligence in a common pool, and thus establishing common control of the switching system, very considerable economies can be effected. This is offset by the need for access both to and from common equipment, but the balance in favour of common control can be very substantial.

Naturally the faster these automatic operators carry out their functions the fewer are needed. Therefore, high speed operation for switching functions and information signalling is required. Then common control is not only used to greater advantage but further, the time it takes to connect two subscribers together is reduced. The volume of the traffic is and will be so great that even one second saved on every call in the busy hour can mean substantial savings in plant.

In considering the need for faster working two important factors emerge and can be stated generally as follows:—
(i) Higher switching speeds are a property of relay action and marker control rather than direct impulse positioning or motor drive to marked contacts.
(ii) Faster signalling is primarily a product of coding information.

It should be understood that if post-dialling delay before the calling party receives ring tone is considered, then a system using direct control of the call by the subscriber's dial offers the least delay on all calls. A common control system employing alternate routing of traffic can lead to long post-dialling delays and for this reason as well as economy, faster speeds are necessary. In searching for greater efficiency of plant, an operating Administration must always take account of service to the subscriber and post-dialling delay becomes especially important in a network where both direct and common control techniques are in use.

It is proposed now to amplify those items listed under (a), (b) and (c), the full implications of which may not be evident at first glance.

SIGNALLING LIMITS

The increase of signalling limits and the useful employment of a high gain telephone would enable smaller gauge cables to be more widely used. Subscriber's line loops of 1000 ohms excluding the telephone, are being used to advantage with 2000 type equipment, and the 400 series telephone. With 2000 type equipment also dial impulsing must be kept within close tolerances of speed and weight ratio.

However, other types of equipment, especially those offering regeneration of impulses, would permit higher line loops from a signalling aspect and provide further incentive to develop a higher gain telephone. Dial adjustment tolerances may also be considerably relaxed.

The signalling limit for junctions in multi-office networks employing 2000 type equipment and D.C. loop signalling is 1200 ohms. A considerable relaxation of this limit is required to enable the various cable sizes to be used to the limit of their transmission capacity. Modern systems allow for this signalling limit to be doubled.

ALTERNATE ROUTING

Alternate routing is probably best understood from the consideration of calls made through a manual operator. The operator, given the destination required, can without further information from the caller, choose the route which will be used to complete the call. Under automatic conditions the facility to make a similar choice of route is known as alternate routing. The exercise of the choice of route can be arbitrarily fixed by the designing engineer so that a definite order of choice is observed. It can then be arranged that the bulk of the traffic in a smooth flow is directed to the route which is the shortest and the cheapest. The balance of the traffic, which will be rough in character since it consists mainly of peaks of traffic, can then be offered, in order, to second and third or more choice routes each representing successively dearer alternatives than the previous one. By this device an increase in the efficiency with which the circuits are used is gained, resulting in a substantial overall reduction in investment in the junction network. A reduction of 25% has been claimed by some authorities and the special features of the Australian network, distance and dispersion of subscribers, suggest ample opportunities for the application of this principle.

For those who are familiar with gradings the overall pattern of alternate routing should present some similarities. The technique of increasing efficiency by commoning up the end outlets of one group of contacts with other groups can be recognised in the arbitrary limitation of the number of circuits on a direct route by overflowing traffic to alternate routes. Whole exchanges can be regarded as groups in a very large grading. The new element which has to be considered is the cost factor which must be derived from the overall circuit cost and efficiency of channels on a particular route.

The application of alternate routing leads to a larger number of routes and a higher degree of mesh trunking which at first sight does not suggest economy. However, with adequate engineering, substantial gains can be made due to increased efficiency and reduced distances, requiring less total copper.

AVAILABILITY

Larger availabilities also increase the efficiency with which junctions and trunks are used. This is illustrated in Fig. 1. Heavy subscriber development will lead to an increasing number of large junction groups and larger volumes of total traffic must be dealt with. Many direct routes as well as backbone routes will require in excess of 20 outlets. It is to be remembered that circuit costs have an important bearing on alternate routing. Failure to increase the availabilities on the alternate routes above the present 20 outlets will prevent the achievement of maximum efficiency and, therefore, lowest cost, so that more trunks will appear to be justified on the direct route with the result that more traffic will be carried on this route than is really justified. The advantages to be expected from direct and alternate routing could thereby be reduced.

TRANSMISSION

Due to the number of exchanges and the distances encountered in the Sydney and Melbourne 15-mile radial networks and the use of direct-controlled step-by-step standard equipment, a large volume of calls using only one or two junction links do not encounter the maximum allowable loss (15 db) between terminal exchanges. The reason for this is that the same links are used on other calls which may involve 3, 4 or 5 junction links when the standard 15 db must not be exceeded. Register-controlled equipment with larger availabilities will permit more direct routing of traffic and more selective use of available circuits. Two alternatives are open, both of which mean a reduction in copper cost. Firstly, advantage may be taken of the higher incidence of one and two link calls, to reduce copper cost while maintaining approximately the same proportion of varying transmission equivalents at present experienced by a subscriber in a local network, or, secondly, a much larger reduction in copper cost may be achieved by designing all one link and a proportion of two link calls to the maximum allowable transmission limit.

SIGNALLING

To consider the signalling aspect further, the signals used for each call are in two categories, operating signals and selection signals. Common terminology is to refer to these as "line" and "information" signals. With the 2000 type equipment there is no separation of "line" and "information" signals as is evident from the following:—

Forward	Backward
Seizure	Proceed to send (dial tone)
Impulsing (digit transfer at 10 i.p.s.)	Supervisory (ring or busy tone).
	Answer (metering).
Clear forward (release)	Clear back (release).
	Release guard.

Modern switching systems permit separation as follows:—

"Line" Signals:

Forward	Backward
Seizure	Answer
Clear forward	Clear back
	Release guard

"Information" Signals:

Forward	Backward
Digit transfer— (5 digits or more/ second)	Proceed to send
	Supervisory

It can be seen that the "information" signals do not occur during the speaking period so that V.F. tone signalling may be used without expensive guards to prevent false operation, provided that suitable arrangements are made to split the caller from the circuits over which the signals are being sent. This is necessary to avoid trouble due to the caller whistling or talking whilst setting up the call. "Line" signals will vary according to the channel used, and may be D.C. or A.C. providing that, if V.F. is used for the latter, suitable voice guards are provided.

A suggested separation is that V.F. "information" signals should use frequencies below 2000 c.p.s., and a V.F. "line" signal would be chosen from the range between 2000 and 3000 c.p.s. in accordance with the C.C.I.T.T. recommendations.

High speed "information" signalling is achieved by the use of coded signals and, for intra-exchange operation, D.C. signals in binary code form may be used so that each digit is represented by a two-element code. Multi-V.F. signals may also be used for this purpose.

For inter-exchange application it is common practice overseas to use multi-V.F. to reduce distortion and signalling difficulties. The multi-V.F. can be used over any channel which provides a reasonable grade of transmission for speech. A two out of five frequencies or two out of six frequencies code is used, depending on the number of signals required. Each digit or other signal is allocated a specific combination of two frequencies which are sent simultaneously. The duration of the signals varies with different systems, some employing the 50 mS on and 50 mS off technique and others a continuous signal until an acknowledging "proceed-to-send" signal is received. The latter method is self-checking. A group of five or six frequencies may be selected for each direction of transmission depending on the number of signals required. For example, some systems use a specific "proceed-to-send" signal for each digit according to its position in the subscriber's number. That is, the signal will indicate whether the third, fourth or sixth digit is required. If yet more signals are needed, three out of eight V.F.s can be used.

The advantages offered by this type of signalling are:—

Speed

Freedom from D.C. circuit limitations

Facility for error detecting.

The speed advantage is apparent when compared with impulse sending which at best might be increased to 20 i.p.s. The time taken to send 7 digits by impulsing will vary according to whether the digits are large or small, but, if an average of five impulses per digit is assumed the time will be 4.9 seconds plus the time to pull the dial and exclusive of any inter-digital pauses made by the subscriber. The same number of digits regardless of their individual value may be transmitted within one second using coded signalling and no inter-digital pauses are needed. "Proceed to send" signals for each individual digit can provide a means of checking that the digit has been received but this requires an extra second making a total of two seconds for the 7 digit transmission. By this means also a digit signal which is faulty when received, may be called for repeatedly until correctly received. In those systems using a specific proceed-to-send signal for particular digits the facility is also offered of detecting that digits are missing due to premature or faulty dialling. It is then possible to release the equipment back to the subscriber's line circuit which will pass busy tone to the calling subscriber. This avoids the unnecessary use of extra switching plant for a call which could not mature successfully.

In addition to these safeguards, the uniform two element content of the two out of five, or six, frequency codes is self-checking in that the absence of one of the elements, or the presence of a third, indicates trouble. There are no such safeguards against errors in direct pulsing systems.

It may be thought that there is no advantage in high speed signalling so long as a slow dial is retained. However, with common control no selecting stages need be taken into service until all digits, or a sufficient number of them have been received. The connection may then be very rapidly set up so that, despite the initial delay, no appreciable post-dialling delay occurs before ring tone is received. Furthermore, high speed signalling and switching prepare the way to increase subscriber signalling speeds by means of button senders or punch card equipment at the subscriber's telephone, when and if these facilities become commercially attractive. Both of these facilities are being developed overseas in conjunction with coded signalling from the subscriber's premises to the exchange.

Another factor which limits the advantage of high speed working is that for a number of years a large volume of calls must be completed by the existing step by step equipment which is incapable of responding reliably to speeds higher than 10 i.p.s. This must be accepted, and the registers must be designed to provide for both high speed and 10 i.p.s. interworking as required. At the present rate of development the existing type equipment should comprise only one quarter of the installed automatic equipment by 1982.

PADS

The use of pads in all connections between subscriber's line and low loss trunk or junction circuits is necessary to control undesirable echo effects which can arise on long connections employing several links in tandem. These echo effects are not only objectionable in conversation but may have a serious effect on signalling in some circumstances.

The alternative to the use of pads in these connections is to operate low loss circuits with lower gains. Since these circuits may be switched to physical junctions or trunks as well as directly to subscribers' lines, the reduced gain must be compensated by a lower allowable loss in those physical junctions or trunks. Therefore, the presence of suitable pads when and where required will enable higher gains to be used in low loss circuits and consequently smaller gauge cables with higher loss in a wider number of applications.

INTERNAL TRUNKING

The most efficient internal trunking

A	BANKS AND WIPERS
B	SELECTING, TESTING, AND POSITIONING EQUIPMENT
C	SUPERVISORY EQUIPMENT
D	IMPULSING EQUIPMENT
	MISCELLANEOUS

Fig. 2.—Make-up of a Telephone Exchange.

of exchanges is obtained from a system which disposes of the originating and terminating traffic at a prescribed grade of service with a minimum number of crosspoints. A crosspoint is a single bank multiple outlet regardless of the number of wires in the circuit. For example, a 2000 type group selector has 200 crosspoints, each of 3 wires. The fundamental importance of this fact in considering alternative types of switching systems will be dealt with in a later article. However, some appreciation of its importance will be gained from the consideration of the major items which make up a telephone exchange.

MAKE UP OF A TELEPHONE EXCHANGE (Figs. 2 and 3)

The four main items of plant constituting a telephone exchange are as follows:—

(a) banks and wipers, or equivalent, plus means of holding.
(b) selecting, testing and positioning equipment,
(c) supervisory equipment including transmission, charging and guarding,
(d) impulse or code receiving equipment.

With 2000 type equipment, which is of the direct control and direct trunking type, these items are dispersed to individual equipments and are retained throughout the duration of a call. However, in fact, only items (a) and (c) need remain with the call for its duration. Items (b) and (d) represent a substantial amount of the total equipment provided in a 2000 type exchange because these items are very inefficiently used. If it is arranged to separate these items into common equipments which may be associated with the call connecting circuits as required, there is no longer the need to hold this equipment idle for long periods during conversations. Furthermore, with the introduction of higher speeds of switching and signalling the time this equipment is associated with the call can be still further reduced. The number of common equipments provided in an exchange can be quite small and may represent only 10% of the total equipment.

To consider item (c) the quantity of this equipment does not change from one switching system to another since its provision is based on the total number of calls which may be in progress simultaneously. If Item (c) is common to all systems then of the remaining three, item (a) assumes paramount importance since when comparing one common control system with another it will represent the major variable component of the exchange. Therefore, the system which uses the least quantity of (a) for the same

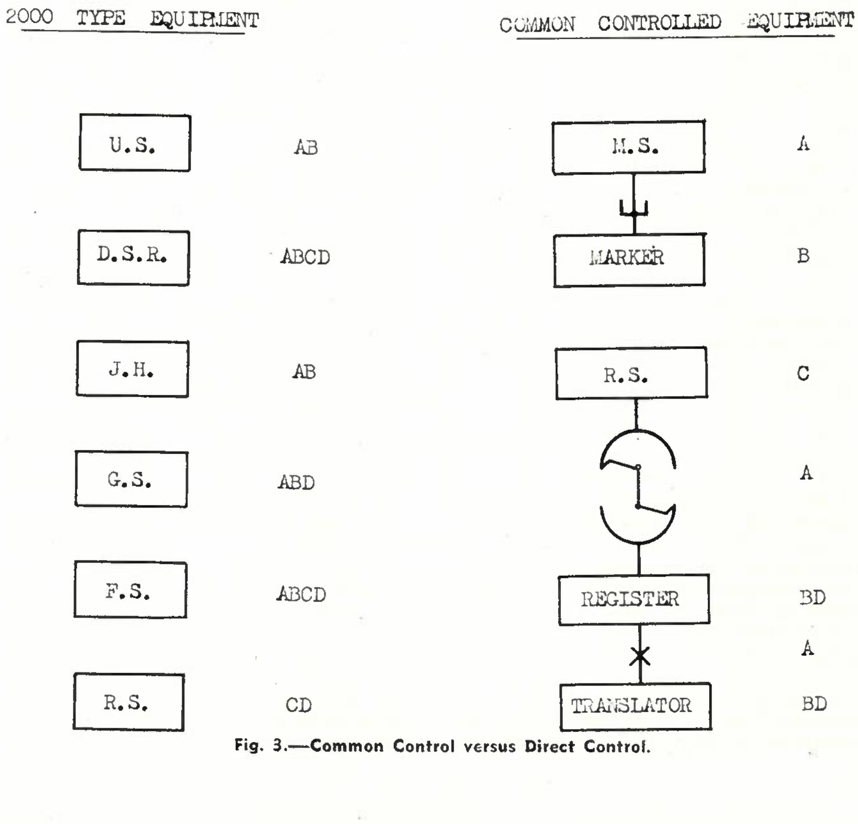

Fig. 3.—Common Control versus Direct Control.

volume of traffic and grade of service, should show an economic advantage when compared to the less efficient systems.

It will be shown in a later article that the systems which employ the minimum quantity of (a) are those featuring small-sized switches in link trunked arrays. Generally, small switch systems use a higher degree of centralisation of controls than large switch systems, and in both cases it is usual to duplicate the controls wholly or in part whenever a fault would interrupt service.

Common control equipment has been recognised for some years as a field of application for electronic circuitry. Electronic controls are not necessarily cheaper than their relay counterparts, but the operating speeds are potentially higher. However, the commercially practical electronic device capable of operating magnets with substantial loads is not yet available and the use of an intermediate slave relay is necessary. Therefore, the advantage of increased speed which might reduce switch and control provision remains a theoretical one. It is to be remembered that controls represent a small portion of the exchange.

Apart from item (a) relays are the next most significant component since they appear in almost all sections of the exchange. Simplification in relay design and a reduction in the number of types used offer opportunities for considerable economy in manufacture.

As this article goes to the printer it has become possible to include the information that the decision has been announced by the Department that only a switching system employing the crossbar switching principle will be satisfactory to meet the future telephone network requirements of the Australian Post Office. It is hoped in the following article to outline some of the technical considerations which have led to this decision.

ACKNOWLEDGMENTS

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The author also acknowledges the A.P.O.'s indebtedness to the many equipment manufacturers who made available valuable system booklets, general circuit descriptions and planning studies to the Department. These references are not given below since they are not generally available.

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THE SYDNEY-MELBOURNE COAXIAL CABLE PROJECT

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INTRODUCTION

This article gives a general description of the main features of the coaxial cable system which is being installed by the Postmaster - General's Department between Sydney and Melbourne. Further articles dealing with technical details of the plant, the cable installation, and other aspects of the project will be published in later issues of the Journal.

HISTORICAL

The first telecommunication facility between Sydney and Melbourne was a telegraph circuit opened for business on October 29, 1858. This channel was provided over an open wire route following in general the Sydney-Melbourne railway line, and with improvements in equipment and line plant this route furnished the only telecommunication channels between the two capitals for many years.

Shortly after the turn of the century, a second open wire route which followed fairly closely along the route of the telegraph line was constructed and the first Sydney-Melbourne telephone channel was opened for traffic on June 14, 1907, this channel being provided over a physical 600 lb. per mile copper pair. Over the succeeding years this telephone route has been increased in capacity and modified and improved in a number of respects and it still carries a large part of the traffic between Melbourne and Sydney and also much of the traffic to the many intermediate towns and villages on and near the route. The first two telephone channels were provided by physical wire pairs and then the three-channel carrier telephone system and later the twelve-channel carrier system were introduced; there are now ten twelve-channel systems on this route. The original telegraph route is still in existence in some parts but, as opportunity has offered in the past, the original telegraph route and the newer telephone route have been combined.

With increasing demand for additional channels and an improved grade of service it became necessary shortly after World War II to plan for further facilities. Another open wire route was established via Bendigo, Deniliquin and Bathurst giving additional channels and at the same time an alternative route as a safeguard against the failure of the route along the railway line. This newer route is now carrying nine through twelve-channel telephone systems and a further system will be provided shortly. It was appreciated that the provision of this alternative route via Bathurst would, in conjunction with the railway route, furnish sufficient channels for a limited period only, and also because the railway route was inevitably reaching the end of its useful life with increasing maintenance costs and with technical characteristics inferior to those necessary in a modern telecommunication service, it was necessary to plan for the provision of a main communication system of a new type. In 1950 tenders were invited for a cable or radio communication system which it was considered would provide requirements for a number of years by the addition from time to time of channelling equipment and facilities. About this time, however, a change in economic conditions in the Commonwealth and other factors resulted in some reduction in the rate of development and this project was deferred. However, the stage will be reached about 1961 when further substantial relief will be necessary on the route, and in June, 1957, tenders were invited for a six-tube coaxial cable system.

CHOICE OF TYPE OF SYSTEM

In planning a new system, choice had to be made between radio, cable either of the quad carrier type or coaxial type, open wire or combination of these systems which, with respect to open wire, could include some use of the existing route along the railway line.

Economic considerations were the main factors in making this choice and the necessity for providing service to many intermediate towns along the route had a great influence on the economic comparison of the several alternatives. A thorough investigation showed that it would not be practicable to re-condition the existing open wire route in such a manner as to provide sufficient channels or to furnish adequate standards. An arrangement which at first sight appeared

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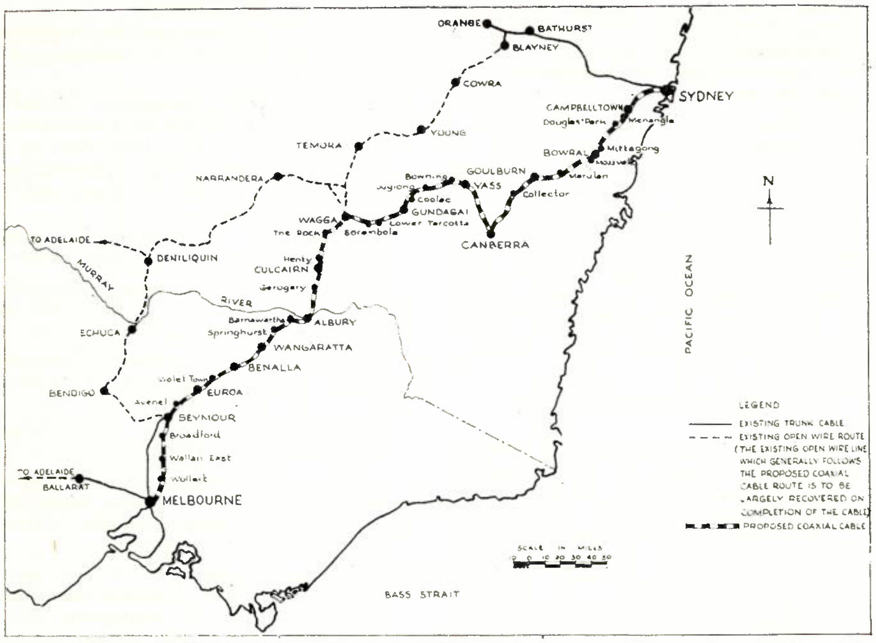

Fig. 1.—Route Plan.

to be very attractive would be the use of micro-wave radio systems involving the establishment of radio stations on eminences some 25-30 miles apart; however, although such a system would provide for services between Sydney and Melbourne and to some or even most of the major towns in between at relatively low capital cost, it was shown that the cost of serving other towns along the route by radio or cable or other means from the main repeater stations on the through system would be such as to make the complete scheme less attractive from the economic point of view than a cable system. Of the two types of cable which would be feasible namely quad carrier cable or coaxial cable, and having regard to the necessity for providing for sufficient channels for a long period of years, it was shown that the coaxial system was the most satisfactory from the economic viewpoint.

Apart from telephone, telegraph, and sound broadcasting programme lines, consideration was also given to the probability that facilities for television relaying would also be needed and this facility could not be provided by quad carrier cable or by open wire. The use of coaxial systems or micro-wave radio systems for long distance television relaying is a general practice in overseas countries where television is well established, and it is reasonable to expect that similar facilities will be necessary in Australia in due course.

The number of telephone, telegraph and sound broadcasting channels estimated as being required for some years could be accommodated on one pair of coaxial tubes of the type recommended by the International Telephone and Telegraph Consultative Committee (C.C.I.T.T.) which is generally accepted as a world standard. (One tube of the pair is used for transmission in one direction and the other tube of the pair in the reverse direction). It would thus be practicable theoretically to furnish the required telephone services with a two-tube cable, but this would make no provision for television, nor would it offer any standby for use in the event of a fault in a working tube. A four-tube cable is, therefore, the minimum size of cable which it would be reasonable to provide, but it was shown that the capital cost and the annual charges for a six-tube cable would be little, if any, greater than for a four-tube cable and as the former would obviously provide for additional telephone or television relay facilities should these be required, it was concluded that a six-tube cable should be laid.

The plan adopted allows for equipping the cable with the appropriate carrier and associated equipment to provide sufficient telephone and other channels to satisfy estimated requirements at 1967 with facilities for readily increasing the number of channels to satisfy estimated requirements at 1982. A coaxial system of the "standard" type to furnish these facilities requires the provision of repeater stations at intervals of approximately six miles and the number of channels could later be further increased, if necessary, by higher frequency working involving the establishment of additional intermediate repeater stations giving a spacing of three miles between stations.

As stated above the open wire pole route following the Melbourne-Sydney railway line has been in service for some fifty years and after careful review it was concluded that it would not be practicable or economical to restore the line to a satisfactory condition except for some sections. Moreover, the plan to duplicate the railway line between Melbourne and Albury to give a standard gauge line right through from Sydney to Melbourne would necessitate a number of alterations to the pole route. The planned coaxial system will provide intrastate and interstate circuits sufficient for many years and it has been decided that most of the pole route will be dismantled on completion of the coaxial project.

THE IMPORTANCE OF THE PROJECT

The Sydney-Melbourne coaxial system will be the largest single project undertaken to date by the Postmaster-General's Department and, apart from providing the necessary trunk channels, an object is to improve, where practicable, all telecommunication services along and in the vicinity of the cable route to give a modern high grade network. This will involve, in addition to provision of the main coaxial system, various minor trunk cables and subscribers' cables which will be laid in the same trench as the coaxial cable, spur cables and carrier systems and, subject to economic and other considerations, the provision of automatic equipment for trunk transit switching, subscribers' services, etc., at towns along the cable route. It will be appreciated that this conception of the project makes it a much larger scheme than might be indicated with attention focussed on the coaxial cable and directly associated carrier equipment.

Three capitals — Sydney, Melbourne and Canberra — with a total population of about 3.7 millions, which is approximately 38% of the total population of Australia, will be served by the Sydney-Melbourne coaxial system as well as the many important and growing towns along and in the vicinity of the cable route. The system will also be a vital part of the trunk line network of the eastern part of Australia which is the most densely populated part of the country and a part which is developing rapidly. This coaxial system will be required to cater for telecommunication services for many years during which period technical, economic and social progress may be expected to bring about a demand for telecommunication services as, for example, colour television transmission, which may be somewhat more exacting with respect to transmission than our present day services.

For the reasons just mentioned and because of its magnitude the undertaking of this project is a most important progressive step. It is even more important because of the expected extensive use of coaxial systems in the future. It will establish standards on which future development will be based and, therefore, the plant used must in all respects be representative of the latest proved techniques. It has not been overlooked that some main trunk systems are being provided by radio and it is to be expected that there will be many more radio systems in the future. The coaxial and radio systems are not mutually exclusive but there is a field—determined mainly by economic considerations—for each, and the two types of system should be engineered to furnish the same quality of service and reliability. Moreover, similar type of carrier equipment are used with coaxial systems and with radio systems.

The increasing use of telecommunication facilities of various types for social, business and defence purposes requires no emphasis and the quality — in the broad sense of the word — of its telecommunication service is some measure of the standard of living of a community. With this in mind it is perhaps no exaggeration to describe this project as one which is not only of the greatest importance to the Postmaster-General's Department, but is also a National work of considerable significance.

CABLE ROUTE

The approximate route selected for the cable is shown in Fig. 1, this having been chosen with regard to route distance, topographic conditions, service to major and minor towns and access. The cable will be laid close to the highway as a general rule, but will be routed across country to reduce the length where this is an economical proposition. The route distance is about 590 miles and for the greater part of this distance steel tape armoured cable will be buried in the ground generally at a depth of 4 feet. Through towns the cable will be placed in ducts and the total route distance in ducts will be of the order of 85 miles.

Main attended repeater stations will be located at intervals averaging 42 miles and at these stations carrier channels may be taken from the coaxial tubes to serve the towns concerned. As shown in Fig. 1 the selected locations for these repeater stations are Campbelltown, Bowral, Goulburn, Canberra, Yass, Gundagai, Wagga, Culcairn, Albury, Wangaratta, Benalla, Euroa and Seymour. At these main repeater stations (and also at the terminal stations at Melbourne and Sydney) the coaxial equipment will share accommodation with other existing or proposed plant such as other carrier equipment, exchange equipment, etc., and as a number of the existing departmental buildings at these centres have little or no spare floor space, extensions and/or additional buildings are being arranged. In addition, unattended repeater stations which will not be equipped to derive channels from the coaxial tubes will be necessary at intervals of approximately six miles, giving a total of about ninety such repeaters. In almost all cases, these minor repeater stations will be established in buildings of about 10 ft. x 12 ft. floor area provided specifically for the coaxial project. The type of building to be provided is shown in Fig. 2.

It was stated earlier that additional facilities could be obtained from this cable by the addition of further intermediate repeaters giving a spacing of three miles. In planning and surveying the route of the cable, consideration is being given to the selection of sites for these extra repeaters which may be required later as well as, of course, to the selection and acquisition of sites for the repeaters which will be required at six mile intervals from the outset.

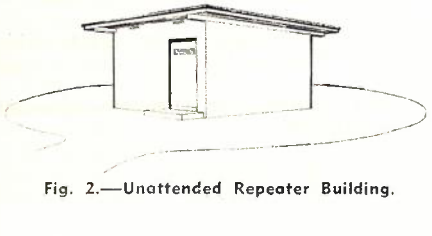

Fig. 2.—Unattended Repeater Building.

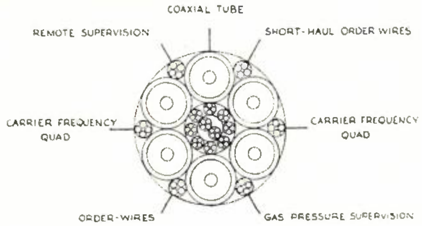

Fig. 3.—Cable Cross Section.

MAIN FEATURES OF THE PLANT

The form of the 6-tube cable proposed is indicated by Fig. 3. Each of the 6-tubes of 75 ohm impedance consists of a solid copper inner conductor of 0.104" diameter, which is separated from the outer tubular conductor by polythene spacers at intervals of approximately 1.3" along the length of the cable. The outer conductor is formed from a soft copper tape and over the coaxial tube so formed there will be two mild steel tapes applied helically, and paper tapes. Six such tubes will be stranded around a core of ten 20 lb. per mile quads and there will be six 20 lb. quads in the six outer interstices formed by the laid up tubes. Overall, there will be paper tapes, lead sheathing, and armouring where necessary. Further information on the cable characteristics was given in a recent article in this Journal (1).

Some of the paper insulated quads in the cable are required for control and alarm circuits and others will be used for trunk telephone circuits between intermediate towns along the cable route; included amongst the quads will be some which will be suitable for operation with short-haul carrier telephone systems. The main telephone channels will be carried on a pair of coaxial tubes and the system was intended to carry at least 16 super groups of sixty telephone channels each (a total of 960 channels) for which a band width from 60-4092 kc/s is required. However, to provide adequate transmission of television signals in accordance with Australian standards, it is necessary that a band-width of 6 Mc/s be used, and as it would be advantageous to equip all coaxial tubes in the cable with the same type of repeater equipment, it is planned to use 6 Mc/s plant throughout. This additional bandwidth also has the advantage for telephony that the number of channels may be increased at a later date by a further 300 to a maximum of 1,260.

As stated previously, the telephone channels will be carried on one pair of coaxial tubes, one tube being used for north to south transmission and the other for south to north transmission. The voice frequency channels are modulated in four stages to arrive at the band of frequencies transmitted over the coaxial tube as follows:—

(i) Channels are taken in "pre-groups" of three and modulated each with its own channel carrier frequency and the upper side bands selected to give a "pre-group" occupying the frequency range of 12-24 kc/s.

(ii) Four such "pre-groups" are again modulated with appropriate carriers and the lower side bands selected to form "groups" containing 12 channels and occupying a band 60-108 kc/s. These are called "basic groups".

(iii) Five basic groups are again modulated and the lower side bands selected giving a "basic super-group" of 60 channels occupying a band 312-552 kc/s.

(iv) As the fourth modulation step the super-groups are each modulated with an appropriate carrier frequency into their respective positions in the line frequency band transmitted. For a system of 960 channels involving 16 super-groups of 60 channels each,, the transmitted band is 60-4028 kc/s.

A feature of the system is the use of standard frequency bands for the groups and super-groups. This facilitates interconnection between the coaxial system and other types of systems such as the standard 12-channel cable or open wire carrier systems. Groups of channels may be dropped off from the coaxial system at intermediate repeater stations for connection to spur routes or to provide local services. The frequency bands involved in the four stages of modulation are shown in Fig. 4. A broadcast programme channel of bandwidth 10 Kc/s can be transmitted within any 12-channel basic group in lieu of three telephone channels.

For transmission of the Australian Standard 625 line television, the video signals from the television studio are modulated and transmitted over the coaxial tube using the vestigial side band system occupying the band 556-6056 Kc/s.

The general form of equipment mounting adopted is shown in detail in another article in this Journal (2). Equipment is housed in cabinet type racks which are 102.4" high, 23.6" wide and 8.7" deep and which will be placed back to back. The various types of units are assembled as slide-in chasses which plug into the rack framework. On each chassis are mounted units and sub-assemblies which are readily replaceable. Transistors will be used in terminal equipment up to the basic group stage. Provision will be made for the transmission of calling and dialling signals using "in-built" equipment operating on a frequency of 3825 cycles per second which is outside the speech band.

A most important requirement is that service over the coaxial system be as free from interruption as is economically practicable, and to this end a comprehensive system of controls and alarms will be provided, and vital items of equipment as, for example, the super-group carrier supply units, will be provided in duplicate. Certain of the paper insulated pairs in the cable will be used for the transmission of alarm signals from unattended to attended stations.

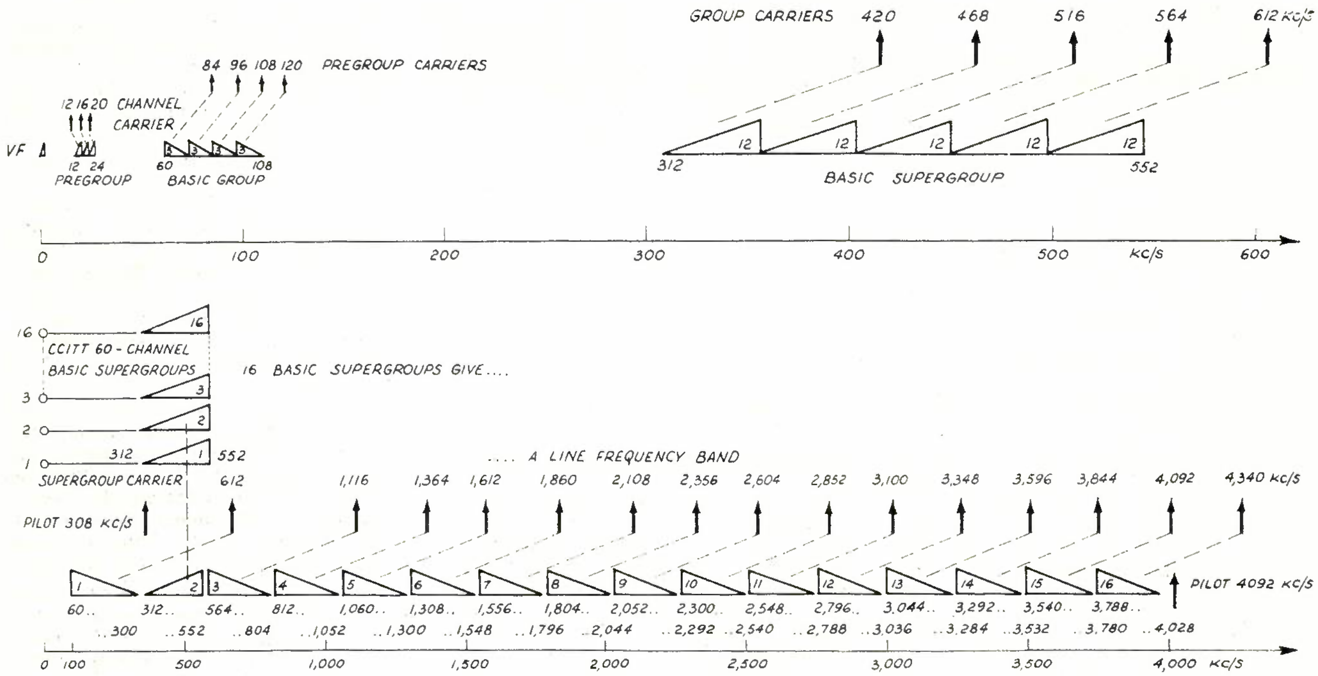

Fig. 4.—Modulation Plan

The various alarms will indicate such conditions as line amplifier tube failure, pilot failure, unauthorised entry into equipment buildings, etc. An order wire telephone service which is independent of the normal power supply at each unattended repeater station will be provided between stations over paper insulated pairs. Pilot frequencies will be transmitted with the system line frequency band so as to provide for automatic level and equalisation adjustment to cater for temperature changes and other variables.

Power for main repeater stations will be obtained from the commercial power supply and as a common cause of interruption to service is failure of power, main repeater stations will be equipped with "no-break" power plant. Power is fed to the equipment from a continuously running alternator driven by a motor across the A.C. mains supply with the motor alternator combination having on the same shaft a D.C. motor. In the event of failure of commercial power supply the D.C. motor runs from a 136 volt battery and will maintain power to the equipment until such time as a reserve diesel alternator set starts automatically.

Power to the unattended repeater stations will be fed along the coaxial cable itself with a voltage of approximately 1,500 single phase 50 c.p.s. between the inner conductors of a pair of tubes. In the event of it being necessary to open the cable sheath and work on the cable, this high voltage will be disconnected at the unattended repeater station adjacent to the point at which attention is being given to the cable and power will be supplied to the unattended stations beyond by a mobile power unit.

EXECUTION OF THE PROJECT

Contracts have been placed for the Sydney-Canberra section of the cable to be manufactured by Felten & Guilleaume, of Western Germany (Agent Electronic Industries Imports of Melbourne) and for the Canberra-Melbourne section to be made in Australia by Olympic Cables Pty. Ltd. The equipment has been ordered from the Telecommunication Company of Australia Pty. Ltd. and will be manufactured by Felten & Guilleaume Fernmeldeanlagen (an associate company of Felten & Guilleaume) also of Western Germany. The cable and equipment contracts cover minor trunk cables to be laid in the same trench as the main coaxial cable, jointing fittings, loading coils, gas alarm equipment, testing instruments, power plant, spare parts, minor installation materials, and other items of equipment and materials necessary for the complete coaxial installation.

Other equipment required for the project considered in its broadest sense such as carrier telephone systems for spur routes, subscribers' cables, and exchange equipment will be included in contracts placed from time to time in the normal way.

The cable will be installed by departmental staff and it is intended to make extensive use of mechanical appliances for trenching, cable laying, back filling, etc. These techniques were specially devised for the Sydney-Melbourne route, but will be first used on the Melbourne-Morwell project (see article (3) in this issue). The selection of the precise route for the cable and a detailed survey are well advanced to determine the location of joints, manholes, loading points, minor repeater station locations, depth of excavation, methods of crossing rivers and gullies, special treatment required because of the proximity to power lines or danger of corrosion or soil erosion, and the other features which must be planned well ahead of cable installation. The Telecommunication Company of Australia will install the equipment purchased under contract from that Company and will co-ordinate all contract work.

The cable is programmed for delivery at the rate of thirty miles per month, commencing towards the end of 1959, and cable laying, building construction, equipment installation and other aspects of the project are being programmed to match cable delivery. Installation work will commence at the Sydney end of the route and work south. It is expected that Sydney-Canberra telephone channels will be ready for service by June, 1961, and Sydney-Melbourne channels by December, 1961. Other channels, including television relay channels, will be provided, as far as possible in order of urgency of needs, as the cable and equipment work progresses.

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THE MELBOURNE-MORWELL COAXIAL CABLE

*J. F. SINNATT, B.Sc.**

Fig. 1.—Map of S.E. portion of Victoria showing centres connected by the Melbourne-Morwell Coaxial Cable. Dotted lines indicate proposed spur connections.

Laying of the first major coaxial trunk cable in Australia between Melbourne and Morwell commences in July this year. Many of the new techniques and equipment to be used on the Sydney-Melbourne Coaxial Cable (1) will be used first on the Melbourne-Morwell cable and experience gained will be invaluable for the larger project. The purpose of this article is to briefly describe external plant aspects of the Melbourne-Morwell project and give a preview of some of the new methods and equipment which will be used on this work. An introductory article (2) on coaxial cable appeared in the last issue of the Journal.

PLANNING

Provision of the cable represents the first stage in a comprehensive plan for meeting development in eastern Victoria. It will provide immediately for channels serving the Central Gippsland area, and later as the comprehensive plan is extended the cable will provide a means of meeting development in South Gippsland, by a spur from Warragul to Korumburra, and also in the Mornington Peninsula, by a spur from Dandenong to Frankston. (See Fig. 1). It is also expected that as further progress is made with the planning of facilities between Victoria and Tasmania, it will become necessary to route a proportion of these channels via Gippsland, and the cable will have adequate capacity for this purpose. The cable will terminate at Morwell as this is the Secondary Trunk Switching Centre for the important group of towns in the Latrobe Valley area comprising Moe, Yallourn, Morwell and Traralgon, which had a combined population of over 40,000 at the 1954 census. Morwell is also the Primary Trunk Switching Centre for the whole of the central and eastern Gippsland areas.

It is estimated that within the 20 year date there will be 1,900 channels in the Melbourne-Dandenong section, reducing to 600 channels beyond Dandenong. Short distance minor trunk circuits are additional and the requirements for these totalled over the whole route between Dandenong and Morwell amount to 900. Provision of a high capacity system is therefore necessary, and composite coaxial cable has been selected as the solution, because it provides a ready and economical means of meeting both long and short distance requirements. A high capacity radio system would cater for the long distance channels, but would not be suitable for the short distance trunks or junctions along the route.

CABLE DESIGN

A six tube coaxial cable will be provided between Melbourne and Dandenong (21 miles), and a four tube cable between Dandenong and Morwell (75 miles). The Melbourne-Dandenong section will be unarmoured and wholly in ducts, while the Dandenong-Morwell section will be mainly armoured and buried direct in the ground. The four tube cable for the latter section (Fig. 2A) will have five 20 lb. carrier type quads laid up with it, one in the centre and one in each of the outer interstices. A layer of eighty 10 lb. local type pairs, of which 74 pairs will be loaded, will be provided to serve the intermediate exchanges. Control and alarm circuits will also be accommodated in the layer pairs. The five interstice quads will not be used initially, but will be reserved for future short haul carrier working when the capacity of the VF pairs is exhausted. In the Garfield-Bunyip and Moe-Morwell sections, where the intermediate circuit requirements are particularly high, separate minor trunk cables will be laid at the same time as the main cable. A separate cable already exists between Drouin and Warragul.

All the intermediate exchanges between Melbourne and Dandenong are included in the present Melbourne Metropolitan Unit Fee Network and will not be served by the new cable. Layer pairs are therefore not required in this section and the interstice quads need not be suitable for carrier working. The make up of the cable for this section is illustrated in Fig. 2B. The four tube cable will be manufactured in Victoria by Austral Standard Cables Pty. Ltd. At the time of writing a contract had not been placed for the six tube cable.

ROUTE AND REPEATER LAYOUT

The cable route will generally follow the main road or railway line, and will pass through all the important intermediate towns along the way excepting Yallourn. Main stations with carrier

Diagrammatic illustration of cross-sections of the Coaxial Cables.

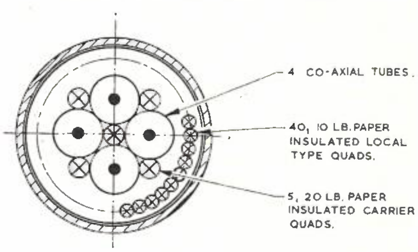

Fig. 2A.—Dandenong-Morwell Section.

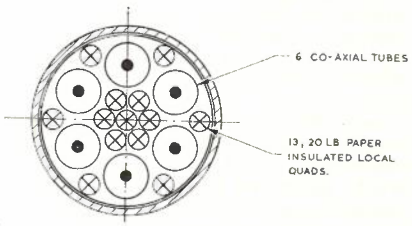

Fig. 2B.—Melbourne-Dandenong Section.

* Mr. Sinnatt is Acting Divisional Engineer, Trunk Cable Planning, Lines Section, Central Office.

terminal equipment will be established at Melbourne, Dandenong, Warragul and Morwell, and possibly later at Pakenham East. Intermediate stations with repeater equipment only will be provided between the main stations at intervals not exceeding 5.8 miles. There will be three intermediate stations between Melbourne and Dandenong, seven between Dandenong and Warragul, and five between Warragul and Morwell. The first two repeaters out of Melbourne will be accommodated in existing metropolitan exchange buildings, but at the other locations special buildings of dimensions 12 ft. by 10 ft. by 8 ft. and constructed of double brick or pre-cast concrete slabs will be erected. These buildings will be similar to those to be provided on the Sydney-Melbourne route (1). Care was taken to site one of these intermediate repeater stations at Pakenham East so that it could be replaced by a main station later without affecting the general layout. Power for the repeater equipment will be fed from the main stations to the intermediate stations over the inner conductors of the coaxial tubes, but commercial power will be connected to the buildings for emergency purposes, and for supplying current for lighting, heating, test equipment, etc., as required.

CABLE INSTALLATION AND PROTECTION

Buried Section: In order to secure the cable as far as possible from mechanical damage during service, it will in general be laid at a depth of 4 feet. To enable the cable to be laid at this depth, and to protect it from damage during installation, particularly crushing and tension faults, the mole plough method will not be used, but rather a trench will be provided over the whole of the buried sections. Maximum use will be made of mechanical aids, and the working force will be split into functional groups. All obstructions will be located and overcome by advance parties to avoid delays to the main trenching and cable laying teams. The first party provides gates for access to private property sections and installs pipes at rail and major road crossings using horizontal earth boring equipment. The second advance party clears and disposes of timber, grades the surface, and rips the trench to the full depth using a hydraulically controlled ripper blade mounted on a tractor. (See Fig. 3). This action locates obstructions and permits appropriate treatment in advance of the trenching party. Where stone is encountered by the ripper, rock-free loam or sand is spread over the track by local contractors. This advance party also trenches where required at steep slopes, drains and creeks using drag-line equipment. The trench and lay party then excavates along the pre-ripped path to a depth of 4 feet using a high-speed bucket-wheel ditching machine. A road grader places half the bedding material in the trench, the cable is laid in 500 yard lengths from a trailer fitted with crawler tracks and hauled by a winch rope, the grader places the balance of the bedding material over the cable in the trench and then backfills the spoil in 12-inch layers, consolidating with a special tamping wheel attachment. Holes for jointing are dug using a hydraulic grab. After backfilling of the route, cable markers are set and pasture grasses sown over the disturbed surface. Other soil erosion measures to be taken include the provision of check dams along the trench. It had been intended to lay the cable from a modified straddle carrier but this equipment will not be available in time. The work parties will be housed in caravans, with hot and cold running water, showers, electric lighting, etc., at main camps.

Joints and loading coils in the buried sections will be buried also, and suitably protected. A small bore insulated lead tube will be brought up each side of a joint—these tubes will serve as radon injection points for fine location of faults, and will also enable measurements to be made of any current flowing in the cable sheath, and of the potential of the sheath to earth. Experience will show whether these arrangements will be required so frequently on other main coaxial cables, but special care is being taken with the Morwell cable as the route parallels a DC electric railway line for much of its length.

Duct Section: Lengths of up to 500 yards will be drawn into ducts to reduce the number of joints and minimise variations in cable characteristics. This can be accomplished using new methods of rodding ducts by pneumatic or "Roductor" equipment, a tension limiting winch for hauling the cable, roller guides for leading the cable round bends and through changes in level in manholes, and providing a pulling eye bonded to the copper components of the cable with an epoxide casting resin to achieve the full tensile strength of the cable and prevent distortion of the coaxial tubes.

Joints in manholes will be protected by bolt-on heavy steel split tubes and the cable between the joint and the duct mouth protected by either polythene pipes or by ferritic nodular cast iron couplings, also bolted on.

Gas Pressure Alarm System: The gas pressure alarm system will be supplied by L. M. Ericsson of Sweden, and will be of a type new in this country as far as trunk cables are concerned, in that contact manometers are not required. An air cylinder is connected to the cable at each repeater station. When a fault occurs in the cable sheath, air escapes and is replaced from the gas cylinders provided at the repeater stations on each side of the fault. Each time the pressure in a cylinder drops by a pre-determined amount, a pulse signal is sent to the main station. By comparing the rates of receipt of pulses, i.e., the rates of gas flow, from the repeater stations on either side, the location of the fault can be approximately determined. The Contractor claims an accuracy of 200 yards. For fine location, if required, radon is injected into the cable and the point of escape determined with a Geiger counter or scintillometer.

Jointing and Terminating. Ericsson jointing methods will also be used. The jointing technique is based on that of the Bell System in America, and differs from the British method described by D. Barry (2). The central conductor is joined by a sleeve which is given an hexagonal crimp using pliers similar to the A.P.O. 40 lb. jointing tool, and the outer conductor is joined by a sleeve rolled down on to it by means of a special rolling tool. Support for this rolling operation is provided by a steel sleeve inserted inside the tube. No soldering is required for the jointing process. Fig. 4 illustrates some of the tools and material. At terminal and repeater stations the tubes are jointed

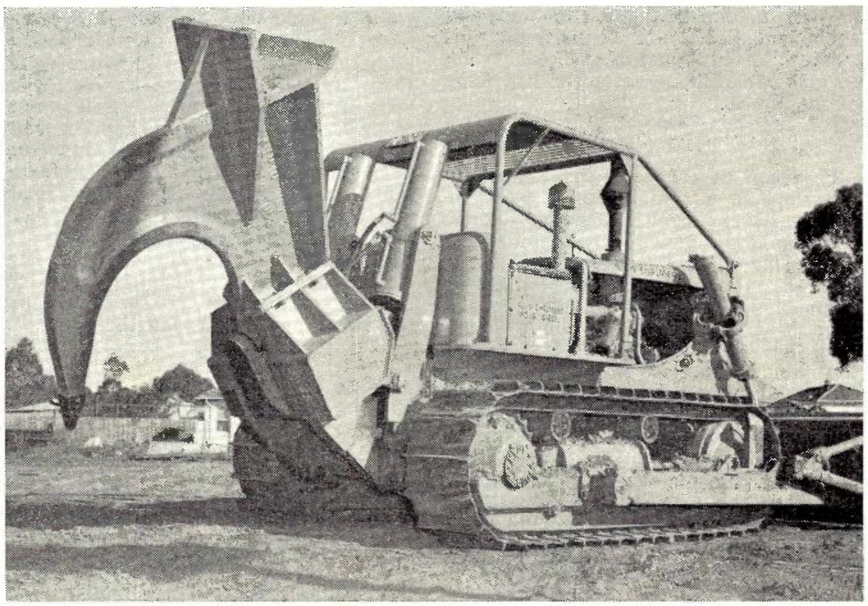

Fig. 3.—Heavy duty tractor mounted ripper blade designed to rip trench to four feet depth in all soil conditions.

to individual lead covered distribution tubes mounted in a pre-cast pothead cap, while the paper insulated pairs are terminated in epoxide resin units fitted with U-links. The sleeve for the pothead joint is formed from copper sheet to avoid the creep that would be experienced with a normal lead sleeve of the same diameter subjected to a continuous gas pressure of 10 lbs. per sq. in.

WORKS ESTIMATES AND CONTROL CHARTS

Present standard Work Units are unsuitable for use in estimating costs of major jobs of this type employing a comparatively small number of men, grouped in highly mechanised functional task forces. It is intended to prepare the estimate in terms of performance targets for particular works functions. The starting point is the rate of cable installation required—in this case five miles per week based mainly on the rate of cable supply. The required functions of the job are then split into appropriate task force groupings and the establishment of the forces in terms of men and machines determined. The number of manhours for each task is then estimated from the number of men required and the time allowed. Provision is made for reserve machines and operators and for ineffective time and staff relief. The cost of installing the Morwell cable at a general depth of 4 feet as estimated by this method is expected to be less than £1,000 per mile. This figure excludes cable and accessories but includes items of material not directly associated with the cable such as gates, sand, and markers as well as labour, administration and incidentals. It includes also camping allowance and depreciation allowance for mechanical plant and caravans and other camping equipment. The total estimated cost, including material, of the Dandenong-Warragul section (45 miles) is £193,000.

The above method of estimating shows up the provision made for the execution of any given function to a much greater extent than does standard estimating practice, and facilitates the preparation of Progress and Cost Control Charts. These Charts are a valuable supervisory aid in ensuring that production targets are being met, and they also highlight cases where over or under-provision of capacity has been made, enabling prompt corrective action to be taken.

TRAINING OF STAFF

As extensive use will be made of mechanical aids and some of the plant is completely new, special training is being provided for mechanical aid operators. Training on the job is neither practicable nor desirable, and as the Department does not possess a suitable school for the purpose, instruction in the use of heavy mechanical plant is being carried out at the School of Military Engineering, Casula, New South Wales, by arrangement with the Department of the Army. Training in the use of lighter plant will be provided by the Victorian Administration or by the manufacturers of the equipment.

Training of jointers will be carried out at the Linemen's Training School Fishermans Bend, Melbourne. Instructors for this course will be briefed by Headquarters staff.

ENGINEERING ORGANISATION

A separate organisation, the Coaxial Cables Section, has been set up in Victoria to carry out work such as the detailed survey of the route, the selection and acquisition of repeater station sites, and the laying and testing of the cable. The section will include a Supervising Engineer, a Divisional Engineer, two Group Engineers and four Line Inspectors. Three of these Inspectors will be in charge of the advance parties, the excavation and laying parties, and the jointing and testing parties, while the other will deal with material supplies and camping arrangements. Operation and maintenance of the mechanical equipment will be under the direct control of the Coaxial Cables Section, the Automotive Plant Section acting in a consultative capacity.

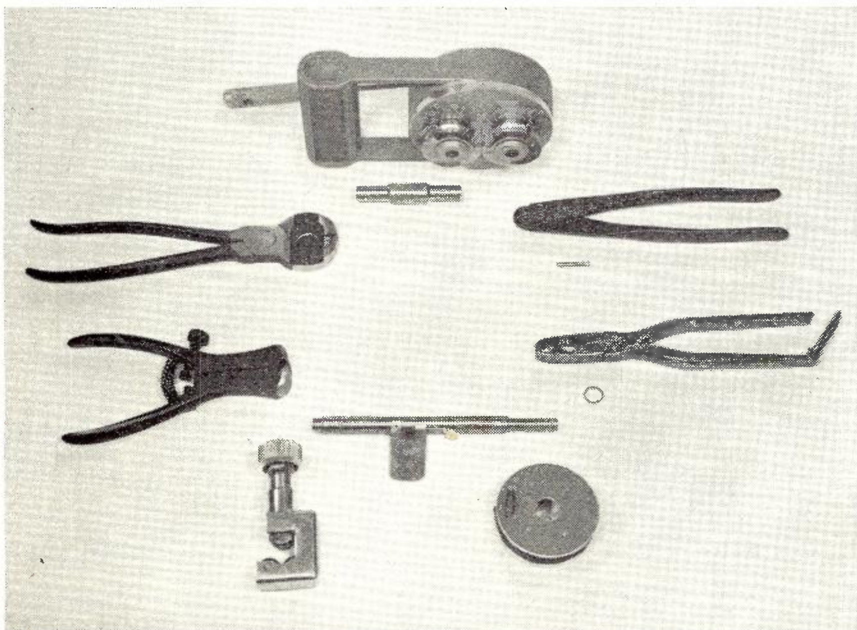

Fig. 4.—Tools and materials used to joint a Coaxial Tube in the Melbourne-Morwell Coaxial Cable.

THE FUTURE

Many of the main trunk routes in the Commonwealth, most of which like that between Dandenong and Morwell are of open wire construction, do not have sufficient capacity to meet both the long distance and the short distance channel requirements, and it is necessary to plan for their replacement on a substantial scale by "broad-band bearers" capable of carrying some hundreds of channels. Such bearers, which are also suitable for relaying television signals, may be either of the coaxial cable or radio type, the choice for initial installation depending on technical, economic, and other factors.

The Postmaster-General has already announced that in addition to the Sydney-Melbourne and Melbourne-Morwell projects, coaxial cables are to be laid between Lismore and Murwillumbah in New South Wales, and Brisbane and Southport in Queensland. Simultaneously, wide band radio systems will be installed between Mebourne and Bendigo, Sydney and Maitland, and Maitland and Lismore.

The Department is closely examining requirements on other main routes such as Murwillumbah to Southport, Adelaide to Port Augusta, Perth to Bunbury and Melbourne to Launceston, and within the next few years it is expected that coaxial cables or wide band radio sysems will be installed in practically all States in the Commonwealth.

ACKNOWLEDGMENTS

The author wishes to thank Mr. H. M. Fitzpatrick, Divisional Engineer, Development and Field Research in the Lines Section at Headquarters, who devised the field organisation and many of the new installation techniques to be used on the project, and Mr. C. H. Hosking, Acting Supervising Engineer, Coaxial Cables, Victoria, for supplying certain information used in this article.

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(2) D. Barry: An Introduction to Coaxial Cables ibid Vol. 11, No. 5.

SHORT HAUL CABLE CARRIER SYSTEMS – PART 2

*M. W. GUNN, B.Sc., A.M.I.E.Aust. and R. W. E. HARNATH, A.R.M.T.C. (Radio), Grad. I.E.Aust.**

SIEMENS & HALSKE SYSTEM TYPE Z12N

General:

The type number of this system is derived thus: Z from zweidraht (two wire), 12 from the number of channels provided per direction of transmission, and N from the subzone network in which it finds considerable application in Germany (radius 22 miles). It provides 12 channels on carriers spaced at 4 kc/s intervals, on each pair in an unloaded cable suitably balanced to 108 kc/s, and transmits speech and associated signals, or V.F. telegraphy. The system was designed on a group frequency basis to keep the cost ratio of cable/voice circuit as low as possible, and to provide for applications where few bearer circuits are available. The system has an inbuilt (optional) signalling facility using a frequency of 3850 c/s, and the channel and group frequencies have been based on the C.C.I.F. recommendations for broadband systems. The use of companders was considered as cable balancing costs could thereby be avoided. However, investigation showed that the savings possible under German conditions were not significant, and in view of the increased maintenance and power required, the slightly impaired dependability and the difficulty of working V.F. telegraph systems over the channels, the use of compandors was avoided. Considerable distances can be spanned with this system as under suitable conditions 10 or more repeaters can be used.

The stages by which the 12 V.F. channels are brought to their line frequencies are shown in Fig. 18. The V.F. channels (300 to 3,400 c/s) are assembled into four 3-channel pregroups of 12 to 24 kc/s which are then translated to the C.C.I.F. basic group 60-108 kc/s. This

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*Mr. Harnath is a Group Engineer in the Long Line Equipment Section, Central Office.

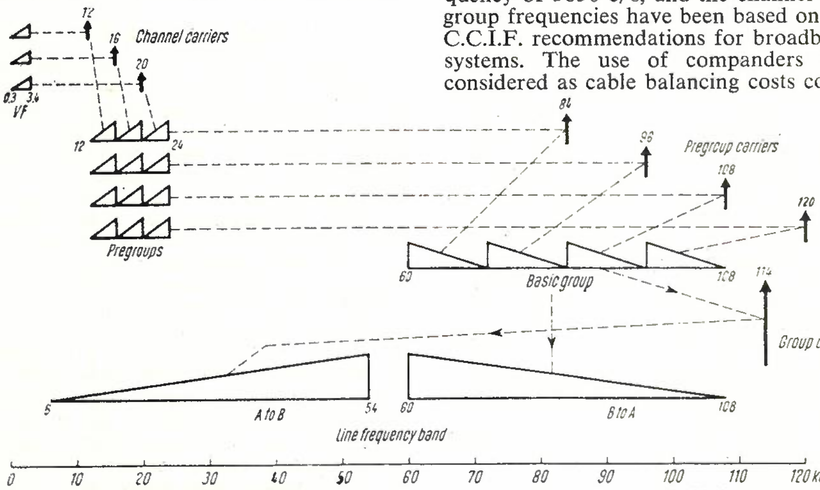


Fig. 18.—Frequency Allocation and Modulation Plan—Type Z 12 N System.

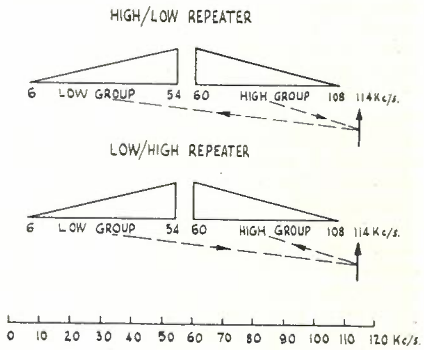


Fig. 19.—Repeater Frequency Allocations—Type Z 12 N System.

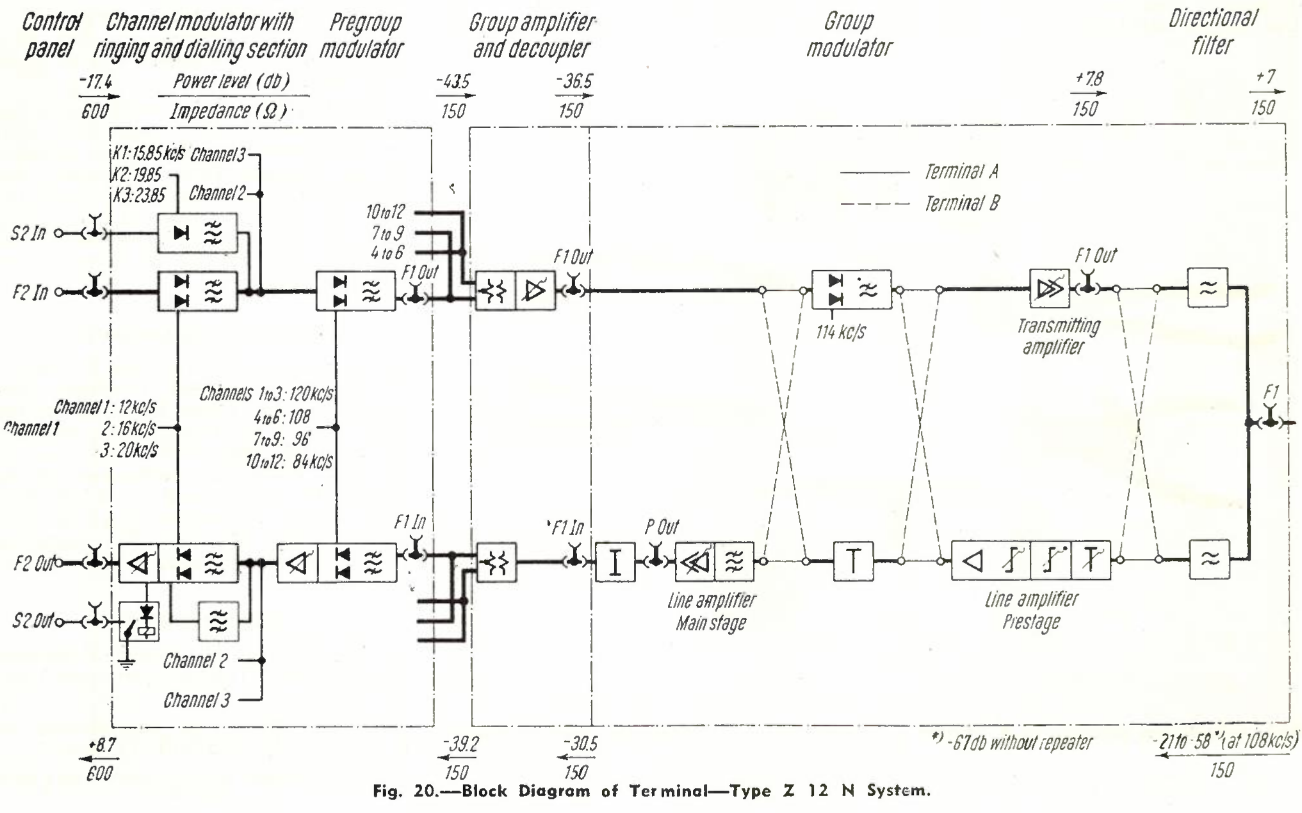


Fig. 20.—Block Diagram of Terminal—Type Z 12 N System.

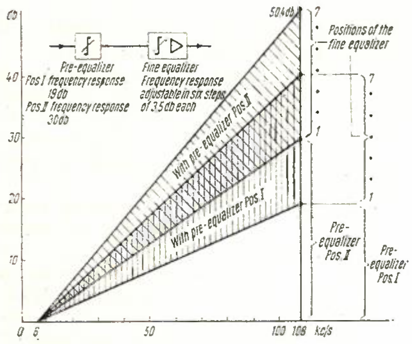


Fig. 21.—Variable Equalisation.

group goes directly to line for transmission in one direction and is translated with a group carrier of 114 kc/s to the position 6-54 kc/s for transmission in the opposite direction. Frequency frogging is available at repeater stations if required, and controls third circuit effects as for the Philips system described previously. The frogging frequency is 114 kc/s and Fig. 19 shows the frequency allocations at a frogged installation.

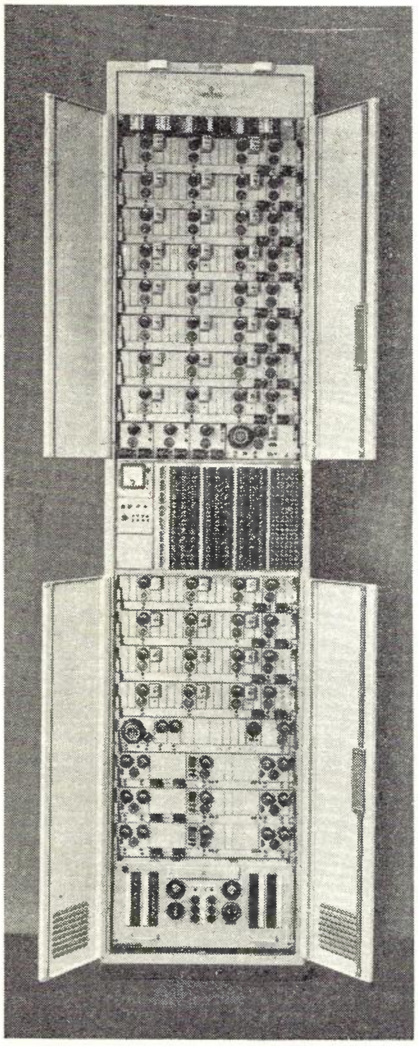


Fig. 22.—Terminal Bayside with Three Complete Type Z 12 N Terminals.

Terminal Equipment

Electrical Functions: A block diagram of a terminal station (excluding the carrier supply and the 4-wire terminating sets) is given in Fig. 20, which indicates the signalling frequencies, the channel and group frequencies, and the levels and impedances at the various points. The transmitting level per channel is +7 db and the receive level limits at 108 kc/s are –21 to –67 db for no repeaters, –21 to –58 db for 1 or 2 repeaters, –21 to –54 db for 3 to 10 repeaters, and –21 to 49.5 db for more than 10 repeaters. A feature which facilitates installation is the adjustable line equaliser. The range of adjustment is shown in Fig. 21 and the setting accuracy is ± 1 db over the group being equalised.

Signalling: Ringing and dialling signals are transmitted via a frequency of 3,850 c/s, which is intermediate between the upper and lower frequency limits of adjacent channels. The signal frequencies for each pregroup are produced by modulating the channel carriers 12, 16 and 20 kc/s with the signal generator frequency 3,580 kc/s. Ground pulses at "S2 in" are reproduced as ground pulses at "S2 out", and signalling impulses may be passed during the conversation if desired. Signal impulses are transmitted at a level of –4.3 db at a point of zero level. Interference of this signalling tone into the associated V.F. channel approximates –45 dbm (flat) at a point of zero relative level. Filters are available to reduce this to –65 dbm if required. Alternatively, the channels are suitable for the transmission of V.F. signals in the range 300-3,400 c/s. An interesting point in the signalling circuit design is that the demodulator amplifier is used to provide the amplification required, which results in the use of only one tube per channel unit.

Carrier Supply: Crystal oscillators are used to provide the channel and group carrier frequencies. A 4 kc/s master oscillator (thermostatically controlled for V.F.T. transmission) produces the channel carrier frequencies directly from a saturated choke harmonic generator, and the group frequencies via a 12 kc/s amplifier from another harmonic generator. The frequency 114 kc/s is produced from a separate thermostatically controlled oscillator. A complete carrier supply is provided for each three terminals (that is one rack). For large installations a centralised supply providing for 960 channels is available.

Physical Layout and Construction. A terminal bay of three systems is illustrated in Fig. 22 and the layout is shown in Fig. 23. The bay is of cabinet construction, 8′ 7″ high, 24″ wide and 9″ deep, and bays may be placed side by side or back to back. The doors are closed when the system is in service, and this gives an installation a uniform neat appearance. The doors are readily removable if required. A convenient pull-out writing shelf is fitted below the testing jack field. The bay illustrated is so wired that it may be equipped as a terminal bay for three systems or a repeater bay for eight systems or with intermixed equipment, without cabling changes. It will also serve as a pure channel modulator bay for four systems or as a group modulator bay for ten systems.

The individual units which comprise a terminal are assembled on slide-in chassis which connect to the bay cabling by means of blade contacts. A typical chassis assembly is that of the channel modulator illustrated in Fig. 24, and the chassis guides and female blade contact strips are shown in Fig. 25. This is built up of three channel units (with inbuilt signalling), and the associated pre-

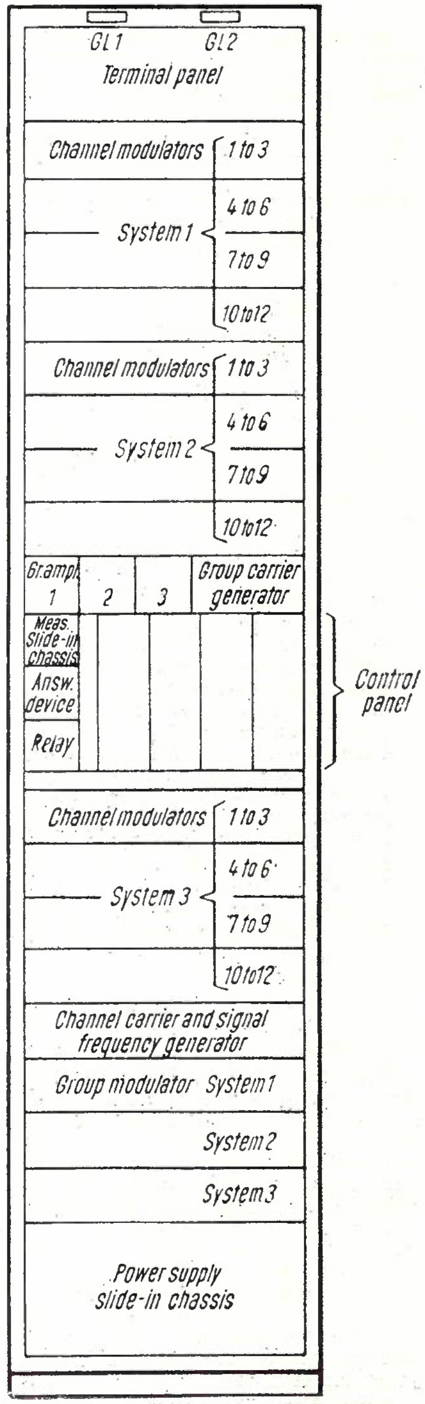


Fig. 23.—Terminal Rack Layout—Type Z 12 N System.

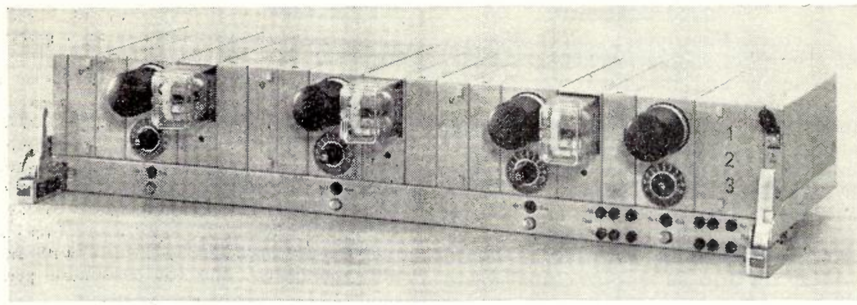


Fig. 24.—Type Z 12 N System Channel Modem Chassis Providing for Three Channels with Associated Pre-Group Modulator.

group modulator and amplifier unit. Each sub-unit of each unit (for example, the channel amplifier sub-unit of the channel unit) is assembled by clamping to the chassis and soldering to the chassis wiring which in turn connects to the chassis blade contacts. The illustration of the assembly of a channel amplifier (Fig. 26) shows the tabs which connect to the chassis wiring. Underneath the assembled units is the chassis supervisory strip which carries alarm lamps, test jacks and U connectors. The chassis is fixed to the bay by toggle locks at each end. The chassis on which some units are mounted are not full width, for example the group carrier chassis is two-fifths full width, but the principles of assembly are similar to that of a full width chassis.

The contents of the chassis comprising a terminal bay are:—

Channel Modulator Chassis: This contains three channel units and associated signalling receive relays, and the pregroup modulator and amplifier unit. Group Modulator Chassis: This contains the group modulator, directional filters, the transmission amplifier, and the receiving equaliser and amplifier. Channel Carrier and Signal Frequency Generator Chassis: This contains the 4 kc/s master oscillator, the 12 kc/s amplifier, the 4 to 12 kc/s harmonic generators, the channel and pre-group carrier filters, the signalling frequency generator, and the carrier level measuring switch.

Group Carrier Generator Chassis: This contains the thermostatically controlled 114 kc/s crystal oscillator with supervisory relay.

Group Amplifier Chassis: This contains the group amplifier and decoupler.

Four-Wire Terminating Sets: Four-wire terminating facilities are given on separate bays of similar dimensions to the terminal bay. The four-wire bays first delivered held eighteen slide in chassis each accommodating two four-wire terminating sets, but for later deliveries this capacity has been increased to 96 sets per bay. Each set comprises a hybrid coil, pads and a compromise network, the pads being adjustable by U-link connectors. A control panel which makes available the input and output circuits and the compromise networks, is provided for each bay.

Valves Used: The system is economical in the use of valves, and uses 70 for 3 complete terminals. Only one type of tube is used in the system, the type C3m pentode developed by Siemens for carrier frequency and low frequency work. It uses a 20 volt heater taking .125A.

Alarm Facilities: A bay alarm system indicates failures of voltages or valves. Alarm lamps indicate the bay and the individual unit in which the fault exists. Individual alarms are extended to cover channel unit tube failures.

Measuring Facilities: A control panel is provided on each bay and is accessible with the bay doors closed. On the terminal bay this panel provides access to the V.F. circuits and their signalling leads. It also has a measuring slide-in chassis, which carries a level meter for measuring carrier levels, and also if desired an 800 c/s oscillator. Further test jacks are provided on the supervisory bars of the slide in chassis assemblies, and anode current tests are made at this point.

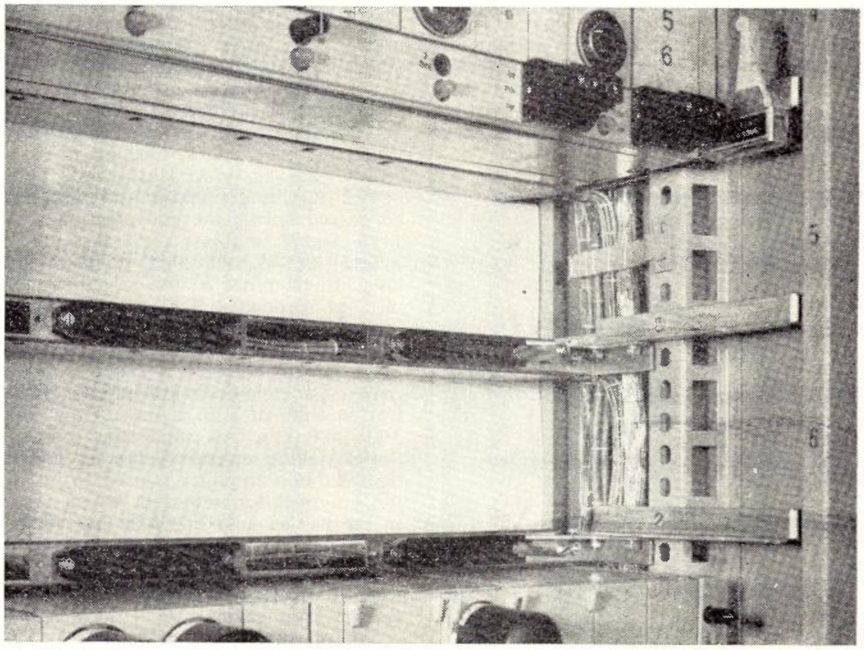


Fig. 25.—Channel Modem Jacking Details.

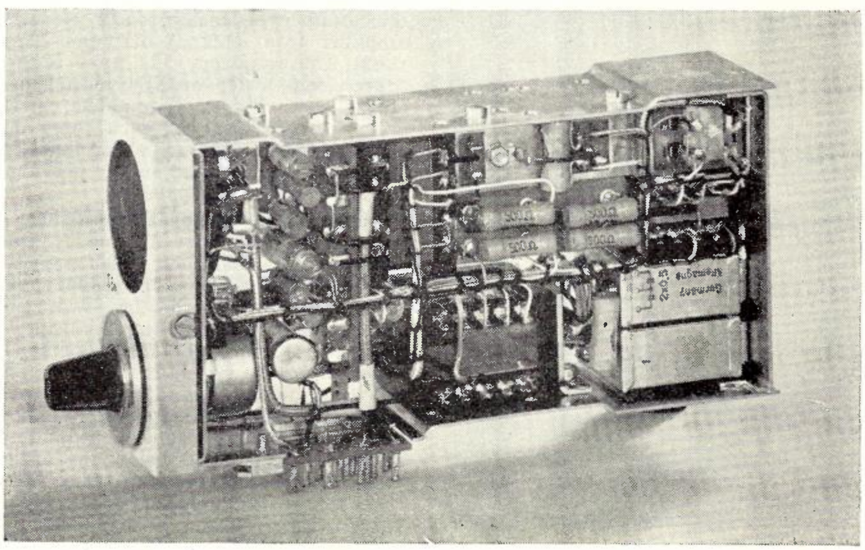


Fig. 26.—Channel Amplifier Unit Excluding Valve Type C 3m.

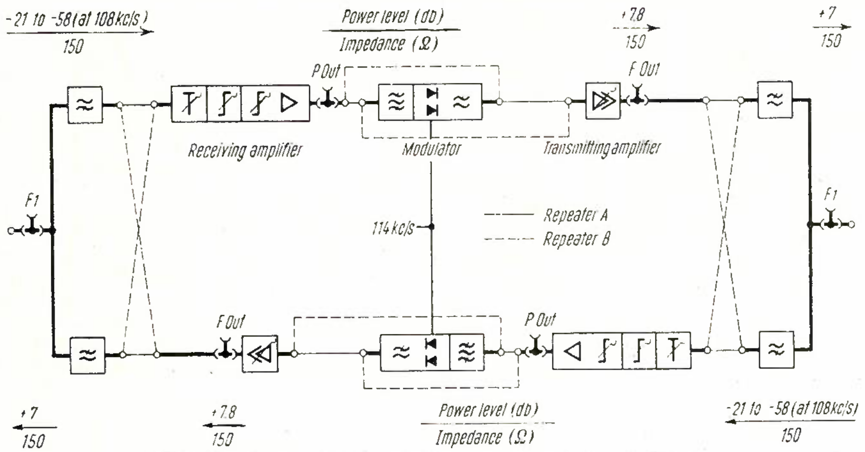


Fig. 27.—Block Diagram of Repeater—Type Z 12 N System.

Power Supply: The anode and heater voltages and the relay voltage are taken from the A.C. supplies via a power supply slide in chassis. The voltages required are 212 volts and 20 volts. The A.C. input limits are 220 volts ± 2% at a frequency 40-60 c/s. The power consumption of a terminal bay equipped with 3 system terminals is approximately 540 V.A., and for a repeater bay complete with 8 repeaters is 485 V.A. Protection against mains failures at each of the stations concerned is given by suitable "no break" mains standby plant which also regulates the supply. Alternative power chassis which provide for installations using a single anode battery (212 volts), or an anode battery plus a filament battery (20 volts), are available if required.

Dimensions and Weights: The standard bay measures 8′ 7″ high x 24″ wide x 9″ deep. A terminal bay equipped with 3 system terminals weighs 740 lbs., a repeater bay fully equipped with 8 repeaters weighs 550 lbs.

Repeater Equipment

Electrical Functions: A block diagram of a repeater station is given in Fig. 27 which indicates impedances, and possible working levels, which are governed to some extent by the cable noise. If the loss between two terminals exceeds 75 db at 108 kc/s, repeaters are required. The maximum repeater section loss, provided the line noise is sufficiently low, is 65 db with 1 or 2 repeaters, 61 db with 3 to 10 repeaters, and 56.5 db with more than 10. Frogging is carried out about 114 kc/s.

Physical Layout and Construction: The standard bay as described under "Terminal Equipment" is used and the layout is given in Fig. 28. The bay accommodates 16 line amplifier chassis assemblies which provide 8 complete repeaters. Each chassis contains the receiving and transmitting amplifiers, adjustable equaliser, modulator, and directional filters for one direction of transmission. A group carrier supply chassis, similar to that provided for terminal installations, gives the frogging frequency of 114 kc/s.

APPLICATION OF SYSTEMS

General: The systems described in the previous sections are being used to derive additional trunk and junction circuits in New South Wales and Victoria as shown in Fig. 1. The Skillman systems have mainly been used for deriving additional junction circuits, under relatively small and isolated applications, while the Philips and Siemens & Halske systems have been used more extensively on established minor trunk routes. A summary of the electrical characteristics of the systems is given in Table 1. The attenuation/frequency characteristics of the most commonly used cables were given in a previous article.

T. S. Skillman System, RY432: A typical application of the 6-channel systems is in the outer metropolitan area of the Melbourne network. Here, requirements existed for the relief of several relatively small cables. The provision of a small number of systems on these routes has allowed the cable relief works to be deferred.

The particular routes concerned are:—

(a) Greensborough/Yarrambat, over 5.3 miles of 40 lb. P.I.Q.L. and P.I.Q.T. Cable.

TABLE I.
ELECTRICAL DATA SUMMARY

	Skillman Type RY.432	Philips Type STR.113	Siemens & Halske Type Z1 2N
Channels/physical pair	6	8	12
Mode of Transmission	S.S.B. transmitted carrier.	S.S.B. suppressed carrier.	S.S.B. suppressed carrier.
Channel Bandwidth	300-2700 c/s.	300/3400 c/s	300/3400 c/s
Line Frequencies	1-24, 28-52 kc/s.	6-54, 60-108 kc/s.	6-54, 60-108 kc/s.
Frogging Frequency	—	114 kc/s	114 kc/s
Carrier Spacing	4 kc/s	6 kc/s	4 kc/s
Signalling Frequency	Carrier	4300 c/s	3850 c/s
Signal Level Relative to S.B. Level	+12 db	—6 db	—4.3 db
S.B. Line Levels and Impedances	0 db/130-150 ohm	+ 3.5 db) to)HG/150 ohm — 1.8 db) — 6.5 db) to)LG/150 ohm —13.7 db)	+7 db/150 ohm
Two-wire Input	0 db/600 ohm	0 db/600 ohm	0 db/600 ohm
Four-wire Input	—4 db/600 ohm	— 3.5 db) to)600 ohm —12.6 db)	—17.4 db/600 ohm*
Four-wire Output	+4 db/600 ohm	— 3.5 db) to)600 ohm + 4.5 db)	+8.7 db/600 ohm*
Max. Attenuation of One Repeater Section	46 db (10 miles 20 lb. PIQL)	70 db (11 miles 20 lb. PIQL)	62 db. (10 miles 20 lb. PIQL).
Power Supply	50V D.C. 130 D.C.	220V A.C. ± 5% 50-60 c/s.	220V A.C. ± 2% 40-60 c/s.

Note *Adjustment provided in 4.W. Terminating Sets.

(b) Greensborough/Research, over 6 miles of 40 lb. P.I.Q.L. Cable and

(c) Preston/Thomastown, over 1.5 miles of 10 lb. P.I.Q.L. and 2.2 miles of 20 lb. P.I.Q.L. Cables.

The equipment is installed in exchange buildings, and in some cases 8′ 6″ racks have been used to meet the requirement of the low ceiling height available in the small exchange buildings. Continuity of filament supply is assured by the exchange battery, and the provision of a small anode battery provides against the possibility of mains failure.

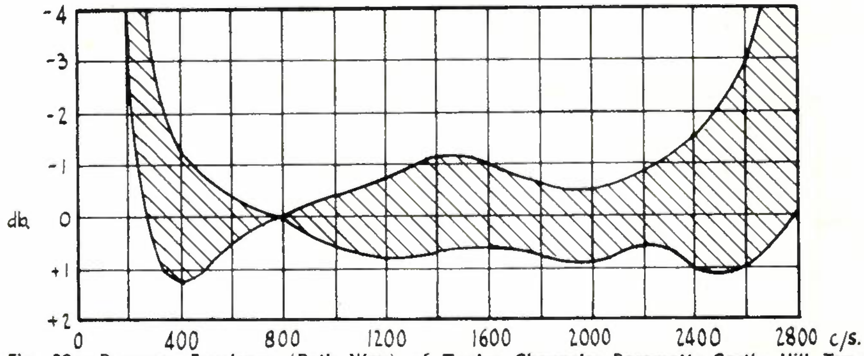


Fig. 29.—Response Envelopes (Both Way) of Twelve Channels: Paramatta-Castle Hill Type RY 432 Systems.

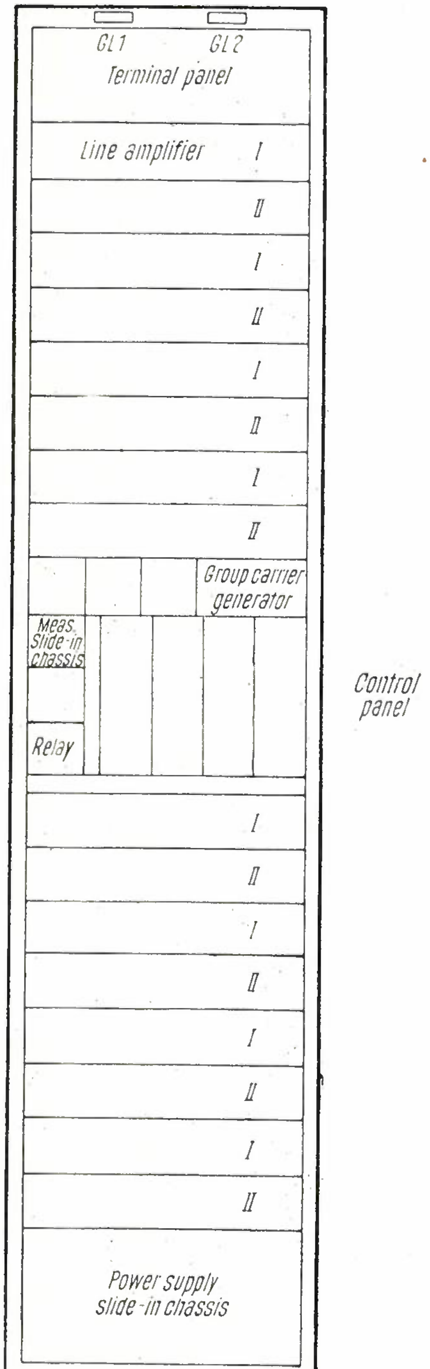


Fig. 28.—Repeater Rack Layout—Type Z 12 N System.

These cables are particularly free of noise, and for this reason some inter-channel crosstalk troubles have been encountered, which are further accentuated by the trombone-trunking scheme used. As described in the earlier section, the received gain in the demodulator amplifier is increased by 10 db in the return direction of the 4-wire path during the period before the arrival of the supervisory reversal. During this period, therefore, the crosstalk level is increased by 10 db, and the modulation scheme used with this type of system results in the crosstalk being intelligible. In order to overcome this difficulty, pulse type signalling of a modified form has been adopted in both directions. Under these conditions carrier is transmitted at all times except during pulses, and the facility of increasing the receiver gain by 10 db has been limited. Previously the level change of 10 db necessitated rather critical adjustment of the signalling receiver in the return direction, but the revised version is such that a complete break in the carrier is given during the reversal pulse which has made the adjustment of the signal equipment very much easier and infrequent. It is hoped that this subject will be discussed further in a later article on carrier dialling.

Other installations of these systems have been made in New South Wales between Parramatta/Castle Hill (4.5 miles of 20 lb. P.I.Q.L.) and Katoomba/Lawson (8.36 miles of 20 lb. P.I.Q.L.). Because of the inherent noise in the cables in these installations less trouble has been experienced with crosstalk, but it is anticipated that the modification of signalling relay sets now in use in Victoria will be extended to the N.S.W. installations.

The general response envelopes of two systems between Parramatta and Castle Hill are shown in Fig. 29.

Philips System Type STR.113: The application of this system is at present confined to the Sydney junction and minor trunk networks. 6 type STR.113/13 systems are operating between North Sydney and Dee Why exchanges with repeaters at Balgowlah. Repeater sections do not exceed 34 db at 108 kc/s with the result that the derived circuits give basic noise figures of 60 db weighted and better. The bearers used were selected to have crosstalk characteristics better than 60 db at 108 kc/s, and no cable balancing bays were required.

9 Systems of the later STR.113/11 version are operating between City North and Avalon. Avalon is a multi-metering area giving subscribers direct access to the Sydney automatic network. Multi-metering requires the transmission of signalling tones simultaneously with speech on a channel. The signalling characteristics of this system are not suitable for operation with signalling tone transmitted continuously. The 4300 c/s tone is transmitted at a level of —6 db relative to line-up level, and causes interference in the associated voice channel at a relative level of approximately —35 db weighted. Thus the signalling path is not completely independent of the voice path, and this has necessitated the development of special relay sets differing from the usual relay sets used with junction carrier equipment. The circuits of the standard sets are given in Figs. 4 and 5. These sets are normally operated with tone on in the idle condition. In the "go" direction, this tone is removed when the channel is seized, returned during impulsing, and then again removed during conversation. In the "return" direction, it is removed for the metering or supervisory functions, but remains for non-metered calls. In the North Sydney-Dee Why installation, the incoming circuits have been modified for pulse operation in the "return" direction, which obviates the difficulty of tone on during conversation with non-metered calls. With this change, the equipment is providing satisfactory service, but there is a limitation in the private wire circuitry which necessitates all out-going sets being installed at Dee Why. For the City North-Avalon route a further modification was used giving pulse operation in both directions, which provides completely independent signalling functions. When correctly adjusted, the signalling distortion over the derived channels is less than one millisecond under all conditions of operation, including variations of 10% in power supplies and ± 3 db in the overall cable attenuation.

In the North Sydney-Dee Why installation, as only one repeater station, Balgowlah, was used, no mid-section equalisation was provided. On the Avalon route, using 5 repeaters, mid-section

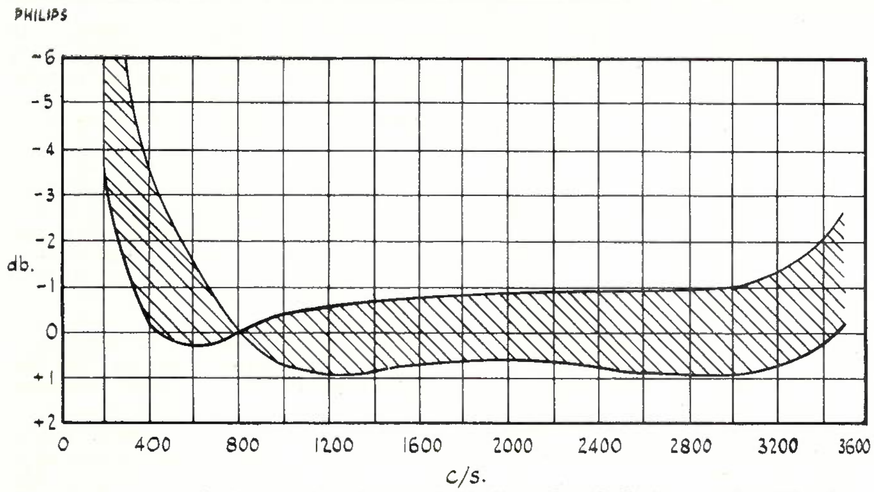


Fig. 30.—Response Envelopes (Both Way) of 48 Channels: North Sydney - Dee Why Type STR 113 Systems.

equalisers were provided at Dee Why. When equalisation commenced in the City North-Avalon direction, difficulty was encountered in setting these equalisers. A number of resonant circuits, which may be series or parallel connected are provided to smooth out the "bumps" in the accumulated line characteristic. Unfortunately, each network is not independent of the others, with the result that an endeavour to smooth out one irregularity results in other irregularities being introduced. When it was found that the adjustment time was so long, a statistical investigation of the overall line characteristics of the North Sydney-Dee Why systems was made. This showed that, assuming similar cable characteristics for the longer route, the deviation from a straight overall characteristic should not cause more than 1% of derived channels to fall outside specification limits. The remaining mid-section equalisers at Dee Why were therefore left out of circuit, and it was found that the analysis was correct when applied overall between City North and Avalon. The difference between the systems with and without mid-section equalisers was sufficiently small not to influence the channel frequency responses. In the Avalon-City North direction no mid-section equalisers were used, and again it was found that the overall frequency response limits were met generally. However, in both directions, and either with or without mid-section equalisers, it was found that a characteristic "bump" in the overall frequency response occurred between 6 and 10 kc/s. This appears to be due to the characteristics of the slope equalisers, and not the cables used, and results in slight deviations beyond the specification limits for channel 1 in both directions.

The channel responses of the 48 channels on the North Sydney-Dee Why route are sketched in Fig. 30 and are satisfactory. On the Avalon route the channel responses are also satisfactory, with the exception of channel 1, which in some instances does not quite meet the specification limits because of the equalisation difficulties mentioned in the previous paragraph.

Siemens and Halske System Type Z12N: A minor trunk network of some magnitude is being built up with these systems in the east part of the metropolitan area of Melbourne. Details of the network are given in Fig. 31.

The Melbourne-Frankston application illustrates the development of older routes originally served with V.F. cables. The cable was laid in 1940. It is a composite cable; it starts in Melbourne as a 54 pr. 40 lb. per mile quad trunk plus 400 pr. 20 lb. quad local and tapers to a 54/40 lb. plus 56/20 lb. cable at Frankston. The 54/40 lb. pairs were originally loaded with 88 mH coils but one pair of each quad was deloaded during 1949/50 to provide bearers suitable for operation to 108 kc/s. Of the 27 pairs deloaded, the 24 pairs showing the best crosstalk characteristics were selected. These were balanced with crosstalk balancing frames and 20 pairs were used for the installation of type K systems using two cable pairs per system and working 12-60 kc/s Frankston-Melbourne and 60-108 kc/s Melbourne-Frankston. The use of Siemens and Halske systems has doubled the capacity of the pairs available and on present development figures should enable the cable to meet requirements for a number of years.

The Melbourne-Belgrave application is unusual as part of the route consists of 5.72 miles of stainless steel sheathed aerial cable. Aerial cables are used only to a limited extent in Australia and this installation is the first of this particular type of cable. The Siemens & Halske systems do not incorporate automatic regulation but temperature changes on the aerial cable will not be significant as a 55°F variation is required to change the attenuation at 108 Kc/s by 1 db.

The envelopes of the responses of 72 of the Melbourne-Frankston channels are given in Fig 32, and illustrate the quality of the equipment. Channel weighted noise on these circuits averages —78 dbm with peaks approximating —63 dbm. Relatively short repeater sections, compared with the 60 db sections that these systems are designed to cover, and the relatively high line levels of the systems ensured these good figures

Inter-system crosstalk is better than 70 db and equalisation by the system variable equalisers is to within ± .6 db. The 3850 c/s signalling tone of these systems interferes into the associated voice channel at a level approximating —45 dbm (flat) at a point of zero relative level. In normal operation this is inaudible, and no special measures have been taken for its reduction.

CONCLUSION

Since the introduction of the first cable carrier systems during the 1930s, the reduction in cost of terminal and repeater equipment has enabled the distances over which economical provision of carrier cable equipment can be made, to be successively reduced. Modern systems achieve economy by miniaturisation, advanced circuitry, new mechanical construction, and in some cases the relaxation of filter requirements made possible by channel spacings wider than the 4 kc/s spacing used on long haul systems. The progress which has been achieved in the reduction of floor area required per channel end, has resulted also in decreased accommodation charges. Attention paid to the provision of long life components and valves should result in less maintenance. Where plug-in type equipment is provided in fairly concentrated quantities, maintenance costs may be reduced still further by establishment of equipment service centres where routine tests and repairs can be carried out on the individual system units on a "change-over" basis. When transistorised equipment of these types becomes available as it will in the very near future, further improvements in maintenance charges should result, and an even higher degree of miniaturisation should become possible. One of the main difficulties existing in miniaturised equipment using electron tubes is the dissipation of the heat generated and this limitation no longer exists in transistorised equipment.

The three systems described are interesting in that, although designed with the same basic goal of reliable performance with minimum size, the actual designs resulting have assumed very different forms, both mechanically and electrically.

Development is still continuing on the application of carrier equipment to short V.F. cables. One of the most

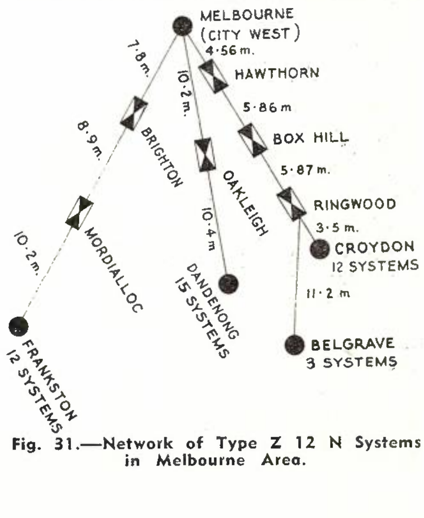


Fig. 31.—Network of Type Z 12 N Systems in Melbourne Area.

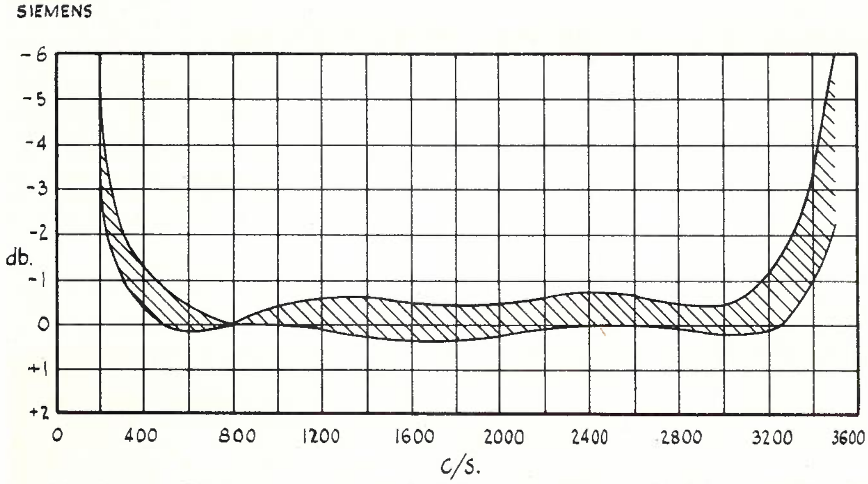


Fig. 32.—Response Envelopes (Both Way) of 72 Channels: Melbourne-Frankston Type Z 12 N Systems.

recent is the outcome of a joint investigation by Philips and the Netherlands P.T.T. Administration into the properties of the cables used in the Dutch local networks. This has indicated that it is more profitable to use a few pairs over large frequency bands rather than many pairs over a small band. In turn, this has led to the proposal to place 120 channel systems on these cables and in the case of a 54 pair cable the installation of four 120-channel systems on four phantoms is possible. This represents a considerable advance in the potential circuits available from these cables.

The cost relativity between cable carrier and other alternative means of provision of short haul circuits is still changing in favour of cable carrier systems. Because of the many factors involved the minimum distance above which systems should be provided varies with individual applications. The installations on the Melbourne-Frankston and the Melbourne-Belgrave routes discussed above are economic applications. On present costs, in very general terms, installations over distances greater than 15 miles are likely to prove more economic than other means of provision. However, further applications of cable carrier systems to a wider field of use depends, in the main, on the reduction of the capital costs and the maintenance costs associated with their use.

LETTER TO EDITORS—A MATTER OF MODULATION

The following reply to Mr. R. Kitchenn's letter (Vol. 11, No. 4) has been received:

11 Panoramic Grove,
Glen Waverley, Victoria
May, 1959

The Secretary,
Postal Electrical Society of Victoria,
G.P.O. Box 4050, Melbourne.

Sir: I was surprised to notice that there were no replies from the "experts" in your October, 1958 and February, 1959 issues to the views expressed by your intrepid correspondent, Mr. R. G. Kitchenn on page 131 of the June, 1958 issue.

There being apparently no contrary opinion, I take it we may assume that Mr. Kitchenn has established his case for a very substantial relaxation of the existing Departmental limits on transmission medium distortion for single channel telephone circuits. It remains, I presume, only for the experts to amend the appropriate Departmental transmission objectives.

Assuming this to be the case and bearing in mind that this letter is an informal one, perhaps you will permit me to enlarge on the last paragraph of R. G.K.'s letter in which the modulation depth of radio transmitters is discussed?

Consider a programme line feeding a radio broadcast transmitter (AM or FM). Typically the circuit is lined up on a 1000 c/s tone and when the programme is applied, the level is monitored using a volume unit meter and adjusted so that programme peaks modulate the transmitter 100%. The capabilities of the radio transmitting medium are thus fully employed with optimum results.

The position, however, is very different in the case of a single channel telephone circuit provided by frequency modulated VHF radio equipment. For practical reasons the speech level is not monitored and in any case it is not permissible to adjust the level. The radio equipment is usually designed with a pre-emphasis characteristic of 6db per octave and the maximum allowable frequency deviation is ±15kc/s. It is reasonable to assume that the deviation will not exceed ± 15 kc/s provided that the crest value of the audio input voltage under speech modulation conditions does not exceed that value which, at a frequency of 1000 c/s, results in a deviation of ± 10 kc/s. The same audio input voltage would, of course, result in a deviation of ± 8 kc/s at 800 c/s and it is reasonable therefore to regard a deviation of ± 8kc/s at 800 c/s as corresponding to 100% modulation.

Now it is common practice in some parts of the Commonwealth to line up these single channel radiotelephone systems so that an 800 c/s one milliwatt tone at the trunk test board, that is a point of zero relative level, gives ± 5 kc/s deviation or 4db below "100% modulation". Since it is also reasonable to assume that the crest value of the voltage on a line carrying speech is about 4db higher than the crest value of the steady 1000 c/s tone which gives the same VU reading, then it follows that a OVU talker (measured at the trunk test board) would just fully modulate the transmitter. In point of fact, however, the mean sending speaker level is about −12 VU (see T.J.A. June, 1957, page 27) which leads one to suspect that many of our VHF single channel telephone systems are grossly undermodulated.

Some speaker levels, of course, are appreciably higher than the value quoted whilst others are lower. If the modulation depth were increased by (say) 12 db, the occasional high speaker level could be at least partially taken care of by a limiter, although in any case a slight over-modulation of an FM transmitter does not have serious results. Apart from a small increase in emitted bandwidth there might be a modest increase in distortion but this, as already established by R.G.K., can be tolerated.

In the last paragraph of R.G.K.'s letter an experiment was quoted in which an increase in modulation depth of 12 db resulted in negligible loss of comprehension and a test tone distortion of 12%.

The relatively high test tone distortion presumably resulted from operation of the equipment at phase deviation levels for which it was not designed and which are never encountered under speech modulation conditions. This difficulty can easily be overcome by using a lower test tone level for lining-up purposes, say—8dbm.

Finally, let us consider the so-called "linearity" of a single channel telephone circuit. For the linearity test the line-up 800 c/s tone of one milliwatt at a zero level point is increased by 8db which should result in a similar increase of 2db (or very close to it) at the far end. This test is particularly objectionable when applied to a radio system since, in order to meet this requirement, the phase deviation corresponding to a standard one milliwatt test tone must be kept low. If it were arranged that a suitable level of 800 c/s line-up tone (say −8dbm) should give "100% modulation" that is ± 8 kc/s and the level of this tone were then **reduced** by 8db, the conditions would be roughly comparable with programme circuits and no difficulty with the linearity test would result. The continuation of the linearity test in its present form however, can only result in drastic inefficiency in the use of the radio medium.—
Yours faithfully,
26/5/59 A. BACON.

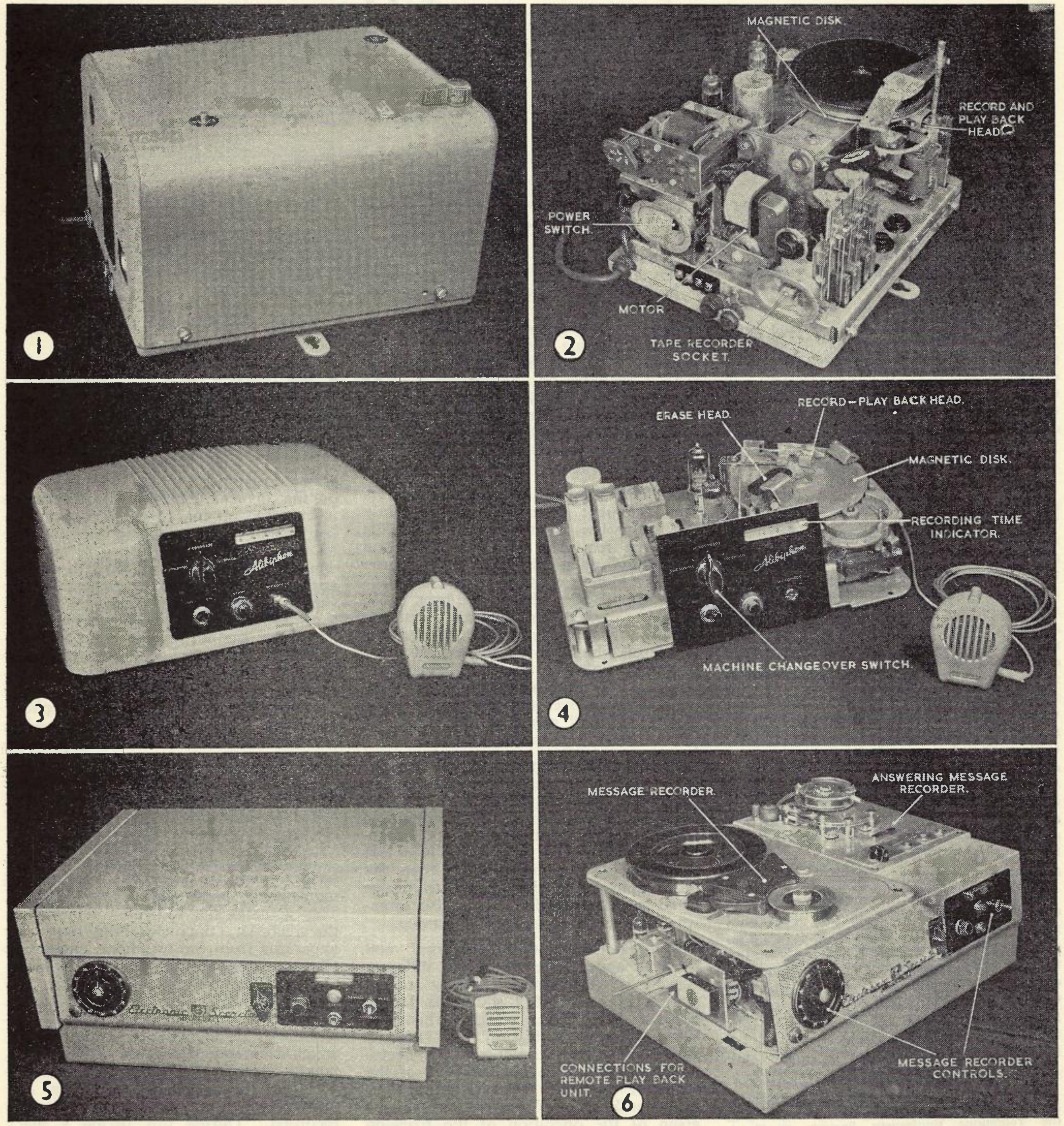
AUTOMATIC TELEPHONE ANSWERING MACHINES

*F. R. RAY, M.I.E.E.
J. D. COWHEY

INTRODUCTION

During the last few decades, changing economic conditions in commercial and industrial life have served to foster the development of mechanical and electrical aids to human effort, in order to bring about the more efficient utilisation of available manpower. Examples of this may be seen in labour saving devices such as calculating machines, typewriters, etc., used in offices and in the development of "automation" for the control of manufacturing processes in industry. In the Telecommunications field also, corresponding development has taken place (e.g., the replacement of manual exchanges by automatic exchanges) and progress is continuing. The purpose of this article is to describe one phase of this development, relating to subscriber's equipment.

Executives and other important officials of large business concerns usually have a secretary available to answer



Figs. 1-6.—Telephone Answering Machines. 1 & 2 Ericsson. 3 & 4 Alibiphon. 5 & 6 Electronic Secretary.

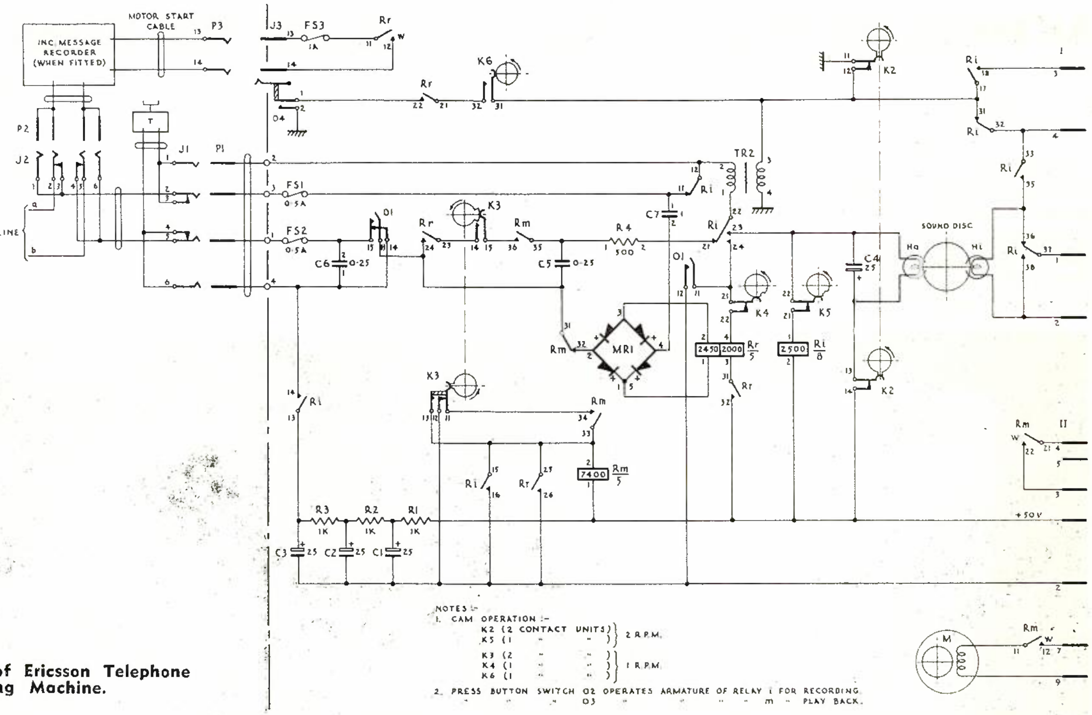


Fig. 7.—Circuit of Ericsson Telephone Answering Machine.

incoming telephone calls during any periods when they are absent from their offices, or are otherwise unavailable, but other subscribers, including owners of one man businesses, have to hope that any persons attempting to telephone them during their absence will "try again" later.

FACILITIES PROVIDED

To meet the requirements of the latter class of subscriber a device known as a "telephone answering machine" has been developed by a number of different commercial firms. This device is intended to be switched across a subscriber's line during his absence from his office, and is designed so that a previously recorded announcement will be repeated over the subscriber's telephone line, from the equipment at the subscriber's premises, to any person who telephones to the subscriber. This recorded announcement would include the name and telephone number of the subscriber and would state that in the absence of the subscriber the call was being answered by a telephone answering machine. Advice would also be given as to when the subscriber was expected to return and would possibly quote an alternative number which could be called for the purpose of leaving a message.

All types of telephone answering equipment provide the facility described above, but the more elaborate types also provide means whereby, after listening to the pre-recorded announcement, a caller may dictate a message addressed to the absent subscriber, which will be recorded on the machine at the subscriber's premises. Upon returning to his premises the subscriber may "play back" any messages which have been recorded during his absence. A total capacity for up to 60 minutes recording time is available on one type of machine for recording all these incoming messages. Before departing from his office, the subscriber would of course erase any messages to him which had been previously recorded.

At least one type of telephone answering equipment is designed so that while the subscriber is still absent from his office he may call his own telephone from any other telephone in the area and, by remote control, initiate a "play-back" of all calls which have been made to him during his absence. This is achieved through the medium of a pocket oscillator which whilst being held close to the transmitter of the calling telephone will send a tone within the voice frequency range over the line, and actuate the "play-back" mechanism in the telephone answering equipment.

An essential component of all types of answering equipment is the recording medium. This may be either a steel wire, a magnetic tape, or a disc or drum coated with magnetic material. Experience indicates that steel wire is a less satisfactory recording medium than the other materials, being liable to cause some speech distortion. It is also somewhat prone to breakages in service.

Figures 1-6 show the external and internal appearance of three different designs of telephone answering equipment. Figs. 1 and 2 show the L. M. Ericsson type, Figs. 3 and 4 show the West German "Alibiphon" and Figs. 5 and 6 show the U.S. "Electronic Secretary." In order to give an idea of the scope of telephone answering machines in general, a brief description will be given of the operation of the Ericsson telephone answering machine.

THE ERICSSON TELEPHONE ANSWERING MACHINE

The telephone answering equipment is connected in the circuit between the subscriber's line and the subscriber's normal telephone set by means of a 4-point plug and jack which extend the 2 line wires and the 2 wires from the normal telephone instrument to the control switch on the answering machine. This switch is mounted on the cover of the answering machine for switching the machine on and off, and beside it is a rectangular window in which one of three signs will appear, depending on the position of the switch. When the switch is turned towards the window, the appearance of a telephone symbol in the window indicates that the telephone is connected to the line and can be used by the subscriber in the normal manner. When the subscriber wishes to use the telephone answering machine he turns the switch towards the "record" button in the top right-hand corner, whereupon a white sign becomes visible in the window. This indicates that the telephone line is switched over from the telephone to the answering machine.

In order to record a message the subscriber raises the telephone handset and momentarily presses the "record" button. This actuates the recording relay Ri in the recorder, thus switching over the apparatus from the telephone line to the telephone. A motor relay is now operated and starts the recorder motor, and the magnetic disc commences to rotate. For a duration of about 2 seconds current flows through a demagnetising coil which is mounted in front of the disc, thereby demagnetising the disc as it rotates past the coil. This will erase any message which may have been previously recorded. During this period a black sign appears in the window.

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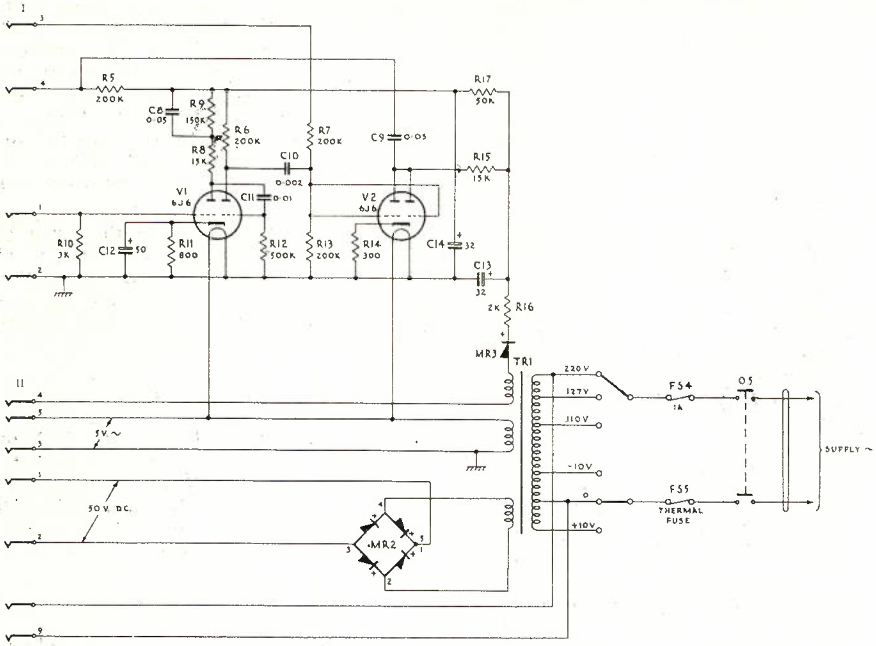

The "recording and play-back" head then commences to describe a spiral movement on the disc, and a white sign appears in the window to indicate to the subscriber that he can start to record his message. The time available for recording is about half a minute. The size of the white sign increases until, at the end of the recording time, it completely fills the window.

The speech currents generated in the telephone transmitter pass through the amplifier on their way to the recording head which magnetises the magnetic foil, on which the message is consequently recorded.

At the end of the recording period a switching action takes place in the recorder, by means of the motor-driven cams, and contacts actuated by them, whereupon the magnetic recording device repeats the above-described process but with the amplifier in reverse connection. The recorded message can thus be heard in the telephone receiver and be checked by the subscriber.

At the end of the play-back period, the motor-relay is de-energised by action of the cam contacts, and the motor stops; at the same time the recorder is again connected to the telephone line. The recorder is now at rest, but with the amplifier connected, and is thus ready to receive and answer incoming calls. It should be noted that the play-back procedure described above can be carried out at any time desired, by depressing the play-back button.

An incoming call to the answering machine is answered afer a delay of approximately 10 seconds. This delay in looping the line permits the telephone bell, which is across the line, to give a short ring. If the subscriber is available to take the call personally he may do so by lifting the handset off the telephone and the answering machine will then not complete its cycle of operation. The subscriber may also interrupt the machine if it is in the act of delivering an answering message by lifting the telephone handset and turning down the switch on the right hand side of the unit. The recorded message does not suffer adverse effects and the machine can be switched back on to the line again when required.

On a call to the machine the incoming ringing current operates a ringing relay and the line is looped after the delay referred to above. The circuit to the recorder motor is completed and the play-back is connected to the telephone line through the amplifier. The answering message is then delivered to the caller. On completion of a ½ minute period the circuit arrangements are such that the message is repeated, this assists the caller to memorise the message or to make a note of the information which is given. On completion of the repeated message the machine will stop automatically.

The facilities which are self contained in this particular type of telephone answering equipment do not allow an incoming caller to leave a recorded message of his own, for the subscriber to listen to upon his return to his office. However, provision is made in the design of this model for the external connection, if and when required, of any commercial type of tape recorder, upon which incoming messages could be recorded.

Figure 7 shows the circuit drawing for the Ericsson machine, and the following is a brief description of the circuit operation involved in answering an incoming call:—

CIRCUIT OPERATION OF ERICSSON MACHINE

When the lever controlling the "01" springset, at the bottom right hand side of the front panel is in a position where the telephone symbol can be seen through the glass window, the telephone operates normally, with the answering machine out of circuit. When this lever is in a position where the white flag can be seen the machine is ready to receive an incoming call. When an incoming call supplies ringing voltage to the machine, the ringing current operates relay Rr via rectifier MR1 and contacts 15/13 of "01" and contacts Rm 31/22 and capacitor C7. Relay Rr then locks over its second winding via its contacts Rr 31/32. Contacts Rr 25/26 complete a circuit to energise Rm relay. Contacts Rr 23/24 prepare the circuit for completing the establishment of the call.

When Rm operates, contacts Rm 11/12 close the circuit for starting the motor, contacts Rm 21/22 connect the H.T. supply for the amplifier valves. The filament voltage is connected continuously.

Contacts Rm 31/32 disconnect the incoming ringing current from the ringing relay Rr. With relays Rr and Rm operated, and the motor started, cam K3 (contacts 14/15) completes the circuit for tripping the incoming ringing. The dimensions of the built-up portion of cam K3 are such that a delay is introduced before tripping the ringing current, sufficient to enable the subscriber personally to answer the call if he is present.

The circuit for the connection to line of the pre-recorded announcement (via transformer TR2) is completed through Rm 35/36 and K3.

Five sets of cams, operated by the motor, are provided. These cams serve to mechanically operate various springsets. Cams K2 and K5 rotate at a speed of 2 r.p.m. while cams K3, K4 and K6 rotate at 1 r.p.m. The operation of the cams is as follows:—

K3 holds the motor in operation throughout the 2 cycles, via K3, 12/13.

K4 releases K4 21/22 after 1 minute, causing ringing relay Rr to restore and consequently shutting down the motor and returning the circuit to normal.

K5 is used when recording, and via K5, 21/22 maintains the holding circuit for relay R1 for the duration of 1 cycle.

K6 is used only when a separate tape recorder is used in association with the answering equipment for the purpose of allowing a caller to record his own message after he has listened to the pre-recorded message.

K2 11/12 provides a short circuit for winding 3-4 of transformer TR2, during the time the playback head is travelling from the periphery to the centre of the sound disc to commence the repeat announcement. At the end of one minute the connection to the exchange is released via cam K3, 14/15, and the answering machine is then free to answer another call.

The resistance—capacitance—coupled amplifier comprises three stages. The first two stages are for voltage amplification, for which the two halves of the 6J6 double triode "V1" are used. The third stage is a power stage, for which the two halves of the 6J6 double triode "V2" are used, connected in parallel. Only the third stage is used for recording, while all three stages are used for playback.

A special feature of the Ericsson machine is that the handset of the subscriber's telephone set is used for recording the message, no separate microphone being necessary.

THE ALIBIPHON

The Alibiphon offers substantially the same facilities as the Ericsson machine which has been described above in some detail. Special features of the Alibiphon include:—

(i) The Alibiphon uses a separate external microphone for recording the subscriber's message, instead of utilising the handset of the subscriber's telephone as with the Ericsson machine. This "microphone" is also used for monitoring the recorded message.

(ii) The subscriber's announcement is recorded on a disc, provision being made for erasing any previous recording.

(iii) A visual indicator is provided on the front of the equipment. The movement of a pointer over a scale indicates the passage of the allotted time, thereby assisting the speaker in the recording of the message.

THE ELECTRONIC SECRETARY

The Electronic Secretary also includes practically the same facilities as the Ericsson machine. Certain special features which are included are:—

(a) The Ericsson machine contains provision for the external connection of a commercial type of tape recorder for the purpose of permitting an incoming caller to record a message. With the Electronic Secretary (Figs. 5 and 6), a wire recorder, for recording incoming messages, is built into the set. This allows for the recording of a large number of different messages up to a total of 60 minutes recording time.

(b) On the particular model of the Electronic Secretary illustrated in Figs. 5 and 6, the subscriber's answering message is recorded on a continuous length of tape. Various lengths of tape may be obtained to give up to a maximum of 3 minutes running time. The actual length of tape governs the total running time allowed for the answering message together with the incoming-call message.

(c) A remote-control "play-back" attachment, as described earlier in this article, is an optional facility obtainable with the Electronic Secretary.

CONNECTION TO DEPARTMENTAL LINES

L. M. Ericsson Machine—The L. M. Ericsson Telephone Answerer is connected to the telephone line by means of a special plug and socket. The socket incorporates a terminal strip on to which the telephone line is terminated, and the line is extended via a pair of wires to the telephone terminal block. The answering machine is connected to the associated plug. The Company which supplies the answering device is required to make available to the Department the combined socket and terminal strip which the Department will wire in to the telephone line.

Alibiphon—In the case of this type of answering device the Department provides an isolating key and terminal block. The key is connected in the telephone line in such a manner as to permit the answering device to be isolated from the line during testing of the telephone service. The block which is wired to the key is the connecting point between the Departmental circuit and the answering machine.

Electronic Secretary—In the event of approval being granted for the use of the Electronic Secretary the connection of the machine to the line will be in a manner similar to that specified for the Alibiphon.

MAINTENANCE

The clearing of faults in telephone answering machines is not undertaken by Departmental staff but the machines must be maintained to the satisfaction of the Department by the company supplying the equipment.

CONCLUSION

Although the idea of the Telephone Answering Device is not new it is only recently that machines have been manufactured that incorporate dependable construction, simple operating procedure and acceptable quality in the recording and playback of the answering message. The L. M. Ericsson Telephone Answerer and Alibiphon have been approved for connection to the public network and the examination of the Electronic Secretary with a view to granting approval for the connection of this machine is being finalised. At present only the "answering only" types of machine have been approved.

METHODS OF NUMERICAL FILTER DESIGN — PART I

*E. RUMPELT, Dr.-Ing.**

INTRODUCTION

General: This article is the first of a series covering general design methods for electrical wave filters. The electrical wave filters which will be discussed have been restricted to linear, passive networks.

Simplifications for Facilitating the Design: The following simplifications are made for facilitating the design of filters:—

(i) The terminating impedances at filter input and output are assumed to be constant and resistive.

(ii) Filters are assumed to be pure reactance networks, that is there is no power dissipation in filters.

The error made by these simplifications can be estimated and, if necessary, either taken into account at some stage during the design, or compensated by additional networks and components.

Filter Components: The major components or electrical wave filters are inductors and capacitors. Auxiliary components are transformers, and, in very few instances resistors. Certain combinations of inductances and capacities, which are hard to realize in practice, are sometimes replaced by electro-mechanical equivalents such as piezo-electric crystal resonators or magneto-strictive resonators.

Filter Structures: The most important filter structure is the ladder network and it is used in the majority of filters. Next in importance is the lattice network and its equivalents which, however, are restricted to symmetrical filters or filter sections. Other structures, such as partial fraction circuits, have little or no practical significance.

Design Methods: There are two principal filter design methods: the image parameter method and the insertion parameter method.

In the latter method the filter is treated as one unit. This permits the best possible performance to be obtained from any filter with a given network complexity, but at the same time it makes the design cumbersome and lengthy.

In the former method the filter is mathematically split up into simple sections, which makes the computations comparatively easy. However it is necessary to match the individual sections to one another at their junctions and this somewhat restricts the free choice of design parameters.

The difference in performance between a filter designed with the insertion parameter method, and a similar one designed with the image parameter method is not very conspicuous, barring exceptional cases.

*Dr. Rumpelt is a Divisional Engineer in the Research Section, Central Office. This article was presented originally as a series of lectures at the Royal Melbourne Technical College, and is published with the kind permission of the College.

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2. THE IMAGE PARAMETER THEORY APPLIED TO FILTERS

The Image Parameters and their Definitions: The image parameters of a four-pole network are its two image impedances and its image transfer constant.

The image impedances are defined as those impedances which, when terminating the network at both ends, will cause no reflections at their junctions with the network. The image impedances can be mathematically expressed as the geometric means of open-circuit and short-circuit impedances of the network:—

$$Z_{I1} = \sqrt{Z_{oc1} Z_{sc1}}, \quad Z_{I2} = \sqrt{Z_{oc2} Z_{sc2}}. \qquad \text{.... ....} \quad (2.1)$$

The image transfer constant is defined as one half the natural logarithm of the complex ratio of the input voltage and current product to the output voltage and current product when the output is terminated by its image impedance. In this definition the words "input" and "output" may be interchanged.

$$\theta = \tfrac{1}{2} \ln \frac{V_1 I_1}{V_2 I_2} = \alpha + j\beta$$

α = image attenuation (in nepers)
β = image phase shift (in radians)

As in the case of the image impedances, the image transfer constant can be expressed in terms of the open-circuit and short-circuit impedances of the four-pole network.

$$\coth \theta = \sqrt{\frac{Z_{oc1}}{Z_{sc1}}} = \sqrt{\frac{Z_{oc2}}{Z_{sc2}}} \qquad (2.2)$$

Definition of Pass-bands and Stop-bands: In pure reactance networks, as filters are assumed to be, the open-circuit and short-circuit impedances are purely imaginary, positive or negative. Their products and ratios are therefore positive or negative real. In the first case the square root is real, in the second case it is imaginary. The image impedances and coth θ are therefore either real or imaginary; the former are real where coth θ is imaginary, and vice versa.

In frequency ranges where coth θ is imaginary the image attenuation is zero and the filter has a pass-band. In frequency ranges where coth θ is real the image attenuation is not zero and the filter has a stop-band.

3. INSERTION AND RETURN LOSS AS BASIS OF FILTER DESIGN

Pass-bands and stop-bands of a filter, as defined by the image parameter theory, differ somewhat from the practical pass-bands and stop-bands. These are determined by the insertion loss performance of the filter when operating between resistive terminations. The pass-bands may also be specified in terms of return loss of the filter.

The insertion loss deviates from the image attenuation owing to mismatch between the image impedance and the terminating resistances.

3.1: Definition of Insertion Transfer Constant: The insertion transfer constant of a four-pole network is defined as one half the natural logarithm of the complex ratio of the voltage and current product at the terminals of a load Z_L when fed directly by some source, to the voltage and current product at the same load when the network is inserted between source and load.

$$P_L = \frac{1}{2} \ln \frac{V_0 I_0}{V_1 I_1} = A_L + jB_L$$

A_L = insertion loss (in nepers)
B_L = insertion phase-shift (in radians)

As $V_0 = I_0 Z_L$ and $V_1 = I_1 Z_L$:

$$P_L = \ln \frac{V_0}{V_1} = \ln \frac{I_0}{I_1}$$

$$A_L = \ln \left|\frac{V_0}{V_1}\right| = \ln \left|\frac{I_0}{I_1}\right| \text{ (in nepers) or}$$

$$A_L = 20 \log \left|\frac{V_0}{V_1}\right| = 20 \log \left|\frac{I_0}{I_1}\right| \text{ (in db)}$$

$$B_L = \arg \frac{V_0}{V_1} = \arg \frac{I_0}{I_1} \text{ (radians)}$$

3.2 **Relation between Insertion Transfer Constant and the Image Parameters:** The insertion transfer constant can be expressed in terms of the image parameters and the terminating resistances, R_1 and R_2, as follows:—

$$P_L = \theta - \ln \frac{R_1 + R_2}{2\sqrt{R_1 R_2}} + \ln \frac{R_1 + Z_{I1}}{Z\sqrt{R_1 + Z_{I1}}} + \ln \frac{R_2 + Z_{I2}}{2\sqrt{R_2 Z_{I2}}} + \ln \left(1 - \frac{R_1 - Z_{I1}}{R_1 + Z_{I1}} \cdot \frac{R_2 - Z_{I2}}{R_2 + Z_{I2}} e^{-2\theta}\right) \qquad \text{.... ....} \quad (3.1)$$

The first term in this formula is the image transfer constant, the second, third and fourth terms are due to mismatch between the various impedances and the last term is due to multiple reflections in the filter between its ends. The insertion loss is obtained as the sum of the image attenuation and the logarithms of the **magnitudes** of the above expressions.

4. RELATIONS BETWEEN INSERTION AND RETURN LOSS, AND THE IMAGE PARAMETERS UNDER VARIOUS CONDITIONS

As the terminating impedances of a filter are assumed to be constant and resistive, the second term in Eq. (3.1) is constant and will be called the basic loss A_t of the terminations:

$$A_t = 20 \log \frac{R_1 + R_2}{2\sqrt{R_1 R_2}} = \text{const. (db)}$$

The basic loss disappears if $R_1 = R_2$.

To simplify the remainder of Eq. (3.1) the matching factors p_1 and p_2 are introduced—

$$p_1 = \left|\frac{Z_{I1}}{R_1}\right| \qquad p_2 = \left|\frac{Z_{I2}}{R_2}\right|$$

4.1 Insertion Loss in the Bass-band of a Filter

In the pass-band of a filter the image impedances are real and the image attenuation is zero. The insertion loss is therefore:—

$$A_L = -A_t + 20 \log \frac{1 + p_1}{2\sqrt{p_1}} + 20 \log \frac{1 + p_2}{2\sqrt{p_2}} + 20 \log \left|1 - \frac{1 - p_1}{1 + p_1} \cdot \frac{1 - p_2}{1 + p_2} e^{-2j\beta}\right| \text{ (in db)} \qquad \text{.... ....} \quad (4.1)$$

The second and third terms are called the reflection losses, and the last term is called the interaction loss. The second or third term disappears if p_1 or p_2 equals 1, respectively. The last term disappears if p_1 or p_2 or both are equal to 1, and also for special values of the image phase-shift.

4.2 Limits of Pass-band Insertion Loss:

For calculating the insertion loss in the pass-band of a filter operating between specified resistances R_1 and R_2 it is necessary to know the image impedances and the image phase-shift. It is however possible to determine limits of the insertion loss with the knowledge of the image impedances only.

4.2.1 **Symmetrical Filters:** Symmetrical filters are defined as having identical image impedances at both ends, that is $Z_{I1} = Z_{I2}$. The best terminating conditions for a symmetrical filter require $R_1 = R_2$. This can always be enforced with the help of a transformer The basic loss is then zero.

With $p_1 = p_2 = p$ the limits of the pass-band insertion loss are given by:

$$A_{L\,max/min} = 20\log\frac{(1+p)^2}{4p}\left(1+\frac{(1-p)^2}{(1+p)^2}\right)$$

$$A_{L\,max} = 20\log\frac{1+p^2}{2p} \text{ (in db)} \quad \ldots (4.2)$$

$$A_{L\,min} = 0$$

The function of $20\log\frac{1+p^2}{2p}$ will be called the reflection loss function.

4.2.2 **Antimetric Filters:** Antimetric filters are defined by the following relation between the two image impedances: $Z_{I1} Z_{I2} = R_o^2$, where R_o is a constant resistance. The best terminating conditions for an antimetric filter require $R_1 R_2 = R_o^2$.

With $p_1 = 1/p_2 = p$ the limits of the pass-band insertion loss are given by:

$$A_{L\,max} = -A_t + 20\log\frac{1+p^2}{2p} \quad \ldots (4.3)$$

$$A_{L\,min} = -A_t$$

4.2.3 **General Filters:** If a filter is neither symmetrical nor antimetric and the matching factors p_1 and p_2 are independent of one another, the extreme values of the passband insertion loss are given by:

$$A_{L\,m_1} = -A_t + 20\log\frac{1+p_1p_2}{2\sqrt{p_1p_2}} \quad (4.4)$$

$$A_{L\,m_2} = -A_t + 20\log\frac{1+p_1/p_2}{2\sqrt{p_1/p_2}} \quad (4.5)$$

The upper limit of the insertion loss is given by Eq. (4.4) if $p_1 p_2$ deviates from 1 more than p_1/p_2. It is given by Eq. (4.5) if p_1/p_2 deviates from 1 more than $p_1 p_2$.

If one of the two matching factors, for example p_2, approaches 1 much closer than the other one, then the last two terms in Eq. (4.1) may be neglected as compared with the second term and the insertion loss becomes approximately:

$$A_L \doteq -A_t + 20\log\frac{1+p_1}{2\sqrt{p_1}} \quad \ldots (4.6)$$

4.3 **The Transducer Loss of a Network**

The maximum power which can be taken out of a voltage source with an e.m.f. E and a resistance internal impedance R_1 is $N_0 = \frac{E^2}{4R_1}$.

The transducer loss of a four-pole network connected to this source is obtained when the power N_2 taken from the network output is compared with the maximum power N_0.

$$A'_L = 10\log\frac{N_0}{N_2} \text{ (in db)} \quad \ldots (4.7)$$

The relation between transducer loss and insertion loss is:

$$A'_L = A_L + A_t \quad \ldots (4.8)$$

4.4 **Definition of Return Loss**

If the network is a pure reactance four-pole, such as a filter, all the power which is not take up by its load is returned to the source. This power is:—

$$N_e = N_o - N_2 \quad \ldots (4.9)$$

The return loss is defined by:

$$A_e = 10\log\frac{N_0}{N_e} \quad \ldots (4.10)$$

Eq. (4.9) combined with Eqs (4.7) and (4.10) yields the important relationship between transducer loss and return loss of a **reactance** four-pole:

$$10^{-0.1A'_L} + 10^{-0.1A_e} = 1 \quad (4.11)$$

4.5 **Lower Limit of Return Loss in the Pass-bands of Filters**

On the basis of Eqs. (4.11) and (4.8) the lower limit of the return loss in the pass-bands of filters may be calculated from the upper limit of the insertion loss. The results are:

Symmetrical and Antimetric Filters

$$A_{e\,min} = 20\log\left|\frac{p^2+1}{p^2-1}\right| \text{ (in db)} \quad \ldots (4.12)$$

General Filters

$$A_e = 20\log\left|\frac{u+1}{u-1}\right| \quad \ldots (4.13)$$

where $u = p_1p_2$ or p_1/p_2, whichever deviates more from 1.

If a filter is well matched to its terminating resistance at one end only ($p_2 = 1$),

$$A_e \doteq 20\log\left|\frac{p_1+1}{p_1-1}\right| \quad \ldots (4.14)$$

where p_1 is the matching factor at the other end.

4.6 **Insertion Loss in the Stop-bands of Filters**

In the stop-band of a filter the image impedances are imaginary and there is a substantial image attenuation. The image phase-shift is an integral multiple of $\pi/2$.

Owing to the image attenuation the multiple reflections between the filter ends are rapidly damped and the interaction loss may be neglected. The insertion loss is then:

$$A_L = \alpha - A_t + 20\log\left|\frac{1\pm jp_1}{2\sqrt{\pm jp_1}}\right| + 20\log\left|\frac{1\pm jp_2}{2\sqrt{\pm jp_2}}\right|$$

which may be written as follows:—

$$A_L = \alpha - A_t - 6 + 10\log\frac{1+p_1^2}{2p_1} + 10\log\frac{1+p_2^2}{2p_2} \quad \ldots (4.15)$$

For symmetrical and antimetric filters terminated as mentioned earlier the two matching factors are: $p_1 = p_2 = p$ and $p_1 = 1/p_2 = p$ respectively. The last two terms in Eq. (4.15) become equal and the insertion loss is:

$$A_L = \alpha - A_t - 6 + 20\log\frac{1+p^2}{2p} \quad \ldots (4.16)$$

$A_t = 0$ for symmetrical filters.

4.7 **Reflection Loss Function A_r and the Return Loss Function A_e**

Reflection loss function:

$$A_r = 20\log\frac{1+p^2}{2p} \quad \ldots (4.17)$$

Return loss function:

$$A_e = 20\log\left|\frac{p^2+1}{p^2-1}\right| \quad \ldots (4.18)$$

Values are given in Table I.

TABLE I

p or 1/p	1.02	1.03	1.04	1.05	1.07	1.10	1.15	1.20	
A_r				0.01	0.02	0.04	0.09	0.14	db
A_e	34.1	30.6	28.1	26.2	23.4	20.4	17.1	14.9	db
p or 1/p	1.25	1.30	1.35	1.40	1.45	1.50	1.60	1.70	
A_r	0.21	0.30	0.39	0.48	0.59	0.70	0.93	1.17	db
A_e	13.2	11.8	10.7	9.8	9.0	8.3	7.2	6.3	db
p or 1/p	1.80	1.90	2.0	2.5	3.0	3.5	4.0	4.5	
A_r	1.42	1.68	1.94	3.2	4.4	5.5	6.6	7.5	db
p or 1/p	5.0	5.5	6.0	6.5	7.0	8.0	9.0	10.0	
A_r	8.3	9.1	9.8	10.4	11.1	12.2	13.2	14.1	db

For p or 1/p $>$ 10; $A_r \doteq 20\log p/2$

A TRANSISTORIZED HEARING-AID TELEPHONE

*J. N. BRIDGFORD, B.E.E.**

INTRODUCTION

This article is concerned with the development of a transistorized amplifier suitable for use as a hearing aid attachment for a standard 300 type telephone. (Design and development of this amplifier was completed before the introduction of the 400 type telephone.) The transistorized amplifier is intended to replace the vacuum tube amplifier that has been used up to the present. The two amplifier types are briefly compared below.

(a) The vacuum tube amplifier with its attendant H.T. power supply (derived from the 230 V A.C. supply) is physically quite large and is usually housed in a separate box near the normal telephone, but the smaller component size and simpler power supply associated with a transistorized amplifier make it possible to build a complete amplifier into the existing telephone case. The absence of any large additional equipment is expected to be more pleasing to the partially deaf subscriber.

(b) The simpler wiring associated with a transistorized amplifier introduces the possibility of a printed circuit construction.

(c) With a transistorized amplifier there is no need for an A.C. operated power supply—the required low voltage supply can be derived from the normal telephone transmitter current.

(d) When the vacuum tube amplifier is switched on there is a slight delay in operation due to the "warm up" period of the filament. A transistorized amplifier operates instantaneously on application of the supply voltage.

In general, the small size, low power consumption, ruggedness and reliability of operation of the transistor make it especially suitable for use in this hearing-aid amplifier application.

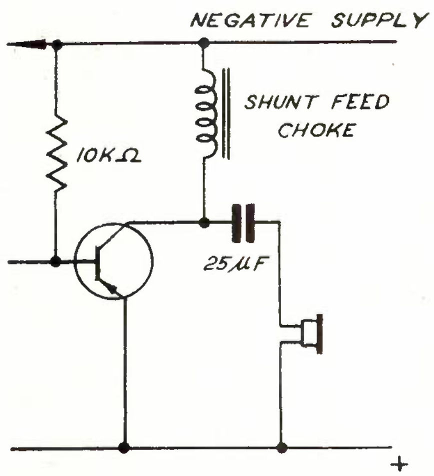

Fig. 1.—Single Transistor Amplifier Circuit Diagram.

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Two transistorized amplifiers are examined viz.

(a) a single transistor amplifier

(b) a twin transistor push-pull amplifier.

The performance characteristics of the complete amplified telephone employing each of the above amplifiers in turn, are examined.

REQUIREMENTS OF A HEARING-AID TELEPHONE AND AMPLIFIER

The hearing aid telephone should include a transistorized amplifier in the receiver circuit, i.e., the amplifier is to operate directly into the 2P receiver of the normal telephone.

Size and Layout

The complete amplifier and associated power supply should be built into the existing 300 type telephone. The only external indication of the enclosed amplifier will then be the amplifier gain control knob which will protrude through the rear of the telephone moulding. All circuit components should be kept to a minimum size and the complete amplifier and power supply should preferably be of the printed circuit construction.

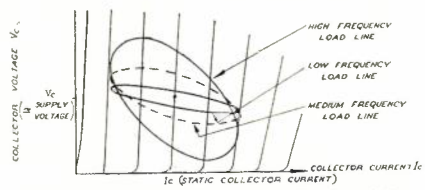


Fig. 2.—Single Transistor Amplifier Load Line characteristics.

Amplifier Insertion Gain Requirement

Insertion gain, defined for the purpose of this application as the ratio

Voltage at receiver terminals of the amplified telephone
———————————————
Voltage at receiver terminals of the normal telephone

for a given input signal, expressed in db, is used to compare amplifier performance.

From an initial study of the amplifier gain requirement it would appear that a high insertion gain is desirable, but investigation into the practical application of the amplified telephone shows that the maximum allowable gain is severely limited by stability criteria, viz. the amplifier is to be used in conjunction with a 300 type telephone and examination of the feedback path from receiver to transmitter via the handset shows that with increasing amplifier gain (and consequent increased receiver output) it is possible to obtain a feedback loop gain greater than unity, which in turn causes decreased stability and even sustained oscillation. The conditions for an unstable telephone depend on the telephone circuitry, telephone input line conditions and the nature of the air path between the receiver and transmitter of the handset.

As will be seen later, the above considerations limit the insertion gain at 1 kc/s to a maximum of 20 db.

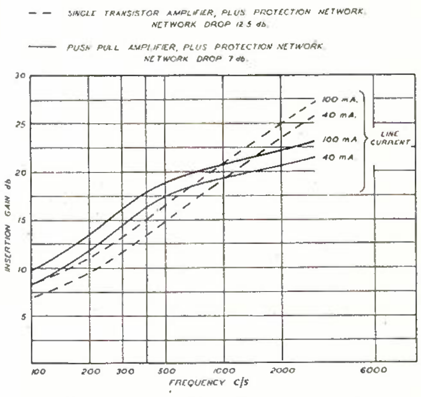


Fig. 3.—Amplifier Insertion Gain.

Amplifier Power Supply

The transistor amplifier power supply should be derived from the normal telephone line currents and should be capable of providing a substantially constant amplifier supply voltage when excited by line currents ranging from 40 to 100 mA.

The power supply must be capable of providing sufficient voltage to ensure satisfactory amplifier operation over as wide a range of input speech signals as possible.

As will be seen later, the power supply impedance appears in series with the telephone transmitter and hence will cause a drop in transmitting efficiency and may give rise to unwanted feedback effects.

In view of the above, a power supply of the lowest internal impedance consistent with sufficient output voltage and of good regulation is required.

Transistor Protection

High voltage transients may be developed in telephone lines under normal,

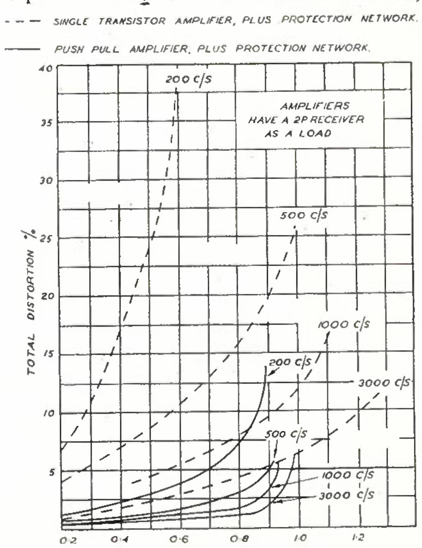


Fig. 4.—Amplifier Distortion characteristics.

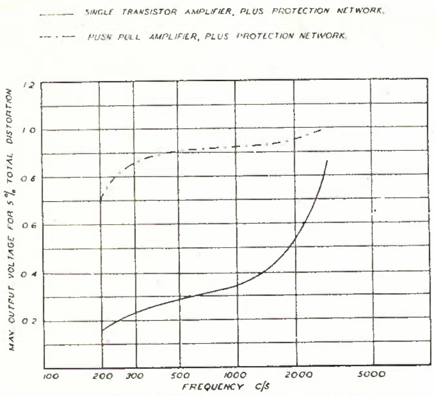


Fig. 5.—Output-frequency characteristics for constant output distortion of 50% total.

testing, or fault conditions. Voltages which are too small to operate normal protective apparatus can cause transistor damage. Transistors can also be destroyed by excess voltages applied only during the operation period of the normal protective equipment. Some sources of excess voltage are:—

(a) Reversal of line voltage for metering purposes.
(b) Falsely applied ring current.
(c) Line faults.
(d) Electric storms.
(e) Switching or failure of nearby power lines which may induce high voltages in telephone lines.
(f) Voltages applied during insulation testing procedure.

In order to prevent impairment or even complete destruction of the transistor properties, it is essential to prevent these high voltages from being applied directly to the transistor electrodes. Thus some form of protective network must be provided at the input of the amplifier to isolate the transistors from these large voltage fluctuations. This protective network should have the minimum deleterious effects on the operation of the amplifier and should be small in size.

Amplified Telephone Side-Tone

Connection of the amplifier in front of the receiver will increase the side-tone level by approximately the amplifier gain. This increase in side-tone is not undesirable as far as the partially deaf subscriber is concerned because the amplifier gain is adjusted to suit his particular requirements, but it may cause instability around the handset loop as mentioned previously. Thus any reduction in side-tone is desirable, since it allows a higher amplifier gain to be utilized.

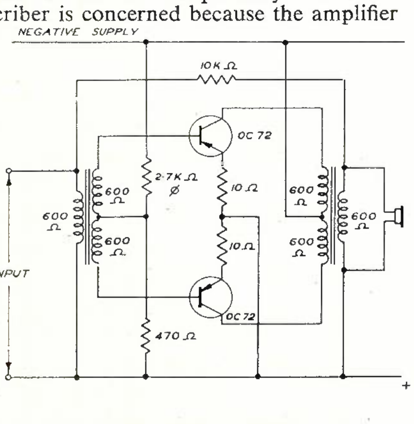


Fig. 6.—Push Pull Transistor Amplifier Circuit diagram.

Amplifier Performance

The amplifier and associated protective network should produce an insertion gain which is substantially constant over the voice frequency range (100 c/s-3 kc/s) with a total harmonic distortion less than 5% for the level of input speech signals encountered in most cases.

Maximum Output

When operating under maximum input speech signals, the amplifier output should not be high enough to cause pain. Pain level for speech is approximately 120 db above the threshold. Examination of the characteristics of a 2P receiver shows an average sensitivity of +42 db relative to 1 bar/volt. Since 1 bar is approximately equivalent to +74 db above threshold a 2P receiver operating with an input of 1.6 volts will produce a sound output of approximately +120 db above threshold. Thus it is seen that to prevent excessive output, causing discomfort to the subscriber it is desirable to limit the output receiver voltage under all conditions to less than 1.6 volts.

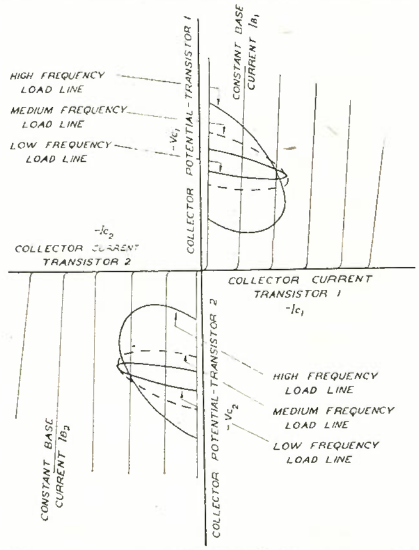


Fig. 7.—Push Pull Transistor Amplifier Load Line characteristics.

REALISATION OF REQUIREMENTS AMPLIFIER PERFORMANCE

The performance characteristics of both push pull and single ended transistorized amplifiers have been examined and compared. Measurements were carried out on two amplifiers, viz.

(a) A single transistor amplifier with an L-C coupled load.
(b) A twin transistor, transformer coupled push pull amplifier.

The possibility of using a single ended transformer coupled amplifier was investigated, but was considered to be inferior to the L-C coupled type.

The grounded emitter method of transistor connection has been used throughout because of the suitability of its characteristics.

Single Transistor L-C Coupled Amplifier

The circuit diagram of the single transistor amplifier tested is shown in Fig. 1. In order to understand the operation of this amplifier, consider the transistor static $V_c - I_c$ (collector voltage - collector current) characteristics together with a superimposed load line (fig. 2).

The load line shape is determined by the magnitude and phase angle of the load impedance presented to the collector. In this application the LC coupled collector load consists of the impedance of a 2P receiver and investigation into the nature of this impedance shows it to be inductive with a fairly constant phase angle of approximately 60°. This type of load gives rise to an elliptical load line—Fig. 2 shows typical load lines, for various frequencies, superimposed on the transistor $V_c - I_c$ characteristics. Examination of these load lines show:—

(a) Gain is a function of frequency, i.e., the gain of a grounded emitter transistor amplifier is proportional to the magnitude of the load impedance and hence the increased impedance of this inductive load at higher frequencies results in an increased high frequency gain.
(b) Because of the constant phase angle characteristics of the load, the overall amplifier phase change from input to output is approximately constant over the whole frequency range.
(c) At higher frequencies, the output voltage swing is limited by transistor saturation ($V_c \rightarrow 0$) and the magnitude of collector supply voltage.
(d) At lower frequencies, the output voltage is limited by transistor cut-off ($I_c \rightarrow 0$) and the magnitude of the static collector current.

As it is desirable to have the maximum undistorted output over the whole frequency range, the limiting factors (c) and (d) above are of considerable importance. At high frequencies ($\simeq$ 3 kc/s) the output voltage peak value closely approaches the static collector potential. However, to obtain a comparable output voltage at the lower frequencies, a large static collector current is required. The maximum collector current is limited by the maximum transistor collector dissipation allowed, the power supply regulation and the D.C. voltage drop across the shunt

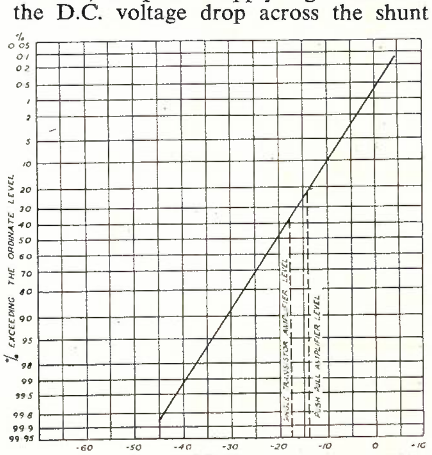


Fig. 8.—Estimated Distribution of Telephone Receive Levels.

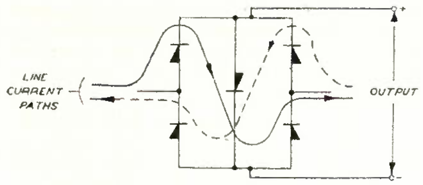


Fig. 9.—Power Supply Rectifier Arrangement.

feed choke. These limitations restrict the static collector current to a value which results in a very low undistorted output at the lower frequencies as shown in Fig. 5.

Increasing the collector current decreases the input impedance, which in turn increases the loss of the input protective network (see Appendix I).

Experimental measurements have shown that for a single OC72 transistor amplifier, operating in grounded emitter, a series base bias resistor of 10 K ohm provides the optimum collector current.

The amplifier was provided with an optimum designed protection network as described in a later section and the overall gain and distortion characteristics were obtained. These are shown in Figs. 3, 4 and 5.

Push Pull Amplifier

Fig. 6 shows the push pull transistor amplifier circuit diagram and Fig. 7 shows the corresponding $V_c - I_c$ characteristics together with a number of typical load lines. Examination of the load lines shows that, in comparison with the single transistor amplifier, a much higher undistorted output at the lower frequencies can be obtained without excessive static collector current flowing. The limitations imposed by stability requirements on the maximum allowable amplifier gain allows the use of considerable feedback. This further reduces the output distortion — the overall distortion characteristics are shown in Figs. 4 and 5.

As can be seen from Fig. 6, two feedback loops have been employed. The feedback introduced by the series emitter resistors greatly increases the input impedance which in turn permits a more efficient protection network to be designed.

A mathematical relationship between input impedance and series emitter resistance has been derived in Appendix II and results in the equation:

Input Impedance

$$Z_{in} \simeq r_b + \frac{r_e}{(1-a)}$$

where r_b = total base resistance

r_e = total emitter resistance.

and $\frac{1}{(1-a)} \simeq$ current gain of the grounded emitter stage.

Thus it may be seen that any increase in the value of "r_e" appears in the input impedance multiplied by the current gain (this factor is in the order of 30 for transistor type OC72).

The insertion gain and distortion characteristics of the twin transistor push pull amplifier are shown in Figs. 3, 4 and 5.

Comparison of Amplifier Types

Comparison of the insertion gain and distortion characteristics in Figs. 3 and 5 of the two amplifier types (each provided with a protection network) shows the push pull amplifier to produce far less output distortion than a single transistor amplifier of comparable gain.

The low distortion characteristics of the push pull amplifier enables a better grade of service to be provided for a much larger percentage of calls. Fig. 8 is an estimated distribution of telephone receive levels based on measurements made at Melbourne City West Exchange (see Ref. (3)) and an estimated distribution of line attenuations having a mean of 7.5 db and a standard deviation of 2.5 db.

The overload voltage of the push pull amplifier at 1000 c/s (i.e. the level at which 5% total harmonic distortion is encountered) is 0.92 volts (see Fig. 5); the equivalent voltage at the input to the telephone is 0.158V. (See Ref. (4)). This corresponds to an equivalent volume level of –14VU. Reference to Fig. 8 shows that this amplifier should be able to handle 75% of all received calls with the volume control set to its maximum position without introducing objectionable distortion. The corresponding input level to a telephone having a single transistor amplifier is –17.5 VU; reference to Fig. 8 shows that this type of telephone will only handle 62% of incoming calls, if the protection network is included; if it is not included, the telephone will only handle 8% of incoming calls with the volume control set to its maximum position.

The physical size of the push pull amplifier is no bigger than the single transistor amplifier, the small size being obtained by the use of miniature coupling transformers.

Transformer coupling eliminates the use of electrolytic coupling condensers thus reducing fault liability.

In spite of the slightly higher initial cost, the push pull amplifier with its superior performance characteristics and greater reliability is recommended for use in this application.

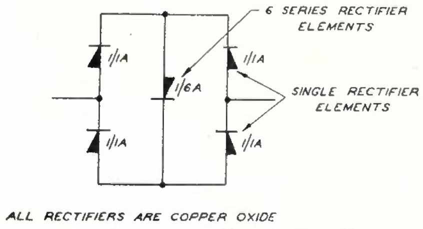


Fig. 10.—Power Supply Circuit.

AMPLIFIER POWER SUPPLY

Power Supply Voltage

As has already been mentioned, the power supply impedance appears in series with the transmitter and excess power supply impedance can cause appreciable

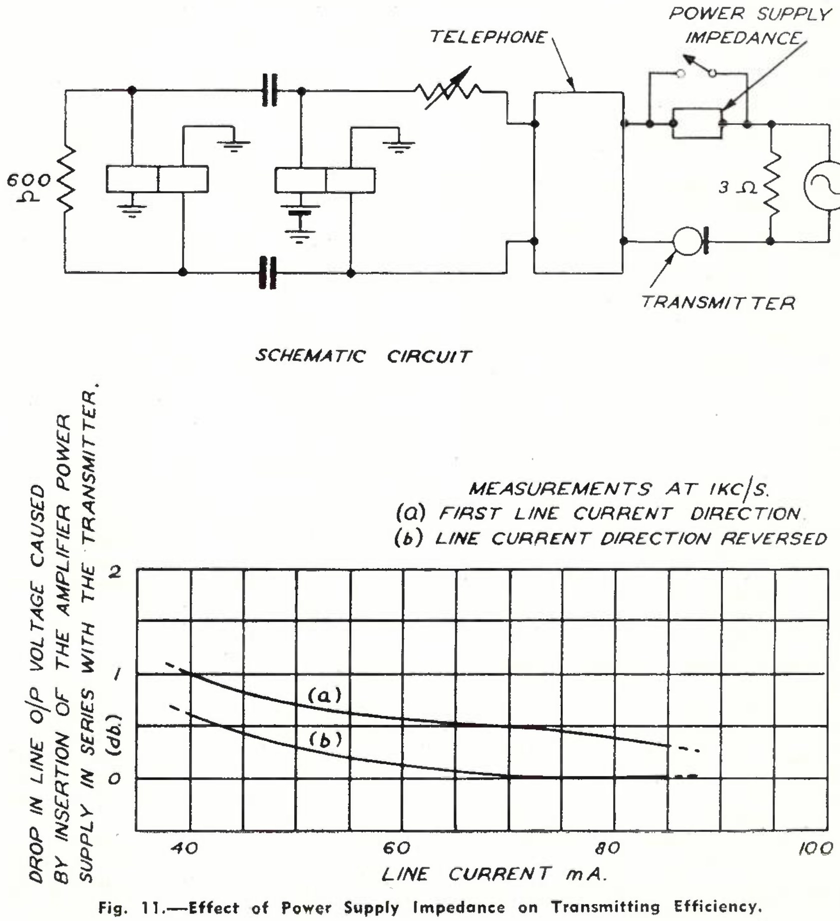


Fig. 11.—Effect of Power Supply Impedance on Transmitting Efficiency.

loss in transmitting efficiency. This suggests the use of a low AC impedance power supply. On the other hand, the power supply should provide sufficient voltage to enable the amplifier to handle the maximum range of input speech signal amplitudes without excessive distortion or overload.

With these two conflicting factors in mind, a supply voltage of approximately two volts was adopted as a design figure.

Arrangement of Power Supply

During the normal course of operation of the telephone, the direction of the line current is reversed to facilitate metering of calls and thus the power supply derived from these line currents must be capable of providing a unidirectional voltage from this reversible source. The method adopted uses a bridge rectifier network.

Two methods of connecting the rectifier network were considered, viz.

(1) the network connected in parallel across the telephone transmitter; and
(2) the network connected in series with the telephone transmitter.

The first method was considered undesirable because an open circuited transmitter (due to a faulty transmitter or removal of the transmitter) may cause the full exchange battery voltage (approx.

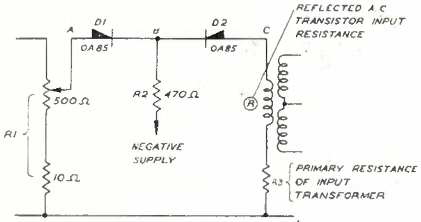


Fig. 12—Protection Network for Push Pull Amplifier.

50 V.) to be applied to the transistor power supply unit. Also with the parallel connection of the rectifier network, changes in the impedance of the transmitter (movement of the transmitter can give considerable impedance fluctuation) cause greater variations in the power supply output voltage than in the series form of connection. Method (2) was employed. The required voltage is developed across the forward resistance of a rectifier unit connected across the output terminals of the bridge. The non-linear forward resistance of the rectifier unit produces a substantially constant output voltage for all line current values and therefore is more suitable than a resistive source which develops a voltage proportional to the current through it. The circuit arrangement is shown in Fig. 9 and the normal and reverse current paths have been illustrated.

Power Supply Rectifier Types

The rectifier type used should be such as to provide a relatively constant output voltage, of the required value, over the whole range of line currents (40-100mA).

Three types of rectifiers were considered:—

(i) Germanium point contact type OA85.
(ii) Selenium junction type rectifier.
(iii) Copper oxide barrier type.

In the case of the germanium OA85 rectifiers, two units in parallel are neces-

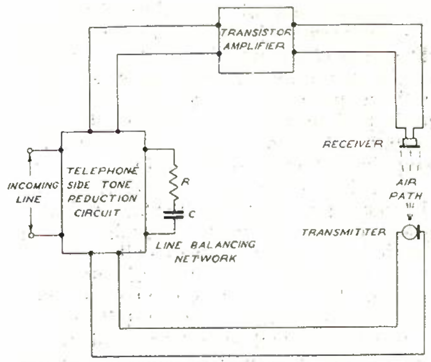


Fig. 13.—Amplifier Telephone Feedback Path.

sary to carry the line currents and even then both units are operating very close to their maximum current limits. This arrangement is unsatisfactory because of the uncertainty of the "load sharing" characteristics of the parallel rectifiers and the poor output voltage regulation.

Six series copper oxide rectifiers or four series selenium rectifiers could be used with almost identical results. Copper oxide rectifiers were finally adopted since they provide better regulation and have a lower A.C. resistance.

Final Power Supply Arrangement

The finalised power supply consists of a copper oxide bridge arrangement as shown in Fig. 10. The diagram shows that for a given direction of flow, there are effectively eight rectifier elements carrying line current. The incremental (or A.C.) resistance of these eight elements is approximately 31 ohms at low current values and drops considerably at higher currents. This resistance introduced in series with the telephone transmitter causes a slight drop in transmission efficiency which is shown by Fig. 11.

This power supply when used in conjunction with the push-pull amplifier, limits the maximum attainable receiver output level below that required for subscriber discomfort, i.e., threshold of pain.

TRANSISTOR PROTECTION

As mentioned previously, application of excessive voltages to the base input of a grounded emitter transistor amplifier can cause serious transistor damage. Excessive negative base potential gives rise to base and collector currents in excess of the allowable transistor junction forward current limits. On the other hand, positive potential applied to the base "biases" the emitter base junction in the non-conducting direction and excessive voltage can result in "Inverse Voltage Breakdown" of the transistor junction (see Ref. 5).

Manufacturer's data for the OC72 transistor give a maximum limiting value of forward collector current of 110 mA and examination of the OC72 characteristic curves show this collector current to correspond to a base-emitter voltage of –0.4 V. Thus in order to prevent excessive junction current it is necessary to limit incoming negative voltage transients to a maximum of 0.4 V.

Reference to the results obtained in Ref. (5) shows that positive base potentials need not be limited to such small values. However protection against overload in this direction must be provided since voltage transients of a destructive magnitude can be obtained.

In the case of the push pull amplifier, however, both positive and negative input voltage transients produce overload in the conducting direction of one of the transistors and hence both the positive and negative potentials must be limited to 0.4 V maximum at the amplifier input.

Form of Protection Network

The above protection requirements can be met by the use of a simple resistor and diode network as illustrated in Fig. 12.

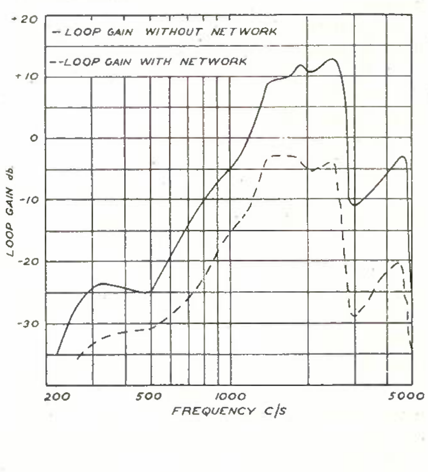
Point contact type OA85 diodes are used since the ratio of "back resistance" to "forward resistance" is very high, they are physically small, they operate efficiently at the low voltages available and have a high peak inverse voltage rating (> 100 V). Resistor R_2 (Fig. 12) is returned to the amplifier negative supply voltage in order to bias the diodes in the conducting direction and the amplifier variable gain control is incorporated in resistor R_1. The three resistors, R_1, R_2 and R_3 are designed to provide the required network protection properties and at the same time produce a network which has minimum attenuation to normal incoming speech signals.

Operation of the Protection Network

Under normal conditions, the two diodes D_1 and D_2 are biased in the conducting direction, the bias currents flowing through the diodes being determined by the values of resistors R_1, R_2 and R_3 and the magnitude of the negative supply voltage. Thus B and C assume some static potential determined by the bias currents.

A large positive potential suddenly applied at A is transmitted through diode D_1 (which remains conducting) and the resulting rise in potential at point B cuts off diode D_2 thus introducing a high resistance between B and C; point C is thus isolated from the high voltage at B.

The potential change of point C can be kept within the required limits by appropriate choice of the original diode bias conditions.



LINE FED FROM RELAY AND 48 VOLTS APPLIED. TRANSMITTER CURRENT 83 mA

Fig. 14.—Loop Gain characteristics of Amplified Telephone.

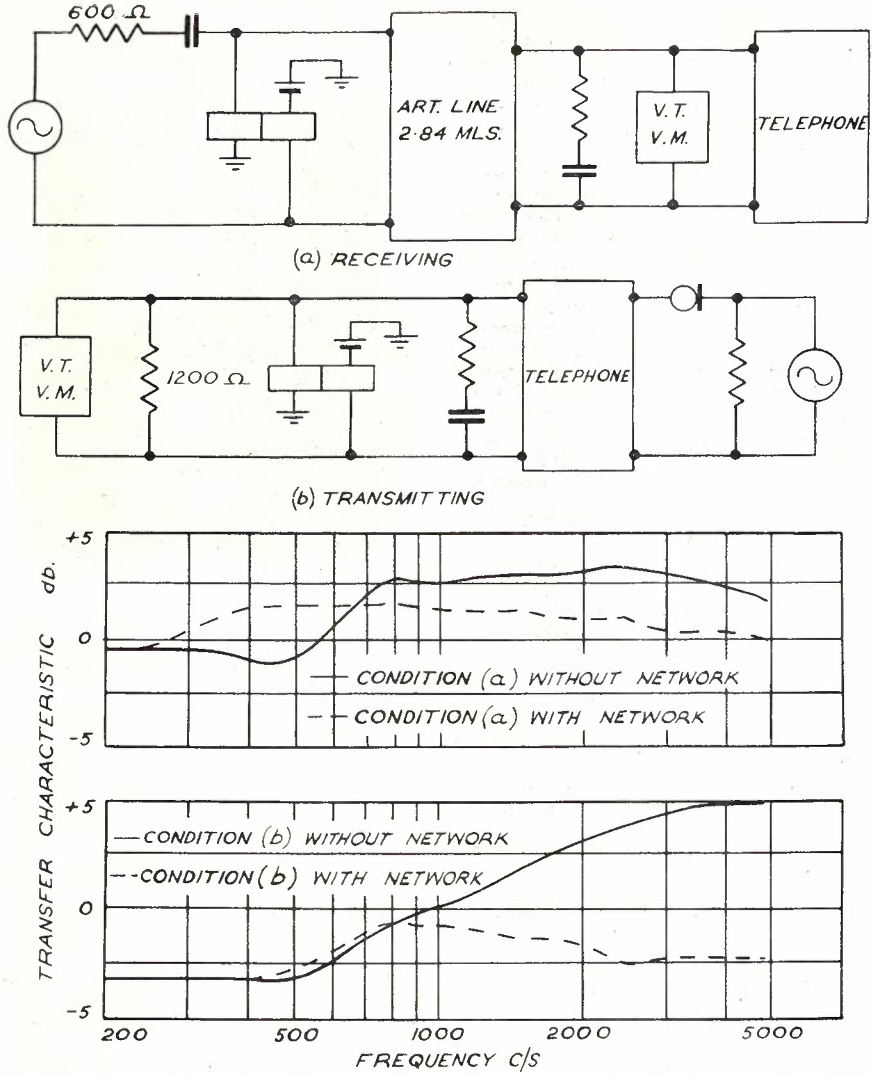


Fig. 15.—Effect of Stabilising Network on Transmitting and Receiving Efficiencies of Amplified Telephone.

A large negative potential applied at A cuts off diode D_1 and point B assumes a potential primarily determined by the series circuit of R_3, D_2 and R_2. Thus it is seen that transistor protection against excessive input voltages can be achieved by correct choice of the network components.

The protection network, however, must also have a low attenuation to the normal speech input signals, a further factor influencing the choice of resistor values. It is here that the magnitude of the amplifier input impedance becomes important, i.e., low input impedance is accompanied by an increased network A.C. attenuation (because of the diode resistance in series with the input). The optimum network component values for the push pull amplifier is shown in Fig. 12.

AMPLIFIED TELEPHONE STABILITY

Section 2.2 mentioned the instability problem of the amplified telephone. Increased amplifier gain is accompanied by an increased receiver output signal which can be picked up by the transmitter and re-introduced into the telephone circuit, thus completing a feedback loop. It was found that with normal use of the telephone handset on short lines, positive feedback, sufficient for sustained oscillation, could be obtained with an amplifier gain as low as 12 db.

For oscillation to commence, the gain around the above described loop must be greater than unity and have the correct phase characteristics. Thus at first it would seem that some form of phase changing network introduced into the feedback loop could be used to stabilise the circuit. Examination of the feedback loop, however, reveals that this simple modification is impracticable, as the feedback loop contains an air path from the receiver to the transmitter of the handset and variations of the nature and length of this path (by introduction of reflecting surfaces, for example) cause changes in both the phase and magnitude of the total loop gain. To illustrate this effect, consider a 2 kc/s tone input to the transmitter. In air this tone has a wavelength of approximately six inches, therefore if the feedback loop air path length is six inches there will be no phase change from receiver to transmitter, but slight alteration of the air path length, to say, nine inches, gives rise to a 180° phase change. Thus it becomes evident that in order to prevent oscillation, the loop gain magnitude must be kept below unity.

In the telephone there is a side tone reduction circuit which reduces the fraction of the transmitter output that is induced into the receiver circuit. The fundamental operation of this side tone circuit depends on an R-C network which is used to "balance" the incoming lines, i.e., the closer the balance network impedance approaches the incoming lines impedance, the smaller the side tone (and hence receiver output) becomes for a given transmitter signal. For a given line it is usually possible to obtain a good balance (and hence low receiver output) by adjusting the simple R-C network values and the improved balance between the line impedance and the lumped network reduces the overall loop gain. Fig. 13 shows a diagrammatic representation of the complete feedback loop. The problem then becomes one of obtaining a practical method of improving the "balance" between the incoming line impedance and the lumped network impedance. The line impedance presented to the telephone varies considerably in practice and it is economically impossible at this stage to provide a suitable balance network for all line conditions that may arise. The practical solution therefore becomes a selection of a maximum allowable amplifier gain that can be adopted (see Section 2.2) and used in conjunction with a single simple form of balancing arrangement to give satisfactory results under all normally encountered conditions.

There are two methods of improving the sidetone reduction circuit "balance".

(a) Modification of the existing telephone R-C network to give a better line balance.

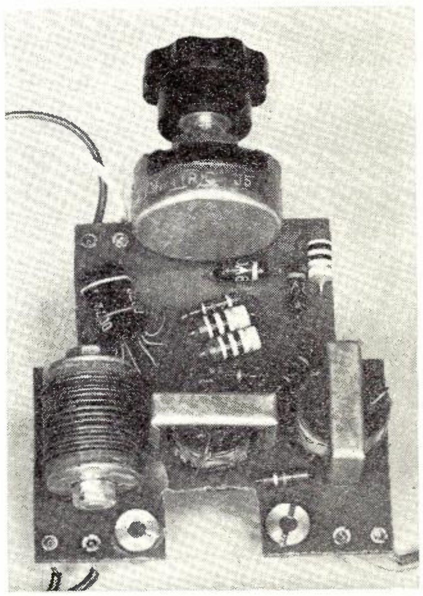


Fig. 16.—Experimental Printed Circuit Amplifier—top view.

(b) The introduction of an extra balancing network across the telephone line input terminals.

From the preceding discussion it appears impractical to provide adequate balancing of all line conditions by means of method (a). Also, this method would be undesirable because it involves considerable alteration to the existing telephone circuitry. In the case of method (b), the line impedance variations are shunted and "smoothed out" by the added network. However, care must be taken to avoid too severe shunting of the line, with a consequent drop in receiving and transmission efficiencies.

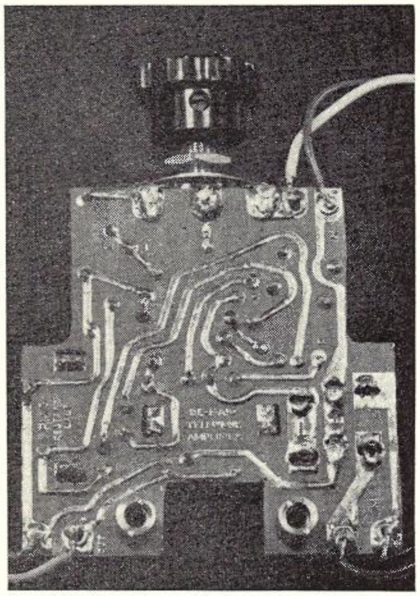


Fig. 17.—Experimental Printed Circuit Amplifier—underneath view.

Tests on the push pull amplified telephone with a network connected showed that with normal telephone usage it is possible to operate the amplifier with an insertion gain of 20 db and complete absence of oscillation under all line conditions, the more complete "balance" being provided by a simple series R-C network (600 ohm 0.25 μF) shunted across the line input terminals. Fig. 14 shows the loop gain measured both with and without the added network. These curves were obtained for the worst possible case of unbalance (short line conditions) and comparison of the two curves shows the loop gain to be decreased by at least 10 db by insertion of the line shunting network. A "safe", maximum loop gain of –3 db was obtained.

Fig. 15 shows the effect of the line shunting network on the transmitting and receiving characteristics. Each curve was obtained under the worst possible line conditions as illustrated by the accompanying block diagrams. Although Fig. 15 shows a considerable drop in transmitting efficiency and high frequencies, it must be kept in mind that these results were obtained with a virtually zero line length, i.e., a condition when a slight increased telephone attenuation can be tolerated. With longer lines the drop in transmission would become less because the line impedance presented at the telephone input becomes lower and more capacitive and hence would not be so "heavily shunted" by the added parallel R-C network. This is verified by the curves for condition (a) in Fig. 15. In this case, the R-C network was used in conjunction with a long line and resulted in relatively low attenuation due to inclusion of the R-C shunting network.

In view of the above results, it appears that if a hearing aid amplified telephone employing the transistor push pull amplifier described in this article is used in conjunction with a short line and tends to be unstable, considerable improvement can be achieved by connection of a 600 ohm, 0.25 μF series network across the line input terminals. However, under long line conditions the amplified telephone is not expected to be unstable.

MAGNETO TELEPHONE APPLICATION

Practically all that has been said in connection with the A.T. can be directly applied to the magneto telephone case, the only salient difference between the two applications being the slightly higher supply voltage available in the magneto telephone, i.e., transmitter current is obtained from a 3 V dry cell.

The amplifier and protection network operating off the 3 V battery will perform as well as, if not slightly better than, the A.T. arrangement. The higher supply voltage necessitates a slight alteration in the base bias supply network (See Fig. 6).

EXPERIMENTAL PRINTED CIRCUIT AMPLIFIER

Figs. 16 to 18 show a complete push pull amplifier, power supply and diode protection network with a printed circuit construction suitable for use in 300 type C.B. telephones. Fig. 18 shows the amplifier installed in the normal 300 type telephone moulding — no mechanical

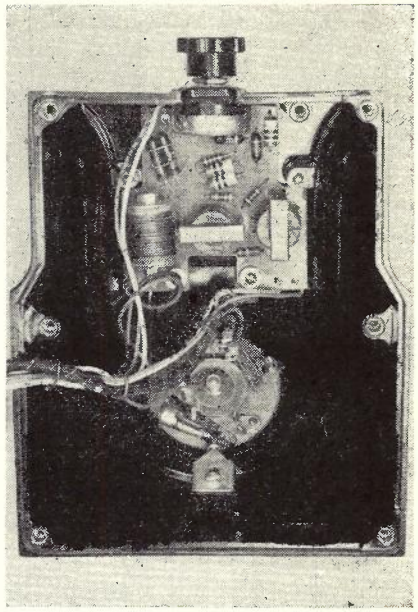


Fig. 18.—Experimental Printed Circuit Amplifier—mounted in 300 type telephone.

re-arrangement of existing components is required and the additional wiring necessary is kept to a minimum. The volume control knob protrudes out from the rear of the telephone moulding. Fig. 19, which shows the vacuum tube amplified telephone, facilitates comparison of the two types of amplified telephone.

CONCLUSION

A twin transistor push pull amplifier has been developed for use as a hearing aid attachment for the 300 type telephone. The complete amplifier and power supply is built into the existing telephone case and provides an insertion gain of 20 db.

The amplifier transistors are adequately protected against excess line voltage

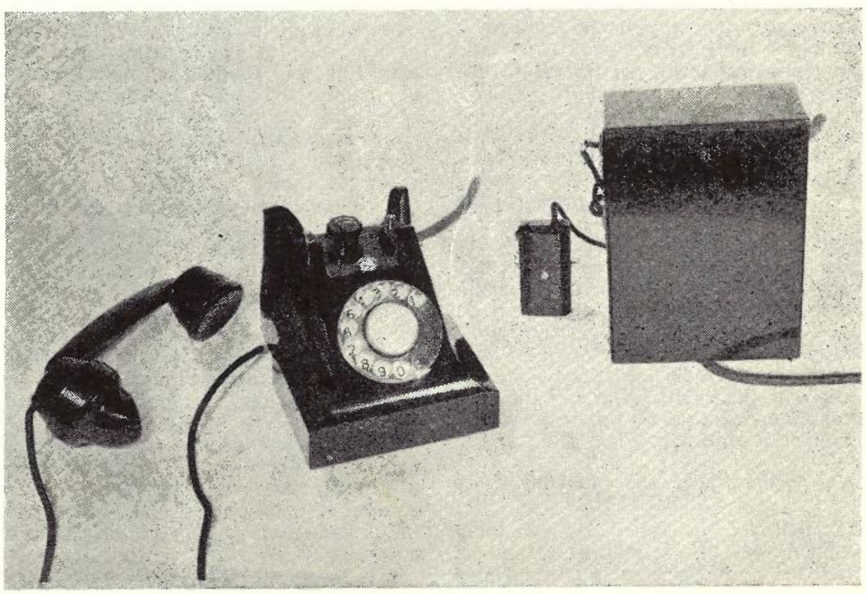


Fig. 19.—Amplified Telephone Employing Vacuum Tubes.

transients by means of a simple, compact and reliable resistor-diode network.

A series R-C network can be placed across the line input terminals of the amplified telephone in order to increase telephone stability.

APPENDIX I

Relationship between Emitter Current and Input Impedance of a Grounded Emitter Amplifier Stage

Consider the input impedance of a grounded emitter transistor stage, with load impedance Z_1.

$$Z_{in} = \frac{\Delta^h + h_{11} Y_1}{h_{22} + Y_1} \quad (1)$$

where $\Delta^h = h_{11} h_{22} - h_{12} h_{21}$,

h_{11} h_{22} h_{12} and h_{21} are the grounded emitter "h" parameters. (See ref. (2) for definition of h parameters.)

$$\text{and } Y_1 = \frac{1}{Z_1}$$

On substitution of typical OC72 values of the grounded emitter h parameters both Δ^h and h_{22} become negligible and (1) can be written:—

$$Z_{in} \simeq \frac{h_{11} Y_1}{Y_1} = h_{11}$$

It has been found (Ref. (2)) that,

$$h_{11} \simeq \frac{k}{I_e} \qquad k = \text{constant}$$

hence it can be said

$$h_{11} \propto \frac{1}{I_e}$$

$$\text{or } h_{11} \propto \frac{1}{I_c} \text{ (approximately)} \quad (2)$$

$$\text{and thus } Z_{in} \propto \frac{1}{I_c}$$

where I_e = emitter current

I_c = collector current.

APPENDIX II

Expression for Input Impedance of a Grounded Emitter Amplifier Stage

Expressing the input impedance of a grounded emitter transistor amplifier stage in terms of the equivalent T network parameter (Ref. (2)) yields:—

$$Z_{in} = \frac{r_e r_b + r_c \; (r_e + r_b (1 - a))}{r_e + r_c (1 - a)}$$

simplifying

$$Z_{in} = r_b + \frac{r_e r_c}{r_e + r_c (1 - a)}$$

and since normally $r_e \ll r_c (1 - a)$

$$Z_{in} \sim r_b + \frac{r_e}{(1 - a)}$$

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2. J. N. Bridgford, "Junction Transistor Parameters". Research Laboratory Report No. 4403.

3. D. Tonkin, "Speech Level Measurements at Melbourne Trunk Exchange." Telecom. Journal of Australia, Vol. 11, No. 1, June 1957.

4. R. W. Kett, "Transmission Performance Ratings of Current A.P.O. Subscriber's Telephone." Research Laboratory Report No. 4165.

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BOOK REVIEWS

Elementary Telecommunication Practice. J. R. G. Smith, A.M.I.E.E., 1958. English Universities Press Ltd., pp. 293. Australian price, 23/6.

Chapter Headings: Magnetic effect of an electric current — Heating effect of an electric current — Telegraph codes and circuits — Telephone and telegraph systems and provision of plant — Cables — Manual exchange equipment — Soldering — Primary and secondary cells — Receivers and transmitters — Corrosion — Identifying and testing wires -- Components used at Radio frequencies — Appendix, Circuit diagrams — Index.

This book has been produced to meet the needs of students (mainly B.P.O. Technicians) studying for the examination in Elementary Telecommunications Practice of the City and Guilds of London Institute.

The various topics are dealt with in a similar practical way as in the Australian Post Office Course of Technical Instruction and at a comparable level. Practical examples of course apply to British Post Office practices which differ in some respects from those of this country.

Each chapter is followed by exercises which are questions from typical City and Guilds examination papers and in addition there are some specimen answers similar to those published in the supplement to the Post Office Electrical Engineers' Journal. It should, however, be studied in association with the Principles of Telecommunications Engineering, Volume 1.

The book is well written, illustrated and produced, the index is adequate and it is a very good introduction to telecommunications practice.

The Australian price is high however, and it offers little more to the student than does the Course of Technical Instruction. —W.R.D.

Principles of Telecommunications Engineering, Vol. 1. H. R. Harbottle and B. L. G. Hanman, 1957. English Universities Press Ltd. pp. 373. Australian price 33/-.

Chapter Headings: Magnetism — Static Electricity — Current Electricity — Heating Effect of an Electric Current —Magnetic Effect of an Electric Current — Electromagnetic Induction — Chemical Effect of an Electric Current — Electrical Measuring Instruments — Potentiometer and Wheatstone Bridge — Capacitors — Sound: Microphones and Receivers, Speech and Hearing — Intro. to Radiation of h.f. Alternating Currents — Electronic Theory of Matter — Appendices — Answers to Exercises — Index.

This book has been produced to meet the needs of students (mainly B.P.O. Technicians) studying for the first year examination in Telecommunications Principles of the City and Guilds of London Institute.

Compared with similar topics as dealt with by the Australian Post Office Course of Technical Instruction, this book covers more of the historical background of each topic, tends to deal with each subject more academically and with less reference to practical telecommunications, and treatment is at a slightly higher mathematical standard. This is to be expected, of course, as this volume is the first of three that cover the three year syllabus in Telecommunications Principles.

The style is clear and concise and the text is well illustrated with diagrams associated with the text, and each chapter is followed by problems and exercises to which the answers are given.

Although the domain theory of magnetism is not covered the coverage of each chapter appears satisfactory for the purpose of the book. The conventional direction of current is used throughout.

The index is good and although C.G.S. Units are used throughout, M.K.S. units are dealt with in one appendix.

The quality of production is satisfactory but the Australian price is high and the book is not recommended for study by Technicians (including Senior and Supervising Technicians) unless further background or a more mathematical treatment of the various subjects is desired, for example by instructors.

—W.R.D.

THE TELEPRINTER EXCHANGE SERVICE — AUTOMATIC LINE CONCENTRATOR

D. Y. McFADDEN, A.M.T.C., A.M.I.E. Aust.*

INTRODUCTION

In a previous article[1] the growth of the Telex Service was discussed, together with the measures being taken to cope with it, particularly in the capital cities. None the less evident is the demand for service from some country areas, or centres, about 30 miles or so from capital cities, which are expanding rapidly, but which in most instances have not a sufficient number of subscribers in any one centre to warrant the supply and staffing of a switchboard. The connection of each subscriber by long lines to the nearest switchboard is also usually uneconomical, even if the calling rate is high.

The solution which has been adopted by the A.P.O. is to provide equipment at a country centre which allows a group of subscribers to share a number of lines back to the nearest manual switchboard. The concentrator described here allows up to 18 subscribers to share up to 8 lines in this way. The equipment has been designed to run on an unattended basis, and to automatically connect a called or calling subscriber to the switchboard. There may be periods of course when all the available junctions to the parent switchboard are in use, in which case the call will be abandoned and another try made later. A concentrator of a similar type has been in use in Great Britain for some years [2], and also in the U.S.A. since 1942[3].

GENERAL FEATURES

To ensure that the savings in line and operating costs are fully realised, the design of the concentrator has been kept as simple as possible, while at the same time providing as many safeguards against failure as deemed necessary. Only 3000 type and polarised relays, and B.P.O. No. 2 uniselectors are used throughout, thereby simplifying the maintenance, which is quite important as the equipment may be accommodated away from main switching centres. To further reduce complexity, a call between two subscribers off the same concentrator is "trombone trunked", or in other words trunked to the parent switchboard and back, tying up two junctions. However as the great majority of calls are expected to be to subscribers not on the same concentrator, this is not likely to be a serious disadvantage.

As stated previously, up to 18 subscribers may be served over up to 8 lines or junctions. The provision of junctions to cater for the number of subscribers connected will naturally be governed by their traffic requirements, but as each junction is terminated in a plug-in type relay base, the addition to, or reduction of, the number of junctions provided is relatively simple on the equipment itself. For a small installation the concentrator can be installed with only the number of junction relay sets required at the time of installation, thus reducing to a minimum the amount of redundant equipment provided, but allowing for quick expansion later.

The concentrator is rack mounted, and is entirely self contained apart from power supplies. It incorporates a test panel from which functional tests of each selector can be carried out, although provision is also made to conduct some tests from the parent switchboard.

CONSTRUCTIONAL DETAILS

Fig. 1 shows a view of the concentrator, which is mounted on a 20¼" by 8' 6½" rack. The eight selector relay sets and the test and common service relay sets have RSR 20 bases, while the L and K relays are mounted in flanges covered by a single dust cover. The test panel and jacks appear at a convenient height on the rack, and the alarm relays are in a mount at the side. Positive and negative fusing is mounted on the left hand side of the rack, and terminal blocks are mounted at the rear.

*Mr. McFadden is a Group Engineer in the Telegraph & Workshops Section, Central Office.

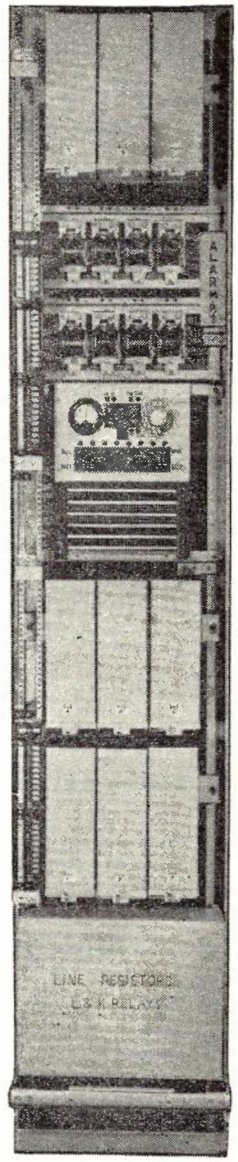

Fig. 1.—The Concentrator Rack.

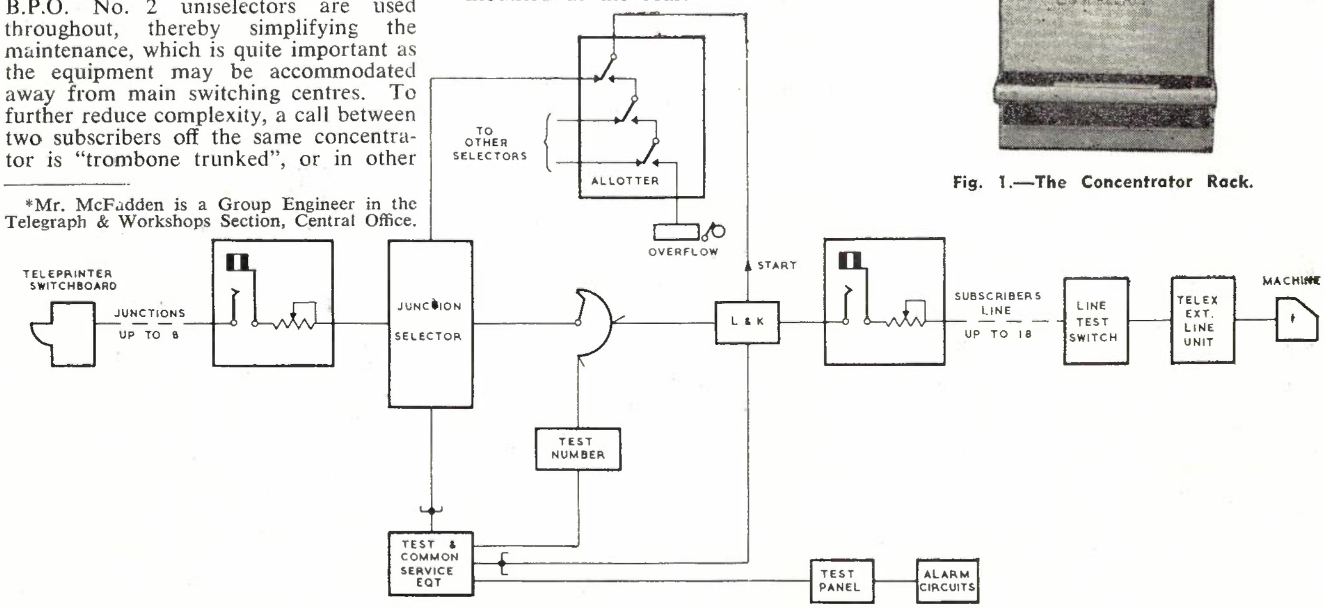

Fig. 2.—Block Schematic of Concentrator.

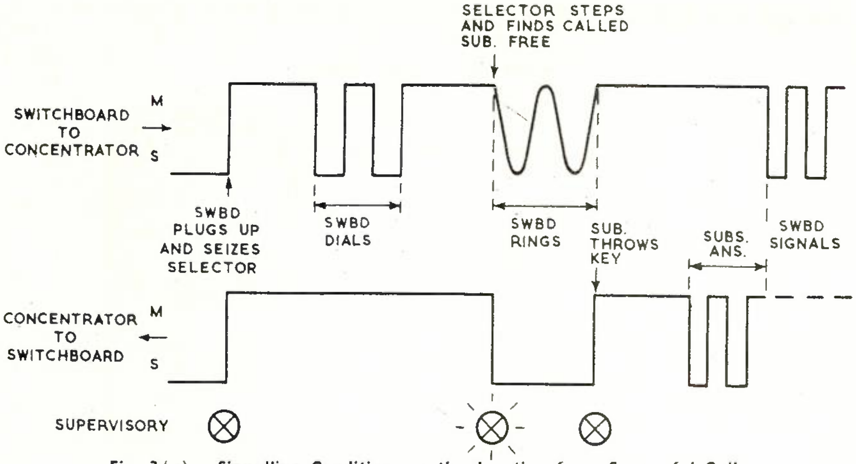

Fig. 3 (a).—Signalling Conditions on the Junction for a Successful Call.

FACILITIES OFFERED BY THE CONCENTRATOR

A brief list of the facilities offered is given below. The important ones will be discussed in detail later in this article.

(a) Up to 18 subscribers may be connected over up to 8 junctions to the parent switchboard. For smaller installations only the number of selector relay sets required are provided. The numbering is arranged so that subscribers 1 to 9 are reached by dialling 1 to 9 respectively. The second group of 9 are reached by the codes 01 to 09.

(b) The unit is automatic in operation and will run unattended.

(c) P.B.X. groups of up to 9 lines can be provided, and night service may be given on any line in the group.

(d) Provision is made to allow one junction to be terminated in a machine located in the vicinity of the concentrator, say at the local Post Office. From this machine telegrams may be sent out to subscribers connected to the concentrator, but the circuitry is so arranged that calling subscribers have no access to it.

(e) Safeguards are provided to prevent faulty selectors or junctions interfering with traffic. A selector will automatically lock itself out of service if a junction fault is suspected, or if a fault develops in the uniselector mechanism.

(f) A number of tests on individual selectors may be carried out from the test panel on the rack, and other tests may be conducted from the switchboard. Metering of line currents, the busying of selectors, and a check of locally generated signals are all made from this panel.

(g) Alarms are arranged so that the rack may be tied in with a normal exchange alarm system with prompt alarms on fuses, but with a delayed warning on selector lock out. However the concentrator is provided with its own lamps and alarm bell should the unit be located away from other apparatus.

PRINCIPLES OF OPERATION

Detailed circuit operations are given later in this article, but the general principles of the operation of the concentrator will be discussed first. Fig. 2 is a block schematic of the concentrator, showing the parent switchboard, and one subscriber. Each switchboard junction terminates in a junction selector directly coupled with a uniselector, which is multipled with the uniselectors of the other junctions. L and K circuits are connected to this multiple, each L and K relay belonging to a particular subscriber. Test and common service equipment is shared by all selectors.

When the subscriber originates a call, a start signal from his L and K circuit is fed to the next free junction selector by contacts of the allotter, the uniselector runs and locates the calling line, and the switchboard "call" lamp glows. If all selectors are engaged, a "busy" signal is returned from the test and common service equipment. Test numbers are connected to the multiple, enabling tests to be made on the selectors and their relay sets from either the test panel or the switchboard.

Call to Concentrator from the Switchboard: The switchboard operator plugs up to a free jack terminating one of the concentrator junctions, and a selector is seized at the distant end. Fig. 3(a) shows the conditions on both sides of the junction during such a call. The selector returns mark, indicating that the required number may be dialled. During dialling the uniselector steps accordingly, and upon reaching the wanted line the selector relay tests it, and if it finds it free returns space, causing the supervisory to glow. This lets the switchboard operator know that the line has been found, and that ringing may commence. When the called subscriber answers, the selector again returns mark, the supervisory darkens, and the call proceeds as for a normal Telex call.

The Called Subscriber Busy: This condition is shown in Fig. 3(b). The switchboard plugs up and dials, but at the end of dialling the operator's machine bumps rhythmically, signifying that the called party is busy. The circuitry is so arranged that pulses of spacing battery of approximately 20 milliseconds duration occur at about ½ second intervals. This timing causes the non-printing LTRS combination to be received every ½ second.

Call from Subscriber to Switchboard: The subscriber operates his key to "call" and causes a free uniselector, determined by the allotter, to search for his line. Upon finding the line, the uniselector stops, and the selector relay set sends mark to the switchboard, operating the "call" lamp. The switchboard answers and the call proceeds as for a normal Telex connection.

All Junctions Busy: The subscriber operates his key to "call", but immediately his machine "bumps" rhythmically, indicating that all junctions are busy; to clear down and try later.

Guard Circuits: Guard circuits are provided in the selector to remove a faulty junction or uniselector from service automatically and to operate an alarm on so doing. Two conditions are covered:—

(i) A subscriber originates a call but receives no reply from the switchboard after a reasonable time. This could indicate a junction fault, and upon his clearing, that selector is locked out of service. Upon recalling he is allotted another selector. This condition could arise if the switchboard operator were delayed for some reason in answering the call, and the subscriber cleared down.

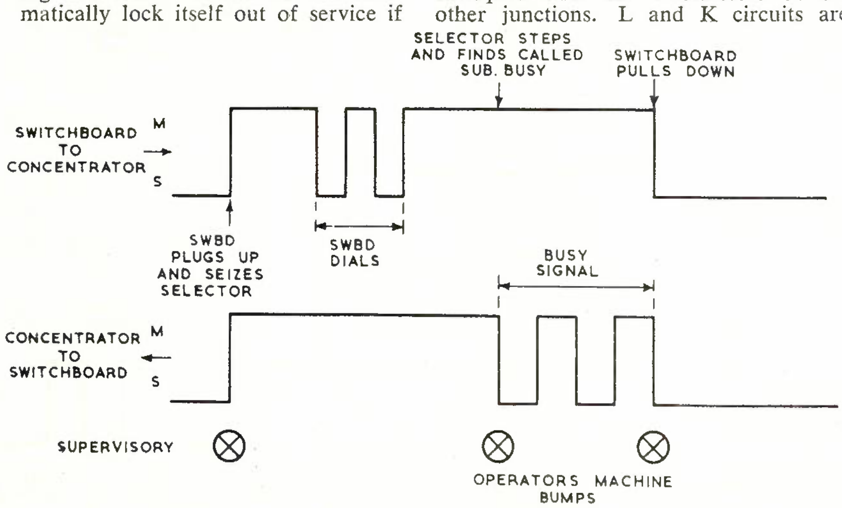

Fig. 3 (b).—Signalling Conditions when the Called Party is busy.

However in this case the junction would not be at fault, and so under the lock-out condition the switchboard call lamp is flashed. The selector may be returned to service by plugging a cord into the jack at the switchboard.

(ii) A fault may develop in the uniselector mechanism or the selector relay set preventing the calling party's line from being found by a particular selector. This selector is automatically locked out, and the caller switched to another selector. This fault sounds the local alarm, but cannot be cleared from the switchboard.

TESTING FACILITIES

As a check against selector performance, tests can be made on individual selectors from the test panel on the rack. The switchboard operator can also check a junction and its associated selector and uniselector by dialling test numbers. The test panel on the rack is shown in Fig. 4, and carries a dial, a milliameter, display lamps, test number call keys, an overflow register, and a busy test signal key. A test and busy key and "selector in use" lamp for each selector are also provided. Jacks are fitted to all junction and subscribers lines for testing purposes.

Selector Dialling Test: A free selector can be seized, and stepped to one of the two test numbers by dialling 001 or 002 from the test panel. 001 is connected to simulate a single current, and 002 to simulate a double current subscriber. As the selector relay set has to discriminate automatically between single and double current subscribers, a major part of the circuitry can be checked by these tests. Lamps on the test panel check the polarity of signals which would be sent to the switchboard and subscriber from the selector under test. The answer by the called party is simulated by the operation of a single or double current call key.

Selector Test from the Switchboard: The switchboard operator can carry out a test on any junction and its associated selector equipment by dialling either of the two test numbers. Fig. 5 shows the signalling conditions in the junction. Supervisory signals are the same as for a normal call up to the commencement of ringing, that is the supervisory should light after dialling. The test number circuit is so arranged that when ringing is sent out, the "busy" signal is reverted to positively indicate that the test circuit has been reached. If the selector had incorrectly stepped to a free subscriber's line, mark would be returned when he answered after ringing, or if it had stepped to an unused outlet or a busy subscriber, busy would be returned before ringing.

Calling Subscriber Search Test: Two keys on the test panel represent the call keys of a single current and double current test subscriber. If a selector is seized for test by throwing its test key, and one of these two call keys is operated, the selector will search for the calling test number. A lamp display checks the functioning of the selector and polarity of signals which would be sent to the switchboard during the test.

Busy Signal Test: The locally generated busy signal may be checked visually on a lamp display.

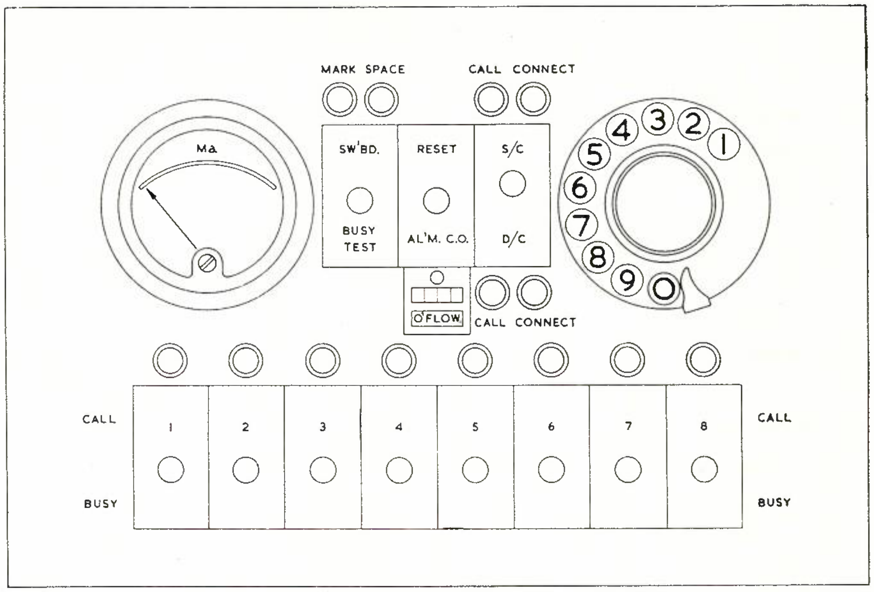

Fig. 4.—The Test Panel on the Concentrator Rack.

Overflow Register: The number of calls made by subscribers connected to the concentrator when all junctions are in use, is counted on an overflow register. From this information a review of the allocation of junctions can be made if necessary.

Busying of Selectors: A selector may be busied out at the concentrator by the operation of the appropriate busy key. If the switchboard operator plugs up to the junction associated with that selector, she immediately receives "busy" bumps on her machine. This is not the same condition as for a busy subscriber, when busy is returned after dialling. A busied selector is bypassed by calling subscribers connected to the concentrator.

CIRCUIT OPERATION

General

Basically, as mentioned earlier, each junction to the parent switchboard is terminated at the concentrator end (after passing through jacks, line resistances and test keys) in a relay set called the discriminating junction selector, and its associated 8 level uniselector. The discriminating portion of the selector's title comes from the fact that it automatically discriminates and adjusts its signalling, ring through and supervisory circuits to suit either single or double current subscribers.

For incoming calls to a subscriber connected to the concentrator, the selector acts as a final selector, and is stepped by the incoming impulses to the wanted party's number, but when a subscriber connected to the concentrator originates a call, it acts as a line finder, and searches for the calling line. We shall now examine the circuit in some detail, for various conditions of operation.

Call Incoming to Concentrator from Switchboard

(See Fig. 6)

(i) **Seizing:** At rest, spacing battery appears on the send and receive lines. Upon plugging up at the distant switchboard, marking battery appears on the concentrator receive line via 1RV2, KCA, KCB normal, to operate A via MR1. SA operates from A2, and SA1 operates B. B6 causes the busy signal

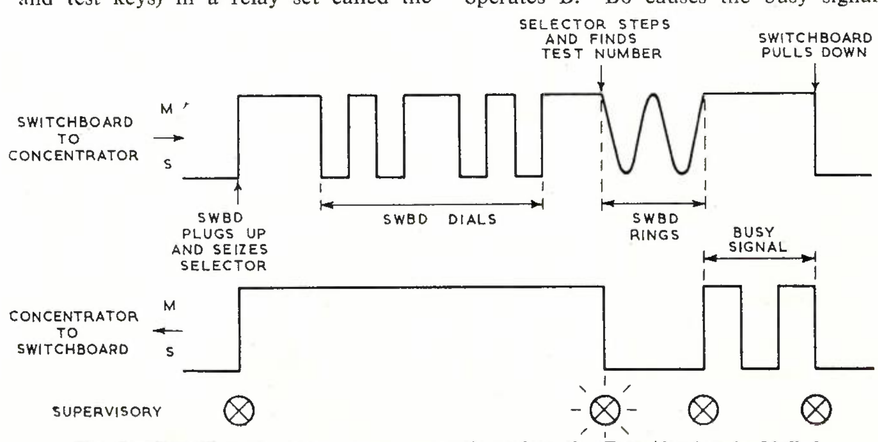

Fig. 5.—Signalling Conditions on the Junction when the Test Number is Dialled.

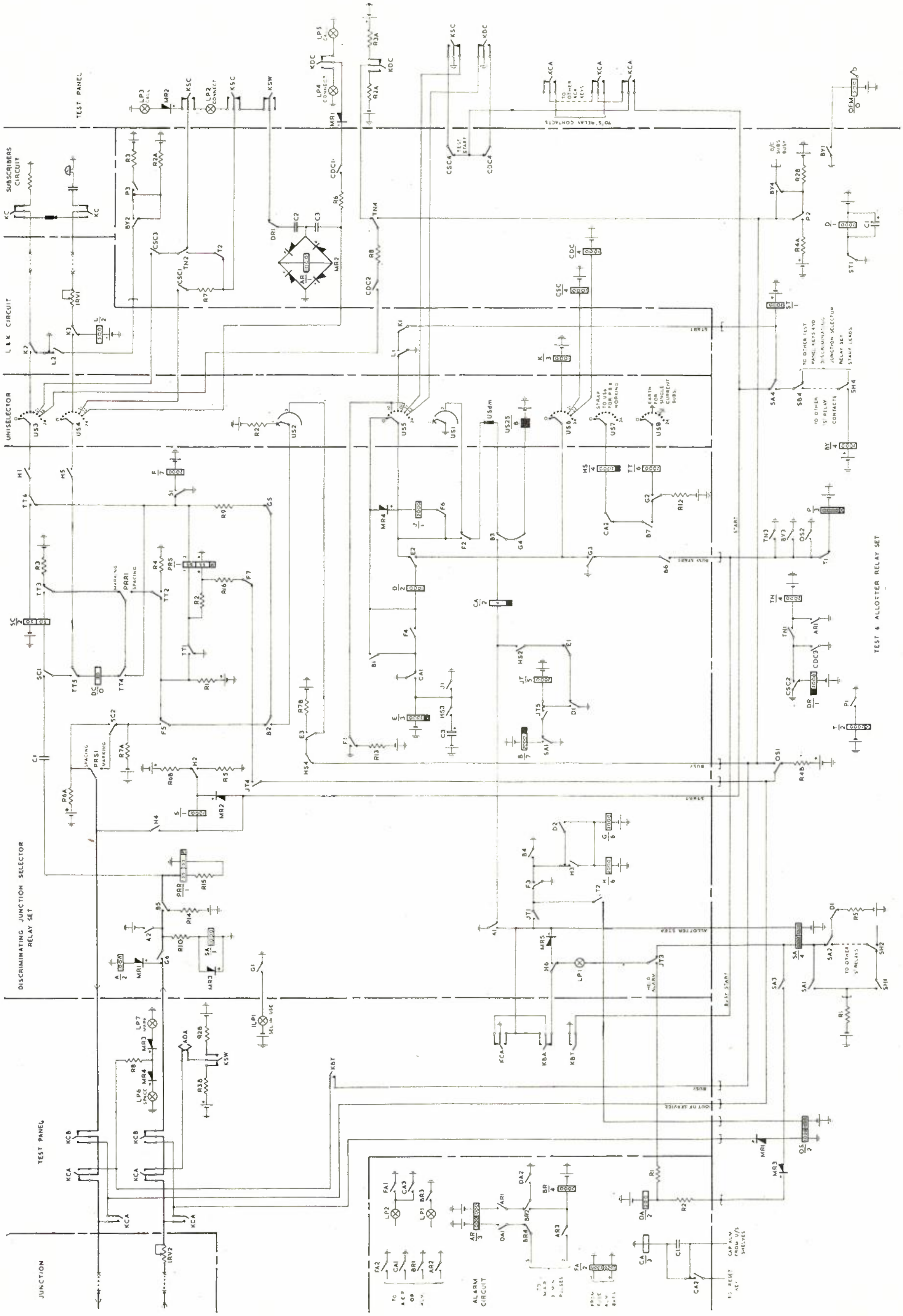

Fig. 6.—General Schematic. Note that Spark Suppression and some Battery Feed Resistors have been omitted for simplicity.

generator, the interacting relays P & T, to start via G3 normal. B2 connects US2 wiper via G5, R9, PRS, and the negative battery on US2 home position overrides the spacing battery in PRS 4-6 winding and moves it to mark. PRS1 returns mark to the switchboard extinguishing the call supervisory. At the same time A1 operates SA in the allotter, ensuring that the selector is not seized by a calling subscriber on the concentrator. SA holds by its own contact SA1, via JT3, LP1, H6 KBA, KCA to earth. B5 connects PRR to the incoming line, and also completes the ringing circuit.

(ii) **Dialling:** The return of mark to the switchboard signifies that a selector has been seized, and that dialling may commence. Incoming impulses step the uniselector from A1, via CA which holds during the impulses B3, G4 to the magnet. When the train of impulses has been completed, CA releases, and if the called party is free, D operates in series with the K relay via US6, E2 operated, D winding to earth via B1, CA1. E has already been operated by CA1, and because it is slow releasing, allows D to test during its release time. E3 maintains a marking bias on PRS during the stepping of the uniselector. Let us assume that the called party is a single current subscriber and that he is free. D. operates, and D2 allows G and H to operate, and lock to B4. G3 removes the busy start earth and holds K, also earthing the multiple to prevent seizure by another selector. G6 removes A from the concentrator receive line, but SA remains operated to the incoming mark. G2 provides battery to operate TT to the single current making earth on US8.

(iii) **Ringing:** Relay SC, which is the single current supervisory relay, operates to the earth behind KC via K2 operated, US3, H1 and TT6 operated. SC2 causes spacing battery to be returned to the switchboard, denoting that ringing may commence. Ring comes in from the junction and goes via C1, SC1, TT5, H5 operated, US4, K3 operated, 1RV1 to the bell at the subscriber's machine.

(iv) **Subscriber Answers:** Upon the subscriber throwing his key, KC, to answer, the signalling loop is completed as follows:—negative battery, SC winding, TT6, H1 operated, US3, K2, KC, single current machine, KC, K3, US4, H5, TT5 operated, SC1 normal, SC winding, TT3, PRR1, TT4, PRS 1-3 winding, TT1, R1 to positive battery. Note that SC releases when the subscriber throws his key, and remains released as the current though each of its windings is equal and opposite. SC2 releasing again returns mark to the switchboard, extinguishing the supervisory, and signifying that the called party has answered, and SC1 removes the ringing circuit from the incoming line.

(v) **The Call is Connected**: The calling parties' signals key PRR, which repeats them to the single current loop, and thus to the called subscriber's machine. As PRS is biased to space via R2, when incoming signals cause PRR1 to go to a spacing direction, the machine loop is opened, and PRS would tend to move to space, thus repeating back incoming signals to the caller and mutilating his copy. However PRR spacing contact provides a path to hold PRS to mark during spacing excursions via R4, TT2, PRR1, TT4, PRS 1-3 winding, TT1, to positive battery behind R1. Signals from the called party's machine also open the loop during spacing, but PRR is at mark, and PRS repeats these signals faithfully, and its contacts return them to the switchboard and the calling party.

(vi) **Supervision:** Supervisory circuits are now operative to look for clearing signals from both parties, as the selector will not release until both parties have cleared. Relay SA, mentioned earlier, is made slow to release by MR3 in order to hold over normal teleprinter signals, but to release on a long spacing signal, since MR3 short circuits the relay coil with space incoming. SA holds up B, and supervises the switchboard side of the connection through the selector. Relay S operates in a similar way, supervising the subscriber's side, and it remains held via H4 and H2 while PRS is at mark. S1 operates F, which adds a second holding earth to H and G at F3. Thereafter both B and F have to release before G and H, which control the selector, can release.

(vii) **Clearing:** Let us say that the calling party clears first; SA releases, and B releases, but G and H remain operated. The space incoming from the junction opens the subscriber's loop, but PRR1 tends to hold PRS to mark (see (v) above). The subscriber's machine will run open, so he clears. When the called party clears, SC operates to the earth behind his key via US3, H1, TT6, and SC2 returns permanent space to the switchcobard via PRS1, causing the supervisory relay S to release. Both supervisory lamps will now be alight at the switchboard, and the call is pulled down. In the meantime a homing circuit for the uniselector has been provided from US1, F2 released, US dm, B3 and G4 released, and the selector homes. TT releases, and PRS remains held to space via TT1, its own 1-3 winding, R9, G5, B2, F5 all released, to spacing battery at R1. The selector and switchboard are now resting at the normal spacing condition.

If the concentrator subscriber had released first, SC and PRS would return space to the switchboard, and SA would release B, G and H when the other party cleared.

Dialling a Two Digit Number

As there is provision for up to 18 subscribers, some have to be allotted 2 digit numbers. These are prefixed by 0, so that the 15th subscriber would be reached by dialling 05. When the switchboard dials 0, the uniselector steps to contact 10, but no K relay is connected to that outlet from US6. CA releases, but E remains operated because of its slug, and is held by J1, as J operates from negative battery, R13, F1, US5 on contact 10, F6, MR4, B1, to earth at CA1. The 5 is now dialled, J releases when the selector steps off 10, and D tests the outlet as described previously. The same circuit operates when the test number is dialled, except that it is brought into use again on contact 20, since the test number is 001 or 002.

Call Originating from a Subscriber Connected to the Concentrator

(i) **Seizure of a Selector:** Let us take the case of a single current subscriber originating a call. Upon throwing his call key KC, a path is provided for L in the L and K circuit to operate, via K3, RV1, KC, single current machine, KC, K2, L2 to earth. L1 removes an earth from US5, thus marking it, and transfers the earth to the common start lead, operating ST in the test and allotter relay set. L holds via L2 operated to negative battery behind BY2 and R2A.

(ii) **Searching for the marked outlet:** The start signal also proceeds to the next free selector, allocated by the allotter contacts SA4, SB4, etc. This start operates S in the selector to the battery behind H2. S1 operates F and F5 switches negative battery from R7A via B2, G5 normal to move PRS to mark, thus lighting the switchboard call lamp. An earth from CA1 normal via US5 home position, B1 operated, is routed to the uniselector magnet through F2 operated, US dm, B3 and G4 normal, and the uniselector commences to search. L1 contacts of each subscriber in the normal position provide earths on their respective contacts on the bank, and the uniselector runs until it encounters the unearthed contact, where the L1 is operated. F1 operated applies an earth to contacts 10 and 20, allowing the selector to pass over them. (10 and 20 are used as holding contacts to allow J to operate for 2 and 3 digit numbers respectively).

(iii) **Stopping the Search:** A short circuit path exists around D while an L1 contact is normal, but upon reaching the marked position D operates, and since there is no path for the magnet to re-operate the selector stops.

(iv) **Switching Through:** D2 operates G and H, which hold to F3. H1 and H5 switch through the subscriber's line and G3 allows TT to operate. The signalling circuit sets itself up for single current working in the same manner as described for an incoming call.

(v) **Action in the allotter:** The purpose of the allotter is to transfer the common start lead from the L1 contacts to the next available selector once one is seized, either by an incoming or locally originated call. Each selector has a corresponding S relay shown as SA to SH in the figure (SA belongs to selector No. 1, SB to No. 2 and so on to SH for selector No. 8). SA, in our example, operates when H6 provides a path for it via MR5, KBA and KCA to earth, and SA4 transfers the start lead to SB4. which routes further calls to the next selector.

(vi) **The Switchboard Answers:** SA in the selector relay set is switched to the concentrator receive line by G6, and SA operates when the switchboard returns mark upon answering. B operates, connects PRR to the incoming line, and provides a second holding path for G and H.

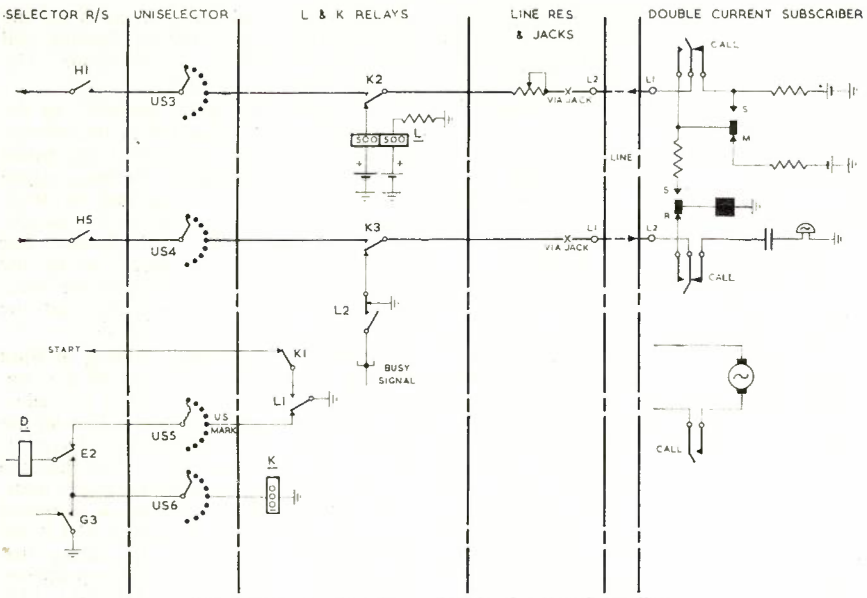

Fig. 7.—Connection to a Double Current Subscriber.

(vii) **Supervision and Clearing:** The supervision and clearing is exactly the same as for an incoming call.

Call Incoming to a Double Current Subscriber
(See Fig. 7)

Essentially the circuit operation is the same as for a single current subscriber, except for the transmission of the ring and the signalling circuit out of the selector.

(i) **Stepping of the Uniselector:** When the selector has been stepped to the wanted party's outlet, D and K operate as described previously. TT does not operate however, as no earth appears on US8 contact for a double current subscriber. Spacing battery will be returned from the subscriber's premises from KC normal, and this battery returns PRS to space via US3, H1 operated, TT6 normal, PRS 1-3 winding, TT1 normal, to earth. (PRS goes to mark when the selector is seized, from the negative battery via US2, B2 operated, G5 normal).

(ii) **Ringing**: This return to space is the "go ahead and ring" signal, and ring incoming from the junction causes PRR to vibrate. PRR1 repeats the ringing to the subscriber's bell via TT4 normal, DC winding used as a filter, TT5 normal, H5 operated, US4, K3.

(iii) **Signalling Circuit:** When the subscriber answers, by operating KC, the signalling circuit appears as follows:—

(a) Sending to subscriber. PRR tongue, via TT4 normal, DC winding, TT5 normal, H5 operated, US4, K3, KC to the teleprinter magnet.

(b) Sending from subscriber. Teleprinter contacts, KC, RV1, US3 H1 operated, TT6 normal, PRS 1--3 winding, to earth at TT1. Note that the bias circuit on PRS is inoperative.

(iv) **Clearing and Supervision:** Say the calling party clears first. SA releases as space is bypassed by MR.3, and B releases. Now when the called party clears, S and F release, and G and H release allowing the selector to home. If the called party cleared first, S and F would release, and the selector would home when the calling party cleared, upon SA releasing.

Note that the L relay for a double current subscriber has a second winding permanently energised. This winding tends to oppose the operate winding of L to prevent false calls being made should the rectifier in the subscriber's premises be switched off, presenting a path to earth through internal bleed resistors. The current in this winding is insufficient to operate L however.

Call Originating from a Double Current Subscriber

The subscriber operates his call key, and marking battery on the line operates L, which has positive battery behind it. L1 sends a start earth to the allotter and the selector made available by it, and the search commences in exactly the same way as for the single current case. Relay TT does not operate when the marked line is found, and the signalling circuit functions for double current operation.

Call to or from a Subscriber on a Trunk
(See Fig. 8)

It is possible that a subscriber could be connected to the concentrator over a trunk. The circuit operates in a similar manner to a normal double current subscriber, except that the second L winding is not connected. For an outgoing call to the subscriber, ringing voltage is fed over L2, and when he answers, mark is repeated from the trunk equipment sending contacts. When the subscriber originates a call, mark repeated from the trunk equipment contacts operates L over L1, to the positive battery behind it.

Calls Made to a Busy Circuit

(i) **Incoming Call from Switchboard, Called Subscriber Busy:** When the selector steps around to the marked outlet, D will test for the battery behind K denoting a free selector. If the number is busy, an earth will appear on the multiple from the G3 contact in the selector already connected, and D does not operate. G3 and B6 have already started the busy signal generating circuit, comprising the interacting relays P and T in the allotter. When CA releases, E releases, and "busy" is fed from P2 in the allotter, via HS4 and E3 normal, US2, B2 operated, G5 normal, R9, to PRS 1-3 winding, and PRS repeats the signal generated by P2 swinging between marking and spacing battery. At the switchboard the operators machine "bumps" rhythmically, informing her that the called party is busy.

(ii) **Single Current Subscriber Originating a Call, All Selectors Busy:** In this case all the allotter S relays will be

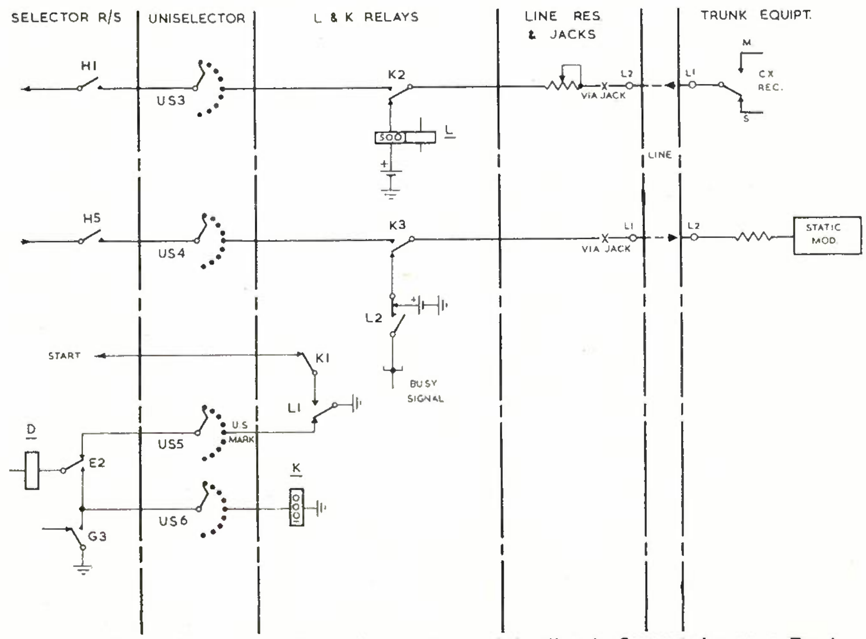

Fig. 8.—Circuit Elements at Concentrator when a Subscriber is Connected over a Trunk.

operated, and the start signal operates relay BY in the allotter. BY2 connects the lever of L2 to P3, and as P pulses, the single current calling loop current is varied from 47 to 8 mA. This allows the machine magnet to release on the 8 mA loop, and reoperate on the 47 mA loop causing the machine to "bump", but L to remain operated. The subscriber returns his key and tries later.

(iii) **Double Current Subscriber Originating a Call, All Selectors Busy:** BY operates from the "start" earth, and BY4 connects L2 lever to the output of P2, which is a pulsing double current signal causing the teleprinter to "bump", denoting all selectors busy.

P.B.X. Operation

(See Fig. 9)

The seizure of the selector by the switchboard is the same as when a normal call is being made. The operator then dials the number of the first line in the P.B.X. group.

(i) **First Line Free:** Upon reaching the first line in the group, D operates in series with K as for a normal call. G2 opens and prevents HS from operating to the earth in the first line in the group on US7.

(ii) **First Line Busy:** The selector steps to the first line in the group, but since it is busy, D does not operate. HS however is able to operate via G2, B7, CA2, and US7 to the earth on the first line. The relay E, slugged by the condenser C3, releases slowly, and E1 steps the selector one step via HS2. CA however reoperates, and reoperates E. If now the second line is free, D will operate, bring up G and H, disconnecting the HS relay, and allowing the call to proceed.

(iii) **All Lines Busy:** This testing and stepping is repeated if the second line is busy until a free line is encountered, or the selector reaches the last line. Here HS cannot operate to any earth, and if the last line is also busy, D cannot operate, so "busy" is returned to the caller by the same circuitry as for a normal call.

Guard and Alarm Circuits

As the concentrator may be unattended for certain periods, safeguards are provided against failure.

(i) **Selector Lock-out — Faulty Junction:** When a subscriber on the concentrator originates a call, relay JT is operated by D1 when his line is found, and JT remains held to SA1 by JT5. JT3 causes the selector PG lamp to glow from the earth behind KCA, KBA, to negative battery behind DA in the alarm circuit. DA operates and allows AR to operate on the "Z" pulse, and light the white rack lamp LP1. BR1 and AR2 are also available to tie in with normal exchange alarms. If the subscriber abandons the call, having received no answer from the switchboard, it may be assumed that a faulty junction has been seized, so the selector must be locked out of service. JT remains operated, and the S relay in the allotter is held up from F3 released via JT1 operated. The glowing PG lamp identifies the offending selector.

If however, the switchboard is slow in answering, a subscriber could clear and lock out an available selector. A subscriber originating a call and then changing his mind could also do so. To guard against this, a warning is given to the switchboard in the form of flashing call light on the locked out junction. The circuit works as follows:

JT2 applies an earth from F3 to the "Out of Service" relay OS in the allotter relay set, and OS starts the busy pulses by OS2. OS1 connects the busy signal via JT4 operated, F7 normal to PRS, which repeats the pulses to the switchboard, flashing the call lamp. The switchboard operator plugs up to the flashing lamp and A and SA in the selector operate. SA1 releases JT and the selector is returned into service.

(ii) **Selector Lock-out—Failing to Find Calling Party:** If a subscriber off the concentrator originates a call, but the selector seized is unable to find his line within a set period, the offending selector is locked out automatically. The holding circuit of a slow releasing normally operated relay D in the allotter is removed when the start earth is applied and if the selector has not found the calling line before D1 closes, SA (or the appropriate relay SB-SH) operates via D1, SA2, JT3, H6 all normal, KBA, KCA to earth, and remains held via R1, SA1. The calling party is automatically switched to another free selector by the operation of SA. The selector remains locked out by SA remaining operated, and the PG lamp glows until the fault is cleared. SA3 provides a circuit for the operation of DA in the alarm circuit, which causes the delayed alarm to operate.

(iii) **Fuse Alarm:** A positive or negative fuse failure operates FA in the alarm circuit through one of its windings. Contacts of FA light the red rack lamp, and apply an earth to the normal exchange alarm system if available. Where no exchange alarm system is available a bell on the rack sounds.

(iv) **Condenser Alarm:** Relay CA in the alarm circuit operates if a suppression condenser short-circuits, allowing CA2 to insert C1, and CA to hold via the reset key, which resets the circuit when the fault is repaired.

Test Panel

The concentrator rack carries a test panel, from which individual selectors can be busied or tested. The panel also mounts an overflow register to count the number of calls attempted by subscribers when all selectors are in use, a milliameter, a dial, and line packs for each subscriber and junction. (See Fig. 4).

(i) **Busying a Selector:** Operating the appropiate busy key in the test panel busies the selector to calls from the switchboard and to subscribers off the concentrator. Contacts of the busy key KBA—

(a) connect an earth to the appropriate S relay in the allotter to operate it and so divert the start earth to the next selector,
(b) divert the incoming line from the junction to the OS relay, polarised by MR1 to look for mark incoming,
(c) divert the outgoing line to the junction to OS1,
(d) remove the earth from H6 in the selector to prevent the alarm from operating from the busied selector.

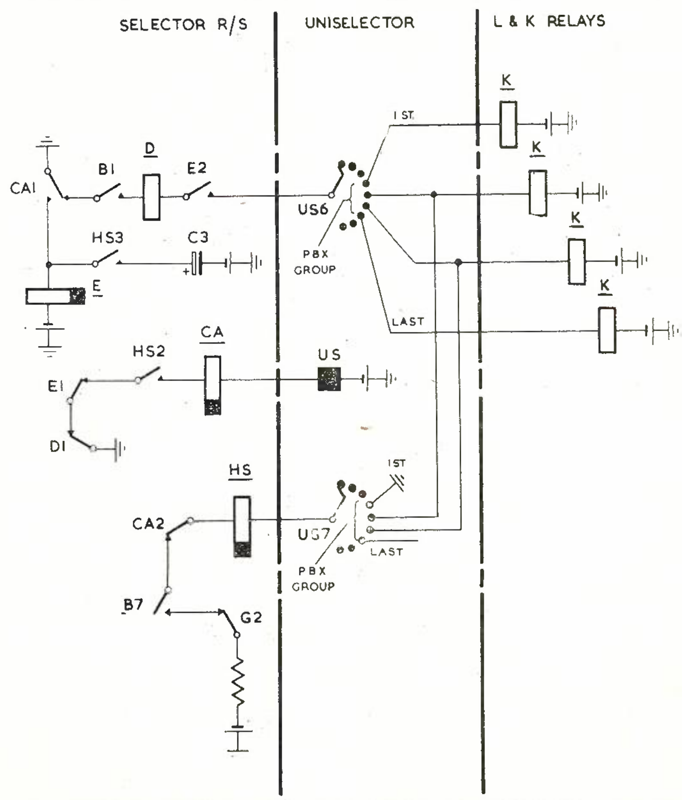

Fig. 9.—Main Circuit Elements for P.B.X. Operation.

When the switchboard plugs up the busied out junction, the mark incoming to the concentrator operates OS, and OS2 starts the busy pulse relays P and T, and OS1 repeats the busy signal to the switchboard, signifying "out of service". Note that this signal is received immediately upon plugging up, and not after dialling, as is the case with a busy subscriber.

(ii) **Incoming Call Test on a Selector:** This test allows a selector to be seized and connected to the dial mounted on the test panel. Test numbers can then be dialled, with lamps giving indications of the signals which would be returned to the switchboard, before and after the subscriber has answered. Two test numbers are provided, one simulating a single current subsciber, terminating in a "call" lamp and a "connect" lamp with a "call answer" key, and one simulating a double current subscriber with similar facilities. The circuit operates as follows:—after observing the "selector in use" lamp to see if the selector is free, the KCA belonging to the selector to be tested is operated. The incoming junction is diverted to the OS relay in the same manner as for a busy selector, and the outgoing line is connected to the output of the OS relay, contact OS1. The output of PRS1 is switched by KCA to the mark and space lamps LP6 and LP7, polarised by MR3 and MR4. Thus the position of PRS can be determined by the appropriate lamp. The input of the selector is switched by KCA to the dial, with spacing battery applied behind KSW. The KCA contacts connected to the mark contact of A1 in the selector operate the appropriate S relay in the allotter, diverting any start signals to the next selector, and open the alarm start circuit by removing the earth from H6. The KCA contacts appearing on the right hand side of the diagram divert the selector start lead to the test number circuit.

(a) **Single Current Test:** KSW is operated, and mark is sent into the selector under test via R2B and the dial. The "mark" lamp LP7 glows, signifying that the selector has returned a mark. 001 is dialled, and the selector steps to contact 21, where D tests and operates in series with the test K relay CSC. The "call" lamp LP3 lights to the negative behind SC in the selector, in effect taking the place of the resistor in the normal single current terminal unit. The "mark" lamp extinguishes because SC2 has reverted space out of the selector, and the "space" lamp lights. This normally signals the switchboard that ringing may commence.

KSC is now thrown, and a loop is presented to the selector across US3 and US4 as follows:—US3, CSC3, TN2, KSC operated, LP2, KSC, R7, CSC1, to US4. The signalling circuit in the selector is in the single current condition because an earth appears on contact 21 of US8, and TT has operated. The "connect" lamp simulates the subscriber's machine, and its lighting checks that loop current is flowing, and thus checks that the selector single current circuit is functioning. SC in the selector releases, and the "mark" lamp comes up signifying that the subscriber has answered. Releasing KSC, KSW and KCA returns the selector to use for normal traffic.

(b) **Double Current Test:** The selector is seized by operating KCA, and then KSW, and 002 is dialled. The "mark-space" lamps give the same indications as for the single current test. When the selector has stopped to contact 22, CDC will operate in lieu of the normal K relay, and the selector rests on that outlet. A mark outgoing from PRR in the selector, via US4, R6, CDC1, MR1, KDC, lights the "call" lamp. The "space" lamp is alight on the panel until KDC is thrown, when it and the "call" lamp extinguishes and the "connect" lamp lights. KDC returns mark to the selector via TN4, R8, CDC2, US3, causing PRS to signal mark into the junction line, lighting the "mark" lamp. Releasing KDC, KSW, and KCA restores the selector to service.

(c) **Subscriber's Call Test—Single Current:** The test allows a chosen selector to search for the single current test number to check its operation. The KCA for the chosen selector is operated and the lamps observed. The KCA contacts shown on the right hand side of the diagram connect the start lead of the selector to the test start lead from CSC4 and CDC4. When KSC is thrown, simulating a call of a subscriber, KSC removes an earth from contact 21 of US5, thus marking it, and applies the earth to the test start lead, and CSC operates. The loop is made through the "connect" lamp which lights, and the "mark" lamp comes up, denoting a call to the switchboard. KSC upon being released should cause the red "space" lamp to light, signifying a clear down by the subscriber.

(d) **Subscriber's Call Test — Double Current**: The procedure is the same as for the single current case except that KDC is thrown. The selector finds the marking on contact 22, and the double current "connect" lamp lights.

(iii) **Busy Signal Test:** KBT, when operated, applies an earth to the busy start, and connects the "mark-space" lamps to the common busy lead. The mark and space lamps flash alternately if the busy signal generator circuit is functioning.

(iv) **Tests from the Switchboard:** A single current and double current subscriber test can be carried out from the switchboard, by dialling the test number, and then ringing. "Busy" is returned if the seector is functioning correctly. Note that for this test busy is returned after ringing, and not before as is the case with a busy subscriber.

(a) **Single Current Test:** The switchboard makes a call in the usual way, but dials the test number 001. The selector steps to contact 21, and CSC operates instead of the K of a normal subscriber. The selector returns space and the switchboard supervisory lights. As proof that the selector has in fact reached the correct test number, the switchboard upon ringing receives "busy" back from the concentrator. Ringing voltage passes through the selector to US4, CSC1, R7, KSC, KSW, DR1, C2, MR2, to operate AR in the test circuit. DR1 is normal since CSC2 is operated. AR1 operates TN, which holds via TN1 and CSC2. TN3 starts the busy signal, and TN2 completes the test loop across US3 and US4 via CSC3, TN4, T2, R7, CSC1. T2 is however pulsing at the busy signal rate, and the busy signal is returned by PRS to the switchboard. Upon plugging down all circuits return to normal.

(b) **Double Current Test:** Upon dialling 002, the switchboard operator causes the selector to step to contact 22, and CDC operates. Space is returned by the selector, lighting the supervisory. Upon ringing, voltage is fed via US4, C3, MR2 to operate AR. TN operates and starts the busy signal generating circuit. TN4 connects PRS in the selector to the busy signal common, and busy is returned to the switchboard.

Connection of a Local Machine

If so desired, number eight selector can be reserved for the connection of a local machine. This could be in the local Post Office, for instance, allowing for the passing of telegrams, etc., to subscribers off the concentrator. This machine does not however receive inward calls from subscribers. To allow this the allotter relay chain contacts SH2 and SH4 may be unstrapped at the terminal block, and SG in fact becomes the last relay in the allotter chain. BY is then strapped to SG4, causing busy to be signalled thereafter when the seventh selector is in use. The local machine is provided with a dial, and a ringing generator, or ring key if exchange ring is available. It is connected to the junction side of the selector, and would normally be a double current machine. When the local machine call key is thrown, the eighth selector is seized, and the desired number dialled. If the subscriber is busy the machine "bumps", but if free the machine "runs open", signifying that ringing may commence. Upon the subscriber answering the machine goes to mark and the message may be passed.

CONCLUSION

Although the next step forward in the Telex Service will be a conversion to automatic working, concentrators of the type described will still play an important part for many years to come. The concentrator after all is only a very small automatic exchange, and as such will become a part of the fully automatic system to provide service to difficult and outlying areas.

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1. "The Development of Teleprinter Exchange Service in Australia," R. McKinnon and D. McFadden; Telecommunication Journal of Australia, June 1958.

2. "Automatic Sub-centres for the New Telex Service," A. E. Forster and C. C. Turben; The Post Office Electrical Engineers' Journal, April 1955.

3. "An Automatic Teletypewriter Switching Office," G. J. Knandel; Bell Laboratories Record, October 1942.

TEST CRICKET SCORE SERVICE

*T. F. REED, A.M.I.E.E.

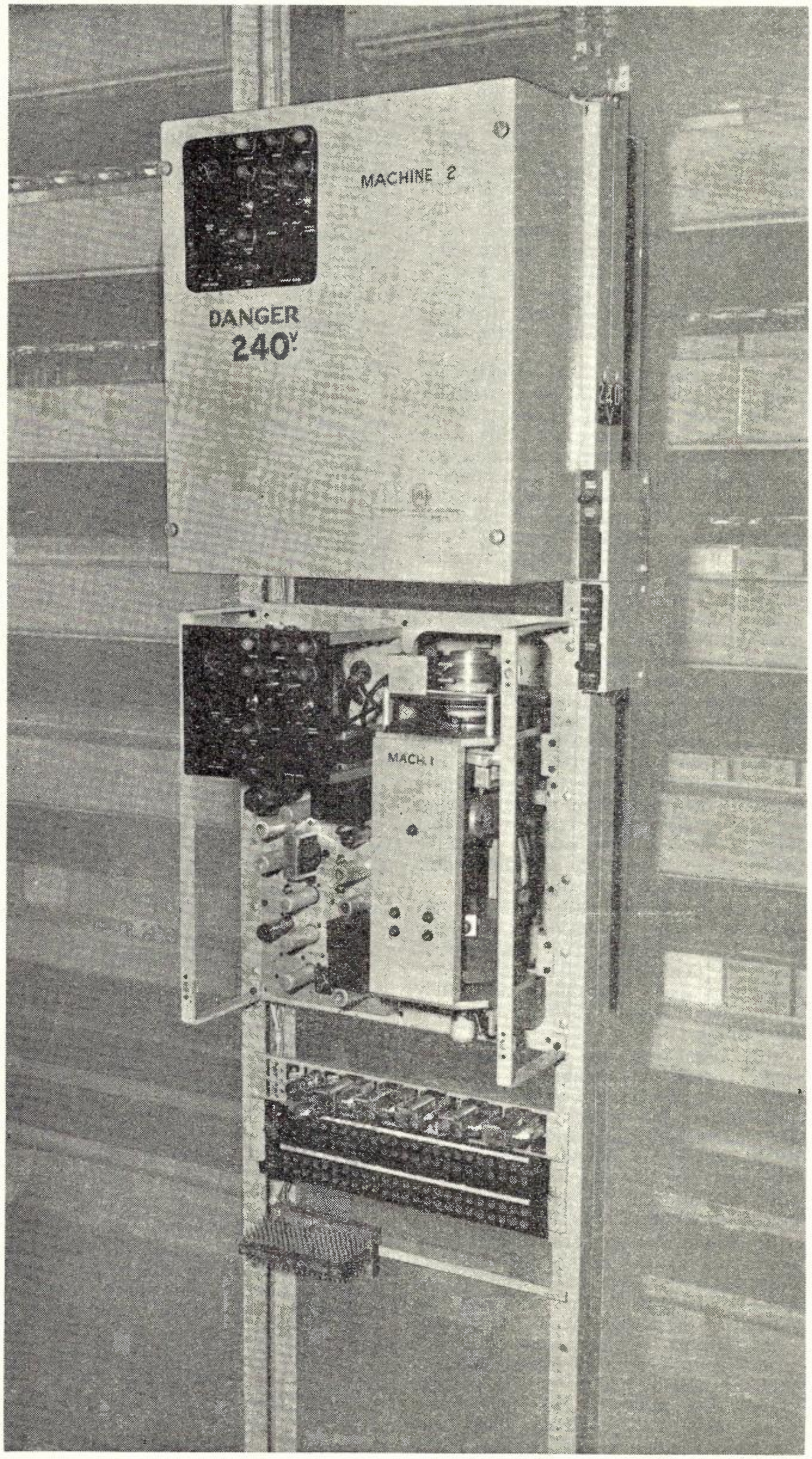

Fig. 1.—Typical Installation of Equipment for Test Cricket Score Service.

In many overseas countries the telephone administrations provide information services for their subscribers covering a wide range of subjects. In some cases as many as 20 different subjects are provided including:—

Time of day
Weather Forecast
Sporting Activities
Theatre and cinema programmes, etc., etc.

Some further details of these services are given in an article by A. W. McPherson in the October 1958 issue of the Journal Vol. 11 No. 5.

The Autralian Post Office has so far provided only Time of Day and Weather Forecast Services (1) as regular services and to gauge public reaction to the provision of further services it was decided to establish a temporary service to provide subscribers in the automatic exchange networks of each capital city with an automatic service giving progressive coverage of the recent series of cricket Test Matches during the M.C.C. Tour. Preliminary arrangements were at the time already in hand to extend the Weather Information Service which had proved so successful in Melbourne, to the other capital cities and at short notice this equipment and installation effort were diverted to provide a Cricket Score Service.

The machines for the Weather Information Service were ordered from a local firm, Byer Recording Division of Rola Co., Australia, who specialise in high class tape recorders and were based on the machines designed by the B.P.O. and described in their Engineers' Journal (2). At the time of approval of the establishment of the Cricket Score Service only a prototype machine had been made and little or no work in the States in the production of the necessary Relay Sets and the provision of switching had been carried out. It reflects considerable credit therefore on the contractor and the States Engineering staff that the initial supply of 10 machines to enable the service to be opened were manufactured, tested and air-freighted to all States (despite the fact that the period coincided with an Air Line Pilots strike) in 10 days and the States installation work engineered and completed in a few weeks.

The service opened in all State capitals on time on December 5, 1958 and despite the somewhat generous switch provision, based on the Weather Information Service experience, the service was completely congested with calls within the first few minutes and continued to the extent that extra circuit provision became a matter of urgency. The position was eased within the next 24 hours by further installation efforts and towards the end of the First Test most

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of the traffic was being satisfactorily handled. The Second Test occurred during a public holiday period and as a result the traffic was considerably less and advantage was taken of this respite to increase the switch provision and trunking still further.

The popularity of this service can be seen from the figures for effective calls given below and the effect of the increased trunking and switch provision between the 1st and 3rd matches is also apparent:—

Approx. effective calls in thousands

	1st Test	2nd	3rd	4th	5th	Total	Av. Calls per sub.
Sydney	342	169	625	475	288	1,899	5.9
Melbourne	364	146	508	383	281	1,682	6.1
Brisbane	195	45	134	119	70	563	6.1
Adelaide	133	43	135	117	62	490	7.2
Perth	106	49	118	123	77	473	9.1
Hobart	44	17	37	29	19	146	9.8

Grand Total—5¼ million calls. Estimated revenue £60,000.

By the time the 3rd Test Match was due to commence, Sydney had 220 circuits available, Melbourne 190, Brisbane 80, Adelaide 70, Perth 40 and Hobart 20. To prevent continuous holding of the circuits a forced release condition was applied at the relay sets, limiting calls to about three repetitions of the message.

With machines of this type it is possibe to record simultaneously with the transmission of the message to line and this was actually done on the Melbourne installation where only one machine was used. It does however call for an experienced operator and does not admit of any mistakes. A second machine was available in case of machine failure but this was not used.

These machines are provided with automatic gain control circuits to maintain a satisfactory recording level with varying microphone input levels due largely to the differing speech levels of different operators. This enables the machines to be operated from a remote position without technical assistance and also removes the need for any volume indicator at the control console. The carriage return mechanism is controlled by an electronic memory pulse automatically recorded on the drum at the end of the message. This memory pulse is picked up, rectified and amplified and used to actuate the release mechanism.

In addition to the metering facilities provided on the B.P.O. machines, the locally made machines have switch positions to enable the cathode currents of all valves to be checked. Certain other minor but important changes have been made to the mechanical details and to the electronic circuit and these have resulted in the production of a well designed sturdy machine which it is expected will prove to be reliable and trouble free in service. The control panel for these machines is illustrated in Figure 1 and a typical installation is shown in Fig. 2.

Fig. 2.—Control Panel for Test Cricket Score Service.

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1. The Melbourne Automatic Weather Information Service. T. F. Reed and D. Gillett. Telecom. Journal, June 1958, Vol. 11, No. 4.

2. An Experimental Answering Machine for Information Services. A. J. Forty and R. J. Turry. P.O.E.E. Journal, January, 1958, Vol. 50, Part 4.

CHANGE IN EDITORS

Mr. E. Bulte has been transferred to the Victorian Administration and because of this has resigned from the Editorial Board. Mr. Bulte has been an energetic member of the Editorial Board and improvements made to the Journal in this issue have been due in no small measure to his efforts. The Postal Electrical Society and the Board of Editors would like to thank Mr. Bulte for the excellent work he has done as Editor and offer him best wishes in his new position of acting Supervising Engineer, Metropolitan Service Section in the Victorian Administration.

Mr. R. Melgaard has agreed to join the Board of Editors in Mr. Bulte's place. Mr. Melgaard is a Divisional Engineer in the Telephone Equipment Section at Headquarters and his work involves the investigation of suggestions received by the Improvements Board. This work brings him into contact with a wide circle of Telephone Equipment personnel and he is, therefore, in an excellent position to carry out his editorial duties.

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,, 10	,, 1 - 6	,,	1954-57
,, 11	,, 1 - 5	,,	1957-59

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THE ALTERNATING CURRENT BRIDGE

J. V. FALL, B.E. (Hons.)

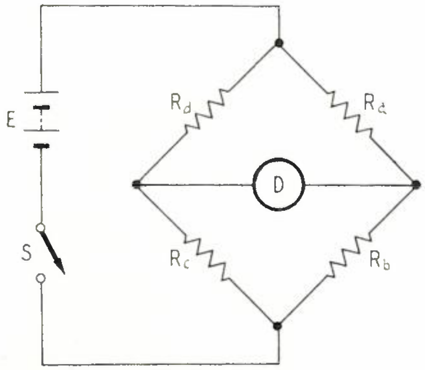

Fig. 1.—The D. C. Wheatstone Bridge.

The bridge network of Fig. 1 was first described by S. H. Christie, in 1833, just two years after Faraday's formulation of the law of electro-magnetic induction. Ten years later it was more publicly announced by Sir Charles Wheatstone with whose name it is associated. Although both DC. and AC. bridges are now available commercially and are extensively employed with elaborate sine wave sources and sensitive vacuum tube detectors, many of the circuits were developed by pioneers in the electrical field before sine wave generators were known.

In 1865, Maxwell developed the inductance bridge of Fig. 2. The bridge was balanced to DC. with the switch closed. The deflection of the ballistic galvanometer on opening the switch then gave a measure of the inductance. By including an adjustable standard inductance, a true null indicating bridge, Fig. 3 was obtained. With appropriate values of variable resistance and inductance, no deflection was obtained on the ballistic galvanometer on opening or closing the switch.

The first alternating current bridge was the double commutator network of Ayrton and Perry, in which a square wave alternating current was supplied to the bridge from a battery by a rotating commutator. On the same shaft a second commutator rectified the current to the galvanometer so that a unidirectional deflection was obtained. In 1891, Wien developed a bridge with an induction coil as a sine wave source and a simple vibration galvanometer as detector.

*Mr. Fall is a Lecturer in the Engineering Department, University of Western Australia.

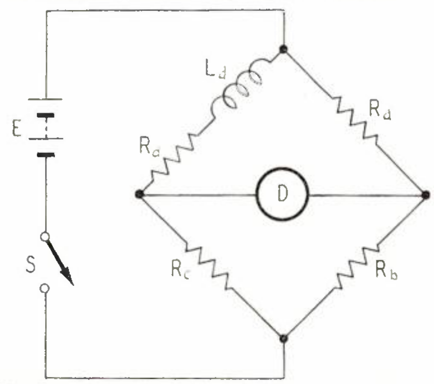

Fig. 2.—Maxwell's Ballistic Bridge. The switch S is closed and the bridge balanced to give a resistance balance. The inductance is determined by the deflection of the galvanometer on opening the switch.

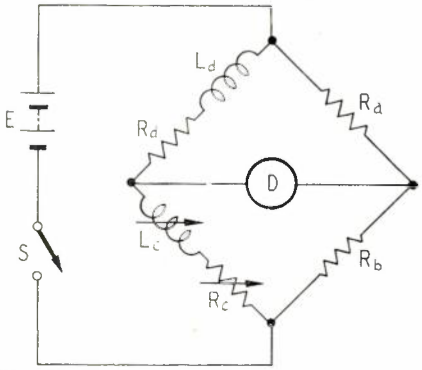

Fig. 3.—Maxwell's Inductance Bridge. L_d and R_d are measured in terms of the variable standards L_c and R_c, by adjusting these standards until no indication is obtained on the galvanometer on opening or closing the switch S.

BRIDGE THEORY

Conditions for Balance: Fig. 4 shows the general alternating current bridge in which all four arms may be complex impedances. The network is supplied from a sine wave source of voltage **E** at points A and C. The detector is connected between D and B. For balance no current flows through the detector, and hence there is no potential difference between D and B. The balance equations may be derived as follows:

With no detector current flowing at balance, the same current $\mathbf{I_1}$ flows through $\mathbf{Z_d}$ as flows through $\mathbf{Z_c}$; also the same current $\mathbf{I_2}$ flows through $\mathbf{Z_a}$ as flows through $\mathbf{Z_b}$. The applied voltage exists across $\mathbf{Z_a}$ and $\mathbf{Z_b}$ in series and also across $\mathbf{Z_d}$ and $\mathbf{Z_c}$ in series. Hence:

$$I_1 = \frac{E}{Z_d + Z_c} \; ; \; I_2 = \frac{E}{Z_a + Z_b}$$

Also the potential across $\mathbf{Z_c}$ equals the potential across $\mathbf{Z_b}$ and

$$I_1 Z_c = I_2 Z_b$$

giving:

$$\frac{E Z_c}{Z_d + Z_c} = \frac{E Z_b}{Z_a + Z_b}$$

and:

$$Z_a Z_c = Z_b Z_d$$

or

$$\frac{Z_a}{Z_b} = \frac{Z_d}{Z_c}$$

which is the balance equation.

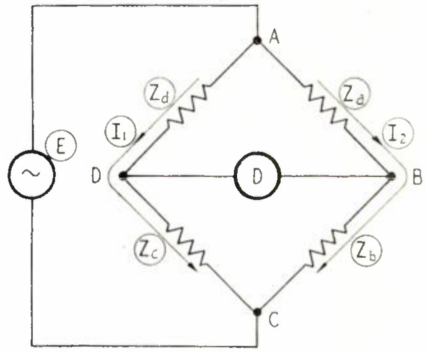

Fig. 4.—The General A.C. Bridge. The currents are shown for the balanced condition in which there is no voltage from D to B and no detector current.
At balance: $Z_a Z_c = Z_b Z_d$

Any combination of impedances which can satisfy this equation may be used in a bridge. However, certain bridges have been evolved which have advantages for particular purposes.

Independent Balance: In a bridge employing complex impedances two elements must be adjusted to obtain a balance. Both a "resistance" and a "reactance" balance must be made, and it is desirable that these balance controls should be independent of each other.

Consider a bridge employed to measure the value of a resistance and inductance in series. On balancing it would be desirable for one control knob to be determined in position by the resistance alone, and the other by the inductance alone. One control could be calibrated in terms of resistance, the other in terms of inductance. A quickly convergent balance would be obtained with this bridge, as relatively few manipulations of the two controls would be required to produce a null. Independent balance is achieved in the Maxwell bridge of Fig. 5

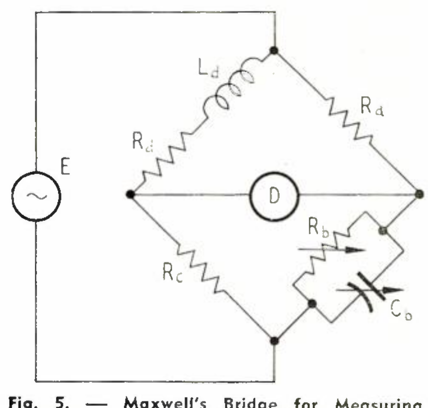

Fig. 5. — Maxwell's Bridge for Measuring Inductance in Terms of Capacitance. At balance: $L_d = R_a R_c C_b$; $R_d = \frac{R_a R_c}{R_b}$

This gives independent balance if R_b and C_b are varied to achieve balance.

provided the balance is produced by varying R_b and C_b. The balance equations for this bridge are:

$$C_b = \frac{L_d}{R_a \ R_c} \text{ and}$$

$$R_b = \frac{R_a \ R_c}{R_d}$$

The value of C_b required for balance depends on the value of the inductance L_d, but not on the value of the resistance R_d. The dial of C_b can therefore be directly calibrated in terms of inductance. In the same way the value of R_b at balance depends only on R_d and not on L_d.

An objection to this type of bridge is that an expensive variable decade capacitor must be employed. Commercial bridges often employ variable resistors only, the advantages of independent balance usually being lost thereby. Fig. 6 shows a Hay bridge for measuring inductance, in which R_b and R_c may be varied to obtain balance.

The balance equations are:—

$$R_c = \frac{R^2_d + \omega^2 L^2_d}{\omega^2 R_a \ L_d \ C_b} \text{ and}$$

$$R_b = \frac{R_a \ R_c \ R_d}{R^2_d + \omega^2 L^2_d}$$

The value of R_c and R_b depends on both R_d and L_d so that independent balance is not achieved. From a practical point of view it is interesting to note that these equations can be rearranged as:—

$$R_c = \frac{L^1_d}{R_a C_b} \text{ and } R_b = \frac{1}{Q \ \ C_b}$$

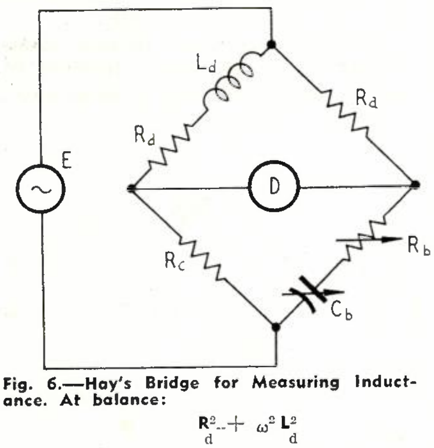

Fig. 6.—Hay's Bridge for Measuring Inductance. At balance:

$$R_c = \frac{R^2_d + \omega^2 L^2_d}{\omega^2 R_a L_d C_b}$$

$$R_b = \frac{R_a R_c R_d}{R^2_d + \omega^2 L^2_d}$$

R_c and R_b are often varied to obtain balance. Independent balance is not achieved.

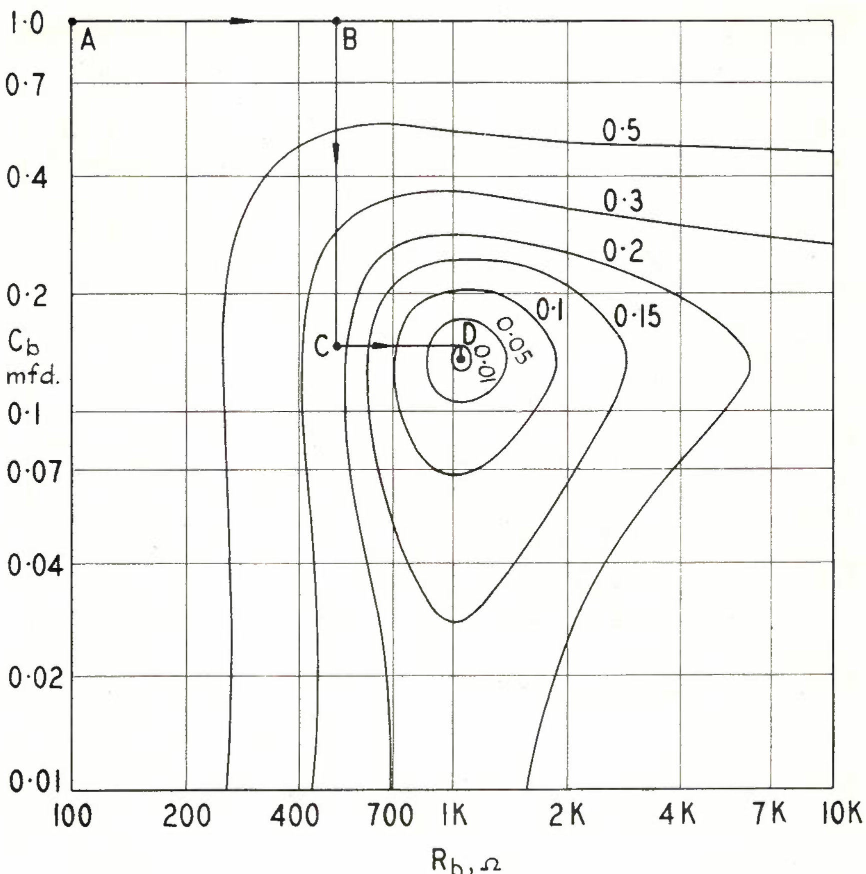

Fig. 7.—Contour Map of the Detector Voltage as a Function of the Balancing Components for a Particular Maxwell Bridge, Balancing with R_b and C_b. A rapid convergence is obtained.

where

$$Q = L_d/R_d \text{ and } L_d = \frac{Q^2}{1 + Q^2} L^1_d.$$

For a given frequency R_c can be calibrated directly in terms of L^1_d, which is approximately L_d if the Q factor is over 10, and R_b can be calibrated directly in terms of Q factor. This is a useful type of calibration.

Convergence of Balance: The rate of convergence of a bridge balance and the difficulties of a sliding balance can be illustrated with the aid of the contour maps of Figs. 7 and 8. Both were drawn for bridges measuring the same low Q factor inductor. Fig. 7 refers to a Maxwell bridge and Fig. 8 to a Hay bridge. In a Maxwell bridge for any setting of the balance controls C_b and R_b there will be a certain output voltage at the detector terminals. If C_b is altered to a new value a corresponding value of R_b can usually be found for which the detector voltage remains unchanged. In fact, there are a large number of combinations of these components which always give the same output voltage at the detector terminals. It is, therefore, possible to draw a graph plotting C_b against R_b, marking in contour lines representing constant detector voltage. In Fig. 7 these lines are drawn for detector voltages from 0.5 to 0.01 volts, while the central dot represents the zero voltage contour which is the required balance point.

The problem of bridge balance is to enter this graph at an arbitrary point, corresponding to arbitrary initial values of balancing components, and by successive adjustment to locate the zero point. If initially $C_b = 1\mu F$ and $R_b = 100\Omega$ (point A in Fig. 7), the detector voltage will decrease on increasing the value of R_b until the point B is reached, after which it will again increase. This is the first step in the partial balance. Setting the resistance to the point B, the capacitance C_b is now decreased, the detector voltage again decreasing, reaching a minimum at the point C. Next, holding the capacitor set at this value the resistance is again varied to obtain a minimum at the point D. One final adjustment of capacitance is now sufficient to produce a satisfactory null.

This is an example of a good, quickly convergent balance. It is convenient to liken the process to the problem of a man situated in a country of which Fig. 7 is a contour map. Starting from an arbitrary position, this man endeavours to locate the deepest depression in the land by first walking east until the lowest point is reached, then turning and walking south until a lower point is reached. After this he again turns east or west and endeavours to find succes-

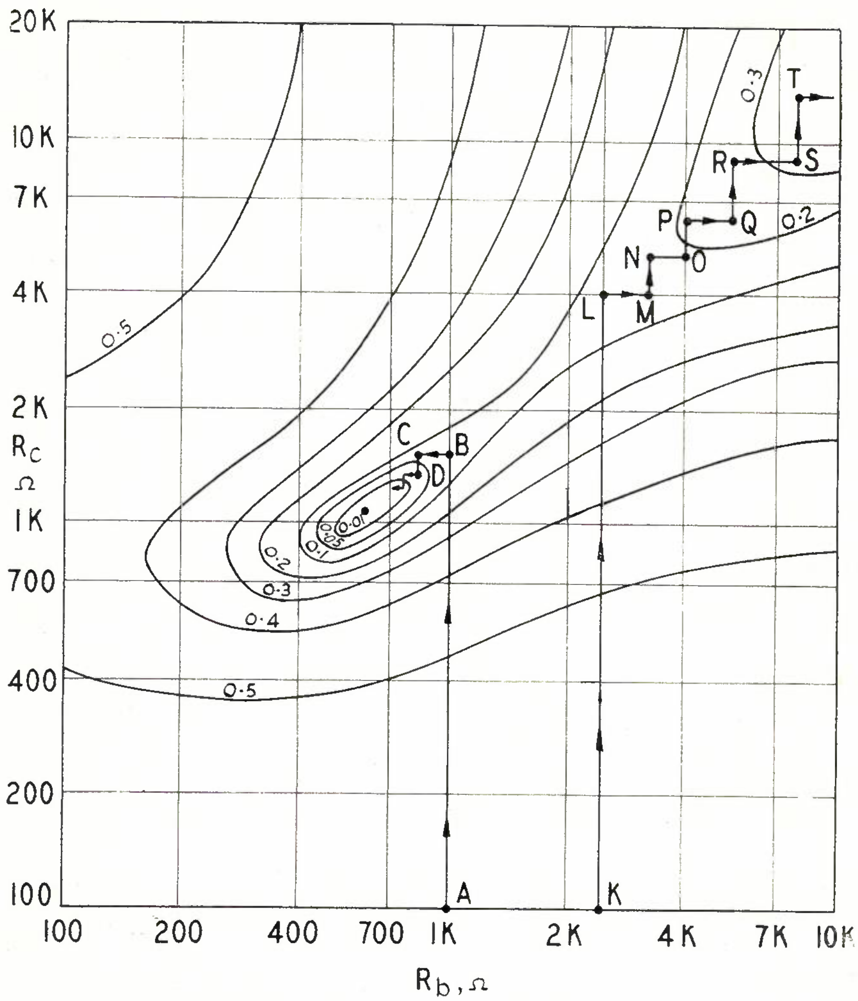

Fig. 8.—Contour Map for a Hay Bridge, Balancing with R_b and R_c, with a low Q Factor Inductor. A difficult balance with slow or misleading convergence is obtained.

sively lower and lower points. With the type of contour depicted in this figure, if the man is constrained to walk only north and south, or east and west, at a given time, then he will eventually reach the lowest point he seeks.

This is not necessarily the case for the sliding balance of the Hay bridge, whose contour map is drawn in Fig. 8. Here balance is carried out by means of the resistances R_b and R_c. This contour map depicts the balance point as the centre of a deep depression located at R_c = 1,050Ω and R_b = 610Ω, with the ground rising rapidly on all sides. A valley runs in the upper right half of the diagram, the floor of the valley climbing out of the null point and reaching a maximum height in the region X (R_c = 2,200, R_b = 1,600), and then dropping to lower values.

The sliding balance is illustrated as follows: If R_b is set to 1,000Ω a partial balance is obtained for R_c = 1,600Ω; if R_b is set to 2,500Ω, then the partial balance is obtained at quite a different value of R_c, namely, 4,000Ω. The balance point of one component appears to slide to a new value every time the other component is altered. If the components are initially at A, a slow and tedious balance results, as illustrated by the succession of points, B, C, D . . . It is even possible to be led away from the balance point rather than towards it in this type of bridge, as illustrated by the succession of points K, L, M, N. . . .

It should now be clear that care should be exercised in selecting a bridge and the type of balancing controls used when measuring certain types of impedance (particularly those with roughly equal resistance and reactance).

Bridges with independent balance controls are to be preferred because of the ease of balance and of calibration. Bridges with dependent balance controls can, however, be successfully employed provided the Q factor of the unknown impedance is not close to unity.

Ratio Bridges: It is possible to classify most bridges according to the manner in which they are used, as either ratio bridges or product bridges; it is possible to draw up the conditions necessary for these bridges to give independent balance.

If, in the bridge of Fig. 4, Z_d is regarded as the unknown impedance to be measured, then at balance:

$$\mathbf{Z}_d = \frac{\mathbf{Z}_a}{\mathbf{Z}_b} \mathbf{Z}_c$$

The bridge is employed as a ratio bridge if the impedances $\mathbf{Z}_a$ and $\mathbf{Z}_b$ are held fixed in a given ratio $\mathbf{A} = \frac{\mathbf{Z}_a}{\mathbf{Z}_b}$, and balance obtained by varying $\mathbf{Z}_c$. If $\mathbf{Z}_d$ consists of a resistance R_d in series with a reactance X_d, and if $\mathbf{Z}_c$ consists of a resistance R_c in series with a reactance X_c, then:

$\mathbf{Z}_d = R_d + jX_d$; $\mathbf{Z}_c = R_c + jX_c$

and $\mathbf{Z}_d = \mathbf{A}\,\mathbf{Z}_c$, giving $R_d + jX_d$
$= \mathbf{A}\,(R_c + jX_c)$.

Independent balance will only result if the complex bridge ratio $\mathbf{A} = A\angle\theta$ possesses angle θ either zero or $\pm 90°$.

Consider firstly, that θ, the angle of the ratio, is zero. This means that the impedances $\mathbf{Z}_a$ and $\mathbf{Z}_b$ are impedances of the same type. They could both be resistances, both pure capacitances, or perhaps even the two halves of the winding of a transformer bridge. Then:
$\mathbf{A} = A + j0$
and the balance equations become:
$R_d = AR_c$; $X_d = AX_c$.
R_c can be calibrated directly in terms of R_d, and X_c can be calibrated directly in terms of X_d. Independent balance is achieved.

The De Sauty capacitance bridge of Fig. 9 is used in this manner.

If the angle θ is $\pm$ 90°; one component could be a resistance, the other a capacitance. Then:
$\mathbf{A} = 0 \pm jA$
and the balance equations become:
$R_d + jX_d = \pm jA(R_c + jX_c)$, so that $R_d = \mp AX_c$; $X_d = \pm AR_c$.

Clearly, independent balance results and X_c can be calibrated in terms of R_d, and R_c can be calibrated in terms of X_d.

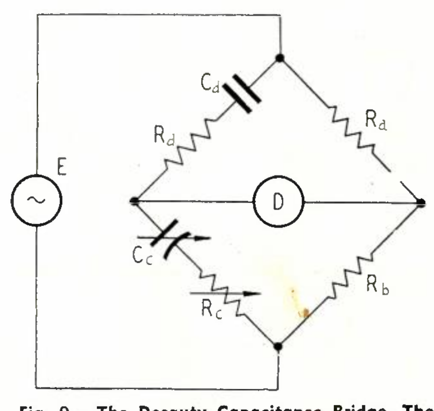

Fig. 9.—The Desauty Capacitance Bridge. The ratio $A = R_a/R_b$ is held fixed, and the unknown components R_d and C_d determined by adjustment of R_c and C_c. At balance: $R_d = AR_c$; $C_d = C_c/A$

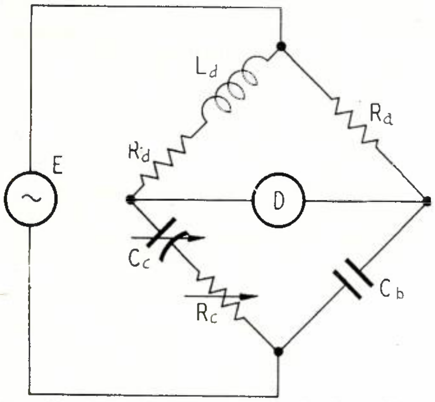

Fig. 10.—The Owen Inductance Bridge. The ratio $A = j\omega R_a C_b$ is held fixed. At balance:

$$R_d = \frac{R_a C_b}{C_c};\quad L_d = (R_a C_b) R_c$$

The Owen bridge in Fig. 10 is an example of this type of ratio bridge.

Product Bridges: The basic balance equations for a bridge may be rearranged in the following form:

$$Z_d = \frac{Z_a Z_b}{Z_b} = Z_a Z_c Y_b$$

where $Y_b = \dfrac{1}{Z_b}$

The bridge is employed as a product bridge if the impedances Z_a and Z_c are fixed in a given product value:

$$\mathbf{Z}_a \mathbf{Z}_c = \mathbf{P} = P\angle\phi$$

and balance obtained by varying Z_b.

If $\mathbf{Z}_d = R_d + jX_d$, and if Z_b can be expressed as its admittance:

$\mathbf{Y}_b = G_b + jB_b$, where one balancing knob controls the conductance G_b alone and the other controls the susceptance B_b alone, then independent balance can be achieved if the angle ϕ of the product value P has value zero or $\pm 90°$.

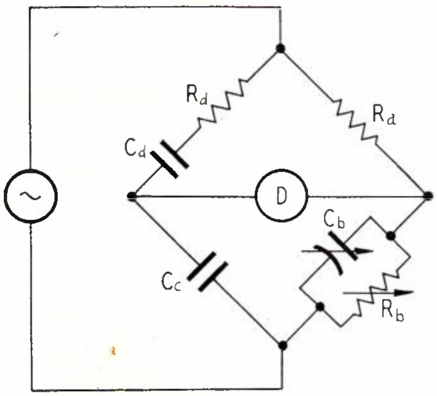

Fig. 11.—The Schering Bridge. The product $P = \dfrac{R_a}{j\omega C_c}$ is held fixed. At balance:

$$R_d = \frac{R_a}{C_c} C_b;\quad C_d = \frac{C_c}{R_a} R_b$$

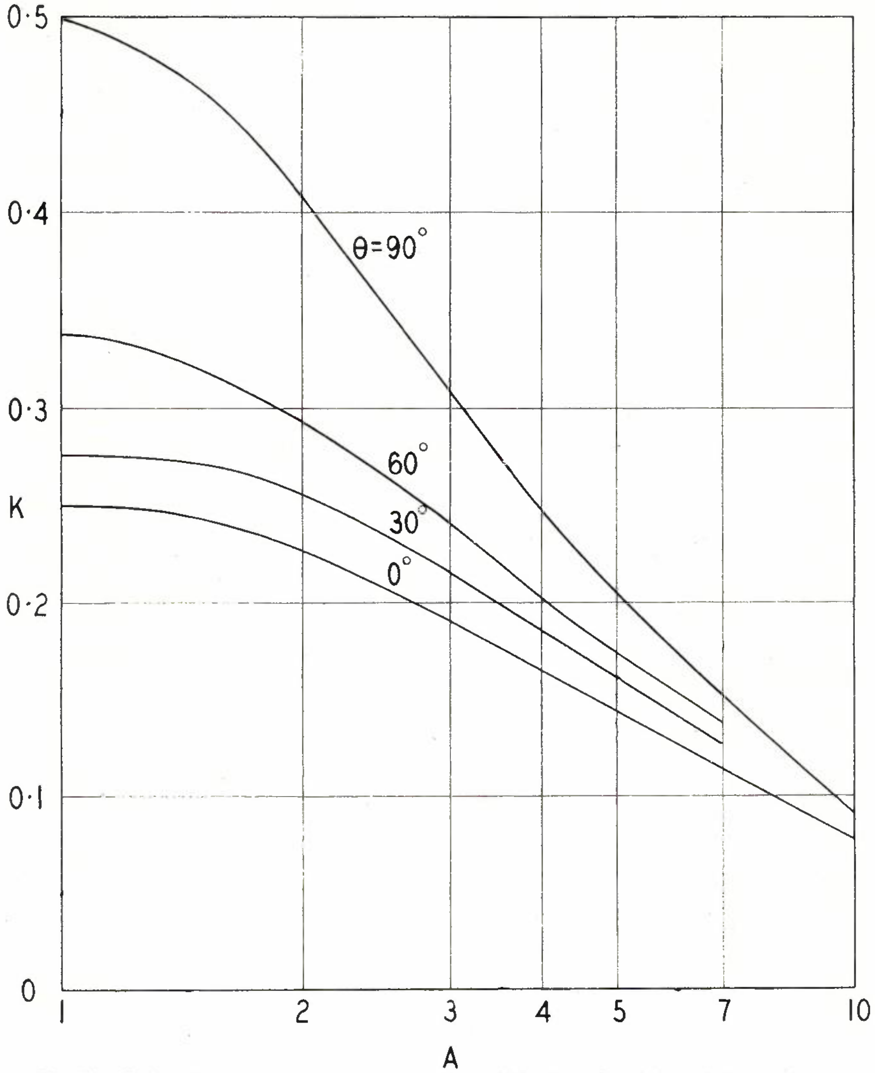

Fig. 12.—Bridge Sensitivity Factor as a Function of the Complex Bridge Ratio $A = A\angle\theta$.

When $\phi = 0$, $\mathbf{P} = P + j0$ and the basic equation becomes:

$$R_d + jX_d = P(G_b + jB_b)$$

R+jX=P(G+jB)

giving:

$$R_d = PG_b;\ X_d = PB_b.$$

The control varying the conductance G_b can now be calibrated in terms of the unknown resistance R_d, while the control varying the susceptance B_b can be calibrated in terms of the reactance X_d.

This method of bridge operation is typified by the Maxwell bridge of Fig. 5. The impedance Z_b is arranged as a resistance R_b in parallel with a capacitance C_b. The conductance of the arm is thus $G_b = 1/R_b$ whilst the susceptance B is ωC_b.

The product value is $\mathbf{P} = R_a R_c$.

It can be shown that if the angle of the product value becomes $\pm 90°$ the balance equations become:

$$R_d = \mp PB_b;\ X_d = \pm PG_b.$$

The Schering bridge of Fig. 11 is an example of this type of bridge.

It will be noticed that in the ratio bridge, the balancing arm consists of two simple elements connected in series, whilst in the product bridge the two elements are usually connected in parallel.

Bridge Sensitivity: It has been shown that a quickly convergent balance is a desirable feature, and that this can be obtained by employing a bridge with independent balancing controls. Of equal importance is the precision to which the balance can be obtained. If it is desired to measure a component to an accuracy of 1%, it is necessary to ensure that the bridge itself can be balanced to a precision better than 1%. Balance precision may be limited by the smallest value of the discrete steps of variation of the balancing components, or by the inability of the detector to observe the small values of detector voltage as balance is approached. Interfering voltages at the detector terminals such as 50 c/s hum or harmonics of the applied voltage may also mask the voltage to be measured and thus limit the precision.

A bridge of high sensitivity is required in order to gain high precision. This sensitivity may be defined as the change in detector voltage per unit of applied voltage, when the bridge is near balance, caused by a fractional change in balancing impedance.

Let a voltage **E** volts be applied to a ratio bridge. At balance the detector voltage will be zero and the balancing impedance, $\mathbf{Z}_c$. If now this impedance is altered by a value $\delta \mathbf{Z}_c$, where this change is very small, then a small voltage will appear at the detector terminals. The bridge sensitivity factor is then defined by:

$$K = \frac{\dfrac{\delta V}{E}}{\dfrac{\delta Z_c}{Z_c}}$$

which may be arranged as:—

$$\delta V = K \beta E \quad \ldots \quad (1)$$

$$\text{where } \beta = \frac{\delta \mathbf{Z_c}}{Z_c}$$

It would be an advantage for the sensitivity factor K to be as high as possible.

From the general bridge of Fig. 4, the detector voltage for infinite detector impedance is:—

$$\left[\frac{Z_c}{Z_c + Z_d} - \frac{Z_b}{Z_a + Z_b}\right] E$$

If Z_c is equal to the required balance value this voltage is zero. When this impedance is increased by δZ_c, the detector voltage becomes:

$$\frac{\delta V}{E} = \left[\frac{Z_c + \delta Z_c}{Z_c + \delta Z_c + Z_d} - \frac{Z_b}{Z_a + Z_b}\right]$$

This can be written as:—

$$\frac{\delta V}{E} = \left[\frac{1 + \beta}{1 + \beta + A} - \frac{1}{1 + A}\right]$$

$$= \frac{A \beta}{(1 + \beta + A)(1 + A)}$$

$$\text{where } A = \frac{Z_a}{Z_b} = \frac{Z_d}{Z_c}$$

Since β is very much smaller than unity, this last equation can be simplified and written:—

$$\delta V = \frac{A \beta}{(1 + A)^2} E \quad \ldots \quad (2)$$

If this is compared with equation (1), it can be seen that the value of the sensitivity factor is:—

$$K = \frac{A}{(1 + A)^2}$$

For an infinite impedance detector this depends on the bridge ratio alone.

If $A = A \angle \theta = A(\text{Cos}\theta + j\text{Sin}\theta)$, the magnitude of the sensitivity factor becomes:

$$K = \frac{A}{1 + 2A\text{Cos}\theta + A^2}$$

Examination of this relationship shows that for any single angle θ, the sensitivity is always a maximum for $A = 1$, this value being

$$K_{max} = \frac{1}{2(1 + \text{Cos}\theta)} = \frac{0.25}{\text{Cos}^2 \tfrac{1}{2}\theta}$$

For a unity ratio bridge with $\theta = 0$, $K = 0.25$; with $\theta = 90^\circ$, $K = 0.5$. A curve of the sensitivity factor as a function of A for various values of angle θ is given in Fig. 12. Values of K for 1/A are the same as those for A.

It can be seen that when the bridge ratio exceeds 10 the sensitivity factor is nearly 1/A for all values of θ.

Unity ratio bridges although desirable from the sensitivity viewpoint may not be convenient in certain practical measurements. Wide range commercial bridges commonly employ a single set of balancing impedances and increase the range of the instrument by changing the bridge ratio in decade steps from, say, 0.001 to 1000. Clearly the sensitivity of balance would drop at the limits of these ratios. The Schering bridge employed to measure the capacitance and loss of high voltage components is a further example of a high ratio bridge.

The Bridge Detector: The sensitivity of a detector required to achieve a certain balance precision may be calculated readily. Suppose a bridge with an infinite impedance detector is to be balanced to a precision of 0.1% and that a total of 10 volts is applied to the bridge. With zero angle unity ratio arms, the detector must be able to observe a voltage $\delta V = K\beta E = 0.25 \times 0.001 \times 10 = 2.5$ mvolts.

If the bridge employed 100 : 1 ratio arms, this voltage would be 100μvolts.

For many practical cases where extreme precision is not required a highly sensitive detector is not therefore necessary. In some circumstances a detector with a sensitivity of 10 μvolts or better may be needed, as in the measurement of a non-linear component, where only a small voltage can be applied to the bridge; again a sensitive detector may be required to achieve even moderate precision of balance for a component which forms but a small portion of the total impedance being measured. This may occur when measuring the resistance of a high Q factor inductor.

The preceding work on sensitivity has been written with reference to infinite impedance detectors. The input impedance of vacuum tube detectors, although not infinite, is often of the order 10^6 to $10^9\Omega$ and for low impedance bridges may be taken as infinite. If the detector impedance is not high compared with the internal impedance seen looking back into the bridge from the detector terminals, the detector voltage is less than that given by equation 1. If the utmost sensitivity is required it is normal to match the detector impedance to the internal impedance of the bridge by means of a suitable transformer. This transformer should have turns ratio 1 : $\sqrt{Z_2/Z_1}$ where the magnitude of the bridge impedance is Z_1 and that of the detector Z_2.

Added sensitivity can be obtained with infinite impedance detectors by connecting a step up transformer between the bridge and the detector. The load on the bridge is now equal to the impedance of the primary winding which should not be less than the internal impedance of the bridge.

In addition to sensitivity and high input impedance it is desirable for a bridge detector to be tuned to the wanted frequency so that it is insensitive to unwanted interfering voltages.

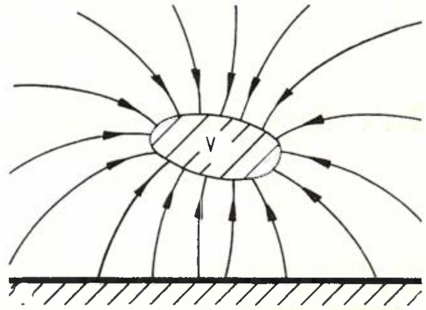

Fig. 13 (a).—Electrostatic Field betwen a Conductor at Potential V and Earth.

SHIELDING AND EARTHING BRIDGES

Whenever a conductor, Fig. 13, is maintained at a potential V above earth potential, an electrostatic field is set up between induced charges on the surface and earth. From the circuit theory point of view it may be stated that a capacitance exists between the conductor and earth, the value being such that the energy stored in the electrostatic field is given by $\frac{1}{2}CV^2$. If any two points are at a different potential, an electrostatic field will exist between them, and this can always be represented by capacitance between the two points. If two separate conductors are maintained at different potentials, there will be not only a capacitance between them, but also a capacitance from each conductor to ground.

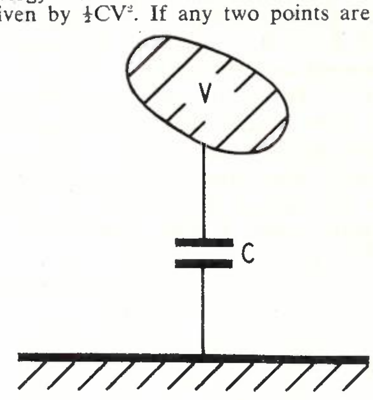

Fig. 13 (b).—Circuit Representation of Electrostatic Field, by Means of a Capacitance between Conductor and Earth. Energy stored in the capacitance must equal the energy stored in the field.

Equivalent Circuit of a Resistor: If current is passed through a resistor, a continuous voltage drop occurs along it from one end to the other. No two

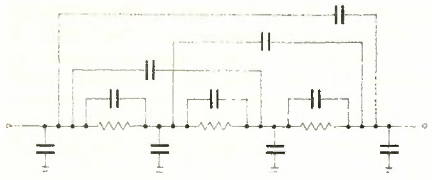

Fig. 14.—Capacitance Distribution on a Resistor Considered to be made up of Three Parts. Complete representation would require the resistor to be broken up into an infinite number of small parts with capacitance between each.

points on the resistor are at the same potential. An exact representation of the component as a circuit element would then show capacitance from every point to every other point and also from every point to earth. Fig. 14 illustrates the situation for a resistor considered to act as three sections only. This is too complicated an equivalent circuit for general use, practical simplifications being shown in Fig. 15 for a simple resistor, inductor and capacitor. It can be seen that the element is represented as a three terminal element with capacitance from one end to the other, together with capacitance from each end to ground. Although the value of a resistor may be fixed, it is clear that the value of the capacitances associated with it will depend on the physical relation of the component to earth which may vary from time to time.

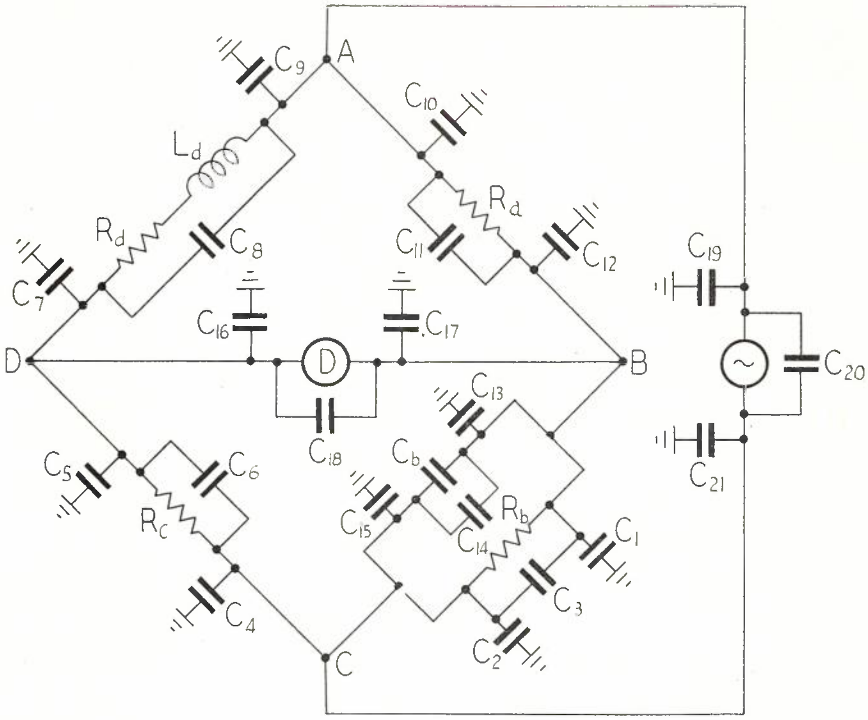

Fig. 16.—A Maxwell Bridge showing the presence of Earth Capacitances which upset the balance.

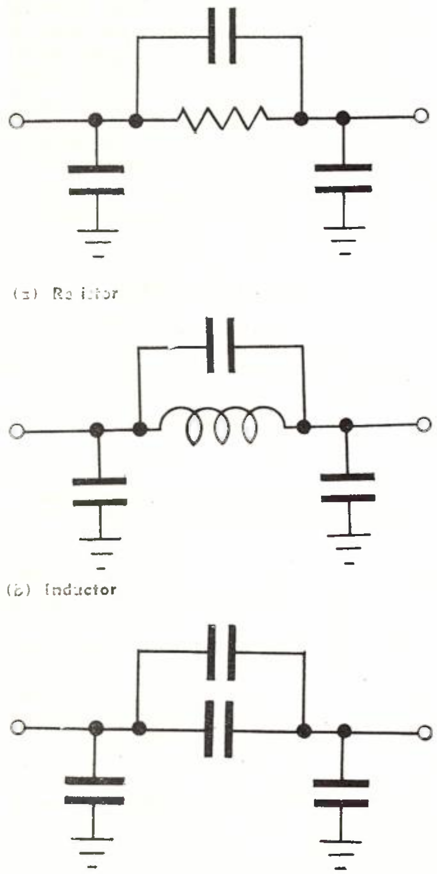

Fig. 15.—Practical Equivalent Circuits of Basic Components.

Earth Capacitance in Bridges: A bridge circuit consists of an assemblage of components all of which possess self capacitance and also capacitance to ground. It is not surprising, therefore, that these upset the balance of the bridge. That this will occur can be seen from the diagram for the Maxwell bridge in Fig. 16, showing the various earth capacities. By combining various capacities, this may be simplified to Fig. 17. For the precision use of a bridge it is necessary that these capacitances be either eliminated or taken into account.

Imagine that the point B on the bridge is physically earthed. Since this point is brought to earth potential, the capacitance C_f is automatically short circuited. Furthermore, at balance the point D is brought to the same potential as B, that is, it becomes a virtual earth, and no current can flow through the capacitances C_h or C_q; these will not therefore introduce errors in the bridge. Capacitance C_p is across the source of EMF and likewise cannot alter the balance equations. C_e is now parallel with C_k, and C_g is in parallel with C_m. These alone remain, together with C_j and C_n. Precision measurements can be carried out only if these capacitances can be measured or decreased to such a small value that they can be neglected.

Shielding of Components: Electrostatic shielding may be introduced to eliminate capacitance between certain portions of a bridge and to reduce others to a fixed calculable value which may be taken into account. Consider a resistor, Fig. 18, completely enclosed in a conducting box, connected to one end of the resistor. With the passage of current, a voltage drop will occur setting up an electrostatic field between the resistor and the inside of the box. No direct field will exist between the resistor and earth since the complete shielding forces all the electrostatic lines of force emanating from the resistor to terminate on the box. There will, however, be an electrostatic field between the outside of the box and earth. There will thus be a fixed, calculable capacitance across the resistor and also one from the box to earth, which will vary with the position of the box with respect to earth. The equivalent circuit, Fig. 18(c), shows a capacitance from D to C, one from D to ground, but no capacitance from C to ground.

If a bridge is constructed with shielded components, with the shielding box at all times connected to the side of the component nearest the detector, all capacitances from the boxes to ground will become a part of C_h or C_f in Fig. 17, and will not alter the balance. The shunt capacitances across the components are fixed and their effect may be calculated. The box shielding eliminates capacitances C_1, C_{10}, C_2, C_{15} and C_{14} in Fig. 16, so that capacitances C_e and C_g reduce to C_{19}, C_{21} being the capacitance of the two sides of the voltage source to ground.

Source Impedance to Ground: If a bridge is carefully constructed of shielded components, the effect of source impedance to ground can readily be determined by balancing the bridge and

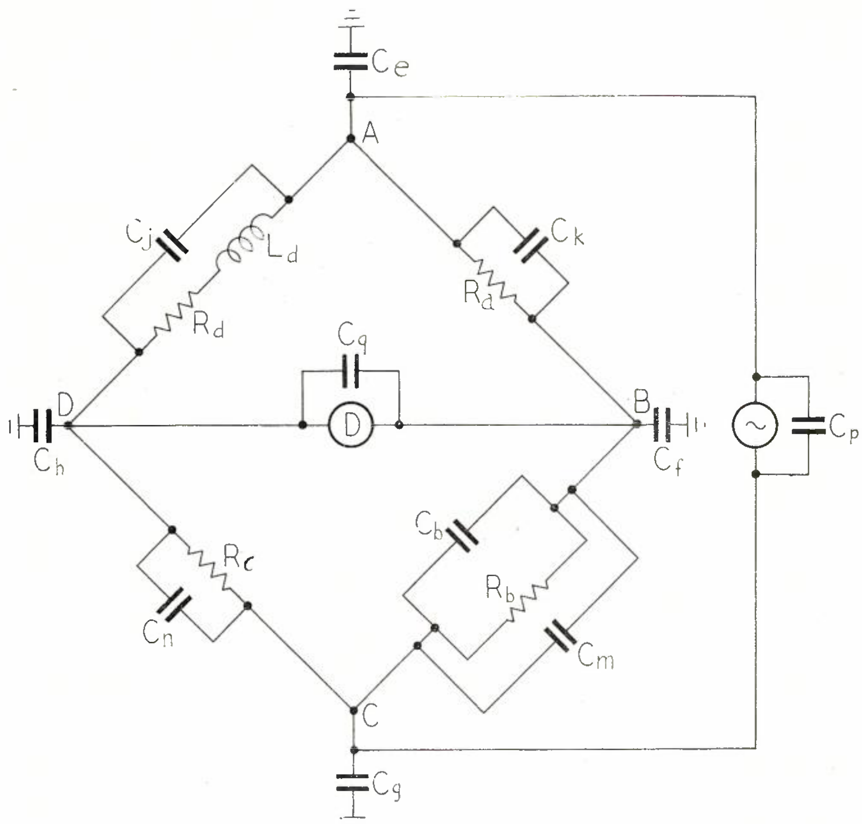

Fig. 17.—Simplification of Fig. 16. $C_f = C_{12} + C_1 + C_{13} + C_{17}$ and so on.

then reversing the polarity of the connections of the source. This interchanges the capacitances C_e and C_g, and will cause the bridge to unbalance. If the unbalance is severe, the effect may be reduced in one of two ways:

(i) By the introduction of a carefully shielded and balanced transformer between the source and the bridge in an endeavour to reduce the magnitude of the capacitances.

(ii) By the addition of further capacitance to C_e and C_g in such a manner that the bridge ratio formed by Z_a and Z_b, neglecting these capacitances, is not altered by their presence. This method is called the Wagner ground.

In a bridge transformer, the secondary winding which supplies the bridge is carefully shielded from the primary. Only mutual inductance coupling appears between the windings. The effective capacitance to earth from each side of the secondary is now the capacitance to earth of the secondary winding itself which is completely isolated electrostatically from the primary. With careful design these capacitances can be kept small and nearly identical so that they may often be neglected in bridge operation. This is particularly true of a unity ratio bridge, since the ratio is not greatly upset by the presence of two shunting capacitances of almost the same value. However, if a high ratio bridge is to be employed, or if high precision is required, a Wagner ground must be employed.

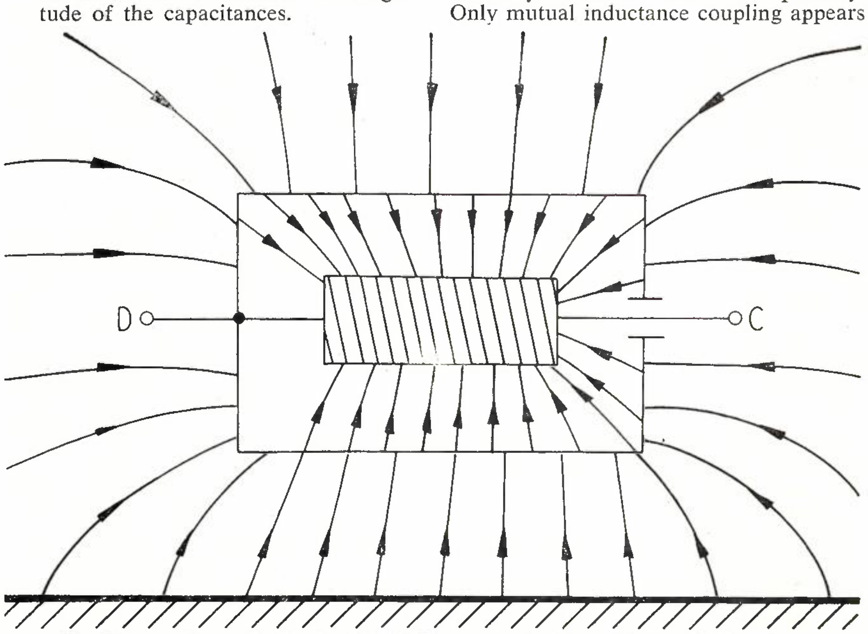

Fig. 18(a).—Shows the Electrostatic Field associated with a Shielded Resistor Box.

The Wagner Ground: Consider the bridge of Fig. 19. Here Z_e and Z_g are the impedances to ground of the source itself. Let additional adjustable impedances be placed in parallel with these, so that the total impedance to ground from the point A of the bridge is Z_e and from point C, Z_g. The point E is earthed. Consider that a ratio bridge is represented so that Z_a and Z_b are fixed. With the detector connected between the points B and E, a null is obtained by varying Z_e or Z_g, thus bringing the point B to earth potential. This brings the ratio of Z_e to Z_g to the same value as the ratio of Z_a to Z_b. The detector is now connected across B and D and the bridge balanced by varying Z_c. This brings the point D to the same potential as the point B. By repeating these adjustments several times, the points B and D are brought accurately to earth potential, and the ratio of the bridge is not altered by the presence of Z_e and Z_g, so that no errors are introduced by these source impedances, and high precision measurements may be carried out.

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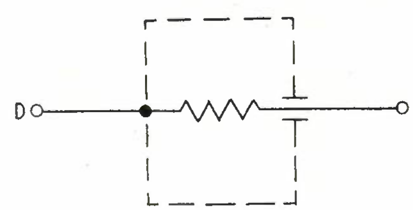

Fig. 18.(b) Depicts a Conventional Circuit Diagram showing a Shield.

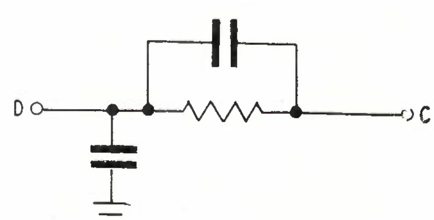

Fig. 18(c).—Indicates the Equivalent Electrical Circuit.

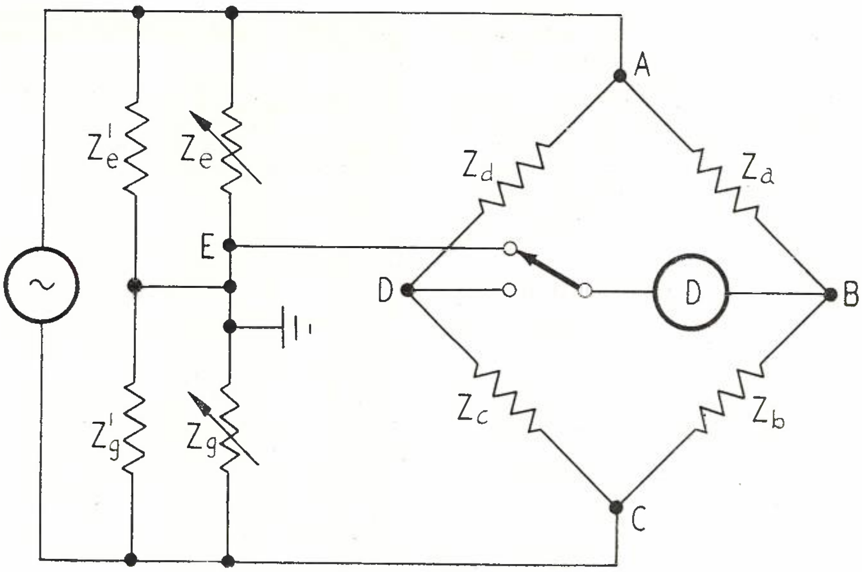

Fig. 19.—The Wagner Ground.

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ACKNOWLEDGEMENT

The Author wishes to thank Mr. K. W. Taplin for reading the manuscript and for making a number of valuable suggestions.

AN APPLICATION OF KEY SENDERS TO A LARGE P.A.B.X.

*E. J. ANGEL, A.M.I.E.Aust.**

INTRODUCTION

The first building erected on the site of the "Commonwealth Centre" in the City of Melbourne was opened by the Prime Minister of Australia, The Right Honorable R. G. Menzies on 31st October, 1958. This occasion also marked the placing into service of the first large P.A.B.X. in Australia, using key sender equipment in association with the manual suite.

The "Commonwealth Centre" is an area of land in the north-eastern sector of Melbourne reserved for the erection of buildings which will ultimately accommodate all the State administrations of Commonwealth Departments located in this city. The site comprises two adjacent sections, the development of the first section being planned to accommodate five buildings with an estimated requirement of 5,000 telephones. Accommodation has been reserved in the first building for a P.A.B.X of ultimate capacity of 5,000 extensions, 800 of which are already installed.

FACILITIES PROVIDED

The planning of a P.A.B.X. of 5,000 lines along orthodox lines raises many problems, one of particular import being

*Mr. Angel is Divisional Engineer, Metropolitan Installation Section, Melbourne.

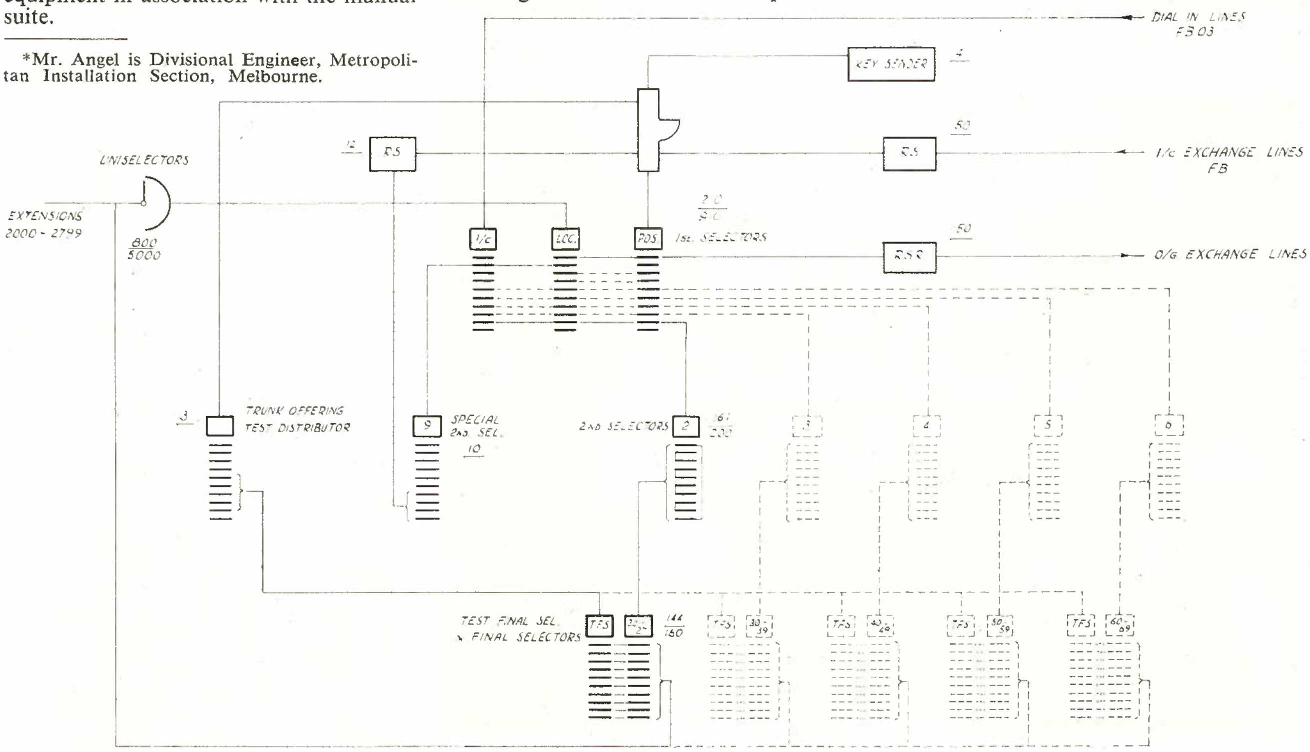

Fig. 1.—P.A.B.X. Trunking Scheme.

that an extension multiple of ultimate capacity of 5,000 extensions is required on the manual positions. After consideration of the relevant problems it was decided to provide the P.A.B.X. with direct indialling facilities from the exchange to the extensions and route only those exchange calls which require operator assistance through the manual switchboard. In the latter case the calls have been routed via the P.A.B.X. automatic equipment using automatic key senders in lieu of providing an extension multiple on the manual suite. Apart from eliminating the necessity for an extension multiple, the number of exchange lines requiring termination on the manual suite was greatly reduced with a consequent reduction in manual positions and operators.

Semi-automatic manual positions were not available for this installation and a method of utilizing the conventional type P.A.B.X. Manual switchboard, equipped with cords and jacks, was developed to enable operation with junctions to automatic equipment, in association with key senders. The automatic key senders enable a higher speed of operation and at the same time materially assist the switch attendant in ease of operation. Special circuits were designed to permit the setting up of calls by means of the key senders both from the answering and calling cords to cater for calls to the P.A.B.X. from the exchange network and calls to the exchange network from P.A.B.X. extensions barred direct exchange access. Also it was necessary to provide special facilities for recalling the operator on calls via the manual suite.

Figure 1 is the trunking scheme for the main switching paths within the P.A.B.X. These are self explanatory but the method of providing trunk offering facilities, whereby the operator gains access to engaged extensions, is of interest. Trunk offering outlets are trunked to special test distributors having access to the various test final selectors, the extension number being set up via the key sender equipment.

The installation represents a halfway development between the orthodox uniselector P.A.B.X. and one equipped with a semi automatic manual suite and as it is the first application of key senders to a large P.A.B.X. in Australia, some aspects of the key senders and their application are of interest.

MANUAL SWITCHBOARD LAYOUT

The front panel and keyshelf layout for the manual positions are shown in Figure 2.

Each position has its own self contained group of incoming exchange lines, representing a complete department or group of small departments, outlets to the P.A.B.X. automatic equipment and information circuits whilst the Trunk Offering circuits are shared by all positions. An emergency appearance of the incoming exchange lines associated with the other positions is also shared by each group of two positions. These are represented by the uppermost right strip of lamps and jacks in Figure 2. The digit key strip on each position is directly associated with its own sender with an emergency key for changeover to the dial.

Each position has a common dialling key and on each cord circuit the operator is able to speak to either party separately or supervise the through call. The normal cord circuit lamp supervisory signals are supplemented by a slow flashing signal to enable the called extension to recall the operator. The facility is obtained from an additional differential relay fitted in series with the "D" relay of each final selector, which is operated when the press button on an extension telephone is depressed—applying earth to one side of the line. All extensions are equipped with such type telephones. The differential relay, when operated, applies 50 volt positive battery to the private wire back to the cord circuit where a poled relay operates and locks via contacts of the speak key of the cord circuit. This starts the operator recall condition which is only terminated by the operation of the appropriate speak key.

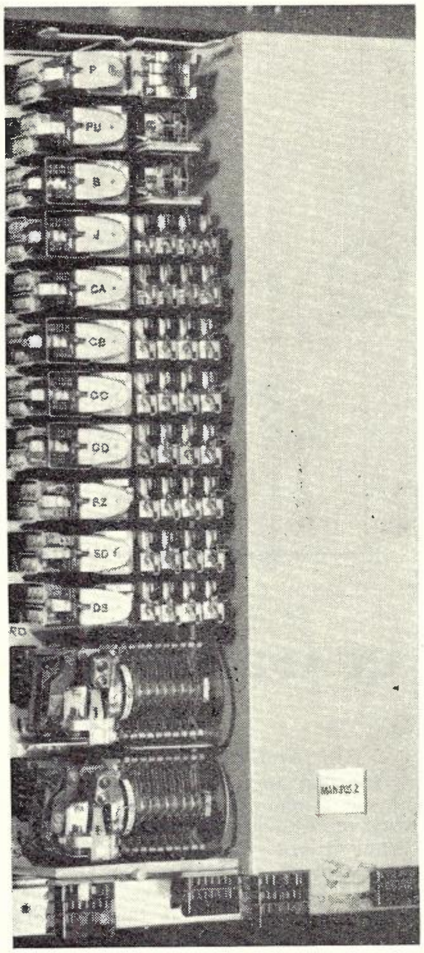

Fig. 3.—Key Sender.

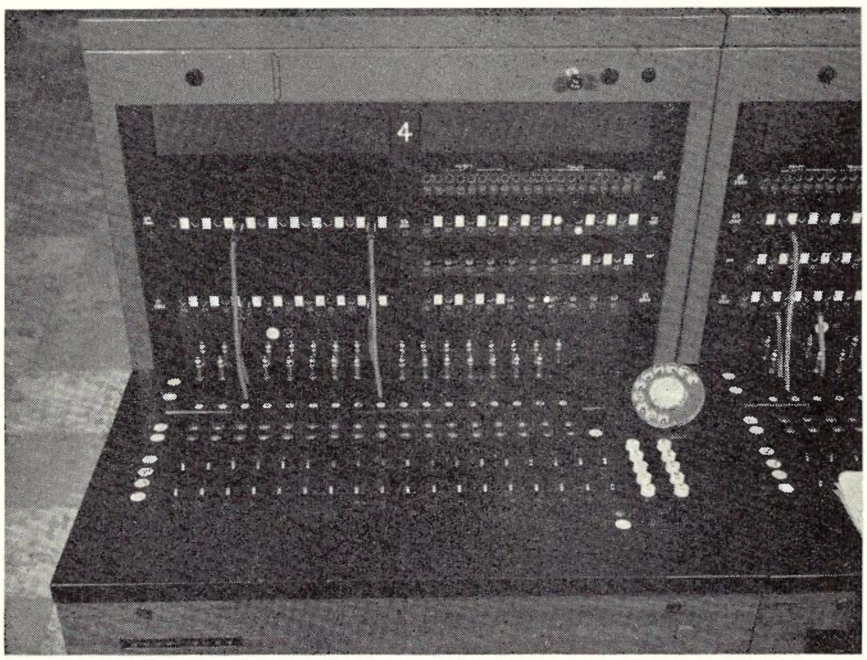

Fig. 2.—Front view of Manual Switchboard.

KEY SENDER EQUIPMENT

The key sender equipment, illustrated in Figure 3, was manufactured by Messrs. Siemens Bros. and Co. Ltd. and has storage capacity for eight digits and provides for automatic clearance of the stored digits. This arrangement allows the setting up of digits in excess of eight, for as soon as a storage is cleared it is available for further use. The senders are made up in the form of relay sets and are jack mounted to conventional type racks made to suit and equipped with an appropriate test panel. Supervisory facilities for the operator are given by means of a lamp associated with the digit keys on the manual switchboard keyshelf. When a key sender is taken and all storages are empty the lamp gives a steady glow, is extinguished while storing is in progress and flashes when all the storages are full. The principal elements of the sender operation are illustrated in figure

4 and some brief notes on its features and operation are given.

Code Storage: Each storage, of which there are eight, has 4 relays (W, X, Y, Z) designated AW/Z-JW/Z. For each digit set up one group of these relays is operated by the digit keys on the manual switchboard keyshelf in accordance with the following code;

Digit Set Up	1	2	3	4	5	6	7	8	9	10
Relays Operated	W	X	Y	Z	WZ	XZ	YZ	WY	XY	WX

The four relays of each storage are known as a Relay Unit 140 type comprising 4 individual relays complete in themselves mounted on a common bracket and occupying a total space equivalent to a standard 3000 type relay. The relays are of the side acting type.

Receive and Send Distributor Switches: These are uniselector digit switches known as the Uniselector Type 1700. The function of the receive switch is to receive the various digits in sequence on the respective storage relay groups whilst the send switch controls the release of the stored digits as impulses in their proper sequence and timing.

Impulse Generation: Impulses from the sender are generated by a capacitance controlled double wound relay. This relay, referred to as a Relay Type 100, is a high speed type with a double changeover type action. The windings oppose one another whilst the condenser is charging and assist one another whilst the condenser is discharging, the capacity governing the operate and release times of the relay. With approximately 6uF the relay pulses at 10 I.P.S. and its operate and release ratio being 2 : 1.

Impulse Counting Circuit: Four relays designated CA-CD in conjunction with the control relays, constitute the basis for the impulse counting circuit and control the number of impulses transmitted for each digit. The basic counting circuit is shown in Figure 5.

When the code marking of a digit is complete the impulse generate relay P (not shown) commences impulsing. Each time P operates relay PX operates due to the charging of condensers C2A and C2B. PX1 extends earth to operate the counting relays CA-CD in series with the second winding of PX. The operated time of relay PX due to the condenser charging, is arranged to cover the period required for current in the counting relays to rise to a sufficient value sufficient to hold relay PX via its second winding. Impulses from relay P are transmitted both to line and the counting circuit the relays being operated in accordance with the following;

Impulses	1	2	3	4	5	6	7	8	9	10
Relays Operated	CA	CB	CC	CD	CA,CD	CB,CD	CC,CD	CA CC,CD	CB CC,CD	CA,CB CC,CD

Contacts of the counting relays are associated, via the SD switch, with contacts of the storage relays for the particular digit and, when the two relay groups represent the same digit, impulsing is immediately stopped by the operation of relay SZ. After the requisite inter-train pause, impulsing is recommenced for the next digit the cycle repeating itself until all stored digits are transmitted.

Inter-Train Pause: This is controlled by the release time of various relays and may be varied between 400 and 1300 M.S. The normal adjustment is for 800 M.S.

Control Circuits: Control of the various functions is obtained from 11,000 type relays supplemented by two high speed relays of single changeover action known as Relays type 88/89. These latter relays ensure the high speed operation required, having operating speeds of 0.5 milliseconds to open the break contact and 1.5 milliseconds to close the make contact. Speed of release is of the order of 1.0 milliseconds to open the make and 3.0 milliseconds to close the break.

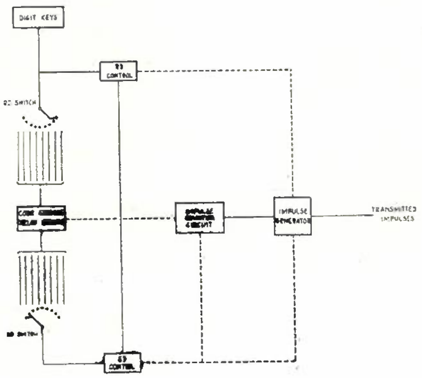

Fig. 4.—Principal Elements of Key Sender.

GENERAL OPERATION

When the sender key is thrown the 4 coding wires from the digit keys are extended via the R.D. switch wipers and bank contacts to a storage relay group not necessarily the first position. Before a clear signal to set up digits is given to the operator, the RD and SD switches are positioned on the same contact. Normally they are in such position except where cancellation of coding has immediately preceded. Upon the receipt of the first digit by the storage relays the RD switch advances one position, transferring the coding wires to the next storage. Upon completion of the first storage the impulse generation is commenced and impulses are transmitted to line and also to the impulse counting circuit. The impulse counting circuit is interrelated to the code storage relays via the contacts of the SD switch. When the relays of the counting circuit and those of the particular storage correspond to the same digit a circuit is completed, to prevent any further impulse transmission. The SD switch moves on to the next position and after the requisite inter-train pause a similar cycle of impulse transmission is completed for the second stored digit. The cycle via the RD switch continues until all digits have been received by the respective storages whilst the cycle on the SD switches continues until all storages are empty.

CONCLUSION

The arrangements provided have generally proved very satisfactory, particularly as they can be regarded only as an improvisation to an existing P.A.B.X. system. During the period of operation the key sender equipment has functioned very well and the operators have become very proficient with them and their associated switching technique. The associated problems and experience gained with this P.A.B.X. give impetus to the need for the development of semi-automatic manual positions of a simple console type together with additional advanced functions such as automatic transfer facilities, special night switching features, camp-on-busy-lines, re-routing of unanswered calls, etc., for future large and medium size P.A.B.X.'s.

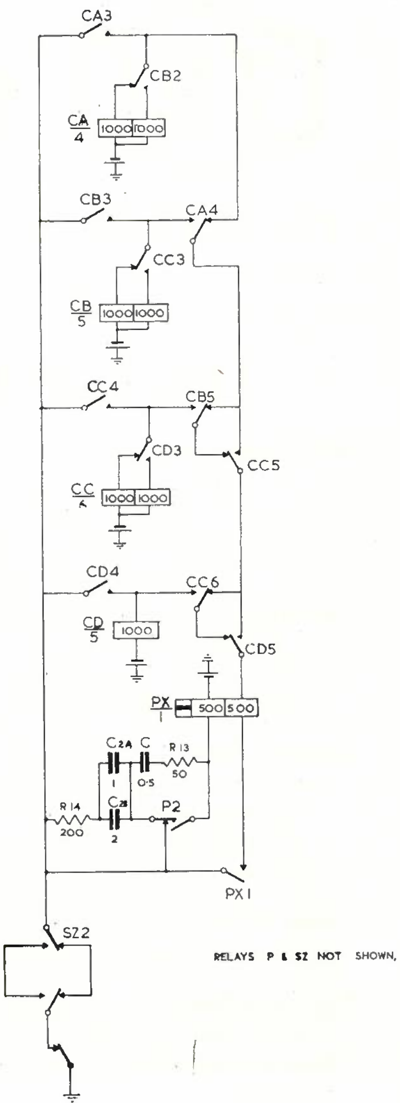

Fig. 5.—Basic Counting Set.

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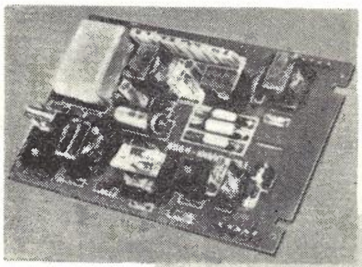

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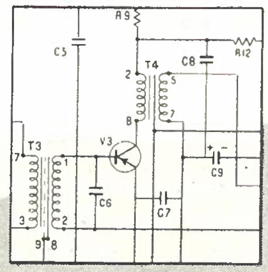

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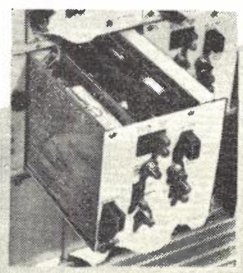

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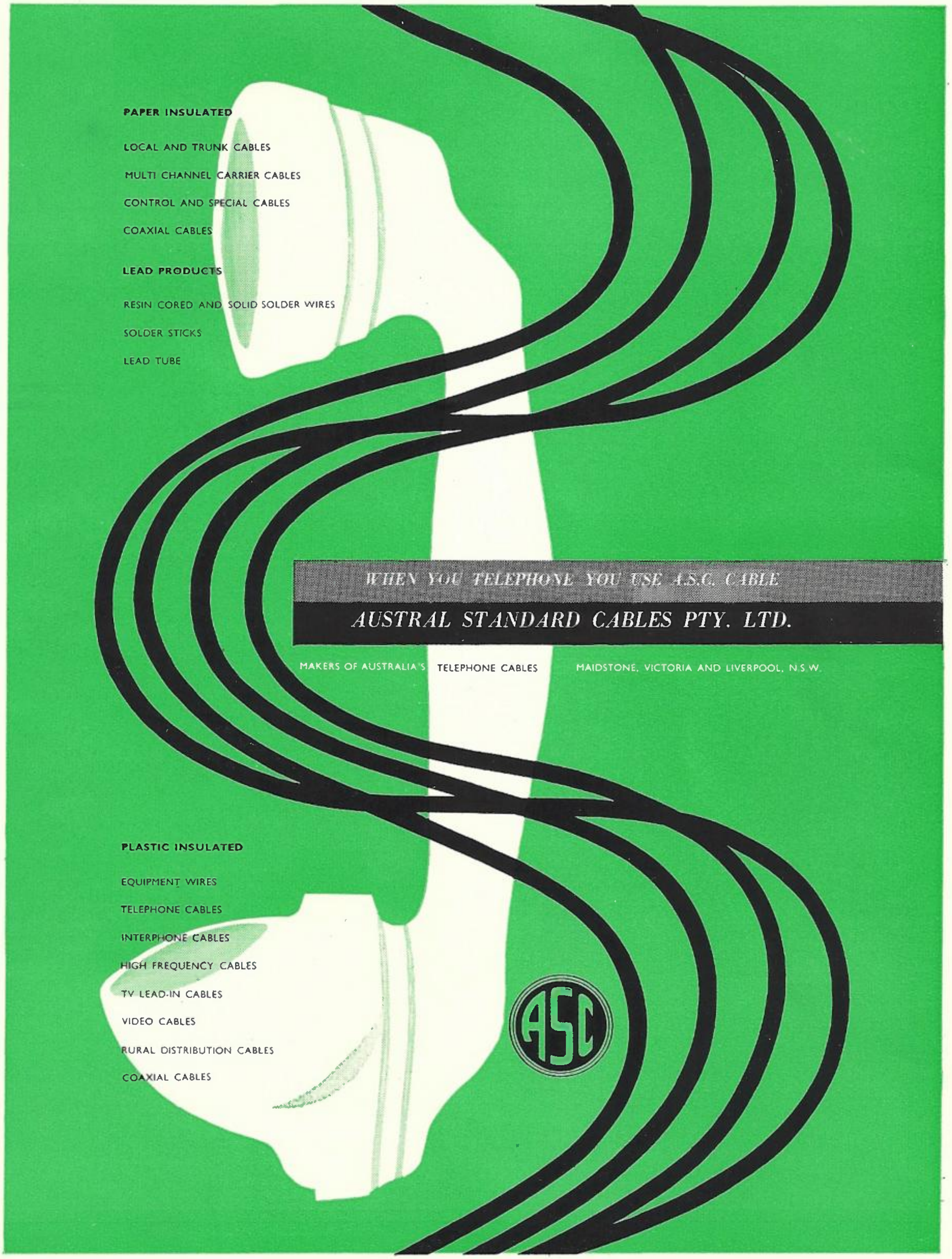
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ANNUAL REPORT OF POSTAL ELECTRICAL SOCIETY

Annual Report of Committee: Year Ending 30th April, 1959

The Committee has devoted most of its efforts during the past year to developing plans in two major related areas of the Society's activities.

Firstly, changes to the Journal were planned, with the object of more attractive presentation, greater circulation and revenue and more benefit to the Journal's readers. Commencing with the June, 1959, issue (Vol. 12, No. 1) the Journal will be published with a new cover, and will contain book reviews and advertisements in addition to its normal editorial content. The supply of articles to the Journal is at present adequate, and this condition is reflected in the increase in size of the Journal over the past year; the editorial content has been raised from 36 pages to 40 pages (in Vol. 11, No. 6) and will show a substantial increase in the next issue (Vol. 12, No. 1).

Secondly, after a survey conducted by the Committee, it has been concluded that it is no longer appropriate for the Society to remain a Victorian body. In fact, as suggested by the title of the Society's Journal, the Society's field is national, rather than restricted to one State. Accordingly, the Committee has in hand preparation of a new draft Constitution which will be placed before the Society members with a view to re-organising on a Commonwealth basis. These two major changes are, of course, complementary: they will each generate benefits which will be felt by our readers, both at home and abroad, our advertisers, and Australian telecommunications services in general.

At present, subscriptions received do not meet publishing costs, despite the fact that all the Society's officers work in an honorary capacity. Losses are met by a subsidy from the Postmaster-General's Department, and it is the aim of the Committee to work towards complete self-support with respect to the Society's activities. The changes presently in hand will contribute towards this objective.

The Journal now has a total circulation of over 2,000 copies and reaches more than 120 subscribers in 30 overseas countries. The Committee is confident that the circulation can and will be increased significantly during the next year. The Committee is grateful to those who have assisted in collecting subscriptions and in distributing the Journal to subscribers in various States; their work minimises overhead costs and reduces secretarial work.

The Society has continued its Victorian lecture meetings, and is indebted to the Principal of the Royal Melbourne Technical College for continuing to make lecture room accommodation available to the Society. Lectures this year have included:—

"Training—where are we going": W. R. Dedrick.

"Line Communications—standards and developments": J. C. Wilson and D. A. Gray.

"The New Look in Mechanical Aids": H. Fitzpatrick and K. Coldwell,

and the Society is grateful to the lecturers for their part in advancing the objects of the Society.

Finally, Committee's thanks are due to the authors of articles published in the Journal and to the Engineer-in-Chief of the Postmaster-General's Department, Mr. E. Sawkins, for his personal interest in, and encouragement of, the Society's activities during the year.

R. G. KITCHENN,
Hon. Secretary,
for the Committee*

*Messrs. E. J. Bulte (President), C. H. Brown, W. Chapman, J. Dowse, J. Hardie, R. D. Kerr, D. Ottrey, J. Vickers, P. Warr, A. C. Wright.

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