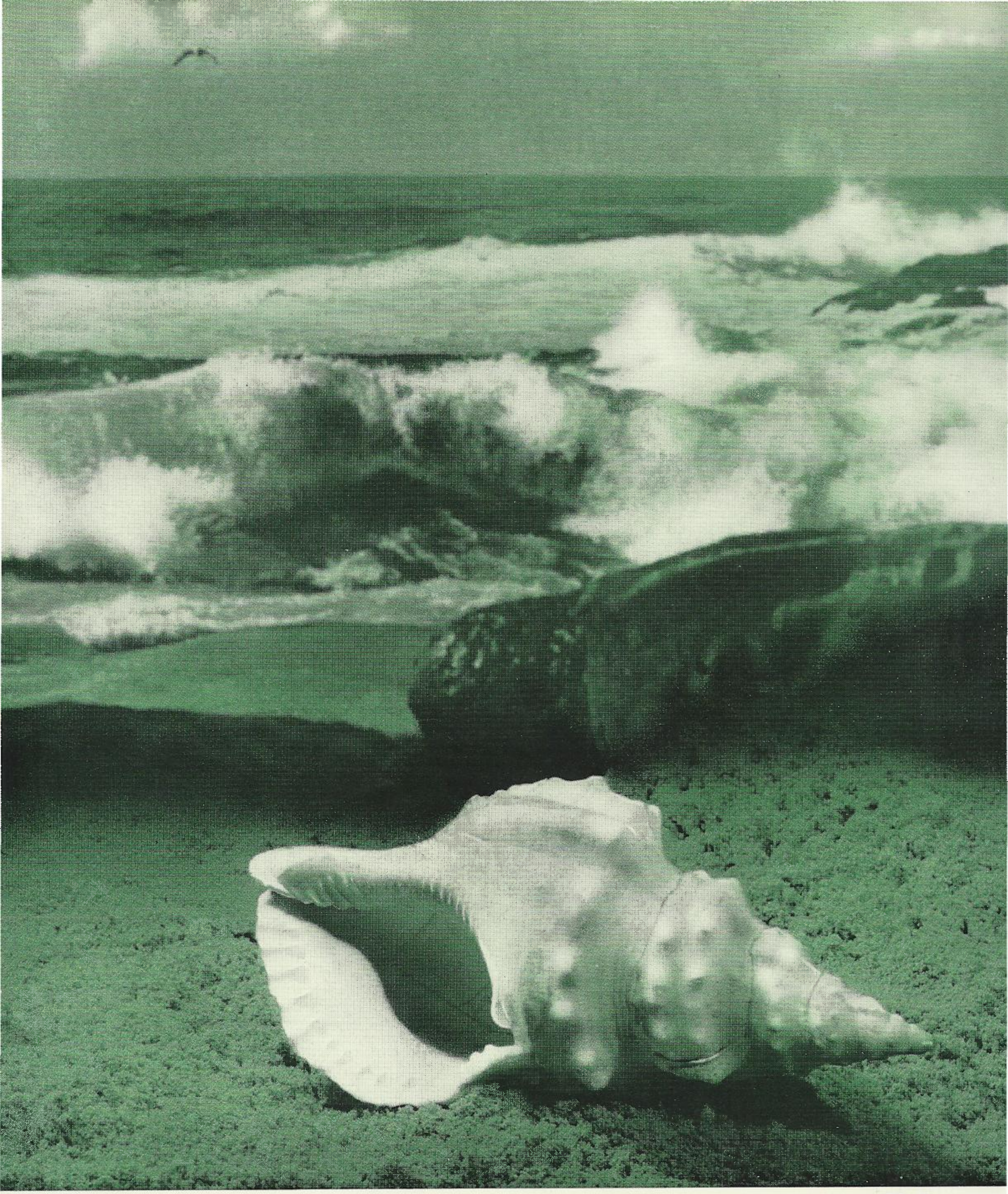
THE Telecommunication Journal OF AUSTRALIA

IN THIS ISSUE

VOL. 12, No. 4 Registered at the General Post Office, Melbourne, for transmission by post as a periodical. JUNE, 1960



A voice by Day and Night Like the seashell, our national communications network is never silent. We are proud of our contribution to its growth.

Standard Telephones and Cables Pty. Ltd.

SYDNEY • MELBOURNE • BRISBANE

AN ITT ASSOCIATE

B208

The

TELECOMMUNICATION JOURNAL

of Australia

VOL. 12, No. 4 — *Registered at the General Post Office, Melbourne, for transmission by post as a periodical.* — JUNE, 1960

CONTENTS

This Journal is issued three times a year by the Telecommunication Society of Australia. A year's subscription commenced with the June issue; succeeding numbers are published in October and February. A complete volume comprises six numbers issued over two years, and a volume index appears in No. 6 of each volume.

Residents of Australia may order the Journal from the State secretary* of their State of residence; others should apply to the General Secretary.* The subscription fee is 10 shillings per year (Australian currency) or 4 shillings each for single numbers. Back numbers are available at the rate of 10 shillings for any three, or 4 shillings for single numbers. Remittances should be made payable to the Telecommunication Society of Australia; exchange need not be added to Australian cheques.

The Journal is not an official journal of the Postmaster-General's Department of Australia. The Department and the Board of Editors are not responsible for statements made or opinions expressed by authors of articles in this Journal.

* For addresses see page 304.

THE NATIONAL TELEPHONE PLAN—SWITCHING

*R. W. TURNBULL, A.S.T.C. (Elec. Eng.), G. E. HAMS, B.Sc. and W. J. B. POLLOCK, B.Comm.**

INTRODUCTION

Articles in Volume 12, Nos. 1 and 3, of this journal have described two of the three basic elements in the design of the future telephone system, the numbering plan and the call charging system. On 1st May, 1960, the group charging plan described in the latter article, was introduced throughout Australia. Extended local service areas, zones and districts for trunk call charging and an 8-rate trunk tariff scale became operative. This was a major step in the implementation of the new telephone policy recently endorsed by the Government. The way has now been prepared for mechanisation of the telephone system to achieve the long term objectives.

This article describes the switching plan which establishes the basic layout and functional design of the national telephone service for its economic development with progressive mechanisation. Upon the fundamental switching plan the numbering and group charging plans were developed. These three elements, suitably co-ordinated, comprise the master plan for community telephone service on a national scale.

The switching plan sets out the framework for the economic disposal of traffic within the system in terms of equipment and plant and also defines the essential technical characteristics which will ensure ultimately, the linking of regional automatic networks into one national network for use by subscribers and operators.

An automatic telephone system requires an adequate number of speech channels within and between exchanges and for use by all subscribers for calls to be made with a reasonable probability of success at first attempt. The basic layout must cater for the automatic routing and switching of a constantly varying and growing telephone traffic load, in a systematic manner, over a transmission and line network having adequate standards of intelligibility, attenuation and stability for satisfactory operation. The rapid establishment and disconnection of calls with supervision of established connections and automatic metering require the use of a comprehensive signalling system to control the system operation reliably and at high speed.

Nation-wide automatic telephone service has become practicable as well as financially attractive through tremendous developments in telecommunications. High efficiency in speech channel usage and improved numbering flexibility will be obtained from the application of the common control crossbar system of automatic switching adopted by the Post Office. The installation of modern high capacity transmission systems using coaxial cables and microwave radio systems will ensure economic channel provision on main routes.

The basic technical characteristics of the Australian plan provide maximum flexibility for the adoption of new and improved equipment and systems as the art advances. In the future national telephone system, the trunk and local networks will lose much of their separate identity. Factors which will bring this about are the extension of subscriber dialling throughout the new local service areas and to the trunk system and increasing application of electronic channel deriving equipment in local networks. Integration of local and trunk networks will be further advanced by the use of similar switching and signalling techniques in the equipment employed. Design specifications incorporating the basic technical requirements, will include adequate definition of the essential conditions to be met by the various classes of equipment for effective inter-working between existing and new plant.

The operator-controlled trunk service has already been mechanised to a considerable extent. Operators can now dial directly to subscribers connected to most of the automatic exchanges throughout Australia. The basic traffic routing arrangements which have already been developed in the network will be suitable, with some modification, for subscriber trunk dialling.

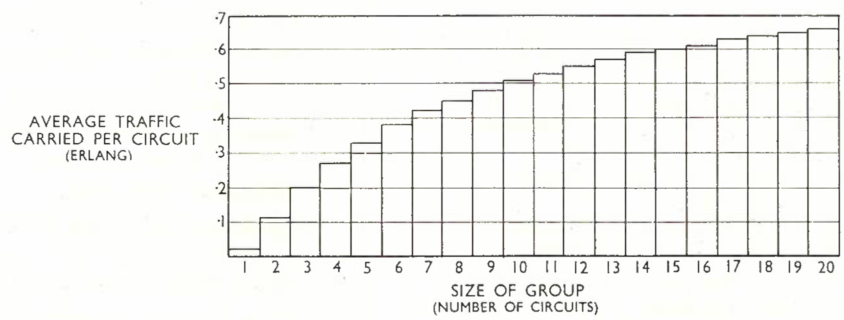
TRAFFIC ROUTING

Two fundamental characteristics of telephone traffic must be taken into account in the design of an automatic switching system to carry the traffic load in the most economical manner. These are:—

(i) The Higher Efficiency of Large Groups of Circuits.

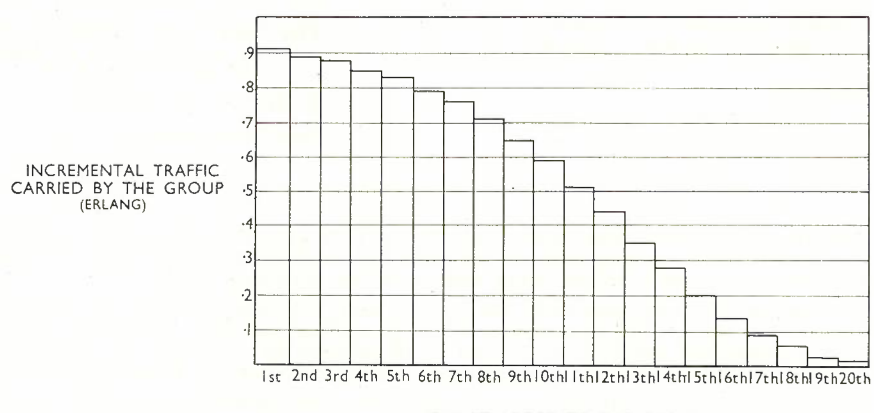
For groups of circuits providing the same grade of service, the average traffic carried by each circuit increases with the size of the group. As an example, Fig. 1 shows this increase in efficiency for groups providing a grade of service of 1 in 50.

TELEPHONE TRAFFIC



AVERAGE TRAFFIC CARRIED PER CIRCUIT IN DIFFERENT SIZED GROUPS WITH FULL AVAILABILITY AND A CONSTANT GRADE OF SERVICE (IN THIS CASE 1 IN 50)

Fig. 1



INCREMENT IN THE TRAFFIC CARRIED BY A FULL AVAILABILITY GROUP OF CIRCUITS, WHICH IS OFFERED 10 ERLANGS OF TRAFFIC, WITH THE ADDITION OF EACH CIRCUIT.

Fig. 2

* See page 297.

(ii) The Diminishing Returns from the Provision of Extra Circuits.

In the case of a route offered a fixed amount of traffic, if circuits are added one by one, each circuit will contribute a diminishing amount to the traffic carrying capacity of the group. This characteristic is illustrated in Fig. 2 which shows the incremental traffic carried by a group of circuits, offered 10 Erlang of traffic, with the addition of each circuit. It will be seen that the later circuits which must be provided, if the grade of service on this group is to be good, are very inefficient. In the example shown, 17 circuits would be required to give a grade of service of approximately 1 lost call in 100 and the 17th circuit provided would only give an increment of .09 Erlang in the total traffic carried by the group.

Considering characteristic (i), the application of automatic switching equipment at intermediate points in a multi-link connection, in place of manual operators, has made it practicable to reduce the setting up time of connections and improve circuit occupancy. It has also resulted in the building up of larger groups of trunks between these points, by combining traffic for various destinations, thereby further increasing average circuit efficiency.

As a development in the application of automatic techniques, modern switching equipment with its greater flexibility and speed allows the principle of automatic alternative routing to be employed with advantage. This gives the opportunity for alternative choices to be made in the routing of calls, not only at the originating exchange, but at all the intermediate points on multi-link connections. Traffic is first offered to the most direct circuit to the destination exchange but, if an "all circuit busy" condition is met the call is routed by alternate paths. By this means, the number of routes which must be provided with inefficient "last choice" trunks is greatly reduced. On many routes, circuits are provided for traffic loading only to the point where the remaining traffic is carried more economically over the available alternate routes.

Automatic alternative routing thereby provides a means of securing the most economical handling of traffic by counteracting the condition of the diminishing return described in (ii) above, and by combining residual traffic into larger and more efficient groups.

Alternate routing improves the performance of the switching system in other ways. It takes advantage of the fact that peaks of traffic within the busy hour or even complete busy hours may not coincide for different routes. Peak traffic overflow from different groups to the same alternate route may not therefore occur sumultaneously. Also, if there is a breakdown on a route, alternative routing gives some protection to the service.

THE SWITCHING NETWORK

The bulk of Australia's population is concentrated in the cities and regions located on or close to the eastern and southern coastline. The telephone traffic is similarly concentrated in these areas. However, the remainder of the population is widely dispersed and it is necessary to provide service to all parts of the continent. The national switching plan, therefore, establishes an optimum traffic routing pattern for inter-exchange connections.

Important questions of the size and location of subscribers' local exchanges, line reticulation and telephone facilities, are related but separate considerations. The local line standards established however, influence the transmission design objective specified for the inter-exchange network. The range of telephone facilities and services provided for the public affect the detailed design of the switching system equipment. In the switching plan described in this article, the factors relating solely to the economic provision of local exchange services are not discussed.

The Basic Network of Final Routes. The foundation of the switching plan is the network of final routes. This network inter-connects all exchanges. The final routes are shown by full lines in Fig. 3, and are defined as routes for which no later choice alternate routes are provided. They are equipped with sufficient circuits to ensure that there is only a small probability of lost calls for the traffic offered in the busy hours, thus controlling the overall system grade of service. Because they are generally large groups, the average efficiency of their circuits is high.

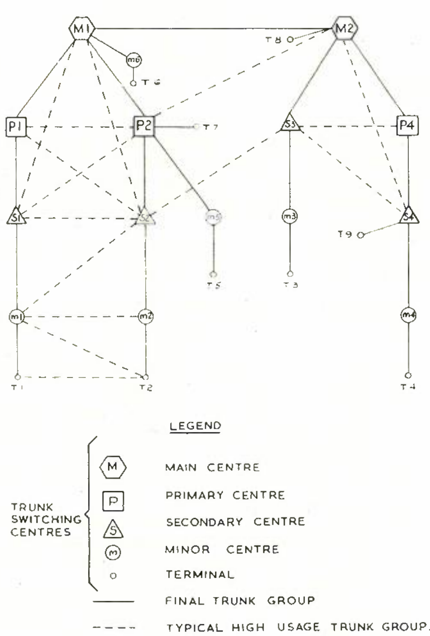


Fig. 3

The Classification of Switching Centres. The switching centres must be classified so that tandem connections are made in a systematic manner. This ensures that the design maximum for the number of links which may be connected in tandem, imposed by switching and transmission considerations, will never be exceeded. It also enables the permissible transmission losses to be assigned to individual routes so that satisfactory performance can be given on multi-link connections.

In Australia, with its great distances and particular distribution of population, five classes of switching centre are used in order to take the fullest advantage of the automatic switching system using alternate routing. The centres are classified according to their position in the final route pattern with respect to centres of lesser order. The classification applies to all exchanges, whether located in metropolitan or country networks, and has no relationship to the number of subscribers' lines connected.

The classification of switching centres with the standard symbols employed, are shown in Fig. 3 and are defined thus:

A **Terminal Exchange** is an exchange which performs no through-switching of inter-exchange circuits.

A **Minor Switching Centre** switches the final routes for Terminal exchanges only.

A **Secondary Switching Centre** switches the final routes for Minor switching centres and also, if required, Terminal exchanges.

A **Primary Switching Centre** switches the final routes for Secondary switching centres and also, if required, Minor switching centres and Terminal exchanges.

A **Main Switching Centre** switches the final routes for Primary switching centres and also, if required, Secondary switching centres, Minor switching centres and Terminal exchanges.

In referring to the final route connection of an exchange, through its parent switching centre, to the Main switching centre, the term "Final Rout Chain" or "Final Chain" is used.

The basic switching plan for the Commonwealth as defined by the network of final routes and the classification of switching centres has been prepared.

In each State, one city is designated as the main trunk centre. The areas served by the main centres, as determined after investigation, are shown in Fig. 4. The areas do not coincide with State boundaries in all cases. Neither do they coincide completely with the A digit allocations (Vol. 12, No. 1, P.4, Fig. 1). This result arises from the different basic objectives governing the design of the numbering and switching sections of the plan. Exact correlation is not necessary, since the plan specifies a register-controlled switching system, in which numbering and routing functions may be separated when required. Within the main switching areas shown in Fig. 4 there are 37 primary and 150 secondary switching centres, each serving a region having a well-defined community of interest.

As with the allocation of the A, B and C digits in the numbering plan, the upper level classifications in the switching plan are expected to be relatively stable for a long period. The major trunk routes are provided between these centres which are located in the principal cities.

The relationship between the switching plan, the numbering plan and the call charging system were mentioned in the previous articles. Numbering Plan

MAIN SWITCHING AREAS IN AUSTRALIA

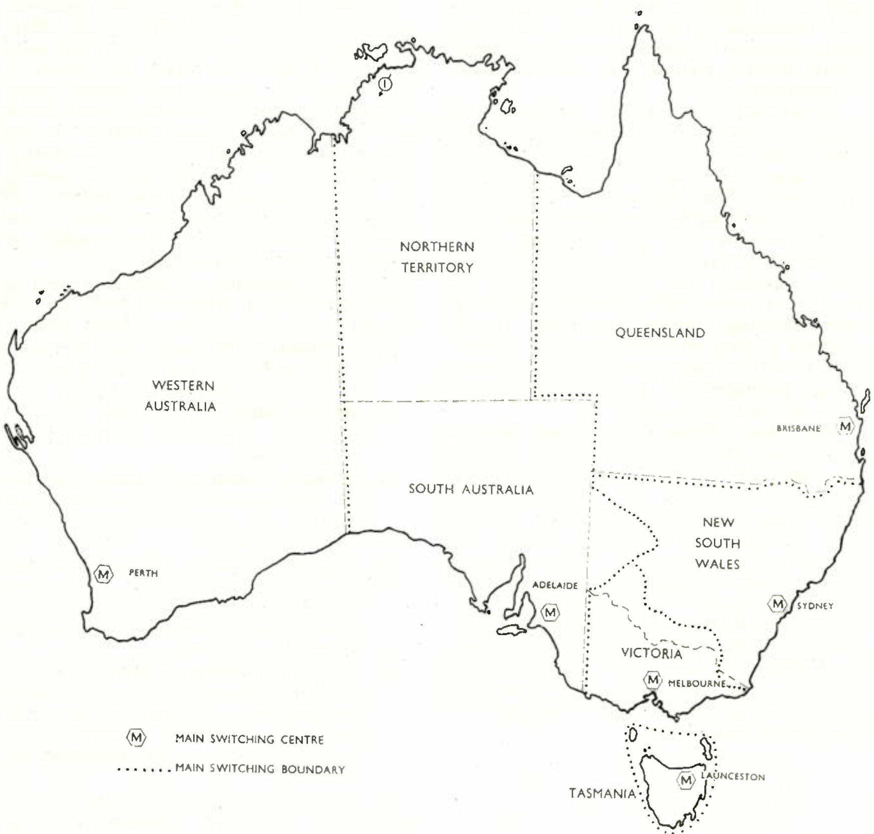


Fig. 4

Areas for rural communities will generally be developed to cater for Secondary switching networks. The grouping of exchanges into Zones and Districts for call charging is based on the planned switching networks.

The maximum number of links which may be connected together ultimately will be 9. This will occur on terminal to terminal calls using the final routing shown by the full lines in Fig. 3. In the early stage of implementation, the maximum number of links may exceed the planned limit. Tandem connection of two Main to Main links will be used in some cases until channel provision is adequate for a mesh of final routes to be established interconnecting all Main switching centres. In practice, connections involving the maximum number of links will be extremely rare since most of the trunk traffic terminates within 100 miles and because direct routes will be tried at many switching centres involved in such a connection before the call is connected over the final chain.

Early-choice Routes Superimposed on the system of final routes is a network of early-choice routes. An early-choice route is one for which one or more alternate routes are provided. It provides a preferred direct link between any two centres, which can carry a portion of the traffic offered more economically than the alternate routes. The number of channels provided on such routes is determined by economic considerations. The optimum division of the offered traffic between a direct and alternate route occurs where the cost of handling marginal amounts of the offered traffic on either direct or alternate routes is equal.

Examples of early-choice routes are shown by dotted lines in Fig. 3.

Control of Alternate Routing. The routing of traffic throughout the network of early-choice and final routes will be automatically controlled by the switching equipment so that:—

(i) Calls cannot be routed over one link more than once during the establishment of a connection.

(ii) The design maximum of 9 links is not exceeded.

(iii) The transmission loss assigned to early-choice circuits may be as high as possible, within the limits set by the transmission plan.

To achieve this control, the following conditions will be applied.

(a) At each switching centre, encountered in setting up a call, early-choice routes will be tested in order for a free outlet commencing with the most direct route, before a call is offered to the final route.

(b) Calls originating in one final route chain and switched to another will then only be switched to exchanges of lower classification in that chain —they will not be switched to centres of higher classification, or to a third chain.

An example of the possible alternate routes for a call between Albury and Wagga, two large centres in New South Wales, is shown in Fig. 5. The diagram shows their relative geographical position and the order in which the outgoing routes are tested at each switching centre.

ESTABLISHMENT OF MULTI-LINK CONNECTIONS

The development of the national automatic telephone system with closed numbering and a multi-link interconnecting system employing alternate routing can only be accomplished efficiently by the application of "register-controlled" switching equipment.

Switching systems may be considered in two broad categories:—

(a) direct-pulsing systems

(b) register-controlled systems.

Direct-pulsing systems are based on the principle that selection of an outlet at each stage of switching is made as each digit is dialled by a subscriber. Numbering and routing are, therefore, mutually dependent. The greater the number of switching points encountered in the routing of a call the greater the number of digits which would need to be dialled by a subscriber. The national plan could not be implemented using the direct pulsing switching principle exclusively.

Register-controlled systems allow the routing and numbering to be substantially independent. However, even with such systems there are advantages to be gained by a systematic allocation of numbers. The register is a control device which is associated with the connection only during the setting up of a call. It is interposed between the subscriber's dial and the routing selectors. It stores the digits dialled and translates the dialled information into the form required for the connection to be established. The number dialled need only define the destination, the register-translator supplies the information on how best to reach that destination from its own particular location. By using this switching principle simple closed numbering can therefore be used with the type of switching plan described.

Register-controlled switching equipment will be used for the development of the future telephone system. There are many methods of register control, however, and the general specification of the preferred method and of the associated signalling system is as follows:

Method of Register Control. More than one register will be used in the setting up of a typical connection. A register at the originating exchange, or its parent switching centre, will control the setting up of the connection. It will store the number dialled and will transmit digits on demand from registers at other switching centres involved in the connection. Registers at these centres will call, by special signals, for sufficient digits to allow only their centre's part, in the setting up of the connection, to be performed. At intermediate switching centres on long distance calls these digits will usually be the ABC digits of the national number. Finally, a centre will be reached from which the switching of

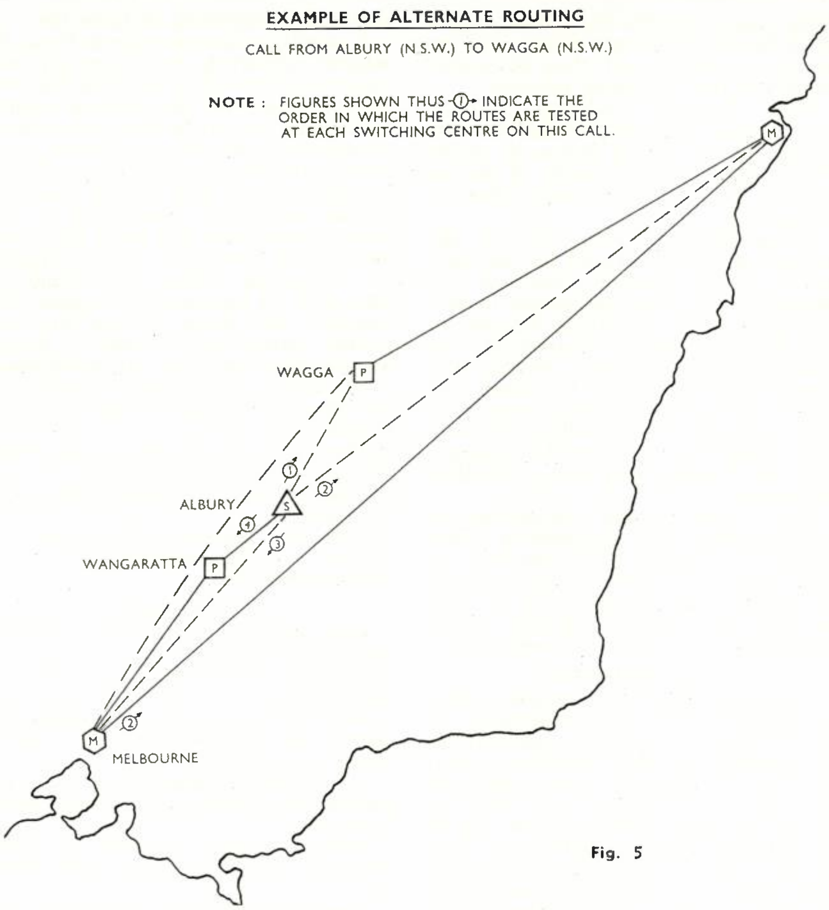


Fig. 5

the call can be completed. A register at this centre may signal for the called subscriber's number or the code receivers in the terminal exchange switching stages may call for digits from the originating register.

Signalling. With the type of register control described above some post-dialling delay may be experienced on calls which traverse a number of links. However, in the past, subscriber-controlled automatic service in Australia has been provided by direct operating switching equipment. Consequently the public is unaccustomed to post-dialling delay. High speed signalling and switching will be employed with the register-controlled system in both the junction and trunk network to reduce the post-dialling delay to a minimum and so avoid unfavourable comparison between existing and new equipment.

Reduction in the setting up time also means less time during which expensive plant is held unprofitably and, in some cases, a reduction in the amount of common equipment which must be provided.

In the future register-controlled switching system, the inter-exchange signalling functions will be performed by two separate but complementary signalling systems.

Line Signalling. Certain signals are transmitted and received by the individual line relay sets and are not controlled by the common equipment which is temporarily engaged during the setting up of a connection.

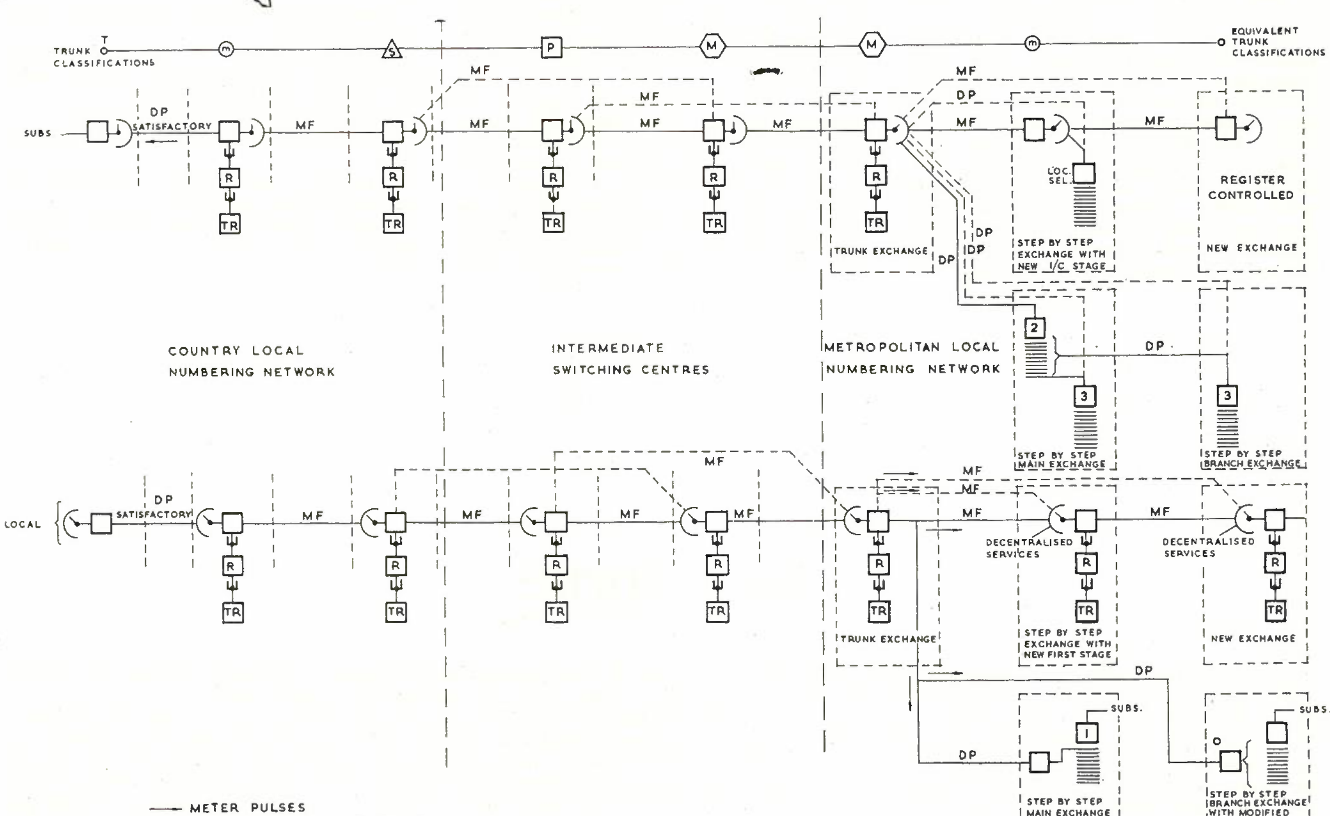


Fig. 6

Signals of this type will include:—
- seizure
- answer
- clear forward
- clear back
- release guard
- blocking

It will be possible to use many existing types of line signalling systems to provide these signals. Direct current, 50 c/s, in-band voice frequency signalling using suitable frequencies, and out-of-band signalling systems, may all find application in the future network.

Information Signalling. These are the signals exchanged between the common equipments which are temporarily engaged during setting up of a connection.

Multi-frequency code signalling has been selected as the most suitable method for high speed transfer of the information signals in the forward direction. With this signalling method transfer of information at a speed of approximately 10 digits per second can be achieved. Each multi-frequency code will consist of two frequencies enabling the signalling to be self-checking and very reliable. Six frequencies in combination are used for forward signals, giving 10 codes to represent the decimal digits and 5 auxiliary codes.

Multi-frequency codes are required also for backward signals to control the forward transmission of information and to provide an indication of terminal conditions.

Different frequencies will be used for forward and backward signals so that simultaneous transmission may occur.

Dial Pulsing. Although press button sending devices may ultimately be provided generally with the subscriber's instrument, enabling high speed code signalling to be used, for many years the dial will be the standard signalling device. Dial pulses will therefore be received by the exchange equipment from subscribers' telephones. The existing exchanges which have been developed with direct operating equipment will continue to use dial pulse inter-exchange signalling until economies in plant provision or restrictions in numbering flexibility make desirable the provision of a more flexible first stage switch. The exchange concerned will then participate directly in the high speed network.

New Terminal exchanges in the country may also transfer dialled information to their parent centres by means of dial pulsing for simplicity in the design of these normally unattended exchanges.

A considerable amount of trunk signalling equipment designed for dial pulsing is already available. Some of this equipment may find application in providing the "line signalling" function or for the dial pulsing requirement between Terminals and their parents. It is possible also that whilst the major networks are predominantly using dial pulse signalling, early choice routes to them may be satisfactorily equipped with the existing dial pulse signalling equipment.

Fig. 6 shows typical connections between country and metropolitan Numbering Plan Areas. The signalling on each link, the metering pulse transmission and the incorporation of new, modified and existing exchanges in the metropolitan networks are indicated.

TRANSMISSION

The introduction of automatic switching makes possible the development of the efficient and economic national interconnecting network described above. The use of alternate routing and the possibility of as many as 9 links in tandem on calls, however, give rise to transmission problems. Subscribers may obtain successive calls, even to the same destination, over varying numbers and types of channels. The transmission plan must be designed to ensure satisfactory and reasonably comparable transmission on all calls.

The ideal would be to operate all channels at zero loss since this would make the transmission level independent of the number of channels in the built up connection. However, to ensure stability of connections and to prevent the unacceptable echo conditions that would arise due to the long distances involved in Australia, present transmission facilities must be operated at some loss.

A new transmission plan is being developed, specifying the losses on individual links in such a way that the overall attenuation on any built-up connection should be satisfactory. Provision of satisfactory transmission, however, is not fully in the hands of the system designers. Speech level and hearing sensitivity of the subscribers conducting a telephone conversation and room noise level surrounding them are factors affecting the connection, which are beyond the control of the transmission engineer. The standards laid down for the inter-connecting network will provide a margin for variations in these end conditions.

To ensure satisfactory transmission the plan will specify certain objectives to control:—

(a) Overall attenuation of the connection.
(b) Stability of the connection.
(c) The amount of objectionable echo present.
(d) The noise present on the circuit.
(e) The cross-talk conditions.
(f) Distortion limits.

CONCLUSION

Summarised, the Australian switching plan provides for:—

Extensive use of the principle of alternate routing.

Early choice routes, on which the number of circuits provided is determined by economics.

A back-bone system of final routes engineered to achieve a good overall grade of service.

Switching centres classified as Main, Primary, Secondary, Minor and Terminal.

Maximum multi-link connection of 9 links ultimately.

Register-control of switching, with high-speed multi-frequency codes used for transfer of information.

It has the following features:—

Achieves the most economical use of plant.

Ensures a satisfactory standard of transmission on all calls.

Avoids excessive post-dialling delay on calls routed over multi-link connections.

BACK COPIES

The Society has available in quantity, back copies of most issues of the Journal from Volume 5 onwards. Volume 12, Number 1 is out of print, but reprints of the two articles on co-axial cables may be obtained for a total cost of 3/-.
These Journals may now be supplied, on demand from State Secretaries* at 10/- per set of three or at 4/- per single copy. Back copies of some earlier numbers are available, but it is recommended that inquiry first be made to the State Secretary,* as to the availability of any particular number. In the event of the Society being unable to supply any number, it will act as an agent to assist subscribers in obtaining a copy. The Society does not repurchase Journals, but readers having copies which are no longer required should give details to the State Secretary*, who may thus be able to advise other readers where the back copies may be obtained.

* For addresses see page 304

TOOWOOMBA CROSSBAR EXCHANGE

N. D. STRACHAN, A.M.I.E.Aust., A.M.I.E.E.*

INTRODUCTION

World-wide interest has been aroused by the decision of the Australian Post Office to adopt L. M. Ericsson's Crossbar switching system (References 1, 2 and 3) and the Toowoomba project is particularly significant as it is the first Australian installation of crossbar equipment employing the full register system and many other interesting features. The type of crossbar exchange installed at Templestowe, Victoria, which is similar to that installed at Sefton, New South Wales, is described in an earlier article (Reference 4) and some of the reasons why a crossbar system has been selected are set out in Reference 1. An introductory article on the Toowoomba project was published last year (reference 5).

The purpose of the article which follows is to describe the installation by the A.P.O. of a crossbar exchange at Toowoomba, Queensland.[1] In addition it will also describe briefly the operation of the equipment, detail some of the features peculiar to crossbar and compare this case with 2000 type equipment.

The Task. At the time of cutover the city of Toowoomba was served by:—

(a) A magneto lamp signalling exchange (C.B. No. 1) consisting of 14A and 2B positions with a capacity of 3,000 lines, situated on the first floor of the Post Office. The original positions were installed in the year 1911.

(b) A C.B. exchange, consisting of 10A and 2B positions (C.B. Minor No. 10) with a capacity of 2,800 lines, located in a prefabricated hut at the rear of the Post Office. The first positions of this exchange were installed in 1951.

(c) A trunk exchange consisting of:—

(i) 15 magneto lamp-signalling trunk positions, the original positions being installed in 1920.

(ii) 12 positions using C.B. switchboard carcases. These were installed in 1952.

(iii) One trunk B, one auto-A, and two information positions.

(iv) A 1200 line 2000-type exchange at Middle Ridge, a suburb of Toowoomba.

It is interesting to note the growth of the city. In 1924 there were 1,340 subscribers connected, and growth was an average of 42 p.a. until 1944. In 1944 there were 2,196 subscribers. In 1960 there are 5,241 subscribers connected to Toowoomba, and 1,019 to Middle Ridge, a total of 6,260.

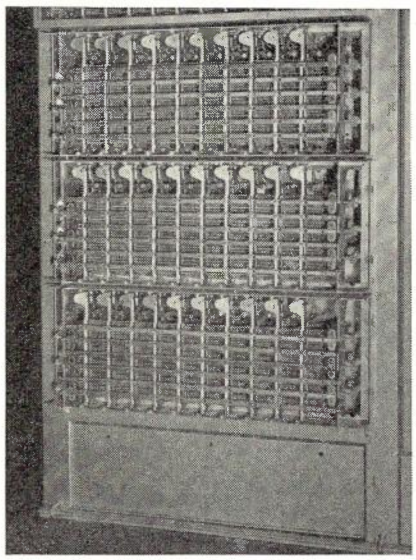


Fig. 1.—Crossbar Selectors.

The task was to convert the remainder of the subscribers in Toowoomba to automatic working by the installation of two exchanges. One is at Newtown, a suburb, where a 2,000-type exchange of 1,000 lines capacity was installed., and the other is Toowoomba situated in the centre of the city, and is the crossbar exchange of 6,300 lines capacity. The existing trunk exchange is to remain until the purchase of an automatic trunk exchange some time in the future.

The original plan was to install the three exchanges as step-by-step main exchanges with five digit numbering as follows:—

Toowoomba	2xxxx
Newtown	4xxxx
Middle Ridge	5xxxx

With the introduction of the crossbar exchange the plan was altered to make the smaller exchanges, Newtown and Middle Ridge, work as full satellites with "trombone" trunking. The registers at Toowoomba handle all calls in the net work, and thus all subscribers on the three exchanges receive dial tone from Toowoomba. The first selectors at Middle Ridge were removed and the five digit numbering retained.

Conventions. The following conventions are followed in this paper:— Firstly, traffic is referred to the subscriber. If a subscriber makes a call, such traffic is originating or outgoing, and the calls to a subscriber are terminating or incoming traffic. Secondly, the uniselector symbols in the crossbar trunking diagram represent crossbar selectors.

MECHANICAL COMPONENTS

The crossbar system uses no other components than relays of various types and crossbar selectors. No rotary selecting switches of any kind are used.

Relays. The general purpose relays contain three spring piles with a maximum of eight springs per pile. The armature residual of this relay is a nylon plate fixed only at one end to the armature, and the thickness of the plates used ranges from 0.05 m.m. (1.96 mil.) to 0.25 m.m. (9.85 mil.), the standard

1. The equipment being purchased for wide scale use in Australia differs in two significant respects from this installation. The method of signalling within and between exchanges will use multifrequency V.F. rather than d.c. code and the normal register stores for the A.R.F. system will accept 10 digits and be cyclic in operation beyond this number.

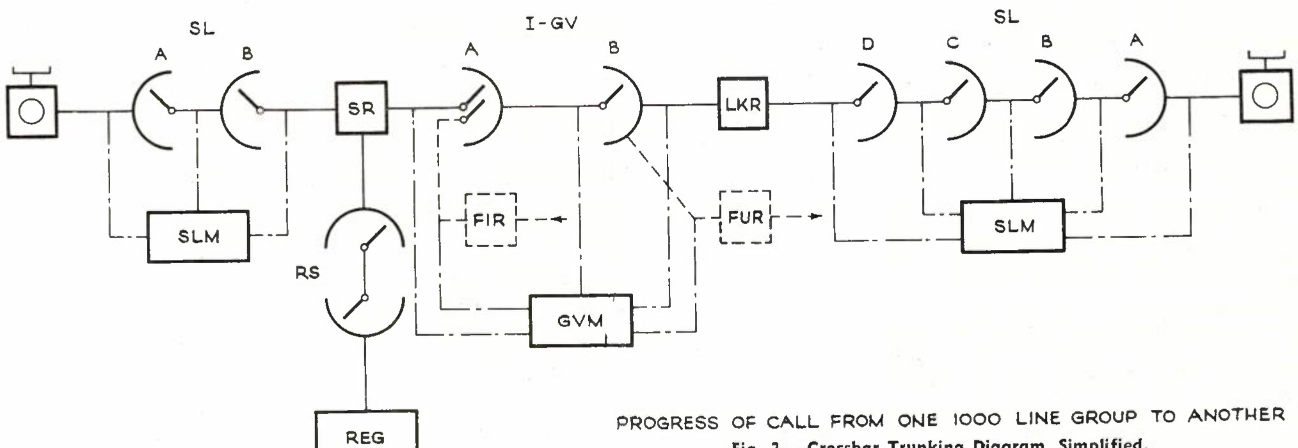


Fig. 2.—Crossbar Trunking Diagram, Simplified.

* See page 297.

being 0.15 m.m. (5.9 mil.). The springs are lifted by bakelite combs instead of lifting pins. The armature is pivoted on a knife edge, and its stroke and pressure are adjusted by means of a lip and curved spring support respectively. Adjustment can be carried out without removing the armature. The spring sets are adjusted for lift by means of screws in the armature. Each relay can have a maximum of six coil tags of which the inner two connect to the first or inner winding and the outer two to the third winding. The contact pressure is normally of 25 grams with a tolerance of "plus 8 minus 2", and the relay travel varies from 0.8 m.m. (31 mil.) to 1.3 m.m. (51 mil.). The usual travel is 1.0 m.m. (39 mil.) or 1.1 m.m. (43 mil.).

The line and cut-off relays are in effect an integral unit consisting of two coils fixed to the same yoke and operating a common springset by the use of lifting combs. This combination saves using two separate relays and additional wiring. Twenty line relays form one relay set.

There is a miniature relay which occupies the same volume as a spring pile on the general purpose relays. It contains a maximum of four contact springs and is small, cheap and used where the technical possibilities of the other relays are not required. It can be mounted on a relay yoke in place of a spring pile or it can be mounted separately, in which case six of these units can be mounted in the space required for a single relay.

The by-path system has accentuated the need for a single switching device, the multi-coil relay, to replace a number of simple relays. It is used to connect, for example, a device A to any other of a group of devices B_1 to B_n or any one of devices A_1 to A_n to another group B_1 to B_n. It consists of a bank of ten operating coils and armatures operating a maximum of twelve springs. The ten armatures can be operated independently of one another. The relay has contact strips common to all armatures, similar to those on the crossbar selector. Only twin contact make springs are used, and the relay itself simplifies the equipment by obviating the necessity of multipling over many relay springset terminals. If necessary the contact bars can be split into two units each having five springsets as the contact strips are made with wiring tags at each end.

Thermal relays are used where a substantial time delay is required, e.g., alarm circuits, and can be mounted in the space usually occupied by the right-hand springset (front view) of a general purpose relay. It has four contact springs.

For certain functions, e.g., in signal circuits, polarized relays are used. They may be adjusted as centre stable or side stable as circuit conditions require.

Crossbar Switch. The crossbar switch is not a new invention, for the first practical switch was developed in Sweden in the year 1900. It consists of ten vertical armatures, and five or six horizontal selecting bars. Selectors with five horizontal bars are used in the registers to store the dialled digits. The selectors with six horizontal bars are used in the speech paths and in the register finder. Each vertical works as a separate selector with twenty outlets and a switch can thus have ten calls in progress simultaneously.

The horizontals are provided with two coils each, which will energise the horizontal in one direction or the other. These horizontals are used for a very short moment when a vertical is set to a particular outlet. When a vertical is set two horizontals are first operated, and they indicate which outlet is to be used in the vertical. After that the vertical is operated, and the inlet of the vertical will then be connected to the outlet indicated by the horizontals. Once the vertical is operated the horizontals can release, and the vertical will still be set to the selected outlet. The same horizontals can be used again for setting other verticals within the switch.

With six horizontals the verticals have 20 outlets with a maximum of five wires through connection. All contacts in the crossbar switch are twin contacts of pressure type, made of a silver-copper alloy, and thus they should be less noisy than the contacts in the step-by-step system, which are sliding base metal contacts.

The movements in the selector are confined to short armature strokes and spring travel, and the switch should require little maintenance from the wear viewpoint. Fig. 1 shows several crossbar switches.

CROSSBAR PRINCIPLES

The exchange is of L. M. Ericsson manufacture, System ARF10, Type ARF101. It embodies the following principles:—

Firstly, it is a register controlled system.

Secondly, it is a link system operating on the common control by-path principle with conditional selection.

Considering the first feature, the registers receive all the dialled digits, store them and then send the information to the following selector stages to set up the call. The register is capable of translating the received information into some other information; it is capable of re-

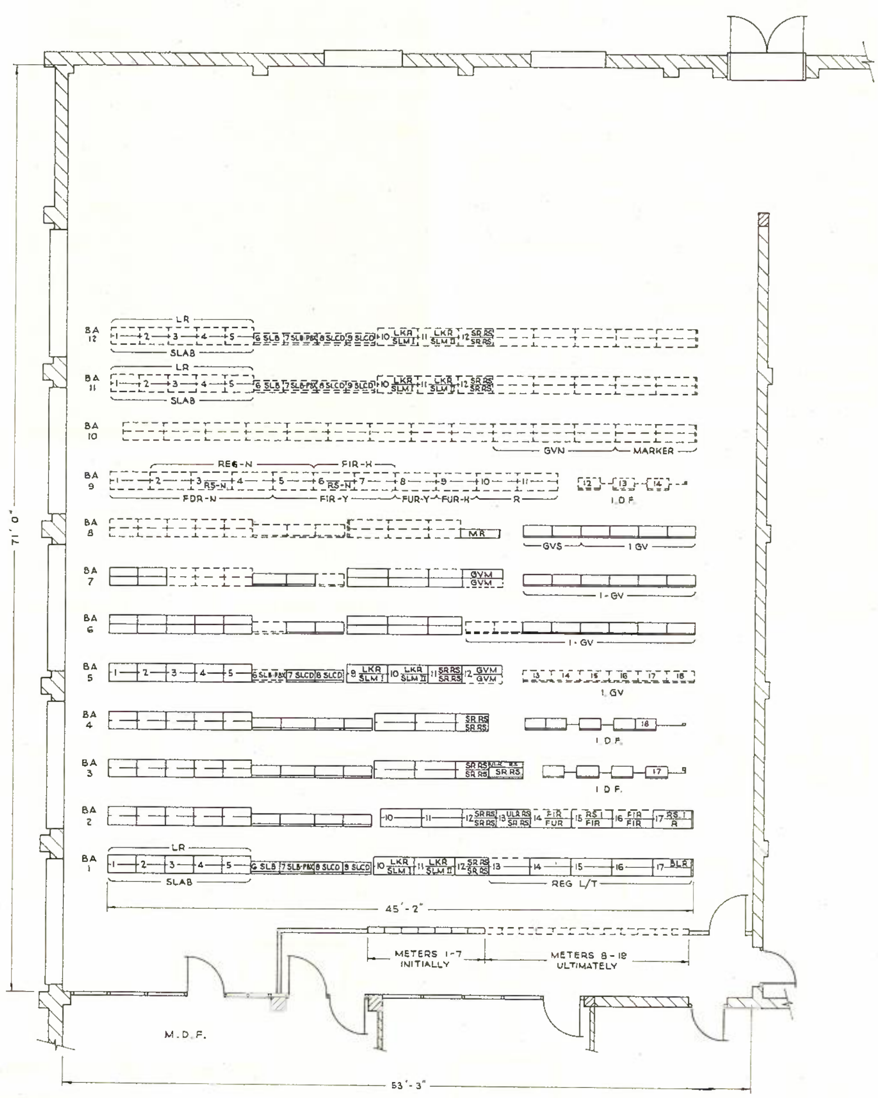


Fig. 3.—Crossbar Floor Layout.

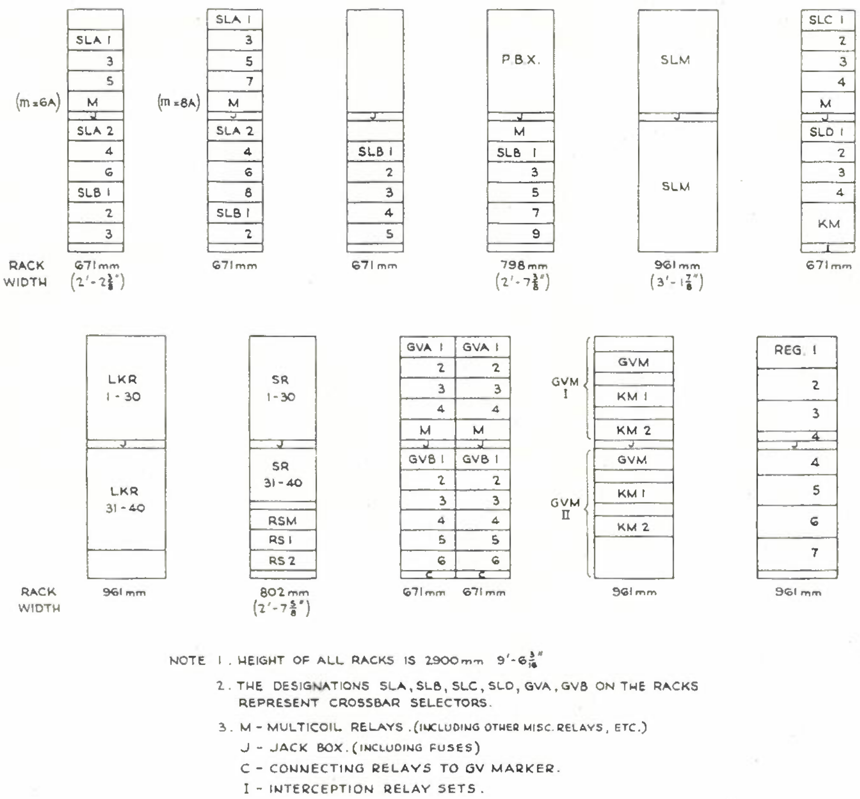


Fig. 4.—Face Layout of Crossbar Racks.

peating information as required in the completion of a connection through a number of selector stages; it does not send information until the markers are connected. The registers are only held for the dialling and setting up time.

Consider the second feature. For the reason that the time of setting the selector is short compared with the time it is occupied by calls, the control of the selectors is concentrated in a small number of control devices. Such a common control device is called a marker, and it selects a free path through the selector stage, after which it sets the crossbar selectors accordingly. For the selection the marker uses the by-path principle which means that the controlling and directing functions of the switching units are fed over a by-path separate from the speaking path. The by-path principle is usually applied when the common device controls the setting of several selectors simultaneously.

The holding time of the common equipment is very short so only a small number of control devices is needed. In the subscriber stage at Toowoomba there are two markers in each group of 1,000 subscribers. Because of the small number the cost of such common control equipment does not affect greatly the cost of the system, and it can therefore be designed to incorporate very reliable elements. Also since the selectors in the speech circuits are freed from all complicated equipment that would be liable to wear, they are very dependable in operation.

There are two stages in the crossbar exchange. They are called the "subscribers' stage" and the "group selector stage". (Under certain conditions there may be more than one group selector stage). Each stage is divided into partial stages, the subscribers into four, and the group selector into two. The stages are in tandem, and the connections between them are called "links". The links between the different partial stages are arranged so that a particular vertical in one partial stage may reach all or the majority of the verticals in the associated partial stages. In this way the capacity of the selector stage is increased far beyond the capacity of the basic unit, which is the vertical of the crossbar switch.

When a marker selects a path through a selector stage, it selects a free outlet only on condition that it can be reached via a free link. This is referred to as "conditional selection".

CROSSBAR TRUNKING

Fig. 2 shows in simplified form the trunking of the crossbar exchange, the abbreviations used in the figures being explained in the Appendix. This figure shows the path taken by a call from a subscriber in one 1000-line group to a subscriber in the same 1000-line group, and also a call to a subscriber in another 1000-line group.

In the first case the call begins at the originating telephone, progresses through A and B partial stages of the subscribers' stage within which he is located; through the group selector stage which connects the call to the same 1000-line group and through the four partial stages of the subscribers' stage to the called subscriber. In the second case the group selector stage directs the call to the other 1000-line group; and then through the four partial stages of the subscribers' stage to the called subscriber.

Making a Call. When a subscriber lifts his telephone handset, his line is looped in the usual manner, and his line relay (LR) is operated. This relay calls one of the markers operating in the 1,000-line group to which the subscriber belongs. Selection of a marker is ran-

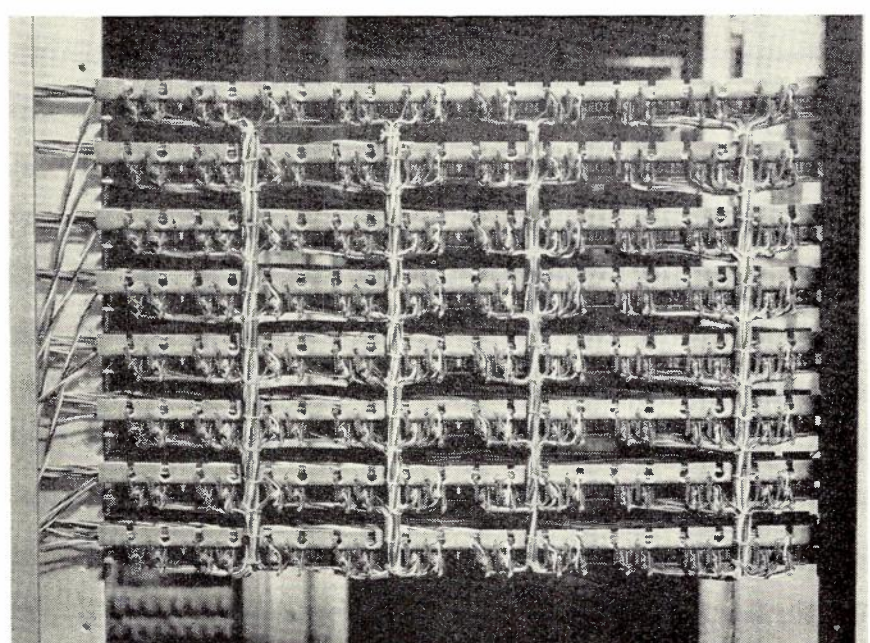


Fig. 5.—Commoning of Group Selector Routes on I.D.F.

dom, and provided no marker is busy the subscriber has an equal chance of being connected to either marker.

The marker identifies the calling subscriber and registers the hundreds, tens and units digit of his number. After that the marker knows which outlet in the multiple should be used, and by conditional selection the marker then selects a suitable SLA-SLB link for connection to a free SR with access to a free register. The marker then sets the SLA and SLB selectors according to the selected path. (The SR circuit contains the feeding bridge for the calling subscriber and effects the metering of the call.) Upon connection to the SR circuit, the marker of the register-finder is called. The calling SR is identified, a free register, REG-L is selected which is then connected to the SR circuit through the register-finder.

After the free register has been connected the SL and RS markers are released and are then available to handle further calls. At this stage the subscriber receives dial tone and can proceed to dial.

Consider first of all a call within the crossbar exchange. As the subscriber dials, the impulses are received by the register, which counts and stores them. The storage unit is a small crossbar selector with five horizontals and five verticals. The digits are stored by operating the horizontal selecting bar corresponding to the digit dialled, and the first vertical for the first digit, the second vertical for the second digit, etc., and thus five digits can be stored.

After storing all the digits the register calls the group selector marker, GVM. This marker identifies the calling inlet, which in this case is the SR circuit. The marker connects a code receiver to the inlet and the register sends the requisite number of digits to determine the route out from the group selector, which in this case will be a route to a particular 1000-line group in the crossbar exchange. In Toowoomba, the first two digits are necessary to determine this route, and they are sent from the register by a d.c. code, in the form of polarity reversals of 10-15 m.s. duration. These determine the route from the group selector, and the lines in this route are then tested. In this case a free LKR in the particular 1,000-line group is required. A free LKR is selected by the marker through a by-path and the selectors in the GVA and GVB stages are set. The group selector marker then releases and is free to serve new calls.

(The LKR circuit has a feeding bridge which is the speaking battery for the called subscriber and it also controls the ringing facilities.) After seizure the LKR calls a code receiver for the subscribers' stage. (This is situated in the SLC/D rack, there being one code receiver for every forty LKR circuits.) The register sends the code for the last three dialled digits to the code receiver which registers

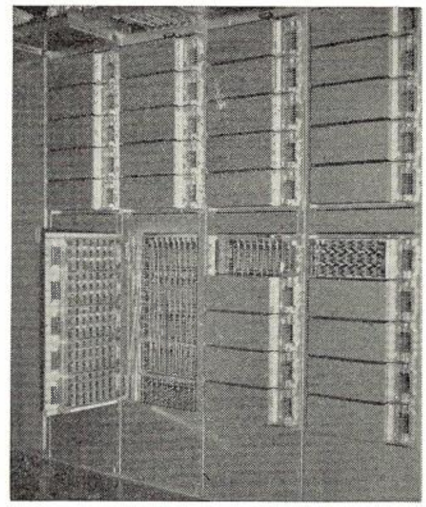


Fig. 7.—SLA/B Racks, Rear View.

the digits on relays. The code receiver then tests to find if the called subscriber is on interception and refers the number to the P.B.X. equipment to ascertain if the number is a P.B.X. service. If the number is a P.B.X. service, the P.B.X. equipment selects a free auxiliary line. This is transferred to the code receiver and the digits of the dialled (directory) number are discarded. The P.B.X. equipment is then released. If the P.B.X.

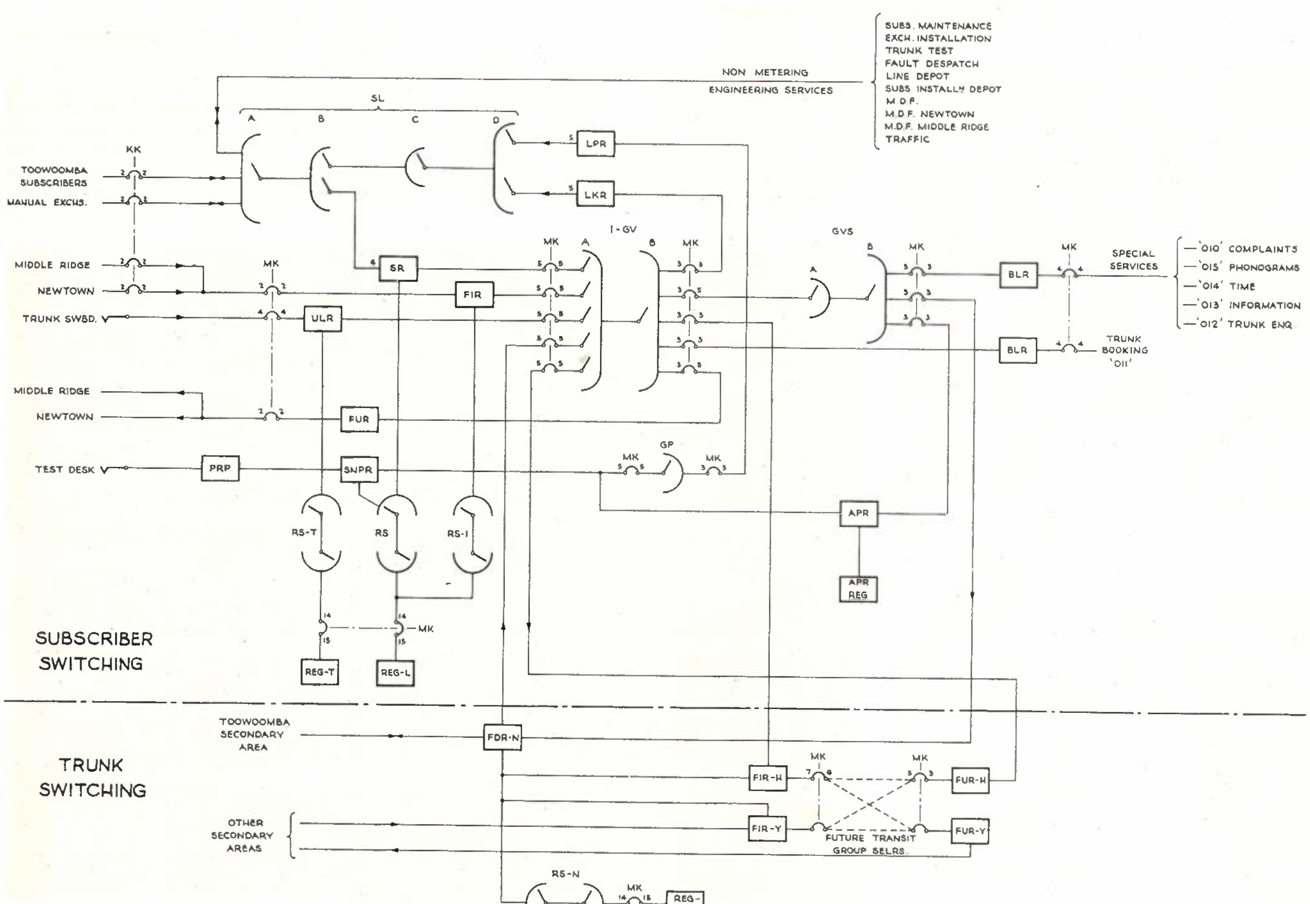


Fig. 6.—Crossbar Trunking Diagram, Toowoomba.

equipment is faulty, the call is allowed to extend to the dialled number.

The marker for the subscriber's stage is then called. The code receiver is identified and connected to the marker. The last three digits of the called subscriber's number (or free auxiliary number) are transmitted to the marker and registered on relays. The marker then tests to ascertain whether or not the called number is free. In the case of a P.B.X auxiliary line, the P.B.X equipment ensures that two almost simultaneous calls to the same directory number cannot select the same auxiliary line while the marker is setting up the first connection. It also finds and selects a free path through the four partial stages from LKR to the wanted subscriber's line. The required horizontal and vertical magnets are operated in SLD, SLC, SLB, SLA. This is done whether the subscriber is idle or busy, to enable trunk offering to be effected if required. The marker before it releases sends a signal to the register to indicate whether the called subscriber is idle or busy.

If he is idle the register is disconnected and ringing signal and ring tone are sent from LKR. If the called subscriber is busy the whole connection is released and the caller is connected to "line lock-out" in which state he receives busy tone from his own line equipment with only the cut-off relay operated. While the caller listens to busy tone nothing but the cut-off relay is held.

When the called subscriber answers, the ring is tripped and the SR circuit is prepared for metering. The meter operates with 48V negative from SR circuit over a separate metering wire when the caller restores his handset.

If the call is to a subscriber in a step-by-step satellite exchange the process is the same up to receiving dial tone from the register. After the subscriber has dialled the first digit of the satellite (e.g. 5 for Middle Ridge) the register recognises that the call is for a step-by-step exchange and immediately calls the group selector marker. This equipment proceeds to find a free junction to the satellite and connects the register through outgoing relay set FUR to the incoming second selectors. The group selector marker also sends a signal to the register and further digits are sent out as decadic impulses (10 i.p.s.) to operate the bimotional switches. The register releases when the last digit has been sent. If the register waited as before to receive all digits before connecting to the step-by-step exchange, the post dialling delay would be 5 to 6 seconds and this is not desirable as the speed of connection would be slower than a normal call in a step-by-step exchange. If the called subscriber is busy, busy tone is fed from the final selector and the whole connection is held until the caller replaces his handset or until the throw-out feature of the SR operates. Metering of the call is the same as for the previous case.

If the caller is situated in the step-by-step exchange (Middle Ridge or Newtown) and calls another subscriber in his own exchange, his uniselector searches to find a free junction to the crossbar exchange and he enters in an FIR circuit. This circuit is connected (as SR) to a free register from which the caller receives dial tone. The digits are dialled and as the call is for the step-by-step exchange, the register and group selector operate as for the call just described. If the called subscriber is busy, busy tone is sent from the final selector in the satellite exchange or if the caller does not hang up, from the FIR after time release.

If the caller in the step-by-step exchange originates a call for a subscriber in the crossbar exchange all digits are received by the register and the call is set up as for a call wholly within the crossbar exchange. If the called subscriber is busy, the caller receives busy tone from the incoming relay set FIR, all other equipment in the crossbar exchange being released. In the case of calls from step-by-step exchanges, metering takes place on answer.

FEATURES AND FUNCTION

Subscribers' Stage (SL). The subscribers' stage is divided into four partial stages. The first two, A, B, are used for both incoming and outgoing traffic while the other two C, D, are used for outgoing traffic only. For outgoing traffic internal blocking can be kept low even when the connection consists of only A and B stages, since there are paths to a large number of B selectors from the calling subscriber's line. For incoming traffic a particular inlet shall be connected to a particular outlet, and to limit the internal blocking two additional stages are incorporated, C and D. In this way all LKR circuits in any 1,000-line group can reach any subscriber in that group.

The traffic capacity of the system is indicated by the letter "m" which indicates the number of verticals per 20 subscribers in the SLA stage. The exchanges are manufactured in three basic sizes, m = 6, 8, and 10. In Toowoomba the first four 1,000-line groups have an "m" value of 8, while remainder have an "m" value of 6.

Within each basic size the number of SLB selectors can vary, which is designated by the letters A, B, C, or D after the "m" figure. In Toowoomba the first four 1,000-line groups are of m = 8A and the next two m = 6A. The equipment for the last 300 lines is of size m = 6B because no size 6A is made below 800 lines. The rack SLB/PBX in suite 7 (Fig. 3) carries the additional SLB selectors until the 1,000 group is fully equipped. The rack eventually becomes redundant in this group and can be used elsewhere if desired. It is readily possible to increase the S L stage capacity from 8A to 8B or 6A to 6B, but a change from 6 to 8 requires replacement of certain racks and is not desirable if it can be avoided. The face layout of the racks is shown in Fig. 4.

The following table shows how the number of verticals in the partial stages

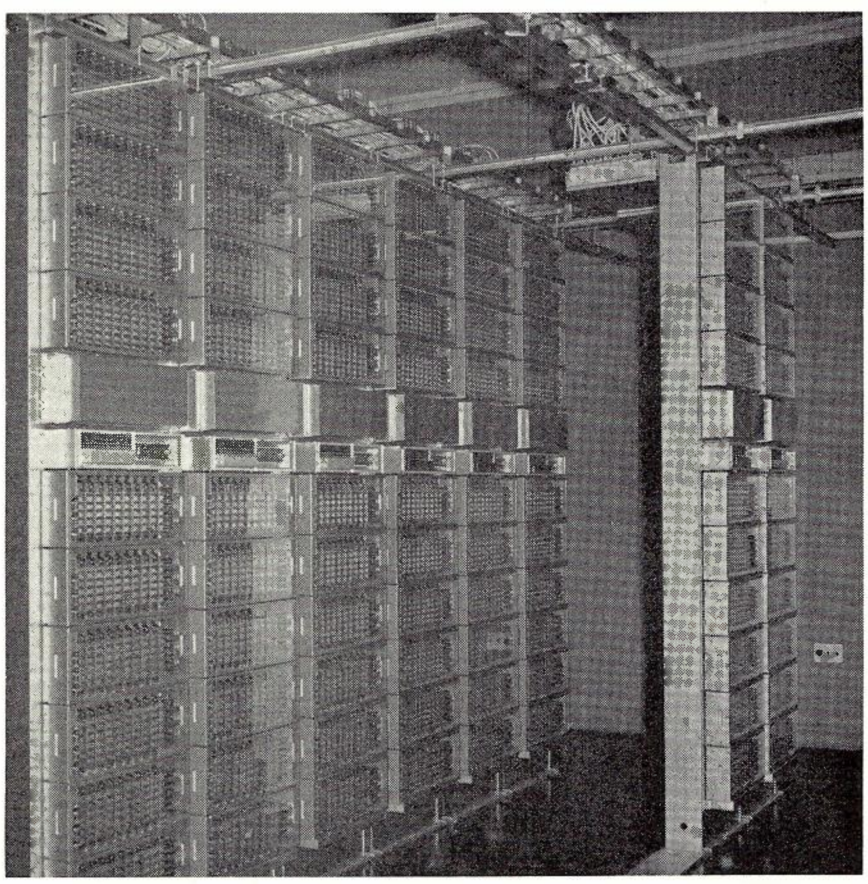


Fig. 8.—Group Selector Racks, Front View.

Size	Number of Verticals					Max. Traffic 1000 line		
	SLA Per 20 Subs (m)	SLB		SLC (Can vary see text)	SLD			
		Outg.	Inc.			Outg.	Inc.	Total
6A	6	75	75	80	80	48E	42E	90E
6B	6	100	100	120	120	58E	48E	106E
6B	6	100	100	80	80	58E	45E	103E
8A	8	100	100	120	120	69E	67E	136E
8A	8	100	100	80	80	70E	55E	125E
8B	8	100	150	120	120	68E	78E	146E
8C	8	125	175	160	160	83E	92E	175E
10A	10	125	175	200	200	88E	116E	204E
10B	10	150	200	200	200	106E	123E	229E

varies for different sizes. The table also shows the traffic handling capacity of the different sizes.

The SLC/D verticals are provided in multiples of 40 and at Toowoomba two such groups are provided for each 1,000-line group. Each SLC/D rack (see Figs. 3 and 4) contains four SLC and four SLD crossbar selectors, and each 1,000-line group contains two such racks. The table above gives the normal number of SLC/D verticals.

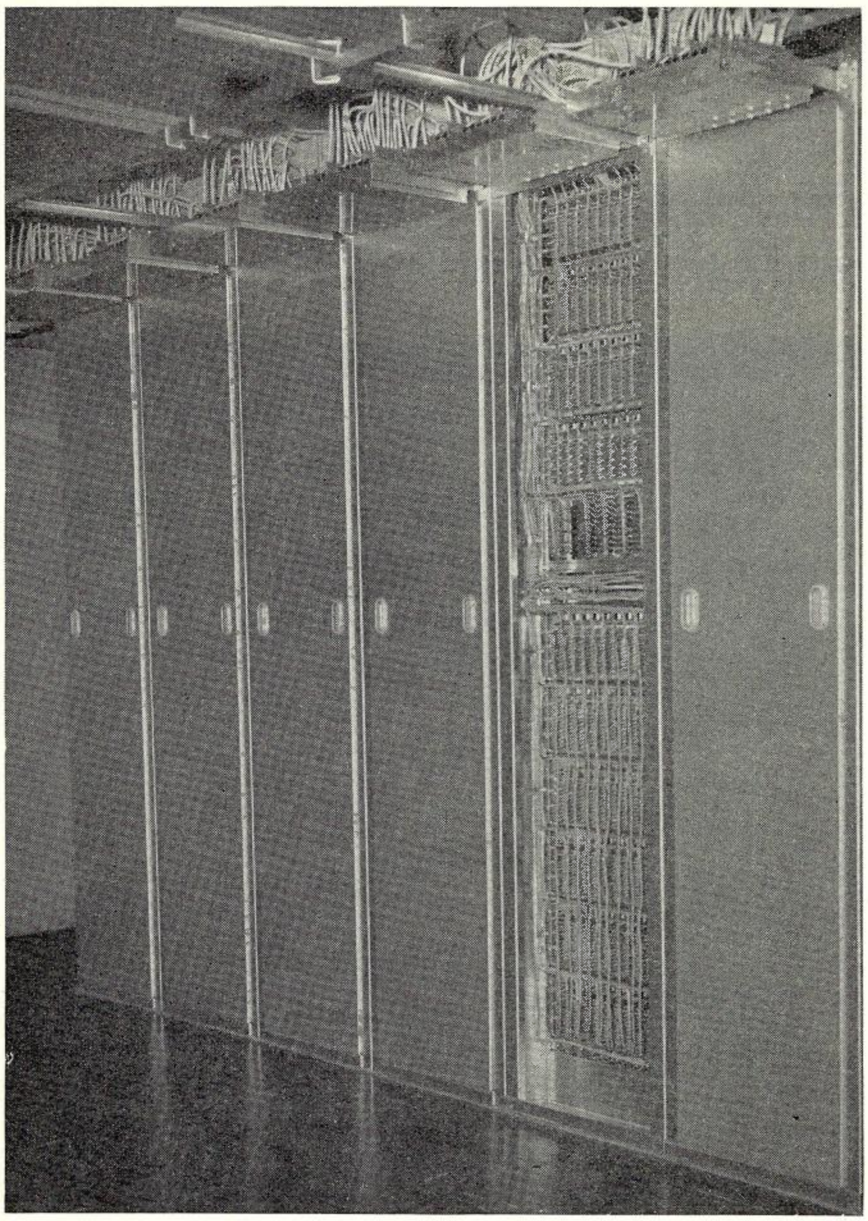


Fig. 9.—Group Selector Racks, Rear View.

The marker connects an outgoing call to the register in approximately 0.5 seconds. Thus the subscriber receives dial tone on putting the receiver to his ear. The part of the marker provided only for outgoing traffic is occupied for about 0.5 seconds while that part common to outgoing and incoming traffic is occupied for about 0.37 seconds.

For incoming traffic an inlet to the SLD stage (i.e. an LKR) is connected to the called subscriber in about one second. During this time the code receiver of the SL stage is occupied. The part of the marker provided for incoming traffic is occupied for about 0.56 seconds while the common part is occupied for about 0.46 seconds.

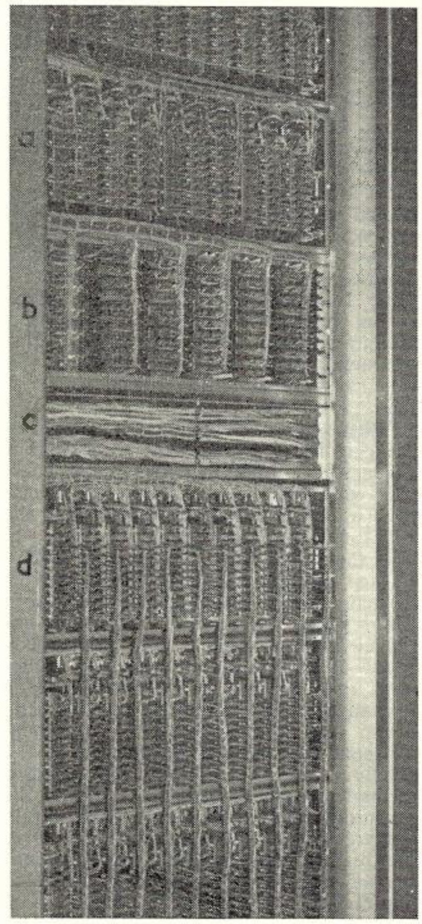


Fig. 10.—Group Selector Rack, Rear View.

Group Selector Stage (GV). The group selector stage I-GV is divided into two partial stages A and B. This stage is made up of group selector units which consist of two identical racks of group selectors having 80 inlets, 120 links and 400 outlets. This is an expansion (i.e., $\frac{\text{number of links}}{\text{number of inlets}}$) of 1.5.

A group selector unit is shown in Fig. 4, each unit consisting of two identical racks. The outlets can be arranged in routes of different availability. For example, the 400 outlets can be 20 routes with availability 20 (single routes). If required some routes can have an availability of 10 (an additional relay set is required in the group selector marker) and the special group selector GVS at Toowoomba is capable of accommodating 10 routes of availability 10, and 15 of 20. By suitable strapping, double routes, that is, routes of availability 40 can be arranged by combining two routes of availability 20. The first route of 20 is tested then the second route of 20. In Toowoomba 40 outlet routes are used for the first four 1,000-line groups (m = 8A).

The difference in traffic handling capacity depending on the outlets per route is as follows:—

Grade of service of 0.005, a traffic of 40E and the same average traffic load per GVA inlet;

For an availability of 20 the number of lines required in the route is 72;

For an availability of 40 the number of lines required is 60.

Alternate routing is possible, so that should there be no free outlets in the direct route, an alternate route can be tested. It is possible to arrange for an alternate double route, so the direct route could be a double route as well as the alternate route. (The routes in the group selector stage correspond to the levels in the step-by-step system, but in the crossbar system the routes are independent of the digits dialled.)

The switching time of this stage varies from about 0.4 to 1.0 seconds depending on whether it requires one, two or three digits to determine the route or if alternate switching is employed.

Grading in the manner encountered in step-by-step equipment does not appear in the crossbar exchange. Outlets from the various GV units for a particular route are connected together by a form of commoning. A route may lead to another exchange over 50 junctions. The eight GV units may have an availability of 20 to this route. That is, there are eight groups (i.e. eight GV units) availability 20, 160 outlets, 50 trunks. As sequential searching is not done (as in a bimotional switch) the aim is to give an equal load to all the trunks. The commoning of the outlets on the I.D.F. is done in such a manner that this is achieved. Fig. 5 shows this commoning on one route. Small forms are made for this connection then terminated on the I.D.F. Strips.

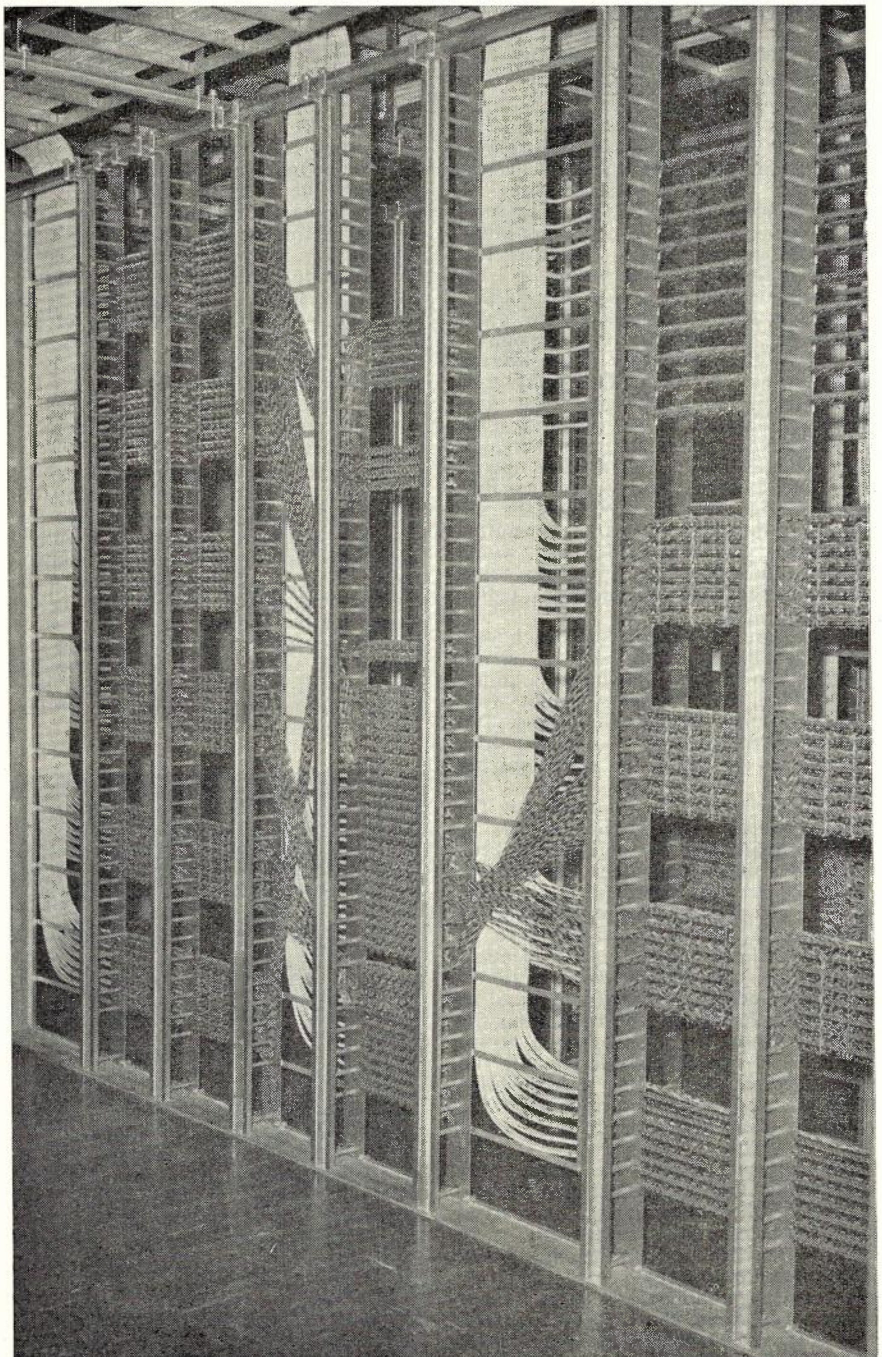


Fig. 11.—I.D.F. Rear View.

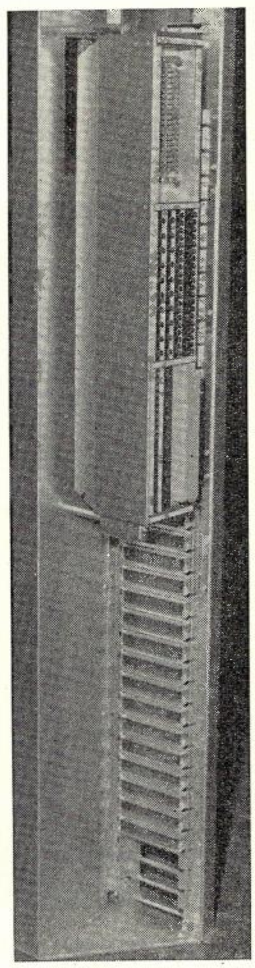


Fig. 12.—Relay Set Rack, Right-hand Side.

Register-Finder. The register-finder connects certain devices to the registers, using a crossbar selector controlled by a register-finder marker. In Toowoomba, there are two types of register-finders. One connects forty SR circuits to any one of ten registers and consists of two crossbar selectors; the other connects any one of sixty-four FIR circuits to any one of twenty registers, and consists of four crossbar selectors.

Markers. The markers control the choice and setting of the horizontals and verticals in the various stages. First of all consider the marker for the subscribers' stage. In Toowoomba there are two identical markers for every 1000-line group and both can be in operation simultaneously. Each group of 200 subscribers (i.e. each rack SLA/B) has a call indicator located in the SLA/B rack, i.e., five per 1000-line group. This call indicator calls one of the markers and the marker is connected to the calling group. The choice of the marker is random, depending on the half cycle of an alternating current. After the connection of the marker, the calling subscriber is identified. Relays operate indicating the last three digits of the caller's number and other relays in turn operate to indicate the free SLA verticals which have access to the calling subscriber. One of these verticals is then chosen by conditional selection, so that the selected SLA vertical can be reached from an SR which has access to a free register. A free SLB vertical is then selected, and the selected SLB vertical determines the SR circuit to be used, as these circuits are connected to the inlets of the SLB verticals. When the SR is selected and the SLA and SLB horizontals and verticals are operated, the register-finder marker is called and upon the connection of the SR circuit to the free register, both markers are released.

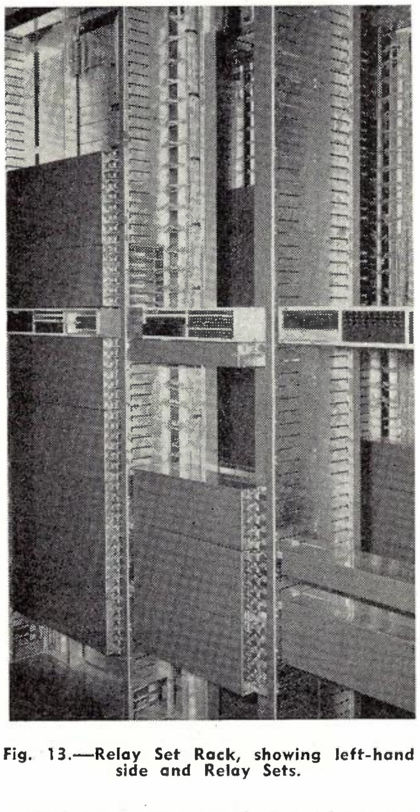


Fig. 13.—Relay Set Rack, showing left-hand side and Relay Sets.

On incoming traffic the marker is seized after the code receiver has received the code for the last three digits of the called subscriber's number and ascertained whether or not the called subscriber is on interception and whether or not the called subscriber is a P.B.X. service. The code receiver operates relays in the marker to indicate the last three digits of the wanted number. Other relays operate to indicate free links between the calling LKR and called subscriber. Horizontals and verticals are selected and operated and the marker is then released.

If when a caller makes a call and no marker is free, the delay principle is followed and the caller waits until a free marker is available. In most cases the caller is not aware that delay may have occurred as a short waiting time would not cause inconvenience. The marker is occupied for a very short time on each call (100 to 600 m.s.) and overloading of the marker is only likely to occur when an exceptionally large group is served by the marker, or if the average call duration is short. The delay time increases as the marker operating time increases because as the operating time increases, the marker load also increases, and for this reason the marker operating time must be as short as possible. With a load or about 4,000 calls per hour, an increase in marker operating time from 400 m.s. to 700 m.s. would increase the delay time from 1.8 seconds to 10.0 seconds. In practice this situation would not arise.

There are two markers in each subscriber's stage, and they can work simultaneously with the following two limitations. First, both markers cannot work simultaneously within the same 200 group. Secondly, they cannot work simultaneously within the same crossbar selector.

Consider now the marker for the group selector stage. This marker is smaller than that for the subscribers' stage; this marker has been divided into the code receiver part and the marker GVM. The former part consists of an identifier to identify the eighty inlets of a group selector unit (i.e. two identical GV racks), and a code receiver to receive the code for the digits required to determine the route. The translation for different traffic routing is done by strappings on an interchangeable block in the code receiver. The GVM part contains the test and selection equipment for selection of an idle outlet in the marked route.

If the group selector has routes with availability ten (special group selector stage GVS in Toowoomba), the marker must have an additional relay set.

It is possible to provide the group selector unit with double markers and in that case an additional relay set is provided to distribute the calls between the two markers. Double markers are used only in small exchanges where the failure of a marker would seriously interrupt the traffic through the exchange.

In Toowoomba the arrangement is that each group selector unit is served by a code receiver and two group selector units and their code receivers are served by one marker. There are eight group selector units and one special group selector and these are served by five group selector markers. Thus the failure of one marker does not cause a serious interruption.

The marker unit tests and selects a free outlet in the required route. The test is done electronically using cold cathode tubes. The marker design for all group selectors is the same, and thus it is possible to arrange the routes in different ways for the two group selectors served by the same marker. The first group selector can be connected to the same marker as the special group selector stage.

Register. The register consists of three relay sets. One contains a crossbar selector with five verticals and on this are stored the digits dialled. As the digits are dialled the impulses of each digit are counted on relays which then control the operation of the horizontals and verticals. The second relay set contains relays associated with the sending of the d.c. code and the third generates and sends 10 i.p.s. when the call is to a satellite exchange. The functions of the register are determined by strappings on a small terminal block on the rear of the crossbar selector.

The limits for dialling are 8 to 22 i.p.s. with a weight ratio 30/70 to 50/50. The minimum interdigital pause for this system is 350 m.s. These relaxed dialling conditions are possible as all impulses are received by an impulsing relay in the register and stored. This circuit is designed for the wide limits as there is no impulse repetition with its attendant distortion. A faster speed of dialling has the tendency to reduce the holding time of the register, and the number of registers required.

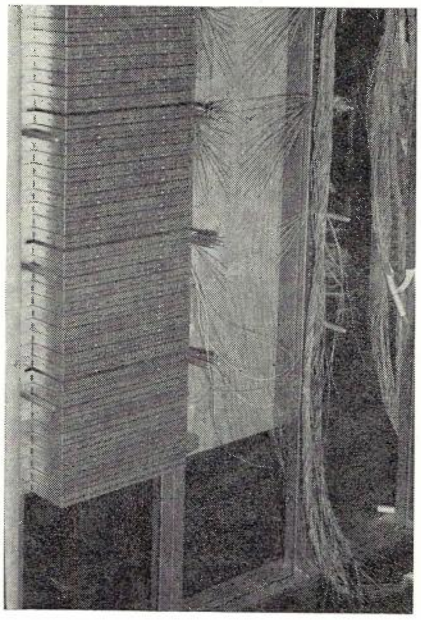


Fig. 14.—Meter Racks.

Signalling System. The signalling between the markers and the registers is done with a direct current code with polarity reversals, of 10-15 m.s. duration. The polarity of the "a" wire for the various digits is:—

Digit	Code
1	+
2	+ —
3	+ — +
4	+ — + —
5	+ — + — +
6	— + — + —
7	— + — +
8	— + —
9	— +
0	—
"11"	+ — + — + —
"12"	— + — + — +

The codes "11" and "12" are used as special markings and are used for example, to indicate traffic to an interception operator.

The signalling system in the exchange is as follows:—

Direction	Signal	Remarks
REG to GVM	Digits	To set stage.
REG to SLM	Digits	To set stage.
GVM to REG	Repeat	REG to repeat digit sent already.
,, ,, ,,	Idle	GV has found free outlet to special service.
,, ,, ,,	Congestion	Congestion in GV.
,, ,, ,,	Proceed	Send next digit when called for by marker.
	Step-by-step	Go over from a.c. code sending, to sending with 10 i.p.s.
SLM to REG	Malicious Call tracing	REG changes SR to last party release.
,, ,, ,,	Busy	Subscriber busy.
,, ,, ,,	Proceed or idle	Send next digit. After all digits means called sub. free.
,, ,, ,,	Congestion	Congestion in SL

For the revertive signals the same d.c. code is used as follows:—

Code	Corresponds to Digits	GVM to REG
—	0	Proceed with next digit.
— +	9	Change register to send following digits at 10 i.p.s.
— + —	8	Change register to send digits at 10 i.p.s. from the third digit.
— + — +	7	Change register to send digits at 10 i.p.s. from the second digit.
+	1	Repeat digit.
+ —	2	Congestion.
+ — +	3	Change register to send following codes without revertive signals between digit codes (e.g. to REG-N).
+ — + —	4	Freesignal for special services (e.g. to "011").
		SLM to REG
—	0	Idle signal, or proceed.
— +	9	Busy.
+	1	Interception or malicious call.
+ —	2	Congestion.

Throw-out Feature. To ensure that switching equipment is not held for lengthy periods due to a fault condition or other reason, some of the equipment will automatically disconnect the call and send back busy tone to the caller from his line relays. Some examples of this feature are as follows:

SLM throw-out time 800m.s.	Release is initiated on seizure and the marker's function must be complete within this time.
Register throw-out time 45 secs.	Release is initiated on seizure and dialling and register functions must be complete by this time.
SR throw-out time 1½ mins.	Release is initiated when the called subscriber is tested and ring signal sent out. Answer signal must be received within this time. Also if the called subscriber after answer, replaces his handset, release takes place if he has not relifted his handset within 1½ mins.
GVM throw-out time 1 sec.	Release is initiated on seizure and wanted route must be selected and switched by this time.

P.B.X. Function. One of the SLB racks of the first four 1000-line groups contains the P.B.X. equipment for the 1000-line group. Each rack contains 80 P.B.X. relays, and each P.B.X. subscriber needs one of these relays per four lines. For example, a subscriber with a call line and four auxiliary lines would have two P.B.X. relays. The theoretical maximum number of P.B.X. lines per 1000-line group is 320, and if more lines are required another P.B.X. rack can be installed. The P.B.X. equipment is prestrapped for directory numbers with the last two digits the same (e.g., 21711, 23433), and there are 100 such numbers in each 1,000-line group. Provision is made, however, for other numbers to be used as P.B.X. directory numbers if required. Any number within the particular 1,000 line group can be used as an auxiliary number and it is not necessary for them to be sequential. As the spare numbers are common only a few numbers must be reserved for growth within the 1,000-line group. The P.B.X. equipment is taken into use on all calls and is occupied for about 0.16 seconds for a normal subscriber and about 0.22 seconds for a P.B.X. subscriber. At cutover there were 176 directory and 267 auxiliary PBX numbers in Toowoomba.

Interception and Malicious Calls. Equipment is available for interception service, and each terminating call is tested for interception service as the code receiver is receiving the codes for the last three digits.

The equipment consists of a board with a jack for each subscriber. Into this board three kinds of plugs can be inserted, depending on whether the called number is a changed number service, a temporary intercepted service or unallotted number. A subscriber on interception may make an outgoing call without the assistance of an interception operator. This equipment is not available in Toowoomba and initially interception will be given in the usual manner from the M.D.F.

If an unallocated code is dialled (e.g. a 1,000-line group not installed) the group selector routes the call to relay sets which send N.U. tone to the caller.

A facility for malicious call tracing is available if required. Normally the SR circuit is connected for calling party release, but for malicious call tracing the SR is converted to last party release.

If the exchange has an interception position, this equipment is used to effect the last party release feature, but if it is not, the P.B.X. equipment is used.

Multimetering. Multimetering impulses may be sent from the trunk exchange as polarity reversals on the speaking wires. This method and others are at present under test.

The register, on recognising a code as being of a multimetering nature, operates a relay to change the metering conditions of the SR from local metering to multi-metering.

Barred Subscribers. It is possible to bar subscribers access to certain codes and testing for a barred subscriber is done by the register. The barred subscribers have a rectifier in the telephone instrument and by sending a reversal of polarity towards the calling subscriber the register can recognise a barred subscriber. This facility has not been used initially at Toowoomba as such a test towards subscribers in a satellite step-by-step exchange would cause a premature meter pulse to operate the caller's meter.

Public Telephones. The usual post-payment multicoin public telephones are used at Toowoomba and as the polarity on the incoming side of the SR does not change after answer (reversal being used for barred subscriber test) an auxiliary relay set has to be inserted between the public telephone and the line circuit to reverse the polarity of the speaking wires on answer.

Alarm System and Ring Supply. The exchange does not contain an Alarm Equipment Rack for centralised alarm equipment. In its place each suite is served by suite control equipment, which also feeds the common services. The equipment consists of a control box at the end of each suite suspended from the runway. The box contains test jacks and keys for isolation and testing. Through the box are fed test lines, alarms, tones, pulses for line lock-out, A.C. supply used for choosing a marker, etc. Alarm lamps are located underneath the control box, as well as on each rack. As the requirements of each suite differ according to the racks it contains, the controls are made to suit each individual suite. The suite control form which extends for the whole suite length, is made on the job and connected to the racks, and is placed on the runway on the top of the racks. Departmental ring and tone supply equipment is used.

TOOWOOMBA TRUNKING

Fig. 6 is the diagram showing the interconnection of the equipment, and the figures at the I.D.F. points indicate the number of wires per circuit. It is not similar to a step-by-step trunking diagram for no quantities of equipment are indicated. While considering the path of a call the main items have been mentioned and the other items will now be dealt with.

A call from a satellite exchange is connected to an incoming relay set FIR. This is connected to a GVA vertical and through its register finder RS-I to a register. Thus when a satellite subscriber lifts his receiver, his uniselector searches to find a free junction and tests into an auto-auto repeater (later to be modified for multi-metering) in his own exchange, which is connected via a junction to an FIR at Toowoomba. Upon seizure the repeater engages the FIR, and a free register is connected and dial tone sent to the caller. The FIR is capable of repeating multi-metering impulses as polarity reversals of the speaking wires.

Outgoing calls to satellite exchanges pass through the outgoing relay sets FUR. Back busying is employed in these circuits and the auto-auto repeaters.

Junctions from the trunk exchange are connected to circuits ULR and free line signalling is used. These circuits are connected to a GVA vertical and through a register-finder RS-T to registers REG-T. The register-finder RS-T gives 40 circuits access to 10 registers and it has provision for accepting digit information from key senders or from dials, and returns dial tone on seizure.

Outgoing junctions to the various service levels pass through circuits BLR.

Circuits PRP and SNPR enable the test desk to be connected to the test selector relay set LPR to test subscribers' lines.

The APR is a test robot. It can be called from any subscriber's instrument and controlled by dial impulses. It gives the results of tests by means of tone codes. It checks dial speed, bell ringing, insulation ("a" to earth, "b" to earth, "a" to "b") and loop resistance. Because the SR and LKR circuits have feeding bridges and cannot be through connected the test path must be used. A special direction digit is dialled, followed by the lines own number. This causes a connection to be set up from the APR to the test selector relay set LPR. The connection is controlled by the normal registers and upon the connection being set up, busy tone is heard and the receiver is restored. This releases the connection to the APR, but following stages are held from the APR. Ringing signal is sent and measurements commence on lifting the receiver. The different tests are obtained by dialling different digits.

The trunk switching portion of Fig. 6 is to allow a limited amount of subscriber dialling to take place before the installation of an automatic trunk exchange.

Whereas the local register REG-L can store up to five digits, the trunk register REG-NY is more complicated and can store up to nine digits. When a trunk code is dialled followed by a subscriber's number the group selector marker is called as soon as the code is recognised as a trunk dialling code. The group selector connects to free circuit FIR-H which then calls in the trunk register, and all the dialled digits are then repeated to this register and it then completes the connection over the trunk network.

The determining of the charge rates and traffic routing is handled by a common analyser in the marker of the trunk switching stage, not shown in Fig. 6 as it

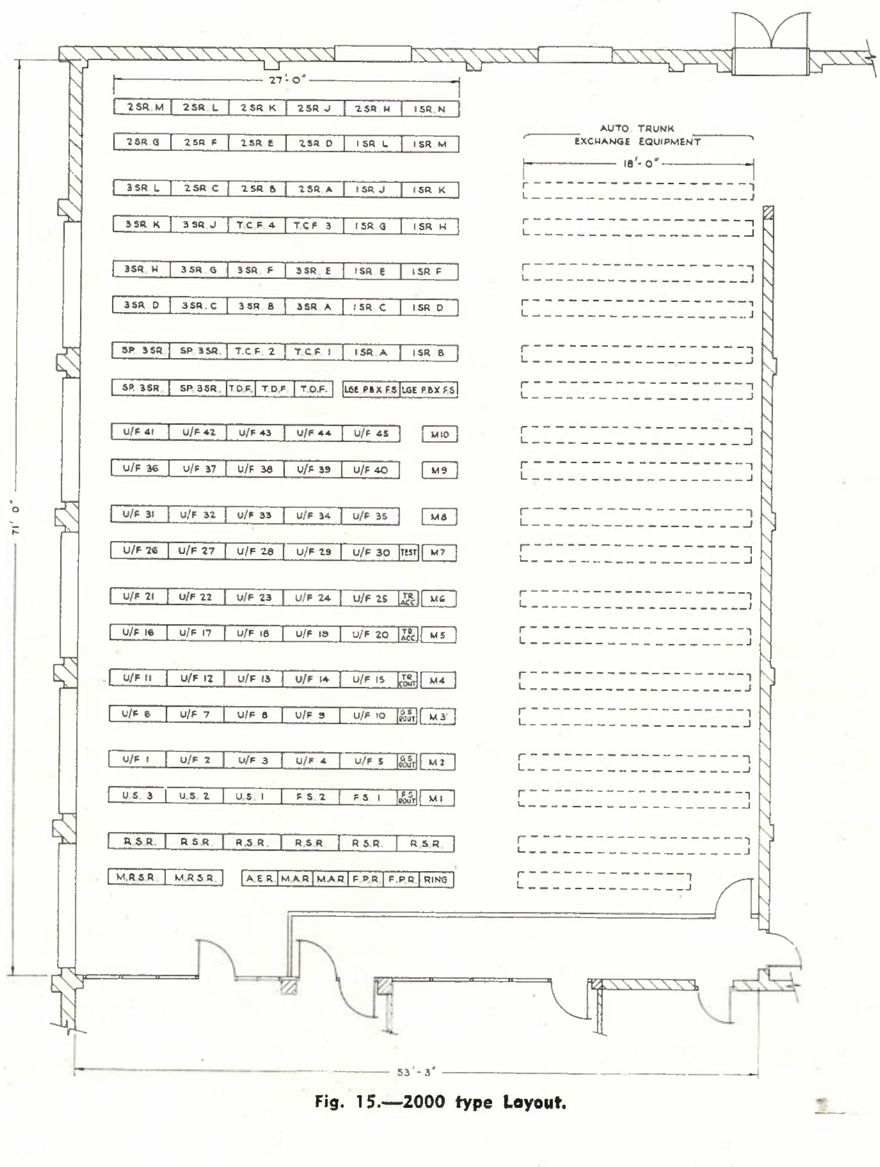


Fig. 15.—2000 type Layout.

is not required until the transit group selectors are installed. Fixed fee working will be used initially to which the trunk register has access. Sufficient number of digits are transferred to the marker which after an analysis of the data sends back the rate information via the trunk register, to FIR-H where it controls the metering conditions. The necessary pulses are generated in special equipment and fed to the trunk circuits, and repetitive metering takes the form of polarity reversals over the speaking wires. This equipment is not yet installed at Toowoomba.

CROSSBAR LAYOUT

Fig. 3 shows the layout for Toowoomba. In each 1,000-line group there are five SLA/B racks each accommodating 200 subscribers. In the first four 1000-line groups (size m = 8A) there is an SLB, and SLB/PBX rack. Two SLC/D racks are provided for each 1000-line group, each rack being equipped with four SLC and four SLD selectors.

On the rear of the SLA/B racks the line and cut-off relays are mounted in jack-in relay sets with twenty circuits per base. Fig. 7 shows the rear view of five SLA/B racks. Each group of five relay sets are mounted on a hinged gate which can be opened to give access to the selector multiple. Visible in the open gate is the selector multiple of the SLA stage and part of SLB. Also to be seen are the mounting brackets and plugs for the line relay sets.

It will be readily seen that the crossbar selectors in the selector racks are an integral part of the rack and they cannot be jacked out. They are supplied wired as shown in the figure.

Racks 10 to 12 in suites 1, 2, 3, 4, 11, 12 and racks 9 to 11 in suites 5, 6, 7 are of the relay set type and accommodate jack-in type relay sets. Fig. 12 shows the right hand side of such a rack. The supervisory panel is shown in a vertical position for transport. Above and below this panel can be seen the plug units. These racks are placed back to back. For example, in suite 1, rack 10 on the A side contains one of the markers for the 1000-line group. On the B side the LKR relay sets are located (see Fig. 3). Rack 12 contains SR relay sets and register-finders. Each rack contains 40 SR circuits, a register-finder marker and two crossbar switches RS1 and RS2 each with six horizontals. These connect the SR circuit to the registers and enables each such group of 40 SR circuits to have access to 10 registers. In each 1000-line group rack space for the maximum number of SR circuits

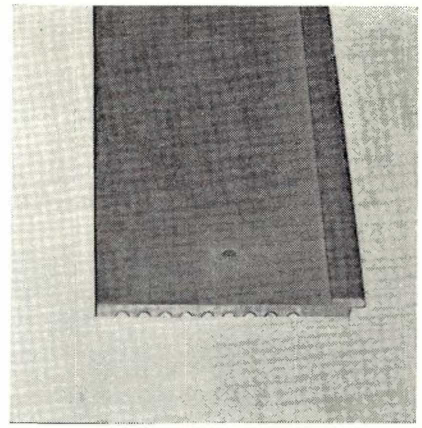


Fig. 17.—Selector Rack Base Plate.

required for each size is installed initially. For example, in size 8A rack, provision for 100 SR circuits is provided, and for size 6A, 75 circuits. This entails the provision of 2½ racks per 1000-line group for the former size, and 2 racks for the latter. These racks can be seen in Fig. 3.

Consider now the racks that are common to the whole exchange. The only

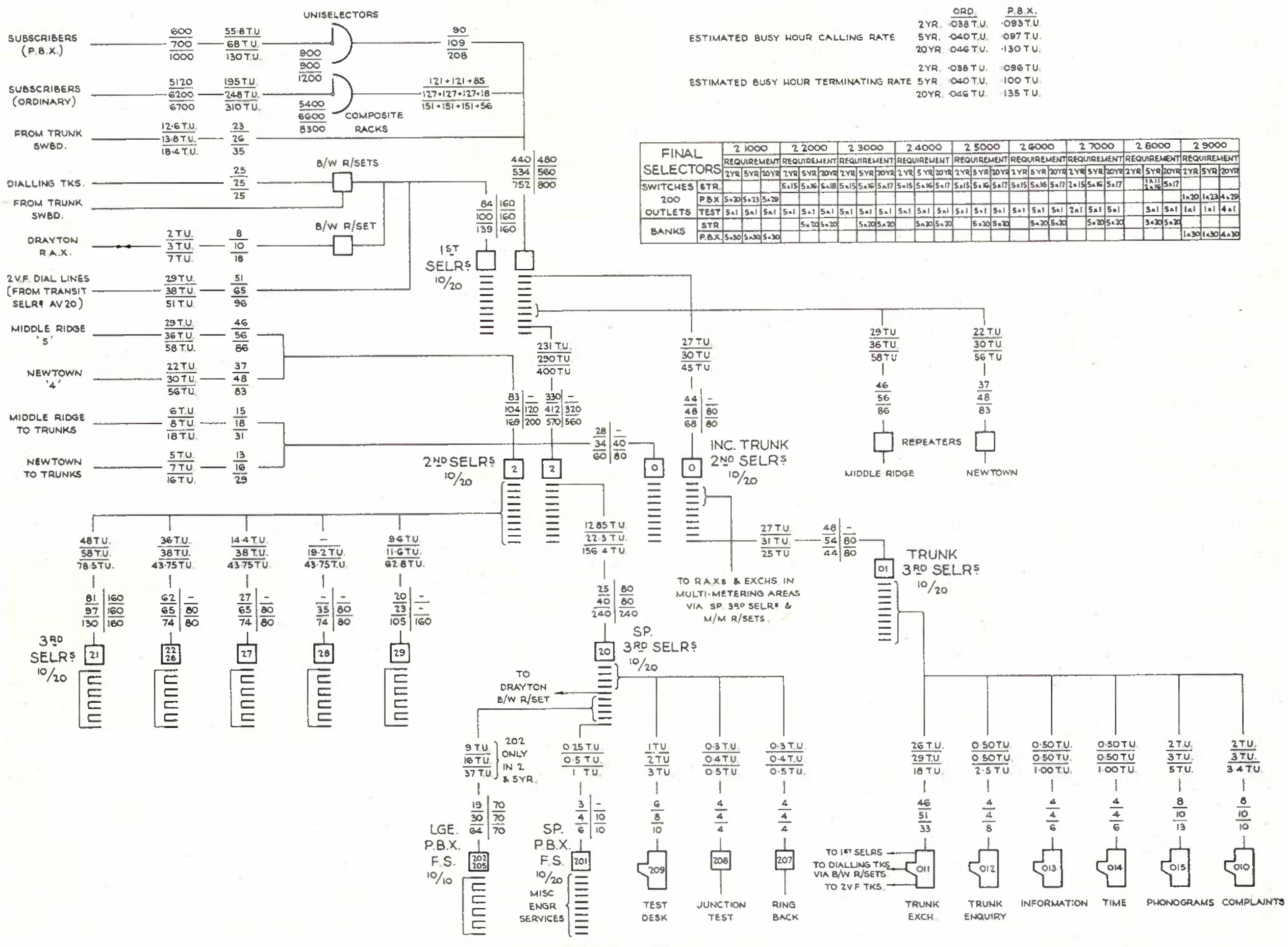


Fig. 16.—2000-type Trunking Diagram.

other selector racks are the group selectors. A general view from the front is shown in Fig. 8. Referring also to Fig. 4 the selectors above the jack box are GVA, and those below are GVB. Fig. 9 shows a rear view, one cover being removed to show the wiring of the selectors. The covers are of prestressed hardboard, so they fit snugly and securely. Fig. 10 shows a close-up view.

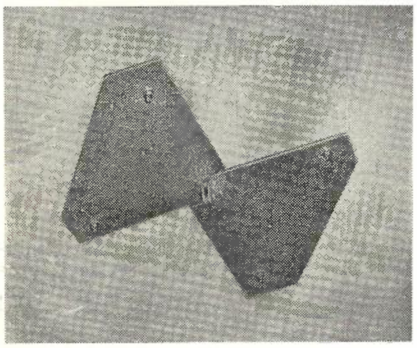


Fig. 18.—Relay Set Rack Base Plate.

The designations on the figure refer to:
(a) GVA crossbar selector No. 4
(b) Multicoil relays on the right, general purpose relays on the left.
(c) Wiring of the supervisory panel.
(d) GVB 1 with GVB 2 and 3 below.

A group selector rack contains four GVA selectors and six GVB selectors and two such racks are combined to form a group selector unit. Each unit has 80 inlets (i.e. the number of verticals in the GVA partial stage), and 400 outlets from the GVB partial stage (200 from each rack).

All wiring of the selector racks that is to be connected to equipment is terminated on plug units at the top of the racks. The cables leaving the racks outside the racks are plugged in as shown. In order to avoid damage during transport these jacks and plug units lie flat against the racks and for the same reason the glass in the covers of the selector racks is replaced by stiff cardboard.

The group selector marker rack accommodates two markers on each rack, each marker serving two group selector units (i.e., four racks). The relay sets are in effect strip mountings with jack-in facilities, the largest accommodating 98 relays. All components associated with a circuit are mounted in the relay set. For example, the condenser is designed with the physical shape of a relay, and uses the same mounting bolt. It is mounted in the same way as a relay.

The I.D.F. is centralised and a rear view of this equipment in suite 4 is shown in Fig. 11. From Fig. 6 it can be seen what connections are made on the I.D.F. The terminations in Fig. 11 show the terminations of the outlets from the group selector stage. On the top right-hand side are the GVS outlets while the remainder (except the middle rack) are the 20 routes from the first group selector. The figure shows the outlets of the eight group selector units cabled and terminated. Commoning and jumpering are done on the side shown, the bolts covered with insulating material being used as jumper rings.

In Fig. 5 some jumpers can be seen to be inclined. These common outlets from two routes combined to form a double route (routes 1 and 11). The horizontal jumpers are connections to the inlets of the LKR circuits. The route is seen in Fig. 11 on the right-hand side, top jumpered. The figure shows the rear of the strips with the first GV unit on the bottom and the eighth on the top strip.

Other racks are of the relay set type shown in Figs. 4, 12 and 13.

The meters are mounted facing into the passage-way and are five digit type mounted in strips of ten. Each meter is driven by a pawl in a similar manner to that of a lever escapement. The driving pawl is solidly connected to the armature and is pivoted in the frame. On operation of the armature the driving pawl moves a ratchet tooth on the unit wheel half a step and on release a further half step. The number wheels are made of nylon. The strips of ten meters are mounted under a common cover with individual designations above the number wheels. Fig. 14 shows a part of a

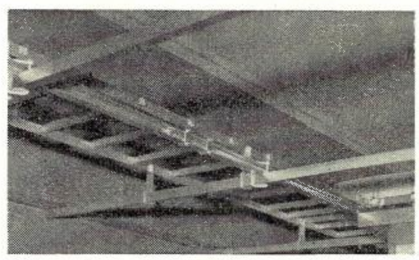


Fig. 19.—Superstructure.

rack of meters (without the designations). Each meter is held to the mounting strip by means of a metal spring and it is only necessary to remove this, and the wires from the coil tags to remove the meter. The rods at the side of the meters are to mount equipment to photograph the meter if this form of recording readings is desired.

COMPARISON BETWEEN CROSSBAR AND 2000-TYPE EQUIPMENT SPACE REQUIREMENTS

The layout in Fig. 3 shows the area occupied by 10,000 lines of crossbar equipment in addition to the trunk dialling equipment in suites 9 and 10. The order of the suites shown dotted may not necessarily be followed at the time of installation.

The exchange is laid out in 1000-line groups each suite being completed by racks common to the whole exchange. The suites have a length of 45 feet 2 inches and the crossbar equipment lends itself to such a suite whereas the 2000-type does not. It is preferable, though not essential, to keep all the racks of the 1000-line groups together, and so suites of shorter length are possible. However, it is not desirable to split the marker racks for cabling reasons. (All the cabling is terminated on one marker and the second rack is connected to the first by a form which runs down rack 1, along the floor under a shield and up rack 2.) It is also not desirable to separate the SLC/D racks as they are commoned by a form over the jack boxes. It is desirable to locate the SLA/B racks near to the M.D.F., and situate the I.D.F. in central position.

As the equipment consists of some double-sided racks and racks back to back, the conception of equipment and wiring aisles is absent. All aisles are of the same width and are in effect equipment aisles. In 2000-type the dimensions are, equipment aisle 2 ft. 4½ inches, wiring aisle 1 ft. 6¾ inches and rack width 1 ft. 3½ inches. In the crossbar layout the aisle width is 2 ft. 3½ inches (700 mm) and the rack width is 1 ft. 4¾ inches (425 mm) maximum.

The distance from the face of one rack of one suite, across the equipment aisle, the next suite, the wiring aisle, to the face of the next suite in 2,000-type is 6 ft. 6¼ inches. The same relative measurement in crossbar is 7 ft. 4½ inches. Therefore, more suites of 2000-type equipment than crossbar can be installed in a given length. In Toowoomba using the position of suite 1 in the crossbar layout as datum, 16 suites of crossbar equipment can be installed, and 19 of 2000-type. Fig. 15 for the 2000-type layout shows 20 suites because suite 1 is nearer to the partition than suite 1 in the crossbar, the meters of the 2000-type being included in the equipment room. It would not be a feasible proposition to install the meters for the 2,000-type layout in the partition as the racks are 2 ft. 9 inches wide, compared with the crossbar width of 1 ft. 3¾ inches (400 mm), and less than half the number of racks could be installed.

The position of meters is a contentious one. With 2000-type layout the best place seems to be with the equipment, but with the policy to keep persons out of the switch room, the meters are better located elsewhere. Although the meters at Toowoomba have been located in the partition, it is for the want of a better place. No separate room is available for their installation which is felt to be the best solution. It is well nigh impossible to seal the meter rack because of the spaces between the strips of ten and a slightly wider space between each 100 group. Also the top and

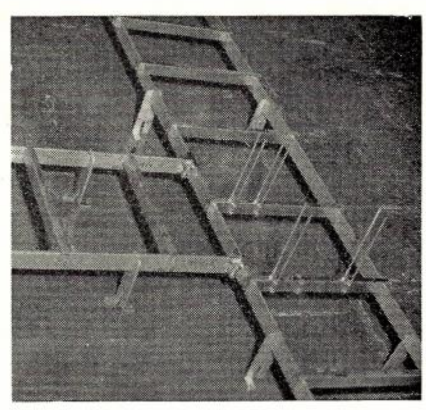


Fig. 20.—Runway Components.

bottom of the rack are open for a foot or so and must be closed. Cabling must come along the rear of the partition and down the racks, and as the rear of the racks faces the first row of equipment, the meter wiring must be protected by a guard from damage by passers-by. The construction of a removable partition immediately behind meter racks would help to solve the situation, but if enclosed in a room these problems would not arise.

In the Toowoomba equipment room, assuming no trunk equipment of any description was installed, it would be possible to install about 16,000 lines of crossbar. Fig. 15 shows a suggested layout for Toowoomba for 2000-type, the trunking diagram being shown in Fig. 16. This is based on the same calling and terminating rates as the crossbar exchange. The 2000-type layout is based on a six rack suite and the figure shows 10,000 lines of equipment. More could be installed in the dotted portion shown reserved for trunk equipment, but a four rack suite would not be conducive to a good local exchange installation. If perchance it was decided to use this space, thus another 3,000 lines or so could be accommodated, although the result would sacrifice neatness.

The ceiling height of the Toowoomba building is 13 ft. 6 inches, based on a 2000-type installation. A recommended free ceiling height for crossbar is 11 ft. 1$\frac{7}{8}$ inches. At Toowoomba fluorescent lighting has been installed over the passage-ways between the suites and the underside of the fitting is eight inches from the ceiling. The high level runway is 2 ft. 7$\frac{1}{2}$ inches from the ceiling, but this could be varied by altering the height between the high and low level runways which is approximately 1 ft. Thus it may be possible to reduce the ceiling height by 1 ft. 6 inches. (If troughing is used in place of runways the ceiling height could possibly be reduced by as much as 2 feet.)

As the supervisory panel, containing fuses, blocking keys, battery jacks, etc., is at eye level no travelling ladders are provided in the aisles.

INSTALLATION TECHNIQUES

The quantities of equipment installed were:—

Item	Quantity
SR	4 x 66 2 x 60 1 x 30
LKR	2 x 60 2 x 58 2 x 66 1 x 32
ULR	50
FIR	103
FUR	104
BLR (for '011')	40
BLR (other)	52
RS	15
RS-I	2
RS-T	2
REG-L	40
REG-T	10
REG-K	2
GV stage	8 units
GVS	1 unit

In addition to the table above, the numbers of the various racks can be ascertained from the layout in Fig. 3.

The first thing to do when undertaking an installation is to mark out the floor. It is usual with step-by-step equipment to ascertain the floor levels referred to a datum point, using a surveyor's level for the job. From this information the amount to be taken off the wooden plinths is calculated so they can be contoured in the workshops to ensure that when placed on the floor, the tops of the plinths are level.

In the crossbar installation wooden plinths are not used. Instead metal base plates are used, and the floor level is accepted as it is and the plates attached to the floor without any packing. To lay out the floor the centre line of each suite was marked, and this was done by simple geometry.

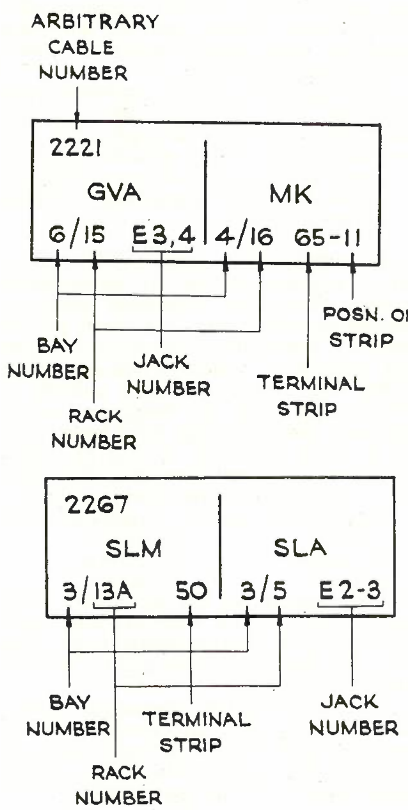


Fig. 21.—Cable Identification Tags.

The ironwork drawing indicated the position of the base plate for the selector racks, and the centre lines of the base plates for the relay set racks, all measured from a datum point. Fig. 17 shows an end section of the selector rack base plate, which is extruded aluminium, and Fig. 18 shows the steel base plate for the relay set rack. The selector rack base plates were cut to length and centred on the suite centre line, then fastened to the floor by means of Ramset pins. A template was used to mark the position of the fastening holes of the relay set base plates, then screwed Ramset pins were driven into the floor and the plates fastened by means of nuts. The position of the plates on the length of the suite is not critical. The relay sets plug in on their right-hand side and are held by a bracket on the other fitting into a slotted plate on the rack. Thus there is a latitude of $\frac{1}{8}$ inch or so.

The three tapped holes shown in the plates in Fig. 18 are for securing other plates to hold the rack uprights. One of these, and the method of connection of the relay set rack are shown in Fig. 12. Usually the crossbar base plates are fastened to the floor by expanding metal cylinders driven into holes in the floor. However, the use of the Ramset Gun enabled the work to be done easier and quicker.

After the floor had been made ready to receive the racks erection began by taking the racks out of the cases. Crossbar equipment is 9 ft. 6 3/16 inches (2900 mm.) high, and as the selector racks are only about half the width of 2000-type selector racks, handling is much easier. A selector rack cased weighs about 900 lbs., and uncased about 600 lbs. To erect the racks a mechanical gantry was tried but was unwieldy and cast aside, for 8 or 9 men could lift the rack out of the case, carry it to its position and place it upright quite easily and quickly. In this manner racks were erected at the rate of five per hour. The selector racks were the first to be installed, and this work commenced with rack 1 in suite 1.

The first was erected and temporarily stayed. A level was taken, and the height of the tie-bar angle-iron wall support marked. This was fastened to the wall and the transverse tie-bar structure begun. The spacing of these tie-bars varied but was about 6 ft. 0 inches. Also racks of all types are fastened longitudinally by a tie bar along the face of the racks at the top (see Fig. 8) and secured to the side walls. Thus as more and more racks were installed the tie-bar structure grew to secure them. Fig. 8 also shows the transverse tie-bars. The bottom of the selector racks is fastened to the base

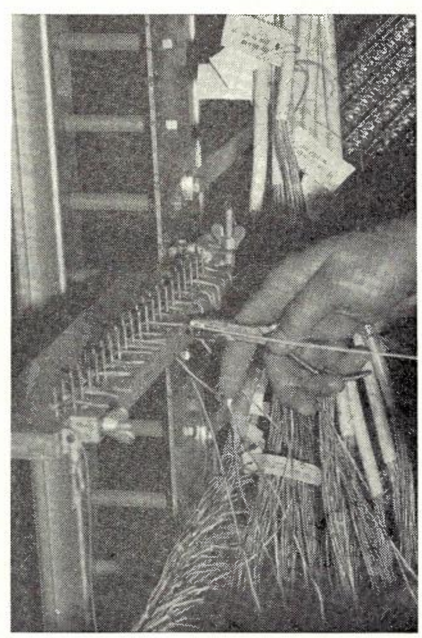


Fig. 22.—Stripping I.D.F. Cables.

plates by means of "J" bolts over the lip of the floor plate, Fig. 17.

The section of the tie-bar is in the form of a "U" and can be seen in Figs. 8 and 19. All fastening is done by means of "U" bolts and clamps. The latter figure shows the fastening of the tie-bars and the fitting of the runways.

For securing the relay set racks, these being placed back to back, another tie-bar is placed along the top. That is, for the relay set racks there is a tie-bar on each side of such racks in each suite. These racks are secured by means of brackets and screws to their base plates. After the racks were erected they were checked and adjusted to a vertical position by means of a plumb-bob.

After this the runway was erected. The layout provided for a low level runway running longitudinally over the top of the racks in each bay for its full length. Over the I.D.F. racks there is also a high level longitudinal runway. There are four transverse runways, two low level, and two high level. The latter were located in such a manner that the bay length was divided into about three equal parts and the former were located at the extreme ends of the bays over the aisles.

The components of the runways are shown in Fig. 20. The runway is assembled on the spot. The side members are taken and the slats pushed on at the required spacing as indicated by the template. There are three widths of runway, 200 ($7\frac{7}{8}''$), 300 ($11^{13}/_{16}''$), 400 ($1'\ 3\frac{3}{4}''$), and 500 ($1'\ 7^{11}/_{16}''$) mm., but the first was not used at Toowoomba. The support brackets are fastened by "U" bolts to the tie-bar, and the runway is held by friction. Joints of "T" shape are made with clamps as shown, and a longitudinal joint can be seen in Fig. 19. Where a gradual rise is required jointing clamps making an angle of 30 degrees with the horizontal are used.

The cable support pins are supplied in one metre lengths, and are cut to the length required and placed in the holders which are a press clip fitted on the slats. The length of the pin is such that it will be a little higher than the ultimate cable block. Before cabling commenced a list of the cables to be run was made, and two tags for each cable was typed. These were tied, one at each end of the cable for identification. Examples of these tags and the information recorded on them are shown in Fig. 21. Also some of these tags can be seen in Fig. 22. They were removed after installation.

While the cables were being run, the blocks were laced temporarily. Later, when the blocks had been tidied, these ties were removed and the block glued with a special type of plastic glue. Permanent lacing was used however where the cable blocks were in a vertical plane, e.g., I.D.F., M.D.F., where the cables changed level, and other places where required, such as some bends. Fig. 23 shows a general view of the cabling during the installation.

The cabling diagrams supplied showed the number of cables and the size between racks in the different suites, and the terminations on the various racks. All the cable blocks and the particular runways each cable would use were determined on the spot.

The cable is P.V.C. insulated and sheathed. The colour of the sheath is white and the three sizes of cable used were 42 wire, 63 wire and 105 wire.

These cables are made up as follows:
105 w—core of 21 pairs, then 21 triples
63 w—21 triples
42 w—21 pairs.

In each case the cable is colour coded in a manner similar to underground cable. There are reference pairs or triples in each layer, but these are ignored in terminating. The pairs or triples are selected at random at the end of the cable first terminated. The colours of the various wires are designated on the terminal strip drawings by a letter within a circle as shown in Fig. 24, which indicates the termination of a 42w cable on a plug unit on the selector racks.

Some of the colour designations are:

a—blue	d—white
b—yellow	e—brown
c—red	f—green

The diameter of the cable wire is 0.5 mm. (0.197"). The wire for other purposes, such as making forms, is the same but wire for battery and earth is 0.8 mm (0.315") diameter.

Having cabled the exchange, terminating began. All cables connected to selector racks are plug ended and are inserted into a jack-field at the top of the selector rack, as seen in Fig. 7. This end is terminated first. The pairs (or triples) are chosen at random, stripped and terminated according to a certain pattern (see Fig. 24). The pairs (or triples) are identified at the other end of the cable, and can be placed on a forming board in their correct sequence. Fig. 25 shows an identification set. The user completes an electrical circuit which lights a lamp with a number engraved on the lamp cap. The circuits number is then read directly.

Where both ends of a cable terminate on a relay set rack, one end is terminated first by selecting pairs at random, and buzzing the cable when terminating the cable at the other end. All cables were terminated using these methods. Also at times a helical spring was used to keep wires in sequence. The spring was expanded and the identified wires placed in the coils. On release the spring holds the wires until laced into a form.

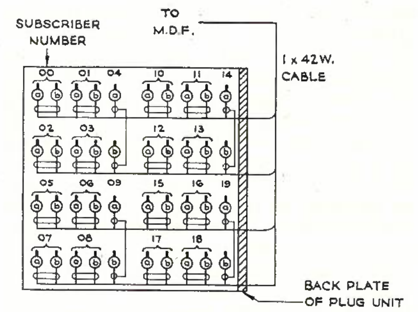


Fig. 24.—Forty-wire Plug Termination.

The forty-wire plugs and jacks on the selector racks and the eighty-wire plugs and jacks on the relay set racks are made up of a basic plug and jack unit. The contact members consist of flat plates, one fork shaped and the other as a knife-like flat pin. The forked contact part is placed at an angle in relation to the making flat pin. When the latter is inserted into the forked contact, a contact point is obtained on each side of the pin. Torsion set up in each prong of the fork ensures adequate contact pressure. Forks and pins are mounted with free movement so they align themselves when coupled. Each plug has twenty contacts.

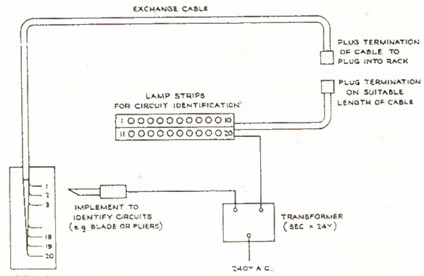


Fig. 25.—Cable Identification Set.

The forty-wire plugs of the selector rack are made up of two of these basic components, while the plugs on the re-

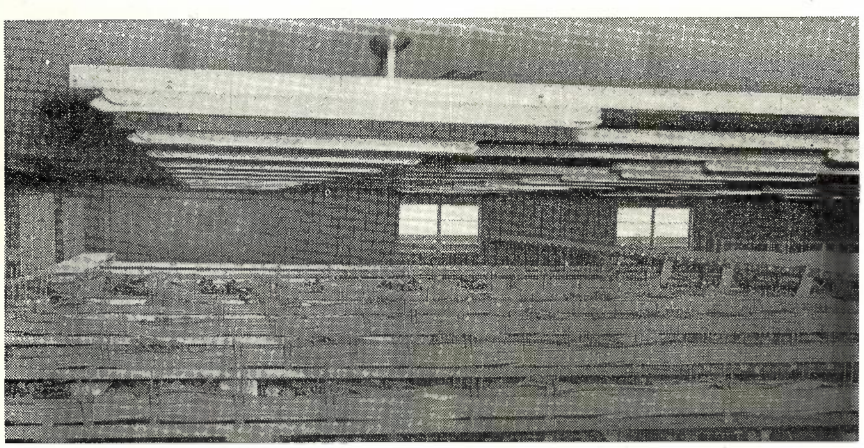


Fig. 23.—Top View during Installation.

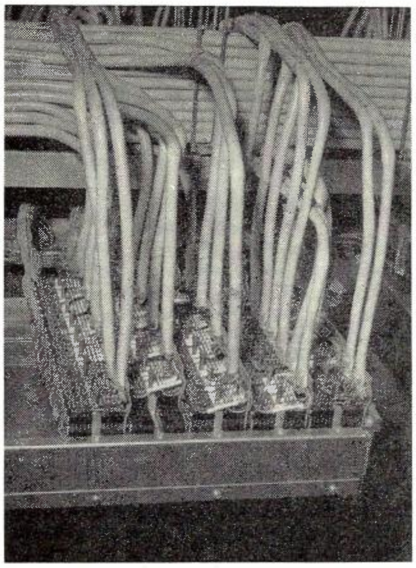


Fig. 26.—Selector Rack Jackfield.

lay set racks are made up of four. The latter can be seen in Fig. 12 while the former can be seen in Fig. 26.

To form out the cables forming boards are used. Fig. 14 shows such equipment being used to form the meter cables. Its thickness is equal to the length of unstripped wire extending from the laced form to the meter tag. Thus cutting and stripping was carried out with combined cutter and stripper pliers, by placing the nose of the pliers against the forming board. Fig. 27 shows an aluminium forming board, and Fig 28 shows it in use. Its length is equal to the height of a rack and it is attached as shown. It is used for forming the cables to be terminated on the relay set racks, and is adjustable so that the length of the stringer can be varied. It has sixty-six rows of tags corresponding to the number of plug units on the rack. Each row has sixteen tags. The plug units form a block of 5 x 16 terminals, five wires are identified and looped over the appropriate tag of the forming board. As identification is not by colour code, the five wires are cut to different lengths to indicate the first, second wire, etc. After forming the wires are laced and terminated.

Fig. 22 shows a forming board used on the I.D.F. The wires are identified and placed in correct sequence, and as indicated in the figure, the placing of the nose of the pliers against the forming board ensures that the wires are cut and stripped correctly. Fig. 29 shows an I.D.F. strip. These are in two sizes and accommodate twenty circuits of three or five wires per circuit.

For terminating the forty-wire plugs and the eighty-wire plugs on the relay set racks, special jigs are used to hold the plug units. Fig. 30 shows a jig for terminating the forty-wire plugs. It also shows a completed plug and Fig. 26 shows completed plugs inserted in the jack-field at the top of a selector rack. These plugs are held in position by a stud. No covering is provided on the jack box.

For terminating the cable on these plugs the sheath is stripped from the cable after leaving sufficient length of cable to come over the side of the runway and reach the jack whose plug is being terminated. The cable is then clipped to the back of the plug by a plastic clip and this back plate is then fastened in the jig by means of a wing-nut at the back. Leaving one pair spare, half the remaining pairs are then sleeved with plastic tubing (two and a half pairs per sleeve) as these are the pairs that are terminated at the front of the plug. The wires are then cut to the correct length as measured by the grooves on the top of the jig. (Fig. 30 shows this hinged plate hanging down.) The tool that cuts the wire also strips it to the correct length. After all wires (except the spare) have been cut and stripped the top plate of the jig is swung out of the way and the two terminal blocks that make up the plug are inserted in the jig. The wires are then picked up with the aid of a pair of light-weight long-nose pliers and the stripped end held over the tag which is to be terminated. The wire is taken past the tag and the stripped end bent back over the top of the tag. The wire is then forced over the tag by another specially shaped terminating tool which locks the wire into the hole of the tag and the groove at the top to ensure the wire does not come off when the tool is removed. Figs. 31, 32 and 33 show the method of using these tools. All plug and jack units using this type of plug and jack are terminated in the same way using jigs to suit forty-two, sixty-three or 105 wire cable or the eighty point units on the relay set racks. This method of termination with this particular type of tag is faster than the termination of tags in step-by-step equipment.

To terminate the strips on the I.D.F. the wire is threaded through the hole in the tag with long-nose pliers and crimped tightly. Resin core solder is only used for maintenance, but for installation work solid solder is used and the resin flux is placed on the tags by means of a brush.

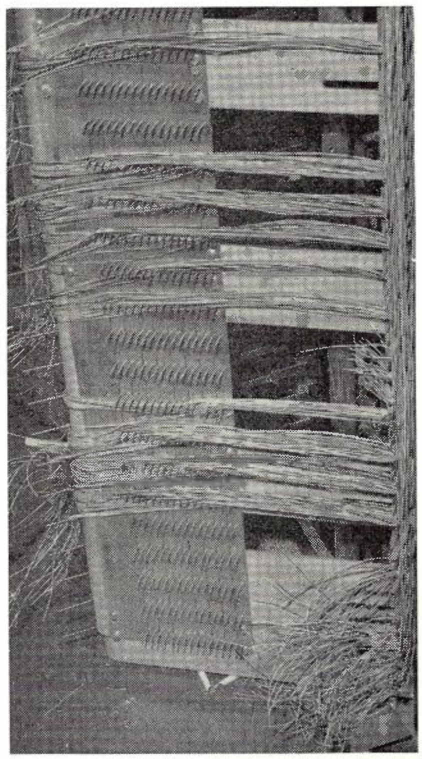


Fig. 28.—Forming Cables.

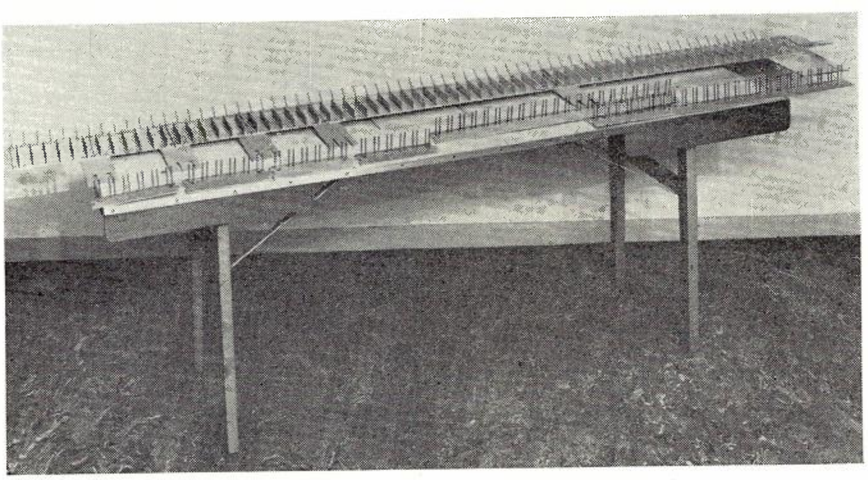


Fig. 27.—Forming-board for Relay Set Rack.

Some of the tools used on the installation were different from those normally used, such as used for the termination of the plug units shown in Figs. 30 and 32. These tools are used for wire with diameter of 0.5 mm. If wire of diameter 0.8 mm. has to be terminated, pliers with specially shaped jaws are used.

Fig 34 shows a few of the tools used. On the extreme left is a cable sheath cutter. This is held clamped over the cable and a circular motion used to cut the sheath. The cutters are adjusted to cut the sheath but not the insulation of the wires of the cable.

Next is a sheath stripper used to cut the sheath longitudinally so it can be removed easily. It is designed to cut the sheath only, causing no harm to the wires in the cable.

The third tool from the left is a pair of pliers for stripping only. The jaws are adjustable so the tool strips but does not cut the wire. The jaws are wider at the end than at the hinge so the tool can be used for stripping on any part of a length of wire.

Next is a pair of pliers, side cutter and stripper. It is adjustable so that while one side of the pliers cuts the wire the other only cuts the insulation and strips. Thus the wire is cut and stripped to a predetermined lengh.

The tool on the right is another adjustable cutter and stripper. This is the most used tool of this kind, being used for cutting and stripping the wires to be terminated on plug units and I.D.F. terminal strips. Fig. 22 shows this tool in use.

The soldering iron used has a rating of 100 watts, and is constructed in such a manner that the bit is at an angle to the handle of the iron. The bit is large and is tapered wedge shaped. The iron has a small stand which enables it to be placed at rest on a plane surface, or hung from some convenient point. It was the practice to have a large number of bits in reserve, the user changing a bit when necessary. After many used bits had been collected they were reconditioned in a single effort for reuse.

A headset test phone was used for testing in preference to instruments such as a test lamp. This headset has one earphone and in place of the other, a three position switch enabling the operator to select one of the three conditions phone only, condenser in series with the phone or battery (dry) in series.

Other tools for erecting iron-work, adjusting switches, etc., are peculiar to this exchange because of its type, and because dimensions are in metric units.

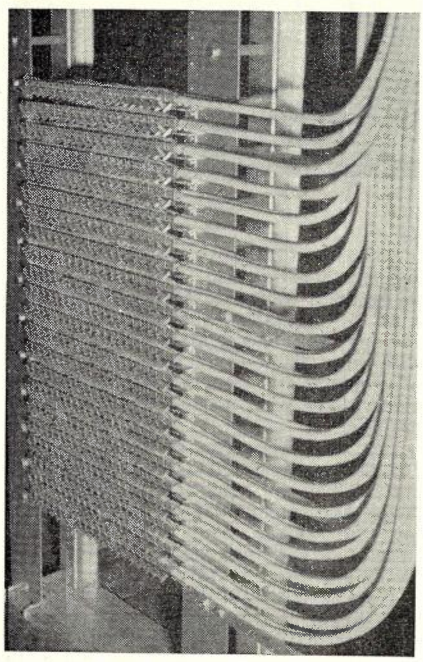


Fig. 29.—I.D.F. Termination.

POWER DISTRIBUTION

The distribution is by means of power cable. From the distribution panel in the power room the distribution is multi-stranded copper cable covered with a white P.V.C. sheathing. Sectional area is 150 sq. m.m. (0.233 sq. in.).

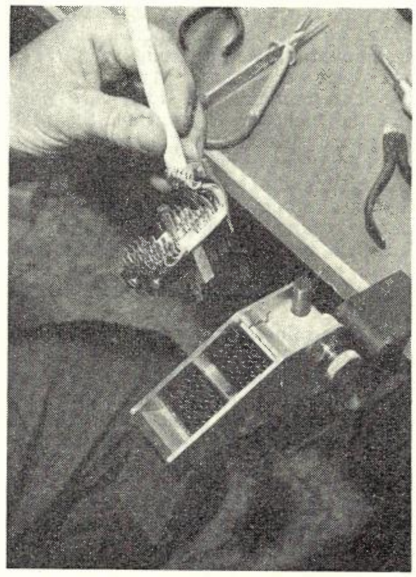


Fig. 30.—Jig for Terminating 42w Cable.

Each bay has its power distributed from a 100A fuse located in a box suspended beneath the centre high-level runway. There are two positive and two negative cables (in parallel) feeding bays 1 to 5, the remaining three being fed separately in a similar manner. The number of bays per feed can be varied to keep the distribution within the permissible voltage drop. For Toowoomba the distribution has been based on 0.5V

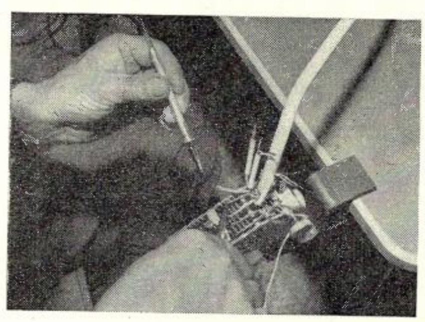


Fig. 31.—Terminating 40w Plugs.

drop between the battery and the distribution board, and 1.5V between the battery and the most distant rack in the particular distribution.

The power cable runs along the top of a high-level transverse runway and loops under at the distribution points, where the wire is bared of insulation and clamped in the distribution box.

The feed from the 100A bay fuse to the racks is in similar cable with a sectional area of 35 sq. mm. (0.054 sq. in.). There is one positive and one negative cable feeding the selector racks, and the same number in the form of a ring feeding the relay set racks, which are back to back. Each rack is fused with a 15A fuse, except the GVM which, having two markers per rack, has one fuse per marker. From the rack fuse small power cables lead to the circuit fuses in the supervisory panel.

The 100A and 15A fuses consist of fuse wire between silver plated electrodes. When the fuse blows, a one amp. pilot fuse also blows and this allows a spring-loaded plunger to complete an alarm circuit. The fuses also have a semi-circular disc which rotates through 180 degrees exposing a white surface to indicate the ruptured fuse.

The circuit fuses are fuse wire with small discs clamped on the wire. These hold movable springs, which when the fuse blows restore to complete an alarm circuit and break the testing circuit of the device the fuse protects. Selecting a device which has no potential is therefore prevented.

The discharge is estimated to be about the same as for 2,000-type equipment. In the power room the usual Departmental equipment is installed.

CONCLUSION

It is expected that features of testing and cutover of the exchange will be the subject of a future article.

ACKNOWLEDGMENTS

The author wishes to thank Mr. L Estberger of L. M. Ericsson, who kindly perused the draft, and who contributed suggestions for its improvement. Thanks are also recorded for the work of various other colleagues who assisted in the collection of data, preparation of drawings, photographs, etc.

The photographs in Figs. 27, 30, 31, 32, 33, 34 are reproduced by courtesy of L. M. Ericsson, the remaining photographs being taken at Toowoomba.

The opinions expressed in this paper are not necessarily those of the Postmaster-General's Department, Australia,

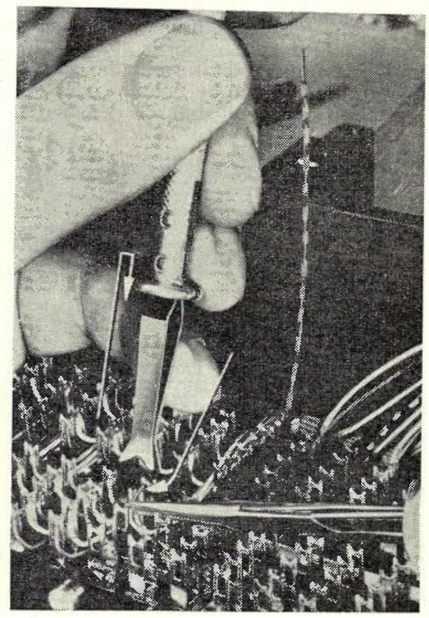


Fig. 32.—Terminating 40w Plugs.

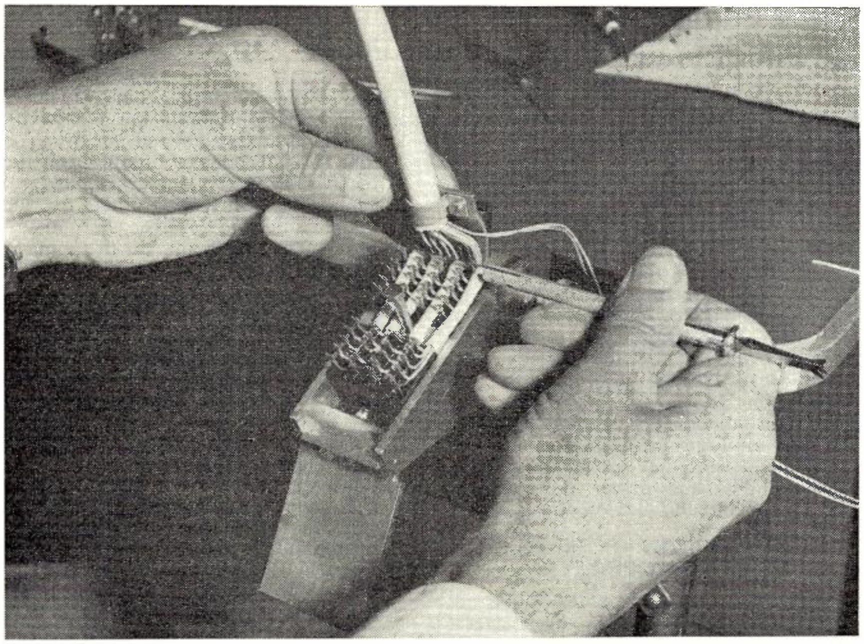


Fig. 33.—Terminating Tools.

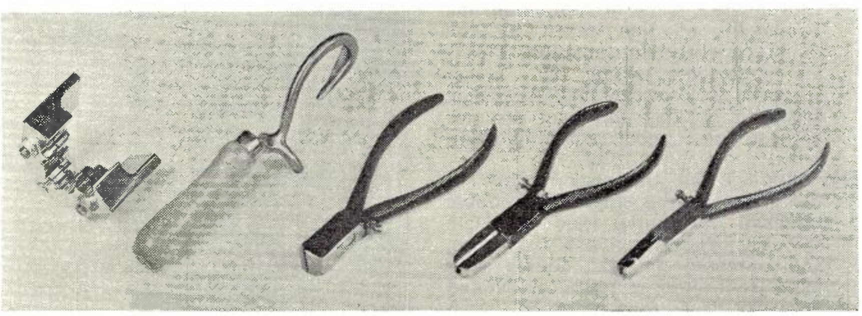


Fig. 34.—Selection of Tools.

L. M. Ericsson Pty. Ltd., Melbourne, or Telefonaktiebolaget, L. M. Ericsson, Sweden.

REFERENCES

1. "Australian Post Office Adopts Crossbar Switching System", F. P. O'Grady, The Telecommunication Journal of Australia, June, 1959, Volume 12, No. 1.

2. "Automatic Switching Systems—The Key to Economic Telephone Networks", N. A. S. Wood, The Telecommunication Journal of Australia, June, 1959, Volume 12, No. 1.

3. "Australian Post Office Adopts L. M. Ericsson's Crossbar Automatic System", F. P. O'Grady. The Telecommunication Journal of Australia, October, 1959, Volume 12, No. 2.

4. "Features of the Crossbar Exchange at Templestowe, Victoria", L. C. Haig, The Telecommunication Journal of Australia. October, 1958, Volume 11, No. 5.

5. "Toowoomba Link Type Crossbar Automatic Exchange", F. P. O'Grady, The Telecommunication Journal of Australia, February, 1959, Volume 11, No. 6.

APPENDIX

Abbreviations Used in the Text

A, B, C, D — Partial Stages in the Subscribers' and Group Selector Stages

APR—Test Robot.

APR-REG—Register for Test Robot.

BLR—Relay set outgoing to service levels.

DK—Traffic control plug unit on racks for connection of occupancy indicator and other devices.

FDR—Relay set for bothway trunks.

FIR—Relay set incoming from satellite exchanges.

FUR—Relay set outgoing to satellite exchanges.

FIR-Y, FUR-Y, FIR-H, FUR-H — Relay sets serving unidirectional trunks.

GP—Test Group Selector.

GVM—Marker for Group selector stage.

GVS—Special Group Selector stage.

I-GV—First Group Selector stage.

KK—Main Distribution Frame.

LPR—Test Selector Relay Set.

LKR—Relay set which controls the ring, and supplies speaking battery to the called subscriber.

LR-BR—Line and cut-off relays.

MK—Intermediate Distrtibution Frame.

MR—Public Telephone Relay Sets.

SNPR, PRP — Circuits connected with the test desk.

R—Miscellaneous Relay set rack.

REG-L—Register for subscriber's local traffic.

REG-N—Register for trunk traffic.

REG-T—Register for trunk operators.

RSM—Marker for Register Finder.

RS—Register Finder.

RS-T—Register Finder for operator.

RS-I—Register Finder for incoming traffic.

RS-N—Register Finder for trunk traffic.

SL—Subscribers' Stage.

SR—Relay set which contains the speaking battery for the calling subscriber, and effects metering.

SLM—Marker for Subscribers' Stage.

ULR—Relay set incoming from the trunk exchange.

PERTH-DERBY RADIO LINK

*J. MEDCALFE-MOORE, A.M.I.E.E., A.M.Brit.I.R.E.**

GENERAL

The introduction of a high frequency radio telephone link between Perth and Derby, Western Australia, follows present-day techniques where dual channel single sideband (Independent Sideband) transmitting and receiving equipment is used to provide a number of speech and telegraph circuits. This article outlines the principles of single sideband operation, discusses the advantages gained from its use, and describes briefly the transmitting and receiving equipment used at Perth and Derby.

PRINCIPLES OF SINGLE SIDEBAND OPERATION

Amplitude modulation is used in both double sideband and single sideband operation. When a carrier of frequency f_c is amplitude modulated by a single audio frequency f_1 the resultant signal produced is made up of three frequencies, the carrier frequency f_c and two sideband frequencies $(f_c - f_1)$ and $(f_c + f_1)$. The two sidebands are spaced equi-distant on either side of the carrier frequency.

When speech frequencies are used to modulate the carrier, a number of different frequencies go to make up the audio signal, and sideband components are produced corresponding to speech frequencies. The carrier frequency and the sideband component frequencies in the upper and lower sidebands make up the combined wave-form of a double sideband transmission. As both the upper sideband and the lower sideband in the double sideband transmission contain the same intelligence, it is not necessary to transmit both sidebands in order to transfer a signal from the transmitter to the receiver. Additionally, the carrier itself carries no intelligence. From the point of view of transferring the signal from the transmitter to the receiver, it is not necessary to transmit the carrier.

It can be seen therefore, that in an amplitude modulated system the carrier and one of the sidebands can be dispensed with before transmission, the remaining sideband only need be transmitted. The transmission of such a signal is known as single sideband suppressed carrier operation. Normally, on high frequency single sideband radio links a low level pilot carrier is transmitted, as will be discussed later.

When a second sideband derived from a second audio channel is added, so that a common pilot carrier is used with two independent sidebands, the system is called independent sideband (i.s.b.) transmission.

In the i.s.b. system of operation the pilot carrier is transmitted at a reduced level relative to the peak power of the sidebands, usually 26db below peak envelope power. The two independent sidebands are derived from two completely different audio sources.

It can be shown that the power distribution in an amplitude sine modulated d.s.b. transmission, for 100% modulation, is such that the carrier power is twice the power in the two sidebands together. It can be seen that the presence of the two sidebands for a 100% sine modulated carrier makes the power of the modulated wave 50% greater than the power contained in the unmodulated carrier. Of the total power radiated, two-thirds of it is in the carrier, and one-sixth in each of the two sidebands. For degrees of modulation less than 100%, the power contained in the intelligence bearing sidebands decreases rapidly as the degree of modulation decreases, e.g., if the carrier is modulated 50%, it can be shown that the amplitude of each sideband will be one quarter the carrier amplitude, the total sideband power now will be only one-eighth the carrier power. (1).

ADVANTAGES OF SINGLE SIDEBAND OPERATION

Compared with double sideband, single sideband operation has several advantages, including the following:—

(a) For the transmission of the same audio signal, the single sideband transmission takes up only half the bandwidth of that taken by the double sideband transmission. This is an important saving of channel space in the crowded high frequency spectrum suitable for long distance point-to-point radio communication links.

(b) Assuming that the peak voltage in the power output stage of a double sideband transmitter and a single sideband transmitter are the same, and assuming that the double sideband transmitter is 100% modulated by a sine wave, then it can be shown that where the gain of the double sideband and single sideband receivers are identical, an improvement of 6db in signal/noise can be achieved at the receiver. This is because in the case of the double sideband transmission, the peak carrier voltage will be V. When 100% sine modulated the amplitude of the modulated carrier will be 2V, each sideband being 0.5V. In the case of the single sideband transmission, ignoring the low level pilot carrier, the peak amplitude will be 2V, or four times that of each sideband in the case of the double sideband transmission. The single sideband signal, for which a locally generated carrier of correct frequency and level is supplied at the receiver, will give an audio output from the receiver which can be expressed as V_a. Assuming that no selective fading is present, the two sidebands in the double sideband transmission will arrive at the receiver in the correct phase relationship, and their effect will be additive at the receiver detector output, giving an audio signal of $0.5v_a$. The single sideband signal will, therefore, be 6 db higher than the double sideband signal. A further 3 db improvement in the case of the single sideband signal can be achieved because the single sideband receiver need have only half the bandwidth of the double sideband receiver, so that the noise-power output from the receiver used for single sideband reception is only half that of the double sideband receiver. A total improvement of 9 db in the signal/noise is therefore achieved for single sideband operation. (2)

(c) A considerable saving in transmitter power input consumption is achieved with a single sideband system as compared with double sideband operation, because during periods of no modulation the single sideband transmitter emits only a low-level pilot carrier.

(d) Selective fading and wave interference due to multi-path propagation can result in serious non-linear distortion to a double sideband high frequency radio signal. Listeners to high frequency broadcast programmes are familiar with this particular type of distortion, which causes speech and music to become

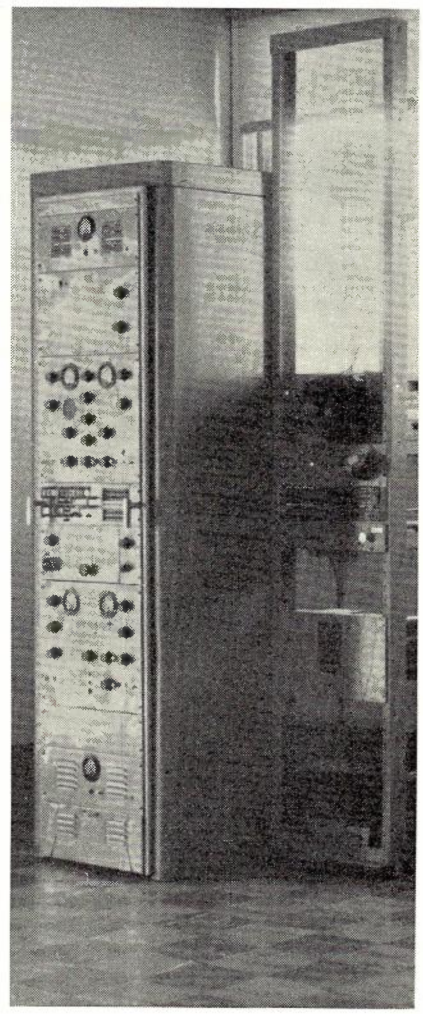


Fig. 1.—The Independent Sideband Drive Unit.

* See page 298.

harsh and unpleasant to listen to. This type of distortion is absent with single sideband operation. Selective fading occurs when conditions along the radio path between the transmitter and the receiver do not affect waves of slightly different frequencies in a like manner. It has been found in practice that frequencies making up a double sideband modulated carrier wave, differing by as little as 100 c/s, fade independently. This is because the individual frequencies making up the modulated carrier wave travel along paths of different lengths. The lengths of the paths vary continuously, due to the changing conditions in the ionosphere. As the difference in path length depends on the frequency of the components of a modulated carrier wave, it will be seen that the different frequencies which make up the modulated carrier will not always arrive at the receiver in the same phase relationship as existed at the transmitter. Frequently, at a given instant, the received carrier frequency will be severely affected, while the sideband frequencies are unaffected. In the case of the single sideband transmission, however, selective fading of this type does not occur because only one sideband is present at the input to the receiver, and this sideband is demodulated in the receiver by a locally generated carrier of the correct frequency and level.

INDEPENDENT SIDEBAND DRIVE UNIT

The independent sideband unit, (Fig. 1), accepts two separate audio frequency inputs (referred to as Channel A and Channel B). Each channel occupies a frequency range of 0.1 to 6 kc/s. The output from the drive unit consists of an independent sideband signal centred on a reduced level carrier at 1.6 Mc/s with channel A covering the range 1.6001 Mc/s to 1.6060 Mc/s, and channel B covering the range 1.5940 Mc/s to 1.5999 Mc/s, (Fig. 2). The peak sideband output available from the drive unit is 0.5W, with a pilot carrier level adjustment within the range –6db to –32db relative to 0.5W.

The reduced or pilot carrier serves two purposes, firstly it operates the automatic gain control facility in the distant receiver, thus maintaining the average audio output from the receiver at a given level when fading is present at the receiver input, secondly it enables an automatic frequency control facility in the distant receiver to adjust the receiver tuning, by keeping the frequency of the local oscillator in the receiver at the value necessary to produce the precise intermediate frequency required to maintain the pilot carrier frequency within the narrow passband of the crystal filter, used to separate the pilot carrier from the received sidebands.

The level of the pilot carrier is an independent sideband system is determined by a number of considerations. Firstly, it is kept at a low level, relative to the sidebands, in order that for a given power output, as much as possible of the radio frequency power output from the transmitter is available for the sidebands. Secondly, inter-channel crosstalk is increased if a high level pilot carrier is employed. Thirdly, the level of the pilot carrier must not be reduced too much or, it may, at times, fall below the receiver noise level. This could then result in an unsatisfactory signal to noise ratio in the pilot carrier channel on occasions when the signal to noise ratio in the sideband channels is just sufficient to produce a workable signal. In this event, the pilot carrier would not be suitable for the purpose of automatic frequency control. In practice, a peak sideband to carrier ratio of 26db has been found to be a satisfactory compromise, and this ratio is the one generally used on independent sideband radio links.

The drive unit, which is located at the transmitting station, accepts two separate audio signals each up to 6 kc/s. Referring to Fig. 3, and taking channel A only, signals from line are passed through a high-pass filter to remove any components below 100 c/s. Audio frequencies below 100 c/s must be excluded from the system because such frequencies might produce sideband signals too close to the pilot carrier. If such signals were within the passband of the carrier-selector filter at the distant receiver, the operation of the automatic frequency control facility in the receiver would be adversely affected. The audio frequencies in the band 100-6000 c/s are then amplified by the channel amplifier which has an adjustable gain. A level indicator, which can be switched to channel A or channel B, is provided to measure the output level from the channel amplifier. A pre-set attenuator is provided between the channel amplifier and the input to the first modulator. The amount of pre-set attenuation introduced by the attenuator is determined by the nature of the audio signals, e.g., speech, multi-channel voice frequency, telegraph, facsimile, etc., the principle being to prevent signal peaks from exceeding +6dbm at the input to the first modulator. Signal peaks of +6dbm produce the maximum rated sideband output of 0.5W from the drive unit. Peaks in excess of +6dbm cause overloading, resulting in signal distortion and interchannel crosstalk.

The signals are applied to the balanced modulator together with a 100 kc/s carrier. The 100 kc/s signal is provided by a crystal controlled oscillator which is common to both channel A and channel B. The output from the 100 kc/s modulator contains both sidebands, the upper sideband (100.1-106 kc/s) and the lower sideband (94-99.9 kc/s) together with a carrier leak signal of low level, relative to the sidebands, due to imperfect modulator balance. The output from the modulator is amplified and then passed through a crystal filter which selects the lower sideband (94-99.9 kc/s). The sideband filter has very sharp band-pass characteristics, and the output from the filter is substantially a single sideband signal. Audio signals applied to channel B input undergo a similar process as applied to channel A, except that the sideband filter in channel B selects the upper sideband (100.1-106 kc/s).

Channel A signals and channel B signals are then combined and passed through a 100 kc/s carrier stop filter which removes the 100 kc/s residual or carrier leak signal. The attenuation of this filter is nearly constant at 1 db for frequencies in the range (94-99.9 kc/s) and 100.1-106 kc/s) while it rejects a band extending to a few cycles on either side of 100 kc/s. The pilot carrier, which is derived from the 100 kc/s crystal controlled oscillator, is now introduced at a controlled level. The reason for first balancing out the 100 kc/s carrier at the first modulator, and eliminating the residual carrier by means of a carrier stop filter, is that the carrier leak signal from a balanced modulator varies with ageing of components and temperature effects, whereas the re-introduced carrier at controlled level results in a final carrier which is independent of such changes. It is most necessary to maintain the ratio between the peak sideband power and the pilot carrier power, because the pilot carrier is used for automatic gain con-

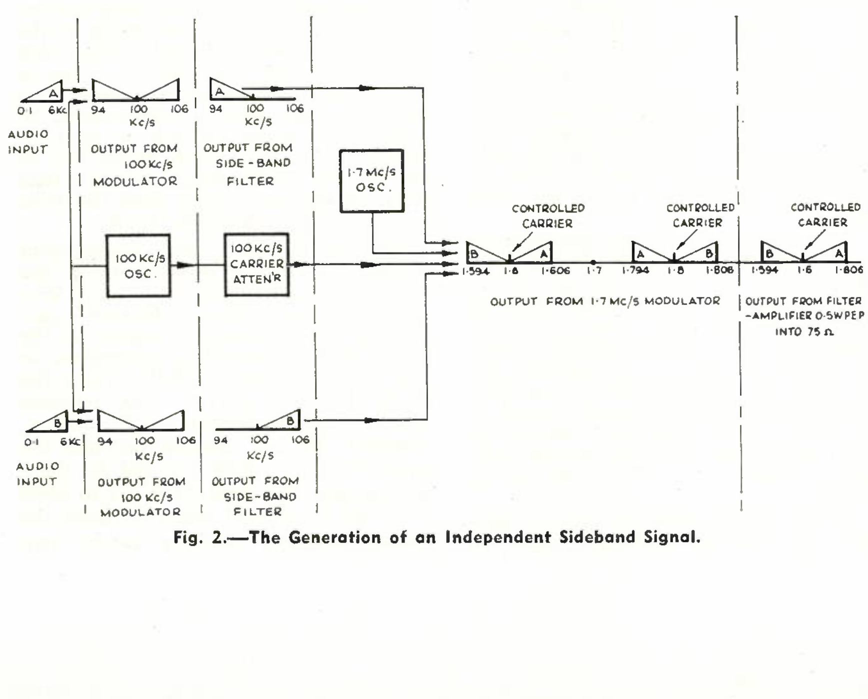


Fig. 2.—The Generation of an Independent Sideband Signal.

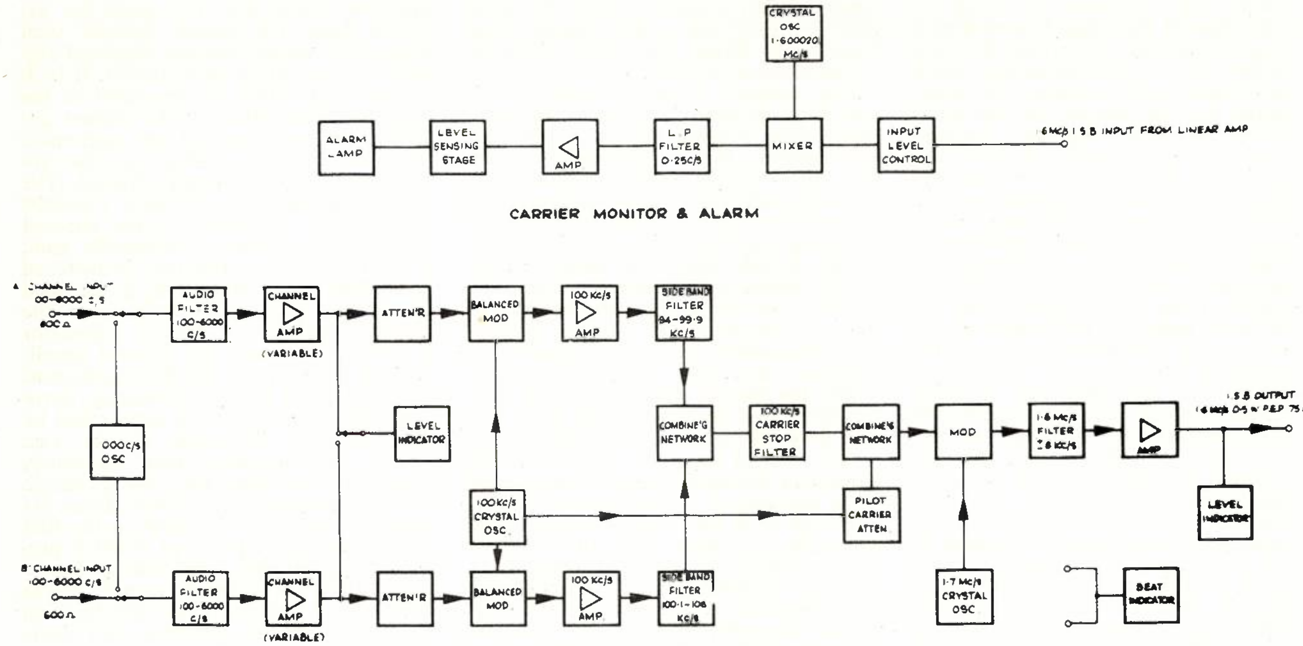


Fig. 3.—Block Schematic Diagram of Independent Sideband Drive Unit.

trol purposes at the distant receiver. Variations in the transmitter power output of the pilot carrier would vary the audio-frequency output of the receiver.

The combination of the upper sideband, lower sideband and pilot carrier completes the formation of the independent sideband signal. This composite signal is applied to the second modulator together with a 1.7 Mc/s carrier, provided by a crystal controlled oscillator. The output from the 1.7 Mc/s modulator is taken through a filter which selects the lower sideband (1.594-1.6-1.606 Mc/s), and it will be seen that channel A now occupies the band (1.6001-1.606 Mc/s) and Channel B occupies the band (1.594-1.5999 Mc/s). The output from the filter is amplified to a peak sideband level of 0.5W into a 75 ohm load.

SIGNAL LEVELS

With the drive unit set up for normal service and with a steady single tone signal applied to the A channel IN or B channel IN, the drive unit will deliver a mean power output at 1.6 Mc/s of +21db relative to 1 mW. When both A and B channels are simultaneously energised by the steady tone, or when the level of the steady tone to one channel is increased by 3db, the drive unit will deliver +24db relative to 1mW. When speech is applied to either channel the peak output of the sideband to which the speech is applied should not exceed +27db relative to 1mW in order to obtain satisfactory performance as regards low level inter-channel cross-talk. The level indicators used at the input and at the output of the drive unit do not indicate peak levels of speech because of the relatively long time-constant of these meters. Peak levels of speech are indicated on the level meters at the Radio Terminal, where the outgoing signals from the near end subscriber and the incoming signals from the distant end subscriber are carefully controlled.

The line-up or setting of the levels in the drive unit is carried out under steady tone conditions. A steady tone of 1000 c/s is applied to the A channel IN and the A channel amplifier gain control is adjusted until the drive unit output at 1.6 Mc/s is +21db relative to 1mW. The steady tone is then applied to B channel IN and the B channel amplifier gain is adjusted for an output of +21db relative to 1mW. Under operating conditions the 1000 c/s line-up tone is sent over the A channel and B channel land-lines from the Radio Terminal, where the four-wire transmit-receive circuits are combined into a two-wire circuit, suitable for connection via a telephone switchboard to a subscriber's telephone instrument. The level of the 1000 c/s line-up tone sent to line on the A channel and the B channel from the Radio Terminal is 0 dbm. At the transmitting station the tone is amplified to overcome line losses, and is then applied to the input of the drive unit, and, as previously described, after adjustment of the channel amplifier gain, results in an output from the drive unit of +21db relative to 1 mW per channel.

Before dealing with the speech levels sent to line from the Radio Terminal the opportunity will be taken to discuss normal speech levels, with particular reference to the peak power levels encountered with average telephone-speech in English, because it is essential that the peaks of speech applied to the drive unit input on either channel, should be of such a level as to just energise the drive unit so as to produce a peak sideband output of +27db relative to 1mW.

Speech at reference volume is registered by a volume indicator when the pointer on the indicator dial swings to 0db on the scale approximately every 3 seconds. The zero point on the scale being the position of the pointer when a sinusoidal voltage at 1000 c/s, corresponding to 6mW in 600 ohms is applied. The peak power of reference speech is generally assumed to be 6mW (+8dbm), but short duration peaks in excess of this power do occur. (3)

At the Radio Terminal a voice operated gain adjusting device (vogad) is used in the transmit path which, in addition to raising the average level of low level speech, restricts the peaks of reference volume speech or speech peaks higher than reference volume, to +6dbm. The level indicator used at the Radio Terminal is designed to read peaks of speech, and when this indicator peaks up to +6dbm, the full peak sideband output of 0.5W is obtained from the drive unit at the transmitting station. The level indicator at the output of the channel amplifier in the drive unit which registered 0dbm on 1000 c/s line-up tone when the mean power output from the drive unit was +21db relative to 1mW, now swings up only to approximately -2dbm on speech peaks, due to the time-lag of the meter, at which time the peak sideband output from the drive unit is +27db relative to 1mW.

Each of the 6kc/s wide independent sideband channels derived from the drive unit is sub-divided into two 3 kc/s speech channels. This sub-division is carried out at the Radio Terminal by the use of audio channelling equipment, so that the A channel land-line from the Radio Terminal carries two separate speech channels, known as A_1 and A_2 channels. The A_1 channel occupies the band 250 c/s to 3000 c/s, and A_2 channel occupies the band 3250 c/s to 6000 c/s. The B channel land-line from the Radio Terminal similarly carries two

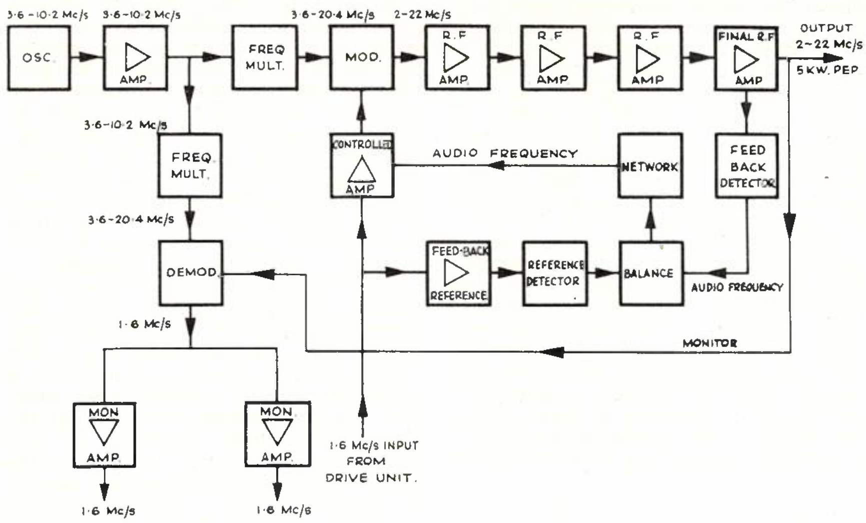


Fig. 4.—Block Schematic Diagram of Independent Side Band Transmitter.

separate speech channels occupying similar frequency bands as those shown on the A channel land-line. The two B channels are known as B_1 and B_2 channels. Thus, the drive unit is capable of simultaneous handling of four 3 kc/s wide speech channels.

As previously stated, when only one speech channel is carried on a 6 kc/s wide sideband, the peaks of speech can be allowed to reach +6dbm at the output from the channel amplifier in the drive unit, and peaks of speech at this level develop the full peak sideband output of 0.5W from the drive unit. In a four-channel system, the peaks of speech can be allowed to reach approximately the same level as allowed for a single channel, i.e., the peaks of speech in each one of the four channels can be allowed to peak up to approximately +6dbm at the output of the channel amplifier; this is because of the intermittent nature of speech, and the unlikelihood of sustained peaks of speech occuring simultaneously in two or more channels. Because of this, there is no noticeable loss of signal to noise ratio when changing from single channel to four channel operation.

At present, on the Perth-Derby i.s.b. link, A_1 and A_2 channels are used for speech and B_1 channel carries a multi-channel voice frequency telegraph system. B_2 channel is normally idle, but can be used to carry one of the speech circuits normally carried on A_1 or A_2 channels or the B_1 V.F.T. system, by suitable patching arrangement at the Radio Terminals.

The V.F.T. equipment is located at the Radio Terminals at Perth and Derby. Twelve different tones are used for the mark and space signals, which are keyed by machine or hand operation. At any instant, there is always a total of six tones simultaneously passing to line from the V.F.T. equipment to the transmitting station. The level of each of the tones used, measured at the output of the drive unit channel amplifier, is –8dbm, which results in an output from the drive unit of –14db relative to the full peak sideband output of 0.5W.

CARRIER MONITOR AND ALARM

The pilot carrier radiated by the independent sideband transmitter is continuously monitored, any variation of more than ± 3db from the set level being used to operate an alarm signal.

The complete independent sideband signal at 1.6 Mc/s, derived from the output of the transmitter via the frequency translator demodulator, is fed back to the drive unit at a controlled level and applied to the input of the carrier monitor and alarm circuit (Fig. 3.) The complete signal consisting of sidebands and pilot carrier is heterodyned against a signal 20 c/s higher in frequency than the 1.6 Mc/s pilot carrier. The independent sideband signal voltage and the heterodyne signal voltage are added and then applied to a diode rectifier. The radio frequency components are then filtered out in a resistance capacitance filter and the resulting 20 c/s beat signal due to the carrier is selected by a low pass filter.

The first sideband component which appears at a frequency of 100 c/s above the pilot carrier beats with the 1.600020 Mc/s heterodyne signal and produces an audio signal of 80 c/s, this frequency being attenuated by at least 46 db in the low pass filter. The 20 c/s signal is amplified and after rectification by two delayed circuit diodes, the output is used to operate the alarm relays via a d.c. amplifier.

Over the normal working range of pilot carrier level the peak value of the 20 c/s voltage lies between the two delay voltages on the two diodes. If, at any time, the peak value of the 20 c/s voltage is above or below both delay voltages an alarm condition is signalled. The settings of the levels is such that a ± 3db variation in pilot carrier level actuates an alarm circuit.

INDEPENDENT SIDEBAND TRANSMITTER

The independent sideband transmitter used on the Perth-Derby radio link (Fig. 4) is a high frequency transmitter with a frequency range of 2 to 22 Mc/s, and a power output of 5kW, P.E.P. (See Fig. 5). Automatic starting and tuning control facilities are incorporated in the transmitter, and a total of six crystal controlled spot frequencies may be set up and selected anywhere in the 2 to 22 Mc/s range.

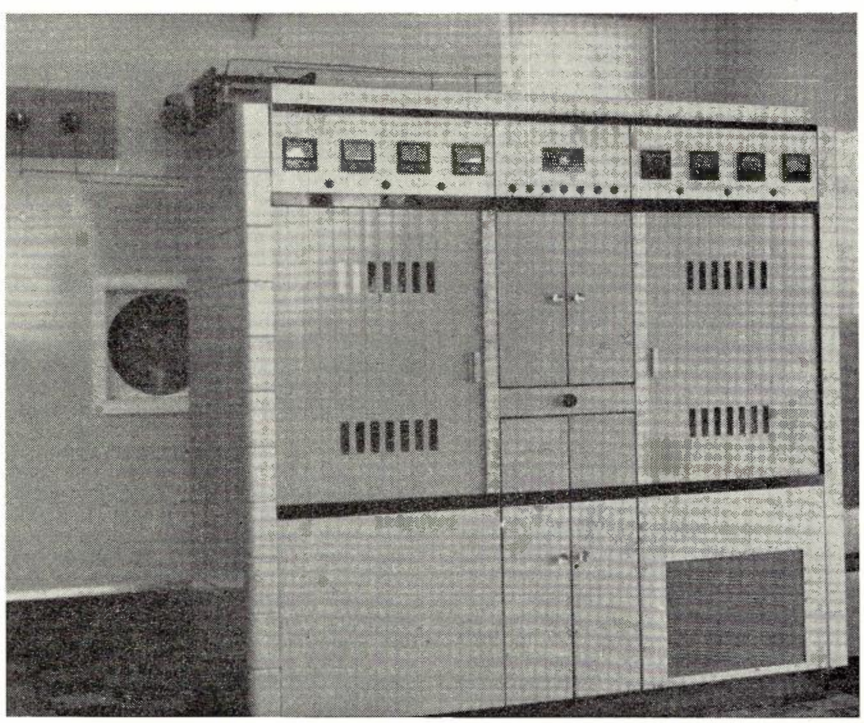


Fig. 5.—The Independent Sideband Transmitter Unit.

The transmitter is capable of transmitting two independent 0.1 to 6 kc/s channels, one on each side of a low level pilot carrier. Each 0.1 to 6 Kc/s channel can be sub-divided, so that two 3 kc/s telephone channels or several voice frequency telegraphy channels or a combination of speech and telegraphy channels can be provided.

The independent sideband transmitter consists of a frequency translator and monitor section, a chain of radio frequency amplifiers and a feedback unit.

The crystals for the six spot frequencies are located in the frequency translator unit and are contained in a thermostatically controlled oven which maintains the temperature at approximately 60°C.

The required crystal is selected by one section of a channel selector switch and controls a Pierce oscillator. The next stage consists of an amplifier operating at the fundamental or crystal frequency. The output of this amplifier is divided into two and fed to two identical frequency multipliers. One of the multipliers is in the transmitting chain and provides the heterodyning voltage for the modulator. The second multiplier is in the monitor chain and provides the heterodyning voltage for the demodulator.

The relationship between radiated frequency (f_r) and crystal frequency (f_x) is:—

(a) for frequencies below 5.6 Mc/s

$$f_x = f_r + 1.6 \text{ Mc/s}.$$

(b) for frequencies from 5.6 to 10 Mc/s

$$f_x = \frac{f_r + 1.6 \text{ Mc/s}}{2}$$

(c) for frequencies from 10 to 22 Mc/s

$$f_x = \frac{f_r - 1.6 \text{ Mc/s}}{2}$$

The heterodyning voltage is fed to the grids of the modulator valves (2 type 807's) in parallel; the 1.6 Mc/s signal from the drive unit being fed to their cathodes in push pull after passing through a remote cut-off controlled amplifier stage, which is provided as a control for the envelope error feedback system.

A class A radio frequency amplifier, consisting of a pair of type 807 valves in push-pull, follows the modulator, and the output from this amplifier feeds the power amplifying stages.

The relationship between radiated frequency f_r and crystal frequency f_x is such that the positive sign applies for values of f_r below 10 Mc/s, and the negative sign applies for values of f_r above 10 Mc/s. This is a convention which is followed internationally on independent sideband services, and results in a narrower range of frequencies being required from the carrier generating stages than would be the case otherwise, e.g. radiated frequencies in the range from 2 to 22 Mc/s are provided by stages covering the range 3.6 to 20.4 Mc/s. With independent sideband transmitters covering higher frequencies in the high frequency bands, for instance, the range 4 to 30 Mc/s, where a drive frequency of 3.1 Mc/s is usually employed, the carrier generating stages only have to be designed to cover the range 7.1 to 26.9 Mc/s, instead of 7.1 to 33.1 Mc/s as would otherwise be the case.

The convention referred to in the preceding paragraph, results in channel A being radiated on the high-frequency side of the pilot carrier for radiated frequencies above 10 Mc/s, and on the low-frequency side of the pilot carrier for radiated frequencies below 10 Mc/s.

The radio frequency amplifying chain consists of three stages of linear amplifiers. The first of these three stages employs two type 807 valves in parallel, class A operation. The next stage uses three type 5.D22 valves in parallel, operating class AB1. The final radio frequency amplifier utilises a grounded-grid circuit, employing a triode valve, type BR191. The output of the BR191 is coupled through an unbalanced line to a phasing network which allows matching to a balanced line of 600 ohms.

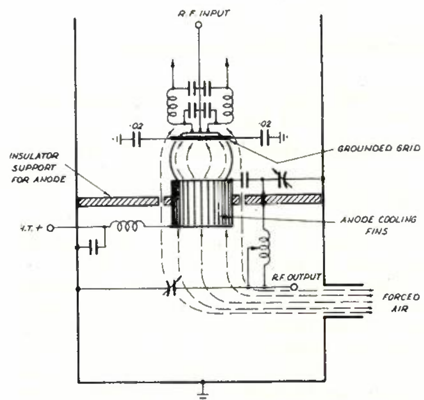


Fig. 6.—The Grounded Grid R.F. Output Stage.

In single sideband transmitters it is absolutely essential that all amplifiers and modulator stages are operated linearly, so as to avoid intermodulation frequencies which result in inter-channel crosstalk. Probably one of the main causes of non-linearity in radio frequency amplifiers is the flow of grid current, when the grid of a driven valve is allowed to become positive with respect to the cathode, resulting in a change of impedance seen by the grid of the valve when looking back towards the source of the driving voltage. Non-linearity due to the flow of grid current will occur if a stage is overdriven, and mainly occurs in the high-power stages of the transmitter.

In order to obtain a high efficiency, it is the practice to fully drive and load the high power stages of an independent sideband transmitter, so that the full rated peak envelope power output of the transmitter is obtained on peaks of speech. If, however, the level of the peaks of speech applied to the transmitter input in a given channel are too high, non-linear distortion occurs not only in that particular channel alone, but it results also in the production of intermodulation components which often fall in adjacent channels, resulting in crosstalk between channels.

In order to reduce the risk of grid current and so maintain linearity, high power gain tetrodes in parallel, operating class AB1, are employed in the penultimate stage of the transmitter. The class AB1 stage can be fully driven on peaks of speech without the grid swinging positive with respect to the cathode. This stage is followed by the grounded-grid radio frequency power output stage, which has the advantage of a much more constant input impedance than the more conventional type of amplifier.

The drive from the high power gain tetrodes is applied directly to the filament centre-tap of the grounded-grid BR191 valve. This technique is a further aid in reducing the effect of grid current on linearity. In the grounded-grid amplifier, the grid-cathode load due to the anode current tends to swamp the load due to the grid current. In addition, the grounded-grid amplifier does not have to be neutralised. This is because the radio frequency currents flowing through the plate-grid inter-electrode capacity, as a result of the oscillatory voltages developed in the anode circuit of the valve do not flow through the input circuit as in the more conventional type of amplifier. Thus, the inter-coupling and energy transfer between input and output circuits is avoided, the grounded-grid of the valve acting as a shield between the anode and cathode. The grounded-grid output stage of the independent sideband transmitter is, therefore, substantially free from the type of feedback that causes instability.

In the grounded-grid amplifier, since the input voltage from the preceding stage is in series with the output voltage, any change of loading in the output circuit will be reflected back to the preceding stage. Because of this, great care must be taken to see that shunt leakage resistance and capacitance changes on transmission lines and aerials are kept to a minimum during wet weather, or during periods of high humidity. This can be achieved by the use of specially designed insulators, particularly for use on the transmission line between the grounded-grid output stage and the aerial. This type of insulator, while providing the necessary support and maintaining the correct spacing for the transmission line, presents a minimum of contact area between the surface of the insulator and the radio frequency conducting leg of the transmission line. With other types of transmission line insulator, where the area of contact between the surface of the insulator and the leg of the line can be large, changes can occur in the characteristic impedance of the transmission line when the surface of the line insulators become wet during rain or during periods of high humidity. If this occurs on a transmission line connected to a transmitter having a grounded-grid amplifier output stage, the detuning effect on the transmitter and the power output from the final stage can change considerably compared with the conditions existing when the surface of the insulators is dry.

The grounded-grid arrangement in the final radio frequency amplifier allows a very compact arrangement to be used for housing the anode tuning inductance and other components in the output circuit (Fig. 6). These units are located in the lower part of the R.F. cabinet, in an airtight compartment immediately below the valve anode. With this arrangement, radio frequency current returns symmetrically on the inside walls of the compartment and direct radiation from the anode stage is thereby reduced to a minimum. Forced air for cooling the system is drawn in through a dry-mesh filter located at the lower front of the power supply cabinet and is forced into the airtight compartment below the valve, this compartment acting as an air duct. The air stream cools the anode tuning inductance and the other components in the compartment, as well as the valve anode, filament and grid seals, and is finally discharged through vents at the top of the R.F. cabinet.

AUTOMATIC TUNING

The transmitter has provision for the automatic selection of any one of six pre-tuned frequencies. After first pre-tuning the transmitter on all six frequencies, the desired frequency is selected by means of a channel switch on the front of the transmitter. At Perth, frequency changes are achieved by manual operation of the channel switch. At Derby, where the transmitting station is unattended, frequency changes are initiated from the receiving station, where a remote control unit is located and used for dialling over a land-line to the transmitting station. In addition to dialling frequency changes, the remote control unit is used to dial the transmitter on and off.

Using the automatic frequency selection facility, a frequency change on the transmitter can be achieved in not more than 30 seconds. The H.T. is removed at the beginning of the frequency change and is then automatically reapplied at the end of the frequency change.

The automatic tuning mechanism in the R.F. amplifier section of the transmitter, consists of an electric motor driving a main shaft to which each tuning element is coupled by a separate magnetic clutch. Associated with the tuning elements for each stage is a selector head consisting of six cam and switch assemblies, one for each pre-set frequency. Each cam is set to operate a switch which de-energises the associated magnetic clutch controlling the turning of tuning controls when the latter are in the position giving precise tuning of each stage.

When a frequency change is set in motion, all the magnetic clutches are energised and the tuning controls are driven round by the motor until each tuning control stops in the pre-set position determined by the appropriate cam on the selector heads. The motor continues to rotate until the last magnetic clutch becomes de-energised and disengaged from the driving shaft. The frequency translator and feedback unit are equipped with separate motors and selector heads. These motors are energised at the same time as the main motor in the R.F. cabinet.

FEEDBACK

A feedback system is incorporated in the transmitter to reduce distortion and stabilise the gain. The system used is known as Envelope Error Feedback. A sample of the output from the grounded-grid output stage is applied to the feedback circuit. The signal picked up by a small pick-up disc capacitor, located near the anode of the grounded-grid valve, is rectified. The signal produced by rectification consists of direct current and low frequency components corresponding to the envelope of the modulated output of the transmitter. At the same time, a portion of the 1.6 Mc/s input signal to the transmitter is amplified and then rectified by a rectifier similar to the one used to rectify the feedback signal. The outputs of the two rectifiers are balanced against each other and if there is no distortion present there is no difference output. In practice, there is always a certain amount of distortion due to non-linearity in an amplifier giving a high power output, and this distortion results in an output from the comparison circuit. This output is applied to the input of the controlled amplifier to which also is applied the 1.6 Mc/s signal from the drive unit, (Fig. 4). The phase of the error signal applied at this point is such that inherent distortion is reduced, in accordance with normal negative feedback application.

FREQUENCY TRANSLATOR MONITOR

The monitor circuit in the translator section of the transmitter, consists of a frequency multiplier, demodulator and 1.6 Mc/s amplifiers. The heterodyning signal from the crystal oscillator stage is fed through the frequency multiplier stage to the balanced modulator. A sample of the final R.F. amplifier signal, picked up by a disc capacitor near the anode of the grounded-grid valve is also applied to the demodulator. By heterodyne action in the demodulator a 1.6 Mc/s output is obtained from the demodulator. This output is then applied to two identical amplifiers. The 1.6 Mc/s output from the amplifiers is taken separately by coaxial cable to the drive and monitor unit. One output is used for a signal for the carrier fail alarm circuit, and the other output is applied to the monitor unit to enable analysis of the independent sideband signal to be made, and to provide aural monitoring of the sideband signals.

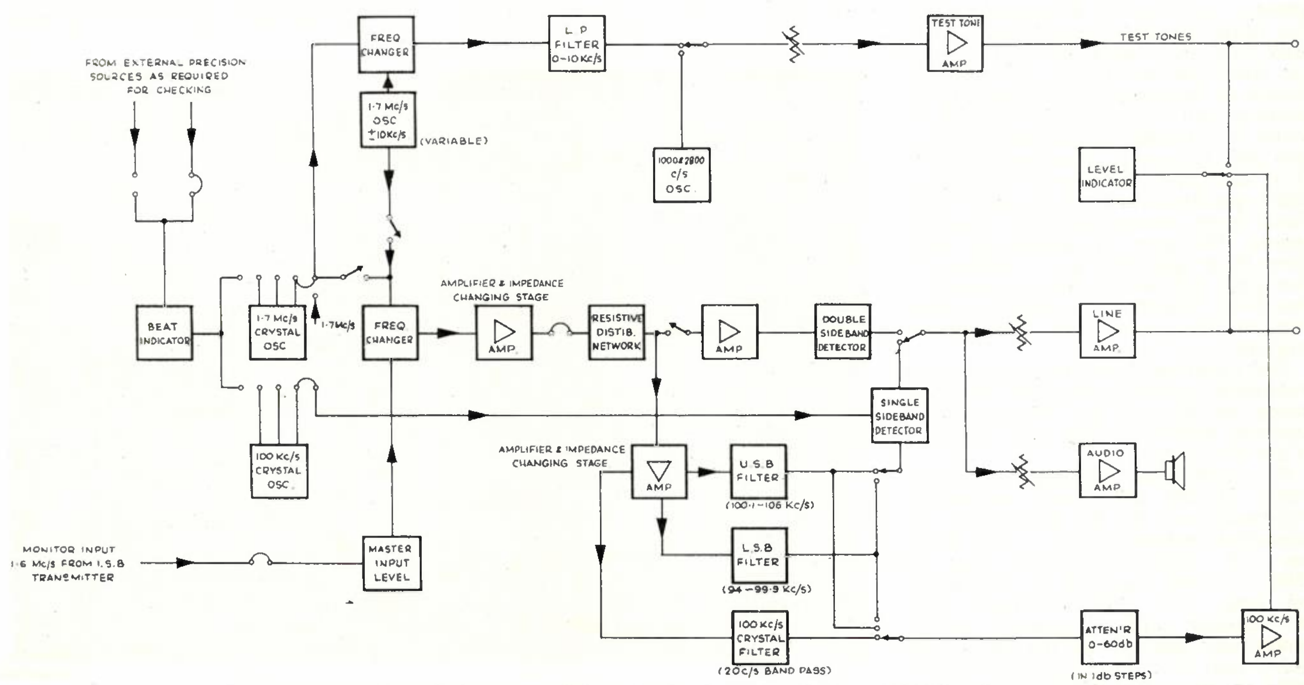


Fig. 7.—Block Schematic Diagram of Independent Sideband Monitor.

INDEPENDENT SIDEBAND MONITOR UNIT

The independent sideband monitor unit (Fig 7), is provided to enable analysis to be made of the transmitted independent sideband signal, and to provide aural monitoring of the signals on the two sidebands.

As a spectrum analyser the unit can be used to cover a range of 10 Kc/s on either side of the 1.6 Mc/s pilot carrier. By means of switching, the monitor unit can also be used to measure the level of the pilot carrier, and to check the pilot carrier to see if modulation causes any disturbance to pilot carrier level. In addition, the monitor unit can be used to measure intermodulation products generated in the transmitter or drive unit when two equal amplitude tones are applied simultaneously to the same channel, and to measure noise and/or cross talk that may be present in the drive unit/transmitter system.

MEASUREMENT OF NON-LINEAR DISTORTION

The measure of non-linear distortion produced in the drive unit and/or transmitter is the level of the third order, fifth order and higher order intermodulation products, produced when two equal amplitude tones are simultaneously applied to one sideband channel.

Although great care is taken in the design of all amplifiers used in the drive unit and transmitter of an independent sideband system, it is not possible to produce units having completely linear characteristics, such units only approach this ideal. It will be found therefore, that the output voltage from such units is not exactly proportional to the input voltage, and new frequencies appear at the output of the units which are produced in the units themselves. When two radio frequency voltages, f_1 and f_2, differing only by an audio frequency, are applied simultaneously to the radio frequency amplifiers of the drive unit and transmitter, and the output from the monitor in the translator section of the transmitter is applied to the monitor unit and analysed, it will be found that besides frequencies f_1 and f_2 and their harmonics, new frequencies of $2f_1$-f_2 and $2f_2$-f_1 (third order intermodulation products) and $3f_1$-$2f_2$ and $3f_2$-$2f_1$ (fifth order intermodulation products) appear. The point of importance about these third and fifth order products is that they fall within the pass-band of the tuned amplifier, resulting in distortion of the signal and inter-channel crosstalk.

The distortion level of the drive unit transmitter system is expressed by measuring the level of the intermodulation products relative to the level of either of the two tones.

For non-linear distortion measurements in the drive unit transmitter equipment used for the Perth-Derby independent sideband link, two tones, one of 1000 c/s and one of 2800 c/s, are supplied by the monitor unit. The 1000 c/s tone from the monitor unit, is applied to the appropriate channel of the drive unit under test. The level of this tone is 0dbm at the output of the channel amplifier, and results in an output of +21db relative to 1mW from the drive unit. The 1000 c/s tone is then removed from the channel and equal amplitude 2800 c/s tone is applied in its place and an output of +21db relative to 1mW is again obtained from the drive unit. The two tones are then applied simultaneously to the channel under test, and the 1.6 Mc/s output from the drive unit increases to approximately +24db relative to 1mW. With a 1.6 Mc/s signal of this level applied to the transmitter the radio frequency output from the final stage is 0.5 peak envelope power (P.E.P.).

The audio tones applied to the drive unit channel under test, say channel A, when translated to radio frequency become $(f_c + f_1)$ and $(f_c + f_2)$, where f_c = the radio frequency carrier, f_1 = 1000 c/s and f_2 = 2800 c/s. Nonlinearity of the drive unit-transmitter system give rise to third order intermodulation products which fall at 800 c/s from the pilot carrier in the unloaded channel and at 4600 c/s in the loaded channel, and a fifth order intermodulation product of 2600 c/s in the unloaded channel. The fifth order intermodulation product of 6400 c/s and even order frequencies all fall outside the passband of the tuned amplifiers and filters.

The method by which an intermodulation product is isolated and then measured in the monitor unit can be understood from a study of the block schematic diagram of the independent sideband monitor unit (Fig. 7). With equal amplitude tones of 1000 c/s and 2800 c/s at the correct level applied to the drive unit, say channel A, and the 1.6 Mc/s signal applied to the transmitter, the demodulated 1.6 Mc/s signal from the translator section of the transmitter is applied to the input of the monitor unit. The 1.7 Mc/s variable oscillator in the monitor unit is first adjusted to zero beat against the 1.7 Mc/s crystal oscillator, the zero beat indication being observed on the level indicator by operation of the appropriate switches. The output from the variable 1.7 Mc/s oscillator is then applied to the frequency changer in place of the 1.7 Mc/s crystal oscillator which is usually used for demodulation in the monitor unit. The level indicator is now switched to the output of the 100 Kc/s amplifier and the frequency of the 1.7 Mc/s variable oscillator is adjusted to 1.701 Mc/s. The input signal to the drive unit contains frequencies of 1.601 Mc/s due to the 1000 c/s tone, and 1.6028 Mc/s due to the 2800 c/s tone. After mixing in the frequency changer, which is being fed by the demodulation frequency of 1.701 Mc/s, the frequency changer output contains signal frequencies of 100 Kc/s due to the 1000 c/s tone and 98.2 Kc/s due to the 2800 c/s tone. Of these two signals, only the 100 Kc/s signal is accepted by the 100 Kc/s ± 20 c/s crystal filter, and the level of this signal, referred to as the principal component, is shown on the level indicator which is connected to the filter output via the 0–60db attenuator and 100 Kc/s amplifier. The master level gain control at the input to the monitor unit is adjusted to give a reference reading, usually 0db, on the level indicator centre zero scale.

Having adjusted the monitor unit for reference level, the 1.7 Mc/s variable oscillator is adjusted to a frequency of 1.7 Mc/s-0.8 Kc/s, the 800 c/s intermodulation component in the B channel thus falls in the 20 c/s passband of the crystal filter. The 0-60db attenuator is then adjusted to give the same reference scale deflection. The level of the 800 c/s intermodulation product with reference to the principal component is then read directly from the calibrated 0-60db attenuator scale. In order to mea-

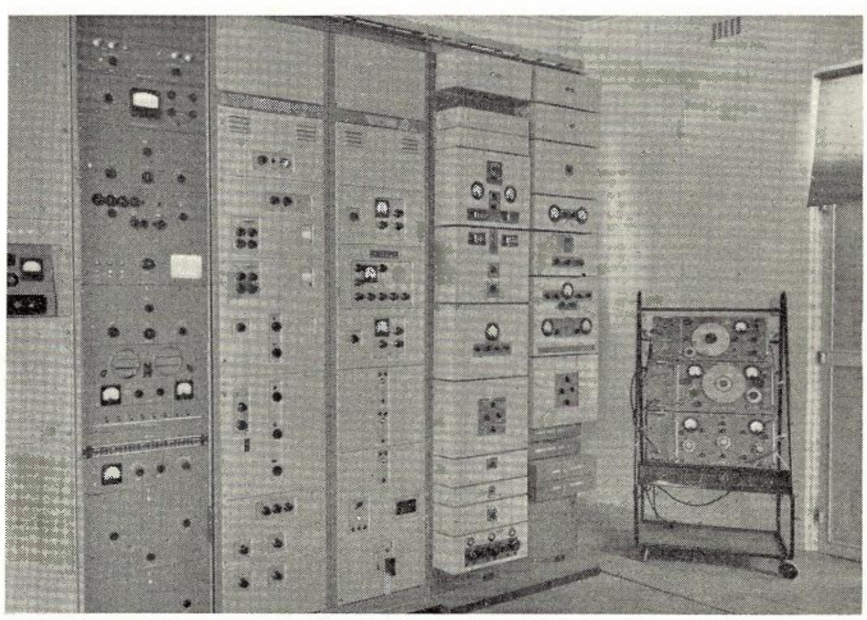


Fig. 8.—The Independent Sideband Receiver Unit.

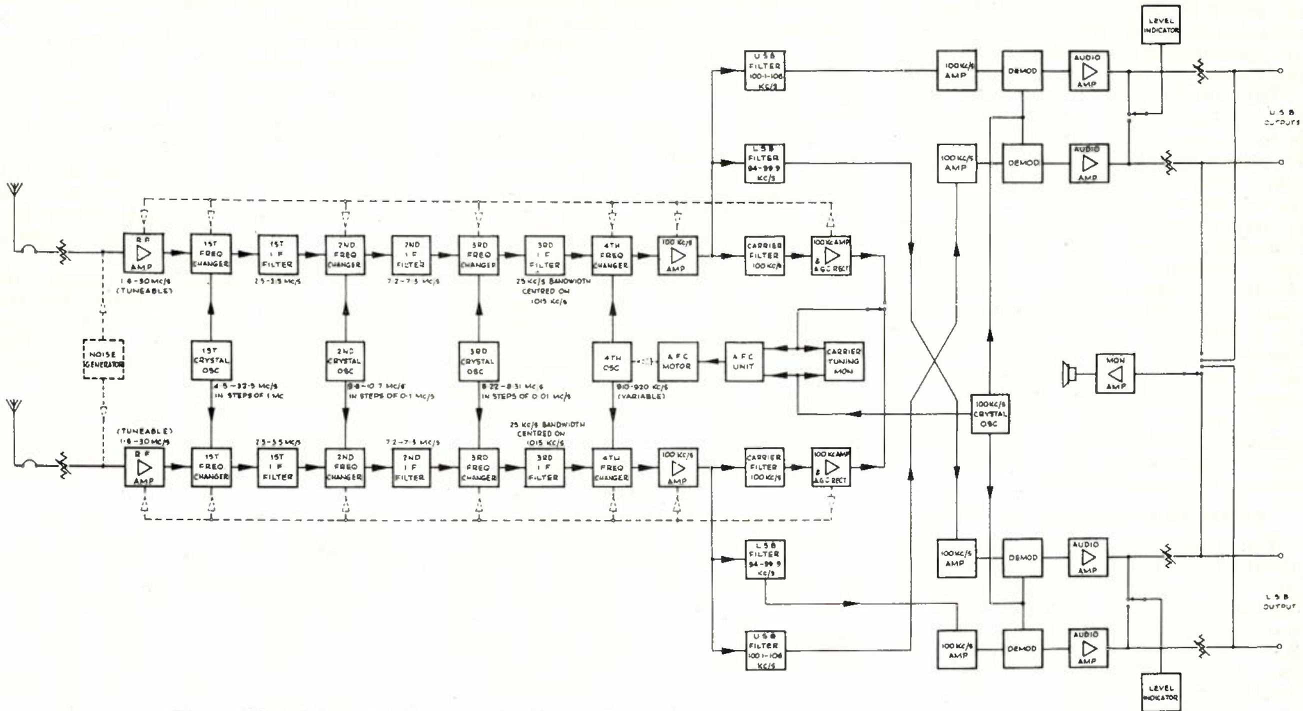


Fig. 9.—Block Schematic Diagram of Dual Path Independent Sideband Receiver.

sure the 2600 c/s component in the B channel, the variable oscillator is set to 1.7 Mc/s-2.6 Kc/s.

The level of the third order intermodulation products should be not greater than – 42db with reference to P.E.P. referred to the level of the principal component, while the level of the fifth order component is in the region of – 50db with the same reference.

In addition to its use as a spectrum analyser, the monitor unit can be used for the measurement of carrier level and carrier compression, checking the level of the pilot carrier compared to the level of the sideband signals and for the measurement of frequency response of either sideband channel.

INDEPENDENT SIDEBAND RECEIVER

The receiver used on the Perth-Derby radio link (Fig. 8), is a dual-path independent sideband receiver designed for continuous operation on point-to-point high frequency radio services. It provides continuous coverage from 1.6-30 Mc/s.

The main design features of this type of receiver include its suitability for the reception of two 3 Kc/s wide telephone channels on each of the two independent sidebands, ease and accuracy of tuning, good sensitivity, good selectivity with facilities for restricting the bandwidth of each sideband crystal filter from the normal 6 Kc/s to 3.5 Kc/s.

The receiver contains two separate and identical paths, which share common oscillators (see Fig. 9). Each path has separate inputs, which are fed from space-diversity aerials, though no provision is made for combining or path selection of the signals received by the two separate receiver paths. This is because diversity reception of independent sideband radiotelephone signals has, in general, no advantage over single path reception, and no satisfactory method of combining or selecting the sideband signals from the two paths has yet been developed. This problem is made more difficult with independent sideband radio-telephone signals, compared with on-off telegraphy signals or double sideband signals, because of the relatively wide audio bandwidth involved—6 Kc/s per sideband—and the fact that path selecting devices in space diversity receivers are not able to differentiate between the different types of selective fading within an audio frequency band.

In the case of reception of multichannel voice frequency telegraphy signals on one or more of the 3 Kc/s wide speech channels advantage can be taken of space diversity reception by the selection of the path delivering the better signal at any instant. This can be arranged independently in the terminal telegraph receiving equipment. The radio frequency signal from the space-diversity aerials is fed to the continuously tunable R.F. amplifier in each path via a 40db adjustable attenuator. A decade type of tuning is used for frequency selection, which allows the receiver to be set to any desired frequency in the 1.6-30 Mc/s range with an error of less than 1 Kc. A total of 42 crystals is used in the frequency selecting system of the receiver so the provision of a separate crystal for each frequency on which it is required to receive is unnecessary.

Three frequency changers, each fed by crystal controlled oscillators, follow the tunable R.F. amplifier. The selector switches for the crystals associated with the oscillators are arranged in a decade system. The output of each oscillator (which may be a harmonic of the actual crystal frequency) is applied to the associated frequency changer and the difference frequency between this and the signal is selected by the filter at the output of each frequency changer.

The fourth frequency changer, which is fed from a highly-stable continuously variable oscillator, has its tuning dial calibrated from 0-10 Kc/s in 0.5 Kc/s steps. The frequency of this oscillator is controlled by the action of the automatic frequency control motor, which maintains the difference-frequency output of the fourth frequency changer exactly at 100 Kc/s.

The 100 Kc/s output signal from the fourth frequency changer is amplified and then fed to three crystal filters. One filter selects the upper sideband (100.1-106 Kc/s), another filter selects the lower sideband (94-99.9 Kc/s) and the third filter selects the pilot carrier signal 99.97-100.03 Kc/s). When the width of the sidebands is to be restricted to 3.5 Kc/s, the connections of the upper and lower sideband filters are changed to make the passbands (100.1-103.5 Kc/s) and (96.5-99.9 Kc/s) respectively.

The output from the upper and lower sideband filters is fed to identical paths, consisting of a 100 Kc/s amplifier, demodulator and audio amplifier.

As mentioned elsewhere, the convention followed on independent sideband radio links is for the upper sideband to be designated channel A when the pilot carrier frequency is above 10 Mc/s, and for channel A to be the lower sideband when the pilot carrier frequency is below 10 Mc/s. In order that a given audio outlet from each path of the receiver is always associated with channel A, and the other outlet with channel B, switching facilities have been provided in the receiver. When it is set to receive a frequency below 10 Mc/s, relays associated with the ganged switches are not operated, but when set to receive a signal above 10 Mc/s the relays located in each detector and audio amplifier circuit are automatically operated, and perform the reversal of the A and B channels.

The 100 Kc/s ± 6 Kc/s signal from the sideband filters after amplification is fed to the signal grid of a pentagrid frequency changer. A 100 Kc/s signal taken from the crystal oscillator supplying the automatic frequency control unit, is applied to the injection grid of the frequency changer valve and the difference frequency, which is the audio-intelligence, appears at the output of the stage. The audio signals are then taken via a 100 Kc/s stop filter to the audio amplifier. The audio amplifier, consisting of two stages, delivers a maximum output of + 16dbm per sideband.

The output of each audio channel is metered by a dbm meter and a monitoring loudspeaker can be switched to any one of the audio outlets.

AUTOMATIC GAIN CONTROL

The automatic gain control voltage is obtained from the pilot carrier signal after the latter has been selected by the narrow carrier filter and amplified. Backward acting a.g.c. is applied to the tuned R.F. Amplifier, frequency changers and the 100 Kc/s amplifier following the fourth frequency changer. The a.g.c. characteristics are such that an 80 db rise in a 1 uV signal input to the receiver, does not result in more than a 5db change in the audio output.

Since fading on high frequency radio circuits is mostly selective in nature, and since the a.g.c. facility is operated from the pilot carrier, it is necessary to use a relatively large discharge time-constant in order to prevent an increase in the audio output from the receiver occurring when the carrier undergoes selective fading. A delay time of approximately 10 seconds enables sustained changes of incoming signal level to be corrected, but prevents the gain from changing appreciably during periods of typical selective fading. Although the a.g.c. voltage has a comparatively slow decay time due to the time constant of the capacity-resistance combination used, it has a very rapid rise on the conduction of a diode valve, when the signal strength rises sufficiently to overcome a pre-set delay voltage.

Although the a.g.c. facility can be made most effective in correcting relatively slow changes in the average received signal level over a range of some 80db, more rapid changes of audio output level, due to propagation conditions, usually of approximately 15db, do occur at times. In order to overcome this variation in level, a voice operated gain adjusting device (v.o.g.a.d.) is employed between the output of the receiver and the input to the radio terminal equipment. The vogad is installed as a unit of equipment at the radio terminals at Perth and Derby.

AUTOMATIC FREQUENCY CONTROL

A particularly accurate type of frequency control has been incorporated in the receiver. Its function is to maintain the pilot carrier signal within the pass-band of the highly selective carrier filter, during periods of slight drift in the frequency of the incoming pilot carrier frequency or, during small changes in frequency of the crystals controlling the receiver oscillators.

An electro-mechanical system of control is used, whereby a motor-driven condenser adjusts the frequency of the oscillator feeding the fourth frequency changer. The a.f.c. unit is fed with the 100 Kc/s pilot carrier signal and also with a 100 Kc/s signal from the local 100 Kc/s crystal oscillator. The two signals are mixed in a system of phasing networks and modulators. A four phase output at the difference frequency between the incoming pilot carrier and the local 100 Kc/s crystal oscillator is obtained. These signals are applied to four windings, spaced at 90° round the stator of a small motor. The rotating magnetic field set up causes the rotor of motor to revolve at the difference frequency, and to drive, through gearing, the variable capacitor in the tuned circuit of the fourth frequency changer oscillator. The frequency output from this oscillator is therefore changed, the beat frequency reduced to zero, at which time the motor stops. Should the frequency of the pilot carrier then continue to drift in the same direction, the rotating field will rotate in the opposite direction, the variable capacitor will again return the output of the fourth frequency changer to the required 100 Kc/s.

The electro-mechanical system of a.f.c. is capable of maintaining the receiver properly tuned with little or no residual frequency error, as even the smallest difference between the frequency of the incoming pilot carrier and the local 100 Kc/s crystal oscillator starts the motor revolving at a low speed. This system of a.f.c. is, therefore, superior to another system of frequency control, where a discriminator and reactance valve circuit is employed. In this system, a change of frequency must occur before the frequency correction can be made. There is, therefore, a slight residual frequency error always present. (4)

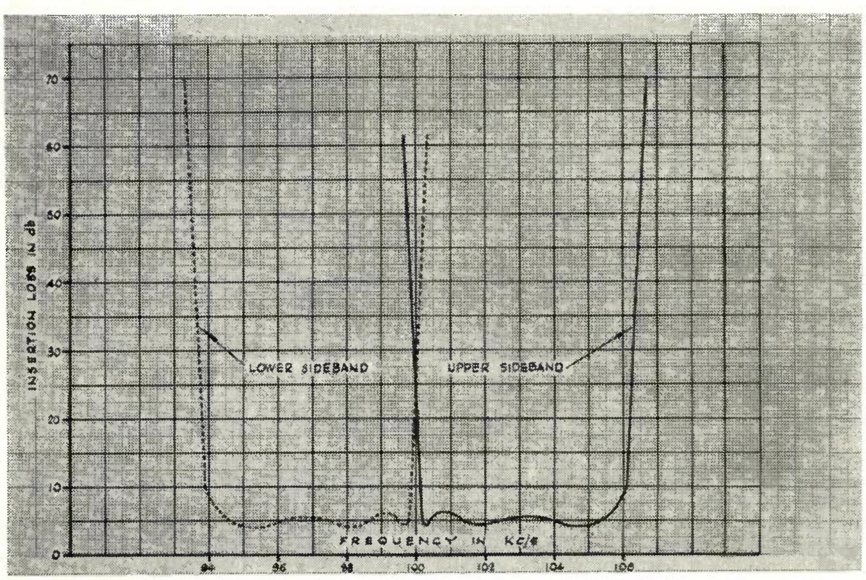


Fig. 10.—The Characteristics of Sideband Filter.

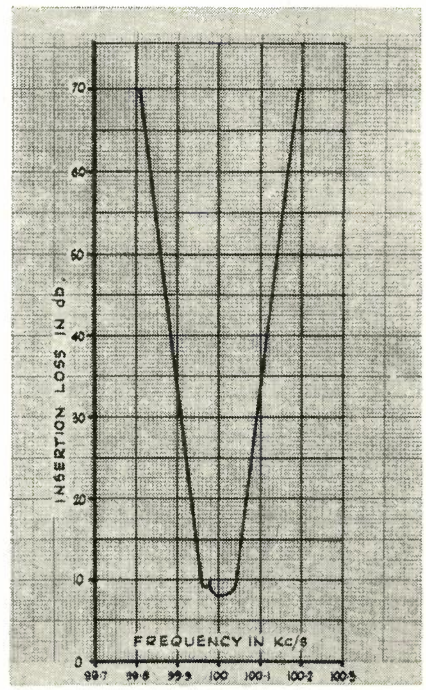


Fig. 11.—The Characteristics of Carrier Filter.

CARRIER TUNING MONITOR

The carrier tuning monitor consists of a small cathode ray oscilloscope and two 100 Kc/s amplifiers, one of which is fed with a signal from the 100 Kc/s carrier amplifier and the other with a signal from the 100 Kc/s crystal oscillator. The outputs from the amplifiers are applied to the "X" and "Y" plates of the cathode ray tube. An associated phase shifting circuit results in a circular trace on the face of the cathode ray tube from each signal. When the frequency of both 100 Kc/s are exactly the same the trace on the cathode ray tube is a stationary straight line. When the frequency of the two signals differ slightly, the line revolves at half the difference frequency, the direction of rotation depending on whether the pilot carrier frequency is above or below the frequency of the local 100 Kc/s crystal oscillator. In practice, it is found that due to noise and/or interference, which fall within the narrow passband of the carrier filter, a departure from the ideal straight line pattern occurs, also slight phasing errors cause the trace on the cathode ray tube to take up the form of a narrow ellipse.

The trace on the cathode ray tube provides a visual monitor of the correct operation of the receiver automatic frequency control system, which is indicated when the trace remains stationary or almost so.

OVERALL PERFORMANCE

The sensitivity of the receiver is such that a sideband signal input of 1 uV, with a pilot carrier 26db below this level, will result in the full audio output of +16dbm, with a signal to noise ratio of 15db. The overall selectivity of the receiver is determined in the main by the sideband filters. The passband is flat within ± 2db for all channels over the range 250 c/s to 6 Kc/s, frequencies more than 500 c/s outside the passband being attenuated by not less than 60db. (Fig. 10).

The bandwidth of the carrier filter is determined by two considerations. Firstly a narrow bandwidth is desirable in order to exclude extra-band noise and other interfering signals (including the sidebands of the signal to which the receiver is tuned) from the 100 Kc/s and automatic gain control rectifier. Secondly the bandwidth must not be so narrow as to risk the loss of the automatic frequency control in the event of a sudden change in the frequency of the incoming pilot carrier or in the frequency of the receiver crystals. A compromise between these two requirements is arrived at in the design of a carrier filter having a passband of 100 Kc/s ± 30 c/s. (Fig. 11).

The receiver noise factor does not exceed 6db for frequencies up to 14 Mc/s. For the band 14-30 Mc/s the figure does not exceed 8db. An in-built noise generator is provided to enable the overall performance of the receiver to be quickly checked. The noise generator can also be used to check that the tuned radio frequency amplifier is correctly adjusted relative to the frequency changer oscillator.

CONCLUSION

The use of an independent sideband system for a radio-telephone link between Perth and Derby has a number of advantages compared with a double sideband system. These advantages include good quality speech signals, and the provision of several speech channels on one transmitter and one receiver due to the absence of non-linear distortion, improved signal to noise ratio on all the audio channels, and a saving of channel space in the high frequency bands suitable for long distance radio communication.

Experience in the use of the equipment has shown that the performance and stability are of a high order, and suitable for long period unattended operation such as is required on the Perth-Derby radio link.

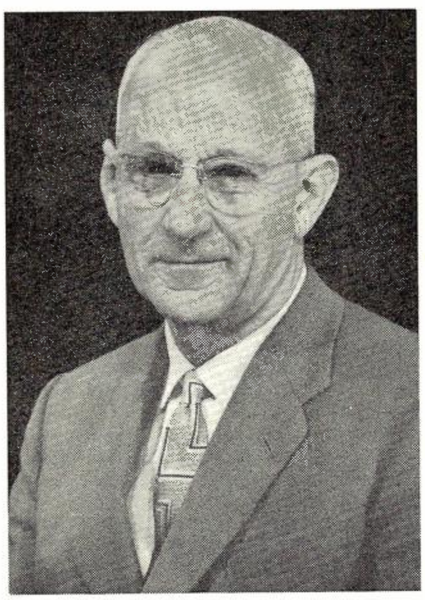
REFERENCES

(1) Radio Engineering: F. E. Terman, 3rd Edition.
(2) P.O.E.E.J., Vol. 45, Pt. 3.
(3) Compendium of Technical Recommendations issued by C.C.I.F., C.C.I.T., C.C.I.R. of the International Telecommunications Union.
(4) Short Wave Wireless Communication, 5th Edition. A. W. Ladner and C. R. Stoner.

ACTIVITIES OF THE SOCIETY

It is with great pleasure that we announce that Mr. F. P. O'Grady, Deputy Director-General, is the new President of the Society for the 1960/61 year.

Mr. O'Grady has energetically supported the Society in the past, particularly by contributing many articles to the Journal and his appointment as President, made on the nomination of the Director-General, will no doubt be widely acclaimed throughout the Society.



MR. F. P. O'GRADY

State Committees for the year 1960/61 are now in office. The State Chairmen are nominated by the State Directors and the other office-bearers are elected by members. The results of these elections were as follows:—

NEW SOUTH WALES

Chairman: M. J. Power.
Secretary: W. A. Brooker.
Treasurer: O. Polmear.

Committee Members:
G. Lewis, S. Bundle, J. Whybourne, G. Black, D. Raines, A. Trevor, R. Ferris
Auditor: R. T. O'Donnell

VICTORIA

Chairman: E. D. Curtis
Secretary: J. S. MacGregor
Treasurer: A. M. Smith

Committee Members:
A. W. McPherson, P. A. Warr, A. C. Wright, W. Kemp, C. H. Brown, W. H. Chapman, J. A. Vickers
Auditor: C. Duncan
Immed. Past Chairman: E. J. Bulte

QUEENSLAND

Chairman: H. W. A. Nicholls
Secretary: F. M. Scott
Treasurer: J. K. Petrie

Committee Members:
C. R. Anderson, C. E. K. Dixon, B. F. Crutcher, E. C. Doherty, A. J. Farrar, J. D. H. Gill, W. C. Harris
Auditor: D. C. Craig

SOUTH AUSTRALIA:

Chairman: V. F. Reeves
Secretary: D. W. McLean
Treasurer: S. McNamara

Committee Members:
D. F. Burnard, E. Colwell, O. G. Bartlett, L. M. Wright, A. K. Forrest, F. E. Cellier, W. Glass
Auditor: G. Hobbs.

WESTERN AUSTRALIA:

Chairman: J. H. White
Secretary: J. Mead
Treasurer: J. Farrell

Committee Members:
W. L. Caudle, L. A. Jones, J. B. Minchin, J. Smith, L. D. Wilkinson, R. W. Wearmouth, T. J. E. Neville
Auditor: L. Nicholls

TASMANIA:

Chairman: G. W. Larsson
Secretary: A. Traill
Treasurer: L. S. Abbott

Committee Members:
C. W. Millar, K. C. Newham, L. R. Jensen, I. J. LeFevre, M. W. Verrier, W. E. Grubb, J. P. Stevens
Auditor: C. H. Volk

INTERACTION CROSSTALK IMPROVEMENT ON THE SYDNEY-MAITLAND CARRIER CABLE

*R. A. LOCKHEAD, Dip.E.E., A.M.I.E.E., A.M.I.E.Aust.**

INTRODUCTION

The 24/40 paper insulated carrier cable installed between Sydney and Maitland was designed to provide approximately 400 telephone circuits on the Northern Route between City North and Maitland. This service was provided in 1957 by the use of twenty-one 17-channel cable carrier systems together with a group modulated 17-channel system which carries 34 channels between Sydney and Gosford. One pair in the cable is reserved for use as a patch line and the remaining pair provides a circuit for the gas pressure alarms. The main terminal stations on the Northern Route are located at City North, Gosford, Hamilton and Maitland. There are repeater stations at Wahroonga, Brooklyn, Gosford, Wyong, Swansea and Hamilton.

Because of the rapid growth of telecommunication requirements since the cable was first put into service, the stage was reached where it became loaded to its maximum capacity on the basis of one 17-channel system on each available pair. To provide additional circuits, plans were made for increasing the capacity to 34 channels by adding 17 additional channels in the frequency range above the existing 17-channel systems by a process of group modulation. To meet the traffic requirements initially, it was proposed to group modulate five systems between City North and Maitland, five systems between City North and Hamilton, and an additional 17-channel group modulated system between City North and Gosford. By this means 170 more channels would be provided on the existing cable.

With the higher frequencies used for group modulated systems that is 72-140 kc/s, three additional repeater stations were considered to be necessary at Doyalson, Belmont and Tarro. The attenuation in any repeater section at the maximum frequency used would then not be excessive, and the noise and crosstalk, which would be aggravated at the higher frequencies, could be kept within acceptable limits.

The need for increasing the number of telephone circuits was urgent and to avoid the delay normally associated with the erection and equipping of new repeater stations, it was decided to group modulate one 17-channel system between City North and Hamilton before additional repeaters were established at Doyalson and Belmont. It was realised that with the higher frequencies involved, interaction crosstalk and noise would become significant. However, by modifying the offices along the route in a similar fashion to offices on the Melbourne-Seymour route (1, 2) it was considered that the interaction crosstalk and noise would be brought within satisfactory limits.

Briefly, the work done on the Melbourne-Seymour route (2) showed that interaction crosstalk at a cable carrier station is caused by unwanted coupling paths between transmit and receive circuits. These paths involve transverse and longitudinal voltages (or currents), or a combination of both, resulting in crosstalk and noise.

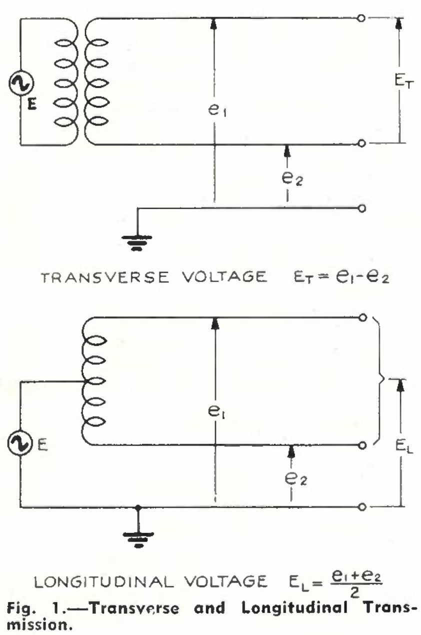


Fig. 1.—Transverse and Longitudinal Transmission.

* *See page 298.*

SOURCES OF NOISE AND CROSSTALK

A main source of noise in cable carrier repeater stations is that due to the potential difference existing between various earth points. This may result in crosstalk and more particularly, channel noise. Dry joints, microphonic valves, intermodulation, faulty insulation and interaction between cable pairs and equipment are also significant sources of noise.

The means of reducing unwanted coupling within a cable carrier station and the steps necessary to minimise or eliminate differences of earth potential are:—

(a) Cabling carrying high level signals should be run in separate forms from cabling carrying low level signals, and the forms should be separated by no less than 3 inches in air. (See also Para. (c).)

(b) The screens of all screened wiring should extend as close to the termination point as practicable.

(c) Cabling carrying high level signals should not be allowed to cross cabling carrying low level signals and where high and low level keys, jacks and terminal blocks are in proximity, adequate separation should be allowed or additional shielding supplied.

(d) All unused or dead wiring should be removed from office runways.

(e) It is desirable that all non-carrier circuits such as gas alarms, programme and V.F. circuits should be removed from carrier cables, but if this is not possible, such circuits should be treated as carrier circuits in all respects. If such non-carrier circuits are used for signaling, V.F.-phantoms or super-phantoms, it is generally necessary to equip these circuits with suitable crosstalk suppression filters.

(f) All earth busbars in the office should be inter-connected at both ends and taken to the lead sheathing of the cables by means of short, direct leads, the object being to achieve the minimum earth impedance in the station.

(g) Suitable de-coupling filters should be fitted to power busbars to reduce noise from these sources and minimise common impedance coupling.

MODES OF TRANSMISSION

The normal method of transmission on balanced-pair cables uses transverse voltages and/or currents. The signal is applied between the two input terminals of any equipment say, a repeater, and the resulting signal appearing between the two output terminals is of interest. Due to unbalances in cable pairs, input and output transformers and other circuit elements, longitudinal components will appear, so that both transverse and longitudinal signals are present at the output terminals.

The other and usually unwanted method of transmission involves longitudinal voltages and/or currents. The longitudinal voltage is the average of the two voltages existing between one leg of the circuit and earth and between the other leg of the circuit and earth. Similarly, the longitudinal current is the average of the currents which flow between one leg of the circuit and earth, and between the other leg of the circuit and earth.

These modes of transmission are shown in Fig. 1 and, subject to the existence of suitable coupling paths, can cause interaction crosstalk and noise at carrier frequencies. The mechanism of these couplings was described in a previous article (1).

If a transverse voltage is impressed on a cable pair and its associated equipment, a longitudinal voltage will appear due to the lack of complete balance, and the conversion ratio between these voltages may not, in the worst cases, exceed 40 db at about 100 kc/s. It has been found that approximately reciprocal conditions exist in most cases and an impressed longitudinal voltage may cause

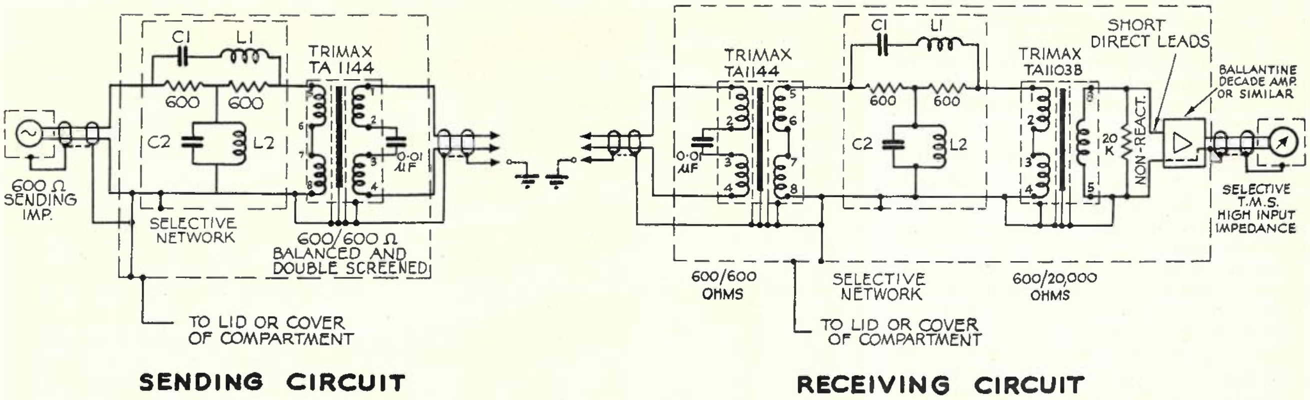


Fig. 2.—Schematic of Test Equipment used for Measurement of Interaction Crosstalk. C1 = 84 pF, C2 = 0.0326μF (Mica), L1 = 11.75mH, L2 = 30.2μH.

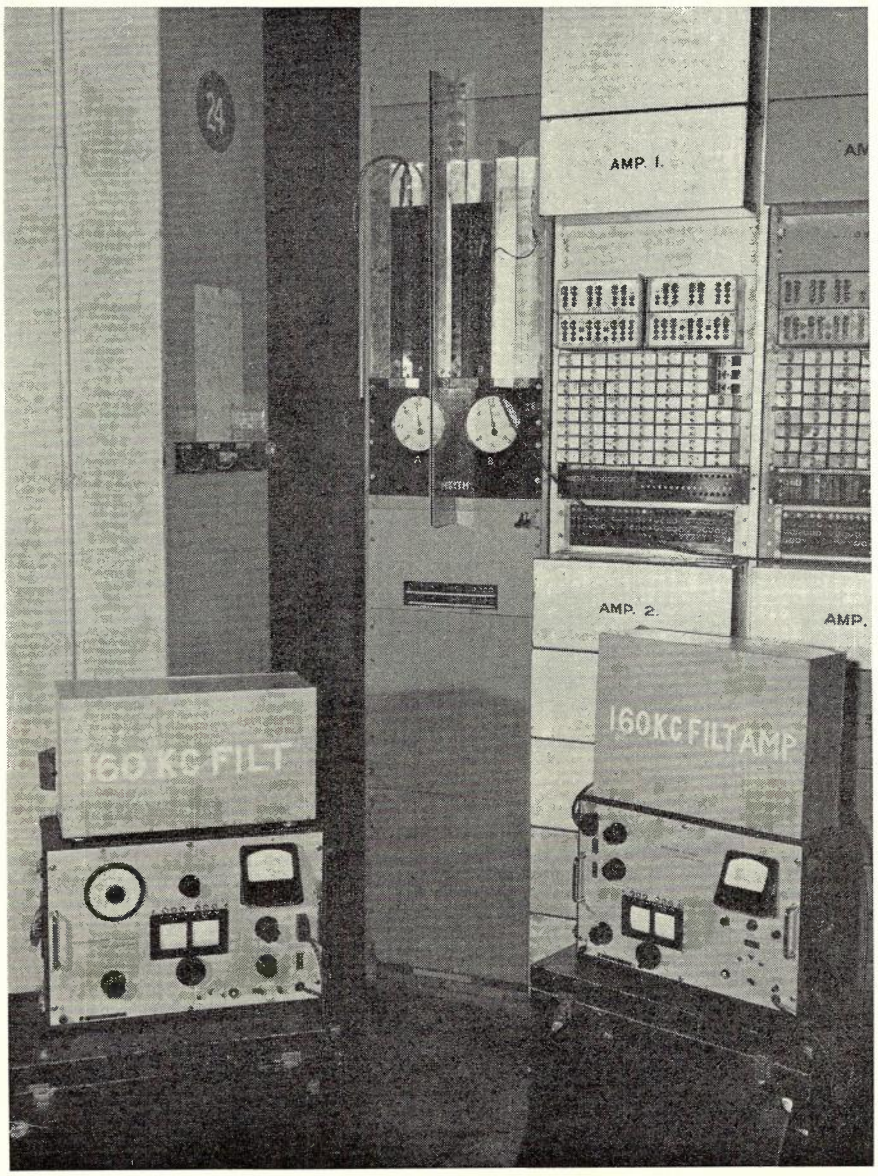


Fig. 3.—Equipment for Measurement of Interaction Crosstalk.
Left: Oscillator and 160 kc/s Filter.
Right: Level Meter with 160 kc/s Filter and Decade Amplifier.
Equipment and Testleads to Cable Heads must be well separated as shown to avoid false readings due to unwanted direct couplings between Send and Receive sides.

a transverse voltage 40 db down only on the longitudinal voltage.

In the following discussion a description is given of the modifications effected at the stations and reference is made to various sources of coupling. Interaction crosstalk figures are given to enable conditions to be compared at the various offices before and after modification.

TESTING

Whereas measurements on the Melbourne-Seymour route were carried out at a frequency of 108 kc/s, a frequency of 160 kc/s was used on the Sydney-Maitland route. This frequency was chosen because it is outside the frequency range of equipment in use on the cable, that is 4-140 kc/s, and consequently enabled measurements to be made without disturbing working systems. The worst interaction crosstalk conditions will usually be encountered in the higher frequency ranges, and the tests at 160 kc/s should therefore be representative of the worst crosstalk. The test equipment to be discussed in the following paragraphs is readily adapted for interaction crosstalk testing of open wire carrier lines.

Fig. 2 shows the circuit of the sending and receiving sections of the test equipment used in conjunction with a Siemens and Halske T.M.S. The circuits are designed for 600 ohm impedance to enable the measurements to be made on a bridging basis on 150 ohms circuits, without disturbing working circuits. The respective input and output transformers of the receiving and sending sections should be carefully balanced and double-screened to ensure invariance of readings with poling.

The selective networks shown are essential when performing measurements on working bearer circuits. They provide attenuation against unwanted spurious frequencies that may be transmitted from the oscillator, and thus reduce the likelihood of channel interference. On the receiving side, the networks provide more accurate selection of the 160 kc/s test frequency and guard the decade amplifier against overload which could be caused by carrier frequencies present on the cable pairs under test. The decade amplifier furnishes additional gain and is used in conjunction with a 600/20,000 ohm step-up transformer to improve the signal-to-noise ratio of the testing equipment. Readings in excess of 160 db at a frequency of 160 kc/s are obtainable.

Tuning of the oscillator and selective receiver is necessary before calibration to ensure that the oscillator frequency and selective receiver setting correspond with the centre of the pass band of the selective networks in the send and receive sections of the test apparatus. This is done by connecting the send and receive leads together, then, with the receiver in the wide band condition, the oscillator is tuned to give a maximum indication on the meter. The receiver, now in the selective condition and set at high impedance, is then tuned to give a maximum indication.

Calibration is required for measurements on each bearer, to take account of variations of impedance from cable pair to cable pair. This is done by connecting the leads from the send circuit to the cable head links of the disturbing pair in the send cable and adjusting the oscillator to send a level of say -25 db reference 775 mV. The receive leads should be connected across the same pair and the oscillator output vernier adjusted to give a suitable indication, say 0 db, on the receive level meter. The adjustment of the vernier on the oscillator output is made for convenience only, since the crosstalk present is measured relative to the calibrated receiver reading.

The receive leads should now be transferred to the cable head links of the disturbed pair in the receive cable and a measurement made in the following manner:—

(a) Increase the level of the oscillator by say, 45 db.

(b) Decrease the attenuator on the receiver until a crosstalk signal appears. If the attenuator has been reduced by say, 80 db. the measured crosstalk would be (45 + 80) db + reading on level meter, say 8 db, that is 133 db.

(c) If an indication on the level meter is present when the oscillator is removed it will usually be found that the reading is noise. This may be confirmed by use of a head receiver at the "listen" jacks of the receiver.

The following precautions should be taken to avoid erroneous readings through unwanted coupling of the test equipment:—

(a) The send equipment and the receive equipment should be suitably spaced. A typical testing arrangement may be seen in Fig. 3.

(b) The send and receive leads should be spaced as far apart from each other as possible (Fig. 3).

(c) If measurements are made prior to the earthing modifications described later, the screens of the send and receive leads should be earthed separately to the respective sheaths of the cables on which the measurements are being made. Care is necessary as earth leads in close proximity have acted as a coupling medium despite the earth leads being connected to individual cable heads.

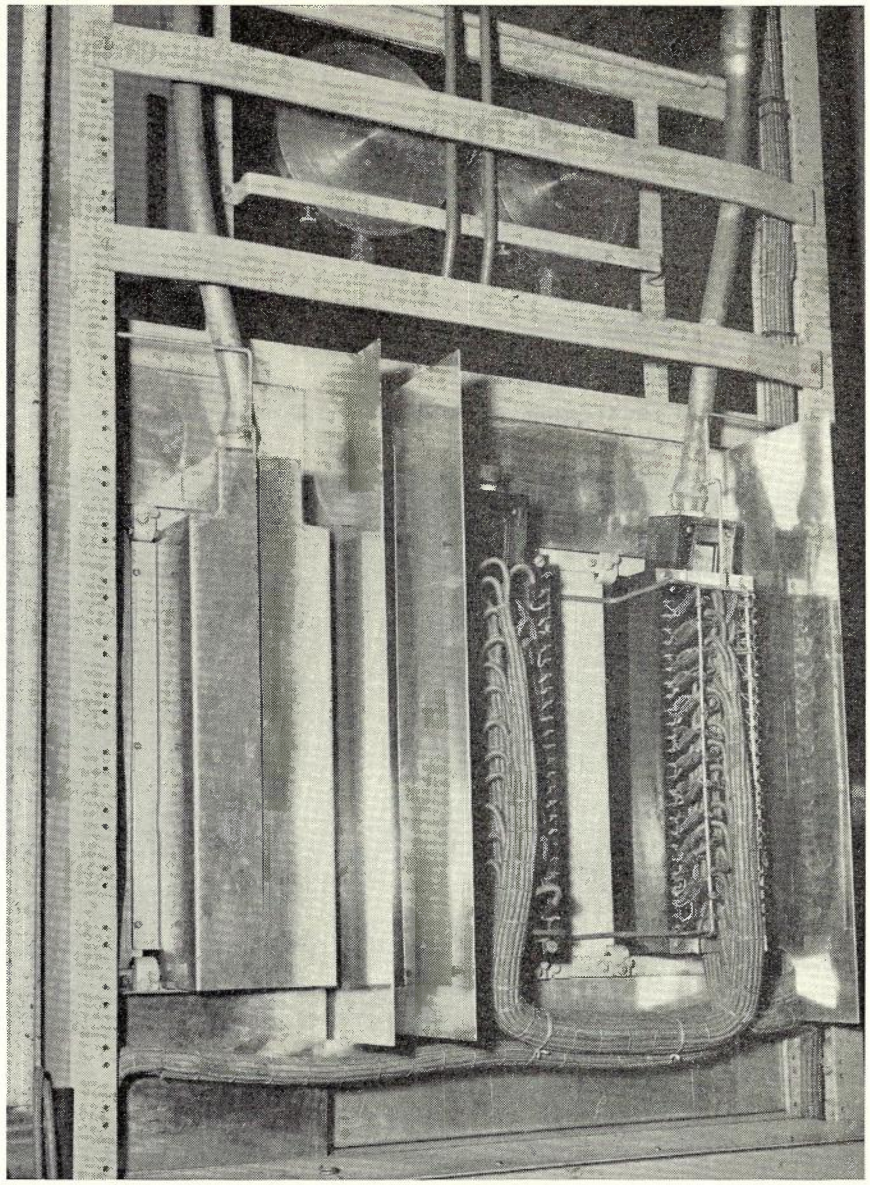


Fig. 4.—Rear of Cable Head Bay at City North showing shielding and cowling around the Send Cable Head.

During the course of the measurements frequent movement of the testing leads is unavoidable as the leads are changed from pair to pair in the respective send and receive cables. This imposes a physical strain on the conductors and in the initial stages of the work, frequent delays occurred due to leads breaking or test clips becoming insecure. Such difficulties were overcome by the use of a shielded cable which employs stranded conductors. The screen on each test lead was brought out as a tail and the two conductors and the screened lead were stoutly fitted to alligator clips in such a manner that no strain was imposed directly on the actual conductors where they joined the alligator clips. In this manner it was possible to complete many thousands of measurements without encountering broken or partially broken leads.

STATION MODIFICATIONS

Initial interaction crosstalk measurements made at repeater stations on the northern cable between City North and Wyong showed that the majority of combinations were worse than the acceptable limit (that is 140 db) and it was evident from inspections of the various stations that poor earthing, crossings of high signal level wiring with low signal level wiring, insufficient shielding, untreated phantom circuits and other non-carrier circuits were contributory causes. Accordingly, steps were taken to modify the stations along the lines already referred to previously, and as discussed in further detail in later paragraphs.

Earthing

At each station, 200 lb. copper wire was used to provide a suitable earth mesh at the send and receive cable-heads. This wiring was extended from the station earth bus-bar down the channel of the iron framework of the cable head rack, along the base, then up the other side and back to the station earth bus-bar. In effect, this constituted a U-shaped structure with the station earth bus-bar closing the U at the two points where it connected. This step was taken to provide a minimum impedance earth circuit and, for the same reason, the noisy and silent earth bus-bars in the station were strapped together where the bus-bar laterals appear at the end of a suite. By doing this, an earth mesh was constructed in the station as distinct from a single earth bus-bar. Stout copper straps were connected to the lead sheath of the cable where it entered the cable-head and these were then taken across to the earth bus-bar in the channel iron. Fig. 4 shows an example of the method used. It will be seen from this figure how the bus-bar is extended to allow for earthing of the screens of the wiring going away to equipment. Both the transmit and receive cable heads are treated in this manner and by this means, together with the other steps described above, each station is effectively reduced to a "one-earth" arrangement.

Measurements carried out when this modification had been completed showed an improvement of interaction crosstalk, and figures of 15-20 db improvement are not unusual with this step alone. The improvement varied from station to station and was dependent on the quality of the original earthing. It was found that in a station where the earthing had been untreated, "reliable" crosstalk measurements were obtainable only by connecting the earth of the send equipment to the sheath of the send cable and similarly by connecting the receive equipment earth to the sheath of the receive cable. However, once the station had been modified to a one-earth arrangement in the manner already described, the measuring equipment may be earthed at any convenient point without any discrepancy in readings. If this result is not achieved it is probable that the earthing requires further attention to make sure that all earths are effectively at the one potential.

Bus-bar and Suite Take-off Filters

In order to reduce coupling between systems at each repeater station (brought about through common bus-bar impedances) a filter was fitted at each suite bus-bar take-off point. This filter consists of a capacitor of 40 μF. connected between the 200V. bus-bar and earth and a capacitor of 100 μF. between the 24V. bus-bar and earth.

These capacitors are of the electrolytic type and they may therefore have a fairly high impedance at higher frequencies. Effective decoupling at these frequencies is achieved by connecting a 2μF. non-inductive paper capacitor across each electrolytic capacitor. Unwanted resonances are suppressed by the incorporation of a 0.5 ohm damping resistor in series with each capacitor assembly. Each assembly is also fused and on latter installations the fuse wire has been chosen to have a resistance of 0.5 ohms, thus avoiding the need for a separate resistor. A typical filter is shown later in Fig. 9.

A similar filter arrangement comprising capacitors of 600 μF. and 2000 μF. is used for the main bus-bars where they enter the carrier room in each office. The provision of these decoupling filters also serves to keep the noise and crosstalk arising from the power plant to a minimum.

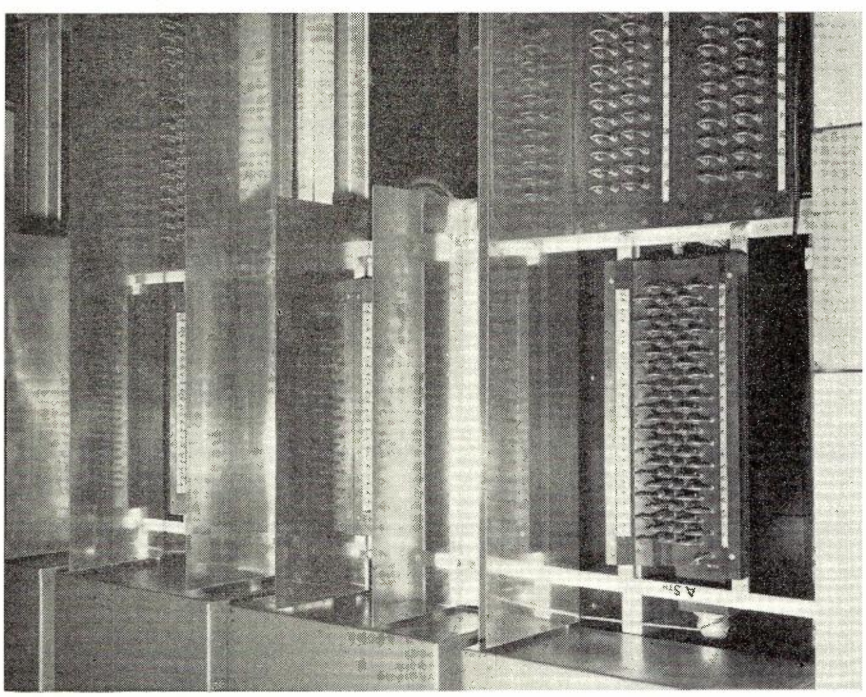


Fig. 5.—Front of Cable Head Bay at Gosford showing shielding.

Shielding

In addition to the earthing practices described, shielding of the cable-heads is necessary because unwanted coupling takes place between the transmit and receive heads through a combination of direct radiation and capacitance coupling. Ideally, both heads should be enclosed by a properly earthed cover, but, in the offices under investigation, this was not practicable and, therefore, other measures were necessary. The desired results were achieved by fitting aluminium shields to the heads in addition to the existing shields which had already been provided by the manufacturer. The additional shielding was constructed from 20 gauge aluminium, mounted in position as shown in Figs. 4, 5, 6 and 7. Since not all cable heads were of the same dimensions, different size shields were necessary at different stations. Furthermore, even with the shields in place, coupling was still found to occur from the front of the cablehead to the wiring at the rear unless screens were fitted across spaces not occupied by equipment. The transmit cable-head is further enclosed by a brass cowling. Access to the wiring is achieved by the removal of four screws, in the event of maintenance or alteration to wiring becoming necessary.

After screens had been fitted and all other modifications completed at Wahroonga, a crosstalk pattern was observed in the measurements in the A-B direction between adjacent U-links on the send and receive cable-heads. For example Pair 13 of the send head was crosstalking into Pair 1 of the receive head, and to a lesser extent into Pairs 2, 3, 4. This pattern was evident even when the wiring was temporarily lifted off the respective heads, showing a clear indication of direct coupling between the U-links. The shields were increased in length and depth to overcome this effect.

Wiring

In a number of offices a considerable quantity of "dead" wiring was removed from runways. At City North and Gosford as much as 300 yards of old cables was discarded. This "dead" cabling has been found to provide unwanted coupling within a station and unwanted wiring should be removed once it is no longer required for existing equipment. Cases were found where "dead" wiring in high level runs was also included in low level runs in other parts of the exchange. This dead wiring degraded the crosstalk measurements to a marked extent until it was located and removed. Careful inspection of the wiring along runways will often show where a high level cable has been accidentally included in a low level run and vice versa. This fault was encountered frequently during the course of modifications and until the offending cabling had been correctly re-routed, poor crosstalk readings were experienced. Where separate runways are not provided for high and low level

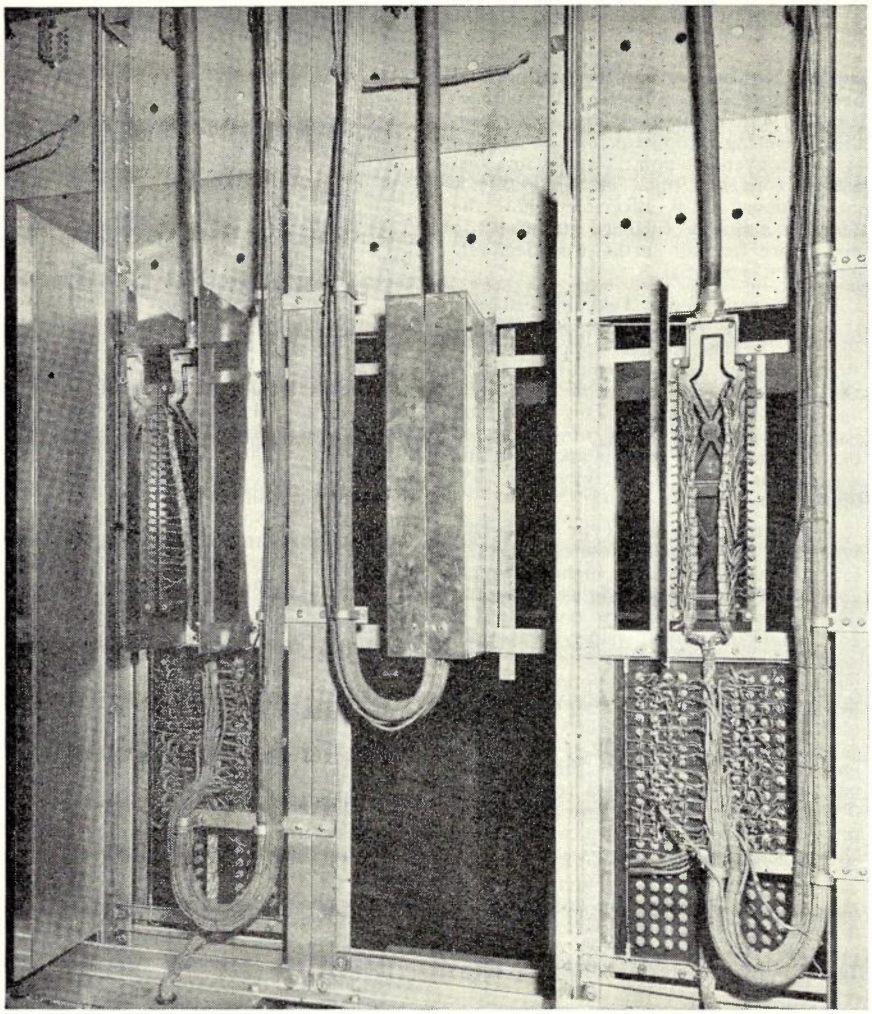


Fig. 6.—Rear of Cable Head Bay at Gosford showing shielding and cowling around the Send Cable Head. Heavy Earthing Wires also shown.

coupling at carrier frequencies and special treatment of these circuits is therefore necessary. On non-carrier circuits the usual procedure is to equip each circuit with a 4 kc/s L.P. filter to provide a high longitudinal suppression to carrier frequencies and thereby reduce the likelihood of unwanted coupling paths. A circuit of such a filter, together with its characteristics, is shown in Fig. 8 and a filter of the type used is shown in Fig. 9. All phantom and gas alarm circuits in each of the cables have been equipped with 4 kc/s L.P. filters at repeater stations between City North and Hamilton. It is desirable to mount these filters as close as possible to the cable head if satisfactory interaction crosstalk figures are to be obtained.

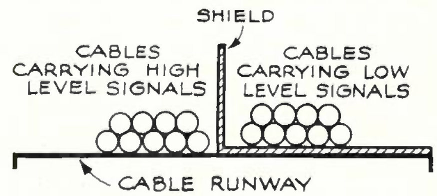


Fig. 7.—High and Low Level Cabling separated by L-shaped Shield.

During overall tests at Gosford poor combinations were noted when testing on Pair 10, (gas alarm pair). The cause was shown to be outside the office and an inspection was made of a few of the manholes in which gas alarm equipment was known to be fitted. These inspections revealed that gas alarm equipment, common to the transmit and receive cables was in use in manholes adjacent to Gosford, Wahroonga and Wyong. This common gas alarm equipment provided effective coupling between the gas alarm pairs of the two cables at carrier frequencies. Arrangements have since been made for the cables to be fitted with separate gas alarm equipment on

wiring, that is wiring carrying transmit signal level and receive signal levels respectively, the cabling must be carefully separated. Where it was not possible to separate the high and low level cabling by at least 3 inches, L-shaped shields were constructed to provide a suitable degree of screening between the respective cable runs as shown in Fig 7.

In a large office, where a considerable number of systems are installed, high and low level wiring "crosses" are likely to be found. As an example, installation work carried out at one station after the modifications described in this paper had been completed, resulted in poor crosstalk figures, that is poor combinations existed where previously, following the prescribed modification, they had all been good. This was the result of several accidental wiring "crosses" which had occurred during installation of an additional system.

V.F. Phantoms and Gas Alarms

V.F. phantom circuits and a gas alarm pair have been provided in each cable on the Northern route. These circuits are known to cause excess longitudinal

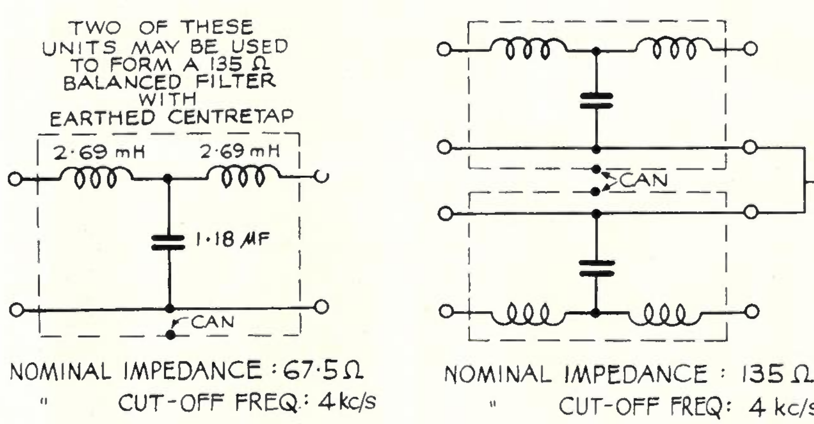


Fig. 8.—4 kc/s Cross Talk Suppression Filters. The characteristics, when operated between the nominal impedances are:

	Attenuation	Long Impedance of Bal. Filt.
0.4 kc/s	Pass Range	—
8 kc/s	18 db	—
12 kc/s	29 db	100 ohms
20 kc/s	42 db	170 ohms
40 kc/s	60 db	340 ohms
80 kc/s	78 db	675 ohms
160 kc/s	96 db	1350 ohms

Current carrying Capacity: Not less than 50 m/A. D.C.

TABLE A—INTERACTION NOISE AND CROSSTALK MEASUREMENTS ON THE SYDNEY-MAITLAND CARRIER CABLE

Station	Sending	Receiving	90–99db	100–109db	110–119db	120–129db	130–139db	> 140 db	Noise	Misc.	Total
City North Unmodified	A–B	B–A		2	122	289	137	23	2	81 db–1	576
CITY NORTH MODIFIED	A–B	B–A		1	3	16	25	232	299		576
Wahroonga	A–B	A–B			2	5	126	220	223		576
	A–B	B–A	7	16	26	248	250	28	—	50 db–1	576
Unmodified	B–A	B–A		1	3	65	292	125	90		576
	B–A	A–B	5	7	3	380	165	12	3	80 db–1	576
WAHROONGA MODIFIED	A–B	A–B				1		20	555		576
	A–B	B–A		1	1		26	467	81		576
	B–A	B–A					1	17	558		576
	B–A	A–B	1			7	209	236	123		576
Brooklyn	A–B	A–B	1	13	23	52	286	187	13	75 db–1	576
	A–B	B–A		7	13	61	349	111	34	77 db–1	576
Unmodified	B–A	B–A			19	79	325	145	7	81 db–1	576
	B–A	A–B	4	12	23	157	306	60	13	73 db–1	576
BROOKLYN MODIFIED	A–B	A–B			1			23	552		576
	A–B	B–A	1				1	183	391		576
	B–A	B–A				1		84	491		576
	B–A	A–B			2			183	391		576
Gosford Unmodified	A–B	A–B	1	1	37	99	266	165	6	87 db–1	576
	A–B	B–A		17	53	123	283	94	5	51 db–1	576
	B–A	B–A	2	10	21	223	234	85	1		576
	B–A	A–B	5	23	52	190	231	68	6	49 db–1	576
GOSFORD MODIFIED	A–B	A–B					1	12	563		576
	A–B	B–A			1			2	573		576
	B–A	B–A							576		576
	B–A	A–B			1			13	561	88 db–1	576
WYONG MODIFIED	A–B	A–B							576		576
	A–B	B–A		1				5	570		576
	B–A	B–A							576		576
	B–A	A–B					1		575		576
SWANSEA MODIFIED	A–B	A–B							552		552
	A–B	B–A	1			1	21	6	523		552
	B–A	B–A							576		576
	B–A	A–B	1			1	21	4	549		576
HAMILTON MODIFIED	B–A	A–B	1			13	29	7	526		576

The figures shown in this table represent the number of combinations measured within the particular ranges.

both the "A" and "B" cables. On repeater sections where separate gas alarm equipment had been installed, the gas alarm pair tested satisfactorily.

Office Equipment

Crosstalk paths may also be found to exist in repeater equipment. For example, unwanted coupling paths in the form of poor backward suppression may occur due to coupling between high and low level signal circuits associated with repeater amplifiers, caused by long circuit leads, and unbalance in input and output transformers. Coupling between filament supply circuits was found at Brooklyn and Gosford and such possibilities should not be overlooked when crosstalk is still evident after the modifications described have been carried out.

RESULTS

Table A gives an analysis of the crosstalk combinations obtained at each of the repeater stations between City North and Hamilton. This table shows the conditions existing before any modifications had been carried out and the overall results obtained after the modifications had been completed at all stations. From this table it can be seen that Gosford and Brooklyn have undergone considerable improvement, whilst significant improvements are in evidence at City North and Wahroonga. Initially more than 70% of the total combinations measured were worse than 140 db, but after the modifications had been completed this applied to only 3% of the total readings. Some of these poor combinations are known to be due to unmodified gas alarm equipment in some manholes along the route. These will improve into the noise region once separate alarm circuits are provided for each cable at the manholes concerned. Further work has since been done towards improving some of the remaining phantom circuits causing bad combinations at City North and Wahroonga.

CONCLUSION

Methods of reducing noise and crosstalk in cable carrier stations have been described but due to the widely varying conditions found at different carrier repeater stations, it is not practical to estimate the exact improvement that may be expected through carrying out any particular part of the modifications. Modifications designed to effect an improvement in noise may, in reducing the noise, disclose that interaction crosstalk is present. Improvements in noise and interaction crosstalk are achieved in stages as different modifications are completed. As the work progresses, the interaction crosstalk will be seen to become confined to a few combinations only and these paths should be treated individually, until no significant crosstalk remains.

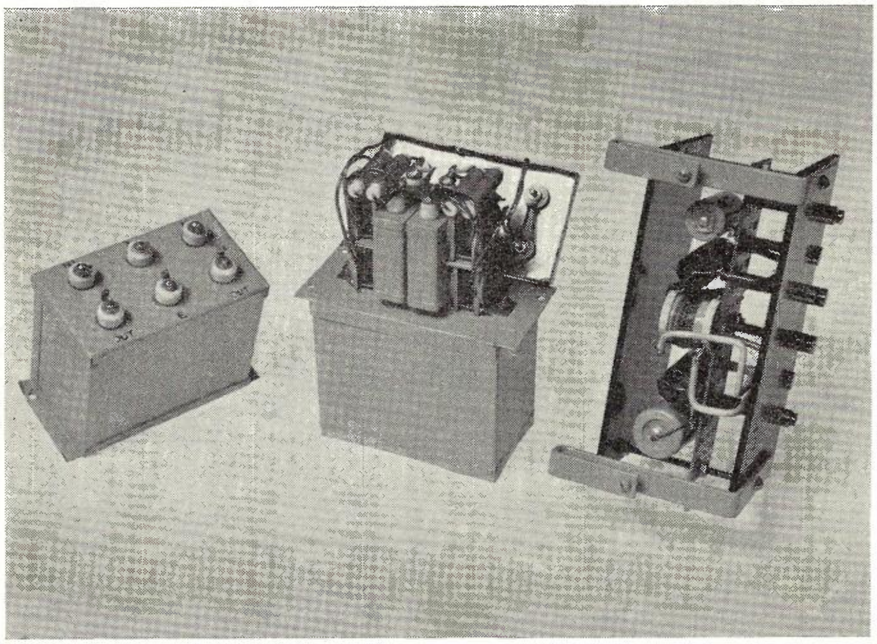


Fig. 9.—4 kc/s Crosstalk Suppression Filters, "in" and "out" of case (left and middle) and Suite Busbar Filter (right).

To assist in examining whether unwanted transverse voltages are involved in causing crosstalk, a useful method is to provide an effective short circuit across a suspect circuit by the use of a series LC circuit resonating at the testing frequency of 160 kc/s. This will often enable a source of crosstalk to be located without disturbing channels carrying traffic since the LC series circuit will short-circuit only the test frequency, and not discriminate against other carrier frequencies which may be present. In extreme cases it may be necessary to remove traffic channels from service and resort to disconnecting equipment from offending pairs before the actual crosstalk coupling path may be located and rectified. However, this should seldom be necessary if the steps outlined are carried out with care.

REFERENCES

1. S. Dossing, Principles of Crosstalk and Noise Suppression at Open-Wire and Balanced Cable Carrier Stations; Telecommunication Journal of Australia, Vol. 11, No. 6, page 180.

2. P.M.G. Department Long Line Equipment Laboratory Report No. 34, Interaction Crosstalk and Noise at Cable Carrier Stations.

MR. J. C. HARRISON, O.B.E., M.I.P.A.

MR. J. C. HARRISON, O.B.E., M.I.P.A.

The Telecommunications Society is aided greatly in achieving its success by the support it receives from so many of the officers of the Department who occupy the higher administrative positions. Mr. J. C. Harrison, who recently retired as Director, Posts and Telegraphs, Victoria, is amongst those who in many ways assisted and encouraged our activities.

Mr. Harrison's work covered many fields during the 50 years he served in the Postmaster-General's Department. He commenced as a telegraph messenger in Launceston in 1910, and until 1926 worked in various fields, including telegraphy, postal and personnel, at the same time studying engineering and passing various subjects of the Departmental engineering examinations. His potential capabilities were recognised in that he was transferred to Headquarters in 1926 as Telephone Traffic Officer. Successive promotions followed to Senior Traffic Officer, Inspector, Chief Inspector, then Assistant Director-General (Telegraphs). After promotion as Assistant Director, Telecommunications Division, Victoria in 1955, he was appointed Director, Posts and Telegraphs, Victoria in 1958.

Mr. Harrison's activities of note included his representation on the Australian delegation to the International Radio Conference and the Plenipotentiary Conference of the International Telecommunications Union at Atlantic City, U.S.A. in 1947, and he attended meetings of the Commonwealth Communications Council in London in the same year. He was also one of the Commonwealth Directors on the Board of Amalgamated Wireless (A/sia) Ltd., from January, 1949 to November, 1951. He also represented the Postmaster-General's Department before the Royal Commission on Censorship in 1944, being the Department's Censorship Liaison Officer with other authorities for many years. He published a brochure entitled "Ninety Years of Telegraph Progress" in 1945. His activities in the telegraphs field were largely responsible for the introduction of the TRESS and TELEX projects.

Mr. Harrison was created an Officer of the Most Excellent Order of the British Empire by Her Majesty Queen Elizabeth the Second in this year's Birthday Honours Awards.

Mr. Harrison remained an active member of the Society from the time of its reconstitution in 1932 and contributed a number of valuable articles to the Journal. Our best wishes go to him in his retirement.

PERTH TERMINAL OF THE AUSTRALIA-LONDON RADIO TELEPHONE LINK

*N. A. BRAYLEY, A.P.T.C., Dip.Elec.Eng., A.M.I.E.Aust.**

INTRODUCTION

In 1954, decisions were made to provide a second radio telephone link between Australia and London. Up to this time, the only Australian-U.K. service existed between Sydney and London. The establishment of a second circuit was intended to enable a more continuous service to be provided as it was anticipated that the ionospheric conditions at Sydney would not be the same as at Perth and that the Perth circuit would probably be available when the Sydney circuit was unusable. Contracts were let in 1955 for terminal apparatus and arrangements were made regarding the accommodation for same at the Perth G.P.O. The area chosen was on the second floor as close as practicable to both existing equipment and operating rooms. The apparatus used on this installation was manufactured by Siemens & Halske, of Germany.

The purpose of this article is to outline and discuss the requirements for a multi-channel terminal for long-distance radio-telephone communication and to provide a brief expose of the way in which this is accomplished by the Siemens and Halske equipment at the Perth terminal. The independent sideband radio equipment for the Australia-London link, as distinct from the telephone terminal which forms a connection to the local telephone is maintained and operated by the Overseas Telecommunications Commission (Australia), a separate body from the P.M.G., and who provide a radio transmitter at Applecross and a radio receiver at Bassendean, W.A. Both of these are connected by about 4 miles of underground cable to the Radio Telephone Terminal situated at the G.P.O., Perth. The receiver and transmitter operate at different frequencies of 12 mc/s, 16 mc/s, 22 mc/s and 24 mc/s depending on transmission conditions. The transmitter power is 30 kW.

In its simplest form the terminal equipment would consist merely of a Hybrid to connect the 2-wire local line with the 4-wire radio path. (See Fig. 1). In practice, however, attempts must be made to compensate as far as possible for the varying conditions such as fading and interference that exist on a radio

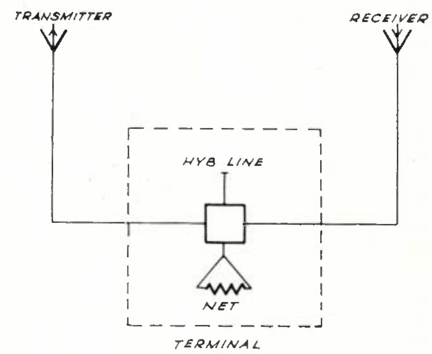


Fig. 1.—Simplest Form of Terminal Equipment.

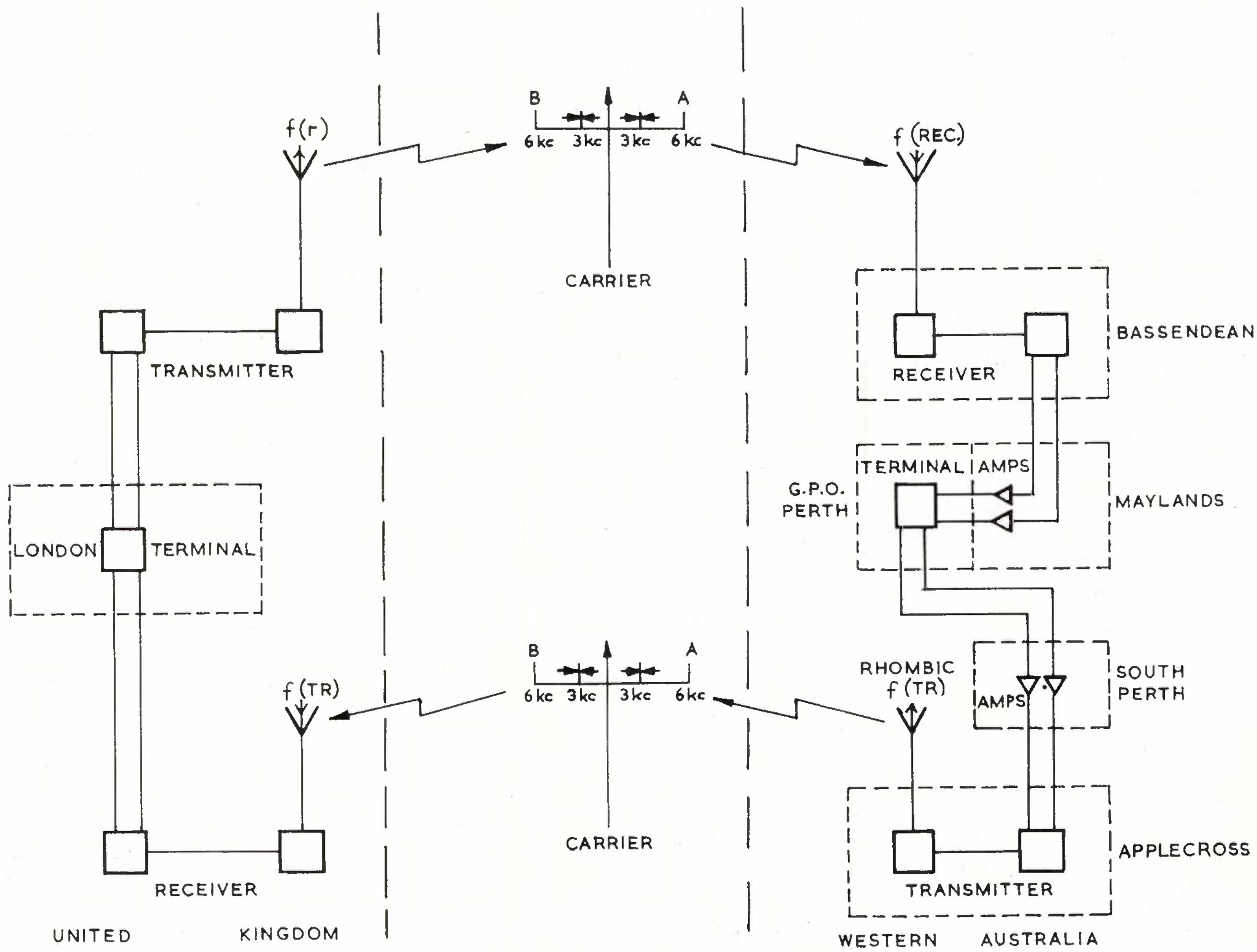


Fig. 2.—Location of Transmitter and Receiver and Method of Connection.

* *See page 298.*

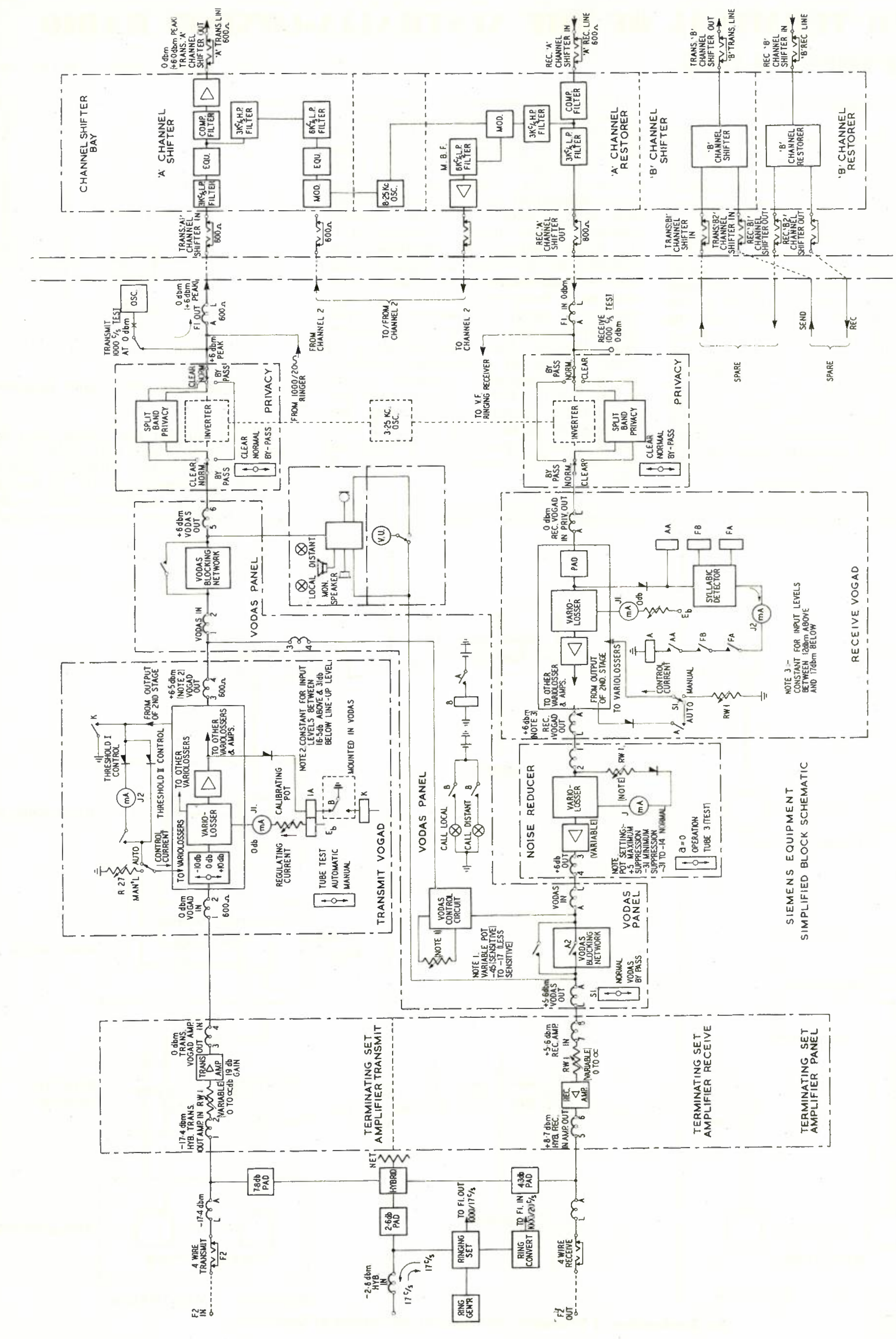


Fig. 3.—Block Schematic and Power Level Diagram.

path of such length in order to provide a reliable and satisfactory service. For the transmission of information, 2 bands of 6 Kc/s widths are provided by the receiver and transmitter which operate their upper and lower sidebands of the carrier frequency independently, i.e., Independent Sideband Working (I.S.B.) (1). The relative location of the transmitter and receiver and the way in which they are connected to the terminal at the G.P.O. by underground cable is shown in Fig. 2.

REQUIREMENTS

1. **4-Wire Working:** From Fig. 2 it can be seen that 4-wire working is necessary and that the intermediate amplification stages at South Perth and Maylands are essential for maintaining a good signal to noise ratio.

2. **Channel Width, Quality and Economy.** As a compromise between quality and economy of band widths, channels of 3 Kc/s width are considered optimum by C.C.I.R. for speech transmission. Thus, after providing two such channels there would still be two available for additional speech or V.F. telegraph service as spares. It is frequently necessary, on account of radio interference, to shift to a portion of the sideband not affected by interference and this is where the existence of a spare portion of the band is sometimes indispensable. This division (See Figs. 2 and 5) of the two provided bands of 6 Kc/s width into 4 channels of 3 Kc/s width can be achieved by a "channel shifter and restorer" which is described later.

3. **Automatic Terminal Gain Regulation.** In addition to providing reliable channels of suitable band widths, another necessary function of the terminal equipment is to ensure that the transmitter is modulated most of the time to as near 100% modulation as possible, so that the full power of the transmitter may be used. To achieve this, it is necessary that weak signals, due either to a low level speaker or to the loss in the line, be amplified to a suitable level and that the overload signals be correspondingly attenuated to prevent overloading of the transmitter. Similar automatic gain regulation must be provided at the terminal at the receiving direction to compensate for fading. These functions are provided by the Siemens Transmitting Vogad and Receiving Vogad respectively.

4. **Interference—Noise Reduction.** As it is not always possible to move to a channel or an R.F. band which is free from atmospheric noise or interference, other means must be sought for the separation at the receiving terminal of signal from noise, in cases where the prevailing interference is comparable with, but not equal to or greater than the strength of the peaks of the signal. This problem is quite skilfully handled by the Siemens Noise Reducer and also the Split Band Privacy equipment.

5. **Prevention of Sing Around.** Because of the different lengths and the various long distance lines that may be connected to the line of the hybrid of this terminal, it is practically impossible to provide a suitable balancing network for all lines. Without perfect hybrid balance and with the aforementioned auto gain regulating device working at times at maximum gain (under low signal conditions), the circuit loop gain will reach a positive value and the circuit will thus be prone to "singing". This condition can be guarded against, by using a device which allows transmission in only one direction at a time by automatically and appropriately blocking the other direction of transmission. The unit used is the Vodas.

6. **Secrecy.** Unlike the suppressed telephone carrier system, the normal amplitude modulated radio signal can be readily demodulated by a simple detector. As secrecy is normally required in telephone communications, equipment for rendering detected signals unintelligible by prior scrambling or inversion is also required.

SIEMENS AND HALSKE TERMINAL EQUIPMENT

The block schematic and power level diagram (Fig. 3) give a simplified illustration of the layout and functions of the terminal equipment in the transmitting and receiving path between the hybrid line and the connecting lines of the radio transmitter and receiver. The dotted lines indicate the boundaries of each panel.

HYBRID

The splitting of the transmitting and receiving paths is done by the hybrid which is a simple transformer device fitted with a balancing network and pads of 4.3 db in the receiving direction, 7.8 db in the transmitting direction and 2.6 db in the line side. The purpose of the pads is to obtain the required levels. The loss in the hybrid itself is approximately 4.4 db.

TERMINATING SET AMPLIFIERS—TRANSMIT AND RECEIVE

The transmitting and receiving terminating set amplifiers are single stage amplifiers which are mounted on the same panel. Maximum gain of the transmitting amplifier is 19.1 db and that of the receiving amplifier is 10.4 db. Their output levels are adjustable over a wide

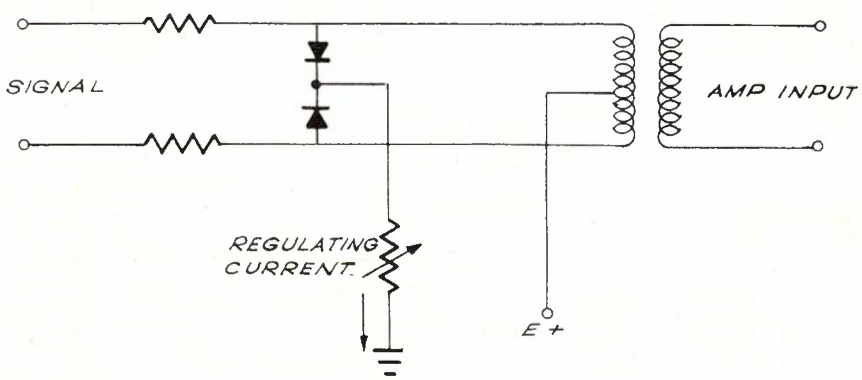


Fig. 4.—Variolosser Control CCT.

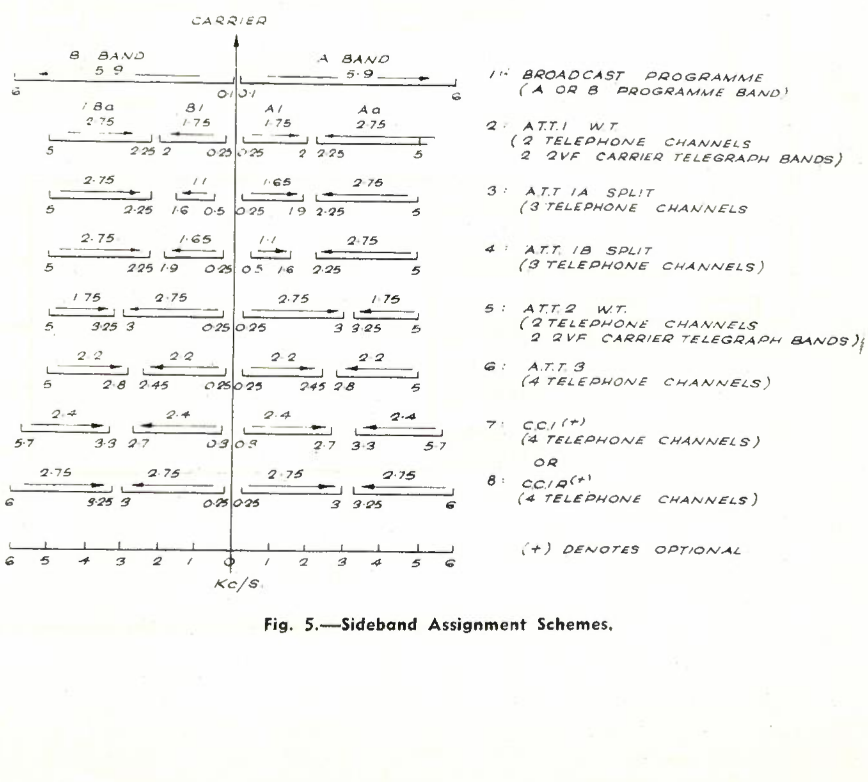


Fig. 5.—Sideband Assignment Schemes.

range in 0.9 db steps by means of voltage dividers in the input of the amplifiers. A 250 cycle high pass filter is fitted on the transmitting amplifier to suppress low noise frequencies which could affect the operation of the succeeding gain regulating equipment.

AUTOMATIC GAIN REGULATING DEVICE—VOGAD

The unit used by Siemens for maintaining a constant output level irrespective of input signal is called the Vogad (Voice Operated Gain Adjusting Device).

Transmit Vogad. The unit consists of a 4-stage amplifier with variable attenuators known as Variolissers which are placed before each of the stages.

The function of the Vogad is—

1. To maintain a peak level of +6 db at its output with the following conditions—
   (a) For average talking volumes (not peaks) between 6.1 db above and 31 db below line up level (0 dbm) with a time delay of 2 seconds in raising the level and 0.2 seconds in lowering.
   (b) A sudden rise of peaks to greater than 6.1 db above the line-up level.
2. (a) To raise the level for sudden drops in syllables while not affecting the average output.
   (b) Provide adjustable compression of the dynamic range of signals.
   (c) To ensure that even the shortest voltage peaks do not exceed the value of +6.5 db.
   (d) To return to a no-signal gain of 15.6 db corresponding to input volume of 21.7 db so that after an interruption in transmission a subsequent call meets with a medium gain, thus avoiding greater regulating jumps.

The above functions are achieved by the 3 threshold stages and a limiter in the Vogad unit. The 3 threshold stages are essentially control circuits which affect the gain of the unit by employing signal currents tapped from the various stages of the 4-tube amplifiers in such a way as to control the attenuation of the Variolosser in the desired sense. Each of the thresholds vary in speed and sensitivity and their duties are as follows:—

Threshold I—1(a) and 2(d) above.
Threshold II—1(b) and 2(a).
Threshold III—2(b).

The shorter voltage peaks mentioned in 2(c) are beyond the scope of threshold III and are clipped by a limiter.

Threshold I Circuit.—The simplified drawing of the control circuit of Threshold I (Fig. 3) may be taken as an example of the mode of operation of the Threshold Controls. The variolossers (Fig. 4) consist of fixed series arm resistors, a centre tapped transformer and a shunt arm network with opposing dry disc rectifiers controlled by the regulating current. The regulating current is introduced at the centre tap of the transformer, passing through both rectifiers in their forward direction. With increased regulating current the resistance of the shunt arm rectifiers decrease so that the through loss of the Variolosser increases.

Operation.—Although the simplified circuit does not show the amplifiers that are used in the control circuit, it may be seen that when the rectifier current from the output in the first stage of the transmission path exceeds a pre-determined value (which is controlled by the calibrating potentiometer), the differential relay A will operate. Regulating current proportional to the signal strength will then flow in the control loop affecting the attenuation of the Variolosser. The time constant which is approximately 2 seconds for raising and 0.2 seconds for lowering the gain, enables the regulation to correspond approximately to the talking volume and not to the peak voltages of individual syllables of very high volume. If the speech in the transmitting direction is inter-

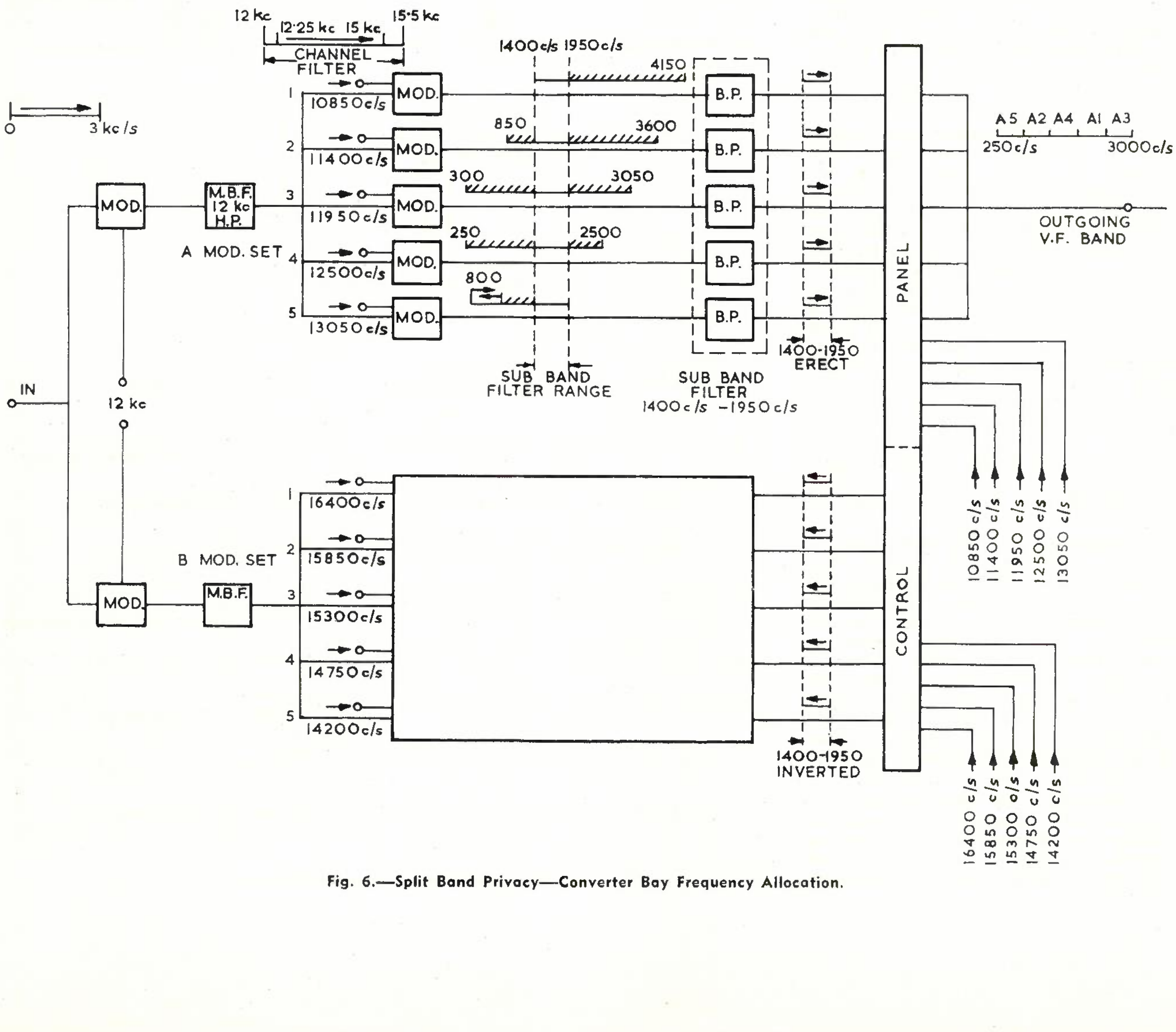


Fig. 6.—Split Band Privacy—Converter Bay Frequency Allocation.

rupted long enough, Relay A will restore and the A contact will open. The current now flowing from the Variolosser will be such as to provide a through gain of 15.6 db, this being the no signal gain of the Vogad. The contact B is activated from the Vodas when the opposite direction of transmission is operated. The effect of operation of B contact is to maintain the original gain of the Vogad during transmission in the opposite direction. The other Thresholds operate in a similar way but differ in sensitivity, speech and sense. To ensure that the circuit regulates to speech and not to noise, the control loops are designed to be more sensitive over the middle range of the voice frequency.

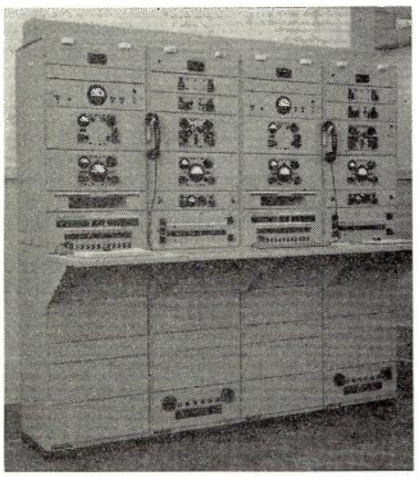


Fig. 7.—Channel Terminal Bay.

Receive Vogad.—The Receive Vogad compensates for the remaining volume fluctuations in speech after the short wave radio receiver has attempted to smooth out the fading phenomena. The Receive Vogad (Fig. 3) is similar to the Transmit Vogad except that it has only two threshold stages, their functions being similar to that of Threshold I and II of the Vogad Transmit, but it differs in that it contains an additional device—a Syllabic Detector. The purpose of the detector is to prevent regulation on regular random noise from the radio path and to allow full operation of voice syllables appearing as voltage signals on the modulated envelopes of up to 16 cycles per second in frequency, this being the average rate of voice volume modulation. The detector embodies a rectifier (detector) and a tuned circuit to enable the recognition of such a condition, and the control circuit is so arranged that this is one of the conditions that must be satisfied before regulating current can flow through the Variolosser. (Refer Relays FA FB in schematic). The control circuits of Threshold I (slow operate) and Threshold II (fast operate), the syllabic detector and limiter combine to ensure that only speech signals are maintained on an average level of +6.0 dbm at the output for input levels varying between +12 dbm and –17 dbm and that shorter duration variations may be kept within the limits while very short peaks are clipped by the limiter.

VODAS (VOICE OPERATED DEVICE ANTI-SINGING)

The Vodas switches a high attenuation pad into either the receive or send transmission path so that at any instant only one portion is open to speech signals. By blocking one or the other direction of transmission, the loop gain of the system is reduced to a large negative value and stability is maintained under all conditions. The Vodas consists of an amplifier-detector and a blocking network in each direction of transmission. A differential relay circuit weighs the level of speech signals in each direction and switches the appropriate blocking network into circuit. The switching time of less than 5 millisecs. ensures that the first syllable is only negligibly clipped. The circuit is so designed that while one person is talking it is only possible for the other to break in by raising the volume of his speech to 10 db above that of the first talker. Each blocking network consists of a pair of transformers with their windings interconnected. Using this arrangement, it is possible to control the two blocking networks by means of a single changeover contact. The insertion loss of each network is 87 db in the blocked condition and 0.4 db in the "through" conditions.

CHANNEL SHIFTER

It will be seen from Fig. 5 that eight combinations for the two 6 Kc sidebands can be used. The one selected for the Perth-London link is that shown in number 8. By means of a switch on the channel shifter and restorer panels, the required assignment plan can be selected. The block schematic (Fig. 3) illustrates the way in which the four 3 Kc wide channels for the Perth-London link are obtained. In the send direction, the A (inner) and B (inner) channels are the unshifted channels which lie between 250 cycles and 3.0 Kc. These are worked on separate pairs of lines to the transmitter. The two "spread" channels (A outer and B outer) are the channels which undergo modulation and work on the lower side band of the 6 Kc/s carrier, the frequency range being 6 Kc to 3.25 Kc (inverted). The A channels work on one pair of wires while the B channels work on the other. The 3 Kc high and low pass filter is used to prevent any reflection due to the impedance change at the crossover point of the high and low pass filters. The restorer uses the same means to translate to voice frequency the outer and inner channels from the receiver. In the transmitting direction the channel modulators are followed in each sideband by a step-wise variable attenuator with which the overall level at the output of the following 2-stage transmitting amplifiers can be so set with the aid of the built-in volume indicator that the transmitter is always modulated as fully as possible. The amplifier which has a low impedance output of 30 ohms feeds a 600 ohm line and raises the level of each channel to +6.0 dbm or a voltage of 1.55v. to provide 100 per cent modulation. Adjustable amplifiers are also used in the restorer panel to raise the signal from the receiver after it passes through the restorer equipment to a level of 0 dbm. Separate power supplies are used for each of the amplifiers and carrier oscillators to avoid any inter-action between channels via the power supply.

SPLIT BAND PRIVACY EQUIPMENT

To satisfy the demand for privacy on the radio telephone link from receivers other than the destined one, the split band privacy equipment is used for scrambling voice signals by splitting the speech band of 250 to 3000 cycles into five sub-bands of 550 cycles wide and interchanging their relative frequency positions according to predetermined combination patterns. In the simplest case, a fixed combination is used for the entire duration of the service which can be manually changed as the need arises. A greater degree of immunity to eaves-

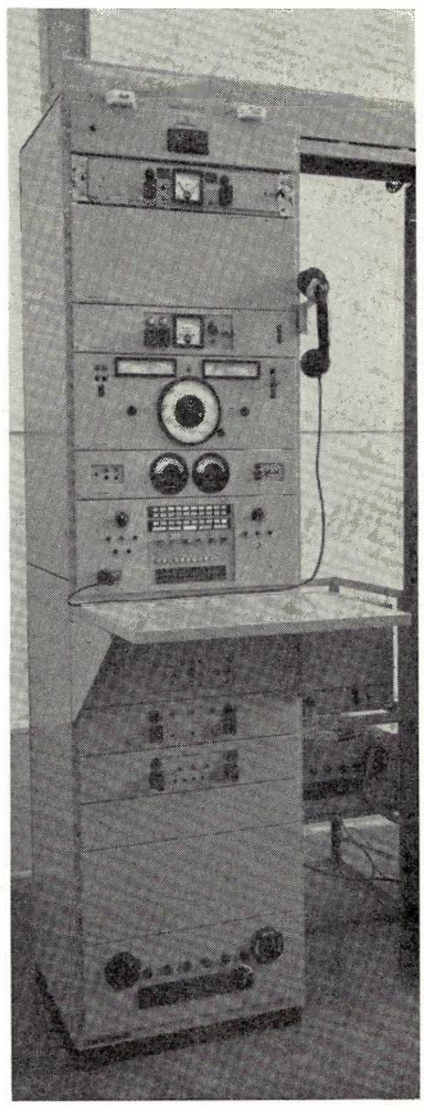


Fig. 8.—Timing Control Bay.

dropping is provided by means of the timing control system which enables the sequential and cyclic variation of a set of combinations according to a predetermined time schedule. All information on these combinations must obviously be known by both transmitting and receiving ends,

Of all the many combinations that could be obtained by rearranging the five sub-bands, twelve of the most useful combinations for the particular purpose are used by this equipment. The privacy equipment consists of three separate units; the carrier supply bay, the timing control bay and the speech band converter bay of which the latter is the most interesting, as in this unit the splitting of the speech band into 5 sub-bands and the restoration of the 5 sub-bands into the speech band is accomplished. The splitting consists principally of modulating and separating the speech band into 550 cycle sub-bands with separate outlets and then translating them in such a way that they all have the same frequency and band width. They are again translated as required to take up the selected relative position. Re-translation to the voice frequency range then takes place. This combination is then unscrambled at the receive terminal by a similar method. The diagram (Fig. 6) shows the stages involved in the transmitting direction. The A mod. provides 5 erect sub-bands while the B mod. provides similar but inverted sub-bands giving a total of 10 partial bands. For the sake of simplicity, a particular combination, using only the erect A sub-bands is shown as an example. The carriers are provided from the carrier supply bay while the switching control is operated by the timing control bay, which by means of synchronous motors, provides the sequential variations. The further use of the split band privacy system is to suppress selective interference due to radio signals (telegraphy). This is done by first finding out in which sub-band the interference lies and then eliminating this sub-band. The system must then be operated with a 4-band privacy combination. The positions "clear" and "normal" shown in the overall schematic are for fixed and time-controlled combinations, respectively.

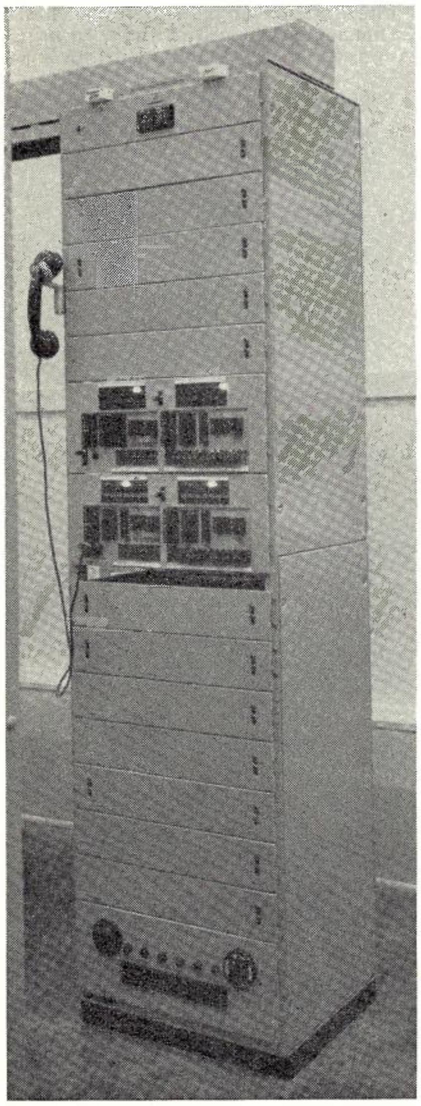


Fig. 9.—Split Band Privacy Bay.

NOISE REDUCER

The transmission path through the noise reducer (see block schematic Fig. 3) consists essentially of a single Variolosser and an amplifier. It operates in much the same way as Vogad with the attenuation of its Variolosser being controlled in relation to the input voltage by the control circuit. Its operate threshold is controlled by potentiometer RW1, which is set just above the ambient noise level. In the operate condition, the noise reducer presents zero loss to incoming signals while in the "blocked" condition of the threshold, the loss of the circuit is about 35 db. Noise voltages which are below the threshold are thus suppressed while incoming speech signals of sufficient amplitude are transmitted without attenuation. The unit can be successfully used provided the noise is not on a par with the average signal level.

V.F. RINGING EQUIPMENT

The ringing equipment consists of (a) a ringing set and (b) a ringing converter which are used to provide V.F. ringing over the radio system.

Ringing Set.—The ringing set receives 17 cycles ring at hybrid line from the switchboard. This ringing current energises a relay in the ringing set which applies 1000/20 cycles V.F. ringing tone to the line at F1 out (Fig. 3).

Ringing Converter.—The V.F. ring tone from the distant end is received at the incoming line at F1 in by the ringing converter which consists of a 1000 cycles tuned circuit, an amplifier and a rectifier for de-modulation. The 20 cycles signal obtained by de-modulation operates a relay in the ringing set and causes a ringing signal of 17 cycles to be sent to the hybrid line.

GENERAL

Layout and Facilities.—Each unit of equipment on the terminal is a slide-in jacked assembly which is easily removed and readily accessible for maintenance. All connecting points of apparatus are situated in the front of the panels and by the removal of U jacks, patching out is allowed if necessary. Each terminal has its own monitoring loudspeaker and volume control. All incoming and outgoing level meters are situated at eye level and renders the technical operation of these terminals a simple affair. Fold-up writing shelves also permit extra space if accommodation of apparatus is being considered. Photographs of the channel terminal, timing control and split band privacy bays are shown in Figs. 7, 8 and 9.

Alarms and Power Supply.—Adequate audible and visual alarms are provided for supply, plate and heater current fail conditions. All units have their own power supply rectifiers converting 250 V A.C. to 24 and 220 V D.C. Overload cut-outs are provided in each supply with automatic changeover of the 24 V signalling supply to exchange battery. All valve plate currents can be measured by one meter on each terminal through suitably shunted current feed jacks.

Fault Occurrence. — This equipment has been in use for 24 hours a day (including service on the Perth-Melbourne link) since its installation and the number of faults which have occurred over this period have been negligible. With the aid of this equipment, the Perth-London path which is 9,100 miles direct, having a looped return path of 140 milliseconds propagation time has been commercial for 90 per cent. of its scheduled time. The same type of equipment is also operting on the Perth-Derby link (1500 miles) (1). A Siemens Double Tone Diversity V.F. Telegraph system is also operating satisfactorily on this path in conjunction with Tress Machine Telegraph System.

Comparison.—The equipment is similar in function to most other types, but differs mainly in layout, level controls and 4-wire privacy, i.e., allowing different privacy schemes for each direction of transmission. An interesting feature from the maintenance aspect is that the same type of tube C3M is used almost exclusively throughout the equipment in voltage and power amplifiers, in triode, pentode and diode connections. Some other types are used but mainly in auxiliary equipment.

REFERENCE

(1) J. Medcalfe-Moore: The Perth-Derby Radio Link. Telecommunication Journal of Australia, Vol. 12, No. 4.

METHODS OF NUMERICAL FILTER DESIGN—PART IV

*E. RUMPELT, Dr. Ing.**

8. DERIVATION OF OTHER FILTER TYPES FROM NORMALISED LOW-PASS FILTERS

There are filter types whose performance characteristics as functions of the frequency can be transformed into those of a normalised low-pass filter with the help of so-called reactance transformations and which, with the latter, may be directly derived from normalised low-pass filters.

Reactance transformations are frequency transformations which transform any realisable reactance network into another realisable reactance network with different frequency characteristics. A reactance transformation itself is a realisable reactance function.

If a low-pass filter, being a realisable reactance network, is transformed by a reactance function the result is another filter with changed frequency characteristics of its image parameters. By suitably chosen reactance transformations a low-pass filter can be transformed into filters with several pass-bands and several stop-bands in the frequency range from zero to infinity. Filter types of practical importance which may be derived in this way are high-pass filters and frequency-symmetrical band-pass and band-stop filters.

The term "frequency-symmetrical" of the latter two filter types means that the filter performance is symmetrical or skew-symmetrical with respect to the centre frequency f_m, of the pass-band or stop-band, respectively. Even functions of the frequency, such as the image impedances in pass-bands and the image attenuation, are symmetrical with respect to f_m, i.e., they have the same values at any two frequencies f and f_m^2/f. Odd functions of the frequency, such as the image impedances in stop-bands and the image phase-shift, are skew-symmetrical, i.e., their values at any two frequencies f and f_m^2/f have the same magnitudes but opposite signs.

Band-stop filters designed with the image parameter method are always frequency-symmetrical (for reasons which shall not be discussed here) and if the insertion loss specifications for such filters are not symmetrical then at any two symmetrically situated frequencies in the above-mentioned sense the more critical one of the two specified loss values must be met.

The same method may also be applied to band-pass filters for which the insertion loss specifications are not symmetrical, but if the latter are very unsymmetrical it is preferable to design such filters in a different way which will be discussed later on and which leads to filters with somewhat less components.

8.1 **Reactance Transformations for Various Filter Types.**

8.1.1 **High-Pass Filters:** The reactance transformation for transforming a high-pass filter into a normalised low-pass filter, and vice versa, is:

$$j\Omega = \omega_c/j\omega \text{ with } \omega_c = 2\pi f_c \quad \ldots\ldots (8.1)$$

f_c is the cut-off frequency of the high-pass filter.

All positive physical frequencies in the functions of the high-pass filter characteristics are transformed to negative Ω–values in the corresponding functions of the normalised low-pass filter, and negative physical frequencies are transformed into positive Ω–values. Frequencies above the cut-off frequency, f_c, are transformed to Ω–values with magnitudes smaller than 1, and frequencies below the cut-off frequency are transformed to Ω–values with magnitudes larger than 1. The cut-off frequency itself is transformed to $\Omega = -1$.

8.1.2 **Band-Pass Filters:** The reactance transformation for transforming a frequency-symmetrical band-pass filter into a normalised low-pass filter and vice versa, is:

$$j\Omega = \frac{\omega_m^2 - \omega^2}{j\omega\,(\omega_{c2} - \omega_{c1})} \quad \ldots\ldots (8.2)$$

where $\omega_m = 2\pi f_m$; $\omega_{c1} = 2\pi f_{c1}$; $\omega_{c2} = 2\pi f_{c2}$; $f_m = \sqrt{f_{c1}\, f_{c2}}$

f_{c1} and f_{c2} are the lower and upper cut-off frequencies, respectively, of the band-pass filter.

By the transformation of Eq. (8.2) those band-pass filter frequencies which lie above f_m are transformed into positive Ω–values of the normalised low-pass filter, and those band-pass filter frequencies which lie below f_m are transformed into negative Ω–values. The frequency range between the cut-off frequencies, f_{c1} and f_{c2}, is transformed to Ω–values with magnitudes smaller than 1 and the frequency ranges above f_{c2} and below f_{c1} are transformed to Ω–values with magnitudes larger than 1. The cut-off frequencies themselves are transformed into $\Omega = \pm 1$. The centre frequency, f_m, is transformed into $\Omega = 0$.

The evaluation of the transformation formula Eq. (8.2) is facilitated by referring all physical frequencies to the centre frequency:

$$y = f/f_m = \omega/\omega_m \quad \ldots\ldots (8.3)$$

With $y_1 = f_{c1}/f_m$
and $y_2 = f_{c2}/f_m = 1/y_1$

Eq. (8.2) becomes:

$$\Omega = \frac{y - 1/y}{y_2 - y_1} \quad \ldots\ldots (8.4)$$

For the inverse transformation from Ω to y and f a quadratic equation must be solved:

$$f = f_m\,[\tfrac{1}{2}\Omega\,(y_2 - y_1) + \sqrt{1 + \tfrac{1}{4}\,\Omega^2(y_2 - y_1)^2}\,] \quad \ldots\ldots (8.5)$$

Solving this equation may be avoided by introducing the auxiliary parameter

$$\varphi = \ln y \quad \ldots\ldots (8.6)$$

With $\varphi_c = \ln y_2 = -\ln y_1$

Eq. (8.4) becomes:

$$\Omega = \frac{e^{\varphi} - e^{-\varphi}}{e^{\varphi_c} - e^{-\varphi_c}} = \frac{\sinh \varphi}{\sinh \varphi_c} \quad \ldots\ldots (8.7)$$

and the inverse transformation can be split up into the following steps:

(i) $\varphi = \sinh^{-1}(\Omega \sinh \varphi_c)$ .... (8.8)

(ii) $f = f_m\, e^{\varphi}$ .... (8.9)

φ is read from a table of hyperbolic sines.

8.1.3 **Band-Stop Filters:** The reactance transformation for transforming a frequency-symmetrical band-stop filter into a normalised low-pass filter, and vice versa, is:

$$j\Omega = \frac{j\omega\,(\omega_{c2} - \omega_{c1})}{\omega_m^2 - \omega^2} \quad \ldots\ldots (8.10)$$

This expression is reciprocal to Eq. (8.2) and the symbols have the same meaning as in that equation.

By this transformation those band-stop filter frequencies which lie above the centre frequency, f_m, of the stop-band are transformed into negative Ω–values of the normalised low-pass filter, and those band-stop filter frequencies which lie below f_m are transformed into positive Ω–values. The frequency range between the cut-off frequencies, f_{c1} and f_{c2}, is transformed to Ω–values with magnitudes larger than 1, and the frequency ranges below f_{c1} and above f_{c2} are transformed to Ω–values with magnitudes smaller than 1. The cut-off frequencies themselves are transformed into $\Omega = \pm 1$. f_m is transformed into $\Omega = \pm \infty$.

By referring all physical frequencies to the centre frequency Eq. (8.10) becomes:

$$\Omega = \frac{y_2 - y_1}{1/y - y} \quad \ldots\ldots (8.11)$$

where y is defined as in Eq. (8.3).

The inverse transformation from Ω to y and f is:

$$f = f_m\left[-\frac{y_2 - y_1}{2\Omega} + \sqrt{1 + \frac{(y_2 - y_1)^2}{4\Omega^2}}\right] \quad \ldots\ldots (8.12)$$

This transformation is again facilitated by introducing the auxiliary parameters φ and φ_c defined as in Eq. (8.6). The transformation of Eq. (8.11) becomes:

$$\Omega = -\frac{\sinh \varphi_c}{\sinh \varphi} \quad \ldots\ldots (8.13)$$

and the inverse transformation can be split up into the following steps:

(i) $\varphi = -\sinh^{-1}(\frac{1}{\Omega}\sinh \varphi_c)$ .... (8.14)

(ii) $f = f_m\, e^{\varphi}$ .... (8.15)

* See page 298.

8.2 **Design Procedure with the Help of Reactance Transformations.**

It can be seen from Eqs. (8.1), (8.2) and (8.10) that in each one of these expressions the cut-off frequencies are essential parameters which must be chosen for the desired filter type before the transformations can be applied. Hereafter the insertion loss (or return loss) specifications for this filter type are transformed into specifications for a normalised low-pass filter which then is designed as previously shown. If during this design a change of the cut-off frequency (or frequencies) becomes necessary the reactance transformation must be changed accordingly, i.e., new cut-off frequencies of the desired filter must be chosen and another transformation of the loss specifications carried out.

The normalised low-pass filter may be completely designed and then transformed into the desired filter type by applying the reactance transformation with the final cut-off frequencies as parameters to the individual circuit elements of the low-pass filter. In this process the general network arrangement of the low-pass filter remains unchanged and the transformed elements are left in the same branches of the network where they were before the transformation.

For example, in the case of a low-pass to band-pass filter transformation an inductance L of the low-pass filter having the reactive impedance $Z = j\Omega L$ is transformed by means of Eq. (8.4) into a circuit with the reactive impedance:

$$Z' = j\,\frac{y - 1/y}{y_2 - y_1}\,L$$

which is a series resonant circuit ($Z' = j\omega L' - j/\omega C'$) with the inductance

$$L' = \frac{L}{\omega_m (y_2 - y_1)}$$

and the capacity

$$C' = \frac{y_2 - y_1}{\omega_m L}$$

Usually the design of the normalised low-pass filter is not carried out beyond the determination of the attenuation peak frequencies. These are then transformed back to physical frequencies with the inverted reactance transformation and the component values of the desired filter are calculated directly with the formulae for this filter type which can be found in most text-books on filter design.

The following design parameters must be known:

(i) The cut-off frequencies (final choice).
(ii) The nominal image impedance (obtained from the pass-band design of the normalised low-pass filter.)
(iii) The attenuation peak frequencies or the corresponding m–values.

With very few exceptions the circuits and the appertaining formulae for the circuit elements found in text-books are for filters in ladder structure, i.e., they are T– or π– sections, or the corresponding half-sections. When applying these formulae care must be taken to ascertain whether the values of the circuit elements are meant for the branches of full sections or of half-sections. The individual sections may be connected in tandem in an arbitrary sequence as long as the principle of equal image impedances at their junctions is observed. Matching sections for producing higher order image impedances of the complete filter are, of course, connected to the ends of the ladder structure. At the junctions of sections there are always identical types of circuit elements circuited in series or in parallel which can be fused into single components.

8.3 **The Differential Delay of Filters Derived from Low-Pass Filters.**

Whereas the values of image impedances, image attenuation and image phase-shift remain unchanged when a reactance transformation is applied and only the frequencies are altered where the transformed filter assumes these values, the differential delay, being the derivative of the phase-shift with respect to the angular velocity, must necessarily be affected by a frequency transformation.

The differential delay of a filter derived from a normalised low-pass filter can, however, be calculated from the differential delay of the latter and the derivative of the reactance transformation which relates the two filters because:

$$\frac{d\beta}{d\omega} = \frac{d\beta}{d\Omega}\,\frac{d\Omega}{d\omega}$$

where $d\beta/d\Omega$ is the differential delay of the normalised low-pass filter and $d\Omega/d\omega$ is the derivative of the reactance transformation.

The derivatives of the reactance transformations for the filter types dealt with above are:

High-Pass Filters.

$$\frac{d\Omega}{d\omega} = \left|\frac{\Omega}{\omega}\right| \quad \ldots . \ (8.16)$$

Band-Pass Filters and Band-Stop Filters.

$$\frac{d\Omega}{d\omega} = \left|\frac{\Omega}{\omega}\,\frac{y^2 + 1}{y^2 - 1}\right| \quad \ldots . \ (8.17)$$

where y is defined as in Eq. (8.3). The relation between Ω and y is different for the two filter types and the evaluation of Eq. (8.17) gives therefore different values for band-pass and band-stop filters.

Eq. (8.17) cannot be used for obtaining $d\Omega/d\omega$ at the centre frequency, f_m, of band-pass filters. In this case the following equivalent formula for this filter type may be applied:

$$\frac{d\Omega}{d\omega} = \frac{1 + 1/y^2}{\omega_m (y_2 - y_1)} \quad \ldots . \ (8.18)$$

9. **Design of Frequency-Unsymmetrical Band-Pass Filters.**

As mentioned in paragraph 8 band-pass filters can be so designed with the image parameter method that they have frequency-unsymmetrical image impedance and transfer constant characteristics. As a rule, however, frequency-unsymmetrical specifications for band-pass filters are given only for the stop-band insertion loss. For the pass-band a constant maximum limit of insertion loss variations or a constant minimum limit of return loss is usually specified which means that the image impedance characteristics should be frequency-symmetrical with respect to the centre of the pass-band. The image impedances can then be designed in the same way as for completely frequency-symmetrical band-pass filters, i.e., the pass-band specifications are transformed with a proper reactance tranformation into corresponding specifications for a normalised low-pass filter and the design carried out in the low-pass filter domain.

In order to get the cut-off frequencies, the centre frequency, f_m, of the specified pass-band is first calculated as the geometric mean of its two limiting frequencies. As a first choice one of the two cut-off frequencies is put in the centre of that transition band which has the smaller relative band-width (the one whose ratio of its two frequency limits is closer to 1). The other cut-off frequency must be symmetrical to it with respect to the centre of the pass-band, i.e.,

$$f_{c1} f_{c2} = f^2_m$$

The image impedance design follows exactly the same pattern as in the case of frequency-symmetrical band-pass filters. After the type and the parameters of the image impedances have been determined the stop-band reflection loss is calculated (still in the low-pass filter domain) as a function of the normalised frequency Ω and then transformed back to band-pass filter frequencies. Subtracting the reflection loss from the specified insertion loss in the two stop-bands gives the image attenuation requirements in these bands and from here on the special design process for frequency-unsymmetrical band-pass filters begins.

9.1 **The Image Transfer Constant of a Frequency-Unsymmetrical Band-Pass Filter Section.**

A frequency-unsymmetrical band-pass filter section with one attenuation peak anyhere in one of the stop-bands has the following function of its image transfer constant:

$$\Theta_s = 2\coth^{-1}\frac{1}{m}\sqrt{\frac{f_{c2}^2 - f^2}{f^2_{c1} - f^2}} \quad \ldots . \ (9.1)$$

f_{c1} and f_{c2} are the lower and upper cut-off frequencies, respectively.

The term under the square root is positive for $f < f_{c1}$ and $f > f_{c2}$ which shows that below f_{c1} and above f_{c2} are stop bands. Within the range $f_{c1} < f < f_{c2}$ the term under the square root is negative, the square root is imaginary and the real part of the image transfer constant, the image attenuation, is zero. This range is therefore the pass-band.

The factor m in Eq. (9.1) determines again the attenuation peak frequency:

$$m = \sqrt{\frac{f_{c2}^2 - f_\infty^2}{f_{c1}^2 - f_\infty^2}}$$

$$f_\infty = \sqrt{\frac{f_{c2}^2 - m^2 f_{c1}^2}{1 - m^2}} \quad \ldots \ \ldots \ \ldots (9.2)$$

For $0 < m \leq 1$ the attenuation peak is in the upper stop-band, for $f_{c2}/f_{c1} \leq m < \infty$ the peak is in the lower stop-band.

$1 < m < f_{c2}/f_{c1}$ gives imaginary attenuation peak frequencies and if realisation of the filter in ladder structure is desired m must not have a value within this range.

For convenient evaluation of the above formulae the frequencies are again referred to the centre frequency, f_m, of the pass-band and with

$y = f/f_m$, $y_1 = f_{c1}/f_m$,

and $y_2 = f_{c2}/f_m = 1/y_1$

Eq. (9.1) becomes:

$$\theta_s = \alpha_s + j\beta_s = 2 \coth^{-1} \frac{1}{m} \sqrt{\frac{y_2^2 - y^2}{y_1^2 - y^2}} \quad \ldots (9.3)$$

with

$$m = \sqrt{\frac{y_2^2 - y_\infty^2}{y_1^2 - y_\infty^2}} \quad \ldots\ldots (9.4)$$

9.2 **Frequency Transformation for Attenuation Design with Templates.**

The use of the template method for the attenuation design is even more time saving as compared to other design methods when applied to frequency-unsymmetrical band-pass filters, than it is in the case of normalised low-pass filters. The necessary condition that Eq. (9.3) can be transformed into the general form of Eq. (6.1) is fulfilled and this is achieved by means of the frequency transformation:

$$e^{\gamma} = y_1 \sqrt{\frac{y_2^2 - y^2}{y_1^2 - y^2}} = \sqrt{\frac{y_2^2 - y^2}{1 - y^2 y_2^2}} \quad (9.5)$$

The factor y_1 in the first of the two expressions gives it a certain symmetry which can be recognised by substituting $1/y'$ for y in the second expression. Its effect is that frequencies which are symmetrical with respect to the centre frequency f_m differ only by their signs after transforming them to γ –values.

For direct calculation of γ the frequency transformation is:

$$\gamma = \tfrac{1}{2} \ln \frac{y_2^2 - y^2}{y_1^2 - y^2} + \ln y_1 \quad \ldots (9.6)$$

γ is real for $y \leq y_1$ and $y \geq y_2$, i.e. in the stop-bands of the filter. It is also real for imaginary values of y.

The transformation of the attenuation peak frequency with Eq. (9.5) gives:

$$e^{\gamma_\infty} = y_1 \sqrt{\frac{y_2^2 - y_\infty^2}{y_1^2 - y_\infty^2}} = m\, y_1 \qquad (9.7)$$

Expressed in terms of γ and γ_∞ the function of the image transfer constant of a section becomes:

$$\theta_s = 2 \coth^{-1} e^{(\gamma - \gamma_\infty)} \quad \ldots (9.8)$$

This is the same expression as Eq. (6.3) and consequently everything else remains the same as in the design of normalised low-pass filters, and in particular the templates for the design are identical. The only disinction is the different and more complex relationship between γ and the physical frequencies. The correlation between γ– and y–values is shown roughly in Fig. 3.

Infinite frequency and zero frequency are at $\ln y_1$ and $\ln y_2$ respectively, on the γ– scale. The range between these two points corresponds to imaginary frequencies. No attenuation peaks must therefore be put within this range if the filter is to be realised in ladder structure. The upper stop-band is transformed to the negative γ– axis with the upper cut-off frequency at $\gamma = -\infty$. The lower stop-band is transformed to the positive γ– axis with the lower cut-off frequency at $\gamma = +\infty$. Above a linear γ– scale the corresponding y– scale is very much expanded near the cut-off frequencies.

9.3 **Design Procedure with Templates.**

For the attenuation design the required minimum image attenuation is transformed point by point from physical frequencies via y –values and with Eq. (9.6) to a linear γ– scale fitting to the template scale. If the previous image impedance design showed that m-derived matching sections are required, the determined Ω_∞ –value must be transformed over the corresponding y_∞ –values (with the proper reactance transformation) into γ_∞ –values with Eq. (9.6). They have equal magnitudes and opposite signs. The appertaining attenuation curves are drawn with the main template if there is a matching section at both filter ends, or with the auxiliary template if a matching section is at one end only. These attenuation curves remain unchanged during the subsequent design which is carried out in the same way as for low-pass filters. The individual attenuation curves extend over both stop-bands, i.e., each curve passes through the range which corresponds to imaginary frequencies. The templates must therefore be longer than is usually necessary for low-pass filter design.

When the required attenuation peaks have been determined they are transformed back to physical frequencies with the inversion of Eq. (9.6) multiplied by f_m:

$$f = f_{c1} \sqrt{\frac{y_2^2 - e^{2\gamma}}{y_1^2 - e^{2\gamma}}} \quad \ldots\ldots\ldots\ldots (9.9)$$

From the attenuation peak frequencies, the cut-off frequencies and the nominal image impedance the components of the individual T– or π– sections of the band-pass filter can be calculated. The sections are connected in tandem in the usual way to form a composite ladder filter.

Each section may produce one or two attenuation peaks, but in the latter case the two peaks must be in different stop-bands, i.e., one in the upper stop-band and the other one in the lower stop-band. Two attenuation peaks in one stop-band cannot be produced by a physically realisable band-pass ladder filter section.

9.4 **The Image Phase-Shift of Frequencey-Unsymmetrical Band-Pass Filters.**

The function of the image phase-shift in the pass-band of a frequency-unsymmetrical band-pass filter section with one attenuation peak is given by Eq. (9.1) or (9.3). In the frequency range

$y_1 < y < y_2$

the image attenuation is zero and the image phase-shift is:

$$\beta_s = 2 \operatorname{ar\,cot} \frac{1}{m} \sqrt{\frac{y_2^2 - y^2}{y^2 - y_1^2}} \quad \ldots (9.10)$$

The image phase-shift of a composite filter is the sum of the phase-shifts of all sections. If two attenuation peaks are produced in one section the image phase-shift is the same as if the peaks were produced in two separate sections.

When calculating the phase-shift of a composite filter the term under the

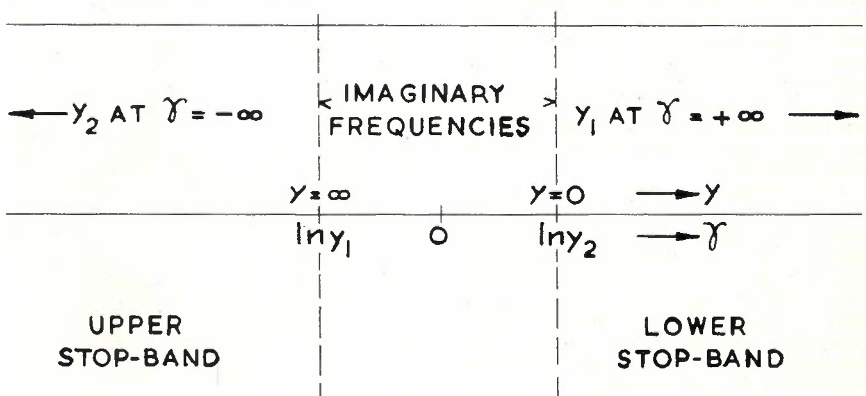


Fig. 3.—Correlation betwteen γ– and y– values.

square root in Eq. (9.10) need be evaluated only once for each frequency. The m-values of the individual sections are calculated from the γ_∞ -values of the attenuation peaks with the formula:

$$m = y_2 e^{\gamma_\infty} \qquad (9.11)$$

The image phase-shift may also be designed graphically with the help of templates. By introducing the frequency transformation:

$$\psi = \tfrac{1}{2} \ln \frac{y_2^2 - y^2}{y^2 - y_1^2} + \ln y_1 \;\ldots\; (9.12)$$

into Eq. (9.10) and using for the factor m in this equation the expression of Eq. (9.11) the function of the image phase-shift becomes:

$$\beta_s = 2 \text{ ar cot } e^{(\psi - \gamma_\infty)} \;\ldots\; (9.13)$$

This is the same relation as in Eq. (7.2) which is the image phase-shift function for a low-pass filter section. The phase-shift design of frequency-unsymmetrical band-pass filters can therefore be carried out with the same phase-shift templates as previously derived for low-pass filters and the design process is also the same. Only the frequency transformation from the ψ– axis to physical frequencies is different, the transformation formula being:

$$f = f_{c1} \sqrt{\frac{y_2^2 + e^{2\psi}}{y_1^2 + e^{2\psi}}} \;\ldots\; (9.14)$$

9.5 The Differential Delay of Frequency-Unsymmetrical Band-Pass Filters.

The differential delay of a frequency-unsymmetrical band-pass filter section with one attenuation peak is obtained by differentiating Eq. (9.10) with respect to y and dividing the result by ω_m because:

$$\frac{d\beta_s}{d\omega} = \frac{d\beta_s}{dy}\,\frac{dy}{d\omega} \quad \text{and} \quad \frac{dy}{d\omega} = 1/\omega_m$$

The derivative of Eq. (9.10) is:

$$\frac{d\beta_s}{dy} = \frac{m\,a}{m^2 + b} \;\ldots\; (9.15)$$

$$a = \frac{2y\,(y_2^2 - y_1^2)}{(y^2 - y_1^2)\sqrt{(y^2 - y_1^2)(y_2^2 - y^2)}}$$

$$b = \frac{y_2^2 - y^2}{y^2 - y_1^2} \;\ldots\; (9.16)$$

at $f = f_m$, $y = 1$ is

$$a = \frac{2(y_2 + y_1)}{1 - y_1^2}$$

$$b = y_2^2 \;\ldots\; (9.17)$$

The general formula for the parameter a is rather complex but both parameters a and b need be evaluated only once for every frequency at which the differential delay is required because these parameters are the same for all sections and only the m–values are different. If the differential delay is needed for estimating the pass-band loss due to dissipation in the circuit elements it is usually sufficient to calculate it only at the centre frequency and at the two limits of the practical pass-band.

TECHNICAL NEWS ITEM

ALUMINIUM ALLOYS FOR POLE HARDWARE

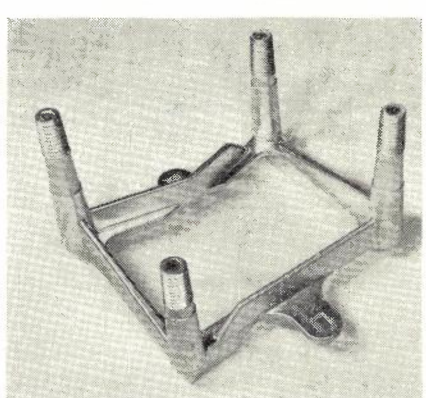
For some years the Postmaster-General's Department has used small aluminium alloy castings in lieu of malleable iron castings or steel forgings for some components of pole line hardware. The alloy used is LM.6 to British Standard 1490 in the chill cast condition. The light weight, high strength, good impact and corrosion resistance of this alloy have resulted in very satisfactory results in all cases to date.

The Department recently commenced a major project in the North-West of Western Australia, which required the partial rebuilding and strengthening of 1000 miles of old telegraph route erected in the 1890's and the erection of two new pairs of wires each designed to operate at frequencies up to 150 kc/s. To reduce the interaction or crosstalk between the two pairs of wires it was necessary for crossovers or transpositions to be inserted on every pole for one pair, and on every second pole for the other pair, a total of about 30,000 being required.

Conventional designs for transposition plates were either a pressed or fabricated steel plate plus four forged steel spindles or a two-piece malleable cast iron fitting including the spindles. For either design the total weight was at least 12 lbs. per assembly and the nearest economic manufacturing source was Adelaide for the plates or cast fitting and Melbourne for the spindles.

In an attempt to reduce freight costs, particularly between Perth and the job site, a distance of up to 1400 miles, a design for a one-piece cast aluminium fitting was prepared. The fitting was designed to carry the heaviest copper wire used on the Department's trunk routes, namely 300 lb. per mile. Minimum weight of this type of casting is essential as the price is directly proportional to the weight of metal used. Detailed stress analyses of each component were made, some sections of the fitting being required to withstand bending moments of up to 5000 inch lbs. plus some torsion and direct tensile load. It was not possible for the sections subject to bending moments to be structural shapes, e.g. channels or H sections and circular and rectangular sections had to be used. However, the design was based on the flexural strength rather than on the tensile strength of the aluminium alloy which enabled stress increases of 35% and 25% to be used for the circular and rectangular sections respectively. The fitting was cast in a six-piece metal mould and the insulator threads were cast integrally with the main casting. Except for the removal of some flash at the major parting line of the die, the fitting does not require any finishing operation or corrosion protection coating. Performance tests on production castings have fully confirmed all design data and calculations. The weight of the casting is less than four pounds and is a little lower in price than the steel assemblies. When allowance is made for the very considerable freight and handling savings, the overall price is very attractive and the new fitting is now standard for all Departmental works for which the approximate annual consumption is 70,000.

Pressed Steel Transposition Plate (complete with spindles)



One-piece cast aluminium alloy transposition plate.

AN ELECTRONIC TARIFF PULSE GENERATOR

*K. A. CURLEY**

INTRODUCTION

An experimental Tariff Pulse Generator (T.P.G.) has been designed and constructed to work in conjunction with the experimental subscriber trunk dialling equipment now undergoing limited field trials in Melbourne. This equipment employs a tariff charging system based on Periodic Time-Zone metering.

In this multi-metering system, the calling subscriber's meter is operated once when the called subscriber answers and then after a short 'free' time, the meter is operated at regular intervals for the duration of the call. The periodicity of the meter pulses depends upon the distance over which the call has been established. It also depends upon the time of day when the call is made, a cheaper tariff being applied at night. The function of the T.P.G. is to provide pulses of the required periodicities and to change them at night.

REQUIREMENTS

(a) The duration of each pulse was required to be sufficiently long to operate a subscriber's meter. The duration chosen was 0.275 ± 0.025 seconds.

(b) The periodicities required were (in seconds) : 1, 2, 2½, 3, 3½, 4, 4½, 5, 6, 7, 8, and 9.

(c) It was to be possible to change the periodicities easily for night rates.

(d) The tariff rates were to be capable of being altered independently of the unit fee charge and by any percentage.

(e) The time accuracy was not to be worse than ± 0.2%. This would mean approximately one-third of a second on a three minute call.

Consideration of these factors resulted in the design of electronic circuits described hereunder.

GENERAL DESCRIPTION

The various pulses are provided from dividing circuits all working from one master oscillator. The oscillator is continuously variable between 20 and 80 c/s. The pulse periods mentioned in this article apply when the oscillator is set accurately to 40 c/s.

As can be seen from the block diagram in Fig. 1, the output of the master oscillator is fed into a pulse shaper and amplifier. These circuits serve to:—

(i) Isolate the oscillator from the remainder of the circuit.

(ii) Produce one output pulse for every cycle of the oscillator.

The output pulses from the shaper are designed to be of suitable amplitude and duration for correct operation of the dividing circuits.

The first divider unit divides the pulse rate by 20. That is, the input pulse rate of 40 pulses per second is changed to a pulse rate of 2 pulses per second.

The output of the first divider is taken to subsidiary dividers. The outputs of these subsidiary dividers are taken to further dividers and so on. This arrangement results in a 'tree' of dividers as shown in Fig. 1.

Outputs are taken from appropriate points and used to operate monostable triggers. These triggers are identical and each contains a 3000 type relay as an output device. From the contacts of these relays the pulses are distributed as required.

DETAILED DESCRIPTION

Master Oscillator: The master oscillator (Fig. 2) is a negative resistance RC type. Conventional temperature compensation prevents frequency drift and a thermistor is used to maintain constant amplitude.

The thermistor, which is shown connected to the cathode of the first triode section of the 6SN7, becomes heated as the oscillator signal amplitude builds up. The resistance of the thermistor decreases and thereby reduces the voltage applied between the grid and cathode of the first triode section. The reduction in the input voltage decreases the output voltage. Since a lower voltage is now applied to the thermistor it cools. This increases its resistance, thus increasing

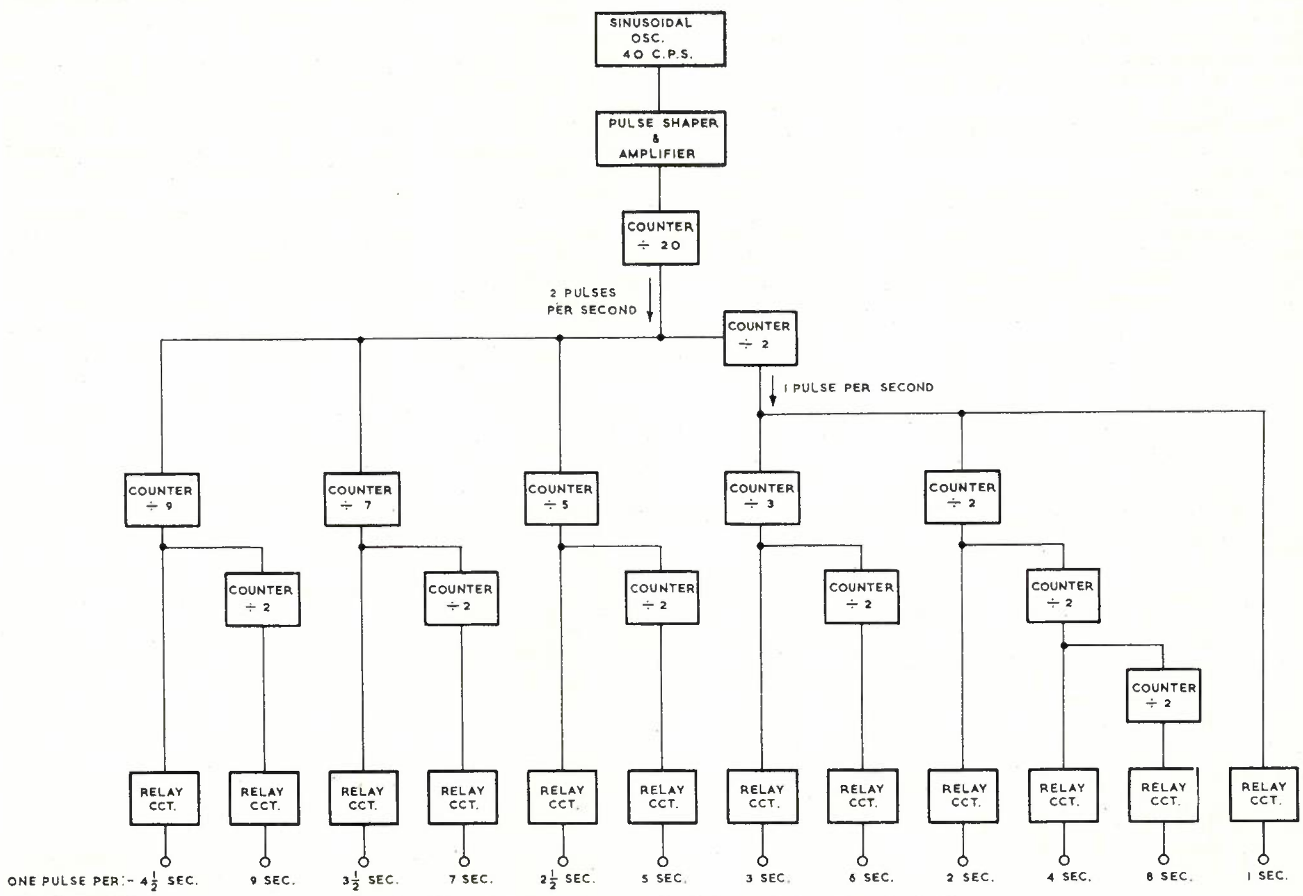


Fig. 1.—Block Diagram Showing the "Tree" of Counting Contacts.

* See page 299.

	1ST STAGE TRIODE 2	1ST STAGE TRIODE 1		2ND STAGE TRIODE 2	2ND STAGE TRIODE 1	
INITIAL STATE	N	C		N	C	
1ST NEG. PULSE IN	C	N		N	C	
2ND " " "	N	C	NEG. PULSE →	C	N	
3RD " " "	C	N		C	N	
4TH " " "	N	C	NEG. PULSE →	N	C	NEG. PULSE OUT →

TABLE 1

	1ST STAGE TRIODE 2	1ST STAGE TRIODE 1		2ND STAGE TRIODE 2	2ND STAGE TRIODE 1		3RD STAGE TRIODE 2	3RD STAGE TRIODE 1	
INITIAL STATE	N	C		N	C		N	C	
1ST. INPUT PULSE	C	N		N	C		N	C	
2ND INPUT PULSE BEFORE FEEDBACK	N	C	−ve →	C	N		N	C	
AFTER FEEDBACK TO 1ST STAGE	C	N	← −ve	C	N		N	C	
3RD PULSE BEFORE FEEDBACK	N	C		N	C	−ve →	C	N	
AFTER FEEDBACK TO 2ND STAGE	N	C		C	N	← −ve	C	N	
4TH PULSE	C	N		C	N		C	N	
5TH PULSE	N	C		N	C		N	C	OUTPUT →

TABLE 2

the voltage applied to the input of the first triode. The output voltage increases and heats the thermistor again. The whole process repeats itself until equilibrium is established. In this condition the oscillator signal level is constant. The oscillator circuit has been designed so that the waveshape fed to the shaper is substantially sinusoidal.

Pulse Shaper: This circuit is shown in Fig. 2 immediately following the master oscillator.

The first valve is a squaring stage.

The second valve is coupled via a very small capacitor which, with the low grid circuit resistors of the second shaper input triode, forms a differentiating circuit. This arrangement transforms the square wave signals into a series of short positive and negative pulses. The positive pulses are almost entirely absorbed by the grid diode action, thus leaving negative pulses only to influence the anode current. The variations in anode current cause positive pulses at the anode where they are coupled to the second triode section which amplifies the pulse. This triode section is operated with cut-off bias so as to suppress any remaining negative signal. Negative pulses from the pulse amplifier are passed into the first divider.

Dividing Circuit: All the dividers in this generator are made up of combinations of elements having two stable states and referred to as basic bistable elements. An incoming pulse triggers the element from one stable state to the other. This particular basic bistable element is built around a pair of triodes enclosed in a single envelope. The circuit of this bistable element may be seen in Fig. 3 where section A shows one basic element.

Each bistable element used in this equipment has an input circuit so arranged that upon receipt of a negative pulse it changes from one stable state to another. That is, one triode section ceases to conduct and the other triode section conducts. The next negative pulse causes it to change back to its original state. Thus for every two negative input pulses the bistable circuit will complete one cycle of operations and be restored to its original state.

The output of any of these bistable elements will be a square wave because the anode current of either of its triodes will be steady until it is triggered by another input pulse. At any instant the anode current of one triode section will be high and that of the other triode section low. When the circuit 'flips over' after triggering the anode which previously drew high current will now draw low current and vice versa. By differentiating the square wave the output becomes a series of positive and negative pulses with one positive and one negative pulse appearing for every two negative input pulses.

By arranging a series of these bistable circuits with a coupling from the output of one circuit to the input trigger point of the succeeding circuit, a divider may be built up.

Referring to section C of Fig. 3 it will be seen that this section consists of two bistable stages. The output of the 1st stage is coupled to the input of the 2nd stage with a 500 pf capacitor which differentiates the output from the preceding stage.

The diode in series with the capacitor can be ignored for the moment. The two stages connected thus form a divide by four counter, i.e., for every four input pulses one output pulse will occur.

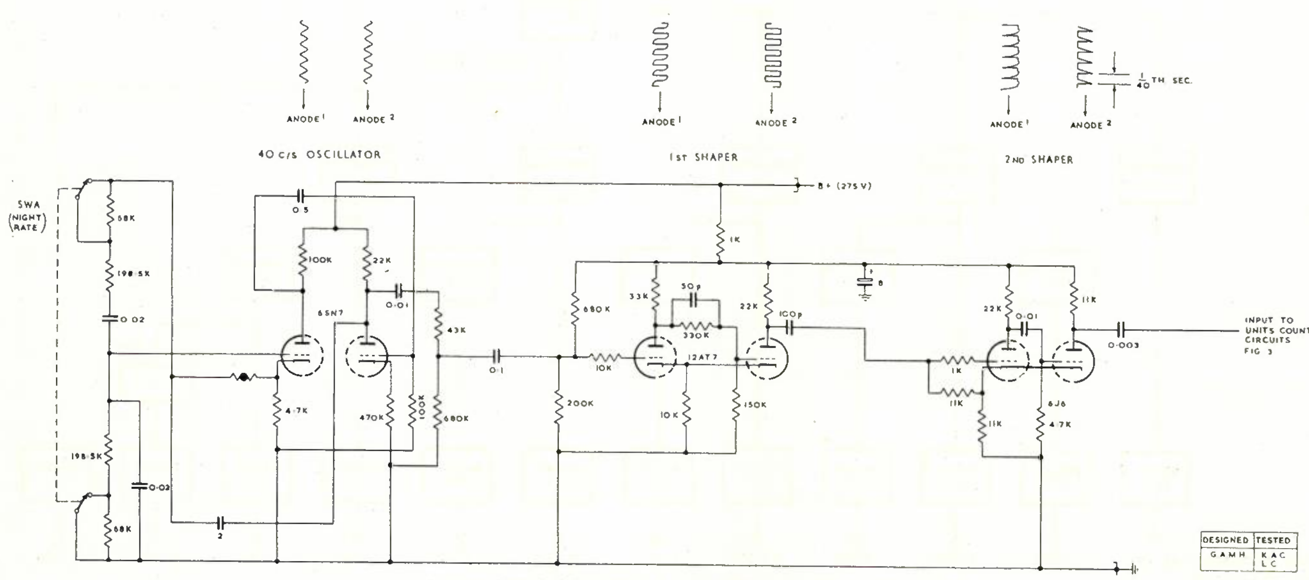


Fig. 2.—Oscillator and Shaper Circuits.

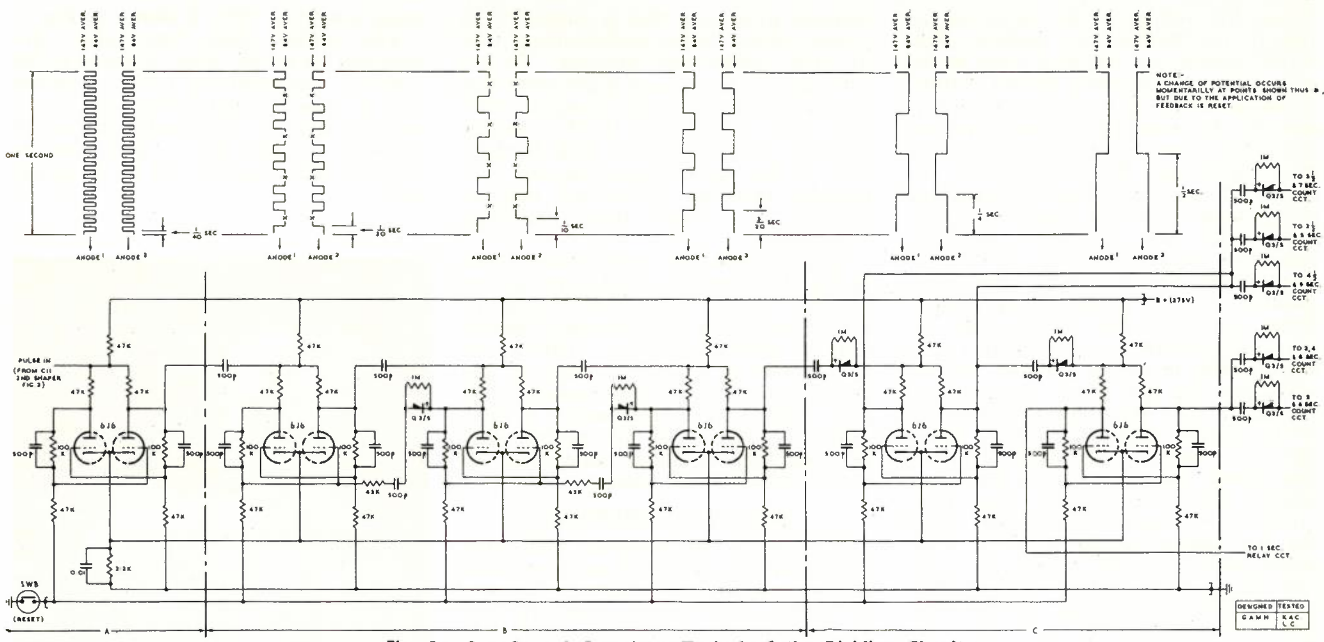


Fig. 3.—One Second Counting—Typical of the Dividing Circuits.

Table 1 shows the progress of operation of this circuit. The initial stable state, or reset condition, is that triode 1 of each stage is conducting (C) and triode 2 of each stage is non-conducting (N).

It will be seen from the table that the condition necessary to develop a negative going output pulse from the 1st stage, is triode 1 changing its state from non-conducting to conducting. This occurs once for every two negative input pulses. The 2nd stage will do likewise, i.e., again divide the pulse rate by two thus forming a divide by four counter. If a third stage was added it would be converted to a divide by eight counter. A fourth to a divide by sixteen and so on. Stages may be added without limit until the division factor is as high as required by the particular application.

Feedback: The binary counting chain described above is only capable of dividing by 2^n where 'n' is any whole number, i.e., 1, 2, 3, 4, etc. In order to produce a counter which will divide by some other factor it is necessary to modify the basic counting chain by the addition of feedback networks.

The feedback paths inject extra pulses into the counter chain so as to make the total effective input pulses up to the number required by the basic binary chain. For example if we had a three stage chain without feedback its division factor would be eight. In order to convert this to a factor of five we would need to add to the counter, pulses which would have the same effect as three additional input pulses. The counter chain would then give one output for every five input pulses. By feeding back one pulse into the first stage we can simulate one extra input pulse. By feeding back one pulse into the second stage we can simulate two extra input pulses. Therefore, if one pulse if fed back into each of the first and second stages, for every complete cycle of the whole counter, a scale of five will result.

Section B of Fig 3 shows this arrangement and Table 2 shows the progress of operation.

When the triode, from which the feedback pulse is obtained, 'flips' from the non-conducting state to the conducting state, a negative pulse differentiated by a capacitor is fed to the grid of the preceding triode. This results in the preceding stage changing its stable state. The purpose of the diode in the feedback lead is to isolate the grid circuit from positive pulses.

One Pulse per Second Output: By examining Fig. 3 as a whole it can be seen, at the left of the drawing, that the pulses incoming from the second shaper are fed into a divide by two circuit followed by a divide by five circuit, followed by two more divide by two circuits making in all a factor equal to $2 \times 5 \times 2 \times 2 = 40$. At the output of the last binary stage one negative pulse is developed for every forty input pulses. This gives a rate of one pulse per second.

At the output of the penultimate binary stage an output of two pulses per second (one per half second) are tapped off to drive further counters in the array.

The diodes in the output leads serve to attenuate unwanted pulses which may be fed back from subsidiary counters.

Other Outputs: A study of the block diagram in Fig. 1 will indicate how each of the required periodicities are obtained. Taking the 4½ second and 9 second outputs as examples, it can be seen that the two pulses per second output is fed into a divide by nine circuit. The output of this circuit is then one pulse per nine half seconds, or, one pulse every 4½ seconds. The 4½ second output is then divided by two to give one pulse every 9 seconds.

Relay Circuits Fig. 4: At various points in the counter 'tree', pulses are taken off to control the relay circuits. These relay circuits translate the short initiating trigger pulses, lasting less than a millisecond, into timed relay operations lasting approximately 275 milliseconds. From the contacts of the various relays the different pulse rates are taken off and distributed as required.

The use of a monostable trigger circuit allows the timed relay operation to be adjusted independently of the length of the trigger pulse. As soon as the circuit is triggered, it commences a cycle of operations which is not influenced by conditions external to the circuit.

In its quiescent state the first triode section has its anode current almost completely cut off whilst the second section is conducting heavily. Upon receipt of a positive trigger pulse the first triode commences to conduct heavily. This

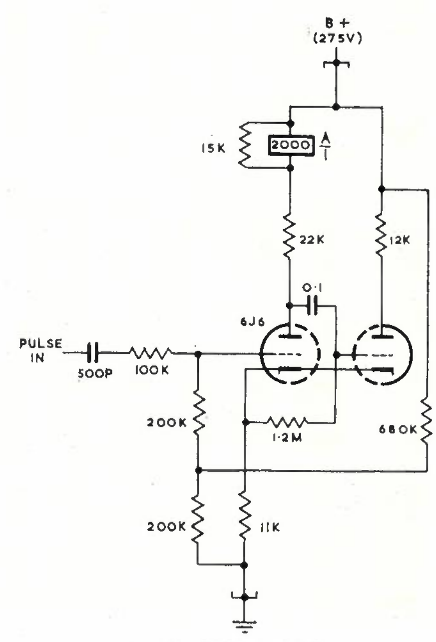


Fig. 4.—Relay Circuit.

causes the voltage at its anode to fall rapidly, i.e., become less positive. This action generates a negative pulse at the grid of the second triode thereby causing its anode current to be almost completely cut off. The reduction in anode current causes the common cathode to become less positive and this action causes the first triode to remain heavily conducting even though the initial trigger pulse may have gone. This condition continues until the negative charge on the 0.1 microfarad capacitor has leaked away through the 1.2 megohm grid resistor. When this occurs the second triode section will commence conducting once more. The increased cathode current will cause the first triode section to be cut off and the circuit will rapidly restore to its original condition. For the whole period of heavy anode current in the first triode the relay coil in its anode circuit will be energised. The relay armature will operate after a short initial lag and remain operated for a short period after the coil current has been reduced to its normal low value. The total period of operation of the relay armature will therefore not be very different from that of the conduction period of the first triode section.

Night Rate: To provide for a cheaper tariff at night, the required percentage reduction is obtained by increasing the resistance of the master oscillator's RC network. This results in all periodicities increasing by the same percentage. Fig. 2 shows this arrangement. A night rate switch removes the short circuit from part of the resistance. In practice the contacts of this switch are duplicated by contacts of a relay that is controlled by a time clock. At the predetermined time all pulse periods are changed. If it is necessary to have some night rates that are a different percentage change to other night rates then separate T.P.G.'s will be provided for these cases. This arrangement is not uneconomical because it is intended that the T.P.G. will only be installed at central trunk switching exchanges.

Reset Switch: The reset switch shown in Fig. 3 is common to all of the divider circuits. When the switch is open the grid of one triode section in each bistable element becomes positive. This causes that section to become conducting and the other section becomes non-conducting. The same triode section in each element is treated in this manner thus ensuring that the initial state of all the divide circuits is the same.

MOUNTING DETAILS

For ease of maintenance each basic circuit element was built as a complete and separate sub-unit which, in the event of failure, could be easily replaced. Fig. 5 shows one bistable element built into turret form. The oscillator, shapers and relay circuits were treated in the same manner.

The complete T.P.G. consists of forty of these units, i.e., one oscillator unit, two shaper units, twenty-five basic counter units and twelve relay units. The units are mounted on a chassis 27 inches long, 7 inches wide and 3½ inches deep. The complete unit is illustrated in Fig. 6.

The units are coupled with circuits which also have been constructed as small sub-units. This is shown in Fig. 7.

The twelve 3000 type relays are mounted on a relay plate attached to the chassis. The complete T.P.G. is jacked into a power supply mounted on a separate chassis. An interlocking circuit arranges for the A.C. supply to be switched off when the T.P.G. is jacked out.

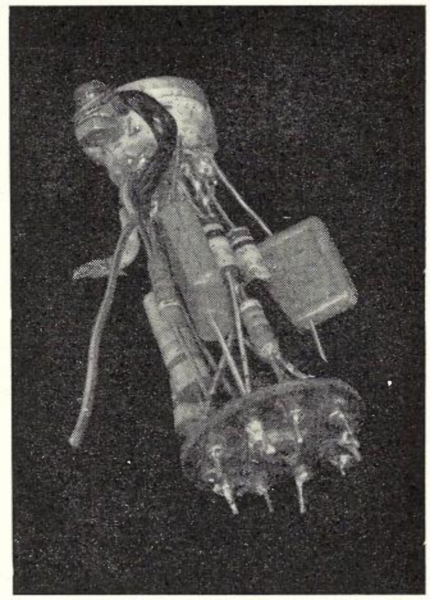


Fig. 5.—One Bistable Circuit Built into Turret Form.

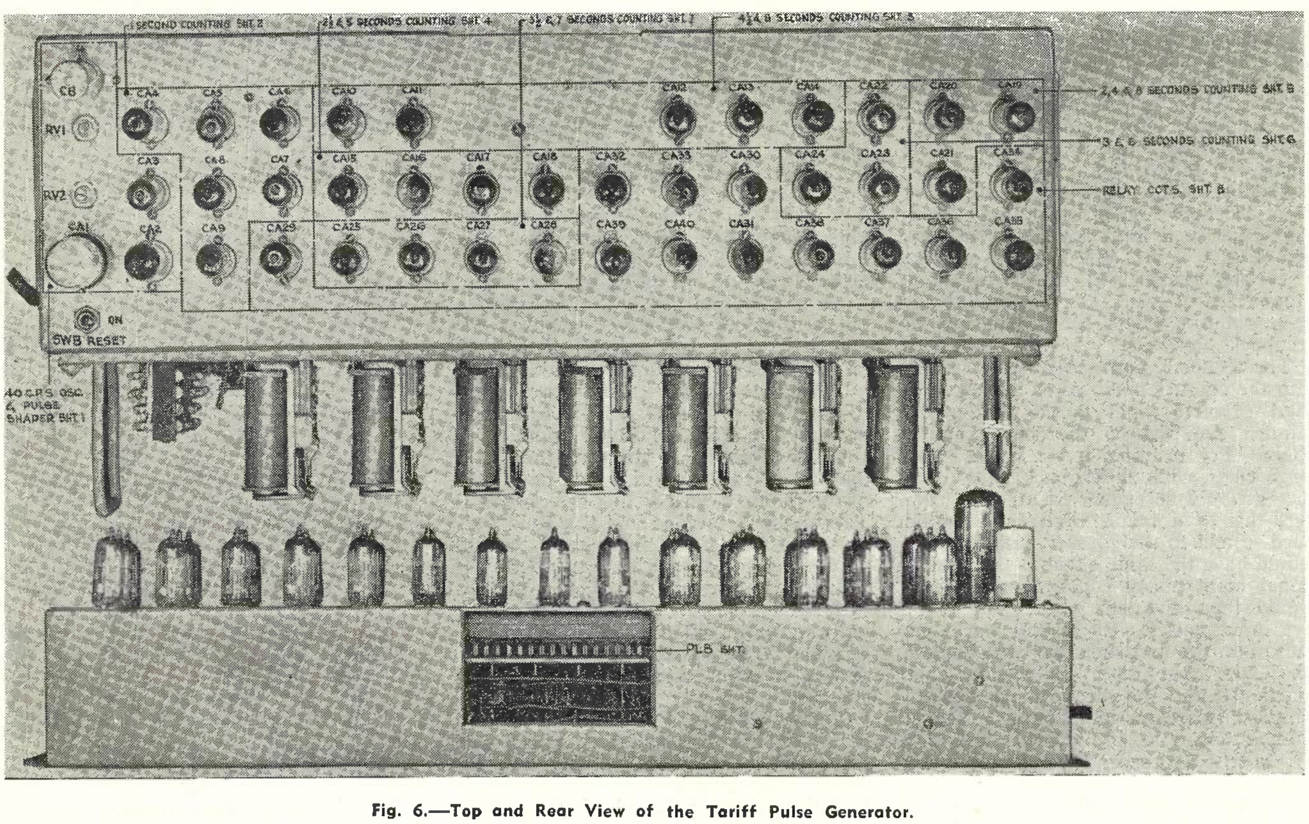


Fig. 6.—Top and Rear View of the Tariff Pulse Generator.

POWER SUPPLY

The high tension voltage is supplied from a full-wave valve rectifier circuit followed by a filter section with capacitor input. A 5R4 is used as the rectifier valve. The output voltage is approximately 275 volts on load. At this voltage the load current is 180 m.A.

The filament supply (6.3 volts) is provided as follows:—

(a) 7 amps from windings on the power transformer;

(b) 12 amps from a filament transformer.

The power supply is mounted on a separate chassis 16" × 5½" × 3½". A 32 point strip of shelf jacks, into which the T.P.G. is plugged, is so mounted on the chassis that, when the two chassis are plugged together, the shelf jacks and plugs are completely enclosed.

CONCLUSION

Three T.P.G.'s have been built and these have been operating satisfactorily since September, 1957. Some troubles have been experienced with the 6J6 valves. The Service C.V. version of these valves would be better suited because of their more robust construction.

Fault finding has not presented any difficulties. The fault can be quickly isolated to a particular section of the circuit and then to a particular sub-unit. The faulty sub-unit is then changed without any 'on the spot' investigation into the particular faulty component.

Equipment to supervise the periodicity and length of each pulse, is yet to be designed. This equipment will include change-over circuits that will switch to a standby generator if any pulse fails.

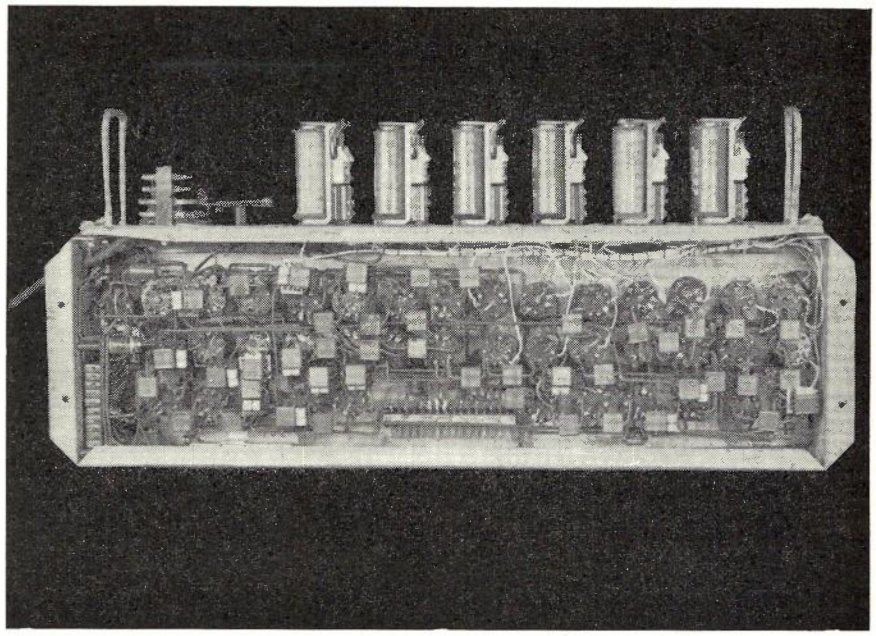


Fig. 7.—The Inter-connecting of the Turrets in the Tariff Pulse Generator.

ACKNOWLEDGMENTS

The Eccles-Jordan trigger and counting circuit is so well known that it is not necessary to mention all the literature appertaining to it. The particular application of these circuits, as used in the T.P.G., was devised by Mr. G. A. M. Hyde, Sectional Engineer in charge of the Telephone Equipment Section Circuit Laboratory. The equipment was constructed and tested by the Laboratory technical staff.

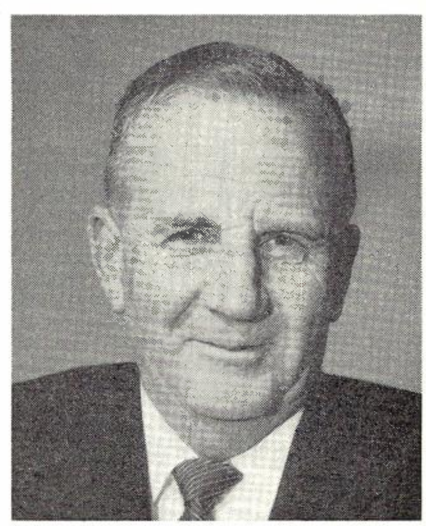
MR. J. HUTCHISON, B.E.(Hons.)

Congratulations are extended to Mr. J. Hutchison on his appointment as Director, Posts and Telegraphs, New South Wales.

Mr. Hutchison commenced in the Department as a Telegraph Messenger in 1918, and later entered the technical field as Technician-in-Training. He showed outstanding ability and qualified quickly as Senior Technician. In 1927 he was selected as an Engineering Cadet and subsequently took his Engineering Degree at Sydney University with Honours in Electrical Engineering. Mr. Hutchison has had extensive engineering experience, including a term in the Department's Research Laboratories in Melbourne.

From 1938 to 1942 he was in charge of the Queensland Radio and Broadcasting Section with responsibility for the installation, maintenance and operation of all radio and broadcasting equipment in that State. He returned to Sydney in 1942, and until his appointment in 1957, as Assistant Director, in charge of Post Office Engineering activities in New South Wales, served in a variety of capacities with particular emphasis on the radio and transmission side.

Mr. Hutchison has been associated with a number of important projects, including the Sydney-Maitland Trunk Cable planning, the installation of the Chief Telegraph Office, Sydney, the first picturegram service and the first programme carrier service between Sydney and Melbourne.



MR. J. HUTCHISON, B.E.(Hons.)

TIME SIGNALS IN AUSTRALIA

*E. F. SANDBACH, B.A., B.Sc.**

During the early days of settlement in Australia most of the State Governments set up observatories which were mainly required for the various services to shipping, including time determination and the provision of time signals. With the advent of Federation and the development of rapid means of communication both by line and radio, the need for so many time determining centres has passed. Thus at the present time the working observatories in Australia are the State Government institutions of New South Wales and Western Australia together with the Commonwealth Observatory at Mt. Stromlo near Canberra. In addition the Queensland Government provides a time service which is operated at Brisbane. Time services in Victoria and South Australia are operated by the Postmaster-General's Department in conjunction with the Commonwealth Observatory which provides the time reference for these services. Tasmania takes time signals from Victoria.

This article is not concerned with the methods and problems involved in the determination of time, which have been described fully elsewhere, for example in Ref. 1. Time determination is carried out in Australian observatories by the use of some of these methods together with observations on radio time signals broadcast by overseas standard frequency and time stations. The accuracy achieved varies with the methods used, which in turn largely depend on the equipment available. Under normal circumstances observatories could maintain an accuracy of ± ⅓rd second or better. However, the errors of time signals from Brisbane may be up to 1 or 2 seconds because of equipment limitations there. In order to distinguish between the high accuracy observatory signals and other time signals that may be produced, for example, at broadcasting stations, arrangements have been made to restrict the generation of the six pip form of signal to the recognized observatories. Steps have also been taken to reduce the possibility of recording time signals at the same time as other programme material with the consequent danger of replaying it at an incorrect time.

In the case of Victoria, special circumstances that existed there have made possible the provision of different apparatus for the generation and distribution of time signals compared with other States, where the observatory or its equivalent maintains a system of precision pendulum clocks which are rated by local astronomical observations or by measurements on overseas radio time signals or by a mixture of both processes. The Postmaster-General's Department Research Laboratories in Melbourne have a special interest in precise frequencies for many of their investigations and accordingly maintain their own frequency standards. Each standard consists of an oscillator operating at a frequency of 100 kc/s. The frequency of oscillation is controlled by a piezo-electric quartz crystal which for best results should be maintained at a temperature constant within a few hundredths of a degree centigrade. An electronic thermostat is used for this purpose. The output from the oscillator is divided electronically to 1 kc/s and then used to drive a special synchronous clock. The whole apparatus is commonly referred to as a "quartz clock". The synchronous clock provides a means of rating the standard oscillator in terms of time determined astronomically because comparison on a frequency basis does not provide sufficient accuracy due to Doppler frequency shifts that occur with movement of the reflecting layers responsible for ionospheric radio transmission. Changes of rate as small as 1 millisecond per day are of interest.

The time comparisons are done by sending to Canberra via land line, 1 second pulses from one of the Research Laboratory quartz clocks once every working day. The time of arrival of these pulses is measured at the Observatory and the difference of the times of arrival over successive days gives the rate of the quartz clock. Allowance is made for variation in transmission time between Melbourne and Canberra by measuring each day the time for transmission of the 1 second pulses from Melbourne to Canberra and return.

A quartz clock rate of 1 millisecond per day corresponds to a frequency difference from the nominal 100 kc/s to 1.16 parts in 10^8. It is thus necessary, in order to determine the oscillator frequency with adequate accuracy in terms of time observations, to consider measurements over a minimum period of 10 days. When operated under proper conditions, that is the minimum of mechanical vibration, temperature change, and power supply disturbance, a quartz clock normally increases in frequency with the passage of time in a manner which can be predicted with reasonable accuracy from the previous performance. However, once the oscillator is disturbed, particularly mechanically or thermally, an unpredictable change in frequency and ageing rate can take place. Hence great care is taken in designing quartz clock equipment to provide the maximum possible reliability.

From the foregoing discussion it can be seen that the Postmaster-General's Department was well placed to undertake the distribution of time signals, in that precise signals were available from the Research Laboratories Quartz Clock and the Department's communication network provided a convenient means for the dissemination of time signals. In 1945, when the Melbourne Observatory was closed, the Victorian Time Service was operated by the Research Laboratories using pendulum clock equipment controlled by one of the quartz clocks. The control was arranged so that if it failed, the pendulum clock system carried on the time service with the inherent accuracy of the pendulum clocks unimpaired. After ten years operation this system was superseded by the installation of the Speaking Clock in Melbourne.

The Speaking Clock has been fully described elsewhere (2). It consists basically of a quartz crystal oscillator and frequency divider chain which produces a highly stable 50 c/s output used to drive both the announcing machine and a special time signal generator. The time signal generator produces the standard "six pip" time signals once per minute and once per hour as well as a special signal for marine navigation purposes commonly referred to as the XNG signal. Distribution of time signals to radio stations and other time service subscribers is arranged by the use of relays with multiple contacts, which operate under the control of the time signal generator. By this means separate contacts are obtained for each time service subscriber. The time signalling equipment at the subscribers premises operates when the contacts are made. Correction of the Speaking Clock is effected by the use of an adjustable phase shifter in the 50 c/s supply line to announcing machine and time signal generator. Adjustment of the phase shifter can either advance or retard both the announcing machine and the time signal machine by precisely regulated amounts. The Speaking Clock prepares itself for correction once every twenty-four hours. On receipt of the correction signals the phase shifter is automatically stepped in the appropriate direction until the phase of the Speaking Clock is identical with that of the correction signals.

The correction signals are generated at the Postmaster-General's Department Research Laboratories by equipment driven from one of the quartz clocks. The proper relation between the phase of the Speaking Clock correction signals and time, as determined by the Commonwealth Observatory, is maintained by regularly comparing the correction signals with the output of the "reference" quartz clock which is directly rated by the Commonwealth Observatory as described previously. Adjustments to the correction signals are made as required to allow for variations in the frequency of the oscillator driving the correction signal generator and to follow astronomical time predictions which are received from the Mt. Stromlo Observatory once per week. Taking all causes of error into consideration any six pip time signal as broadcast by the radio stations in Victoria should under normal circumstances be within ± 1/10th sec. of correct time. The main variations from this accuracy will occur when one of the Victorian stations is taking an interstate programme and broadcasts an interstate time signal.

From the table at the end of this

This article is a reprint of an article which appeared in Cartography, Vol. 2, No. 4.

* *See page 299.*

article listing the various time signals useful in Australia, it will be seen that the most accurate radio time signals available from an Australian station are those generated at the Commonwealth Observatory and radiated over the Belconnen Naval radio station. The Observatory uses its own quartz clock installation rated by astronomical observations to control these time signals. For high accuracy work, corrections to the nearest millisecond are available for the mean time signals from Belconnen. No corrections are published for the rhythmic signals. Accurate signals are also available from overseas countries. It should be remembered in using these signals, that allowance must be made for the transmission time from the station to the point of reception when the utmost precision is required. Further details of the various time signals are set out in Refs. (3) and (4).

The current definition of time has been referred to in (1) that is "the second is the fraction 1/31,556,925.9747 of the tropical year for 1900 January at 12 o'clock in ephemeris time. While this definition is satisfactory for high accuracy astronomical time determination, presents developments in precise time keeping have been directed towards finding a more stable working reference than that provided by a piezo-electric quartz crystal. To this end various atomic and molecular resonances have been explored. One of the early attempts used a resonance in ammonia which occurs at a frequency of approximately 23,870 Mc/s. The intention was that the ammonia resonance be used as a reference for a control circuit to make compensating adjustments for the ageing and other changes of a quartz clock. Due to practical difficulties with the control circuit the overall stability realised was not significantly greater than that obtainable from a high quality quartz clock. Later attempts have been more successful and there is available in the U.S.A. an atomic clock using a resonance in caesium atoms for which a stability of a few parts in 10^{10} is claimed.

The National Physical Laboratory in England have been using an alternative approach; a caesium resonator operating at a frequency of 9192 Mc/s is used to calibrate their standard quartz clocks regularly, thus providing an accuracy similar to the caesium clock but without the complication of the control mechanism. The frequencies and time signals radiated by the English standard frequency station M.S.F. are referred to the National Physical Laboratory caesium resonator. By the time these atomic devices have been in operation long enough to calibrate them in terms of ephemeris time, they will provide a convenient working reference of frequency and time interval of the highest stability. Among a great variety of other uses they will be able to measure the irregularities in the rate of the earth's rotation.

Notes: A. The time signal is originated by the Commonwealth Observatory, Canberra, and is broadcast by Belconnen Naval W/T station. It is of the rhythmic type, comprising a series of 306 signals emitted in 300 seconds of mean time, the concluding signal being on the exact hour. In each series, signals numbers 1, 62, 123, 184, 245 and 306 are single dashes (—) of 0.5 seconds duration and begin at the exact minute. Each dash is followed by 60 dots of 0.1 seconds duration. The beginnings of successive signals, whether dot or dash, are equally spaced at intervals of 60/61 parts of one second of mean time.

The procedure is as follows:—

m	s	
55	00	1st signal, a dash followed by 60 dots
56	00	62nd ,, ,, ,, ,, ,, 60 ,,
57	00	123rd ,, ,, ,, ,, ,, 60 ,,
58	00	184th ,, ,, ,, ,, ,, 60 ,,
59	00	245th ,, ,, ,, ,, ,, 60 ,,
00	00	306th ,, a dash.

This time signal will enable chronometer comparisons of extreme accuracy to be obtained, the method employed being to count the number of intervals from the first dash until coincidence occurs between one of the rhythmic signals and the beat of the chronometer. It is not necessary actually to count the signals. Take the nearest second of each dash by the chronometer and write down the chronometer time of coincidence. The difference gives the number of the rhythmic signal.

B. This time signal which is originated by the Commonwealth Observatory, Canberra, and broadcast by Belconnen Naval W/T station is sent out during 5 minutes. It consists of the transmission of a dot for every second, omitting the dot at the following seconds:

29, 51, 56, 57, 58 and 59 during the first minute;

29, 52, 56, 57, 58 and 59 during the second minute;

29, 53, 56, 57, 58 and 59 during the third minute;

29, 54, 56, 57, 58 and 59 during the fourth minute;

29, 51, 52, 53, 54, 55, 56, 57, 58 and 59 during the fifth minute.

At the end of the 60th second on the fifth minute, a one second dash will be sent, the beginning of which is the time signal. Correction sheets for these signals are available from the Commonwealth Observatory, Mt. Stromlo, Canberra, A.C.T.

C. Interruptions from minute 0 to minute

SPECIAL TIME SIGNALS USEFUL IN AUSTRALIA

Name of Station	Call Sign	Carrier frequency kc/s	Class of Emission	Time of Emission G.M.T.	Notes
Belconnen	VHB VHP	44 6428.5 8478 22485	A_1	0755-0800	A
	VHB VHP	44 6428.5 8478 12907.5	A_1	1355-1400, 1955-2000	A
	VHB VHP	44 8478 17256.8 22485	A_1	0025-0030	B
Beltsville Maryland U.S.A.	WWV	2500 5000 10000 15000 20000 25000	$A_1, A_2, A_3,$	Continuous	D
Kihei, Hawaii	WWVH	5000 10000 15000	A_1, A_2	C	D
Tokyo, Japan	JJY	2500 4000 5000 8000 10000 15000	A_1, A_2	E Continuous F 2100-1100 h. G H	
Adelaide, Radio	VIA	500	A_2	0027-0030, 1227-1230	I
Melbourne, Radio	VIM	500	A_2	0157-0200, 1357-1400	J
Perth, Radio	VIP	500	A_2	Monday to Friday 0057-0100, 1257-1300 Saturday 0057-0100 Sunday 1257-1300	K
Sydney, Radio	VIS	500	A_2	1055-1100, 0255-0300 (except Sundays and Holidays)	L

4, and from minute 30 to minute 34 of each hour, as well as from 19.00 to 19.34 GMT.

D. The audio modulation on WWV and WWVH is alternately 440 c/s and 600 c/s for 3 minute of each five. The time signals are given on WWV as 5 cycles of 1000 c/s tone and on WWVH as 6 cycles of 1200 c/s tone; no pulse is given on the 59th second of each minute for both stations. With WWV the first pulse of each minute is repeated 100 milli-secs. later. The accuracy of time intervals from both stations is $\pm 1 \times 10^{-8} \pm 1$ micro sec. The phase of time signals from both stations is adjusted in steps of 20 milli seconds. Adjustments are made on Wednesdays at 1900 GMT when necessary. Correction sheets are available from the Central Radio Propagation Laboratory, National Bureau of Standards, Washington 25, D.C.

E. All JJY transmissions give the time signal by breaking the 1000 c/s modulation for a period of 20 milli seconds each second and 0.2 seconds each minute, the frequency of the point of emission after each break being at each exact second or minute. The time signal accuracy is 0.001 second with adjustments made in steps of 10 milliseconds. Transmission on 2500 kc/s is from 0700-2300 GMT, with interruptions from minute 29 to minute 39 of each hour.

F. 5000 kc/s transmission is on Mondays only with interruptions from minute 9 to minute 19, from minute 29 to minute 39, and from minute 49 to minute 59 of each hour.

G. 1000 kc/s transmission is on Wednesdays only with interruptions as for F.

H. 15,000 kc/s transmission is from 2100-1100 GMT. Interruptions as for E.

I. The first minute consists of a series of the signal X (—..—) beginning at 5 seconds and finishing at 50 seconds. Similarly the second minute consists of a series of the signal N (—.) and the third minute a series of the signal G (— —.). The period from 55 seconds to 60 seconds in each minute is taken up with three dashes each of 1 second duration with the end of the last dash marking the end of the minute. Accuracy is the same as for other services operated by the State Observatory namely ± ⅓ second under normal circumstances.

J. The XNG signal is similar to I except that the period 55 secs to 60 secs of each minute is taken up with 6 dots spaced at one second intervals each dot having a nominal duration of 1/10th second.

K. As for I.

L. One dash as the seconds 0-1, 10-11, 20-21, 30-31, 40-41 and 50-51 in each minute and a dot at every other second.

REFERENCES

1. Abraham, H. J. M.: Cartography, Vol. 2, No. 3, March 1958.
2. Sandbach, E. F.: The Telecommunication Journal of Australia, Vol. 10, No. 4, June 1956.
3. International Telecommunication Union: List of Special Service Stations (15th Edition).
4. C.C.I.R.—VIIIth Plenary Assembly Warsaw 1956: Report No. 66, Standard Frequency Transmission and Time Signals.

MR. E. D. CURTIS, M.I.E.Aust.

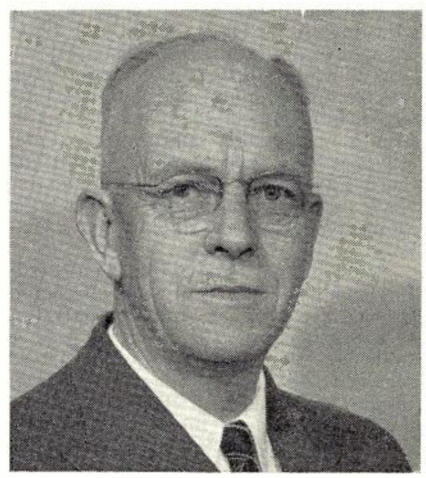
Congratulations are extended to Mr. E. D. Curtis on his recent appointment as Assistant Director, Engineering, in the Victorian Administration.

Mr. Curtis commenced his Departmental career as a telegraph messenger at Brighton in 1916, and entered the Engineering Division as Draftsman-in-Training in 1922, being advanced as Engineer in 1925. Most of his early experience as Engineer was obtained with problems concerning internal plant work, namely, telephone, telegraph and radio equipment. Telephone equipment tasks of interest undertaken during this period included installation of the first "packaged" type R.A.X.'s and Mr. Curtis supervised the first exchange installation in Victoria of 2000 type line finder equipment at Brunswick.

Promotion through the various grades of Engineer followed and positions held included, Assistant Supervising Engineer, Telegraph Service; Supervising Engineer, Radio and Telegraphs (1950), and Superintending Engineer, Planning Branch (1955). Mr. Curtis spent a short period at Headquarters in 1926, and during 1958 he was temporarily transferred as Deputy Engineer-in-Chief, Services.

Mr. Curtis has always supported the activities of the Society, having contributed articles on telegraph problems to the Journal. He has also delivered lectures at meetings of the Society and is the current President of the Victorian Division. Apart from his wide experience, his ready wit and approachable manner will no doubt contribute in a large measure to a successful launching of the new organisation in the State of Victoria.

Mr. Curtis is a Member of the Institute of Engineers Australia.



MR. E. D. CURTIS

THE PREVENTION OF ACCIDENTS

V. J. WHITE, B.Sc., B.A., A.M.I.E.Aust., M.B.Ps.S. *

INTRODUCTION

In the year ended the 30th June, 1959 there were nearly 6,000 lost time accidents in the Postmaster-General's Department (about 7 per 100 staff employed). The total time lost due to accidents during working hours in this period was in the vicinity of 300,000 hours. In the Engineering Division for the same year there were approximately 3,600 lost time accidents (9 per 100 staff) and about 201,000 man-hours were lost. The direct cost of these accidents (time lost plus compensation payments) was about £400,000. It is generally agreed that indirect costs of accidents such as lost production, administration costs, etc., are at least equal to the direct costs. Hence the total loss sustained by the Engineering Division due to accidents at work during the year ended 30th June, 1959 would approach £1,000,000. Add to this the pain, suffering and grief which accidents bring to the worker and his family, and we have a powerful reason why strenuous efforts should be made to reduce accidents at work.

The Commonwealth Government convened a National Safety Conference in Canberra in November, 1958, in order to emphasise the need for active accident prevention measures in industry and to stimulate interest in job safety of Commonwealth and State Departments as well as all private industrial concerns. The Postmaster-General's Department was represented at this Conference by Mr. M. R. C. Stradwick, then Director-General (designate) and Mr. I. M. Gunn, then Supervising Engineer, Lines Section, Central Office, and as a result of subsequent follow-up action, active measures are being adopted in the various Divisions and Branches to improve the overall safety record of the Post office.

This paper describes general principles involved in the prevention of accidents and indicates how they are being applied in the Engineering Division.

GENERAL PRINCIPLES OF ACCIDENT PREVENTION

The following principles apply to accidents in general. They can be used in the workshop, in the exchange or in external plant operations and should be properly understood by every Supervisor and Field Engineer. These principles are:

(1) *Accidents are prevented when there is adequate control of man, his physical environment and the materials, machines, tools and equipment he uses.*

The man in the best position to control these factors is the first line supervisor. In the Engineering Division, Postmaster-General's Department, this is the Party Leader, Line Foreman or Senior Technician in charge of the working party.

(ii) *The First Line Supervisor is the key man in industrial accident prevention.*

This follows from the first principle, but is so important as to require statement as a separate principle.

(iii) *An accident is almost invariably caused or permitted by an unsafe act of a person and/or a physical hazard.*

It follows that if we eliminate the unsafe act and the physical hazard we eliminate accidents. Hence the focus in accident prevention work must be on *potential* unsafe acts and on physical hazards. Because human behaviour is difficult to predict, the surest accident prevention method is to completely eliminate the physical hazard.

(iv) *The first and simplest step in accident prevention work is to identify and eliminate, where possible, the specific physical hazards in the work environment.*

This is a fundamental step. Engineers should know the hazards of each kind of work operation their men perform. In particular, the Field Supervisors (Party Leaders, Line Foremen, etc.) must make sure the specific hazards of each job allocated to the men are clearly identified and ways of eliminating or controlling them clearly understood.

(v) *A person suffering a major injury from an accident caused by an unsafe act has performed the same unsafe act without injury, on the average, some hundreds of times previously.*

It follows that accident prevention work is concerned with the "near misses" just as much as with actual injury producing accidents. Each "near miss" ignored, is just one further lost opportunity to prevent an accident.

(vi) *Methods best suited to accident prevention are also the best methods for control of output.*

It has been stated that the first Line Supervisor is a key man in safety. The Supervisor is also a key man in efforts to increase output of the work force. If this first line of supervision is strengthened then we can expect both safer and better work output.

Knowledge of these principles is not enough—there must be keen interest in safety on the part of both worker and management, and hence ways and means of creating and maintaining interest in safety are required to develop and maintain the vigilance necessary to prevent accidents.

HAZARDS OF PEOPLE

Some writers claim that 90% of all accidents are caused primarily by the unsafe acts of people. Others say that about 5% are caused primarily by either unsafe acts or physical hazards and that 95% are caused by the combined action of both people and hazards. This difference of opinion results mainly from the fact that different people are analysing causes of accidents down to different levels. It can be said that physical hazards exist because of the faults of people so that accidents which on the surface appear to be caused by a physical hazard are, in fact, caused indirectly by unsafe acts of people. Nevertheless, in the final analysis we can say that an accident results from the mixing together of physical hazards and people. Both must be present before an accident can occur and therefore, to prevent accidents we must:—

either (i) eliminate the workman.
or (ii) eliminate the hazard,

Fig. 1.—This condemned pole fell whilst two linemen were at work on it removing spindles and insulators. The hazard could have been eliminated by dropping the pole to the ground complete with fittings.

* See page 299.

or (iii) control the hazard and the workman so that they can exist safely together.

In modern factories many processes are being handled in a completely automatic way. This effectively eliminates injuries because there are no people present to be hurt. In the Postmaster-General's Department automation to this extent is still a long way off so that the elimination of people from the work scene is not a very promising method of preventing accidents. However, the progressive introduction of new mechanical aids to our work operations is a first step in this direction and in so reducing the number of men required on the job we tend also to reduce the chances of injury, provided, of course, the machine is properly designed and adequately controlled. Similarly, the elimination of certain field operations by prefabrication in the factory helps to prevent accidents on the job.

The second step, namely elimination of hazards, is a far more promising means of reducing accidents. By proper planning of work operations, by adequate design of tools and equipment and by wise selection of materials used on the job, many hazards can be removed from the work scene.

However, in many work situations it is impossible or impracticable to eliminate hazards and in these situations the actions of the men and the effects of the hazards must be controlled if accidents are to be prevented.

Therefore, the more we know about hazards the more effectively will we be able to either eliminate or control them. Also, the more accurately we can identify and locate hazards in the work situation the more effective will be our efforts to prevent people from being hurt by them.

HAZARDS IN GENERAL

Hazards may be classified in a variety of ways according to the type of industry concerned. A general classification of hazards which can be used by all kinds of industry is essential if there is to be standardised coding and recording of accident information. J. Reid [2], W. Heinrich [1] and the Australian Standards Association [4] have all provided such a classification.

A classification adopted for use by all Commonwealth Government Departments is given below:—

(1) Machinery including prime movers, pumps, mechanical power transmission apparatus, hoisting and hauling machines, conveyors and the various types of industrial machines.
(2) Vehicles of all kinds, for example, motor vehicles, trams, railway locomotives, bicycles, aircraft, etc.
(3) Electricity, explosives, flames and hot substances.
(4) Harmful substances, for example, acids, dangerous gases, etc.
(5) Persons falling, stumbling or slipping.
(6) Stepping on or striking against fixed or stationary objects,
(7) Handling or moving or falling objects.
(8) Hand tools, including power operated hand tools.
(9) Miscellaneous, including animals and insects.

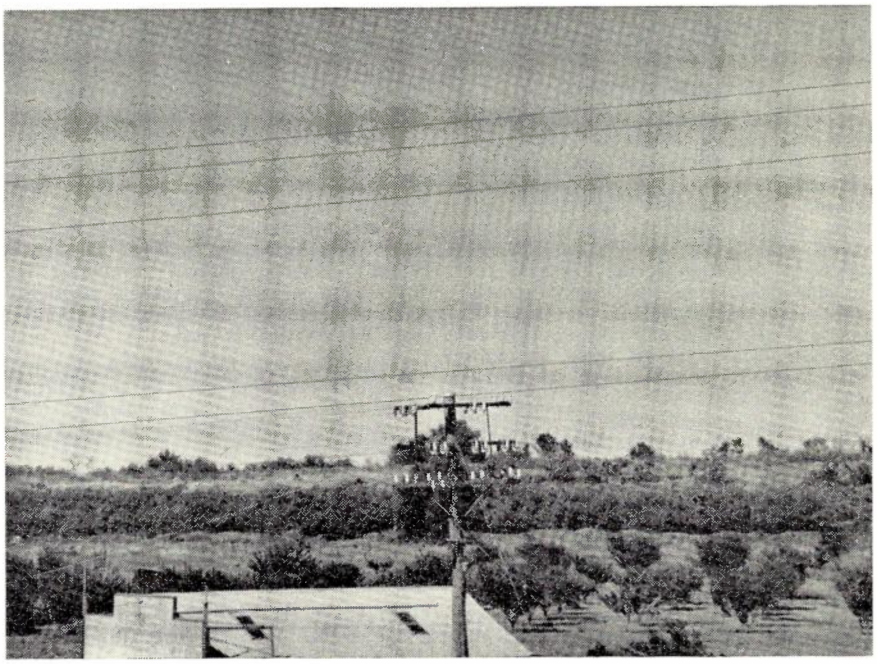


Fig. 2.—The wires shown here are power wires over a new open wire trunk route. The two lower wires are low voltage conductors which contacted the P.M.G. wires and killed a lineman working about 1½ miles away. This under-crossing was erected only the previous day and when climbed the pole this photograph was taken from to check the clearance, they failed to observe the lower set of wires. They were looking from a point higher up the pole and the low voltage wires are then lost in the dark background of the nearby hill. Had this span of wires been erected last the hazard would have been eliminated at least for most of the time the men worked on the wires.

A general classification of hazards such as this one helps recording of accident information, but is not of much help to the Field Supervisor charged with the responsibility of ensuring the work situation is as free of hazards as practicable. He must have definite specific information of actual hazards, such as, for example, that a power line crosses the pole route between pole 100 and pole 101 and the clearance from the Postmaster-General's Department wires is 3 feet. Without knowledge as specific as this, his ability to prevent accidents is severely limited.

After an accident has occurred the hazard causing it stands out unmistakably. Accident prevention calls for the identification, recognition and location of hazards *in advance* of the work operations and this requires continuous vigilance and care on the part of all people involved in planning and performing the work.

HOW TO DEAL WITH HAZARDS

Having located the specific hazards in the work situation the next task is to deal with them, and in general there are three possibilities—

(i) eliminate the hazard completely,
(ii) control its effects,
(iii) ask people to be careful and avoid it.

Take, for example, a dangerous railway crossing. The hazard here is that of being struck by a train. If the crossing is eliminated entirely by an overpass then there is no possibility of accident—the cure is 100% effective. Secondly, the hazard may be controlled by erecting gates which close when trains approach. In this case accidents, although unlikely, may still occur if for some reason the gates do not close as a train approaches—the cure is no longer 100% sure. And, finally, we may merely erect a sign at the crossing asking people to watch out for trains and to proceed with caution. In this case we are relying on people to act in a reasonable manner and our chances of preventing accidents are slim indeed.

It is obvious that the only 100% sure way of preventing accidents is to eliminate the hazard completely. This must always be considered as the first step in accident prevention and every hazard in the work situation must be found and critically examined with a view to eliminating it entirely. Generally, the greatest opportunity to eliminate hazards occurs during the planning stages of a work when, for example, a power crossing may be avoided by careful selection of the route or by the provision of cable. Opportunity to eliminate hazards occurs also at later stages right down to the actual commencement of the work, for example, a party leader may decide that instead of erecting the first span of wire under a power line, he will commence at the other end of the job and erect the wires at the power crossing as the last operation, thus eliminating the hazard at least for most of the time the line is being erected.

There are many situations where it is quite impracticable to eliminate the hazard and steps must be taken to control its effects. In this case the two necessary ingredients for an accident—hazards and people—are present and both must be controlled to prevent accidents. Hazards are controlled by the provision of guards and safety devices such as rope guards, earthing rollers, etc., whilst the workmen are controlled by the Field Supervisor who sees that the men follow prescribed safety procedures and wear personal protective equipment such as safety belts, gloves and protective helmets. Quite obviously the effectiveness of these methods of accident prevention depend heavily on the Field Supervisor and his ability to accurately locate all the hazards in the work environment and to effectively control them and the actions of his men.

The third general method of preventing accidents, that of asking people to be careful, hardly qualifies as an effective method at all. However, it has been mentioned here because it is still the only method used in many places. Take for example the case of the polythene bags used in America by dry-cleaning firms. These bags apparently develop, under certain conditions, static charges of electricity causing the polythene to stick to people's skin. The bags when placed over the head are also an excellent way of dressing up as a spaceman. The action of drawing the bag over the head tends to develop the static electrical charges and the polythene bag collapses around the face and neck, cutting off the air supply with fatal results. Some 40 or 50 children were killed in America in 12 months in this way. One method suggested by a dry-cleaning firm to prevent these accidents was to have the bags marked dangerous. This is an example of the method of preventing accidents in which reliance is placed on warning signs advising peaple to be careful. It is often the favourite method of preventing accidents in the home, is very unreliable and should be used only as a last line of defence after other action to eliminate or control the hazard has been taken.

ACCIDENT PREVENTION IN ENGINEERING DIVISION

Emphasis on Normal Line of Supervision: Probably the most important principle of accident prevention is the one which states—"The first line Supervisor is the key man in industrial accident prevention." This applies particularly to the Engineering Division where a large proportion of the staff are in small working parties scattered over a wide area. For this reason heavy emphasis is placed on the normal line of supervision and prevention of accidents is regarded as a normal and integral part of a supervisor's day to day duties. In order to cultivate safe working habits and to discourage any tendency to regard safety as something special, or apart from routine work, safety precautions are now being included where possible, in the Engineering instructions on the work method, rather than published as a separate set of instructions.

Training of Supervisors: The Department has availed itself of the Commonwealth Department of Labour and National Service Safety Course to establish a cadre of properly qualified trainers who will be available to train Supervisors in job safety. In the Engineering Division these trainers will be mainly used in conjunction with supervisory training courses which will cover all aspects of supervision. In this way prevention of accidents will be firmly established as an integral part of normal supervision.

Accent on Hazards: The basic philosophy adopted is to concentrate on the detection of hazards in the work situation and then to eliminate them as far as possible. This applies at all levels from the design and planning engineers right down to the field supervisor. Thus Material Design Engineers are required to check new materials such as epoxy resins or liquid petroleum gas for health hazards with an appropriate Health Authority. Tool and Equipment Design Engineers check their designs from the safety point of view to ensure they introduce no additional hazard by, for example, exploiting low voltage power tools as far as possible. Engineers engaged on development of methods and establishing standard practices endeavour to apply the eliminate-the-hazard-first approach where possible, so that, for example, in methods of dismantling wire, provision is made for the cutting out of power crossings first before the remainder of the wire is recovered.

In planning work operations Field Engineers should make sure Supervisors know the specific hazards involved in each operation, at each work site and know how best to eliminate or control them.

Although adopted mainly for economic reasons the policy of replacing certain manual operations in the field by machine prefabrication at a central depot or factory has also contributed to the prevention of accidetns. Thus the introduction of pressure treated poles which are dressed by machines has eliminated hazardous manual field work which was the source of many injuries in the past.

Recognition of Importance of the "Near Miss": In a revised accident reporting procedure now being introduced staff are asked to report not only actual injury producing accidents, but also those mishaps or unforeseen events which do not result in injury and which are best described as "near miss". This is an important development because every "near miss" is an opportunity to correct some hazard or unsafe act which, if allowed to continue, will eventually cause an injury. The purpose of having "near misses" reported is to give local management a chance to correct a dangerous situation *before* it causes injury and there is no intention or desire that it be used other than for this mutually beneficial purpose.

Stimulating Interest on Safety: Prevention of accidents is the responsibility of field supervisors who are also charged with the very obvious task of obtaining maximum work output. The organisation is well provided with supervisory checks and control systems to ensure that the attention and interest of Supervisors are directed towards efficiency and productivity so that in general the normal line of supervision tends to be pre-occupied with these aspects.

There is a clear need, therefore, for the Administration to take active steps to ensure that the attention and interest of Supervisors is being continually directed towards its responsibility for the prevention of accidents.

In order to stimulate interest in safety at Headquarters, a Safety Steering Group, with representatives from all Plant Sections, has been set up under the Chairmanship of the Assistant En-

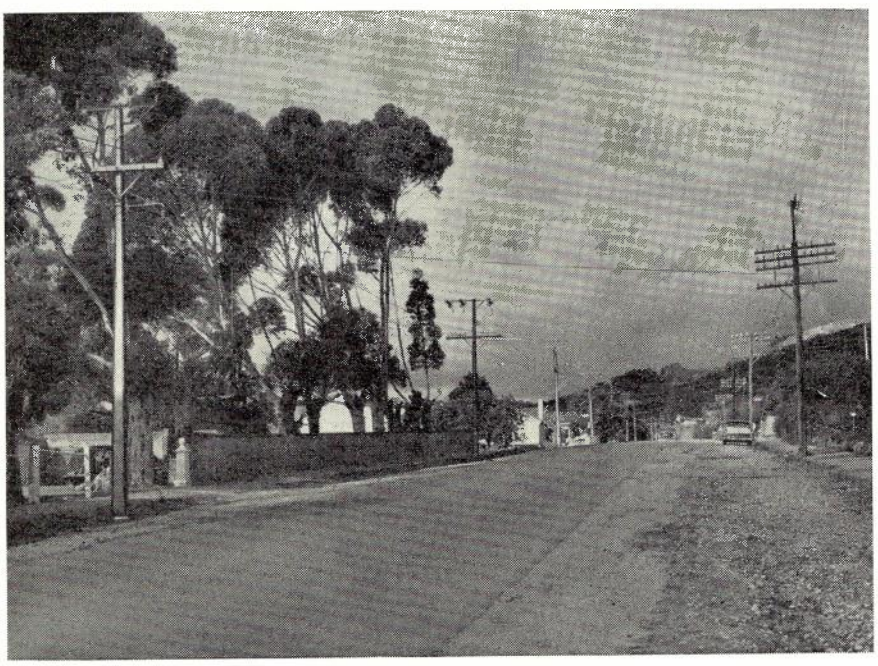


Fig. 3.—This was the scene of a near miss. A street light feed on the power pole at the left of the picture was contacting the steel pole and when the street lights were energised the whole pole including a bracket holding a P.M.G. drop wire was alive. A man working on the second wooden P.M.G. pole down the other side of the street received a shock when he touched both a bracket the drop wire was attached to and an earthed open wire.

gineer-in-Chief, Services. The main function of this group is to co-ordinate procedures for maintaining interest in accident prevention. Trends in accident rates and standardisation of procedures and forms used to report and investigate accidents are other functions of this group.

Some State Administrations have similar Executive Safety Committees operating at Supervising Engineer or higher level. These committees are an excellent aid to management, but they must not in any way lessen the responsibility of Supervisors for the safety of their workmen. In fact, their main task is to see that the normal line of supervision squarely shoulders full responsibility for the prevention of accidents.

The interest of Field Supervisors and workers in safety is stimulated by various means. First of all safety is an important part in training courses for all trainee linemen and technicians. Posters such as Linelights and Service Sidelights are used to drive home the safety message, and staff news sheets such as "On the Line" devote space in each issue to some aspect of safety. Engineers and Field Supervisors are encouraged to devote part of their normal supervisory duties to informal staff discussion groups in which safety procedures, the latest "near miss" or an actual accident are discussed and analysed. Safety films are shown pediodically and safety pamphlets are issued to all workmen.

CONCLUSION

The policy on prevention of accidents in the Engineering Division is to regard safety as an integral part of normal supervision. Supervisory training, including training in job safety is being arranged. Every effort is being made to develop in both worker and Supervisor alike the attitude that safety precautions must be part and parcel of normal work methods.

Emphasis is placed on the elimination of hazards as the first and surest method of preventing accidents and the reporting of "near misses" is being encouraged as a means of providing information on hazards before they cause injuries..

BIBLIOGRAPHY

1. W. H. Heinrich, "Industrial Accident Prevention" (Book); McGraw Hill, New York.
2. J. A. Reid, The Hazard Hunt; Safety Engineering, February, 1959
3. W. H. Goodman, Improved Safety through Effective Communication; Bell Telephone Magazine, Summer, 1956.
4. Standards Association of Australia, Recording Industrial Accidents; Aust. Standard No. CZ6, 1952
5. M. Shafer, Economic Considerations of an Accident Preventive Programme; Telephone Engineer and Management, September 15, 1959.
6. L. F. Scantlebury, Accident Prevention in the Engineering Department; (B.P.O.) Telecommunication Journal, Spring, 1959.

MR. G. N. SMITH, B.Sc., A.M.I.E.Aust.

The Society congratulates Mr. G. N. Smith on his appointment as Director, Posts and Telegraphs, Victoria.

Mr. Smith joined the Department as a Cadet Engineer in May, 1926. He was promoted as Engineer in 1930 and worked mostly in the Research Laboratories on telephone transmission problems, but was also associated with the Bass Strait telephone cable and the Melbourne-Geelong trunk cable projects which were undertaken in the middle 1930's.

He was promoted as Divisional Engineer, Queensland, in 1938, and Assistant Supervising Engineer in 1948. Whilst in Queensland, Mr. Smith was responsible for the installation, planning and maintenance of long line equipment in that State. This period included the active war years which introduced many large and important projects, largely due to the special demands made by the local and U.S.A. armed forces operating from Queensland.

In 1949 Mr. Smith transferred to the Headquarters of the Telecommunications Division as Inspector (Traffic) and was promoted as Controller, Planning and Development in March, 1955. Further promotion as Assistant Director (Telecommunications), Victoria, followed in July, 1958.

Mr. Smith has always given practical support to the activities of the Society. He has contributed five interesting articles to the Journal, and it is confidently expected that with the reconstitution of the Society to include separate Divisions in all States, the Victorian Division will receive strong support from the new Director.

Mr. G. N. SMITH, B.Sc., A.M.I.E.Aust.

THE NEW SOUTH WALES NORTH COAST TRUNK RADIO NETWORK

*J. D. THOMSON, B.Sc., A.M.I.E.E., M.I.R.E.Aust., and W. G. PENHALL, B.E.E,**

PART I—PLANNING

1—INTRODUCTION

Periodically and almost regularly N.S.W. and Queensland suffer severe floods. In New South Wales it is the North Coast (Fig. 1) which suffers most and rarely does a year go by that one district or another is not inundated. In February, 1955, new heights were reached by the flood waters; for the first time in the history of the North Coast, all the major river systems were in simultaneous flood and road, rail and telephone communications were disrupted. This was a flood which departed from the accepted pattern, this was a flood which defeated the plans of the telephone engineers who had designed their system to cope with the flooding of any one of the river valleys but not for the simultaneous flooding of seven rivers, the Hunter, the Manning, the Hastings, the Macleay, the Clarence, the Richmond and the Tweed. This was a unique flood.

The telecommunications facilities suffer from floods in two major ways. Firstly, the flotsam includes substantial objects such as tree trunks, storage tanks, dead cattle, etc. and these sweep along with the flood waters reaching speeds of over 10 m.p.h. Telephone poles, substantial as they are, are not designed to withstand the full impact of a 10 cwt. object travelling at speed and extensive breaks were made in this way in major trunk routes in the flooding of 1955. Secondly, the equipment buildings can be inundated rendering the equipment unserviceable. This happened in a number of towns during the 1955 floods.

The solution proposed for the flooding of equipment rooms is to raise the level of the equipment and this has been carried out. In some places, it has proved practicable to strengthen pole routes and to divert the routes over higher ground. However, there are many places where the cost of diversions and strengthening of construction is exorbitant and an alternative must be sought.

By its very nature radio at frequencies above 30 Mc/s and up to about 10,000 Mc/s incorporates all the qualities of a medium suitable for the solution of the telephone engineers' transmission problem and it was to this medium that the administration turned, attracted largely by the freedom from flood created failures and by the relative speed with which radio circuits can be established.

2—THE PLAN IN OUTLINE

There are four main types of trunk line wholly in the New South Wales trunk network which is organised as a "Star" Network[1]. The trunks join what are known as terminal exchanges to minor switching centres, minor switching centres to secondary switching centre, secondary switching centres to primary switching centres and primary switching centres to main trunk centres. The number of trunks required between the smaller centres may be only one or two while the number required from the primary centre to the main trunk centre can reach hundreds. To meet the different requirements, different types of radio systems are desirable and the following basic radio systems were proposed.

The Single Channel System. This is intended for use between exchanges where very few trunks are required. Ideally it should be simple, reliable and completely self-contained. Briefly the performance of the derived channel must comply with the following standard:

Frequency response referred to 800 c/s.
0-300 c/s below +1.8 db.

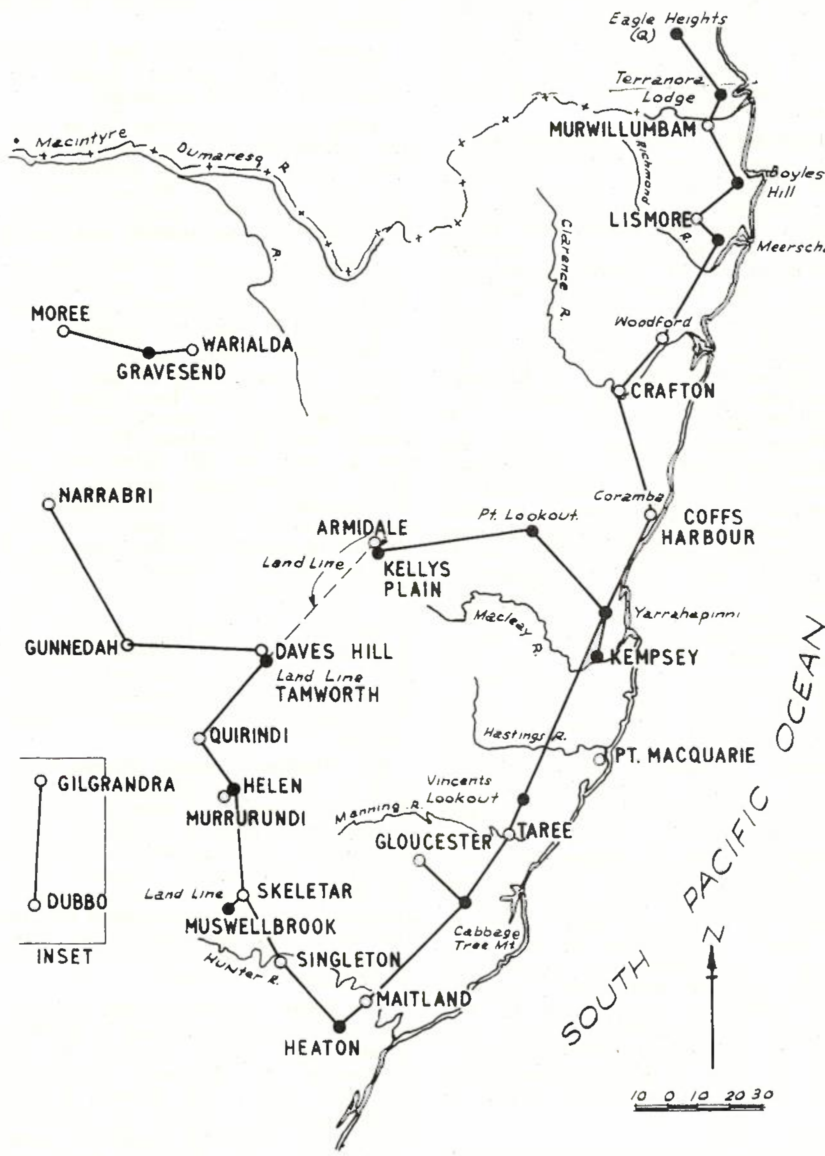


Fig. 1.—Small Capacity Bearer Routes for the North Coast of N.S.W.

* This paper was presented at the 1959 I.R.E. Radio Engineering Convention, Melbourne, Victoria, 1959 and published in the Proceedings of the I.R.E. Australia, October, 1959. It is reprinted with the kind permission of the Publications Board of the Institution. *See page 299.*

1 Freeman, A. H., "The need for radio in the Australian trunk line network", Proc. I.R.E. (Aust.), 19, May, 1958, 206-211.

300-400 c/s +1.8db −2.8 db
400-3,000 c/s ±1.8 db
3,000-3,400 c/s ±1.8 db −2.6 db

Harmonic Distortion. Better than 5% 8 db above test level, i.e., at full modulation (test level is 0 dbm at the sending switchboard and is written 0 dbm, 8 db up on this is then +8 dbmo).

Linearity. The loss measured between switchboards shall be within ±0.25 db of the loss at test level from −50 dbmo to +8 dbmo.

Noise. This is measured on a psophometer which is an electrical measuring instrument with a non-uniform frequency response intended to simulate the effects of interfering noise from all sources on a telephone conversation. Noise measurements made with the instrument are referred to as weighted measurements. For a trunk telephone channel on radio a weighted noise of the order of −60 dbmo is sought. The design of the system must be such that this standard is met after a 10 db degradation of equipment or a 10 db fade. Converted into radio engineers' terminology, this is a signal to noise ratio (that is, 100% modulation to noise ratio) in the Channel of 78 db.

Equivalent. When a constant tone is sent from one end of the system, the level of the tone at the distant end must stay constant to within ±0.25 db over wide variations of temperature, mains voltage and received signal strength. This is referred to as constancy of equivalent. One of the simplest ways to achieve this constancy of level is to use frequency or phase modulation where the level of the modulation after demodulation is independent of RF level over wide ranges of RF level in correctly designed equipment.

These single channels may be required for installation between manual exchanges, between a manual and an automatic exchange, between a magneto and a central battery exchange, etc., and the signalling methods must be made compatible with all the appropriate boundary conditions and existing practices. This type of system was envisaged as meeting the needs of fairly lightly loaded trunk routes such as those between terminal exchanges and minor switching centres and between minor switching centres and secondary switching centres; e.g. between Taylor's Arm (terminal exchange) and Macksville (minor switching centre), and between Gladstone (minor switching centre) and Kempsey (secondary switching centre).

The Small Capacity Bearer. These are used between exchanges where a single channel would be inadequate even to provide the bare minimum of service in the event of disruption of the other means of communication. Again, frequency or phase modulation is used to ensure constancy of equivalent but the system is not self-contained. These systems are designed to provide the equivalent of a pair of wires to transmit the output of a carrier current telephone system. A carrier current telephone system transposes the 300 c/s-3,400 c/s essential speech band in a telephone conversation to different parts of the spectrum. Thus four telephone channels each 300 c/s-3,400 c/s are separately transposed to occupy adjacent parts of the spectrum between 3 kc/s and 20 kc/s. To do this and to ensure that the telephone channels carried by the radio bearer still comply with the brief specification given for the single channel system, the following performance is required of the bearer:

Frequency Response. Within ±1 db from 3 kc/s to 20 kc/s.

Harmonic Distortion. Better than 0.1% 10 db above test level, that is at the level corresponding to full modulation. This requirement usually comes as a surprise to the average radio engineer and high fidelity enthusiast, but it is necessary to ensure that crosstalk from one channel to another does not exceed the level specified for noise in the single channel system.

Linearity requirements are essentially as for the single channel system, consistent with the last paragraph.

Noise. Again, expressing this as a signal to noise ratio, the ratio of full modulation to the noise level measured over the band 3 kc/s to 20 kc/s must be about 70 db to allow reasonable margins for equipment deterioration and fading.

Equivalent. As with the single channel system, a constancy of equivalent to within ± 0.25 db measured over periods of a month or more are required.

These four channel systems are used for the interconnection of larger population centres such as Taree with Kempsey, Grafton with Lismore and Murwillumbah with Queensland. These centres are as much as 100 miles apart and direct communication between them is impracticable and the establishment of repeater stations is necessary. The introduction of repeater stations, however, is not permitted to degrade the performance given above if the circuit length is less than 125 miles. In every installation planned for New South Wales, the 125 mile length was not exceeded. Most of the larger centres connected by these systems are secondary switching centres with direct access to primary switching centres.

The Medium Capacity Bearer. This type of system was intended to connect the primary switching centres with one another or to connect a primary centre with a main trunk centre. Basically, the electrical performance required from this type of system was the same as for the small capacity bearer except that the frequency response needed was from about 10 kc/s to 60 kc/s, i.e. a group of 12 telephone channels.

The Large Capacity Bearer. This system had but one application in the New South Wales scheme and was for the connection of Maitland, a primary switching centre, with Sydney, a main trunk exchange. Again, the electrical performance needed is similar, in many respects, to that for the small and medium capacity systems with the major exception that its frequency response was required to extend up to nearly 300 kc/s in order to carry a telephone "super-group" of 60 channels.

With the equipment of these types, it was envisaged that any break in a trunk route could be bridged by a radio circuit spanning the gap. In the event of any number of breaks in the conventional trunk route, there is always a skeleton service possible which is sufficient for a bare minimum of essential traffic to isolated centres from disaster free areas and, when necessary, between stricken areas.

3—THE SINGLE CHANNEL SYSTEM

The devastation of the 1955 floods left a large number of small places completely isolated. An office survey was carried out to determine which trunk routes could be reconstructed economically in such a way as to make them secure against flood waters. After the initial survey, it was clear that there were at least forty centres whose small trunk line communication needs could not be secured without recourse to radio. Three of them connected to Taree, six to Kempsey, three to Macksville, four to Coff's Harbour, seven to Grafton, ten to Lismore. Also there were sundry other isolated systems. Suitable equipment was already being manufactured in Australia for this phase of the scheme and extension orders were placed.

The problems of installing ten transmitters and ten receivers all at one site and working in the same limited frequency band still had to be solved. Studies in the New South Wales Administration showed that the most pressing problem was one of frequency allocation because all these systems were to be in the 156-172 Mc/s band which was shared by other users and which used a constant 120 kc/s spacing between channels. Hitherto, an almost random allocation of frequencies had been followed and interference problems were solved by individual engineering as required. Calculations in the New South Wales Administration showed that there was only one chance in fifty of allocating a channel free of simple inter-modulation interference. The probability calculations were submitted to the Engineer-in-Chief who instituted a series of measurements[2] to ascertain what the level of interference would be and what controls were needed to ensure compliance with the noise standard specified in section 2.

The outcome of these measurements was a revision of the frequency allocations which had been made. The new plan was based on two groups of frequencies with a guard band between. At any one site, all transmitters were in one group of frequencies and all receivers in another group. As an additional safeguard against the desensitising of a receiver by a high powered transmitter, orthogonal polarisation of transmission and reception was proposed at each site, that is all transmissions were of one plane polarisation and all receptions were of the other polarisation. It was not expected that perfect protection

[2] Medlin, N. "160 Mc/s radiotelephone systems site engineering", Aust. Post Office Radio Section Report No. 42.

would be achieved by this means but a significant reduction of interference was assured and individual engineering was kept to a minimum.

This simple plan was marred, however, by the presence of four P.M.G. Department mobile services at the major centres. The mobile services were committed to vertical polarisation and used base transmitters of 250 watts output. These base transmitters shared a common site with the proposed single channel systems. The frequency allocation plan, as proposed finally, is shown in Fig. 2, which also gives pictorially some idea of the congestion of the spectrum in the major centres. It can be seen also that most of these systems are single hop systems using no repeaters.

4—THE SMALL CAPACITY BEARER SYSTEM

Up until 1955, experience with radio bearer systems of a capacity greater than about five channels had not been too encouraging. It was essential that the equipment to be used for this North Coast scheme should offer the utmost in robustness, reliability and maintenance simplicity. The specifications prepared by the Engineer-in-Chief clearly placed emphasis on these points. Although developments both overseas and in Australia indicated that systems with a much larger capacity were available at a much lower cost "per channel", the proved and tried type of VHF system was preferred to meet our needs. The specification was prepared and competitive tenders called. World wide interest was displayed in these requirements and many organisations of international repute tendered. Contracts were placed with Australian firms for equipment to be manufactured in this country. Field surveys[3] were being carried out concurrently with the calling of tenders and it was expected that a system would consist of two terminals and four repeaters. In the event, no North Coast System was planned with more than three repeaters. A total of sixteen terminals and twelve repeaters were needed to provide the proposed circuits between Maitland and Brisbane.

The frequency band allocated to these systems was 151-156 Mc/s and this is shared by the Postal Department and the Department of Civil Aviation and thus presented a simpler problem from the frequency allocation point of view. Even so, the frequencies previously had been allocated by random methods. A study was made by the Frequency Allocation Sub-Committee and a more flexible and rational distribution of available channels was made resulting in the allocations shown in Fig. 2. Again orthogonal polarisations are used as an additional safeguard. The basis of this allocation scheme is elaborated in the Appendix.

---

[3] Penhall, B. W. G., "Planning and field surveys for VHF radiotelephone systems", Proc. I.R.E. (Aust.), 20, Feb. 1959, 87-93.

[4] Robotham, P., "Propagation survey for a microwave multi-channel telephone trunk system Sydney-Maitland", S.T.C. London, International Report.

Distinct from these purely equipment problems were the problems of the design and construction of repeater stations, the purchase of steel towers, the construction of access roads, the installation of emergency generating plant and the laying of telephone cables to connect to radio terminals. By the careful siting of repeaters, new construction was kept to a minimum and a total of eight brick and two timber buildings were constructed for the Maitland to the Queensland border coverage.

5—MEDIUM AND LARGE CAPACITY SYSTEMS

These systems are more ambitious in their scope than the smaller systems. It came as a surprise to find that the equipment for a system of about 600 channels capacity could be bought for a cost within 20% of a system of only 60 channels capacity and about 100% more than a 12 channel capacity system. This has forced a re-appraisal of this phase of the scheme. To date, it has been decided to connect Sydney with Maitland, using a 600 channel capacity bearer system in place of a 60 channel capacity as first proposed.

The planning of this part of the whole scheme alone, could well be the subject of a paper by itself, but can only be touched on lightly here. Having selected sites for a possible route between Sydney and Maitland, the route was then investigated[4] for susceptibility to fading, overshoot, foreground scatter, etc., which are of significance with large capacity systems working in the 4,000 Mc/s band. This field investigation was carried out by an Anglo-Australian team of about 20 men. The survey took some eight weeks to complete working seven days a week and involved the raising and lowering of a portable guyed mast a large number of times. The lowest height reached by the mast was 75 feet at one site while it was necessary to raise the mast to a height of 200 feet on the most difficult site. These detailed preliminary works are necessary for large capacity systems in the present state of the art and, because of their duration, they do significantly affect the economics of any proposal. However, it is clear that the use of 12 channel systems would be uneconomic but the planning associated with the use of larger capacity systems is continuing and will take some time yet to complete.

PART II—INSTALLATION

6—SPECIFICATIONS

This part of the paper deals with the installation of radio equipment on the North Coast of New South Wales; the reasons for these installations were dealt with in Part I. The aim of the paper

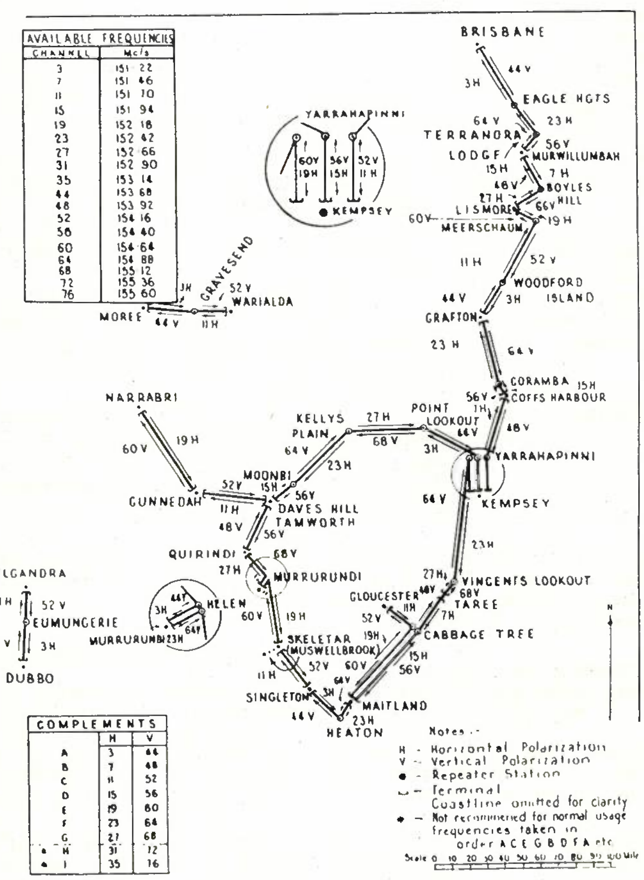


Fig. 2.—Small Capacity Bearer's Frequency Allocation.

is to give some idea of the extent of the radio trunk circuits and some of the difficulties confronted during their installation. To appreciate the problems of using radio for trunk lines it must be realised that the P.M.G.'s Department aims for a weighted channel noise level (1952 CCIF weighting network) from –60 dbmo for short haul trunks to –49 dbmo for long haul trunks. This noise level should be bettered for 99% of the time and includes noise from all sources including carrier equipment and cross-talk between channels. The channel distortion limit is represented by a maximum departure of half a decibel of the output level from the input level when a 800 c/s input tone of 0 dbmo is increased to +5dbmo.

The bulk of the radio equipment for this project has been supplied by two manufacturers and all comments are based upon experience with their equipment. A summary of the relevant equipment specifications is included in Table I. Where necessary the manufacturers' specification has been modified where our experience shows this is justified or where our use has necessitated some change.

The extent of the present and proposed VHF network was given in Part I of this paper; some idea of the amount of work involved can be had from the statistics which follow. A typical terminal station is shown in Fig. 3.

Table 1—Summary of Equipment

	Manufacturer 1	Manufacturer 2
Type of equipment	Single channel system for 156-170Mc/s	4 Channel bearer for 151-156 Mc/s
Transmitter power output (watts) (i) Standard (ii) PA fitted	 10 50	 15 100
Type of modulation	Phase	Phase
RF peak deviation for 0 dbmo input.	6.25 radians	1.25 radians
Transmitter carrier deviation	Crystal frequency multiplied 36 times.	Crystal frequency multiplied 54 times then 21 Mc/s added
Receiver noise factor.	9db (with RF filter)	9 db (with RF filter)
Receiver RF bandwidth (with filters 6 db as normally used) 60 db	20 kc/s 60 kc/s	180 kc/s 500 kc/s
Type of receiver.	Double conversion superheterodyne (IF 22 Mc/s and 1.7Mc/s.)	Single conversion superheterodyne (IF 21 Mc/s.)
Type of repeater	—	Non-Demodulating
Aerials	Manufactured by P.M.G. workshops, being 8 element yagi, having a nominal gain of 10 db, adjustable over the band 160-170 Mc/s and having a nominal impedance of 70 ohms.	

7—STATISTICS OF THE NORTH COAST OF NEW SOUTH WALES PROJECT

Since the inception of this scheme in mid 1955 till the present the installation staff have engaged in the following activities:

The erection of 22 towers of 60 to 120 ft. height having a total length of 2,000 ft and requiring the excavation of 225 cubic yards of rock and earth.

The erection of 36 poles for yagi aerial support having a total length of 1,800 ft.

The erection of 250 yagi aerials.

The running of 15,000 ft. of co-axial cable.

The fitting of 1,200 co-axial cable connectors.

The erection and interconnecting of 100 racks of radio equipment.

Radiotelephone equipment has been installed at 42 stations of which 30 were established solely for radio-telephone equipment.

20 single channel radiotelephone trunk systems have been installed providing 240 channel miles.

Eight 4-channel bearers have been installed providing 1,700 channel miles.

Four mobile telephone systems have been installed using 250 watt base transmitters.

Driven vehicles 500,000 miles.

The survey party have measured in detail the radio propagation characteristics of 150 paths varying in length from 3 to 67 miles.

The installation of 20 auto-start diesel generators from 1½ to 15 KVA capacity totalling 150 KVA solely for use at the isolated stations.

8—INTERFERENCE PROBLEMS

Co-channel Interference (i.e. Channels Sharing the same Frequency). The allocation of frequencies on the four channel bearer project was based on heavy protection by the "FM Capture" effect which test showed gave a protection of up to 50 db against the modulation on unwanted carrier which was down only 10 db on the wanted carrier, but great trouble has been experienced with the beat note between the unwanted and wanted carriers. The level of this beat note appears to be of the order of the level difference of the two carriers below the test tone, i.e., if the unwanted carrier is 40 db below the wanted carrier then the level of the beat note would be approximately –40 dbmo. The frequency of the beat note is the difference of the two carrier frequencies which gives a possible note frequency of zero to 10 kc/s. The solution to this problem appears to be either:

(a) higher tolerances on all oscillators (transmitter and receiver) coupled with very good temperature stability to assure that these resultant tones fall in the order wire spectrum (0 – 3 kc/s);

(b) greater difference of wanted to unwanted carrier levels at the receiver's input created by greater physical separation of co-channel stations or use of aerials with greater directivity; or

(c) greater RF deviation by the channels which would effectively reduce the level of the unwanted beat note.

Co-channel Interference by Reflection. This particular problem was one which is unique in all our experience in the 160 Mc/s band. It was encountered when the Maitland-Gloucester 4 channel system (with a repeater at Cabbage Tree) was being completed. The VHF bearer chain from Maitland to Brisbane had been installed and was carrying traffic; the relative location of this system is seen from Fig. 1. When the circuit was first established from Maitland to Gloucester very heavy intermittent noise in the order wire was reported accompanied by small variations in the received signal strength in the receiver at Cabbage Tree facing Gloucester. It was also reported that intermittently 2VF clearing tones could be heard on the system which was very intriguing as no carrier system had been connected to the system. On examining the frequency allocation plan it was noticed that a transmitter 100 miles away at Yarrahapinni was on the same frequency as the receiver at Cabbage Tree facing Gloucester (see Fig. 4 for profile); at this stage the Cabbage Tree receiver was connected to only one 8 element yagi although it was planned to fit 4 x 8 el yagis. A pen recorder was fitted to the receiver to record received signal strength and the Gloucester transmitter switched off. The interfering signal was identified as the suspected transmitter Yarrahapinni its level being about 4 μV, compared with the normal signal from Gloucester of 40 μV. When the recorder chart was examined after one day the cause of the intermittent interference was evident, the unwanted Yarrahapinni signal showed upwards fading of over 20 db.

A sample recording is shown in Fig. 5. The short duration of the upward fading may be noticed.

It was then decided to install the 4 x 8 el yagi array in the hope that the wanted signal would increase and the unwanted signal decrease. All that happened was that both signals increased by 7 db; the upward fading being still present to the same degree. An additional

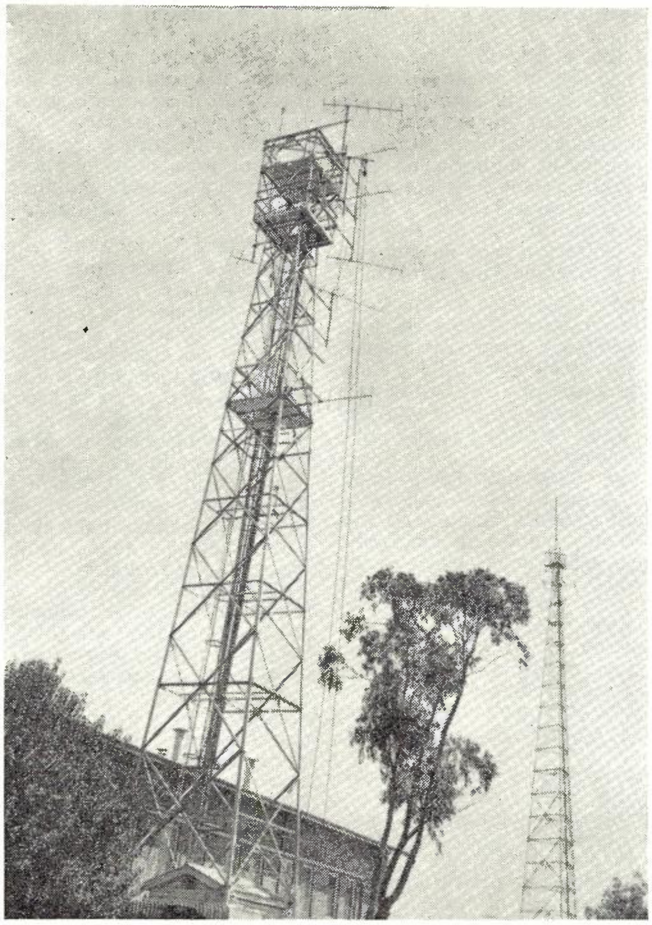


Fig. 3.—Typical Terminal Station (Kempsey Exchange).

8 el yagi was then erected but directed towards Yarrahapinni, the equivalent received signal was measured as 7 μV, being steady within $\pm$ 2 db over a period of 3 days. Calculation shows that the actual path loss w.r.t. half wave dipoles is 156 db between Cabbage Tree and Yarrahapinni; when calculated using Bullington's Method a path loss of 170 db is estimated though little is known of the accuracy of this method with such long paths.

The mystery still remained; why the upward fading only when the receiver aerial at Cabbage Tree was at right angles to Yarrahapinni and why did the signal increase as the gain of the array was increased? The logical deduction was that we were receiving a reflection, but why the frequent heavy upwards fading of very short duration? Now examining Fig. 6, which is a plan view of the Cabbage Tree site, a line of trees will be noticed in the direction of Gloucester; these trees were 100 ft. high and when viewed from the aerial tower (95 ft.) they appeared higher. These trees were originally left in situ to preserve as much natural vegetation as possible, as the site is in the middle of a State forest, and also past experience at 160 Mc/s had shown that such trees had very little effect on path loss. The trees were duly removed and later pen recordings of received signal strength from Yarrahappini show complete absences of the upwards fading previously experienced.

Precipitation Static. A bad form of interference which has been experienced on most of the bearer circuits is that which we assumed to be electrostatic discharge. Its nature is a "crackle" which gradually increases to a roar having a level of over 0 dbmo in the order wire and has been measured in traffic channels at about –20 dbmo. It occurs during the build up of storms at repeater stations, starting 15 to 30 minutes before the rain starts, as soon as the rain begins the noise gradually abates and is gone within 5 minutes. All noises of this type have been proved to originate from receivers at high, exposed repeater stations; there is definitely no link with lightning flashes. Due to the random nature and brevity of this noise it has been difficult to try out any possible solutions, the only one that has been suggested to date is covering or painting the dipole of the yagi with an insulating medium. It has been asserted that the yagi aerials that feed the noisy receiver are not always at the top of the towers.

Car Ignition. One important observation has been noted with the bearer equipment. The level of the audio noise from motor vehicle ignition is not a function of the discriminator off balance current due to the incoming carrier being off frequency, but is dependent to a very large extent on the position of the wanted carrier in the pass band of the receiver relative to the peak of the IF response curve. This effect was first noticed when trouble was experienced with drift in the tuning of IF transformers and the peak of the IF response curve was 100 to 200 kc/s off the carrier frequency. It was then noticed that noise due to ignition was reduced by around 20 db when the carrier frequency was shifted to the peak of the IF response curve even though the discriminator showed an out of balance current corresponding to 100 to 200 kc/s.

To minimise this effect stable IF tuned circuits and crystal oscillators (receiver and transmitter) are required, a suggested overall stability being $\pm$ 30 kc/s for this type of bearer equipment as it was observed that a shift in the carrier frequency of this order caused only a slight rise in noise due to ignition. Another approach may be a different shaped IF pass band as noise is no doubt

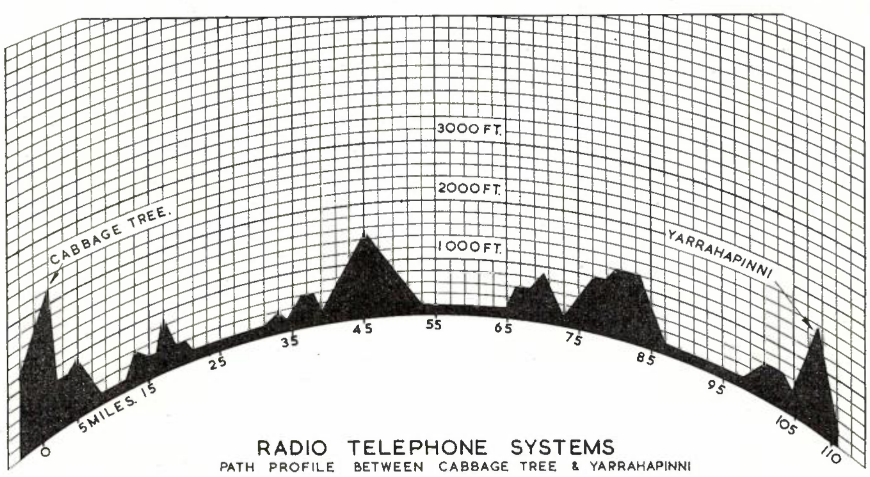


Fig. 4.—Cabbage Tree-Yarrahapinni Profile.

a function of the phase shift and amplitude characteristics of the IF amplifier. The noise appears to be due to the conversion of the amplitude variations of the ignition pulse to phase variations thus rendering the limiters ineffective.

Ignition noise determines the level of the carrier required and at a typical town site this is around 400 μV (–55 dbm). For the bearer equipment used this allows the lower carrier channels to meet the required signal-to-noise ratio. This signal level is for the 10 db gain yagi aerials used and is modified by the relation of the ignition noise source to the direction of the aerial; a figure of around 100 μV might otherwise be acceptable. These figures allow only a small margin for equipment deterioration or path fades.

Transmitter Spurious Outputs. Great trouble has been experienced with interference between transmitters and receivers at the various sites and this has been attributed to the multitude of spurious outputs from the transmitters at 90 to 120 db below the normal output. The transmitters in question obtain their final frequency by first multiplying up from a 4 to 5 Mc/s crystal, then a fixed frequency is mixed two stages from the output to obtain the final 150-170 Mc/s. This last action appears to be the source of a multitude of unwanted outputs.

As an average we were forced to fit 50% of the transmitters with RF cavity filters between their outputs and aerials. At these installations the separation between transmit and receive frequencies is approximately 2.5 Mc/s though as low as 1 Mc/s in one instance. Prior to fitting the filter the interference is recognised by the presence of a tone in the receiver's output, which would appear in one of the carrier channels and make it unacceptable for traffic. Often the unwanted signal is readily seen on the receiver's signal strength meter (limiter grid current) when the wanted signal has failed. As a precautionary measure we now fit filters to reduce all unwanted signals to at least 40 db below the wanted signal.

Summarising we would say that the limit, given in the Department's specification for this equipment, of 80 db down for spurious outputs from transmitters should be modified by a weighting factor which would give limits of 120 db to 150 db at frequency differences corresponding to envisaged transmit, receive frequency separations.

9.—EQUIPMENT PROBLEMS

Most of the equipment troubles have been due to lack of exchange of ideas and comments between the manufacturer and customer during the prototype stage of development, but even so, the number of changes necessitated by underrated components (especially wattage rating of resistors) has been far too high. Also a factor which should be considered more carefully in all electronic equipment is cooling and to this end a very good article has been written by E. N. Shaw[5]. Our application of the principles expounded in this article to a transistor amplifier which had to be incorporated in conventional electronic equipment has reduced the transistor temperature considerably and made the unit workable and on examining the equipment in general use we feel a useful contribution to reliability certainly would result. A short summary of some of the troubles encountered in equipment used on the project is given in the following sections.

Yagi Aerials. Great trouble has been experienced with water finding its way into aerials which we attempted to make watertight; the result is usually a loss in gain of the order of 10 to 20 db and sometimes this loss is of a varying nature. This water trouble has apparently a number of causes:

(a) The yagi aerial used has a large included air volume which apparently contracts during sudden storms and the reduced pressure sucks in moisture through any small holes which may exist. The smaller the holes the worse the trouble as a water film is able to cover them, which ensures that the water enters the interior.

(b) The yagi aerial is adjustable in element lengths and reflector spacing, the adjustable parts are apparently a source of air leaks and consequently water enters.

(c) Inspection covers are large and flexible, making sealing difficult.

(d) The co-axial connection is not shrouded and taping has not proved successful due to proximity of the mounting pipe which prevents perfect application of any tape. Lack of suitable tape for use in all weathers (especially at low temperatures) aggravates the situation. Some type of suitable material which could be applied with a brush may be the answer.

(e) A co-axial matching section is enclosed in the boom to convert the dipole impedance to 70 ohms, this component has proved very susceptible to moisture; alternate means of impedance correction is necessary.

(f) In one batch of aerials steel spring washers were used in dipole assembly, in a matter of a few months these rusted away and caused additional water leaks.

Resistors. On a number of occasions staff have traced noise in a receiver's output to carbon resistors carrying DC. When replaced the noise disappeared. Wider use of wire wound resistors would be appreciated and could be instigated with a little ingenuity. Numerous underrated resistors have also been discovered. As a design procedure it is suggested that all components be listed with their working conditions, obvious cases of wrong rating would then be discovered. The largest practical margin is suggested in wattage ratings remembering that in most equipment the conditions are far from those of free air.

Another problem which is evident is the early failure of miniature ($\frac{1}{4}$ watt and less) resistors when DC is carried by them; failures were running as high as 50% in a particular case with a 1 megohm resistor within one month of installation of the equipment. The solution has been to replace all these resistors with half watt units; no failures have since been recorded. The power dissipated by these particular components was only 0.04 watts and in all cases of failure the resistance had increased to twice or more its normal value when discovered.

Transformers. The failure rate of power transformers of one make of equipment has been unduly high, these were all of the potted type the nature of the fault has been swelling of the

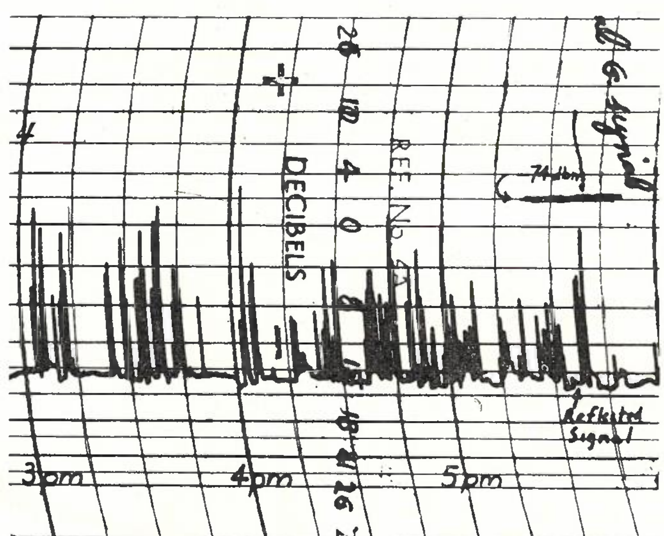


Fig. 5.—Typical Receiver Output Record due to Reflection of Yarrahapinni Signal by 100 ft. trees at Cabbage Tree..

Frequency: 151.22 Mc/s.
100 Watt Transmitter and yagi Aerial of 10 db gain.
Receiver Aerial: 16 db gain yagi.
Co-axial Cable loss 4 db.
Direct Signal Level: –84dbm.

[5] Shaw, E. N., "Heat control in electronic equipment", Electronic Eng., 29, 1957, 13-23, 65-70, 115-118.

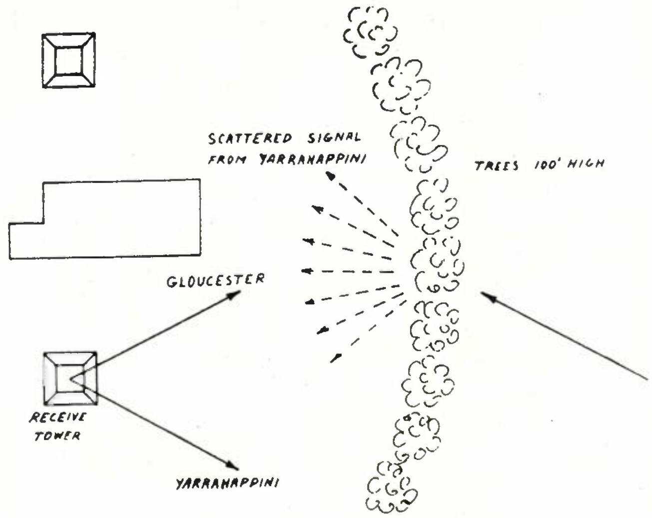


Fig. 6.—Cabbage Tree Site Plan.

transformer box type casing till they were spherical in shape and if not noticed in time they literally exploded. The only electrical effects prior to complete failure have been gradual decrease in output voltage. In another make of equipment the failure rates of audio transformers (again of a potted variety) appears to be high, though sufficient operational time is not available to be conclusive. Apparently potting techniques are not as advanced as we are led to believe.

Vacuum Tube Rectifiers. Again the failure rate is very high when they are worked near their voltage limits (5U4, 5R4's to give 500 to 600 volts). A common failure has been sagging of the filaments when the envelope is mounted in a horizontal plane with the filament in a nominal vertical plane as recommended by manufacturers. The resulting shorts blow fuses, no fault is evident when the fuses are repaired as the filament has cooled and so the true cause remains undetected. The control of the internal structure position relative to the valve base key is very poor, of the order of $\pm 30^{\circ}$. The advent of silicon rectifiers should solve most rectifier problems and their general use is expected in the near future.

Relays. The less said of this problem the better, but it has always been thought that contacts of relays should be mounted vertical so that dust will not settle on the contacts; why some manufacturers differ we do not know.

Switch-hook. Again this design is so fundamental that criticism should not be necessary, but why no follow through to allow contact wiping when the switch-hook is operated?

From the above faults it may be inferred that while a manufacturer channels a lot of engineering effort to the design of say an extremely linear modulator or a very stable oscillator and many experts are consulted for the capacitor with just the right temperature co-efficient, the office boy is allowed to twiddle a slide rule and arrive at the all important factor of the wattage rating of a resistor or the typist suggests that a relay should be mounted a particular way to balance a transformer on the other side of the chassis for appearance sake. All the blame cannot be laid on the manufacturer either. The customer generally has many experienced staff who should be called in at the prototype stage, as we all realise that a manufacturer cannot make even the simplest change once the production is started without greatly increasing costs.

10. SPECIAL DEVELOPMENT PROJECT OF A SYSTEM FOR AUTOMATIC WORKING.

When the contract for VHF Single Channel Equipment was originally let in 1955, equipment capable of working between manual exchanges only was specified. In later years there has been a growing tendency to install RAX's (i.e. Rural Automatic Exchanges) whenever possible and so at the present time 70% of the Radio-telephone single channel installations are between manual exchanges and RAX's. This necessitated a modification to the equipment to allow dialling; two approaches were possible, either use one of the well known tone dialling methods or make the radio equipment itself capable of transmitting DC conditions presented to it, that is, O/C or S/C.

Tone dialling was examined briefly, but it was found that in all cases inband dialling was too complicated and the various tones used were far from standard; e.g. 600 and 750 c/s, 2,220 and 1980 c/s, and 2,200 c/s single frequency. Edge of band dialling also appeared rather complex in filter requirements and

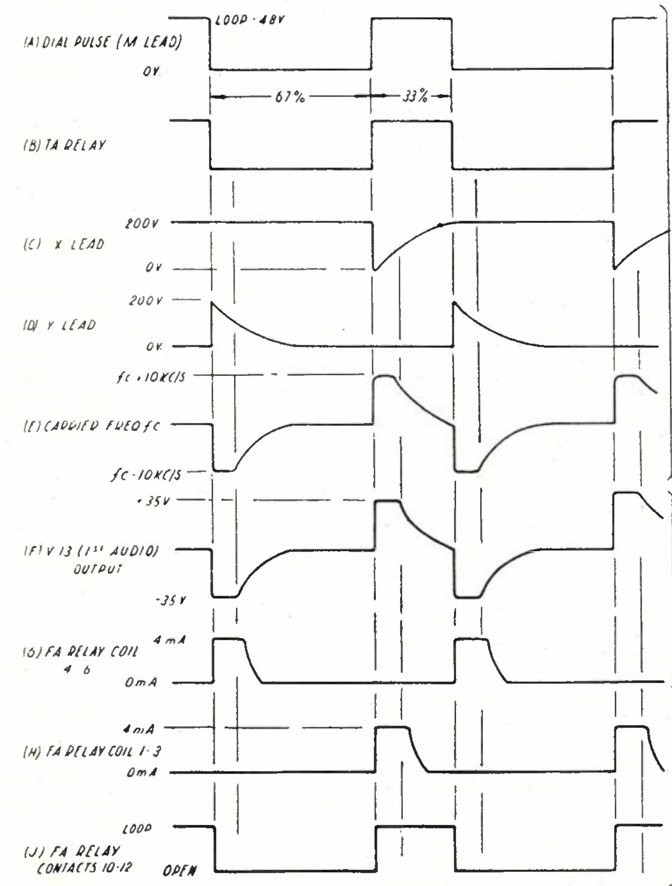


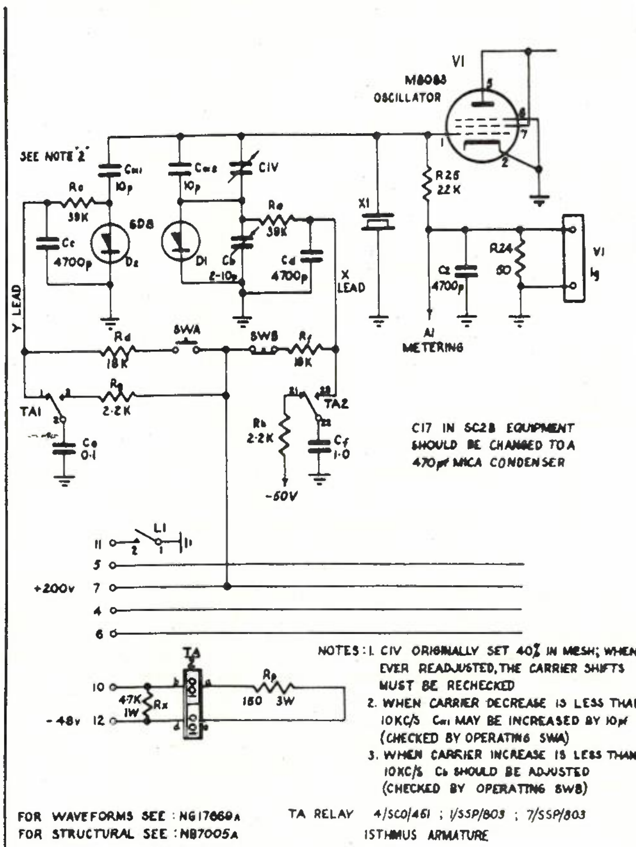
Fig. 7.—RF Carrier Shift Dialling System Operational Waveforms.

again tone frequencies were not standardised; e.g. 3,450, 3,700, 3,800 or 3,850 c/s have all been used. Also such a variety of tones are used to indicate busy tone, ring tone, etc., that any method for dialling using tones for signalling must be approached with extreme caution. Out of band dialling was another possibility, especially as the radio equipment had a bandwidth up to 8 kc/s and only simple filters would be required but this would have precluded the possibility of adding a single channel carrier system which was considered as a future possibility.

Next the idea of an RF carrier shift DC loop was considered. The carrier frequency (160 Mc/s) is shifted 15 kc/s when the line is un-looped, then when loop is presented to the system the carrier frequency is returned to normal. This shift in carrier is sensed at the distant receiver. This method was not tried because of the desirability of having all equipment operating on their allocated frequencies within 0.001%, so as to prevent interference. Operating the discriminator so far off frequency would probably prevent the use of a future single channel carrier system, and also the use of the system when unlooped, which is necessary under certain operating conditions.

It was then decided to use RF carrier shift but having shift present only to indicate the change of state, i.e., we would raise the carrier frequency 10 kc/s for 10 ms to indicate the looping of the circuit, then lower the frequency 10 kc/s for 10 ms to indicate the removal of the loop (Fig. 7). These shifts are obtained by switching capacitors in and out of the crystal oscillator circuit, the duration of the switching being determined by a capacitor discharging through a diode. (Fig. 8). At the distant receiver these frequency shifts are amplified in a transistor frequency selective, amplitude selective, gating circuit. This amplifier attenuates frequencies above 30 c/s at 6 db octave, rejects all pulses of amplitude less than 22 volts input and limits on signals of 28 volts. This circuit provides the necessary voice frequency protection except for a very low frequency, high level whistle which is extremely artificial and never likely to be met in practice. The output of this amplifier drives the coils of a polarised relay which is pulsed to either of its two stable positions, representing O/C or S/C, by the carrier frequency shift pulses. Dialling speeds of 10 c/s are easily accommodated and indications are that impulse speeds of 30 c/s could be carried with very little distortion. One advantage of using positive and negative frequency shifts is that if for some reason a transmitter pulse is missed by the receiver then the circuit will reset itself to the correct sequence of operation on the next pulse. Sequential operation by a positive pulse only allows the send and receive circuits to stay out of synchronism till another pulse is missed.

The final result is a dialling system which gives very reliable performance once initially adjusted, which may be interconnected with the normal trunk network, and is inherently immune from false operation by the various tones in use today. At present this type of system is serving seven RAX's with many more to come.



TRANSMITTER MODIFICATION

Fig. 8.—Frequency Shift Transmitter Circuit for Dialling.

CONCLUSION

This paper is meant as a helpful guide in a limited sense to both the manufacturer and the user of equipment similar to that used by P.M.G. Department on the North Coast of New South Wales and in fairness to the manufacturers we must say that the equipment used has many good features which have not been mentioned, we also feel that they are capable of producing equipment just that little better if attention is given to what is generally thought of as minor details. We feel that the customer is also at fault in not ensuring a constant flow of comments back to the manufacturer but as most engineers dislike writing reports we feel that flow of this information could be helped by personal contact between the engineers concerned. We know that some manufacturers encourage this by sending the engineer responsible for the design of the equipment into the field, but with others all communication is via their sales personnel who, although willing, are not usually closely associated with the particular equipment in its design stages.

Another factor which would benefit both the manufacturer and customer would be interchange of engineering personnel. At the present this is virtually non-existent due to the individual long service leave, superannuation and sickness schemes operated by both private and government organisations. If a unified scheme could be organised, then the exchange of experienced personnel between manufacturer and customer would be encouraged and one of the greatest drawbacks to the development of the Australian manufacturing industry would be overcome. Perhaps the various associations concerned with the salaries and conditions of professional engineers could arrange such a unified "fringe benefits" scheme.

ACKNOWLEDGMENTS

This scheme is the outcome of the extended efforts of countless people. It would be wrong to suggest that there was unanimity among all concerned. There have been moments of doubt, occasions of disagreement, periods of argument and displays, at times, of acrimony even. The authors acknowledge the honest intentions of all those people involved and admit that without those stimulating incidents of dissension the project, still unfinished, would have lost some of its interest. Clearly, this scheme has involved many many people and organisations and the omission of any names in the following long list should not be misinterpreted; the authors have enjoyed the co-operation of all

from whom they have sought it including:

Amalgamated Wireless (Australasia) Ltd.
British Insulated Callender's Cables (Aust.) Pty. Ltd.
Commonwealth Department of the Interior.
Commonwealth Department of Works.
Commonwealth Electronics Pty. Ltd.
Deeco Constructions Pty. Ltd.
Forestry Commission of New South Wales.
Frequency Allocations Sub-Committee.
Hornibrook Mackenzie Clark Pty. Ltd.
Local Electricity Authorities.
New South Wales Department of Lands.
Numerous Shire and Municipal Councils.
Postal Workshops Melbourne and Sydney.
Radio Section, A.P.O. Engineer-in-Chief's Branch.
Standard Telecommunication's Laboratories Ltd., London.
Standard Telephones and Cables Pty. Ltd.
State Electricity Commission, New South Wales.
Telecommunication Company of Australia Pty. Ltd.
And countless landowners and tenants who have exhibited generous patience towards our field parties.

The length of this list, by no means exhaustive, is an indication of the vastness of the whole undertaking.

Finally a special tribute is made to the men at the end of the line, those who dig the holes, mix the concrete, tighten the nuts and bolts, terminate the cables and divorce themselves from their domestic circles for months on end to finish, in the field and at the top of windswept mountains, what we engineers have devised in our warm comfortable offices: of those men we made especial reference to R. T. Bedford and his staff of riggers engaged on tower construction and pole erection and to K. E. Piltz and his technical staff installing the equipment.

Any opinions expressed in this paper do not necessarily reflect the official opinion of the Postmaster-General's Department and the permission of the Engineer-in-Chief to deliver this paper is gratefully acknowledged.

APPENDIX

Rationalised Frequency Allocation Scheme for the 151-156 Mc/s Band

Let the band be divided into channels separated by d Mc/s and let the first channel be at F + d Mc/s, then channel 2 is F + 2d Mc/s, channel 3 is F + 3d Mc/s and odd channels are F + (2a + 1) d Mc/s. Consider two channels A Mc/s and B Mc/s in the band, then the intermodulation products which lie in the band are of the type 2A − B, 3A − 2B, 4A − 3B . . . and 2B − A, 3B − 2A, 4B − 3A . . . .

If A = B − x then all these intermodulation products form the series A − x, A − 2x, A − 3x, . . . A − nx, . . . B + x, B + 2x, B + 3x, . . . B + nx . .

Now let there be two transmitters on **odd** channels.

$$A = F + (2p - 1)\,d \text{ and}$$
$$B = F + (2q - 1)\,d$$

The frequency difference is x = 2 (q − p) d and the intermodulation series are then

$$A - 2(q-p)d,\ A - 2x2(q-p)d,\ \ldots\ A - 2n(q-p)d\ \ldots$$
$$B + 2(q-p)d,\ B + 2x2(q-p)d,\ \ldots\ B + 2n(q-p)d\ \ldots$$

For all values of p and q from 0 to infinity, these products are odd numbered chanels. Thus all simple intermodulation products generated by odd numbered channels appear only in odd numbered channels. Similarly, simple intermodulation products from even numbered channels appear only in even numbered channels.

Considering, now, the more complex products of the form A + B − C, A + 2B − 2C, A + B + C − D − E etc., etc., similar reasoning to the above reveals that "all odd" channels have odd intermodulation products and "all even" channels have even intermodulation products.

The conclusion, therefore, is that at multi-system sites transmitter intermodulation products may be prevented by assigning only odd numbered channels to transmitters and even numbered channels to receivers or vice versa.

Using this concept the frequency allocations in the 151-156 Mc/s band using d = 60 kc/s basic spacing and F = 151.04 Mc/s have been made as shown in Table 2.

TABLE 2

Rationalised Frequency Allocation

Channel	Allocations	Frequency Mc/s
1	C	151.10
3	P	151.22
5	C	151.34
7	P	151.46
9	C	151.58
11	P	151.70
13	C	151.82
15	P	151.94
17	C	152.06
19	P	152.18
21	C	152.30
23	P	152.42
25	C	152.54
27	P	152.66
29	C	152.78
31	N	152.90
33	C	153.02
35	N	153.14
37	C	153.26
39	N	153.38
41	C	153.50
	60 kc/s gap	
42	C	153.56
44	P	153.68
46	C	153.80
48	P	153.92
50	C	154.04
52	P	154.16
54	C	154.28
56	P	154.40
58	C	154.52
60	P	154.64
62	C	154.76
64	P	154.88
66	C	155.00
68	P	155.12
70	C	155.24
72	N	155.36
74	C	155.48
76	N	155.60
78	C	155.72
80	N	155.84
82	C	155.96

C signifies a D.C.A. allocation.

P signifies a P.M.G. allocation.

N signifies not allocated.

A complement for spanning one path in both directions is made up from two allocations 2.46 Mc/s apart, e.g., 1 and 42, 27 and 68 etc.

TECHNICAL NEWS ITEM

TELSTA ELECTRIC WORK PLATFORM

Two "Telsta" Electric Work Platform units have recently been purchased for use in external plant divisions in N.S.W. and Victoria. The Telsta unit, which is used extensively by the Bell Telephone Companies in America, has particular application in running aerial cable and bearer wires. The machine also has application for working on dangerous poles where it would otherwise be necessary to stay the pole so that it will safely support ladders. A further use is for working on poles or wires in difficult situations and for jointing aerial cables mid span between supporting poles where the use of ladders presents problems.

In Fig 1 the machine is being used to assist in the erection of plastic cable by means of a cable lashing machine.

Some interesting features of the "Telsta" unit are as follows:—

(a) The basket is carried at the end of an extendable arm which is mounted on a turret capable of rotation through 360°. This turret is mounted on a 5-ton truck chassis and contains in its base a motor generator which powers all movements of the work platform and, in addition provides 230 volt power at the basket for using electric hand tools such as drills and impact wrenches.

(b) The movement of the basket is controlled by a simple joy stick. A button in the top of the joy stick is depressed by the thumb, after which the knob is merely moved in the direction in which it is desired the basket should travel. The basket can be moved to any position up to 28 ft. sideways from the truck and 30 ft. high, and can be so placed that with the truck standing in the centre of a roadway, traffic can flow safely under the arm while a workman works on the pole. This facility is important in dense traffic where closing of the road would be impracticable, a feature which makes the machine particularly useful on some of the long bridges and heavily used traffic lanes in America, and may also prove of use in Australia.

(c) There is two way communication between the driver in the cab and the operator in the basket. The operator speaks in a normal voice, preferably with his face toward the combination speaker-microphone, and conversation is comfortable under most conditions of traffic noise.

(d) In the event of an accident to a workman in the basket, a master control mounted in the turret of the unit takes precedence over the control in the basket and the driver of the truck can therefore return the basket safely to ground.

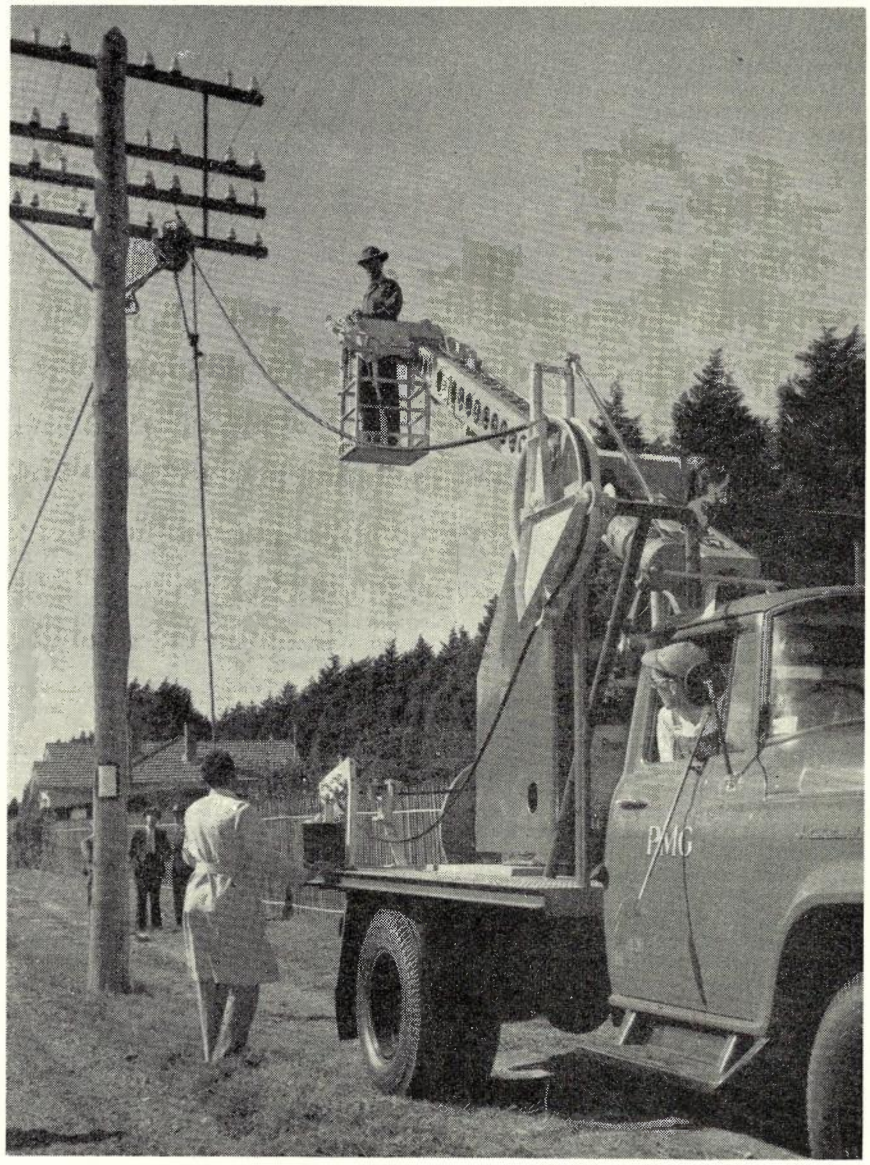


Fig. 1.—The "Telsta" Work Platform.

(e) As a safety measure, the basket is insulated from the truck, and the American practice is to issue staff with plastic insulating helmets. With these two devices the workman is considered reasonably safe from electrical hazards provided, of course, that normal precautions are taken.

(f) When running bearer wire or cable along poles, the bearer wire or cable is mounted on a drum at the rear of the truck and rotation of this drum is controlled by an electric clutch, the pressure on which is varied by a simple knob.

This machine is expected to result in substantial economies in the man-hours necessary to carry out many operations on aerial routes.

OUR CONTRIBUTORS

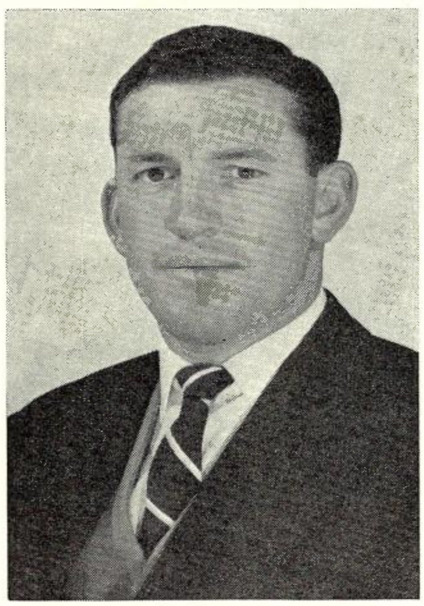
The Board of Editors has decided to adopt a reader's suggestion that in future we publish a photograph and short biographical note on each of our contributors. This follows the practice used in many other Journals and we expect that it will help to add interest to our own Journal.

R. W. Turnbull

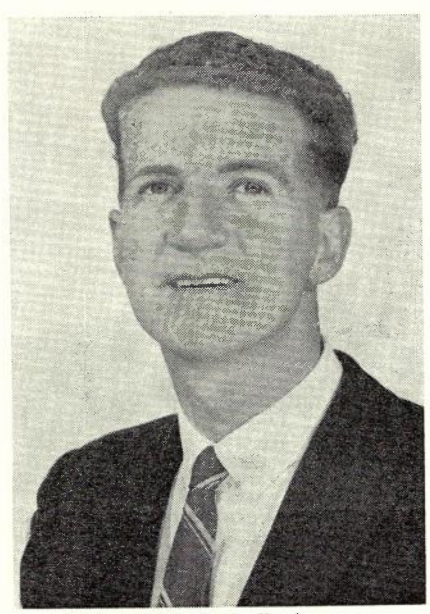
R. W. TURNBULL, Co-author of "The National Telephone Plan—Switching", joined the Post Office as a Cadet Engineer in Sydney, N.S.W. and was promoted as Engineer in N.S.W. in 1937. He holds the Diploma in Electrical Engineering of the Sydney Technical College. In 1945 he was transferred to Post Office Headquarters, Melbourne, where, for ten years, he participated in developmental activities during a period of unprecedented national growth. He was closely associated with the industry established for the manufacture of automatic switching equipment in Australia. In 1955, with the status of Superintending Engineer, he was assigned the task of examining the major problems confronting the Post Office in the development of the telephone system. Following overseas studies in 1956 he was appointed Chairman of a special Post Office planning group, the Automatic Network and Switching Objectives (A.N.S.O.) Committee which prepared the plans adopted for the long term development of the Australian telephone system.

Mr. Turnbull was a member of the Board of Editors of this Journal from 1948 to 1953.

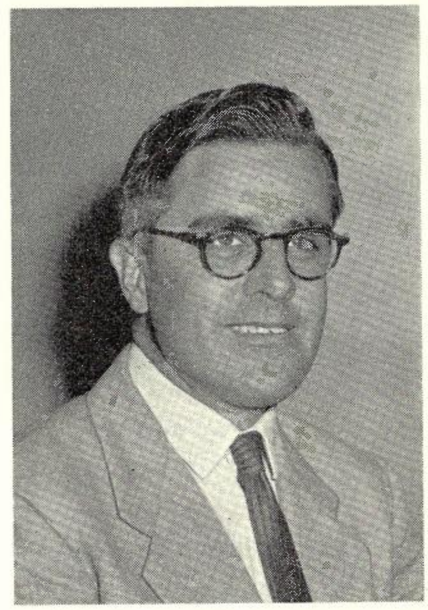
G. E. HAMS, co-author of the article "The National Telephone Plan—Switching", commenced with the Department as a Cadet Engineer in 1947. During his period of training he graduated as Bachelor of Science at the University of Melbourne. At the completion of the Cadetship he worked in the Victorian Administration, first in Telephone Planning and later in Trunk Service, where he assisted in controlling the maintenance of the Melbourne carrier equipment terminal and the semi-automatic trunk exchange. In 1955 he was promoted to the Central Administration as Divisional Engineer in the Systems Planning Section. In 1957 he was co-opted to assist the ANSO Committee in the preparation of the national telephone plan for Australia. He became a member of the Committee in 1958.



G. E. Hams



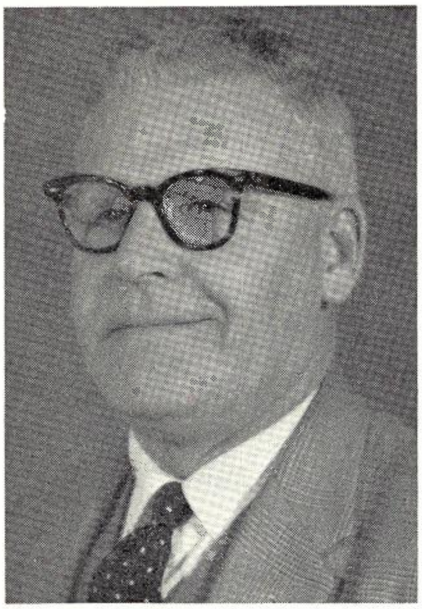
W. J. B. Pollock



N. D. Strachan

N. D. STRACHAN, author of the article "The Toowoomba Crossbar Exchange," is the Divisional Engineer, Toowoomba Project. He was born in Brisbane and after completing a course of Electrical Communications at the University of Queensland, commenced with the Postmaster-General's Department as an Engineer at the beginning of 1949. He served for some years on Metropolitan Installations and Service, and since 1952 has been with the Country Equipment Installation Division. He was appointed Divisional Engineer of the latter Division in 1958.

W. J. B. POLLOCK, co-author of the article "The National Telephone Plan—Switching", joined the Department as a Junior Mechanic in 1938. He served in the Engineering Division in Victoria as Technician and Clerk. After service in the A.I.F. he was transferred in 1945 as a Traffic Officer to the Telephone Branch. Mr. Pollock worked on the Headquarters staff of the Telecommunications Division in the telephone service, and telephone and telegraph planning and commercial fields since 1945. He was appointed to his present position of Assistant Controller, Planning and Development Branch, in 1955. He was a member of the Tariff Committee in 1955 and became a member of the A.N.S.O. Committee when it was established in October, 1956. He holds the degree of Bachelor of Commerce (Melbourne).



J. Medcalfe-Moore

J. MEDCALFE-MOORE, author of the article "The Perth-Derby Radio Link", Group Engineer, Radio Installation, Perth, was born at Stratford-on-Avon, England, in 1912. His first radio experience was gained with Messrs. Siemens Bros. of London, and he later joined the British Post Office, working in the Engineering (Radio) Branch. He then served with the Posts and Telegraphs Department, Malaya, and during World War II was interned by the Japanese in Changi Jail and later in Sime Road prison camp, Singapore. In the post-war years Mr. Medcalfe-Moore worked on the rehabilitation of telecommunications in Malaya and Singapore. From 1953 to 1957 he was Controller, Telecommunications Department, Singapore.

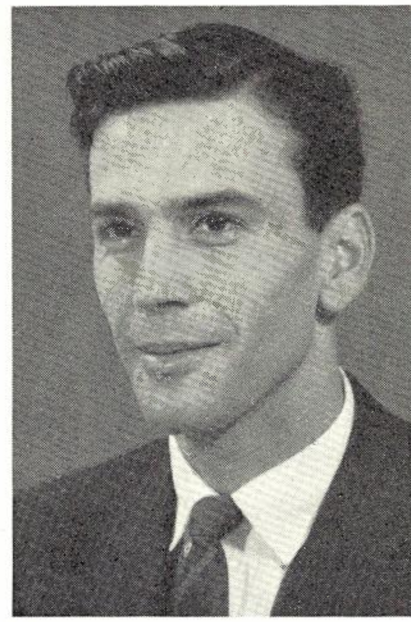
Mr. Medcalfe-Moore resigned from H.M. Civil Service in 1957 when the Malayanisation of the Public Services in Singapore was undertaken. He joined the Postmaster-General's Department in the same year and has since been employed on radio installation. He is an Associate Member of the Institute of Electrical Engineers and an Associate Member of the British Institute of Radio Engineers.

R. A. LOCKHEAD, author of the article "Crosstalk Improvement on the Sydney-Maitland Cable", was born at Scone, N.S.W., in 1923. He received his engineering training at the Ashfield Works of Amalgamated Wireless (A/asia) Limited and as a Development Engineer with this Company he was associated with the production of a wide range of radio transmitting and receiving equipment. In 1955 he joined the Postmaster-General's Department and was attached to the Long Line and Country Installation Section, where he was engaged on the installation of open wire and cable carrier systems. He was transferred to the Transmission Planning Section in 1957. At present he is concerned with the preparation of open wire and cable bearers for carrier and V.F. circuits and the co-ordination of power transmission lines.

Mr. Lochhead holds a Diploma in both Electrical and Radio Engineering and is an Associate Member of the Institute of Electrical Engineers, London and the Institution of Engineers, Australia.

R. A. Lockhead

E. Rumpelt



N. Brayley

N. BRAYLEY, author of the article "The Perth Terminal of the Australian-London Radio Link", was born in 1932 in India, and was educated at Sherwood College, Naini Tal, in the Himalayas and later at Guildford Grammar School and the Leederville Technical College, Perth. He obtained a Cadetship with the Perth Technical College and undertook a full-time associateship course in Electrical Engineering, graduating in 1954. In the following two years he also completed a part-time Diploma in Electronic Engineering. Prior to entering the Postmaster-General's Department, he was a Sales Engineer with Philips Electrical Industries in Perth, dealing with electronic equipment and sound and lighting installations. In 1956 he joined the Postmaster-General's Department and has since been associated with the maintenance of metropolitan exchange and carrier telephone and telegraph equipment.

E. RUMPELT, author of the series of articles on filter design, is a Divisional Engineer in the Research Section, Central Office. From 1937 to 1939 he worked in the Central Laboratories of Siemens and Halske, Berlin, and in the period 1940-1948 was on the staff of the Technische Hochschule at Munich. In this latter appointment he specialised in methods of filter design, in particular the modern insertion loss method, working under the guidance of Professor H. Piloty, one of the pioneers of this method. Since 1948 Dr. Rumpelt has worked in Research Laboratories, Central Office, where he is mainly concerned with Network theory and design.

Dr. Rumpelt graduated from the Technische Hochschule, Munich in 1937 with the qualification Dipl. Ing., and in 1947 gained the Dr. Ing. degree.

K. A. Curley

K. A. CURLEY, author of the article "A Tariff Pulse Generator", joined the Department in 1946 as a Technician's Assistant. He worked initially in telephone maintenance in Melbourne and in 1953 joined the Circuit Laboratory, Telephone Equipment Section, Central Office. He has acted as a Group Engineer at the Circuit Laboratory and is now Supervising Technician, Grade III, in charge of the Laboratory Technical staff.

W. G. PENHALL, co-author of the article "The N.S.W. Trunk Radio Network", was educated at Homebush Boys'

W. G. Penhall

High School and subsequently gained his B.E. degree at the N.S.W. University of Technology in March, 1955. After graduating in Electrical Engineering, he continued his cadetship with the Postmaster-General's Department in various engineering Departments for one year, gaining experience with a variety of communication equipment. In 1956 he commenced work with the Radio Telephone Installation Division, N.S.W. initially in charge of the Survey Party, and his work then encompassed the planning and preparation of proposals for the 4-channel and single channel V.H.F. systems on the North Coast of N.S.W. Since late 1957 Mr. Penhall has been controlling the installation of these systems.

E. F. SANDBACH, author of the article "Time Signals in Australia", received his B.Sc. and B.A. degrees from the University of Melbourne in 1943 and 1950 respectively. He first joined the Research Laboratories staff in 1943 when he was concerned with the investigation and development of pulse modulated microwave radio equipment and

E. F. Sandbach

later the development of a V.H.F. multichannel frequency modulated radio system. After a period spent on design of V.H.F. receivers he was appointed to his present position of Divisional Engineer (Frequency and Time Standards) where his duties have concerned the development and operation of the Post Office frequency standard installation, special frequency measuring equipment, and high precision oscillators.

V. J. WHITE, author of the article "The Prevention of Accidents", joined the Department as a Cadet Engineer in

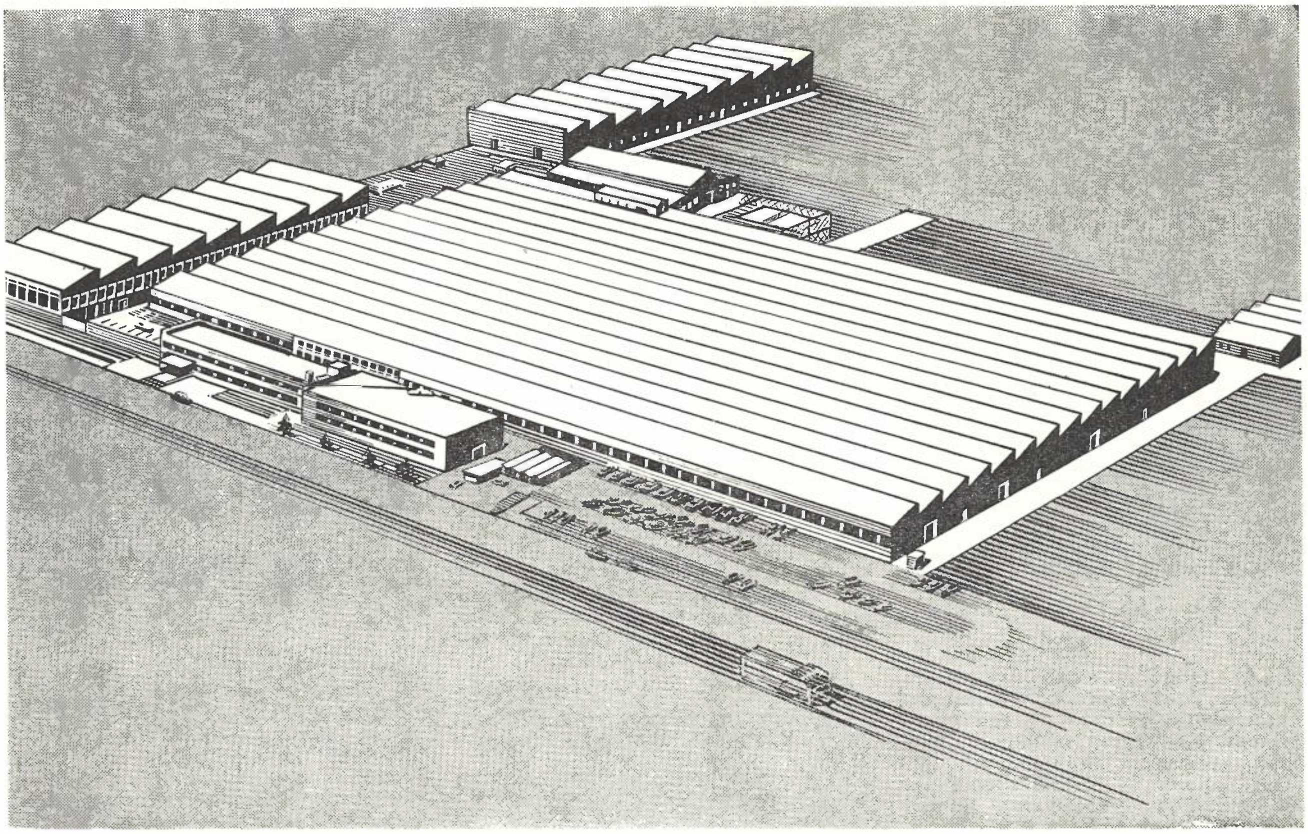
V. J. White

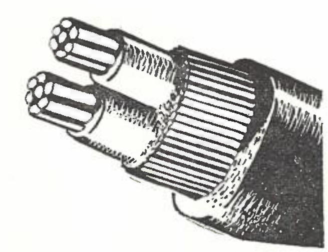
W.A. in 1941. After early experience in the Metropolitan District Works Division, Perth, he acted as Divisional Engineer, Planning, External Plant. He was appointed Divisional Engineer, Lines Section, Central Office, in 1955, and is now Sectional Engineer, Works Methods and Practices in that Section.

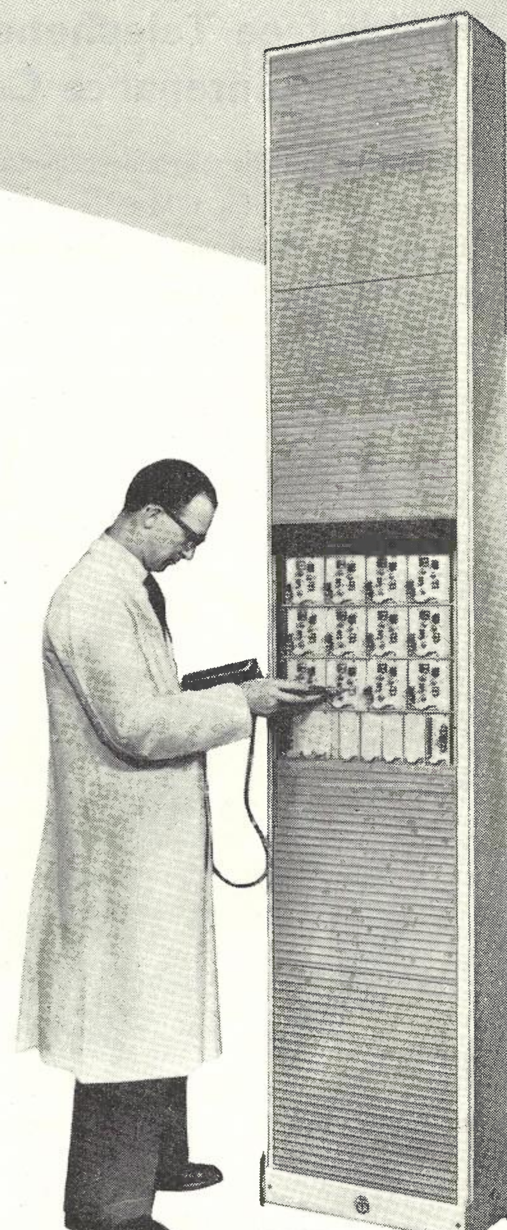
Mr. White holds the degrees of Bachelor of Science and Bachelor of Arts from the University of Western Australia and for a brief period in 1953-54 worked as a Psychologist in the Australian Regular Army. He is an Associate Member of the Institution of Engineers (Australia) and a Member of the British Psychological Society. In 1958 he became a member of the Board of Editors of this Journal.

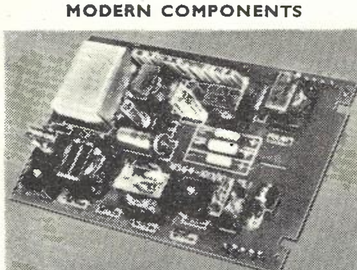
J. D. THOMSON, co-author of the article "The N.S.W. North Coast Trunk Radio Network", entered the Department in 1949 and has since been employed in the Radio Telephone Installation Division. As Divisional Engineer, he is in charge of the installation, planning and acceptance testing of Radio Telephone Systems in N.S.W.

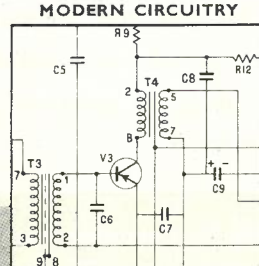
As a Sub-Lieutenant in the Royal Navy, Mr. Thomson was in charge of the maintenance of airborne radio equipment between 1944 and 1947, and then followed one year on radar development work with British Overseas Airways Corporation and one year with Cable and Wireless Ltd., London, on the design and development of electronic telegraph test equipment. Mr. Thomson qualified as a Bachelor of Science, Faculty of Engineering, London in 1944 and holds a Diploma of Associateship of the City Guilds of London Institute. He is also an Associate Member of the Institute of Electrical Engineers, London.

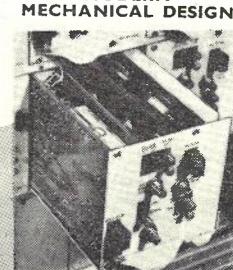


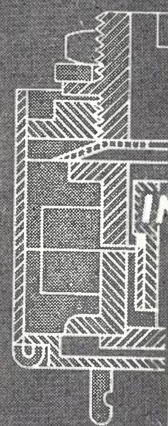







R9
C5
C8
R12
T4
V3
T3
C6
C7
C9





ADVERTISING

All Enquiries to:

Ruskin Publishing Pty. Ltd.
39 Leveson Street,
North Melbourne, Victoria.
Telephone: 30 1207

Revenue

The total net advertising revenue is paid to the the Telecommunication Society of Australia whose policy is to use such funds for improvements to this Journal.

Contract Rate

Space used in any three consecutive issues.
Full Page, black and white, £42 per issue.
Half Page, black and white, £26 per issue.
(horizontal only.)

Casual Rate

Contract rate, plus 10%

Copy Deadline

1st February, 1st June, 1st October.
Published three times each year.

Contributions and Letters to the Editors

May be addressed to:

the State Secretaries or the General Secretary at the following addresses:—

The State Secretary,
Telecommunication Society of Australia,
Box 6026 G.P.O. Sydney, N.S.W.
Box 1802Q Elizabeth St. P.O., Melbourne Vic.
Box 1489V, G.P.O. Brisbane, Qld.
Box 1069J, G.P.O. Adelaide, S.A.
BoxT1804, G.P.O. Perth, W.A.
Box 246C, G.P.O. Hobart, Tas.

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