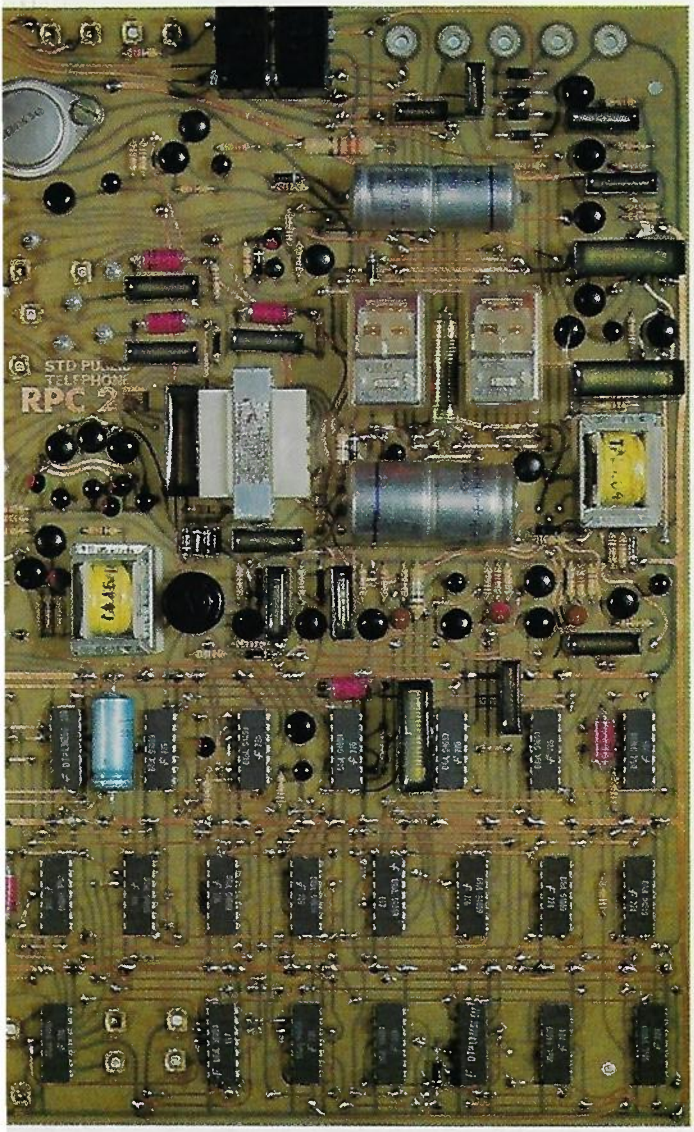
THE

Telecommunication Journal OF AUSTRALIA



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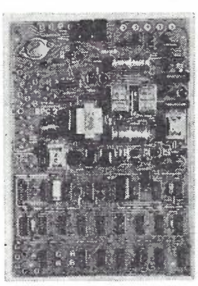

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THE NEW NATIONAL AUTOMATIC TRUNK NETWORK

*I. H. MAGGS, B.E. (Hons.), A.M.I.E.E., A.M.I.E. Aust.**

INTRODUCTION.

In 1967 the Australian Post Office placed in service the first of the new crossbar automatic trunk exchanges, and in so doing established the first elements of the new national automatic subscriber trunk dialling network. The establishment of these initial ARM-20 automatic trunk exchanges represented the culmination of many years of planning, design, ordering and installation activities, and, in addition, demonstrated that the many network problems associated with the integration of this complex switching equipment had been satisfactorily solved. The solving of these network switching problems, both in association with the new equipment and with the inter-working components of the switched network, will now allow the planned programme for the rapid expansion of nation-wide subscriber trunk dialling (S.T.D.) to be implemented as quickly as new automatic trunk exchanges and associated transmission links can be installed and tested.

This article outlines the scope and magnitude of the task ahead of the A.P.O. in creating a new national automatic subscriber trunk dialling system. The timing and extent of the implementation plans needed to achieve the S.T.D. target which the Post Office has set itself will also be described.

THE BASIC PLAN.

The real beginning of the new national automatic trunk switching system can be said to have taken place in the 1958-60 period. In this period the "Community Telephone Plan" was formulated and later accepted by the Government as the way to expand and develop the telecommunications network in Australia. Also the A.P.O. decided to use common control crossbar switching equipment to expand both the local and trunk switching networks.

The "Community Telephone Plan" outlined the overall framework for the future development of an integrated telephone communication system encompassing both the local and trunk networks. The framework this plan presented established the basic national plans for switching, charging, transmission and numbering—all of which are vital in building a totally integrated telecommunication system. It also outlined the plans for the introduction of nation-wide S.T.D., but did not fix any definite timetable for this objective to be realised. As a consequence detailed economic studies were undertaken and these culminated in the presentation of an implementation plan, in 1963, for the establishment of a modern automatic trunk network to handle the rapid growth in trunk calls expected over the next decade. The rapid growth in trunk calls over the past seven years, is clearly shown in Fig. 1. In this period the number of calls increased by 76 per cent. from 76,000,000 to 134,000,000.

The implementation plan provided for calls through this new communications network to be dialled by the subscriber in lieu of the operator, and in this way it was expected that the new network would produce savings of several million dollars each year when compared to the cost of providing an equivalent operator service.

THE S.T.D. OBJECTIVE.

The implementation plan put forward in 1963 called for 66 per cent. of all trunk calls to be dialled by the subscribers by 1975. The objective of this level of S.T.D. was to contain the number of trunk calls handled under manual conditions, to prevent any marked increase in the total number of operators and to prevent any overall expansion of the manual trunk system. This required that the future growth of trunk calls and trunk network development be catered for by automatic means. Therefore, the target was necessary for economic reasons and meant that full advantage had to be taken of the latest technology to ensure that the total trunk system be developed in an economic and sound manner.

Subscriber trunk dialling was chosen as the way in which to expand the trunk system, as it represented the most economic way of meeting the growth in the trunk network and at the same time maintaining a viable telephone network. The 66 per cent. target, arrived at after the comprehensive study, was also claimed to be achievable without major disruption to the steady expansion of the existing telephone system and without alteration to the proposed rate of converting manual terminal exchanges to automatic working. It was expected, also, to be within the level of funds proposed for the expansion of the basic trunk system, within a realistic level of building funds, and, generally practicable, assuming no unexpected changes in the funds that the Post Office may expect to receive as

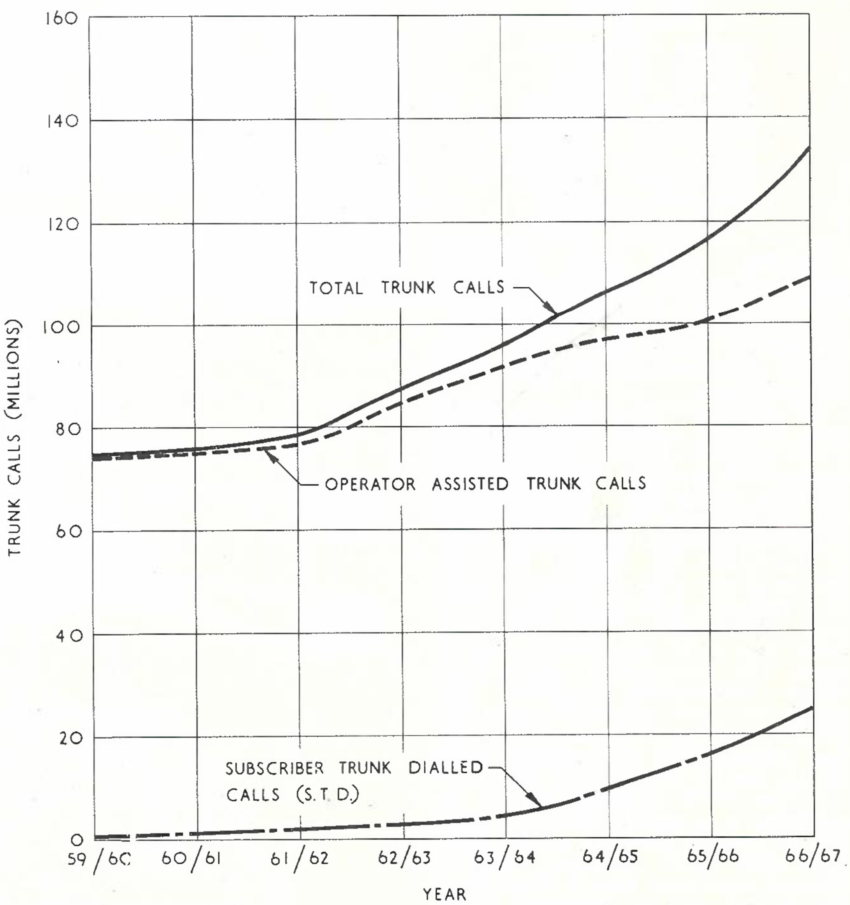

Fig. 1 — Growth of Trunk Calls in Australia.

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its allocation of the nation's resources up to the year 1975.

Summarising, S.T.D. represents the best way of utilising the Department's allocated share of the nation's resources, and, at the same time, is aimed at giving direct financial and service benefits to both the Post Office and to the telephone subscribers.

NEED FOR AN AUTOMATIC TRUNK NETWORK.

Over the past five years the A.P.O. has been equipping many of the major trunk routes with automatic trunk charge determination equipment. In certain areas this technique has slowed the growth of the manual trunk service and, at the same time, yielded financial rewards with a minimum of effort and expenditure. A list of typical major trunk routes that have been equipped with automatic charge determination equipment is given in Table 1. However, even though the majority of inter-capital and major country - city trunk routes had been provided with automatic charge equipment, at June, 1967, only approximately 19 per cent. of all trunk calls were being dialled by the subscriber. This result should be fully understood because now that S.T.D. has been provided on most of the major trunk routes, it will become increasingly more difficult to obtain further percentage S.T.D. gains using this technique.

TABLE 1.

Typical Trunk Routes Equipped with Multimetering Equipment at June, 1967.
Sydney - Melbourne
Sydney - Brisbane.
Sydney - Canberra.
Melbourne - Adelaide.
Melbourne - Launceston.
Melbourne - Canberra.
Wollongong - Sydney.
Newcastle - Sydney.
Geelong - Melbourne.

To understand why the past efforts have produced such a low percentage S.T.D. penetration, it is necessary to examine the national trunk traffic distribution pattern (Ref. 1), which shows that the inter-capital trunk routes only contribute approximately 7 per cent. of the total trunk traffic. It is the provincial areas that originate 72 per cent. and terminate 54 per cent. of the total trunk traffic. This clearly indicates that it is not enough just to equip the inter-capital routes with charge determining equipment and expect to reach anywhere near the S.T.D. percentage target—a fact that has already been well demonstrated by the results up to June, 1967.

If the 1975 objective is to be achieved, it is obvious that automisation of country services, accompanied with wide S.T.D. facilities, must be pursued vigorously over a broad front and to this end an automatic trunk switching system which will allow trunk traffic to be collected, charged and switched irrespective of where it originates or terminates, must be planned and implemented.

1967 represents the year in which the Post Office commences the automisation of the whole trunk network and the full-scale introduction of S.T.D. using new crossbar four-wire switching equipment. This use of modern four-wire switching equipment can be allied with the decision in 1959 to accept the L.M. Ericsson total crossbar system, which included the ARM trunk exchange, the ARF local exchange and the ARK small provincial terminal exchange. It is the L.M.E. ARM-20 trunk exchange which will be used in Australia to meet the requirement of modern four-wire switching equipment. This is the equipment that must be installed in the larger provincial and capital cities of Australia to solve the problem of collecting and distributing trunk traffic on a widespread basis.

THE ROLE OF THE ARM EXCHANGE

As indicated earlier, "The Community Telephone Plan" detailed the basic network plans for the development of the Commonwealth telecommunications network. The plan outlined the switching, numbering, charging and transmission aspects needed to cater for a nation-wide telephone communications network. The section of main interest here, is the switching plan for Australia with emphasis on the adoption of the ARM-20 four-wire trunk exchange. Fig. 2 shows the routing pattern that is being developed for the Australian network and gives an indication of where it is intended to use this new four-wire trunk exchange in the switched network.

Describing the levels of the hierarchy from the bottom, it can be seen from Fig. 2 that the subscribers' terminal exchange is the first collection point

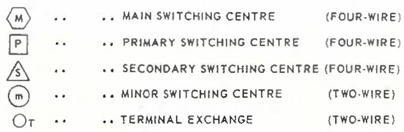

Fig. 2 — National Switching Plan.

of switched telephone traffic. Above the terminal exchange is the minor switching centre, which is the first transit exchange in the network and has been developed as a two-wire switching unit. Above the minor switching centre is the first level of four - wire switching, designated the secondary centre. It is intended that ARM-20 equipment be used to meet the requirement of four-wire switching at this and all other higher order switching centres. The primary switching centre collects and concentrates the traffic from a number of secondary centres and is parented on the Main switching centre. It is proposed to establish five Main switching centres—Sydney, Melbourne, Brisbane, Adelaide and Perth—in the new automatic trunk network.

A major role performed by the secondary switching centre in Australia is its function as the focal point for the entry and exit of trunk traffic to a particular area or region. The ARM exchange is usually the key unit in establishing provincial closed numbering areas and is generally combined with centralised manual assistance for the secondary region to handle both intra-secondary manual assistance as well as providing assistance to operators from other closed numbering areas.

Fig. 3 shows how the ARM exchange is placed at a secondary centre to carry out these functions, and also indicates the different levels of switching between the secondary, minor and terminal exchanges. The key item in Fig. 3 is the ARM-20 exchange, which is located at the secondary

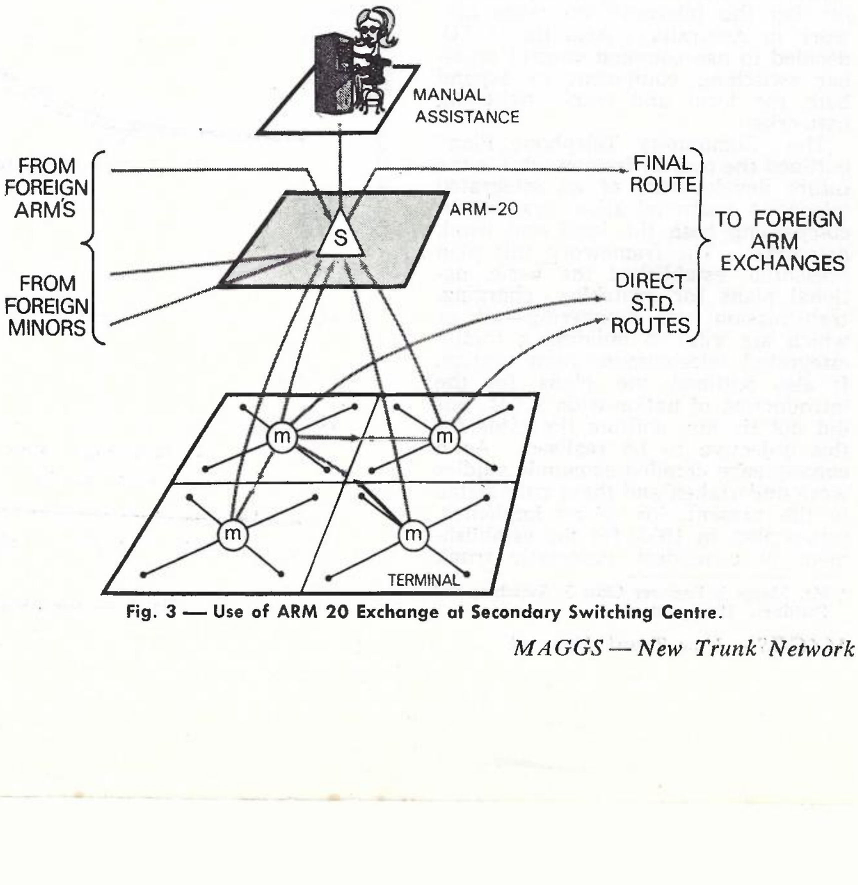

Fig. 3 — Use of ARM 20 Exchange at Secondary Switching Centre.

centre and is the focal point for the manual assistance exchange and the two-wire minor switching exchanges. The secondary centre is closely linked with centralised manual assistance facilities, which will normally be provided with cord or cordless type positions providing similar four-wire switching and transmission facilities as the ARM.

Minor switching exchanges will be capable of full national charging and will not have their switching restricted in any way. Therefore a minor area covering a number of charge zones may have all the intra-minor traffic charged and switched at the parent minor exchange. Any particular minor centre may have direct routes to any other switching centre. On the lower level of Fig. 3 some of the inter-minor links are shown. These direct routes will clear a considerable quantity of trunk traffic collected from the dependent terminal exchanges. Where direct routes are not justified, the trunk traffic will be cleared by following the backbone routing pattern. Fig. 3 shows that backbone traffic from the minor centre will be switched to the parent ARM exchange, which in turn will switch to the parent primary switching centre or perhaps bypass the primary centre and trunk direct to the Main switching centre

The secondary centre (ARM exchange) will normally be the entry point for incoming S.T.D. and manual traffic from other secondary areas. This, together with the tendency to clear trunk traffic out of the area as quickly as possible from the minor exchanges, means that the ARM exchanges will play a predominantly terminating role in the switched network. As the automisation programme penetrates further into the provincial networks and it becomes possible to clear more calls via direct or high-usage routes, the ARM exchange will probably handle something like 75 per cent. of the terminating and 25 per cent. of the originating telephone traffic.

THE NATIONAL ARM SWITCHING NETWORK.

Up to this stage the role of the individual ARM exchange has been discussed in some detail, but it is also necessary to understand what happens when these individual ARM trunk exchanges are linked together. The inter-connection of these ARM exchanges can be said to be the real objective of the national trunk programme, because it is this interconnection of all the individual ARM exchanges that will permit S.T.D. calls to flow freely through the network and allow a rapid and widespread penetration of the S.T.D. facility throughout all metropolitan and provincial areas.

To understand what is meant by "free flow" of S.T.D. throughout Australia it is necessary to consider two individual ARM trunk exchanges with their associated local networks. These exchanges could be located in different States or in the same State. Each ARM exchange is the parent switching centre for a large number of origins and destinations in its own surrounding area. Subscribers can call all other subscribers who also belong to the same switching centre, with the parent ARM providing the correct network switching and charging functions. When an inter-connecting link is placed between these ARM switching centres, then subscribers connected to each individual ARM exchange will immediately have access to all routes, destinations, and subscribers connected to the other ARM exchange. This example demonstrates the network gains of interconnection and shows what will be happening throughout the Commonwealth as additional ARM exchanges are installed and linked to their Main switching centre, which in turn will be connected to all other Main switching centres. For the price of the inter-connection link an immediate step is taken towards the objective of an inter-connected national automatic trunk network dedicated to a rapid and free flow of subscriber dialled trunk calls.

The first elements of the national ARM grid were inter-connected in September, 1967. This occurred in N.S.W., when the three ARM installations at Sydney, Canberra and Newcastle were placed in service and so inaugurated the national automatic S.T.D. network. The implementation of this initial phase in the creation of the national trunk network is outlined in detail in this issue of the *Journal* (Ref. 2).

Later, in November, 1967, two other ARM exchanges at Geelong (Vic.) and Launceston (Tas.) were connected to the three ARM grid exchanges in N.S.W., creating an inter-linked automatic trunk network spanning N.S.W., Victoria and Tasmania.

It is planned that the five initial ARM exchanges will be joined late in 1967/68 or early in 1968/69 with another eight units. The location of these exchanges is given in Table 2.

TABLE 2.—LOCATION AND TIMING OF ARM EXCHANGES PLANNED FOR 1967/68.

ARM Exchange	Programmed Establishment Date.
Sydney	September, 1967
Canberra	
Newcastle	
Geelong	October, 1967
Launceston	
Brisbane	Late in 1967/68
Perth	
Hobart	
Griffith	
Albury	
Goulburn	
Cairns	
Orange	

By the end of 1967/68 it is expected that some 700,000 subscribers (30 per cent. of total subscribers) will be connected to the ARM grid and these subscribers will be able to dial trunk calls to 1.5 million subscribers (64 per cent.) located in Sydney, Melbourne, Brisbane, Adelaide, Canberra, Newcastle, Geelong, Launceston, and a large number of provincial cities in N.S.W., Victoria, Queensland and Tasmania. These estimates show that the ARM grid will rapidly widen its range of destinations, but even with these statistics, and assuming 85 per cent. acceptance of the facility by the subscribers, less than 16 per cent. of all trunk calls can be expected to be dialled by the subscribers over the ARM grid by June, 1968. However, in addition to the 16 per cent. of trunk calls switched over the ARM grid a further 10 - 14 per cent. of all trunk calls is expected to be dialled by subscribers over selected trunk routes provided with multi-metering equipment. The combined total percentage S.T.D. at June, 1968, is then expected to reach approximately 26 to 30 per cent.

By the end of June, 1969, it is planned to have at least 20 ARM trunk exchanges established. Approximately 1.5 million subscribers (60 per cent.) will be connected to the ARM network and will have access to approximately 1.8 million subscribers (72 per cent.). This expansion of the automatic trunk grid, together with other sources of S.T.D. calls is expected to provide for approximately 40 per cent. of the total trunk calls to be dialled by the subscribers.

The graph in Fig. 4 indicates the achieved S.T.D. percentage penetration up to June, 1967, together with the planned rate of S.T.D. penetration over the next three years. The growth of S.T.D. up to June, 1967, has been steady, however, from 1968 onwards it is planned to turn the curve sharply upwards to match the rapid growth in the trunk network and maintain the number of trunk operators at a constant level. This sharp increase in the early years is essential because at the later dates it will become harder to sustain a steady percentage increase once the large S.T.D. gains from existing automatic networks are taken up and the long-term increase in S.T.D. starts to depend on the rate of manual to automatic conversions.

The inter-connected national automatic trunk network that the Post Office is aiming to achieve by 1975 is shown in Fig. 5. With this type of integrated network a trunk call can be made at any location with S.T.D. access to the grid and can reach any destination associated with the grid. This will allow advertising of available codes to be presented on a national basis, as all originating subscribers on the grid will be able to reach the same distinations and can therefore receive the same publicity. Ultimately it is expected that this broad publicity capability will be one

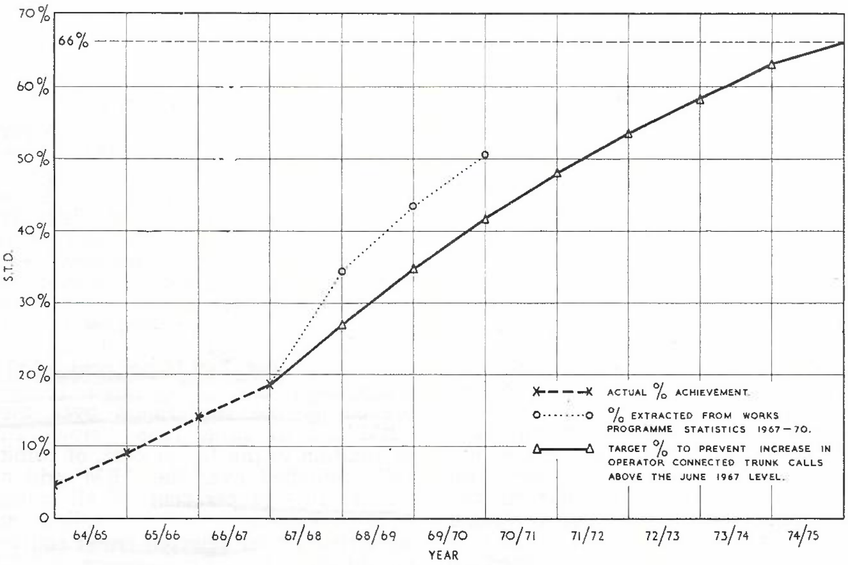

Fig. 4 — % Growth of S.T.D. Calls.

of the key factors which will permit the S.T.D. facility to be exploited to the fullest possible extent.

ARM PROGRAMME AND FUNDS.

An important aspect in planning and establishing a new trunk network is to have a full understanding of the magnitude of the implementation programme. The magnitude of the task that the Post Office has set itself can be measured in two well-understood variables, money and time. It is well-known that unlimited amounts of money and time will solve all problems. However, the Post Office does not have unlimited time in which to automatise the trunk network if it is to remain commercially viable, and the trunk network must compete with all other elements in the Post Office for a share of the limited financial resources available to the Post Office as a whole.

The task of building the new trunk network can therefore be summarised

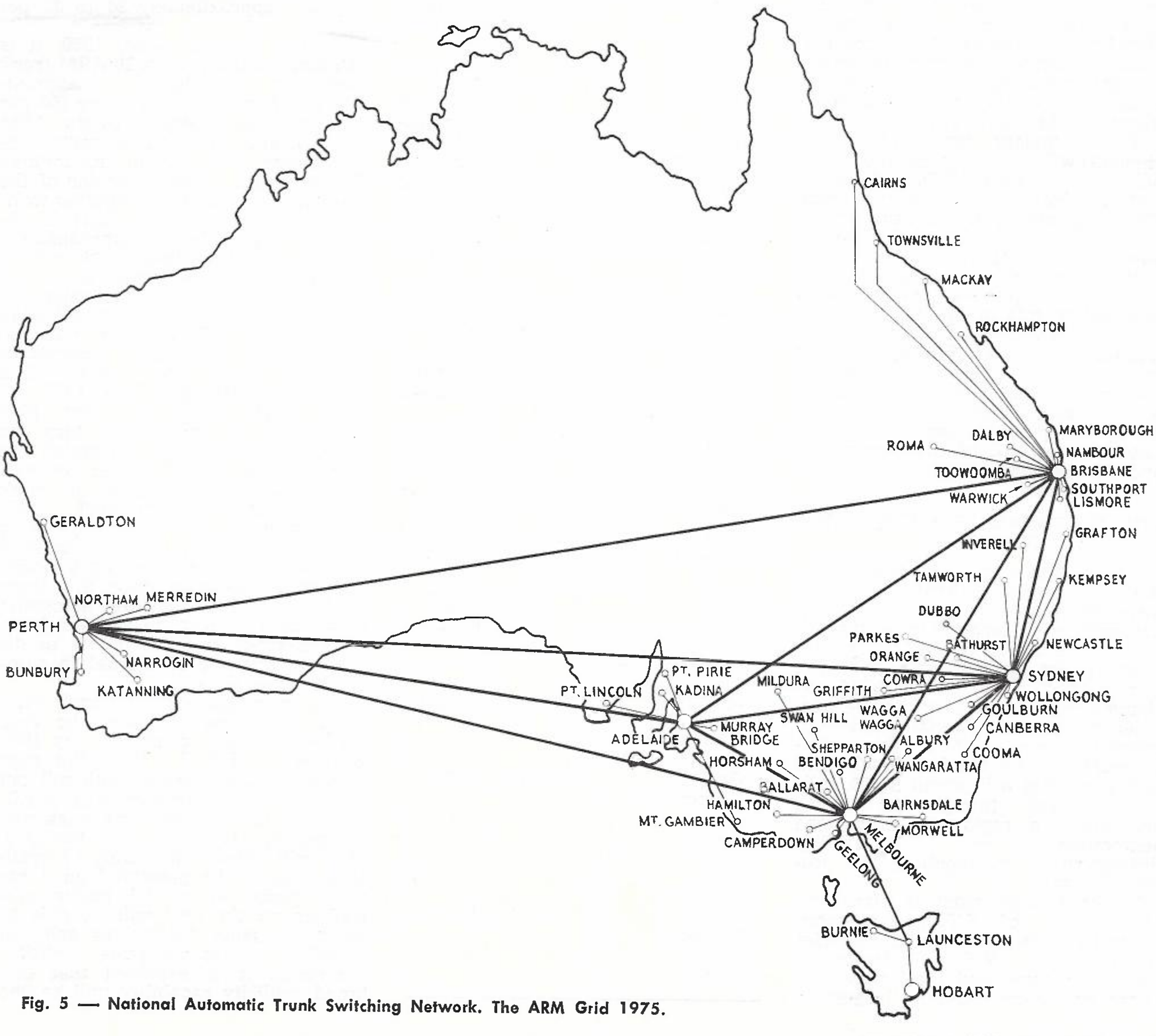

Fig. 5 — National Automatic Trunk Switching Network. The ARM Grid 1975.

as the need to build a reasonably complex network of new trunk exchanges as quickly as practicable consistent with sound financial management.

In 1960 the results of the basic network planning indicated that there would be approximately 650 switching centres in Australia. However, since then there have been considerable changes in the relative cost ratio between modern switching and transmission equipment. To-day, on the basis of the current cost relationship between these items of equipment, it is proposed only to establish approximately 360 switching centres in the Commonwealth. A summary of detailed costs covering both switching and transmission equipment for the period 1965/1975 is given in Table 3. This table shows that the Post Office will be faced with an expenditure of $265m. up to 1975 in establishing the basic automatic trunk network, while at the same time aiming at a target where 66 per cent. of all trunk calls are subscriber dialled. Furthermore, it should be remembered that this is basically the initial or "get started" cost, and as the new trunk system expands the Post Office will need to match this expansion with an appropriate increase in the allocation of funds, material and manpower to the trunk system.

TABLE 3.—SUMMARY OF CAPITAL COSTS FOR 4-WIRE AND 2-WIRE TRUNK SWITCHING, 1965/1975.

Trunk Network Component.	Expenditure.
Automatic 4-wire Trunk Exchanges	$M55
Automatic 2-wire Trunk Exchanges	$M 7
Distant End Terminations	$M 4
Building Requirements	$M 4
Inter-connecting Trunk Circuits	$M195
Total	$M265

An overall picture of the implementation task is given in Table 4, where the programme for installation of both the four-wire ARM exchanges and the two-wire ARF exchanges is presented. At the top of Table 4 the timing for the installation of the five Main exchanges — Sydney, Melbourne, Brisbane, Adelaide and Perth— is shown. These are the main units in the hierarchical switching system and will be the key units in the development of the national automatic trunk network. The first Main switching centre (Sydney) was established in September, 1967; the other four are planned to be completed in 1968. It is essential that these top priority switching centres be established as early as possible to allow the trunk system to be built in a sound and orderly manner. Any other way would be against the inter-connected grid concept and would allow individual switching exchanges to be installed in the network without the added gains of being linked into the total system. The Main switching centres will be fully meshed with each other and will provide the backbone switching network to which the secondary switching centres will be connected. This meshing of the Main switching centres has been clearly demonstrated in Fig. 5.

A total of 55 secondary switching centres are to be established by 1975, in addition to the five Main switching centres. In support of these 60 ARM exchanges it will be necessary to build approximately 200 of the estimated 300 minor switching centres. As already outlined, these minor centres have a real part to play in the development of the communications network, particularly as the majority of them will be capable of complete national charging and switching.

CONCLUSION.

This article has attempted to demonstrate the depth and breadth of planning effort which has been necessary over the last seven years to arrive at the present stage in the development of the national automatic trunk network. It has been necessary to plan effectively the integration of ARM exchanges into the existing network, to develop a national hierarchical switching system and to create the framework for a national closed numbering scheme. This planning effort, together with the associated design, ordering and installation processes, culminated late in 1967 with the commissioning of the first of the new automatic trunk exchanges which established a nucleus for the future development of the national automatic trunk network.

Although the first steps have now been taken, the programme planned up to 1975 means that even greater efforts will be needed from many different sections of the Post Office. if the objectives in the trunk network are to be achieved.

In summary, the present position may be stated as:—

(a) The basic plans, targets and objectives for automatising the trunk network have been well formulated and clearly defined.

(b) While waiting for the ARM-20 equipment, and going through all the processes of obtaining it, purchasing it and getting it into the field, the expansion of the existing manual trunk network has been restricted by providing multimetering equipment on selected trunk routes. As a result of this technique, approximately 19 per cent. of all trunk calls were being dialled directly by the subscribers at June 1967.

(c) The Post Office is now moving into a period where an ever-increasing effort will have to be made, and, in addition, will have to be sustained if 66 per cent. of all trunk calls are to be subscriber dialled by 1975.

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TABLE 4.—THE AUTOMATIC TRUNK SWITCHING PROGRAMME, 1965-1975.

Category.	Total No.	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75
Main Centres	5	—	—	3	2	—	—	—	—	—	—
Secondary Centres	55	—	—	8	8	9	9	8	5	3	1
Minor Centres	200	7	8	22	25	30	25	23	20	20	20

THE ESTABLISHMENT OF AN ARM NETWORK IN NEW SOUTH WALES

*R. McCARTHY, B.E.**

INTRODUCTION.

The following paper describes the commissioning of ARM exchanges at Sydney, Canberra and Newcastle and the establishment of the initial ARM grid in New South Wales. The paper deals with the installation phase rather than with the technical facilities of ARM (Ref. 1), or the network planning aspects of ARM (Ref. 2).

The object of this paper is to present a picture of the scope of the project and to outline the network problems encountered; the co-ordination aspects, the developments, the cutover staging, the cutover technique and the directory publication aspects. To establish a new type of telephone network such as this, considerable developmental work was required and throughout the course of the project, liaison was maintained with the various planning and design groups in order to finalise the planning details and to feed back details of technical facilities and field test results. A number of developments and modifications arose from this, and a section is devoted to these aspects.

The magnitude of the project and the degree of penetration of the ARM grid, called for close co-ordination and for a carefully staged cutover, and a project group was formed (later, the ARM Projects Division) to control these installations. The programming of the two main stages of cutover is outlined and a description is given of the technique used for the first days of cutover.

* Mr. McCarthy is Engineer Class 3, ARM Projects Division, N.S.W.

THE INSTALLATION PROGRAMME.

For a number of reasons it was decided that the three initial ARM installations in N.S.W. should be cutover simultaneously, but that the subscriber traffic should be introduced gradually. These reasons are explained later, but, in short, this provided inter-ARM trunk routes, over which extensive testing could be carried out on the respective ARM exchanges, the new "T" type signalling system (a pulse type signalling system for use on standard carrier circuits equipped with a separate signalling channel), and also the MFC information signalling scheme for trunk distance calls. This method also avoided temporary installation work that would otherwise have been necessary to provide S.T.D. from the Sydney ARM to the other two large centres.

Consequently, the installation programming called for the simultaneous completion of ARM exchanges at Haymarket, Sydney (2600 lines), Canberra (600 lines) and Newcastle (800 lines). These three exchanges were installed by L.M. Ericsson Pty. Ltd., and were each handed over to the Australian Post Office on 30/6/67 for the acceptance testing and commissioning. In many respects these installations were a joint effort by the A.P.O. and L.M. Ericsson Pty. Ltd.. Each Administration contributed to the design work necessary to marry the already established ARM switching device to the A.P.O. telephone network and to develop the installation documentation and testing procedures. The A.P.O. participated in the installation and exchange testing phases in order to provide training for key staff and L.M. Ericsson Pty. Ltd. provided the services of testing officers at each installation beyond 30/6/67 to assist with the commissioning and the field tests on new items of equipment, the ARM registers in particular.

The installation programming also called for completion by 30/6/67 of the access routes from each ARM to its own local area and the completion of as many direct trunk routes as possible. This was to provide for complete testing of the ARM terminating grid before any inputs were connected. The connection of inputs was complicated by the fact that each centre had temporary S.T.D. already established and this required special attention, which is described later. The completion of the direct trunk links to non-ARM exchanges was not possible by 30/6/67, due to late delivery of distant end "T" type line signalling relay sets, and consequently the bulk of early testing was confined to a network comprising these three main centres.

The cutover of these exchanges to

TABLE 1 — TIME TABLE FOR CONNECTION OF SUBSCRIBERS TO ARM GRID

		Subscribers' Lines with STD. Facilities.			
	Period.	Haymarket	Canberra	Newcastle.	Remarks.
Stage 1	Prior to 1/9/67.	61,600	21,000	9,100	Temporary S.T.D. to limited codes.
	1/9/67 to 1/10/67	61,600 (original)	21,000 (original)	as above	Cutover to ARM for same codes (overflow traffic only at Canberra). See Fig. 1.
	1/10/67 to 16/10/67	66,200 (additional)	—	—	Cutover to ARM for all grid destinations except ESG codes.
Stage 2	16/10/67 to 20/10/67	—	—	9,100 original 15,500 additional	,,
	20/10/67 to 30/10/67	35,000 (additional)	—	—	,,
	1/11/67	61,600 (original)	21,000 (original)		,,
	6/11/67 to 28/11/67	32,800 (additional)	—	—	,,
		Eastern Seaboard Grid Cut Over (E.S.G.)			
	28/11/67	195,000 (Total)	21,000 (Total)	24,600 (Total)	Access provided to all ARM grid destinations, including E.S.G. (See Fig. 2.)

TABLE 2 — TRUNKS CONNECTED TO ARM GRID — STAGE 2

Trunk Lines.	Haymarket ARM	Canberra ARM	Newcastle ARM	Dalley Trunk Ex.
Incoming	261	54	85	697
Outgoing	511	85	131	721
Both-Way	—	—	—	181
Total	772	139	216	1581
ARM Total = 1127. Dalley Total = 1581 (at 1/9/67).				

live traffic was programmed to take place in two main stages, with stage 1 commencing on 1/9/67. Fig. 1 shows the stage 1 network, and a subsequent section of this paper describes the implementation of this network. This stage was expected to take approximately two months to fully implement, and stage 2 was programmed for cutover in November. The stage 2 network is shown in Fig. 2 and by 28/11/67 all of these trunk routes were established and full S.T.D. access to codes served by these routes was available to some 195,000 subscribers in Sydney, 21,000 in Canberra, and 24,600 in Newcastle.

The timetable for connection of these subscribers is shown in Table 1 and a summary of the trunks is shown in Table 2, together with a comparison of the trunk terminations that existed at Dalley Trunk Exchange at 1/9/67. These figures alone indicate the magnitude of the project. Also the connection of Sydney subscribers is continuing at a rate which is planned to provide S.T.D. access for more than half a million subscribers by June, 1968. Each of these centres is developing rapidly, and the works programme for 1967/68 provides for extensions at Haymarket for 2400 lines of equipment, at Canberra for 200 lines and at Newcastle for 800 lines.

THE TECHNICAL DEVELOPMENTS.

The ARM exchange is a completely new switching machine for the telephone network, with true 4-wire switching for the speech path and with comparatively high-speed d.c. switching, employing multi-wire connections (up to 168 wires in some cases) between items of common equipment. In addition, the advent of ARM brought the following new concepts:—

(a) A d.c. pulse system for transferring line signals between incoming and outgoing relay sets within the ARM.

(b) A new series of line signals for physical, standard carrier and rural carrier circuits, with whole new families of line signalling relay sets. (L.M.E. pulse type signalling was introduced as the standard trunk distance line signalling mode for use on carrier channels with out-of-band signalling and a completely new series of trunk line signalling relay sets was developed for this purpose.)

(c) New MFC information signals to provide for ultimate echo suppressor switching, for identification of the calling zone of origin and for special routing of some calls (such as calls to the International Exchange or Interception Centre).

(d) A new philosophy with respect to the determination of call charging on S.T.D. calls, with charge analysis equipment centralised in the ARM common equipment and used to set the tariff relays in the respective "Z" type ARM line relay set.

(e) A new type of analyser, called in by the ARM registers, to permit the use of either MFC or decadic information signalling, to minimise the holding time of common equipment and to minimise post dialling delay.

(f) A new transmission plan to the trunk network with a new set of line-up levels and a new set of circuit losses to be determined by the length of the circuit and the type of terminating equipment.

These new concepts combined to create problems in the dissemination of information, the training of staff, the finalising of design, and the manufacturing of equipment. The delays in the delivery of equipment, caused in some cases by design problems and in others by limited manufacturing capacity and import delays for piece parts, resulted in a general carryover of ARM projects from programmed financial years to following years. This left some funds unexpended, which caused difficulties in the allocation of funds for subsequent years, and also created problems in the finalising of planning details for each of the exchanges. The slippage in the commissioning of the ARM exchanges held back the effective circuit gains for various long line installations and created other demands to provide relief for other routes.

Modifications.

Whilst there were obvious gains from commissioning these exchanges as early as possible, the volume of field modification work and the number of items justifying further field testing, posed problems which increased in magnitude the nearer the installations approached to cut-over. For example, field modifications were necessary to each ARM line signalling relay set, approximately 40 hours of modification work was necessary to each ARM register and minor modifications were found necessary to some other ARM items. Modifications were necessary also to each distant end 'T' type signalling relay set. These modifications were generally done by L.M. Ericsson Pty. Ltd., however, the actual cutover date was dependent on the combined efforts of both L.M. Ericsson Pty. Ltd. and the A.P.O. to develop, document and carry out the large-scale modification work required.

ARM Items

A new analyser relay set, SAN type 2, was developed mainly for use at Haymarket ARM, where it was considered that frequent changes to the number length and type of terminating equipment analysis would be necessary. The new design provided for all changes to be carried out on plugs, which could be removed from the relay set, instead of on the tags of multi-coil relays. These relay sets were manufactured by the Sydney workshops and are now being used for all ARM installations in N.S.W.

Another ARM item examined at Haymarket was the analyser finder stage. Because of the very short analyser holding time it was decided that a second marker should be equipped to each finder stage, and it is understood that this will now become standard A.P.O. practice.

The project group also undertook considerable work in the development of the test access, test console and associated remote test equipment for ARM. Documentation and tender specifications were prepared for local manufacture of the test access equipment and the test console, while the design, documentation and manufacture of the remote test console equipment and associated register-TA were carried out jointly by installation, service, and workshop groups of N.S.W.

Local Network.

In parallel with these activities for the ARM exchanges, action was being taken in the local networks to provide circuits to the ARM and to prepare for S.T.D. operation. At crossbar "X" tandem exchanges, relay sets were being modified to comply with ARM line signalling requirements and at crossbar terminals a number of private contracts were let to modify Reg-L to provide for zone of origin signals. Because of proposed changes to MFC signals, to incorporate the 4A series, these latter modifications were kept to a mimimum and alternative interim modifications were carried out to Reg-H1 at the respective ARM. At step-by-step exchanges, relay sets to A.P.O. drawing CE.11256 were being installed for circuits to ARM and an extensive programme was commenced to modify D.S.R. relay sets for working to the ARM.

STAGE 1 IMPLEMENTATION.

A considerable temporary S.T.D. network existed prior to ARM, using different signalling schemes, mainly compelled sequence (T2 type) signalling incorporated in the CE.11248 series of relay sets. It was necessary to absorb all of the Sydney outgoing component of this temporary S.T.D. network into Haymarket ARM. Because of the difference in the line signalling mode, i.e., 'T' type in lieu of 'T2' type, this called for the separate installation of L.M.E. pulse signalling equipment at all country centres already served by the temporary S.T.D. routes. Further, because it was not possible to give the Sydney subscribers facilities that were less than those that some subscribers had already, it was essential that all of these centres and the routes to them be made ready before Haymarket ARM could absorb the Sydney subscribers connected to temporary S.T.D. It was not practical to transfer the Sydney temporary S.T.D. subscribers to the ARM simultaneously because the quantities involved were too great and restrapping of GV stage was necessary at cutover. Routes from a number of temporary S.T.D. terminals to Haymarket were to disappear at cutover and the traffic was to be routed via the respective 'X' tandem. The junctions recovered were sometimes required for the 'X' tandem routes. The capacity of the local network teams to cutover the originating sources (each having its complications requiring sometimes the altering of straps in the ARF GV stage, sometimes the blocking of the direct route and the simultaneous unblocking of the route to the parent GVX tandem), and the capacity of the ARM staffs to handle the volume of work was considered insufficient for a simultaneous cutover.

Junctions.

In the pre-planning and preparation, therefore, it was an early decision to stage a gradual cutover for Haymarket ARM. This had other advantages also, in that, as this was a prototype network, it was desirable to increase the live traffic gradually and to supervise this closely to guard against failure due to unforeseen shortcomings. Furthermore, this method simplified the recovery of channels from temporary S.T.D. routes out of Sydney to build up the ARM routes to their full complement of circuits.

It was decided to cut over 'X' tandem areas in sequence. For the initial cutover in Sydney it was necessary to transfer the traffic from 28 metropolitan exchanges to route to the ARM. These included 21 temporary S.T.D. exchanges and 7 'X' tandem exchanges serving these for overflow routing to the ARM. Blakehurst 'X' tandem area was also added to the initial cutover, as this area, of all non-temporary S.T.D. 'X' tandem areas, was the best suited for the carrying out of facility checks. Fig. 1 shows these originating exchanges, which include the city co-main step-by-step exchanges (Central, York and Dalley), the remainder being crossbar sources. The proposed procedure for connecting subscribers required two routes from Sydney to each temporary S.T.D. centre, working in parallel in this phase of the operation. These routes can be seen in Fig. 2, where all of the centres served by temporary S.T.D. facilities are shown with the respective access codes. This figure also shows the routing to these destinations from the respective sources.

Trunks.

As the forward planning called for parallel trunk routes out of Sydney in the initial stages, arrangements were made to provide additional trunk channels to many of the destinations. This was done by equipping channels to the 1968 planning figures wherever possible. For most routes an increment of channels was available for the establishment of an ARM parallel route, with the remainder of the channels to be recovered from the temporary S.T.D. route, as sufficient S.T.D. sources in Sydney were transferred to the ARM. The increment had also to cater for the inefficiency of two parallel routes and for any non-uniform traffic distribution during the cutover period.

However, the commissioning of the ARMs was progressively delayed, as mentioned earlier. The traffic was for ever on the increase and there were strong pressures to release these channels to provide circuits for operator and temporary S.T.D. routes. This occurred particularly on Interstate routes, where, without exception, the planned increment was subsequently reduced or rearranged. On the Sydney-Melbourne route, for example, an increment of 37 circuits was planned initially for the establishment of the Sydney ARM to Melbourne parallel route. The balance of 59 circuits, to make a total of 96, was to be recovered from temporary S.T.D. after the initial cutover. At one stage the increment of 37, however, was whittled away by the release of 12 circuits for Sydney-Melbourne S.T.D. increases at Christmas, 1966, by the release of 12 circuits for the Sydney-Adelaide transit route at Easter, 1967, and in April, 1967, the release of a further 12 was being considered for the Sydney-Melbourne temporary S.T.D.

Approximately one month prior to cutover a re-allocation of Sydney-Melbourne 12-channel groups was planned, following completion of Super Group 15 of the co-axial cable, which restored the increment to 36 channels, and last-minute rejumpering was arranged for the establishment of the initial route from Haymarket ARM to North Melbourne tandem.

STAGE 2 IMPLEMENTATION.

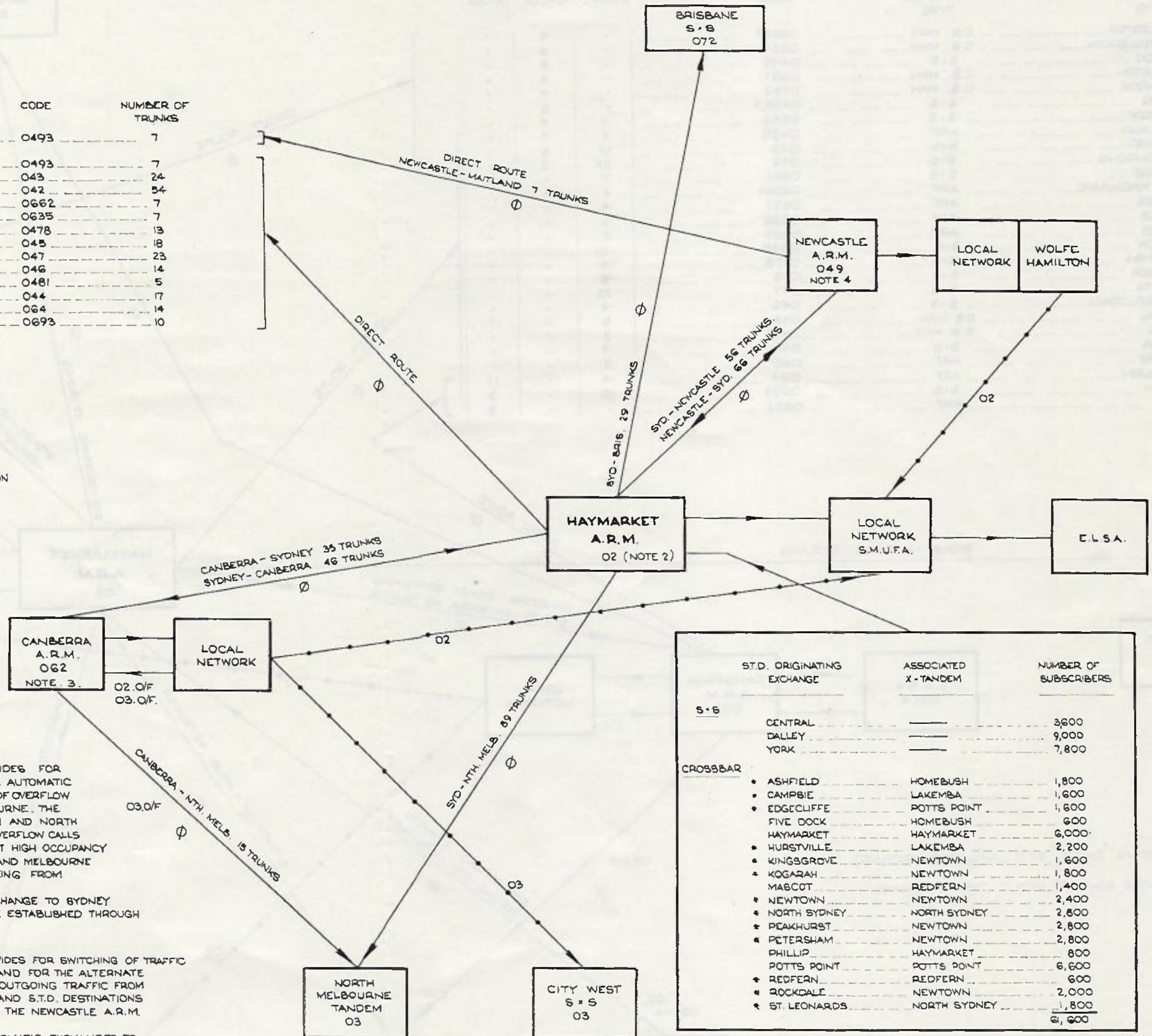
The additional trunk routes connected in this stage are shown by comparing Fig. 1 to Fig. 2, the N.S.W. ARM trunk network that existed at November, 1967. As new subscribers and new routes were connected in this stage, publication and subscriber education was necessary, and this is described in a later section.

The connection of the Sydney subscribers to the ARM in Stage 2 was also progressive and divided into three phases, each phase comprising a group of exchanges with similar equipment types and with similar circuit conditions. For example, between 1/10/67 and 25/11/67, some forty-nine crossbar exchanges, or crossbar portions of hybrid exchanges, were cutover to the ARM. These provided some 134,000 subscribers with S.T.D. access to the ARM grid over and above the 61,600 subscribers connected in Stage 1 (see Table 1). The next phase took in the remaining ten crossbar exchanges, which were located in the Sydney E.L.S.A. areas and which required modifications to Reg. L to provide zone of origin signals. Also, as these routes generally used carrier channels, the supply of distant end 'T' type relay sets was again a critical factor, and the majority of these routes were programmed for cutover in February, 1968. The final phase comprised some forty-six step-by-step exchanges, or step-by-step portions of hybrid exchanges, and the cutover programme for these provided for an even spread, commencing in January and continuing to June, 1968.

For the smaller Canberra and Newcastle networks, it was decided that simultaneous cutover techniques could be used for providing the local subscribers with access to the ARM grid and arrangements were made for mass media publication. In addition, the Newcastle subscribers received publicity in the form of letters and 'How-to-call' cards over the period 16/10/67 to 20/10/67, and the cards provided directory information for the grid shown in Fig. 2. As the commissioning date for the Eastern Seaboard Grid routes had been set for 28/11/67, it was necessary to connect voice announcements to the Sydney - Geelong and Sydney - Adelaide routes at Haymarket ARM to advise the subscribers who dialled the codes served by these routes. The Canberra subscribers were handled in a similar manner, and their letters and 'How-to-call' cards were issued on 1/11/67.

For each cutover, facility and check calls were carried out. These provided a valuable check of dialling, metering and transmission conditions from each originating exchange to the

ROUTE TO	EXCHANGE TYPE	CODE	NUMBER OF TRUNKS
MAITLAND	ARF	0493	7
MAITLAND	ARF	0493	7
GOSFORD	S×S	043	24
WOLLONGONG	S×S	042	54
LISMORE	S×S	0662	7
LITHGOW	S×S	0635	7
KATOOMBA	S×S	0478	13
WINDSOR	S×S	045	18
PENRITH	S×S	047	23
CAMPBELLTOWN	S×S	046	14
BOWRAL	C.B. MAN.	0481	5
NOWRA	S×S	044	17
GOULBURN	ARF	064	14
WAGGA	S×S	0693	10



S.T.D. ORIGINATING EXCHANGE	ASSOCIATED X-TANDEM	NUMBER OF SUBSCRIBERS
S×S		
CENTRAL	—	3,600
DALLEY	—	9,000
YORK	—	7,800
CROSSBAR		
* ASHFIELD	HOMEBUSH	1,800
* CAMPSIE	LAKEMBA	1,600
* EDGECLIFFE	POTTS POINT	1,600
FIVE DOCK	HOMEBUSH	600
HAYMARKET	HAYMARKET	6,000
* HURSTVILLE	LAKEMBA	2,200
* KINGSGROVE	NEWTOWN	1,600
* KOGARAH	NEWTOWN	1,800
MASCOT	REDFERN	1,400
* NEWTOWN	NEWTOWN	2,400
* NORTH SYDNEY	NORTH SYDNEY	2,800
* PEAKHURST	NEWTOWN	2,800
* PETERSHAM	NEWTOWN	2,800
PHILLIP	HAYMARKET	800
POTTS POINT	POTTS POINT	6,600
* REDFERN	REDFERN	600
* ROCKDALE	NEWTOWN	2,000
* ST. LEONARDS	NORTH SYDNEY	1,800
		61,600

* ONLY SUBSCRIBERS CONNECTED TO CROSSBAR COMPONENT OF EXCHANGE HAVE ACCESS TO ARM EXCHANGE

NOTES 1.

STAGE 1 — STAGE 1 WILL BE COMMENCED ON 1-9-67 AND WILL BE COMPLETED BY 1-10-67. NO PUBLICITY IS REQUIRED FOR THE IMPLEMENTATION OF THIS STAGE.

2.

HAYMARKET — INITIAL ESTABLISHMENT OF HAYMARKET ARM EXCHANGE PROVIDES FOR REPLACEMENT OF EXISTING 'TEMPORARY' S.T.D. FROM THE HAYMARKET ARF SPECIAL TRUNK GV. STAGES. SUBSCRIBERS WITH ACCESS TO THE TEMPORARY S.T.D. FACILITIES WILL AT STAGE 1 TRUNK THROUGH THE A.R.M. EXCHANGE TO EXISTING S.T.D. DESTINATIONS.
ROUTES FROM HAYMARKET A.R.M. TO THE RESPECTIVE DESTINATION EXCHANGES TO BE EQUIPPED WITH 'T' TYPE SIGNALLING. TRAFFIC TO CANBERRA AND NEWCASTLE TO ROUTE THROUGH A.R.M. EXCHANGES AT THESE CENTRES. TRAFFIC TO MELBOURNE TO BE ROUTED THROUGH NORTH MELBOURNE TANDEM WHICH IS EQUIPPED WITH REG YI-LM TO PROVIDE M.F.C. SIGNALLING AND LOCAL NUMBER LENGTH ANALYSIS.
ESTABLISHMENT OF ALL JUNCTION ROUTES OUTGOING FROM HAYMARKET A.R.M. TO SYDNEY LOCAL NETWORK AND E.L.S.A. NECESSARY TO PROVIDE FOR SWITCHING OF 'O2' OVERFLOW TRAFFIC THROUGH CANBERRA A.R.M.

3

CANBERRA — INITIAL ESTABLISHMENT OF CANBERRA A.R.M. EXCHANGE PROVIDES FOR SWITCHING OF TRAFFIC INCOMING FROM SYDNEY TO THE LOCAL AUTOMATIC NETWORK AND IN THE OUTGOING DIRECTION FOR SWITCHING OF OVERFLOW CALLS FROM THE DIRECT 'S.T.D' LINKS TO SYDNEY AND MELBOURNE. THE OVERFLOW CALLS WILL BE ROUTED THROUGH HAYMARKET A.R.M. AND NORTH MELBOURNE (REG YI-LM) TANDEM RESPECTIVELY. IN ADDITION 'O3' OVERFLOW CALLS HAVE A FINAL BACKBONE ROUTE VIA HAYMARKET A.R.M. DIRECT HIGH OCCUPANCY S.T.D. LINKS FROM LOCAL AUTOMATIC EXCHANGES TO SYDNEY AND MELBOURNE WILL BE RETAINED AS A PERMANENT FEATURE OF S.T.D. TRUNKING FROM CANBERRA.
OUTGOING TRAFFIC FROM CANBERRA MANUAL ASSISTANCE EXCHANGE TO SYDNEY AND S.T.D. DESTINATIONS TRUNKED FROM SYDNEY A.R.M. CAN BE ESTABLISHED THROUGH THE CANBERRA A.R.M. EXCHANGE.

4

NEWCASTLE — INITIAL ESTABLISHMENT OF NEWCASTLE A.R.M. EXCHANGE PROVIDES FOR SWITCHING OF TRAFFIC INCOMING FROM SYDNEY TO THE LOCAL AUTOMATIC NETWORK AND FOR THE ALTERNATE ROUTING OF OVERFLOW TRAFFIC FROM SYDNEY TO MAITLAND. OUTGOING TRAFFIC FROM THE NEWCASTLE MANUAL ASSISTANCE EXCHANGE TO SYDNEY AND S.T.D. DESTINATIONS TRUNKED FROM SYDNEY A.R.M. CAN BE ESTABLISHED THROUGH THE NEWCASTLE A.R.M. EXCHANGE.
LEVEL 'O' ASSISTANCE TRAFFIC E.G. 'O11' ETC. FROM LOCAL AUTOMATIC EXCHANGES TO BE ROUTED THROUGH A.R.M. EXCHANGE.

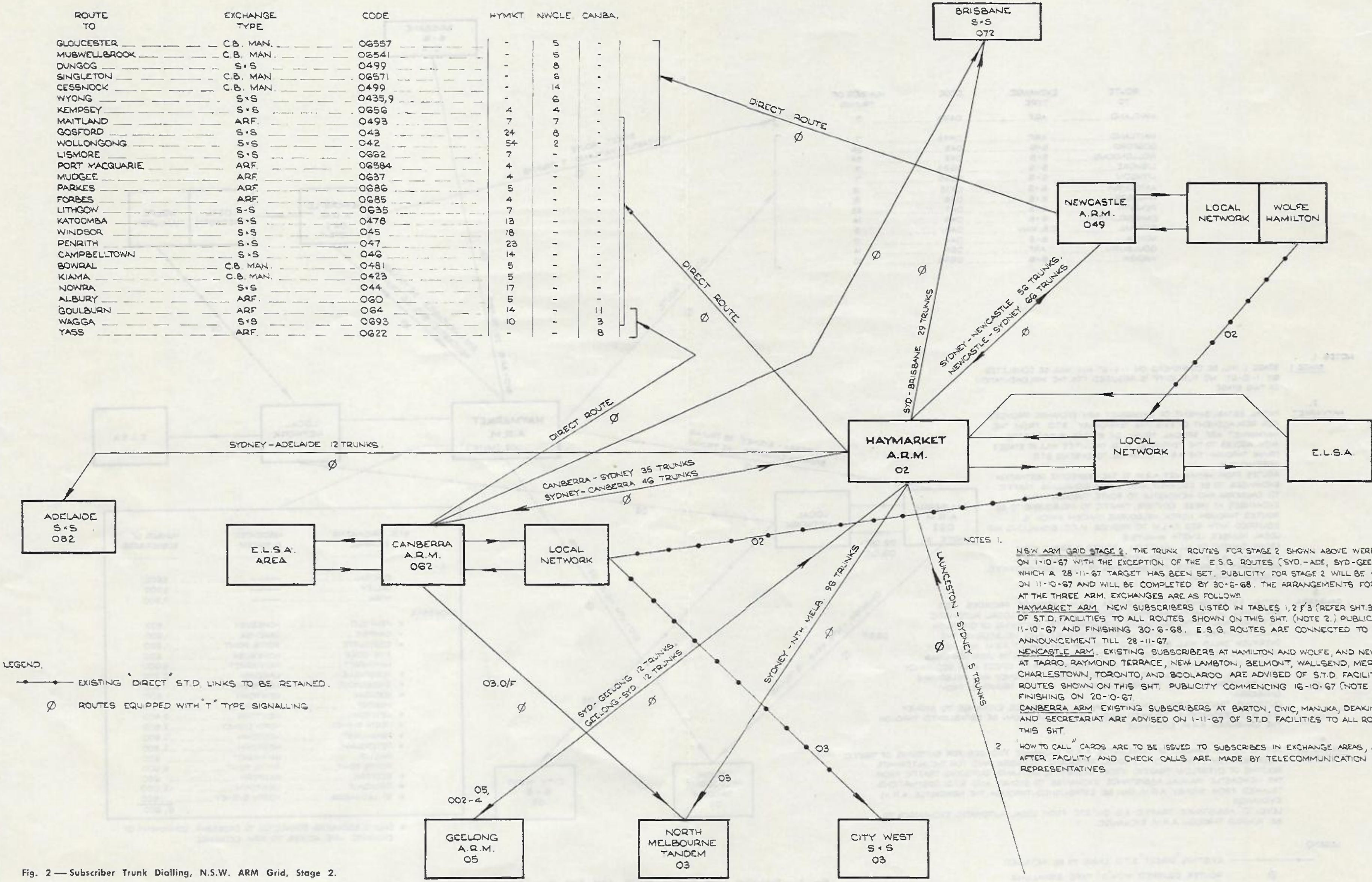
LEGEND

—•—•— EXISTING 'DIRECT' S.T.D. LINKS TO BE RETAINED

Ø ROUTES EQUIPPED WITH 'T' TYPE SIGNALLING.

Fig. 1 — Subscriber Trunk Dialling, N.S.W. ARM Grid, Stage 1.

ROUTE TO	EXCHANGE TYPE	CODE	HYMKT	NWCLE	CANBA.
GLOUCESTER	C.B. MAN.	06557	-	5	-
MUBWELLBROOK	C.B. MAN.	06541	-	5	-
DUNGOG	S×S	0499	-	8	-
SINGLETON	C.B. MAN	06571	-	6	-
CESSNOCK	C.B. MAN.	0499	-	14	-
WYONG	S×S	0435,9	-	6	-
KEMPSEY	S×S	0656	4	4	-
MAITLAND	ARF.	0493	7	7	-
GOSFORD	S×S	043	24	8	-
WOLLONGONG	S×S	042	54	2	-
LISMORE	S×S	0662	7	-	-
PORT MACQUARIE	ARF.	06584	4	-	-
MUDGEE	ARF.	0637	4	-	-
PARKES	ARF.	0686	5	-	-
FORBES	ARF.	0685	4	-	-
LITHGOW	S-S	0635	7	-	-
KATOOMBA	S×S	0478	13	-	-
WINDSOR	S×S	045	18	-	-
PENRITH	S×S	047	23	-	-
CAMPBELLTOWN	S×S	046	14	-	-
BOWRAL	C.B. MAN.	0481	5	-	-
KIAMA	C.B. MAN.	0423	5	-	-
NOWRA	S×S	044	17	-	-
ALBURY	ARF.	060	5	-	-
GOULBURN	ARF	064	14	-	11
WAGGA	S×S	0693	10	-	3
YASS	ARF.	0622	-	-	8



NOTES 1.

N.S.W. ARM GRID STAGE 2. THE TRUNK ROUTES FOR STAGE 2 SHOWN ABOVE WERE ESTABLISHED ON 1-10-67 WITH THE EXCEPTION OF THE E.S.G. ROUTES (SYD.-ADE, SYD-GEELONG) FOR WHICH A 28-11-67 TARGET HAS BEEN SET. PUBLICITY FOR STAGE 2 WILL BE COMMENCED ON 11-10-67 AND WILL BE COMPLETED BY 30-6-68. THE ARRANGEMENTS FOR PUBLICITY AT THE THREE ARM. EXCHANGES ARE AS FOLLOWS

HAYMARKET ARM. NEW SUBSCRIBERS LISTED IN TABLES 1, 2 & 3 (REFER SHT.3) ARE ADVISED OF S.T.D. FACILITIES TO ALL ROUTES SHOWN ON THIS SHT. (NOTE 2.) PUBLICITY COMMENCING 11-10-67 AND FINISHING 30-6-68. E.S.G. ROUTES ARE CONNECTED TO VOICE ANNOUNCEMENT TILL 28-11-67.

NEWCASTLE ARM. EXISTING SUBSCRIBERS AT HAMILTON AND WOLFE, AND NEW SUBSCRIBERS AT TARRO, RAYMOND TERRACE, NEW LAMBTON, BELMONT, WALLSEND, MEREWETHER, CHARLESTOWN, TORONTO, AND BOOLAROO ARE ADVISED OF S.T.D. FACILITIES TO ALL ROUTES SHOWN ON THIS SHT. PUBLICITY COMMENCING 16-10-67 (NOTE 2.) AND FINISHING ON 20-10-67.

CANBERRA ARM. EXISTING SUBSCRIBERS AT BARTON, CIVIC, MANUKA, DEAKIN, RUSSELL AND SECRETARIAT ARE ADVISED ON 1-11-67 OF S.T.D. FACILITIES TO ALL ROUTES SHOWN ON THIS SHT.

2 "HOW TO CALL" CARDS ARE TO BE ISSUED TO SUBSCRIBES IN EXCHANGE AREAS, AREA BY AREA, AFTER FACILITY AND CHECK CALLS ARE MADE BY TELECOMMUNICATION DIVISION REPRESENTATIVES.

Fig. 2 — Subscriber Trunk Dialling, N.S.W. ARM Grid, Stage 2.

hundreds of exchanges and minor offices available from the grid and proved to be a useful method for improving the service when carried out as a co-ordinated check call programme.

PUBLICATION.

Attention was given to the method of publishing the details of the cutover, routes and facilities available to the large number of subscribers involved, and also to possible methods of encouraging the use of the new facility. Subscriber education was also necessary, as the ARM provides some facilities different to those which subscribers connected to temporary S.T.D. were accustomed and completely new to others. As mentioned previously, the timing for establishment of outgoing trunk routes from Haymarket ARM was dependent basically on the delivery of distant end 'T' type signalling relay sets, together with the capacity of the A.P.O. installation teams to install and modify them at short notice. It was decided, therefore, that the initial publication would be covered by individual letters to the subscribers, posted approximately eight weeks prior to cutover. The listing of all outgoing trunk routes would be given later to the subscribers, allowing more time to finalise the access codes for publication, with the issue of new 'How-to-call' cards. For the publication of the cutover, individual letters were sent at cutover. These were prepared approximately six months prior to issue, kept up-to-date and posted (in accordance with the schedule prepared for the 'X' tandem areas), together with the 'How-to-call' cards. The subscribers had already been forewarned of the facilities and the method of operation in the first letter eight weeks prior to cutover.

A comprehensive list of exchanges in N.S.W. had been prepared to show those to which S.T.D. access was desirable, as indicated by trunk docket information. All of these centres, of course, were not available to the initial ARM grid. Nevertheless, a comparison of this list with the trunk routes to be connected, and the exchanges available from the distant exchanges terminating these routes, enabled a comprehensive list to be prepared for publication purposes. The access codes for the various distant exchanges that would apply at cutover of the ARM had also to be checked accurately and to do this it was necessary to consult the Installation Divisions responsible for these areas. Two sets of information finally evolved, a comprehensive list of all exchanges and minor offices available from the grid, for distribution to assistance operators and PBX operators with access to the S.T.D. network, and a concise 'How-to-call' card, listing the major destinations available, for distribution to normal subscribers.

NETWORK PROBLEMS.

Although this paper is not the place to delve into the many technical and facility problems that arose throughout the course of the installation, a brief mention is made here of some particular problems that arose due to this being a prototype network.

Routing.

Whilst the problems on site were being resolved, the true place that the ARM was to take in the trunk network was only beginning to emerge. With the future network promising to offer an ARF type exchange having localised call charging facilities (capable of handling the majority of S.T.D. calls originating in the local area and also in a limited number of charge zones for which it acted as parent), the ARM could easily become part of a reduced backbone network. The rate of provision of broadband bearers and the reduction of the number of planned primary and secondary switching centres also emphasised this possibility.

The preparation of the routing analysis strappings for the initial ARMs was based on the trunking diagrams for initial routes, lists issued by Headquarters indicating the national area codes to be allocated to future ARM installations, and local knowledge of the proposed broadband bearer installations. Very little alternate routing of trunks was provided for in N.S.W. and fully dimensioned direct routes were provided to the majority of country centres served by the initial grid. With all N.S.W. country ARMs of "secondary" status in the hierarchy of the switching plan, it is possible that the Sydney ARM will be the only alternate to direct routes between ARM exchanges in N.S.W. The avoidance of a mesh between all secondaries would certainly minimise the risk of a single route failure, causing catastrophic congestion problems in the whole S.T.D. network, a problem already facing some overseas administrations.

Charging.

The difficulties in regard to charging were mainly those of obtaining reliable information for the access codes of the minor offices and small rural exchanges to be available to the grid. The charge analysis strappings in ARM are carried out on the spring tags of multi-coil relays and are reasonably permanent. A determined effort was made, therefore, to provide for the ultimate charge analysis and to strap for all future codes to be available from the ARM grid. As there had been no previous demand for this type of detailed numbering information, the planning and installation groups were set an arduous task to prepare and check the information.

Analyser Strappings.

The terminating ARM provides analysis to determine the 'type of terminating equipment' and 'number length' for each terminal exchange in its area or for foreign terminals available by means of a direct route. This information is used to determine 'waiting place' functions for the ARM registers, to minimise common equipment holding time and to reduce 'post dialling delay' to a minimum. As against the charge analysis, there is little point in providing for analysis for an access code not yet available, particularly if this code will ultimately be served by a different ARM, which itself will carry out this analysis. On the other hand, it was found that prior to the installation of an ARM in many provincial centres, a direct route was provided from the 'first-in' ARM exchanges to obtain limited S.T.D. access to the centre and to some terminals available from that centre. The problem now became one of relating the analyser strapping programme to the installation programme for ARM and automatic exchanges in all provincial areas. This was necessary not only to avoid unnecessary initial strapping, but also to ensure that all codes were analysed appropriately to coincide with the opening or altering of access codes in the State. It later became necessary to extend the analysis at Haymarket ARM to provide for analysis of the Brisbane and Adelaide local networks (to avoid excessive post dialling delays that can occur for codes strapped as number-length-unknown) pending the installation of ARM exchanges in these cities.

THE CUTOVER.

Mention has already been made of the decision to recover the temporary S.T.D. facilities in Stage 1 of the cutover. This was a fairly logical choice, as this avoided the need for publication, offered an established S.T.D. traffic, which could be transferred in controlled samples to the ARM, and made use of exchange equipment in the Sydney and Canberra local networks, that was already in service for S.T.D. traffic.

As described earlier, the outgoing junction systems for each ARM and the inter-ARM trunks were installed first, and this provided a closed network over which, for several weeks, test calls were made with load testers and automatic exchange testers. Some 30,000 calls daily were made from Haymarket and 6000 daily from each of Newcastle and Canberra over this period till consistently low failures were obtained. For local calls under load test conditions into each type of register group, the exchanges gave the following average results prior to cutover:—

Haymarket	0.28 p.c. failure
Canberra	0.08 p.c. failure
Newcastle	0.09 p.c. failure

For performance tests on routes, up to 1 per cent. failures were obtained on inter-ARM routes, and approximately 1 per cent. failures were obtained prior to cutover to the automatic answering bases at the non-ARM distant end exchanges.

For telephone to telephone check calls carried out prior to cutover, 3 to 4 per cent. switching losses were typical on ARM network calls except for occasions where route problems were subsequently identified. These same trunk calls also indicated that average figures of 3 to 6 seconds can be expected for post dialling delays on calls to codes strapped as 'number length known' in the respective ARM analyser, and 10 to 14 seconds on calls to 'number-length-unknown.' This latter category applied initially for all '072' codes available on the direct route to 1st selectors in Brisbane, but before cutover, action was taken to analyse at Haymarket the Brisbane City exchange numbers for set number length, to minimise the post dialling delay on what was expected to be greater than 70 per cent. of the calls on this route. (This was later extended by further analysis to approximately 90 per cent.). It was also significant that the post dialling delay was silent compared to that experienced on calls via temporary S.T.D. facilities using Reg-L and that no 'burst of ring tone' was provided in the ARM registers. As the Stage 1 cutover had not been publicised, it was possible that some subscriber reaction could result, particularly to the 'number-length-unknown' codes. As happened, observations immediately after cutover showed a tendency for Canberra subscribers to release prematurely on calls to Sydney, with post dialling delays of the order of 5 to 6 seconds, due probably to the fact that the ARM route acted only as an overflow and both types of dialling condition were offered to the subscriber depending on the traffic conditions.

Having established the inter-city grid for testing purposes, it was necessary to extend the grid to all N.S.W. trunk centres shown in Fig. 1. In addition, Interstate routes were necessary to Brisbane, where locally designed and manufactured relay sets were installed, and to Melbourne via the North Melbourne Tandem Exchange, which used new Reg-Y1 (LM) equipment. This installation suffered similar development and modification problems to the ARMs and late delivery of equipment complicated the establishment of this route, which by now was essential to the Stage 1 cutover of the N.S.W. grid, Melbourne being available to temporary S.T.D. subscribers.

Cutover Schedule.

As the cutover date approached, confidence grew in the performance of the system and of the ability to meet the target. Several installation works in the Sydney, Canberra and Newcastle local areas (for installing, testing and commissioning the junctions into the ARM) were dependent on the target being achieved, as was a detailed schedule for facility and check calls from the Blakehurst area and from each temporary S.T.D. exchange as it was cut over to the respective ARM.

A detailed cutover schedule starting on 1.9.67 was prepared for the cutover of the junctions from the Sydney Co-Main step-by-step exchanges to Haymarket ARM. Routes from 'O' level second selectors at each of these exchanges fed '03', '04' '06' and '07' traffic separately to Haymarket ARF exchange for temporary S.T.D. facilities. On this first day '06' codes only were selected for cutover, as this reduced to five the number of outgoing trunk routes that were involved in the cutover, namely Canberra (062), Lithgow (0635), Goulburn (064), Lismore (0662) and Wagga (0693). The junctions were tested and cut over in turn commencing at 7.30 a.m. till the complement for the day had been completed (each day's work usually being completed by 2 p.m.). Simultaneous traffic measurements were taken on the parallel trunk routes to these trunk centres to indicate the appropriate time to recover any channels from the temporary S.T.D. route to build up the ARM route. By the end of the first week all codes had been taken over from these Co-Mains to the ARM, using the same procedure, and all of the Canberra overflow traffic had been diverted to route through Civic (Canberra) ARM.

Between 8/9/67 and 23/9/67 the remaining Sydney exchanges with temporary S.T.D. (all crossbar) were cut over. In this case one route carried all S.T.D. traffic from the respective exchange to the ARM, and a balance had to be maintained for the parallel outgoing trunk routes to all destinations. The build-up of traffic was rapid at this point and approximately 20,000 calls per day were being made through Haymarket ARM at 12/9/67. By 23/9/67 this had increased to approximately 25,000 calls per day, and by 23/10/67 to 40,000 calls per day, of which some 1000 originated at Canberra and Newcastle ARM exchanges.

Post Cutover.

The performance of the grid to date has been very good and the results of test calls and of T.R.T. runs have shown marked improvements to those obtained for the replaced temporary S.T.D. routes. This S.T.D. facility offers inducements to subscribers in terms of the shorter time required to establish a connection and in reduced charges, especially where 'particular person' calls are required.

Subscribers are being encouraged to use the S.T.D. routes, and are also being advised of new S.T.D. routes as they are established by re-direction from the manual assistance centres. However, the final incentive to use the S.T.D. network will depend on continuing good performance. Every effort is being made to achieve this, and also to spot and eliminate congestion points in the grid as early as possible. Minor increases have been necessary already to some routes (e.g., Haymarket ARF to Haymarket ARM, Russell Hill ARF to Canberra ARM), and early indications are that the subscriber reaction to the facility is most favourable.

ACKNOWLEDGMENTS.

Throughout the entire course of the project the degree of co-operation received from all sections of the A.P.O. and from L.M. Ericsson Pty. Ltd. has been outstanding and the author wishes to record his thanks to the many people involved for their assistance, particularly to Mr. P. Egan, Supervising Technician, Grade 4, Haymarket ARM Installation, and to Mr. K. Brown, Field Supervisor, L.M. Ericsson Pty. Ltd., who both made major contributions to the development of ARM installation techniques which have served as the pattern for later ARM works.

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TELEPHONE TRANSMISSION OBJECTIVES

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INTRODUCTION.

This paper was published in 1966 as one of a series presented at an I.T.U. Seminar in Melbourne on the general topic, "Development of a Telephone Network."

The paper briefly describes the evolution of transmission objectives in the Australian network and sets out the present planning rules as far as transmission loss is concerned.

The final section of the paper—"Towards New Objectives"—was revised in late 1967 to take account of later studies, particularly in regard to the specification and assurance of volumes which will satisfy both international (C.C.I.T.T.) and national subscribers' preferences.

TRANSMISSION OBJECTIVES AND THEIR DEVELOPMENT.

The Nature of Transmission Objectives

The determination, achievement and surveillance of telephone transmission objectives is far more complex than the corresponding activities in the switching field. In establishing a connection, one either obtains the wanted party or one does not: a simple binary decision suffices to determine whether the connection has been established to the satisfaction of the subscriber concerned.

The satisfaction derived by subscribers from the transmission characteristics of the connection is a function of many variables; most of them being difficult to specify in objective terms, while some are outside the control of the telephone administration. Included in the latter are room noise, the quality of subscribers' voices and hearing, and the manner in which subscribers hold their telephone instrument while speaking.

Many methods of specifying the transmission performance of a telephone connection have been proposed, adopted and rejected by telephone administrations over the years. These include measures of:

- —the number of repetitions encountered in a free conversation of 100 seconds;
- —the time taken to transmit a given number of ideas (compared with the time using an 'ideal' telephone circuit);
- —counting subscribers' opinions (e.g., 'good,' 'fair,' 'poor,' and 'bad');
- —the loss which must be added to a reference standard telephone connection, as compared with that introduced in the connection under test, to reduce the syllable articulation to 80 per cent. in each case;
- —the loss which must be added to a reference standard telephone connection, to make its received volume apparently equal to that in the connection under test;
- —the proportion of unrelated sentences which are immediately understood by the listener (i.e., without the necessity to review the meanings after reception). This is known as the 'immediate appreciation' method (Ref. 1).

These techniques are described in detail in Ref. 2.

All of the above methods rely on the derivation of objective criteria from subjective tests, and are not easily applicable to the planning of telephone networks, since it is necessary to describe these criteria in terms of the electric and acoustic performance required from the various parts of the network (e.g., transducer efficiencies, frequency response, loss, noise and distortion).

The formidable nature of this task appears to have deterred most administrations in the past from planning their transmission networks in terms of the results of the various methods described above. The last section of this paper describes the present activities of the Australian Post Office in this regard.

HISTORICAL REVIEW.

The development of Australian transmission objectives to the present has largely followed an empirical approach, in which the "worst" telephone transmission performance was defined by a standard connection comprising particular telephone sets, local lines, and interconnecting conditions.

With the development of improved telephone sets, new local line limits were determined in a way calculated to provide 'equality' with the standard, and adjustments were made to the method of defining inter-exchange losses. In 1927, following the adoption in 1926 by the A.P.O. of the decibel as the measure of transmission loss, performance objectives were set for multi-exchange telephone networks in Australia. (Refs: 3 and 4.)

At that time, it was concluded that satisfactory communication in a multi-exchange network would be assured if it were not worse than that provided by two 22-volt central-battery telephones, each connected via a line of 300 ohms resistance to terminal exchanges between which the (800 Hz) loss was 16db. Exceptionally, subscriber loops of up to 450 ohms were permitted, under which circumstances the 800 Hz loss between subscribers' telephones was not to exceed 33db. (Fig. 1a). No other restrictions, such as frequency response, noise and distortion, were prescribed.

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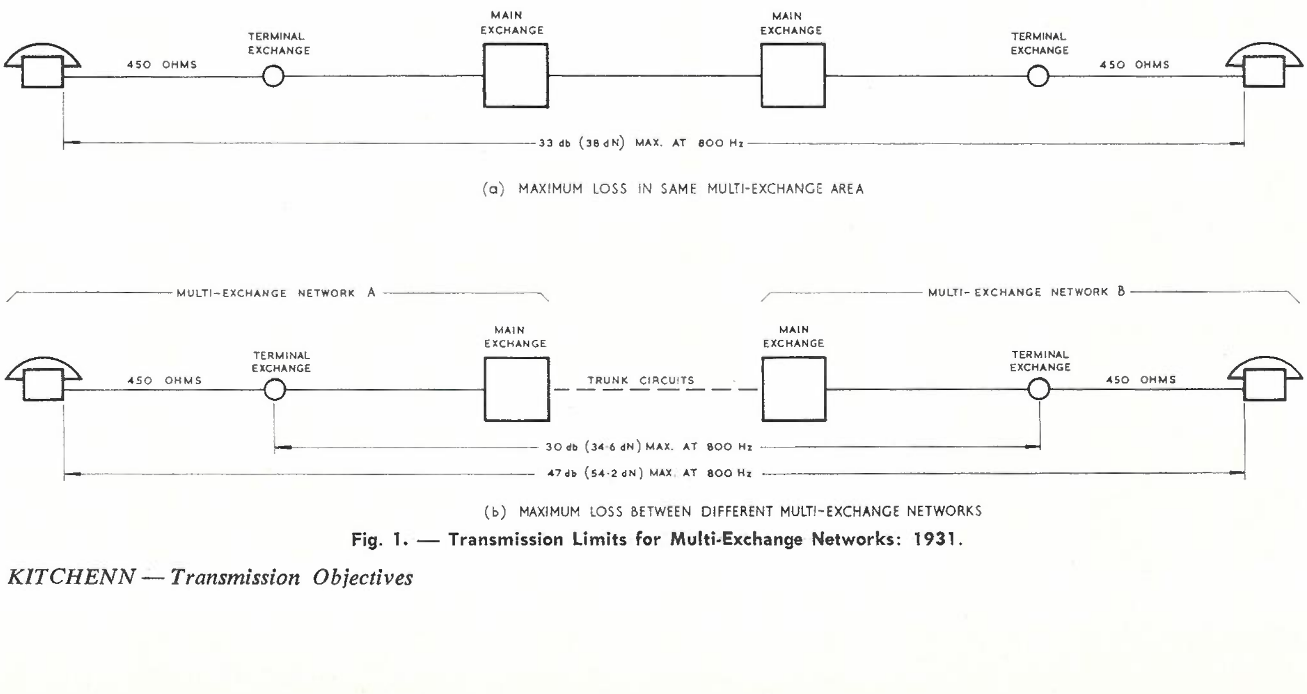


Fig. 1. — Transmission Limits for Multi-Exchange Networks: 1931.

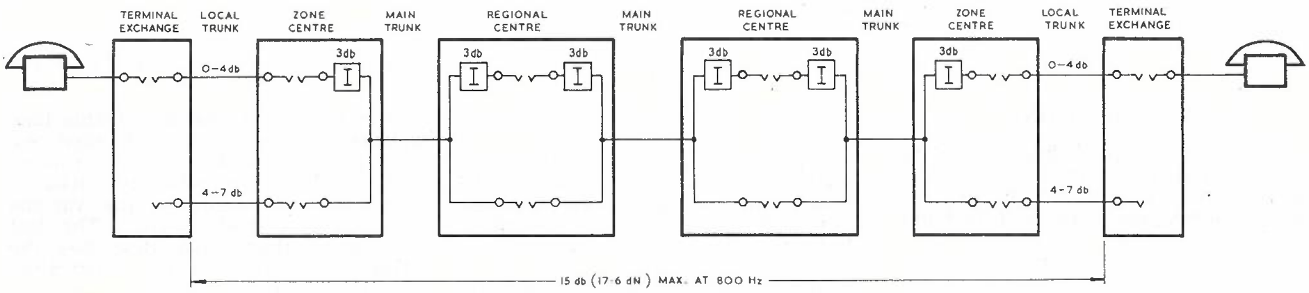


Fig. 2. — Transmission Limits: 1935.

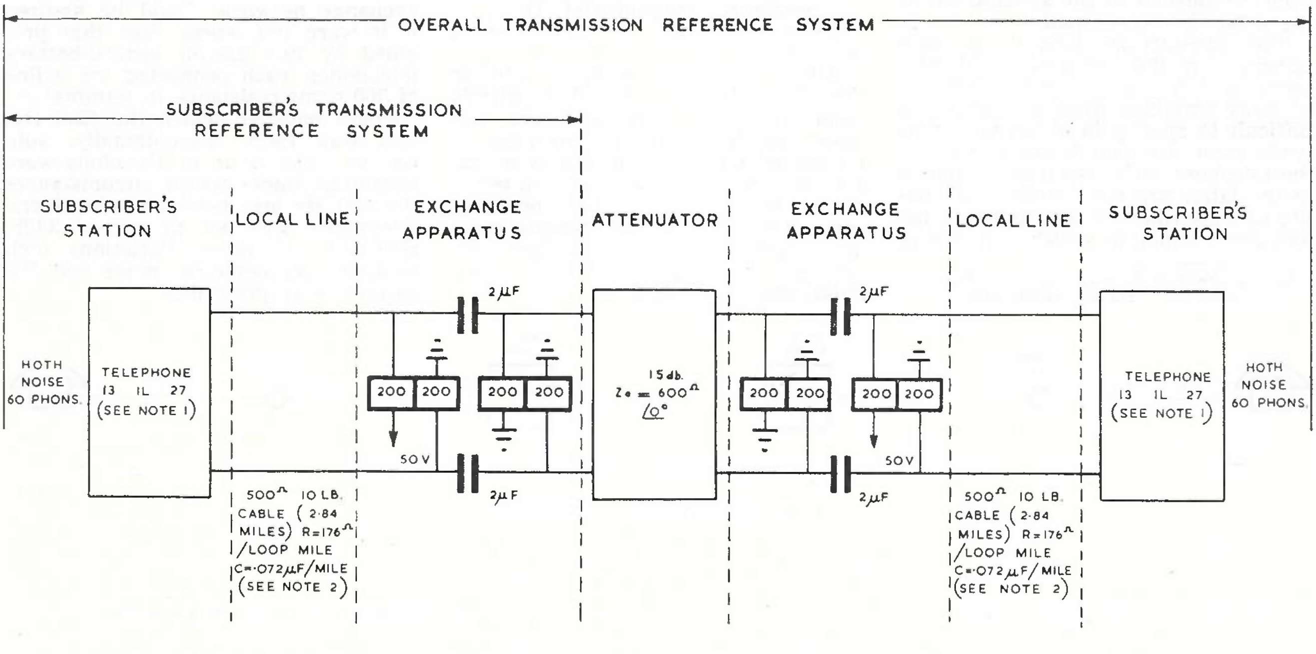
For a connection between telephones in separate multi-exchange areas connected by a 'long trunk line,' the loss objectives were relaxed: 30db between terminal exchanges or 47db between subscribers' telephones, each of which had a 450 ohm loop resistance. (Fig. 1b.) It was noted at the time that 47db represents the greatest loss which can be permitted between two telephones connected by a common battery circuit with a zero loop (i.e., the equivalent of a subscriber's line with no resistance) to enable 'commercial' speech to be conducted. Ten lb/mile (0.635 mm.) cable was then in general use for subscribers' lines with a route distance limit of 1.7 miles (2.74km); 6½ lb./mile (0.507 mm) cable was just being introduced, with a route distance limit of 1.11 miles (1.79 km). (Ref. 4).

By 1935, the planned maximum loss between **all** terminal exchanges had been reduced to 15db (still at 800 Hz), and the problem of instability arising from the use of active circuits was countered by ensuring that low-loss inter-exchange circuits were always terminated by a loss of at least 3db (Ref. 4, 5 and Fig. 2). In the late 1940's, it was recognised that for unloaded cable, the loss at 1.6 kHz was more representative of transmission degradation than the loss at 800 Hz, if intelligibility, as well as volume, were considered. As a result the maximum loss of 15db between terminal exchanges was restated in terms of the higher frequency.

PRESENT TRANSMISSION REFERENCE SYSTEM.

The present overall limiting telephone connection is described in terms of particular telephone instruments (now obsolescent), particular lengths of 10 lb./mile (0.635 mm) cable, inductor-capacitor Stone type 50-volt common-battery feeding bridges, and a 15 db attenuator of 600 ohms characteristic resistance to represent the worst inter-exchange connection. (See Fig. 3.)

Mainly for administrative convenience, subscribers' local ends and the inter-exchange work have their own respective limiting conditions. All improvements in telephone efficiency which have taken place since the reference connection of Fig. 3 was established have been used to increase the transmission loss allowable in the subscriber's loop. The overall transmission performance of a subscriber's limiting local end is nominally constant, regardless of the type of telephone used.



NOTES :-

1. TELEPHONE 13. IL. 27. REFERS TO HANDSET TYPE TELEPHONES HAVING THE FOLLOWING TRANSMISSION COMPONENTS —
   TRANSMITTER INSET Nº 13
   RECEIVER TYPE IL
   ANTI-SIDETONE INDUCTION COIL Nº 27
   } BRITISH POST OFFICE DESIGNATIONS

2. 0·635mm dia, 4·56 km, 109·3Ω/loop km, 44·7 nF/km

Fig. 3. — Present Overall Transmission Reference System.

TABLE 1.—TRANSMISSION LIMITS FOR STANDARD SUBSCRIBERS' CABLES.

Conductor gauge* (lb./mile)	4		6½		10		20	
Conductor Diameter (mm)	0.4035		0.5075		0.6347		0.9025	
Resistance (ohms)	Modern	Obso-lescent		Obso-lescent	Modern	Obso-lescent	Modern	Obso-lescent
	1150	670	920	600	770	500	610	400
Distance: miles	2.62	1.52	3.41	2.22	4.37	2.84	7.0	4.55
Distance: km	4.22	2.44	5.48	3.57	7.04	4.56	11.3	7.33
Attenuation at 1.6 kHz: db	9.16	5.32	9.1	5.88	9.3	6.05	10.2	6.64
Attenuation at 1.6 kHz: dN	10.55	6.12	10.48	6.77	10.7	6.97	11.9	7.65

*Capacitance = 0.072 microfarad/mile = 44.7 nF/km.

CURRENT SUBSCRIBERS' NETWORK OBJECTIVES.

General.

In principle, no combination of exchange feeding bridge, local line and telephone instrument should provide a transmission performance inferior to that shown as 'subscriber's transmission reference system' (S.T.R.S.) in Fig. 3. The reference system represents a typical local end of the 1940's. Although the telephone and gauge of local line is now obsolescent, the 50v. 200 + 200-ohm feeding bridge remains standard at all Australian central-battery and automatic telephone exchanges.

To determine the limiting lengths of cable of various gauges and various types of telephone, it was first necessary to choose the criteria which represented 'equality' with the reference system. In the late 1940's, the A.P.O. followed the British Post Office in the main principles of calculating equality with the reference system. (Ref. 6). The system was basically an assessment of volume performance, with the characteristics of the telephone transmission circuit being calculated as a mean of the values corresponding to 500 Hz, 1000 Hz, 2000 Hz and 3000 Hz, and subscriber line losses being calculated at 1600 Hz.

Calculations of transmitting efficiency took account of the reduction of acoustic/electric efficiency in the carbon microphone with increasing line resistance, and the psychophysical effect of sidetone on the talker: a high level of sidetone causes a talker to reduce the volume of his voice, thus creating a transmission impairment. The sending volume efficiency is assumed (from experimental evidence) to be reduced by 0.15db per decibel increase of sidetone relative to the S.T.R.S.

Sidetone at the receiving end of a connection impairs the receiving transmission performance if acoustic noise is present in the listening room. (Note that the S.T.R.S. circuit includes a Hoth-type noise source of 60 phons at each telephone instrument). Noise picked up by the telephone microphone and reproduced as sidetone in the receiver reduces the signal-to-noise ratio of received speech, and the effect can be described as a reduction in the apparent volume efficiency in the receive direction. The receiving volume efficiency is assumed (from experimental evidence) to be reduced by 0.7db per decibel increase of sidetone relative to the S.T.R.S.

The above sidetone corrections are conventional values; they vary with the absolute level of the sidetone, increasing with increasing sidetone level and decreasing with decreasing sidetone level. However, for the present purpose, it is sufficient to regard them as constant.

A detailed description of the process by which the transmission limits for various telephones and cable gauges are derived is beyond the scope of this paper, but is should be noted that it would be almost impossible for any combination to have exactly the same sending and receiving performances as the S.T.R.S.; either the sending limit or the receiving limit will be reached first, and what is conventionally regarded as 'equal' will in fact have a performance in one direction superior to that of the S.T.R.S. On lighter gauges of cable, for example, receiving performance of up to about 6db better than the S.T.R.S. are obtained when the sending performance is equal to that of the S.T.R.S.

Exclusive Exchange Lines.

Single-Gauge Unloaded Cables: Although limiting line lengths for various single-gauge conductors and all types of telephone in the Australian network (some tens of variations of basic telephone types) can be calculated, the use of such complex data is not justified for planning purposes.

The present transmission limits are therefore simplified, and include some approximations in the interests of simple planning rules. They are under revision at present.

For planning transmission limits for subscribers' lines, automatic and central-battery telephones are classified under two principal types: modern and obsolescent. The modern types include the Type 400 (equivalent to the British Post Office type 706, but without regulation) and the Type 801 (with regulation). (Refs. 7 and 8.) The obsolescent types include British Post Office Types 332 with Type 1L and 2P receivers, Type 162, and earlier models..

Table 1 shows the current limits for subscribers' services. The limits are expressed in terms of distance, resistance and attenuation at 1.6 kHz.

Cables having conductors of 2½ lb/mile weight (0.3175mm) are also in use in Australia. The limit of this cable with modern telephones is at present 1410 ohms (2.08 miles, 3.35 km, 8.86 db, 10.2 dN), but is under review. Open-wire extensions to the above limits are permitted if shorter than 0.5 mile (0.8km).

Single-Gauge Open Wires: Open-wire conductors of cadmium copper (cc) and hard-drawn copper (hdc) are used for subscribers' services in rural areas, with limits as shown in Table 2.

TABLE 2.—TRANSMISSION LIMITS FOR STANDARD SUBSCRIBERS' OPEN WIRES.

Conductor Gauge (lb/mile)	40 cc.		70 cc.		100 hdc.	
Conductor Diameter (mm)	1.27		1.675		2.01	
Resistance (ohms)	Modern	Obsolescent	Modern	Obsolescent	Modern	Obsolescent
	1320	850	1155	750	1078	700
Distance: miles	25.4	16.3	38.5	25.0	61.3	39.8
Distance: km	40.9	26.2	62.0	40.2	98.8	64.0
Attenuation at 800 Hz*: db	6.4	4.1	6.73	4.37	6.75	4.38
Attenuation at 800 Hz*: dN	7.38	4.72	7.75	5.03	7.78	4.05

*Because of the very much smaller capacitance of open wires compared with cables, their effective loss is calculated at 800 Hz.

TABLE 3.—CONVERSION FACTORS: OTHER GAUGES TO EQUIVALENT 10 LB./MILE GAUGE.

Gauge: lb/mile mm diameter	2½ 0.3175	4 0.4035	6½ 0.5075	10 0.6347	20 0.9025	40 cc. 1.27	70 cc. 1.675	100 hdc 2.01
Equivalent 10 lb/mile Resistance	0.55	0.67	0.84	1.0	1.26	0.57	0.66	0.70
Equivalent 10 lb/mile Length	2.19	1.7	1.3	1.0	0.62	0.17	0.11	0.07

Mixed Gauges: Tables 1 and 2 show the limits for single-gauge construction, but this condition is the exception; most subscribers' lines are made up of two or more sections of cable having different gauges. The limit in these cases is calculated by converting the length or resistance of non-10 lb./mile cable to equivalent 10 lb./mile cable quantities, in accordance with Table 3.

Transmission Regulation: The latest A.P.O. telephone (type 801) includes varistor shunts across the line terminals and balance terminals. These varistors reduce the sending and receiving efficiencies of the instrument on lines having a resistance of less than about 400 ohms, thus reducing the range of volumes which would otherwise be encountered with a wide range of subscribers' line lengths.

Two other beneficial effects and one detrimental effect are associated with the varistors:

—the microphone current is reduced on short lines, thus prolonging the life of and reducing the noise generated in the microphone;

—the sidetone ratio is increased at the lower values of line resistance;

—a penalty of the order of one to two decibels is incurred on a limiting line (however, current models provide for disconnection of the varistors).

To reduce microphone current and increase the sidetone ratio in non-regulated telephones on short lines, all lines having a resistance of less than 200 ohms are fitted with a series 330-ohm resistor.

Loaded Cables: In some rural and outer urban distribution areas, the use of inductively-loaded subscribers' cable represents the most economic distribution method, and standard 88mH loading coils are fitted every 2000 yards (1.83 km). This increases the impedance seen by the telephone looking towards the exchange, and can give rise to excessive sidetone due to severe mismatch between the telephone circuit balance network and the line impedance.

To reduce the sidetone to a satisfactory level, a network comprising 470 ohms and 0.15 microfarads in series is shunted across the telephone terminals. This somewhat offsets the potential advantage of loaded conductors, but still yields a worthwhile net gain. The alternatives to this course would be either to interpose an impedance transformation between the line and telephone (with attendant difficulties with 17 Hz ringing and d.c. signalling currents) or to change the belance network in telephones to be used on loaded lines. Neither alternative was considered to be as attractive at the shunt network method.

TABLE 4.—TRANSMISSION LIMITS FOR MODERN TELEPHONES ON LOADED CABLES.

Gauge: lb./mile mm diameter	4 0.4035	6½ 0.5075	10 0.6347	20 0.9025
Resistance* (ohms)	1500	1300	1200	1200
Distance: miles km	3.3 5.3	4.7 7.55	6.5 10.45	12.5 20.1
Attenuation of cable at 1.6 kHz: db dN	6.0 6.9	5.26 6.05	4.94 5.68	5.12 5.9

*Includes the resistance of loading coils assessed at 8 ohms per loop mile (5 ohms per loop km).

Limits applying to loaded cables are shown in Table 4. It should be noted that only modern instruments are used on loaded cables. Transmission performance is equivalent to the S.T.R.S.

Multipled Teed Pairs: It is customary in subscribers' networks to provide for flexibility of cable-pair usage by making certain exchange cable pairs available at several distribution points. This arrangement, known as 'teeing,' applies only to unloaded cables, and requires open-circuited lengths of cable to be connected in parallel with a subscriber's line at a point or points along the length of the line. The effect is to add capacitance in parallel with the line, thus increasing the loss of the line, the loss being more severe at the higher voice frequencies.

Lines subject to such "teeing" have a reduced transmission limit. If the teed length of cable is less than 1000 yards (0.915km), it is neglected. Beyond 1000 yards, the transmission limit is reduced by 1 per cent. for each 100 yards (91.5m) by which the teed

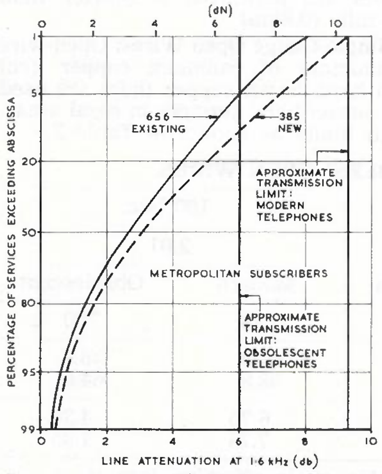


Fig. 4. — Subscribers' Loop Attenuation

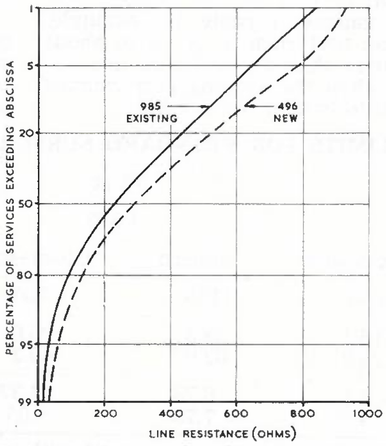


Fig. 5. — Subscribers' Loop Resistance

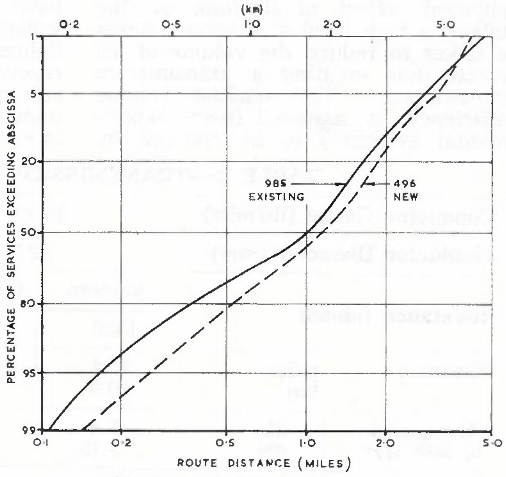


Fig. 6. — Subscribers' Route Distance

cable pair exceeds 1000 yards. This rule is based on the effect of the added capacitance calculated as the average of the effects at 500 Hz, 1000 Hz, 2000 Hz and 3000 Hz.

Non-Physical Systems: Previous paragraphs have described limits which are nominally equivalent on a volume basis; there is no specific description of the frequency response, distortion, and noise of a subscriber's local end, although the development of a noise objective is under study. However, where subscriber's services are provided by non-physical means such as a carrier system on cable or open wire, or by radio, the performance of the link is largely a function of the terminal equipment at the exchange and subscribers' ends, and must be specified in order to purchase, install and maintain the equipment.

Present interim objectives for such equipment provide for relaxed noise, distortion and frequency response performance as compared with the objectives for the inter-exchange network and also permit the use of speech clipping or limiting and pre-de-emphasis to achieve the objectives.

Local-Battery Telephones: In principle, a local-battery telephone offers the possibility of line limits greater than those applying to automatic and c.b. telephones, since there is neither a feeding bridge loss nor a loss due to microphone feed current. However, two other factors are restricting:

- —with some types of local-battery telephone, there is a serious sidetone penalty (although a modified balance network has been designed).
- —a local-battery exchange may be converted to automatic working within the lifetime of the reticulation network, at which time some subscribers would be beyond the permitted limits.

Therefore, the limits applying to automatic and c.b. telephones are also applied to local-battery networks in general. However, it is recognised that such a practice may be an excessive economic burden at small rural exchanges which are unlikely to be converted to automatic within say, five years. Special limits for such cases are being developed at present.

Extension Lines.

An extension telephone may be added to an exclusive exchange line telephone or to a private branch exchange (P.B.X.), which itself may be regarded as a direct exchange line telephone; in each case an extension telephone has access to the public telephone exchange via the extension line and the exclusive line.

In principle, therefore, the limits for exclusive exchange lines should apply between the public exchange and any extension telephone, to ensure a transmission performance no worse than the S.T.R.S. This condition is met in the majority of cases since only a small proportion of exclusive exchange lines approaches the limit (see Figs. 4-6) and most extension lines terminate in the vicinity of the P.B.X. or subscriber's main station.

Cases which do not meet the above condition are few, and measures to ensure compliance would be excessively costly. Present interim rules for modern telephones used as extensions provide for a maximum 1.6kHz loss of 14.5 db between extension and public exchange, provided the feed - current loop resistance does not exceed 650 ohms. Feed current may be supplied by a signalling repeater between the extension and the public exchange. The allowable loss is reduced for feed-current loop resistance in excess of 650 ohms.

Part-Privately-Erected Lines.

In some rural areas of Australia the provision and maintenance of subscribers' lines beyond a certain distance become uneconomic, and various measures may be taken under the Telephone Regulations of the Australian Post Office to provide service to remote subscribers. In one method, a subscriber is permitted to erect and maintain his own line (generally of open wire on poles or trees, single-wire earth-return or a metallic pair) from the point where Post Office plant ceases, to his premises. The Post Office provides a standard (generally magneto) telephone.

Wherever possible, the limits set out for exclusive exchange lines will be met, and where magneto service is likely to be retained for more than five years the limits of Table 2 are extended by the transmitter feed current penalty; a distance extension of up to 40 per cent. is permissible.

In addition, galvanised iron wire of 100 lb/mile (2.17mm) and 400 lb/mile (4.3mm) is permitted, because of its low cost relative to copper and cadmium-copper conductors. Its transmission characteristics are inferior, and the limit for 400 lb/mile galvanised iron conductors is less than that for 40 lb/mile (1.27mm) cadmium copper conductors.

However, some relaxation is permitted when these requirements would entail heavy expense for the subscriber (e.g., in the provision of heavy-gauge copper conductors). If the limits are exceeded by up to 3 db the subscriber is informed that transmission will be tolerable but not up to the normal A.P.O. objectives. With line losses up to 6 db greater than the limit, the subscriber is informed that a fairly high percentage of impaired calls can be expected, and that dissatisfaction will occur at both ends of the conversations. When a subscriber proposes to build a line which will result in the limit being exceeded by up to 12 db, special attention is given to alternative means of provision of service. Other methods are outside the scope of this paper.

The A.P.O. gives technical guidance to subscribers in the construction and maintenance of part - privately-erected lines (Refs. 9, 10, 11 and 12), and customers may purchase some materials from the A.P.O. if they wish.

Up to four parallel parties may normally be connected to a part-privately-erected line on a magneto exchange; if this restriction imposes undue hardship on subscribers, it may exceptionally be extended to six. On central-battery or automatic exchanges, the number of parties is normally limited to two; exceptionally three.

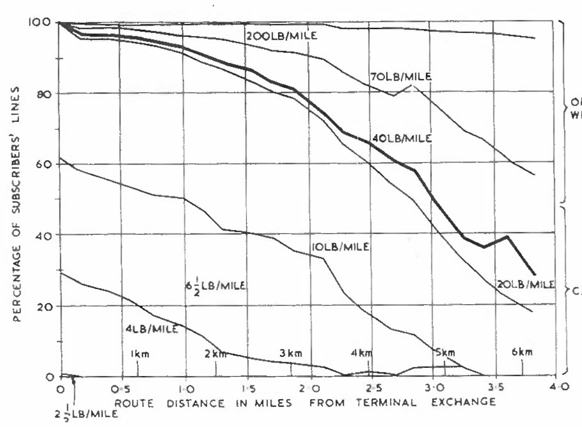


Fig. 7. — Line Make-up: Existing Services.

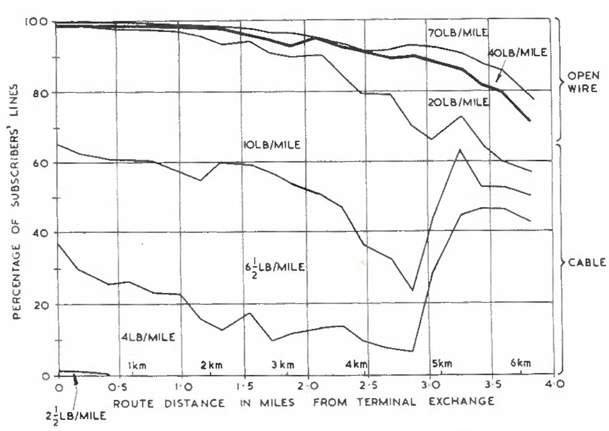


Fig. 8. — Line Make-up: New Services.

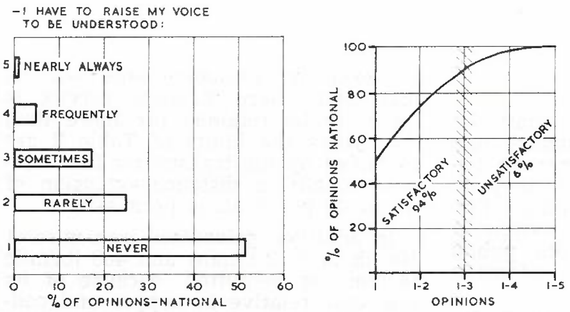


Fig. 9. — Subscribers' Opinions — Talking.

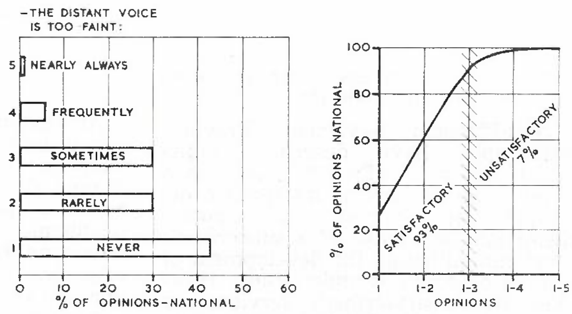


Fig. 10.—Subscribers' Opinions—Listening.

Signalling Limits.

Two limits apply to subscribers' lines provided by a metallic pair: a transmission limit described above, and a signalling resistance limit (i.e., for calling, clearing, dialling, and ringing-current trip), which depends on the type of exchange. The lower of these two is the absolute limit for the subscriber's line.

Modern crossbar automatic exchanges have a signalling limit of 1500 ohms, while some older automatic exchanges have a low signalling limit: 650 ohms. A magneto exchange has a non-critical signalling limit of about 1000 ohms.

Measurement of Actual Performance.

A sample survey of 984 subscribers' local ends was conducted throughout Australia in 1965 as part of a programme to determine the in-service transmission characteristic of the Australian telephone network. In addition, similar details were recorded for the 496 new telephone services which were installed in Australia on 30th July, 1965, to provide comparative data between 'existing' services and 'new' services. Only exclusive exchange lines of 100 per cent. Post Office construction were included in the survey. Fig. 4 shows the distribution of 1.6 kHz attenuation. Fig. 5 shows the distribution of loop line resistance, and Fig. 6 shows the distribution of route distance for the two sample sets.

Details of the make-up of subscribers' lines as a function of route distance are shown in Fig. 7 (existing services) and Fig. 8 (new services).

The sample survey suggests that the Australian network comprises about 86 per cent. central-battery or automatic telephones and about 14 per cent. magneto telephones. Of the central-battery and automatic telephones, about 45 per cent. are classed as 'modern,' while the corresponding figure for magneto telephones is about 36 per cent. These proportions are, of course, increasing year by year.

The survey also yielded subscribers' opinions on various aspects of transmission quality. Opinions on sending efficiency are shown in Fig. 9, and those on receiving efficiency are shown in Fig. 10. Results of surveys such as this provide basic data for the further development of transmission planning objectives and rules.

CURRENT INTER - EXCHANGE NETWORK OBJECTIVES.

General Objectives.

The switching hierarchy in the Australian network is described in Ref. 13 and is indicated territorially in Fig. 11 and symbolically in Fig. 12.

In principle, the maximum transmission loss between two terminal exchanges is 15 db at 800 Hz. Most

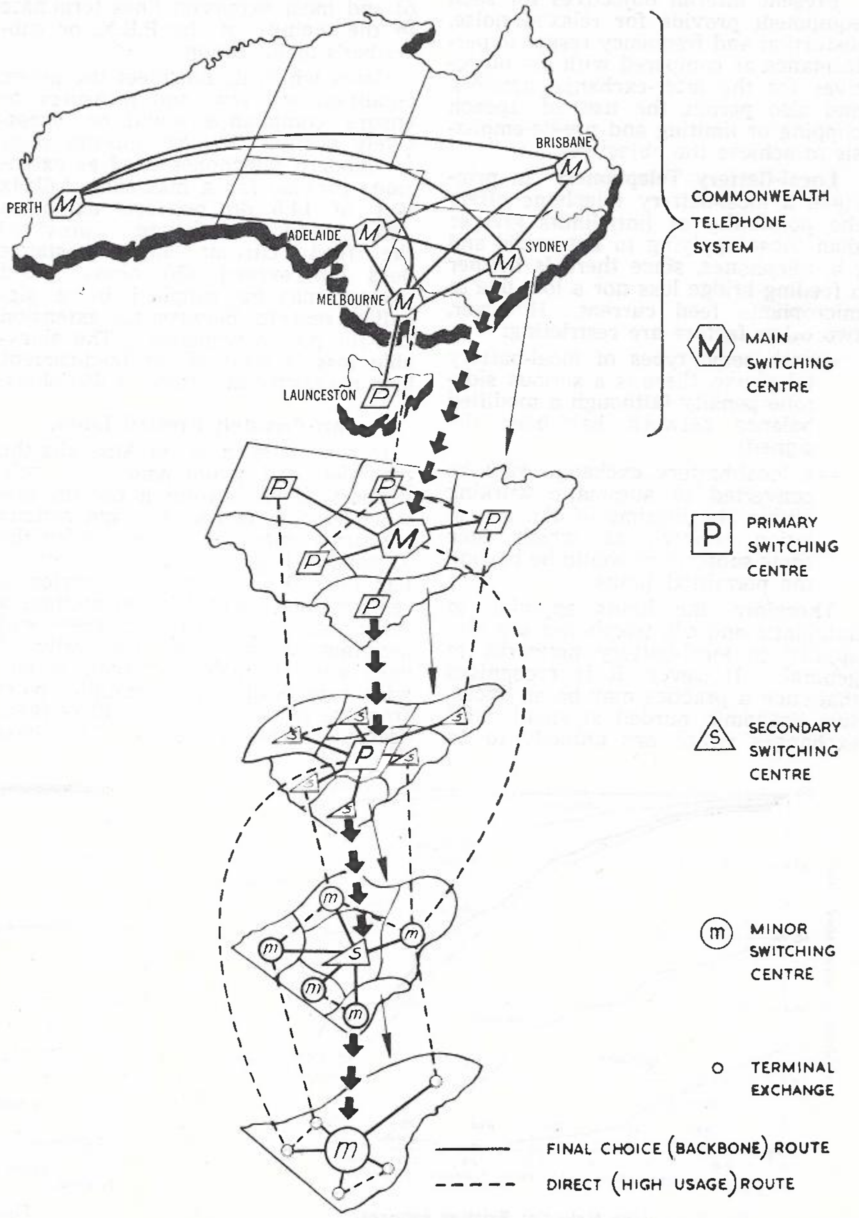


Fig. 11. — Switching Hierarchy (Territorial).

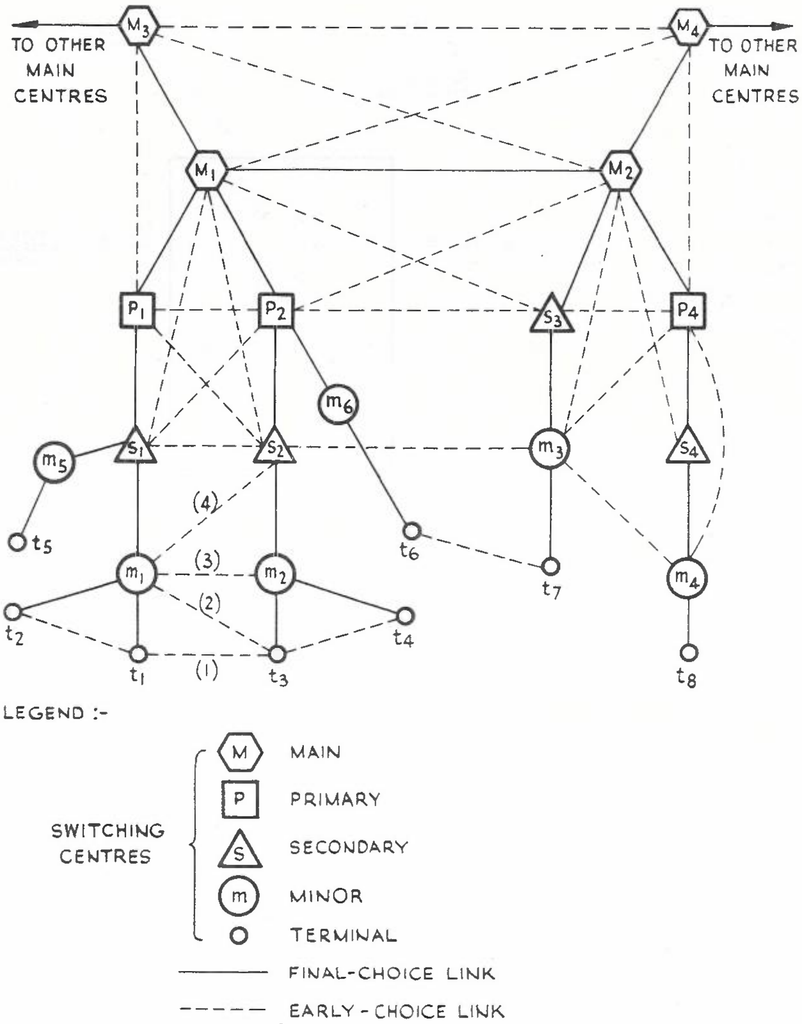


Fig. 12. — Exchange and Link Classifications.

Generally, final - choice links above minor centres have a nominal loss of zero, and the loss of terminal links (i.e., between a minor centre and a terminal exchange) is between 3 db (3.46 dN) and 7.5 db (8.65 dN), with low - loss passive circuits being specially built-out to 3 db. However, to minimise degradations due to near-instability and echo (Ref. 14), the actual loss of nominally-zero-loss links longer than 350 miles (565km) is increased as follows:—

350 to 750 miles (565 to 1200 km) 0.5 db.

Longer than 750 miles (1200km): 1.0 db.

Echo-suppressors are not in general use in Australia, although it is expected that as subscriber-trunk-dialled traffic increases, and actual operating losses of inter-exchange circuits are reduced, they will be necessary, and provision for including them in appropriate connections has been made in the design of the switching system.

Exceptionally, where the maximum link loss of **every** terminal link on a minor trunk switching centre is less than 7.5 db, and where it may be cheaper to provide passive, rather than zero-loss circuits between a minor centre and its secondary centre, the 7.5 db allowance may be allotted to the maximum-loss terminal link and the minor-to-secondary link in tandem (Fig. 13).

The loss on early-choice routes is planned so that the maximum loss of 15 db between terminal exchanges is not exceeded. For new direct links between terminal exchanges a maximum **line** loss of 12 db has been imposed.

Terminal exchanges and minor trunk switching centres are switched on a 2-wire basis; higher-order crossbar centres are switched directional 4-wire, while older 4-wire trunk exchanges use the tail-eating form of connection.

long-distance circuits have a nominal bandwith of 300 to 3400 Hz (2 db points). Some 3-circuit open-wire carrier systems have a channel bandwidth of 300 to 3400 Hz (4 db points), while older 3-circuit open-wire systems have more restricted bandwidths, the worst being 300 to 2800 Hz (2 db points). Passive circuits are inductively loaded with 88 mH coils every 2000 yards (1.83 km).

Noise is permitted to accumulate in proportion to the length of the circuit at 3 pW/km (mean value, any hour, psophometric weighting, referred to a point of zero relative level) with a minimum noise level of —60 dbm0 (1000 pWp0) to account for the irreducible noise from frequency-division multiplex equipment.

The nominal impedance of all transmission equipment and switching centres is 600 ohm.

Division of Loss.

General Network: Fig. 13 shows the current division of maximum loss in the general telephone network.

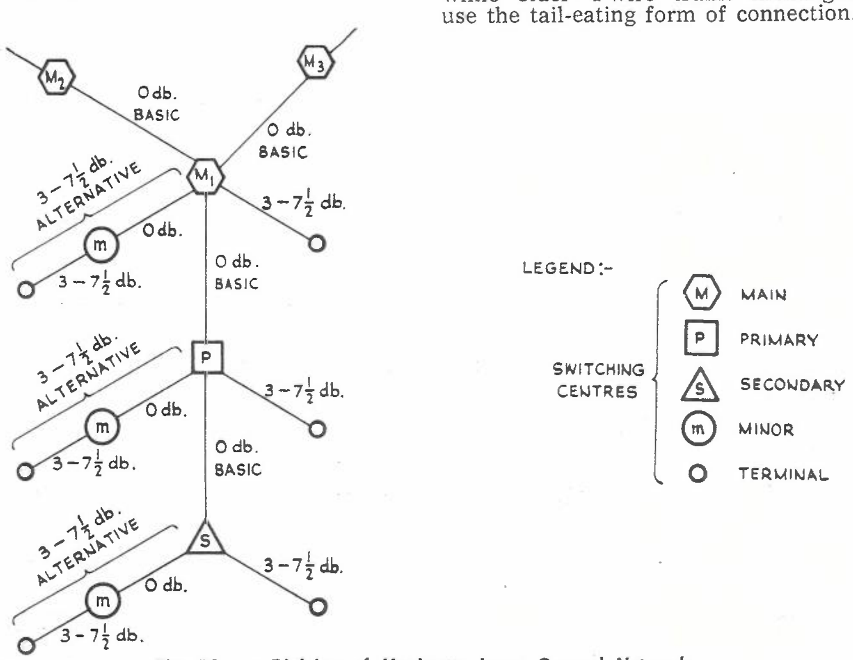


Fig. 13. — Division of Maximum Loss: General Network.

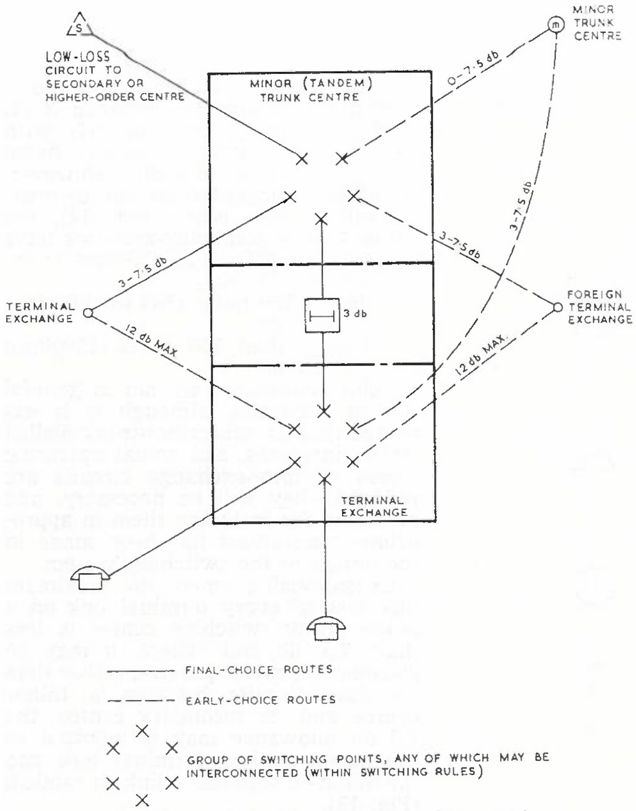


Fig. 14. — Co-location of Minor and Terminal Exchange Functions — Metropolitan Tandem.

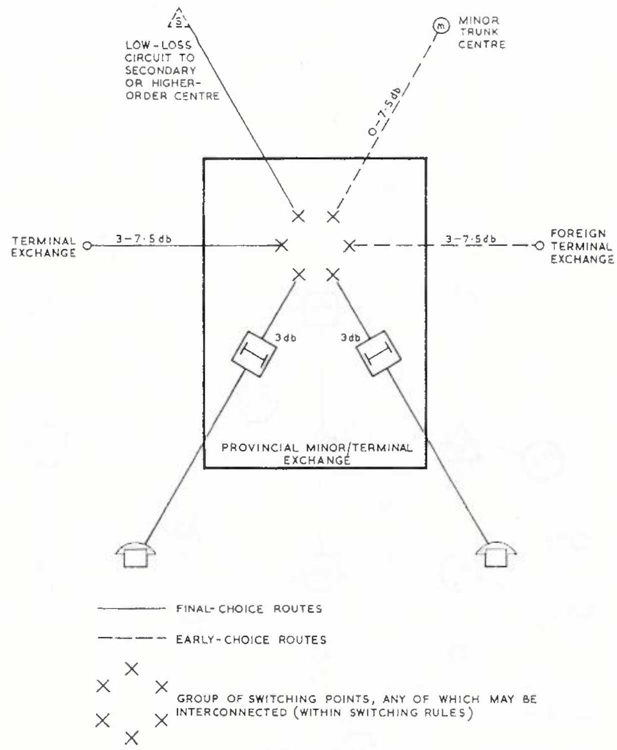


Fig. 15. — Co-location of Minor and Terminal Exchange Functions — Provincial Minor.

The minimum loss of a terminal link (3 db, 3.46 dN) must also be provided where a terminal exchange is in the same building as its minor trunk centre; a 3 db (3.46 dN) pad is included in the link to increase the return loss to a satisfactory value. The principle is shown in Fig. 14 for crossbar exchanges in metropolitan areas. In a metropolitan area, the number of routes and circuits to be provided to other exchanges demands the provision of a 2-stage group selector, which permits the switching arrangement shown in Fig. 14. This is not ideal, since it introduces an unnecessary 3 db penalty on connections to local subscribers from circuits connected to the minor centre, which already have a minimum loss of 3 db.

Fig. 15 shows the transmission conditions at co-located crossbar minor trunk and terminal exchanges in non-metropolitan areas. In this situation, the required number of routes from the minor trunk centre warrants only a single-stage group selector, which restricts the pad switching possibilities. This arrangement introduces unnecessary loss not only on the connections described in the last paragraph, but also on subscriber-to-subscriber calls on the terminal exchange.

Although the arrangements at co-located minor-trunk and terminal exchanges incur unnecessary loss penalties on some classes of call, avoidance of the penalty would be unjustifiably complex and costly, and in no case are the transmission limits exceeded. Indeed, if equality of volume trans-

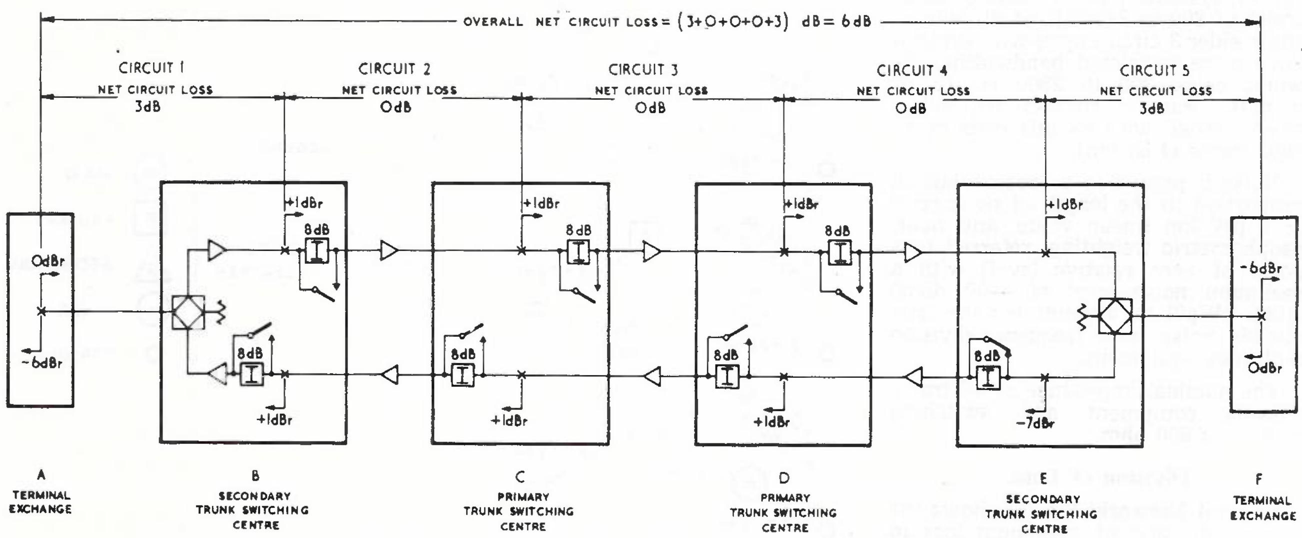


Fig. 16. — Link Losses in a Representative 4-Wire Switched Connection

mission on all connections, regardless of subscribers' locations, is a desirable condition, then the arrangement of Fig. 15 goes some way to ensuring this.

The methods by which the various link losses are achieved are outside the scope of this paper. It is sufficient to note that in a directional 4-wire connection comprising tandem-connected 4-wire links of zero loss, the individual 4-wire links are designed to provide a gain of 8 db from outgoing switch-bank to incoming switch-bank in each direction. Relay set circuitry provides for the inclusion or removal of an 8 db pad in each direction according as the link is in transit or terminal use respectively. Links incorporating the 2w/4w terminating set are provided either with amplifiers (link A-B in Fig. 16) or without (link E-F).

Fig. 16 also illustrates the care needed in defining link losses, because of the variable condition of switchable pads. Apparent anomalies to be resolved in any definition of link loss are illustrated below:—

(a) **Link AB = Link EF = 3 db:—**

But	A to B = 1 db gain
	B to A = 7 db loss
and	E to F = 7 db loss
	F to E = 7 db loss

(b) **Link SD = Link DE = 0 db:**

But	C to D = 0 db
	D to C = 0 db
and	D to E = 0 db
	E to D = 8 db gain

Furthermore, if link AB is connected directly to link EF, the 8 db pad in AB at B is switched out, and

(c) **Link AB = Link EF = 3 db:—**

But	A to B = 1 db gain
	B to A = 1 db gain
and	E to F = 7 db loss
	F to E = 7 db loss

Metropolitan Networks: Although, in principle, metropolitan networks are not different from the general network, the high density of subscribers and exchanges in metropolitan areas has led to special solutions of transmission problems, using the crossbar switching system.

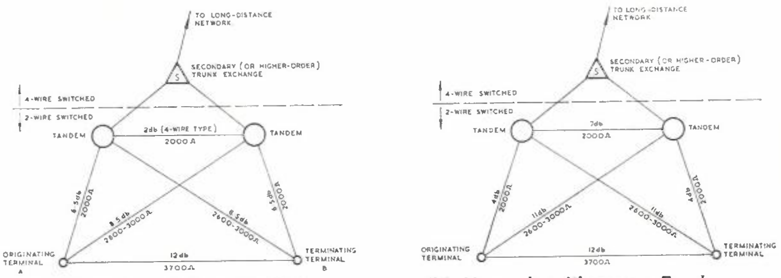
Typical transmission plans for metropolitan networks are shown in Fig. 17. In practice there may be only one tandem exchange serving a small city, in which case the tandem is indistinguishable (from a transmission viewpoint) from a minor trunk centre. In a multi-tandem network the minor trunk exchange transmission facilities may be regarded as being distributed territorially.

Current guidance for metropolitan planning engineers leaves scope for the application of various methods of achieving the specified performance objectives, which require the mean transmission loss (at 1.6 kHz) of busy-hour traffic, in both directions of signalling between any pair of terminal exchanges in the network, to be equal to or less than 12 db. The standard deviation of the loss should be equal to or less than 1.8 db. The maximum link loss of any connection between two terminal exchanges is still retained at 15 db. It will be noted that the objectives are related to the subscribers' transmission experience of the network rather than to the performance of circuits on a particular link. Each metropolitan network will be reviewed in total or by a sample study every few years, to ascertain its compliance with the objectives.

The following are some of the methods which may be used to ensure compliance with the objectives:—

- —Install further circuits on an existing low-loss direct route;
- —Open a new direct route with lower loss than the existing routes;
- —reduce losses on tandem-to-tandem links;
- —Install amplifiers on terminal-to-tandem routes;
- —Reduce the loss on a second-choice route.

These measures have repercussions in other fields. More new routes increase demands on availability at originating terminal and tandem exchanges. A shift of traffic from the backbone route to a tandem-to-foreign-terminal route may require more circuits on that route, as all terminals on the tandem would contribute additional traffic to the route. Similar effects occur in augmenting the terminal-to-terminating-tandem route. Thus the adjustment of the transmission performance of the network may be achieved by changing the traffic flow pattern as well as by adjustment of transmission characteristics.



(a) Network with few Tandems. **(b) Network with many Tandems.**

Fig. 17 — Representative Maximum Transmission Link Losses and Resistance in Tandem Networks.

Transmission Objectives for Telephone Exchanges.

Since telephone exchanges are part of transmission links, it is as important to control their transmission characteristics as it is to control the characteristics of transmission systems.

Australian specifications for crossbar telephone exchanges (Refs. 15 and 16) set numerical objectives for transmission loss (both absolute and as a function of frequency), return loss against a nominal impedance, crosstalk, noise, balance to earth, harmonic distortion and intermodulation, so that the transmission degradations introduced by exchanges may be allowed for quantitatively in the transmission specification for links.

Manual-assistance centres introduce an extra link into a connection, and must be similarly controlled in terms of transmission characteristics. Because calls via a manual-assistance centre may involve up to three passes through the automatic trunk exchange with which it is associated, provision has been made to compensate for the additionad loss incurred. In principle, the net loss introduced as a result of passing a call via a manual-assistance centre should be zero; in practice, a loss of a small fraction of a decibel is permitted on some classes of call via the centre.

TOWARDS NEW OBJECTIVES.

General.

One disadvantage of the present transmission objectives is that, although they set separate limits of transmission loss for subscribers' services and inter-exchange links, they do not (indeed cannot be used to) describe adequately the transmission performance from the subscriber's point of view. The most that can be said about the network is that no connection should exceed a certain amount of loss between telephones. There is no control over the proportion of connections which may approach this loss, and the distribution of loss can be determined only by analysis. Effective planning, of course, demands that the distribution of loss should be pre-determined objectively and that planning rules should be designed to ensure compliance with the desired distribution.

The above discussion refers only to transmission loss, which is perhaps the most important single factor determining subscribers' satisfaction. However, the presence of noise affects subjective loudness, as do restrictions on frequency response. Restrictions on frequency response also affect the ability of a multi-link connection to transmit the multi-frequency voice frequency signals which are used from end-to-end to set up a subscriber-dialled long-distance call.

Although many criteria are available for specifying and measuring the transmission performance of a telephone connection, the most useful for planning, specifying and checking a telephone network appears to be the reference equivalent method (Ref. 17), which is based on the one-way loudness of a telephone connection, as judged by observers in voice-ear tests. Although the A.P.O. is adopting reference equivalents as the principal planning criterion, other auxiliary criteria will be necessary to control sidetone, echo, noise, crosstalk, and frequency response. Some of these may be expressed in terms of a reference equivalent penalty (Ref. 18).

Determination of Transmission Loss Objectives.

International Requirements: Having determined that the principal telephone transmission objectives shall be in terms of reference equivalents, it is necessary to determine the numerical values to be adopted.

C.C.I.T.T. recommendation G.111 states that provisionally the national sending and receiving systems used to set up 95 per cent. (likely to be increased to 97 per cent. on recommendation of Study Group XII.) of actual outgoing or incoming (international) calls in a large country with four national 4-wire circuits should individually meet both the following requirements:—

(a) Sending reference equivalent not greater than 21.3 db (24.6dN).

(b) Receiving reference equivalent not greater than 12.7 db. (14.6 dN).

These reference equivalents are referred to the virtual switching points of the international circuit.

The above recommendation has been interpreted by the A.P.O. as applyiing to all possible connections via the international exchange, rather than to "actual outgoing or incoming (international) calls."

To apply the recommendation to the national network, account must be taken of the difference in relative levels between the international exchange and the national system. The national system has relative levels of +1 dbr at 4-wire switching points, whereas the virtual switching points at the international exchange are defined as —3.5 dbr (outgoing from national network) and —4.0 dbr (incoming to the national network). A connection from a subscriber to the international exchange at Sydney is shown in Fig. 18 for minimum-loss conditions. For clarity, minor trunk switching centres have been omitted from the figure; this does not affect the conclusions.

It will be noted that, referred to the +1dbr switching points of the Sydney main trunk centre, the reference equivalents should be:

(a) Send : 95 per cent. not greater than 16.8db (19.3dN).

(b) Receive : 95 per cent. not greater than 17.7db (20.4dN).

The C.C.I.T.T. specifies only one point on each distribution of reference equivalents.

The actual distribution of reference equivalents may be regarded as the statistical combination of three distributions: one for the subscribers' local ends (sending), and another for the inter-exchange network and the third for subscribers' local ends (receiving). If these distributions are known, compliance with the above conditions may be checked.

Fig. 18 illustrates the result of assuming that the inter-exchange network has a fixed link loss of 3db to the international exchange (the minimum possible). It results in subscribers' local ends being required to meet the following:

(a) Send : 95 per cent. not greater than 17.8db (20.5dN).

(b) Receive : 95 per cent. not greater than 10.7db (12.3dN).

However, these figures cannot be used as a basis for design, since they do not account for the actual distribution of inter-exchange link losses, which may have a maximum value of 9 to 10db from a terminal exchange to the international exchange if via long interstate links.

National Requirements: Another criterion against which the volume performance of a telephone network may be evaluated is derived from the telephone speech loudness preferences of telephone users. In recent Australian tests using two modern telephones (Ref. 18), the receiving party in a telephone conversation was asked to adjust the (unknown) line loss until the received speech loudness was (a) the lowest tolerable, (b) the (highest tolerable), and (c) preferred. Fig. 19 shows some of the results of these tests in terms of reference equivalents. It will be noted that the minimum of adverse opinions occurs at a lower reference equivalent (about 9db) than the maximum of 'preferred' opinions (about 11db).

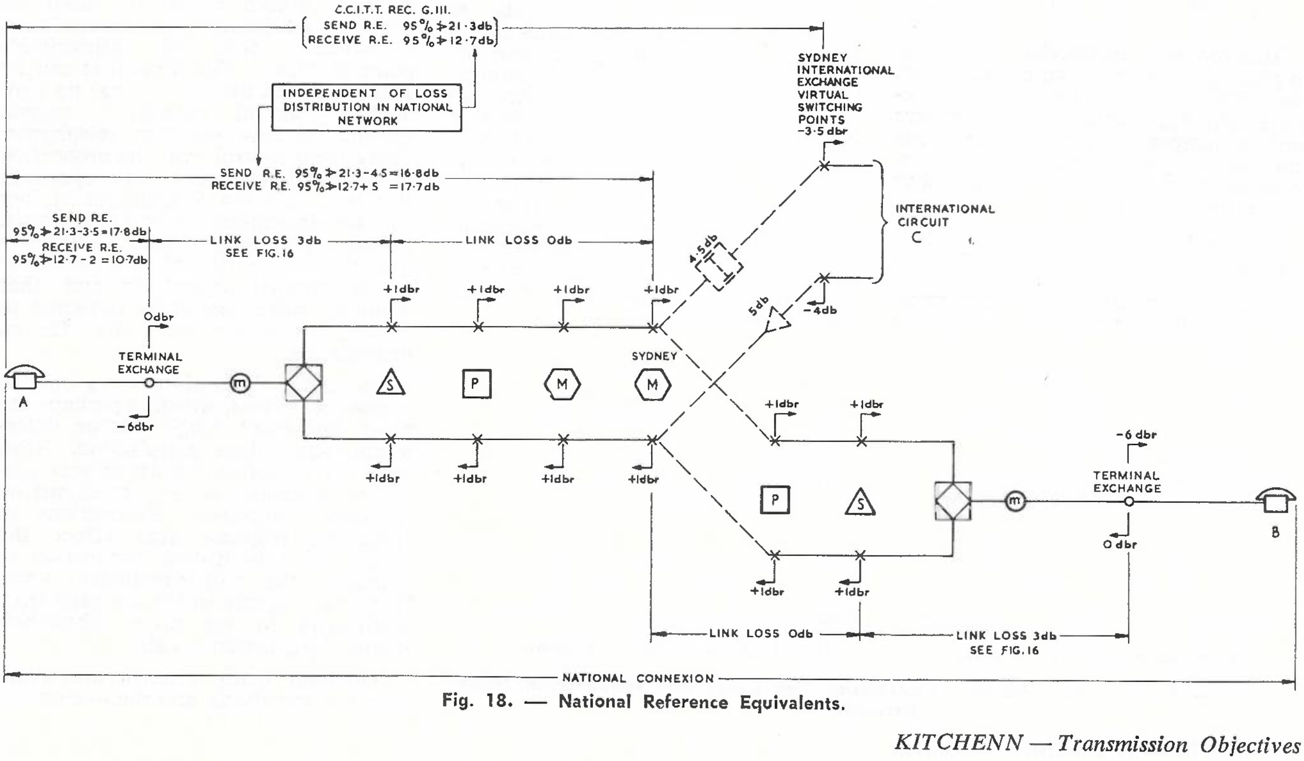


Fig. 18. — National Reference Equivalents.

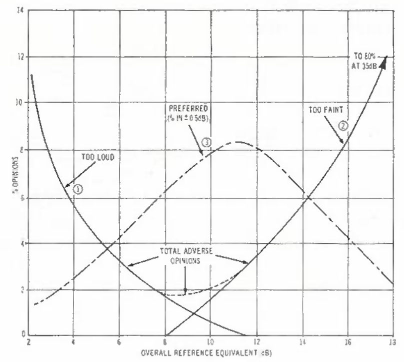


Fig. 19. — Users' Opinions Vs. Overall Reference Equivalent.

Although curve 3 in Fig. 19 refers to a percentage of opinions in + or — 0.5db, whereas curves 1 and 2 refer to the percentage of opinions at a particular reference equivalent, Fig 19 can nevertheless provide a guide to possible transmission objectives for the telephone network.

We could, for example, arrange that the minimum and maximum values of overall reference equivalent should correspond to some specified level of adverse opinions, e.g. (3 to 15.5db; 7.5 per cent. adverse opinions), and set the median of the objective distribution to the maximum 'preferred' opinion: 11db, thus describing at three points one possible objective distribution of reference equivalents.

However, the maximum possible overall reference equivalent under current planning rules is 35db, and a lower limit of about 3db must be set to avoid overloading transmission systems; therefore a symmetrical objective about a median of 11db cannot be a practical proposition.

We are therefore led to test the effects of various test objectives, all having a minimum reference equivalent of about 3db, but having different maximum values. A normal distribution over most of the range may be assumed. These distributions may then be tested for the number of adverse opinions they may yield, using information from curves 1 and 2 of Fig. 19 in the process.

However, objectives cannot be set in isolation from the present performance of the network. Information on subscriber-to-subscriber calls via the inter-exchange network is incomplete at the time of writing, but curve 1 in Fig. 20 shows the calculated performance of metropolitan subscribers own-exchange reference equivalents at about 1973, assuming the continuation of present planning rules. This curve, with a median value of 7db, may be compared with the three test distributions for **overall** objectives shown on curves 2, 3 and 4 in the same figure. This figure is drawn to a scale on which a straight line is a normal distribution.

It is immediately apparent that curve 2 is not a practicable objective:

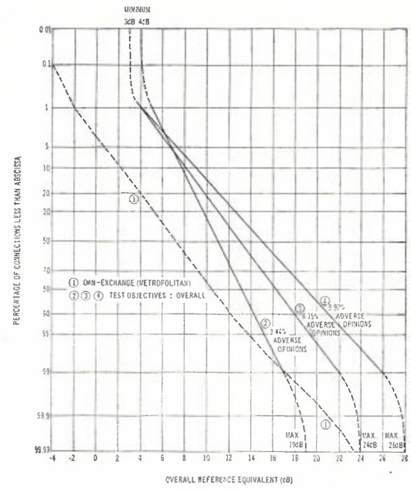


Fig. 20. — Distribution of Reference Equivalents in Possible Objectives.

any objective must have a gradient less (standard deviation greater) than curve 1, since the statistical addition of curve 1 to any real distribution of inter-exchange reference equivalents must yield a standard deviation greater than curve 1. Curve 2, with a median of 11db and limits of 4 and 19 db could be considered as a possible objective only if it were possible substantially to reduce the standard deviation of own-exchange reference equivalents in the existing network. This cannot be contemplated, in view of the vast retrospective action which would have to be taken.

Curve 3, with a median of 13db and limits of 3 and 24db, has a slightly steeper gradient than curve 1 at higher reference equivalents and might be difficult to achieve. It would demand an inter-exchange median loss of less than 13 — 7 = 8db, and a very small standard deviation.

Curve 4, with a median of 15db and limits of 3 and 28db, probably represents an achievable objective without modifying the existing subscribers' networks.

By multiplying the proportion of connections in each decibel slot in a given test distribution by the average probability of encountering an adverse opinion over the range of the slot, and then summing the individual product over the range of reference equivalents, we can assess the overall probability of encountering adverse opinions for each distribution. The adverse opinions likely to be encountered on the three test objective distributions are shown in Table 5.

TABLE 5.

Curve	Median db	Range db.	Adverse Opinions %
2	11	4 to 19	3.44
3	13	3 to 24	6.15
4	15	3 to 28	9.92

It should be noted that even if it were possible to provide all connections at a reference equivalent corresponding to minimum adverse opinions (about 9 db) there would be still just under 2 per cent. of adverse opinions. The perversity of the human animal being what it is, of these adverse opinions, half would be complaining of too much volume, and half complaining of too little.

Planning Implications: No decision has been made (at mid-1967) on the particular objective to be adopted. An initial objective, subject to review in a few years' time, may be close to curve 4 of Fig. 20. Furthermore, this may be regarded not as a precise objective, but as the right-hand boundary of an acceptable distribution. An initial left-hand boundary could probably be a vertical line at not less than —4db (since from Fig. 20 it is seen that some existing own-exchange calls can have reference equivalents of this value).

It has been confirmed by measurement and calculation that the Australian telephone network meets the requirements, not only of C.C.I.T.T. Recommendation G.111, but also the more stringent requirement proposed by C.C.I.T.T. Study Group XII. (Ref. 20). However, performance which just meets this recommendation falls short of Australian preferences, and the latter must therefore determine national transmission planning objectives.

In determining the overall objectives care must be taken in interpreting the results of the Australian subscribers' preference tests and the conditions of the 'preferences' experiment must be recalled: observers were required to make a conscious decision about the three critical levels of loudness ('too faint,' 'preferred,' and 'too loud') and they adjusted the volume themselves. This is an artificial situation which would yield more critical results than subscribers would be aware of in a normal telephoning situation. As a result, predictions of the incidence of unsolicited adverse opinions in the telephone network are likely to be unduly pessimistic if based directly on the results of the experiment. It must not be supposed that distribution of curve 4 of Fig. 20 would result in a transmission complaint for every ten calls made.

Whatever limiting distribution of reference equivalents is chosen as an objective for a given year, the objective still has to be translated into practical (and, if possible, simple) planning rules. Since the objective will be in terms of subscribers' telephone calls, the means of achieving it will undoubtedly vary as subscribers' telephoning habits vary, and as exchange area planning practices vary.

Thus at present, subscribers on a metropolitan terminal exchange typically make calls as follows:—

Own exchange	18%
Local call area	79%
Long distance	3%

Improvements in all subscribers' local ends would improve 100 per cent. of calls, but would be prohibitively costly. Improvements in links from terminal exchanges to other exchanges would be much less costly, and would affect 82 per cent. of calls. Improvements in the long-distance network would affect only a relatively few calls.

Improvements in the links from terminal exchanges to other exchanges would represent a much more efficient investment than improvements to the subscribers' local ends (which would improve 100 per cent. of calls), since the latter exceed the former by at least 10 to 1.

At present and for the foreseeable future, the following factors support the view that transmission loss reductions should be applied first in the lower-order inter-exchange links:—

- —the large proportion of calls using these links;
- —the large proportion of transmission loss controlled by these links;
- —the vast investment and 'inertia" in subscribers' networks;
- —the small scope for improvements in the long-distance network.

An initial assumption, therefore, is that the present distribution of reference equivalents in subscribers' local ends must be accepted substantially as it is, although the possibility of retrospective action to improve the 'tails' of the distribution is not excluded. (Also, of course, planning rules for new services may be designed to exert some control on the future distribution of reference equivalents in local networks.)

In principle, then, we have substantially fixed distributions of send and receive reference equivalents in the local network, and limiting distributions of reference equivalents for the network as a whole, determined by Australian subscribers' loudness preferences; statistical subtraction of the former from the latter will yield a limiting distribution of inter-exchange link losses which should be observed to ensure compliance with the overall objectives.

Statistical subtraction is a difficult process, and it is more convenient to propose trial distribution of inter-exchange losses, and add them statistically to the distributions of own-exchange reference equivalents and see how the resulting overall distribution compares with the proposed overall objective. Two objective limiting distributions have been determined in this way, and are shown in Fig. 21.

Practical achievement and control of the overall objective demand precise specification of the connections to which the objectives should apply. To the present, we have been dealing by inference with all telephone calls in Australia, and this is clearly of no practical use to engineers responsible for State or regional planning. Fig. 21, therefore, is in terms of the calls which originate and terminate within the same secondary switching area; an area in which the local engineer has complete control. The distributions might also be taken as applying separately to the connections originating at each exchange in the secondary area, and terminating within the same area.

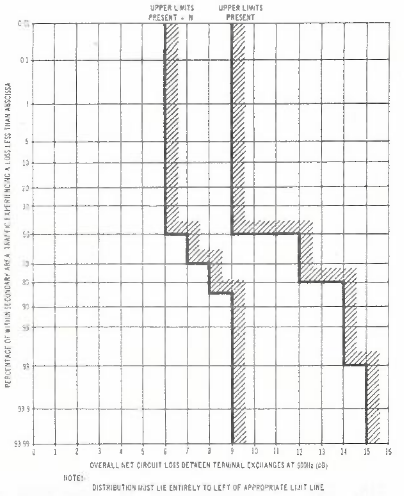


Fig. 21. — Tentative Objectives for Inter-Exchange Connections Within a Secondary Switching Area.

The limit labelled 'present' has been checked against sample calculations of traffic distribution and transmission losses in several metropolitan areas, and is a reasonable representation of current performance.

The limit labelled 'present + n' is a proposed limiting distribution to be met in n years' time, where n has not yet been determined, but should not be more than 4. An inter-exchange network conforming to this distribution can be expected to yield an overall performance within the limit of curve 4 of Fig. 20.

Control of minimum reference equivalents in new subscribers' services will be achieved by means of automatic regulation or planning rules: two modern telephones on zero line have an overall reference equivalent of 3db, but with older telephones the corresponding value can be —4db or less.

Other Objectives.

The A.P.O. is currently developing transmission performance requirements for individual links in the system. In principle, link performance (in respect of noise, distortion, frequency response, etc.) will be specified as a function of the 'height' of the link in the switching hierarchy, and whether it is on a final-choice or direct route. Final-choice links will demand a higher performance than others, since they may form part of a connection comprising the maximum number of links.

A lower standard of performance may be permitted on links which can be used only in connections with a small maximum number of links. Thus in principle, a single direct link between two terminal exchanges may be allocated the sum of all the degradations which occur in the multi-link final-choice connection via two main trunk switching centres. There is also an economic incentive to permit maximum degradations in the most numerous (i.e., lower-order) links in the network. It is envisaged that this approach will permit the use of lower-cost equipment in the lower echelons of the network, while at the same time ensuring satisfactory performance on all connections regardless of the type or number of links employed.

As transmission losses are reduced in a network, the specification of return losses at two-wire switching points and at 2-wire/4-wire terminations becomes of increasing importance. It is not sufficient merely to specify return-loss requirements; a simple method must be devised to ensure that the requirements are achieved and maintained in service.

Data now becoming available from the sample subscribers' transmission survey are providing the essential basic information on the distribution of return loss of subscribers' local ends at terminal exchanges; this is being associated with transmission data from sample inter-exchange terminal links to provide a statistical description of return losses at switching centres.

When this information is complete, it will be possible to estimate the degree to which return losses at these centres should be improved, having regard to the cost of the various methods available (Ref. 21). It is likely that return losses will be specified in terms of results obtained using speech-weighted noise as a signal source and a psophometrically-weighted meter as an indicator (Ref. 22).

A further result of reducing transmission losses will be to increase the problems concerned with the accumulation of noise on connections. The successful provision of voice-frequency data transmission over the telephone network will also depend on the adequate control of electrical noise.

Two things at least are certain:

- —there will be a progressive improvement in telephone objectives over a period of years; and
- —no significant change will be achieved quickly.

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JOURNAL CHANGES

This issue of the *Journal* brings a new look to the presentation of the Contents Page, as well as other changes worthy of special mention.

Presentation styles maintained over a long period give journals an individuality which has value for reader and publisher alike. For this reason, publishers usually resist the currents of change which often find expression in the editorial content of their journals. The changed presentation of contents and miscellaneous publication information introduced with this issue was stimulated, not by a desire for change, but by a need to accommodate an amount of information which could not be adequately presented on a single page.

Readers will also note the addition of author and title information at the bottom of each page in this issue of the *Journal*. This is intended to facilitate article identification.

Another innovation commenced with this issue is on the last page of the *Journal*. This tear-out page carries a repeat printing of the contents on one side of the sheet with abstracts of each article set out on the reverse side, and is being provided for those who wish to retain a loose-leaf ready reference to the contents of each issue. The abstracts will also prove useful for those who keep card index systems.

A particular feature of this issue of the *Journal* is a considerably enlarged Answers to Examinations Section. The new series of "plant" papers in the Senior Technicians' Examination introduced for the first time in July 1967, and the strong support for this section in our recent reader survey, have prompted this action. Special attention to the new examination has been made possible by the cooperation of the Department's Examiners, and the Headquarters Technical Training Unit. The Board of Editors acknowledges with thanks the special efforts made by these people.

THE TRANSMISSION PERFORMANCE PREFERENCES AND TOLERANCES OF TELEPHONE USERS

E J. KOOP, B.E.*

Editorial Note. — This paper was presented to the Institution of Engineers, Australia, Conference on Communications in Sydney, August, 1966. It is published with the kind permission of the Institution.

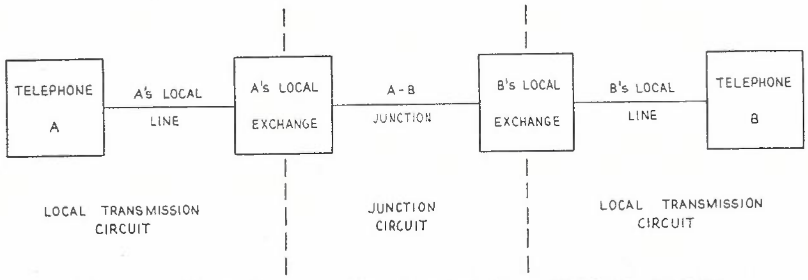

Fig. 1. — Simple Representation of Typical Subscriber Interconnection.

INTRODUCTION.

The design of the public telephone network in Australia is based on providing a transmission performance which is as good as or better than a set minimum standard. This standard, which has an important bearing on the cost of providing the network as well as the degree of satisfaction which it gives to the public, was established originally in the 1920's on a simple loudness criterion. At that time, it resembled the reference standards of telephone transmission used in Britain and in the United States. As improved methods of measurement have become available, the standard has been reassessed from time to time, and on occasions redefined.

This paper describes the tests made recently by the P.M.G. Research Laboratories on telephone users' loudness preferences and tolerances, using opinions as a criterion of transmission performance. These tests were undertaken as a contribution towards the study of the objective desirable in planning and establishing the telephone network.

The first part of the paper deals with transmission performance aspects and the development of standards to evaluate this performance, while the second part describes the actual transmission opinion tests.

THE TRANSMISSION PERFORMANCE OF THE TELEPHONE NETWORK.

The transmission performance of any telephone communication circuit can be described as the effectiveness of the circuit for transmitting and reproducing speech under the circumstances in which it is used. Various factors govern the performance of a circuit; the chief factor is usually transmitted speech volume, which is directly dependent on circuit loss or gain, but others, such as bandwidth, side-tone, frequency response, noise and distortion are significant, and under particular circumstances, may play the dominant role in determining the transmission performance.

In Fig. 1, the three basic links of any subscriber - to - subscriber telephone connection are represented. At each end of the circuit is the subscriber's telephone instrument connected by a transmission circuit to the local exchange. For the majority of the telephones in the network, d.c. feed current for the transmitter is fed from the local exchange, and variations in line length will cause changes in this feed current and will modify the effective loss of the feed line. The third part is the interconnection between the subscribers' local exchanges. In the simplest case, this may be a simple intra-exchange pair of wires. Within the metropolitan area of a large city, it will usually comprise one or more inter-exchange junctions, and over long distances it may also include trunk lines.

Although any of the transmission links in the complete connection may be either a direct metallic circuit, a line carrier circuit, a radio link, or any combination of these three, it is usual to consider the basic transmission circuit as comprised of lengths of cables and to compare alternative forms of transmission paths on the basis of their relative transmission characteristics.

In practice, subscribers' local cables are usually balanced-pair lines with copper conductors having conductor weights per mile varying typically from 4 lb./mile to 10 lb./mile, with extreme cases down to as low as 2½ lb./mile and as high as 20 lb./mile or even higher. These cables are predominantly capacitive, and for economic reasons they are usually used without inductive loading. This results in a characteristic impedance which falls with frequency, and a transmission loss which rises with frequency.

Typical inter - exchange cables are also balanced-pair cables, but because their average length is greater than that for subscribers' lines, they are of heavier gauge (usually 10 to 20 lb./mile) and usually inductively loaded with 88 mH every 6000 ft. to reduce their loss per unit length. They exhibit a fairly uniform low loss through the working frequency range up to near their theoretical cut-off frequency (usually about 3.75 kc/s) and a fairly uniform resistive impedance of about 1200 ohms over their mid-frequency range (300 c/s to 3,000 c/s). Such lines are sometimes transformed to 600-ohm impedance by the use of terminal 2 : 1 impedance step-down transformers.

Most of the trunk line circuits now in use are carrier-frequency circuits on either transmission line or radio link bearers. These circuits are invariably low loss circuits (approaching zero db) and their impedances are designed to be nominally 600 ohms.

TRANSMISSION PERFORMANCE STANDARDS.

The planning of the Australian telephone network has been directed towards ensuring that a connection between any two subscribers within the network can always be established such that it meets a minimum standard of transmission performance.

Because the specification of the transmission performances of any circuit requires the analysis of all of the contributing factors mentioned earlier, it has been convenient for planning purposes to specify the limit transmission performance in terms of a physical circuit involving actual telephones and cables, together with a specified subscriber's ambient noise level. Such a circuit is known as the Overall Transmission Performance Standard (O.T.S.), and is shown in essential detail in Fig. 2.

It will be evident that the Overall Transmission Performance Standard (O.T.S.) is a specific representation of the general form of a subscriber interconnection (Fig. 1), and is so designed that it can be set up in the laboratory as a standard of transmission performance. Standardised electro-acoustic transducers are used, and the local lines can be readily simulated by means of electrical networks and the junction line by means of a 600-ohm attenuator.

Each local end of the O.T.S. is known as a Subscribers' Service Transmission Standard (S.T.S.) and this comprises the telephone, the local line and the exchange feeding bridge.

The origin of the O.T.S. is associated with British and American usage and the early recommendations of the C.C.I.F. (now C.C.I.T.T.) on transmission limits. Basically, it defines a circuit involving standardised embodiments of what were at one time current telephone circuit components. Under specified environmental condi-

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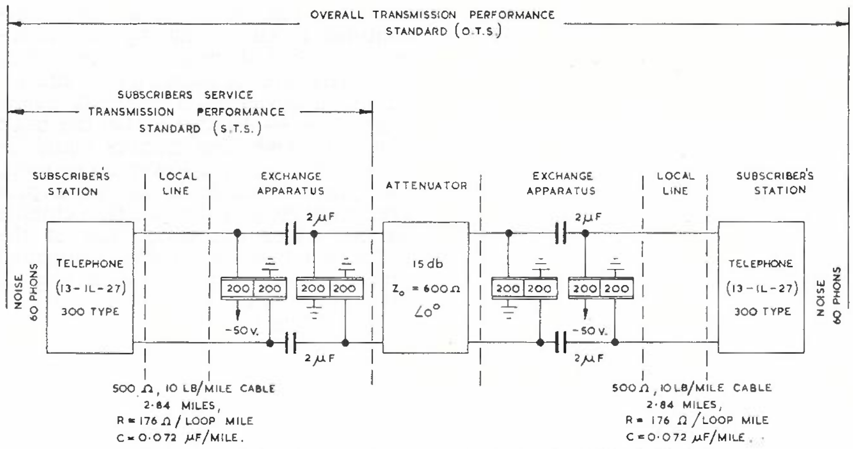


Fig. 2. — Current Overall Transmission Performance Standard.

tions such as 60 phons of room noise, the transmission performance of this circuit permits a practical conversation only with a conscious effort on the part of the user.

TRANSMISSION PERFORMANCE RATING.

At present, transmission planning involves proportioning circuit losses in the network by suitable combinations of transmission circuits and telephones, and controlling impairments such as noise, distortion, etc., so that few, if any, calls set up between any two subscribers will have a transmission performance worse than that of the O.T.S.. In order to carry out this planning aim, it is necessary to rate various combinations of telephone instruments and types of both local and junction transmission circuits against the O.T.S. This is simplified in practice by selecting the local end of the circuit and rating it against the local end of the standard, which is the Subscribers' Service Transmission Standard (S.T.S.). The balance of the circuit is so apportioned that its combined switching, junction and trunk junction losses do not exceed 15 db.

The normal method of rating any circuit against the standard (or comparing any two circuits) is a subjective one involving trained staff speaking and listening over the two circuits and comparing them either on a speech volume basis or on their speech articulation characteristics. One method currently used in the P.M.G. Research Laboratories is the "Immediate Appreciation" method (Ref. 1). This method is a form of sentence articulation testing which does not require a complete comprehension of every word or the writing down of the spoken words. In a simplified form, the performance rating involves the determination of the length of a particular gauge of cable which, when associated with a specific telephone instrument, provides a circuit whose sending or receiving performance (whichever is the poorer) equals that of the S.T.S.

If the objective performance of the telephone instrument is known, and a subjective rating has been made for one particular gauge of cable, it is usually possible to calculate with reasonable accuracy the lengths of other gauges of cable which would provide a similar transmission performance.

Thus the network planning engineer has available for his use tabulations of maximum line lengths of each of the standard cable gauges for each telephone type used in the network.

NETWORK TRENDS.

During the last 20 years there has been a marked improvement in the quality and quantity of trunk line circuits throughout Australia, due in the main to the extensive use of modern multi-channel carrier systems having a high standard of performance, and to the use of high quality bearer circuits, such as co-axial cables. Trunk calls on these circuits compare favourably with good quality local calls.

The majority of subscribers are situated in the populated city areas and are connected to their local exchanges via relatively short local lines of less than two miles. With the availability of high-efficiency regulated telephones, such as the current model colour telephone (type 801), it is possible to provide a relatively high standard of transmission performance on many calls.

This trend to higher quality circuits in the telephone network is also evident in the network of all major overseas telephone administrations. Subscribers' preferences are influencing the planning of these networks; in the U.S.A., for example, the aim is to provide a network in which the majority of calls will be regarded as optimum in the opinion of the subscribers, and recent improvements in the performance of telephone instruments have not been absorbed by allowing higher line losses in network planning. Opinion rating of transmission circuits is replacing other methods of rating and a considerable amount of work has been carried out in the U.S.A., England and Europe (Refs. 2, 3 and 4).

Under this method, two telephone circuits can be compared in transmission performance by comparing their mean ratings resulting from a team of persons conversing in turn over the circuits and each person allotting an opinion category. This method also lends itself to assessing transmission impairments in terms of equivalent circuit losses. (Opinion rating methods and applications are described in detail in Refs. 3 and 4.)

THE PREFERENCE TESTS.

The P.M.G. Research Laboratories recently undertook a series of tests to ascertain telephone users' volume preferences and their tolerance to a range of telephone transmission conditions. Together with results of a survey of the actual network performance obtained by a sampling of subscribers' connections in all States of the Commonwealth, these data enable the P.M.G.'s Department to determine the transmission performance preferences of telephone users, and also to assess the degree to which the preferences of the subscribers are met in the present public telephone network.

The aim of the tests was to obtain a close estimate of the opinion of telephone subscribers, by means of a laboratory test which simulated as closely as possible the typical call conditions of the network. This was done by basing the tests on a current model telephone and a commonly used cable size.

To permit the results to be compared with those of an overseas administration (Ref. 2), transmitted speech volumes were measured during tests so that with the knowledge of the loss characteristics of the transmission circuit, received speech volumes could be calculated for the various circuit conditions.

The more usual type of opinion test involves subjects who are asked to listen to a given level and to rate it in accordance with a multi-point scale. In the tests to be described, subjects were asked to control two-way circuit conditions while conversing with their partner, until each one of three specified conditions, viz., "preferred operating condition," "highest tolerable level," and "lowest tolerable level," were met in turn. It was felt that three conditions only, clearly defined, would make the task easier for participants than if they were asked to rate to a finer subdivision. Allowing them to select their own levels enabled participants to experience a range of levels before deciding their preferences and limits.

TEST CONDITIONS.

Transmission Circuit: A simplified block schematic of the transmission

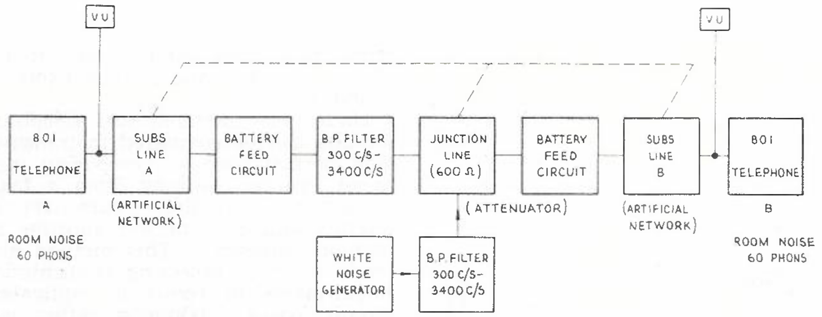


Fig. 3. — Block Schematic (Simplified) of Transmission Circuit.

circuit used in these tests is shown in Fig. 3. Basically, it is similar in form to the circuits of Figs. 1 and 2, comprising two subscribers' transmission circuits (each consisting of a telephone, an artificial cable network and a battery feeding circuit) interconnected by an artificial cable junction circuit of 600-ohm impedance. Both of the subscribers' networks and the junction circuit were variable in increments, giving a total of 21 steps in the overall transmission circuits between the limits of zero subscribers' lines and junction line, to a maximum loss circuit corresponding to subscribers' lines of 3.4 miles of 6½ lb./mile cable at each subscribers' end, plus a junction simulated by a 30-db attenuator. Table 1 gives details of the subscribers' line increments, the junction circuit increments and the combinations selected for each of the 21 available steps. The effective transmission loss of the circuit for each step, relative to step 1 (i.e., zero loss line), was determined by a subjective volume balance against a reference telephone circuit, and these values also are given in Table 1.

The value of 3.4 miles of 6½ lb./mile cable selected as the maximum subscriber's line length for these tests is the current planning unit for that size of cable when used with the 801 telephone. The combination of the 801 telephone, the 3.4 miles of cable, and the associated battery feed circuit, essentially matches the transmission performance of the S.T.S. as illustrated in Fig. 2 and described earlier. It will be noted that the test circuit corresponding to step 16 is essentially equivalent in transmission performance to the O.T.S. and that the maximum loss available in the test circuit, i.e., with step 21, is approximately 15 db higher (in the junction of the circuit) than in the O.T.S.

Line Noise: Artificial line noise in the form of band-limited (i.e., 300 c/s to 3400 c/s) random noise was introduced into the centre of the junction circuit, so that for all loss settings up to that equivalent to the O.T.S., the noise power at the junction terminals was 25,000 pW (psophometric weighting). This was selected arbitrarily to be half the maximum noise power according to C.C.I.T.T. recommendations for line noise on a long intercontinental circuit having the maximum number of links in tandem (Ref. 7). (The level of 25,000 pW is equivalent to a power level of 46 db below 1 mW, i.e. — 46 dbm.) On the basis that very high loss circuits could be expected to have a lower noise level, the junction noise levels were progressively reduced for junction circuits having losses exceeding that of the O.T.S. junction (i.e., 15 db). The actual junction noise levels for each step of the transmission circuit are shown also in Table 1.

Room Conditions: The telephones terminating each end of the transmission circuit were located in separate rooms, each of which provided a similar acoustical environment. During the tests, Hoth-weighted random noise was introduced at a level of 60 db (sound level meter B-weighting), which is the environment noise level under which the P.M.G.'s Department assesses telephone transmission performance.

Operating Facilities: In addition to the basic variable transmission circuit, line noise and room noise, a number of additional features were incorporated into the system for the purposes of either facilitating the conduct of the tests or improving the simulation of typical call conditions.

A major facility contributing to the latter effect was the provision of exchange dialling facilities. Participants were provided with dial tone in their receivers on lifting their handsets. On dialling a six-digit number, standard ringing tone was heard and ringing signal was fed to the partner's telephone. Through transmission was obtained on answering the telephone. During the test, both participants were directed and supervised by a controller who was located in a laboratory adjacent to the test rooms, and who had access to a control panel, which provided a range of monitoring and controlling facilities.

Facilities for remotely controlling the transmission circuit were available to both participants and also to the controller. The circuit performance could be raised or lowered in fine (single) steps or coarse (triple) steps by momentarily depressing the appropriate button of a group of four push-buttons provided on the participants' consoles and on the controller's panel. Other facilities available on the participants' consoles included red limit lamps to indicate high or low circuit limits, green selection lamps designated "preferred operating level," "highest tolerable level" and "lowest tolerable level," by which the controller signalled a participant to make a circuit selection, and a "selection completed" button which enabled that participant to signal the controller on completing the selection.

Among the facilities provided for the controller was a lamp bank which

TABLE I: DETAILS OF TRANSMISSION CIRCUIT STEPS

Line Step No.	Line Components: Sub's line length (each end) (in miles of 6½lb. per mile cable)	Line Components: Junction 600-ohm attenuator (db)	Effective overall loss (relative to Step 1) (db)	Noise at terminals (psophometric) (dbm)
1	0	0	0	—46
2	0.34	0	0.5	—46
3	0.68	0	1.0	—46
4	1.02	0	1.75	—46
5	1.36	0	2.75	—46
6	1.70	0	4.25	—46
7	2.04	0	5.75	—46
8	2.38	0	7.5	—46
9	2.72	0	9.25	—46
10	3.06	0	11.5	—46
11	3.40	0	13.75	—46
12	3.40	3	16.0	—46
13	3.40	6	18.25	—46
14	3.40	9	20.75	—46
15	3.40	12	23.25	—46
16	3.40	15	25.75	—46
17	3.40	18	28.5	—47.5
18	3.40	21	31.25	—49.0
19	3.40	24	34.0	—50.5
20	3.40	27	37.0	—52.0
21	3.40	30	40.0	—53.5

continuously displayed the step condition of the transmission circuit, a v.u. (volume unit) meter to permit measurement of transmitted speech volumes, and a loudspeaking intercommunication system plus audio monitoring across either telephone to aid the verbal instruction of participants during the test.

TEST PROCEDURE.

In the design of the test, special attention was given to the elimination, as far as practicable, of unwanted bias in selection of circuit conditions which might be caused by the method of choosing participants, their pre-conditioning, and the manner of carrying out the tests. Sufficient data were accumulated regarding the participants and test conditions in order that the effect of any of these controlled variations on the test results could be evaluated, and allowed for if necessary.

Selection of Participants: A total of 106 participants was used in the tests. With the exception of a few who were administrative staff interested in the conduct of the test and the ensuing results, the participants were selected from Research Laboratories' staff (from 250 available) to provide participants of both sexes in a range of ages, occupations and background interests. The selection of participants from the various groups such as professional, sub-professional, artisan and clerical staff was made on a random selection basis, and the only staff deliberately excluded were a few with known extreme speech impediments or excessively foreign accents. To minimise embarrassment of participants and to assist in promoting a free flow of conversation during the tests, pairings for the tests were made by selecting participants of the same sex, and unless they were known to be previously well acquainted, they were also chosen from a similar age group and with similar status and backgrounds.

Test Sequence: Preceding each test, each participant was interviewed separately and a questionnaire completed listing personal details such as sex, age, hearing acuity, frequency of telephone usage, and speech impediments (if any). This form provided also for the recording of the participants' special interests and hobbies for the purpose of providing subjects for discussion during the test. During this interview each participant was given a printed information sheet, which gave details of the tests, the test facilities, and what was required of the participants during the tests.

After being directed separately to their rooms, each participant was briefly instructed in the operation of the controls and the response required as a result of a console lamp direction. The participants were in turn required to initiate a call to their partners by lifting the receiver and dialling a given six-digit number, and then while carrying on a conversation were required at the direction of the controller to select a given circuit condition. These were "preferred level" (selected twice), "highest tolerable level" and "lowest tolerable level." The controller recorded the line step selected in each case and the partner's speech volume for each selected circuit condition. The order of the four selections was changed for each successive participant and the actual test sequence as well as the initial line step setting were also recorded by the controller.

Conversation Aids: One of the important requirements of the test was the setting up of a free-flowing natural conversation in order that the simulation of typical telephone conversation conditions could be approached, and to provide the participant making the circuit selection with adequate received speech material on which to make a circuit assessment. The realisation of such conditions was greatly aided by the manner of selecting pairs mentioned above.

To stimulate such conversations where necessary, two aids were provided. One was the listing of the partner's interests and hobbies, and the other was the availability of a number of brief newspaper cuttings on a variety of topical subjects. Very few pairs had difficulty in maintaining a free-flowing conversation, although in some cases the controller had to prompt the participants to get a satisfactory balance of flow.

TEST RESULTS.

The basic data recorded included transmitted speech volumes and circuit conditions (i.e., line step numbers) for preferred, highest tolerable and lowest tolerable level conditions. From the loss calibration of the transmission circuit (Table 1) and the recorded transmitted speech volumes, received speech volumes were calculated for each selection made. The total number of participants were also grouped separately in various alternative sub-groupings such as men/women, professional/sub-professional/non-technical, above 40 years/below 40 years, normal hearing/abnormal hearing, and frequent telephone use/infrequent telephone use. The repeatability of the choice of the preferred operating condition and the effect of the previous line loss setting on the choice were also determined.

Speaking Volumes: The speaking levels were measured as speech volumes at the line terminals of the transmitting telephone, using a standard v.u. meter (Ref. 6). No corrections were made for the change of line impedance with line steps.

Table II shows the means and standard deviations of speech volumes pertaining to the three selected conditions for eleven groupings of participants. The distribution of speech volumes as recorded under preferred listening conditions is shown in Fig. 4 for all participants, as well as separately for men and women.

Received Speech Volumes and Line Loss Selections: From the data it is

TABLE II: MEAN SPEAKER VOLUMES UNDER VARIOUS CONDITIONS

Category	Under max. tolerable level.			Under preferred conditions			Under lowest tolerable		
	No. of samples	Mean (v.u.)	S.D. (v.u.)	No. of samples	Mean (v.u.)	S.D. (v.u.)	No. of samples	Mean (v.u.)	S.D. (v.u.)
All participants	106	—12.5	5.3	212	—11.7	4.6	106	—11.6	4.9
Men only	84	—12.4	5.4	168	—11.3	4.4	84	—11.1	4.5
Women only	22	—12.9	5.1	44	—13.2	5.1	22	—13.5	5.8
Professional staff	41	—13.9	5.6	82	—12.4	4.2	41	—11.9	4.5
Sub-professional staff	27	—10.9	4.7	54	—10.4	3.9	27	—10.3	3.8
Non-technical staff	38	—12.1	5.1	76	—11.8	5.4	38	—12.0	5.8
Above 40 years	41	—12.7	5.0	82	—11.9	3.9	41	—11.5	4.3
Below 40 years	65	—12.3	5.5	130	—11.6	5.0	65	—11.7	5.1
With abnormal hearing	13	—13.1	3.3	26	—12.0	3.1	13	—12.2	2.1
Infrequent phone use	25	—12.3	4.8	50	—11.6	5.0	25	—11.3	4.6
Frequent phone use	81	—12.6	5.3	162	—11.8	4.5	81	—11.8	4.7

Note: 1. Speech volumes measured with v.u. meter at line terminals of transmitting telephone (801 regulated).
2. The maximum observed speech volume was 0 v.u. and the minimum —26 v.u.
3. When seeking the highest tolerable level, most participants reached a zero loss line (i.e. step 1) at least temporarily. Approximately 10% of participants dropped their speaking level appreciably (from 2 to 8 v.u. reduction) on reaching this line setting.

possible to express the selections for the three specified conditions in terms of selected line step numbers, line loss or received speech volumes. It is not satisfactory to use line steps because of the non-uniform attenuation between line steps. Although line loss is a useful measure because of its relation to network planning, in these tests the selections of circuit conditions were based on received levels and hence the distribution of received speech volumes is the most appropriate way to express the distribution of selected conditions.

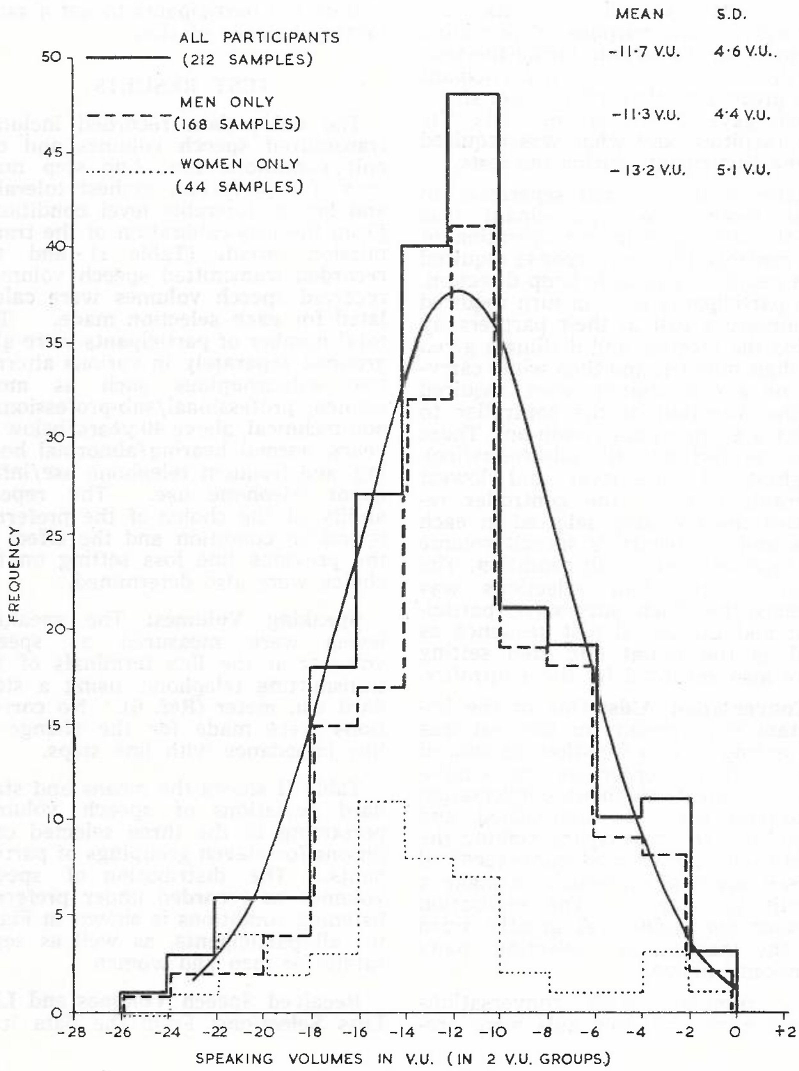


Fig. 4. — Distribution of Transmitted Speaking Volumes (in V.U.) under Preferred Operating Conditions.

Preferred Level: The mean received speech volumes under preferred listening conditions for all categories of participants are tabulated in Table IV. Also included are the mean differences between repeated selections. The actual received speech volume distributions for the three main categories (viz., all participants, men only and women only) are displayed in Fig. 5. Table III. gives mean line losses and mean differences (both absolute and algebraic) in repeating line loss selections, for six of the main participant categories.

Fig. 8 shows the distribution of the mean line loss selections for each value of the twenty previous line loss settings used when selecting the preferred listening condition. A best fit straight line (using the least squares method) has been plotted to show the mean effect of the previous setting on the choice of preferred condition.

Lowest Tolerable Level: Both the mean line loss and the mean received speech volumes selected under the lowest tolerable listening condition are listed for nine participant categories in Table V. The received speech volume distribution for the three main categories are shown in Fig. 6.

Highest Tolerable Level: The 801 telephone used in these tests is a regulated telephone, which means that the efficiency of the telephone is varied automatically according to the condition of the local line. The controlling characteristic is the line current which is determined by the line resistance; the line current controls the resistance of a voltage-dependent resistor located in the telephone and effectively shunted across the line terminals. (See Ref. 8 for a more complete description of the regulating action.) The net result of the regulation is to reduce both the sending and receiving efficiency of the telephone when it is connected to a short (low-resistance) line. Relative to a pair of unregulated telephones, a pair of regulated telephones would be approxi-

TABLE III: LINE LOSS AND REPEATABILITY UNDER PREFERRED LISTENING CONDITIONS

Category	Line Loss (Note 1)			Repeatability (Note 2)		
	No. of samples	(db)	S.D. (db)	No.of samples	Absolute differences (db)	Algebraic differences (2nd rel. to 1st) (db)
All participants	212	8.6	5.03	106	4.1	—0.42
Men only	168	8.9	5.01	84	4.0	—0.56
Women only	44	7.7	5.06	22	4.4	—0.59
Professional staff	82	8.9	4.67	41	3.6	+0.43
Sub-professional staff	54	9.1	5.81	27	3.8	—1.16
Non-technical staff	76	8.1	4.82	38	4.8	—1.26

Note: 1. The mean line loss (under preferred listening conditions) of 8.6 db corresponds to 2.6 miles of 6½-lb./mile subscriber's cable at each end of line and no junction loss.
2. The mean differences in repeated selections of line loss (under preferred listening conditions) of 4.1 db, corresponds to a change in subscriber line length equal to 0.8 miles of 6½-lb./mile cable at each end of the line.

TABLE IV: PREFERRED RECEIVE SPEECH VOLUME (A), AND REPEATABILITY (B)

Category	(A) No. of samples	(A) Mean rec. vol. (v.u.)	(A) S.D. (v.u.)	(B) No. of samples	(B) Mean diff. (v.u.)	(B) S.D. (v.u.)
All participants	212	—19.2	5.5	106	4.6	3.2
Men only	168	—19.1	5.5	84	4.6	3.8
Women only	44	—19.6	5.7	22	4.7	2.6
Professional staff	82	—20.0	4.6	41	4.4	3.5
Sub-professional staff	54	—18.6	6.8	27	4.7	3.4
Non-tech. staff	76	—18.8	5.4	38	4.7	2.8
Above 40 years	82	—18.5	6.2			
Below 40 years	130	—19.6	4.2			
Abnormal hearing	26	—19.4	5.7			
Little use of phone	50	—17.5	4.5			
Frequent use of phone	162	—19.8	5.7			

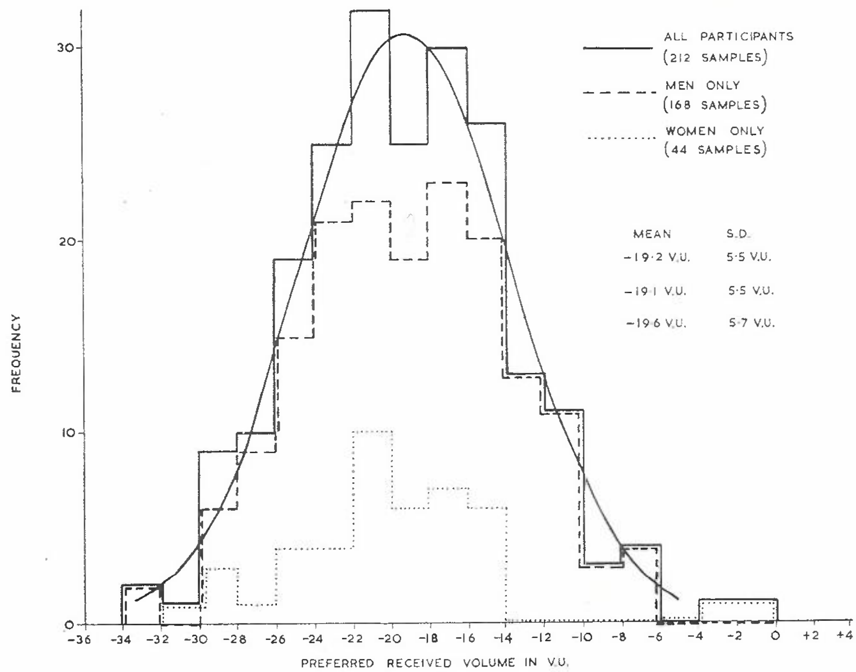


Fig. 5. — Distribution of Preferred Received Speech Volumes.

TABLE V: LOWEST TOLERABLE LEVEL IN TERMS OF (A) MEAN LINE LOSS AND (B) MEAN RECEIVED SPEECH VOLUMES

Category	No. of samples	(A) Mean loss (db)	(A) S.D. (db)	(B) Mean vol. (v.u.)	(B) S.D. (v.u.)
All participants	106	23.4	6.8	—34.5	6.1
Men only	84	24.4	5.9	—34.9	6.1
Women only	22	19.5	8.5	—32.9	6.2
Professional staff	41	23.6	5.4	—35.1	5.0
Sub-professional staff	27	25.0	6.1	—35.5	7.2
Non-technical staff	38	21.9	8.3	—33.1	6.4
Above 40 years	41	23.3	6.7	—35.8	6.0
Below 40 years	65	23.4	6.9	—33.7	6.1
Abnormal hearing	13	22.8	9.2	—34.3	7.6

mately 6 db less sensitive at zero line condition (approximately 4 db less in sending and 2db less in receiving).

The main effect of using regulated telephones in these tests is that intolerably loud levels were experienced only infrequently and that 68 per cent. of all participants indicated that they could have tolerated a higher level than that available.

Accordingly, it has not been possible to present line loss distributions as adequately as for the other conditions selected, and, as an alternative, Table VI. indicates the percentage of participants tolerating a given line loss or less.

Based on the assumption that for all participants who did not reach a highest tolerable level, the necessary increase in level for each participant to do so would result in a mean increase of approximately 2 v.u. for this group, a likely distribution of received speech volumes is given in Fig. 7. Similarly, Table VII. gives the estimated mean received speech volumes for six categories of participants.

Comparisons of the Level Distributions: By simultaneous consideration of all three choices,. a useful overall picture of telephone users' tolerance ranges, and also a better basis against which a comparison can be made with the results of other workers, may be obtained.

Table VIII. lists, for six categories of participants, the means of the individual differences between choices of highest tolerable, preferred and lowest tolerable received speech volumes. Fig. 9 displays the cumulative distribution of line loss selections for all three listening conditions and has superimposed on it various current transmission planning limits. In Fig. 10, the cumulative distributions of received speech volumes for the three listening conditions are shown. Superimposed on this graph are the cumulative distribution curves from Bell Laboratory tests carried out in 1958 (Ref. 2) for the four categories: "intolerably loud," "too loud," "fair or worse" and "poor or worse."

GENERAL DISCUSSION.

In Figs. 4, 5, 6 and 7, which illustrate graphically the distributions of Transmitted Speaking Volumes, Preferred Received Speech Volumes, Lowest Tolerable Received Speech Volumes and Highest Tolerable Received Speech Volumes, respectively, a normal distribution curve for "All Participants," based on the mean and standard deviation of the distributions, has been superimposed. In all cases, the actual distributions for the "All Participants" category are not greatly different from the normal distributions and suggests that they approximate to normal distributions.

For the three selections of received speech volumes, tests of the nor-

TABLE VI: TOLERANCE OF LINE CONDITIONS UNDER HIGHEST TOLERABLE LEVEL

Category	No. of samples	Could tolerate less than zero loss (step 1)	Could tolerate zero loss or less (step 1)	Could tolerate 1 db loss or less (step 3)	Could tolerate 2.75 db or less (step 5)
All participants	106	68%	87.8%	94.4%	97.2%
Men only	84	72.6	86.9	—	100
Women only	22	50	91	—	100
Above 40 years	41	80.5	97.6	100	—
Below 40 years	65	60	81.5	90.8	95.4

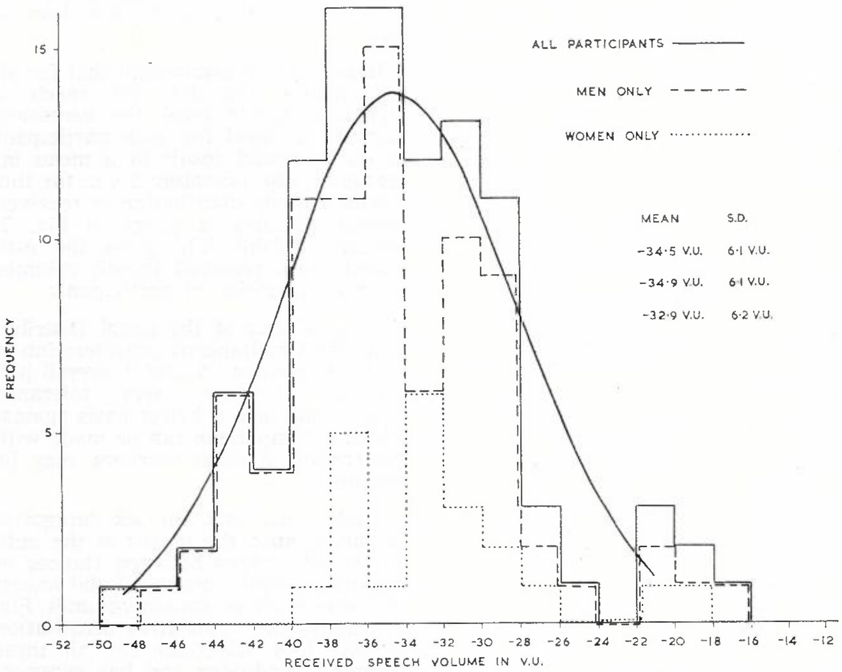


Fig. 6. — Distribution of Lowest Tolerable Received Speech Volumes.

TABLE VII: HIGHEST TOLERABLE RECEIVED SPEECH VOLUME (APPROX.)

Category	No. of samples	Mean receiving speech volume v.u.)	S.D. (v.u.)
All participants	106	—11.3	5.3
Men only	84	—11.1	5.3
Women only	22	—12.0	5.2
Above 40 years	41	—12.3	5.8
Below 40 years	65	—10.7	4.9
Abnormal hearing	13	—11.8	5.2

TABLE VIII: DIFFERENCES BETWEEN THE THREE CATEGORIES OF CHOICE (IN RECEIVED SPEECH VOLUME)

Category	Difference between Preferred and Highest		Difference between Preferred and Lowest		Difference between Highest and Lowest	
	Mean (v.u.)	S.D. (v.u.)	Mean (v.u.)	S.D. (v.u)	Mean (v.u)	S.D. (v.u.)
All participants	7.9	4.8	15.3	6.7	23.2	7.3
Men	8.0	4.9	15.8	6.3	23.8	6.7
Women	7.6	4.4	13.3	7.6	20.9	8.9
Professional	7.4	4.4	14.9	4.7	22.3	6.1
Sub-profess.	8.3	6.2	16.3	8.3	24.8	7.2
Non-technical	8.3	4.2	13.1	7.1	21.5	8.3

mality of the distributions were carried out (Refs. 9 and 10). These tests show that the distributions can be considered as being derived from a normal population.

Tests have been carried out to determine also the statistical significance of the differences in mean speaking volumes and received speech volume selections for various participant categories. In the case of received volume selections for preferred, highest tolerable and lowest tolerable listening conditions (viz., Tables IV, V. and VII.), none of the differences between the means for any of the categories (such as men and women, or professional, sub-professional and non-technical) proved to be significant. The probability of chance occurrence of such differences ranged from a minimum of 8 per cent., to 15 per cent. and higher. For speaker volumes (Table II.) most of the differences of the means for different participant categories were again not significant, but there were a few exceptions which will be detailed in the following discussions.

For the regression line of Fig. 8, the slope has been found to be significantly different from zero, indicating that the previous loss setting has a significant effect on the choice of the preferred loss setting.

Speaking Levels: The speaking levels under preferred listening conditions, measured as transmitted speech volumes at the telephone line terminals, had a mean value for all participants of —11.7 v.u. with a S.D. of 4.6 v.u. (Table II). Fairly recent tests by the Bell Laboratories (Ref. 5, 1960) on speech volumes measured at local exchanges found mean speech volumes ranging from —16.8 v.u. for trunk calls up to —24.8 v.u. for intra-building calls with S.D.'s ranging from 5.9 to 7.3 v.u. If an allowance is made for local line loss and impedance correction (which should not exceed the order of 3 v.u. average), it is evident that the mean speaking level during the tests reported in this paper was at least slightly, and perhaps appreciably, higher than that recorded by the Bell Laboratories.

Following observations over the years by many telephone administrations of the effect on speaking level of received speech level and the magnitude of sidetone present (i.e., the amount of transmitted signal fed back to the speaker's receiver), it is customary to expect a very slight increase in speaking level with a decrease in received speech level and a definite decrease in speaking level with increased sidetone. The typical expected sidetone effect would be a suppression of speech level of 0.12 to 0.14 db per db increase of sidetone level from the normal value.

In these tests, the variations in the mean transmitted speech volume between the lowest tolerable, preferred and highest tolerable listening conditions were not very marked. No significant change in speaking level was observed between the preferred and lowest tolerable level condition despite a change in the mean received speech volume of 15.3 v.u.

Under highest tolerable listening conditions, the mean speaking volume dropped by almost 1 v.u. This is attributed to a noticeable reduction in speaking volume (from 2 to 8 v.u.), which occurred for only about 10 per cent. of the participants and only when the circuit conditions were changed from step 2 to step 1 (i.e., reduced to zero loss). This circuit change resulted in a marked increase in sidetone level, which was proved by independent tests to be the cause for the drop in speaking volume. Although the majority of participants (87 per cent.) chose this zero line condition during the selection of highest tolerable level, fewer than 12 per cent. of these (i.e., 10 per cent. of total) appeared to be affected in any way by the high sidetone level. No satisfactory explanation can be offered for the lack of reaction to high sidetone levels by the remaining participants (approx. 77 per cent. of total).

In general, the mean speaking volumes of the various categories of participants did not vary greatly. The difference in the mean speaking volumes under maximum tolerable listening levels, between professional staff (—13.9 v.u.) and sub-professional staff (—10.9 v.u.) was found to

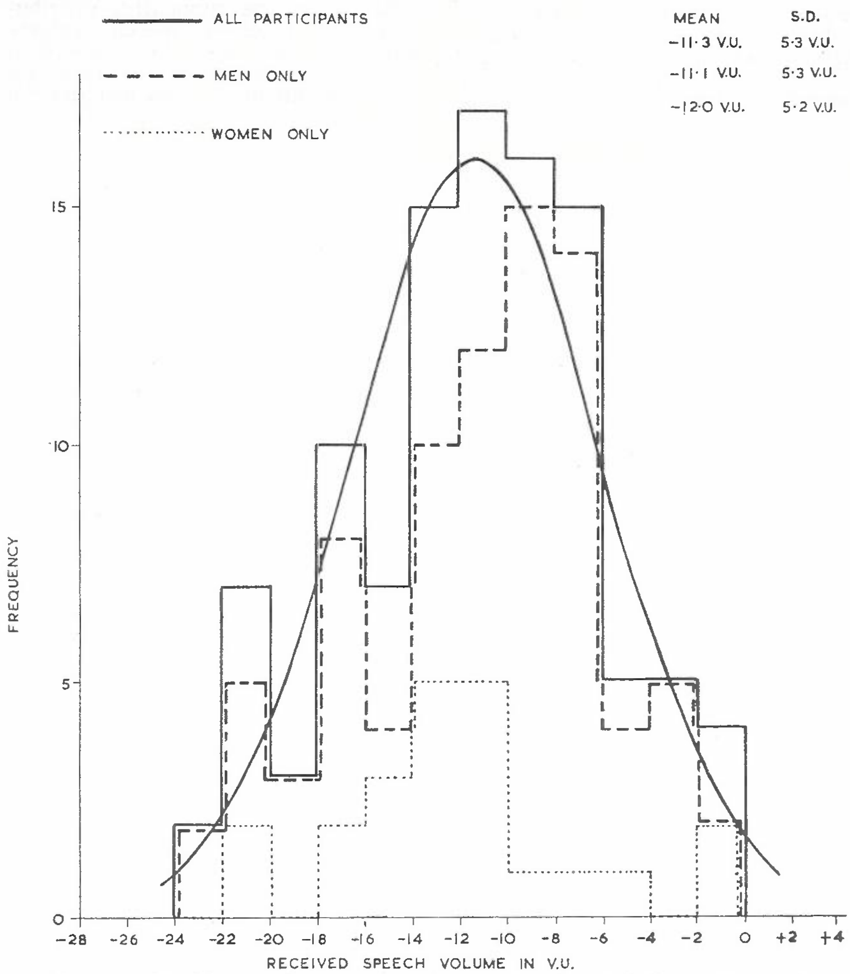
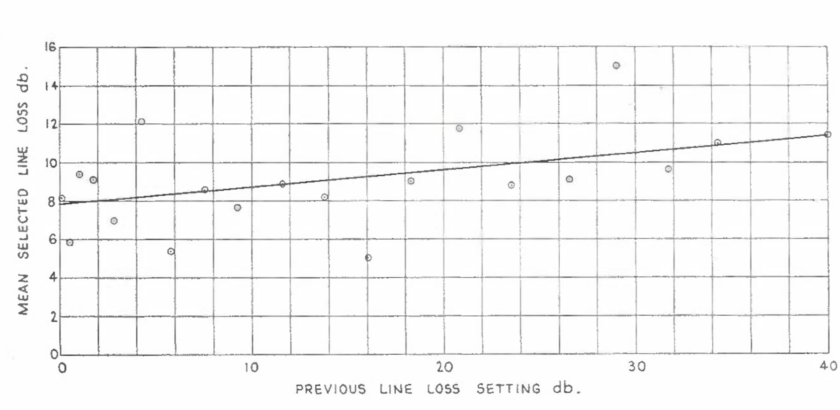


Fig 7. — Distribution of Highest Tolerable Received Speech Volumes (Approx.)



$y = 7{\cdot}87 + 0{\cdot}088\,x$

WHERE x IS PREVIOUS LINE LOSS IN db.

y IS SELECTED LINE LOSS IN db.

Fig. 8. — Effect of Previous Line Loss Setting on Choice of Preferred Line Loss.

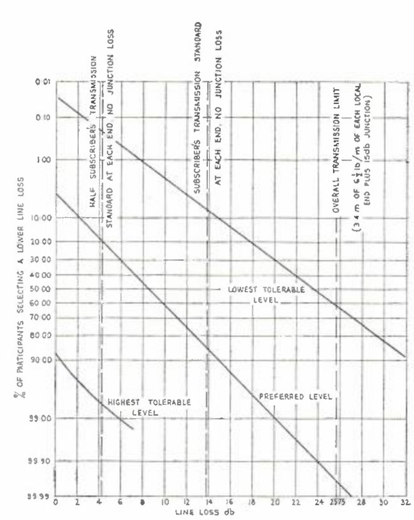


Fig. 9. — Cumulative Distribution of Line Loss Selections showing Current Transmission Planning Limits.

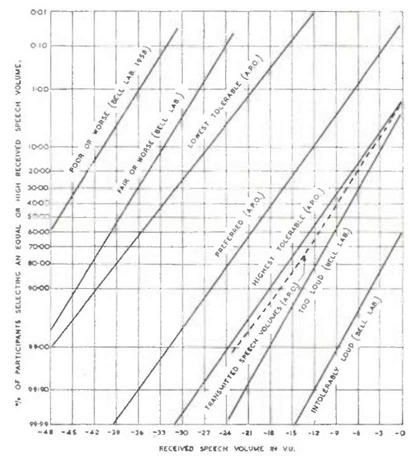


Fig. 10. — Cumulative Distribution of Received Levels in Received Speech Level Preference Tests (showing Bell Lab. 1958 Results).

be significant at the 1 per cent. level, and under preferred listening levels where the mean speaking volumes were —12.4 v.u. and —10.4 v.u. respectively, the difference was found to be highly significant. Under preferred conditions the difference in mean speaker volumes for men (—11.3 v.u.) and women (—13.2 v.u.) was found to be significant at the 1 per cent. level, and under minimum tolerable conditions the difference in the mean speaking levels (—11.1 v.u. and —13.5 v.u. respectively) was significant at the 4 per cent. level. Although similar trends were evident between the various categories under various conditions, none of the remaining differences was significant.

Preferred Listening Conditions: The mean preferred line condition was an overall loss of 8.6 db, equivalent to subscribers' lines of 2.6 miles of 6½ lb./mile cable at each end, with zero junction line. This preferred condition corresponds to a circuit which has approximately 17 db less loss than the O.T.S. (see Fig. 9). Although the transmission planning of the telephone network is arranged so that only a small percentage of all connections approach the limiting performance of the O.T.S., the preferred condition is surprisingly demanding in its transmission performance requirements.

Under these preferred conditions, the mean received speech volume was —19.2 v.u. The Bell Laboratories in the U.S.A. performed tests in 1958 to determine the preferred level of received volume (Ref. 2), and found that a level of —19 v.u. was most frequently selected. Since the telephone used in these tests is estimated to be approximately 2 db or more inferior in receiving sensitivity as compared with the 801 telephone, it is evident that the participants in the local test preferred a slightly higher listening level than did those in the Bell Laboratories' tests.

The mean difference in repeated selections of the preferred condition was found to be 4.6 v.u. in terms of received speech volume and 4.1 db. in terms of line loss. These results suggest that participants had difficulty in detecting, between successive conversations, a change in level of less than about 4 v.u. This is compatible with the general tendency to consider 3 db change in level to be barely perceptible. This inability to detect small level changes introduces an uncertainty of choice which necessitates a large statistical sample in order to achieve an accurate assessment of preferences. The small values of mean algebraic differences of line loss between repeated selections (see Table III.) indicates that this variation in repeating a selection is a random one and little (if any) bias is introduced by the order of selecting.

The effect of the previous setting of line loss on the preferred loss selection as indicated in Fig. 8, is a bias of approximately 1 db in the selected line loss for 11.5 db difference in initial line loss setting. The effect of the initial setting on the overall mean preferred loss was minimised by a random selection of initial line loss settings, and by using a minimum of extreme loss settings.

Although there was an apparent tendency for women to choose a slightly lower received level and a slightly lower line loss than men, and similarly so for professional staff compared with sub-professional staff, none of the differences proved to be statistically significant.

Lowest Tolerable Level: The mean line loss of 23.4 lb, which corresponds to a circuit with a loss 2.3 db less than that of the O.T.S. (see Fig. 9). This corresponds to a mean received speech volume of —34.5 v.u. or a volume 15.3 v.u. lower than the preferred received speech volume. Only 38 per cent. of all participants found the conditions defined by the O.T.S. to be tolerable.

Although women chose a mean received level 2 v.u. higher than men for their lowest tolerable level, there were insufficient women participants for this difference to be significant.

Highest Tolerable Level: As 68 per cent. of all participants were able to tolerate an even higher received level than was available at zero loss, it is apparent that with the sole use of the 801 regulated telephones there is little likelihood of encountering intolerably high level in the telephone network. Because of the number of unregulated telephones (types 300 and 400) which are in the network, (and likely to remain in large numbers for some years), uncomfortably high levels may be experienced occasionally on calls over short lines in the network.

The estimated mean received speech volume was found to be —11.3 v.u. or approximately 8 v.u. higher than for preferred listening conditions. Because intolerably high volumes were not normally obtained during the test, an accurate estimate of the mean level was not possible, and the true mean for the highest tolerable listening condition may be a level several v.u. higher than that estimated.

Although there was a tendency for women participants to be less tolerant of high levels than men, none of the differences between any of the categories proved to be significant.

Tolerance Range: From Table VIII. the mean tolerance range (i.e., the range of received levels for a tolerable conversation) is seen to be 23.2 v.u. with a S.D. of 7.3 v.u. Even allowing for a slight error in estimating the mean highest tolerable received level, the preferred value is noticeably nearer the highest tolerable limit, suggesting that while participants are reasonably tolerant to a wide range of conditions their preference lies toward the higher levels.

Women appear to be tolerant to a range of levels 3 v.u. less, overall, than for men, although there were insufficient women participants for this difference to be significant.

Bell Laboratories' Tests: Fig. 10, which gives the cumulative distributions of received speech volume selections for the three specified listening conditions of the tests reported in this paper, also includes the four conditions, viz., "intolerably loud," "too loud," "fair or worse," and "poor or worse," as used in the 1958 Bell Laboratories' tests (Ref. 2) of received speech level preferences. Insofar as the Bell Laboratories' curves represent limits of intolerance rather than tolerance, and allowing for the fact that the "highest tolerable" level curve may be in error and could perhaps be displaced in the direction of higher levels, the agreement between the two results is fair.

However, it is necessary to take into account that the Bell Laboratories' tests are based on the early type 302 telephone, for which the preferred received speech volume was found to be 19 v.u.. Although this is similar to the figure of 19.2 v.u. obtained for the local 801 type in these tests, it is noticeably higher in level than the estimated preferred speech volume of —23 v.u. for the later model telephone type 500 (Bell Lab. estimate—Ref. 2). This latter type telephone is more similar in characteristics to the 801 telephone. . (Insufficient data are available for accurate assessment of the difference in receive sensitivity of the 801 telephone relative to the two Bell telephones mentioned in Ref. 2.)

Fig. 10 also illustrates the overlap which occurs at any level between the categories used in both series of tests. For example, in the locally conducted tests a received volume of —22 v.u. or higher was preferred by 70 per cent. of the participants, but is considered to be the lowest tolerable by 2 per cent. Another 2 per cent. of the participants selected a received volume of —22 v.u. or lower as their highest tolerable level, so that a total of 98 per cent. of all participants could tolerate a level of —22 v.u. In the Bell Laboratories' tests, at this same probability level, which corresponds approximately to twice the standard deviation limits, a range of received levels between —17 and —29 v.u. falls between the two categories of "too loud" and "fair or worse." Hence approximately 98 per cent. of the participants could tolerate the range of levels from —17 to —29 v.u.

Hence in the Bell Laboratories' tests, participants could tolerate a wider range of levels and generally preferred a slightly lower level than in the tests reported in this paper.

CONCLUSIONS.

The following is a summary of the main results of the transmission preference tests using 106 participants.

Preferred Conditon:

Line Condition: An overall loss of 8.6 db, equivalent to subscribers' lines of 2.6 miles of 6½-lb./mile cable at each end and zero junction loss. This condition is equivalent to a loss of approximately 5 db less than two Subscribers' Transmission Standards, and approximately 17 db less than the current Overall Transmission Standard.

Received Speech Volume: —19.2 v.u.

Lowest Tolerable:

Line Condition: An overall loss of 23.4 db, equivalent to a circuit loss 2.3 db less than that of the current Overall Transmission Standard (O.T.S.). Only 38 per cent. of all participants could tolerate the conditions defined by the O.T.S.

Received Speech Volume: —34.5 v.u.

Highest Tolerable:

Line Condition: Less than zero line tolerated. Only 13 per cent. could not tolerate zero line.

Received Speech Volume: —11.3 v.u.

Speaking Levels:

—11.7 v.u. (as transmitted speech voltage at telephone line terminals.)

In general, the spreads of all results were fairly large, the typical standard deviation being from 4 to 6 v.u. (or db), which corresponds quite well with the results of other similar tests. This large spread is caused by the range of sensitivity of the participants, and the degrees of tolerance which they possess. The effect of this spread is to create a substantial overlap between opinion categories. When this occurs it may not be possible to define an operating range which is satisfactory for a sufficiently large proportion of the users. In this aspect, the results of these tests differed from the Bell Laboratories' tests, due to the large difference between the "lowest tolerable" level and the "fair or worse" category of the Bell tests. For example, if it is assumed that the "highest tolerable" level after adjustment could be considered coincident with the "too loud" category, then a range of received level from —17 to —22 v.u. is satisfactory for 98 per cent. of the users. In the Bell Laboratories' tests, this range extended down to —29 v.u.

The sample size in many of the categories was insufficiently large to give significance to the small observed differences in behaviour between groups. No appreciable bias due to the order of making choices or the prior condition of the line, was evident.

Although telephone users appear to be tolerant of a range of levels of at least 20 v.u., the preferred received levels chosen in the tests were close to the highest tolerable level. In addition, they were substantially above the levels experienced with the current Overall Transmission Standard Circuits which were considered tolerable by only 38 per cent. of the participants. Measured speaking levels appear to be a little higher than those observed overseas (Ref. 5), and the preferred receiving levels were slightly higher (Ref. 2). The inbuilt automatic regulation of the 801 telephone appears to be effective in minimising intolerably high levels on short lines.

The data obtained in these preference tests, together with information about the actual performance of the telephone network, should assist in studies of the Australian public telephone network, particularly in regard to assessing the degree of subscriber satisfaction with the network performance. The cost of providing telephone facilities is likely to be a major factor in deciding whether the network can be planned to provide a higher degree of subscriber satisfaction.

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DISCUSSION.

Mr. P. R. Brett: It is clear from Mr. Koop's paper that it is now technically possible in the densely populated areas of developed countries to provide a telephone service that meets the standard preferred by the customers without a significant increase in cost. This situation contrasts with the case in less affluent countries, and indeed in many of the outback areas of Australia, where the problem is still to provide a tolerable service at an acceptable cost.

Any attempt to provide the sort of service which the customer prefers poses a very real problem of finding out just what it is that he prefers and of keeping in touch with his increasing expectations. A brief example of this is one thrown up by the advent of satellite communications. With a synchronous satellite, a round-trip delay of about half a second occurs and with delays of this order there is a possibility that there will be confusion in conversations, particularly when the delay is combined with echo or other impairments. There have been very extensive efforts by telephone administrations using simulated conditions and real traffic to find out if delays of the order of half a second will cause unsatisfactory service. These investigations have involved large numbers of observations and interviews with actual users of circuits, but I think most people would agree that the answer is not yet definitely established, although it seems that a half-second delay may be tolerable over an otherwise good quality circuit.

Mr. Koop has given an account of an attempt by the Post Office to find out what the customers expect in the way of received volume in a telephone connection. I would like to ask him two questions:—

(i) Could he indicate whether the average subscriber's connection in Australia meets the preferred volume performance as found in the work described in his paper; and

(ii) Could he indicate the technical means that are available to a telephone authority to improve the volume performance of telephone connections.

Mr. J. B. Potter: (a) Considering the size of the telephone user population and the statistical spread in the results contained in the paper, it would appear that 106 opinions is too small to be anything more than a pilot survey to check and evaluate the techniques of data collection used. Does the author in fact consider that the sample is adequate, particularly as a normal distribution has been fitted to the results obtained?

(b) In excluding from the test a number of specific factors, are the results obtained really representative of user preference? For example, many of the defects of trunk channels seem to have been excluded as too have the environmental noises to which business users are commonly subjected such as traffic noise, extraneous voices and general office background noise. Further, how representative were the conversations used in the assessments; how important or trivial was the information contained in the conversation?

(c) Does the use of the Regulated telephone in the tests make the results applicable only to the use of this type of instrument and of less general application?

The Author in Reply.

To Mr. P. R. Brett:

Question (i)—At the present time there are not sufficient data available on the state of the Australian telephone network, and the distribution of calls within the network, to make an accurate prediction of the performance associated with the average subscriber interconnection in relation to the preferred volume performance described in this paper.

However, a sample survey of subscribers' local circuits, i.e., the connection between the subscriber and the local exchange, was taken in 1965, and we can deduce from this that for subscriber lines of mean volume transmission characteristics, the connection will provide preferred volume performance when the junction loss is 4 db. The planning of the network provides for a limit loss of 15 db in the junction portion of any subscriber interconnection. Although the mean junction loss will undoubtedly be less than 15 db, the actual distribution and hence the mean of junction losses on calls is not known.

In this sample survey the subscribers were presented with a questionnaire concerning their opinions on various aspects of their telephone service. In response to the statement "I have to raise my voice to be understood," they were asked to express their view on their own calls in one of the following categories, "nearly always," "frequently," "sometimes," "rarely," or "never." Seventy-seven per cent of the interviewed subscribers were included in the two categories of "never" and "rarely," while only 6 per cent. complained in the categories of "nearly always" or "frequently."

Similarly, in response to the statement, "The distant voice is too faint, 73 per cent. were included in the categories "never" or "rarely," while only 7 per cent. were dissatisfied and gave opinions of "nearly always" or "frequently."

These figures do tend to suggest, on the basis of subscribers' opinions, that the average telephone connection provides a received volume which is generally acceptable.

Question (ii)—If we assume that when we talk about means of improving the volume performance of telephone connections, we are concerned with increasing the proportion of telephone connections which give preferred volume, then this improvement can be brought about in two basic ways:

(1) By shifting the mean transmission performance of telephone connections in the network towards that which would give mean preferred volume performance.

(2) By reducing the spread of performance, i.e., the standard deviation of the distribution, for different connections.

We can best consider ways and means of meeting these requirements by considering separately the junction and local-end parts of the connections.

With modern amplifying equipment such as is used both for single circuits and in multiplex systems, it is possible to achieve the economic replacement of passive trunk and junction circuits used in the past with active circuits of minimum loss consistent with the difficult stability and echo requirements of the two-wire bothway circuits. By such means it is possible to reduce the total loss in these networks from 15 db (the present upper limit) to about 7 db, or less where short passive circuits are possible. The possibility of any further reduction depends upon the reduction of the impedance variations of the subscribers' local ends. At present the wide range of impedances presented to terminal exchanges prevents accurate impedance matching and this in turn limits further reduction of loss below that mentioned above.

Similar considerations limit the extent to which active devices can be used in the subscriber line or in the telephone instrument, but nevertheless with careful engineering definite improvements can be made.

The extension of the use of 4-wire circuits and hence of a 4-wire exchange switching reduces the need for careful impedance matching and hence helps the trend towards better volume performances.

The loss of the longer subscriber loops is at present controlled by limiting their length and by the use of heavier gauge cables for the longer circuits, but because this part of the telephone network is the most extensive, stringent cost restrictions prevent radical changes in this area.

The spread of performance of the local circuits can be reduced by the use of efficient regulating circuits in the telephone instrument so that the volume performance of the local end is substantially independent of the length of the subscriber's line. The efficiency of the regulating circuit in the 800 series telephone is not yet ideal, and is the result of a compromise between ideal performance and low cost.

To Mr. J. B. Potter:

Question (a)—In this investigation, 106 persons were involved and for the more important condition of "preferred volume," this choice was repeated, giving a total of 212 opinions for this category. For each of the two remaining categories of "lowest tolerable" and "highest tolerable" received volume, 106 persons were involved.

The information gained from a sampling measurement depends only upon the sample parameters and the size of the sample does not need to be related to the size of the population from which it is drawn. However, the size of the sample and the manner in which it is taken does affect the precision of the resulting estimation of the parameters of the parent population. In the case of the mean preferred volume estimate, for example, the 95 per cent. confidence limits on the mean are $\pm$ 0.75 v.u. and this precision is sufficient for the purpose of network planning.

It is recognised that the participants in the laboratory tests may not be representative or even truly random samples of the whole population of Australian telephone users, but the lack of significant differences between the results obtained by the different sub-groups of people suggests that this limitation is not important.

In the original planning of this experiment, further measurements with a larger number of participants were planned. However, the information obtained from the tests reported in the paper was found to be sufficient and the larger experiment was not executed.

Question (b)—There are a number of detailed parts to this question, which can best be answered separately.

In regard to the statement about the exclusion of many of the type of defects experienced in trunk channels, is is true that no attempt was made to introduce such peculiarities of carrier trunk channels as carrier leak, non-synchronous demodulation, instability, echo, etc., into the test circuit. However, these were deliberately avoided for the following reasons: Firstly, such defects are not frequently experienced in modern trunk circuits. Secondly, recent observations in typical local exchange traffic has shown that about 97 per cent. of all telephone calls are local-type calls, either within their own exchange area or within the local call area. Hence subscriber exposure to trunk circuits is relatively light and the condition of the trunk circuits would have a very minor influence on the average subscriber opinion. Perhaps the most common form of degradation on trunk circuits is line noise, and line noise typical of that experienced on medium-length trunk circuits was provided in the test circuit.

Depending on the location, environmental noise can have a variety of peculiar characteristics, ranging from the sounds of extraneous voices, traffic, office or factory machines, cafeteria activities, air-conditioning systems, etc. In these preference tests, Hoth-weighted random noise was introduced into the listening environment. Such noise, although not readily identified as a typical background noise for telephone use, has a spectrum similar to that of typical office noise and was set to a level of 60 Phons, which corresponds generally to the levels found in busy offices. In domestic situations, the average background noise is more like 50 Phons, but short bursts of higher levels are quite common. In support of the environmental noise used, it can be described as sounding somewhat similar to certain types of air-conditioning noise and its masking effect on speech can be considered similar to that of typical telephone background noise.

In regard to the nature of the conversations used in the assessments, much effort was directed at ensuring that the participants were immersed in their conversations. Although the subject matter might frequently have been classified as trivial (and, in fact, many real telephone conversations might be similarly classed), the test conversations were monitored by an operator, who did not permit any circuit selections or judgments to be made until he was satisfied that the conversations were well balanced, free flowing, and of sufficient interest to both parties so that they could be sustained for the duration of the test. Aids used for generating such conversations included a list of the hobbies and special interests of the participant's partner and a number of selected newspaper cuttings featuring topical news or controversial comments on subjects of general interest.

In answer to the basic question as to whether the results obtained were really representative of user preference, one can never be really certain that laboratory tests will provide a true indication of subscriber opinions. By paying detailed attention to the conditions of the experiment many of the physical circumstances of a typical call can be reproduced, but there may be many minor psychological reactions which can exert a degree of influence on the opinions expressed. It is considered, however, that sufficient precautions were taken in the design and operation of the tests to be able to use the results as a guide in planning the future telephone network towards meeting subscribed preferences.

Question (c)—The use of the regulated telephone in these tests, together with the use of artificial lines to simulate subscriber's line characteristics in regard to frequency characteristics, sidetone and loss, enable the results to be more directly applied to the network without introducing additional errors which might be involved in applying the information in a practical form. The particular telephone instrument chosen for the tests is one on which the planning of the network is based. Certainly the results will not be directly applicable to unregulated telephones such as the type 400 which is in extensive use in the network (but now obsolescent) and care will be required in making comparisons with similar tests carried out by other organisations. However, these limitations were considered to be relatively unimportant.

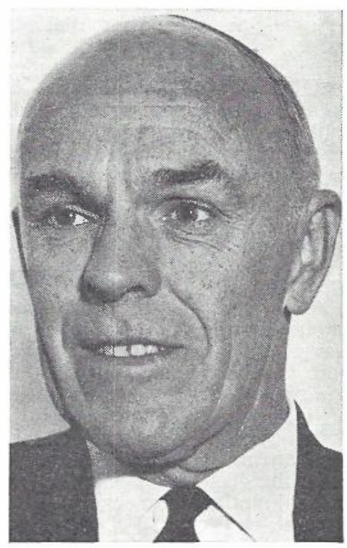
MR. J. MEAD, Dip. E.E., A.M.I.E. Aust.

The contribution which the Telecommunication Society of Australia has made to the industry in Australia over a span now approaching 100 years, is due to the dedicated efforts of many enthusiastic people working in diverse roles in all parts of the country. Outstanding service has, in the past, been recognised through the award of either a Life Membership of the Society or a Life Subscribership to the *Journal*; recently these two awards have been amalgamated into the single award of Life Member.

The West Australian Division of the Society has announced the award of Life Membership to Mr. J. Mead, until recently the Division Secretary. Mr. Mead first became associated with the Society in 1946 when he became the West Australian representative for the *Journal*, an appointment which, expanded to sub-editor in 1954, has continued over a period of 22 years. His sustained energy and enthusiasm has enabled "The West" to be strongly represented in the Journal and for the majority of West Australian members the name of Jack Mead has become irrevocably identified with the *Journal* and the Society.

An indication of the calibre of the man came in 1959 when the foundation of the State Division of the reformed Telecommunication Society of Australia found Mr. Mead prepared to extend his activities to include the role of Secretary of the West Australian Division. In this appointment also he has made a substantial contribution; his ability and drive have been significant factors in keeping the Division's activities running at a high level over a long period.

The Board of Editors is particularly pleased to take this opportunity to record its appreciation for outstanding support, and on behalf of all members of the Society extends congratulations for the award of Life Membership.



Mr. J. Mead

AN S.T.D. COIN TELEPHONE

*A. A. RENDLE, B.A.**

INTRODUCTION.

A new coin telephone, with S.T.D. facilities, is being developed for the Australian network. It is being produced by two separate but co-ordinated efforts, one concerned with a new coin collecting mechanism and the other with an electronic control circuit. The latter has been developed by the A.P.O. and is the primary subject of this paper. The philosophy behind the design of the instrument has been to concentrate all the purely logical operations in the control circuit and thus relieve the coin handling mechanism of all but relatively simple functions. The electronic circuit can be likened to the "brain" and "nerves" of the device, while the solenoid operated mechanism provides the "muscle."

The method of operation on S.T.D. calls is as follows: — As coins are deposited, they fall to an intermediate suspense position. During a call, coins are collected one at a time, in ascending order of value, each coin buying an appropriate conversation time, depending upon its value and the distance of the call. The sequence of coin collection continues until all the coins have been taken; at this stage, after appropriate warning lamp and pay tone signals have been given, the call will be terminated. If the call is ended by hanging up before all the coins have been taken, any remaining in suspense will be refunded.

Multi-metering (Karlsson) pulses are transmitted from the exchange, using 50Hz signals along the line, to indicate the charging rate.

FACILITIES PROVIDED.

This will be a universal coin telephone allowing for operator assisted, as well as subscriber dialled, trunk calls. Emergency and other non-chargeable calls may be made in the usual way without a coin. A single coin is necessary for local calls. It will accept three coin sizes; initially 5c, 10c and 20c, but the mechanism is designed so that it can be adjusted to take a different combination of coins if circumstances demand it at some time in the future.

LOCATION OF EQUIPMENT.

Assuming that an S.T.D. coin telephone can be divided into two essential parts, a coin handling mechanism and suitable computing and control equipment, there are two basic ways of locating these components. One arrangement consists of a coin mechanism at the subscriber's end, in a Public Telephone cabinet, working in conjunction with exchange located control equipment. An example of this approach is the British Post Office 705 telephone, with its corresponding coin and fee checking equipment. This arrangement has one major advantage: the control equipment is easily accessible for maintenance. However, a corresponding disadvantage of separating the two parts is the need for providing communication between them. Apart from the technical difficulty of achieving reliable remote signalling, the restricted communication is almost bound to lead to an undesirable over-simplification of the operating procedure, from which the subscriber will suffer. The second possible arrangement, which has been adopted here, is to locate all the equipment in a single box at the subscriber's end. For this to be an acceptable solution, the control equipment must be made reliable enough to offset the inaccessibility for maintenace. The availability of silicon monolithic logic circuits at reasonable prices has been the chief factor in making this possible.

* Mr. Rendle is Engineer Class 2, Subscribers Equipment Section, Headquarters.

HISTORY OF DEVELOPMENT.

Before the development of the present system, an earlier attempt to produce an S.T.D. telephone was made, based on a straight conversion of Coin Telephone No. 1 and retaining the existing coin mechanism. As coins were deposited in the telephone, their value would have been registered in a pulse counting credit store, which would then have been counted back at an appropriate rate (by meter pulses) during the call. When the established credit had been exhausted, the call would be terminated. A successful model demonstrating this principle was constructed, using resistor transistor logic elements and a stepping motor for the credit store. However, this approach was discarded as, inherent in the design of the mechanism, coins can only be collected in bulk from the suspense position: this means that all coins deposited before answer would be collected on answer, so that, if a wrong number has been obtained, the caller would lose all his money. It was felt that a far better service would be provided if the coins could be collected individually, so that only one small coin need be lost in the case of a wrong number. With this in mind, a specification was written for a coin mechanism able to collect coins in this fashion.

COIN MECHANISM.

Although it is not the purpose of this present article to deal in detail with the coin mechanism, a few comments are necessary to the understanding of the control circuit. The essential feature of the mechanism is that a coin, after being gauged for correct size, falls into an individual suspense position, from which it can be either collected on its own into the coin tin or returned, along with other coins in suspense, to the refund pocket. It is also possible to collect, in bulk, all coins in suspense, for operator assistance working. The method of coin storage is novel and has been specially developed for this instrument; the main aim of the design has been to keep all coin passageways wide and free to prevent coin blockages. This design philosophy has led to a mechanism which will be criticised by some as being too complex, but it will be realised that in fact this complexity is a result of squarely facing all the problems of coin storage, including the ability to cope with bent and misshapen coins. The mechanism has a capacity of five coins of each value; any coins deposited beyond this number will be returned to the refund pocket. The mechanism is operated by a number of solenoids and magnets under the control of the electronic circuit. There will be no balance arms in the conventional sense, depending on the dead weight of the coin; instead, there will be a set of three reed switches (one for each coin value), which will close if one or more coins of a particular value are held in suspense.

POWER SUPPLY.

The power needed to operate the telephone is more than could be drawn from the telephone line. Fortunately, a decision has been taken to illuminate public telephone cabinets continuously and it has been possible to include a small transformer in the special fluorescent light fitting to supply low voltage a.c. power to the telephone instrument. To cover the (hopefully, infrequent) periods of mains failure, the telephone has been designed to remain operating during a power failure for emergency and other non-chargeable calls through an operator. A secondary advantage of using mains power is that the designer of the coin mechanism has been free to use substantial electromagnets where necessary, rather than having to manage with flea power devices operating from line current.

HOUSING THE TELEPHONE.

The method of housing this telephone has yet to be finally decided, but it is likely that a new approach will be adopted. A coin telephone housing has to serve two purposes: protecting the mechanism and providing a storage for coins. The traditional method of solving this problem has been to equip each instrument with an individual case, usually screwed to the wall of a cabinet, with a coin compartment in the lower part. The principle proposed for this telephone is to divorce the case from the mechanism and provide a receptacle for a plug-in mechanism as part of the cabinet installation. The coins would then perhaps run down to a safe located below the floor of the cabinet. The receptacle would have a socket to which the telephone line, power supply and any other services would be wired, which would mate with a corresponding plug on the mechanism. Future mechanisms would all conform to a standard size and shape to fit the receptacle. The main advantages of this principle are that: first, maintenance would become simply a matter of plugging in a replacement mechanism for all but the most obvious faults; second, when a service has to be converted, from non-S.T.D. to S.T.D. working for example, it would be a simple matter to replace the mechanism. A further advantage is that an adequate standard of security can be built into the standard receptacle and coin safe, which will be unaltered if a new mechanism is adopted at any time in the future.

CHOICE OF COMPONENTS.

As mentioned earlier, silicon planar integrated circuits are used to perform all logical operations. There has been some difficulty in selecting a suitable type as the emphasis, to date, in the design of integrated logic circuits has been on their acceptability for computer design, where switching speed is a crucial factor. For a great deal of general purpose telephone work, fast switching is unnecessary; indeed, it may be an embarrassment, as the vulnerability to maloperation from stray noise transients is increased. The components chosen for this application are of the diode-transistor logic (DTL) type, as these offer the best combination of relatively low switching speed (approx. 25nS) and relatively high noise immunity (of the order of 1.0 volt) of readily available current types. A typical gate circuit in this series is shown in Fig. 1 and a clocked flip-flop in Fig. 2.

TYPICAL RESISTOR VALUES

$R_1 = 2.00K\Omega$

$R_2 = 1.75K\Omega$

$R_3 = 5.00K\Omega$

$R_4 = 6.00K\Omega$

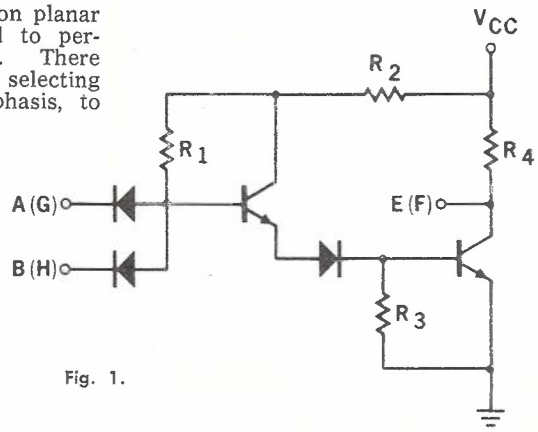


Fig. 1.

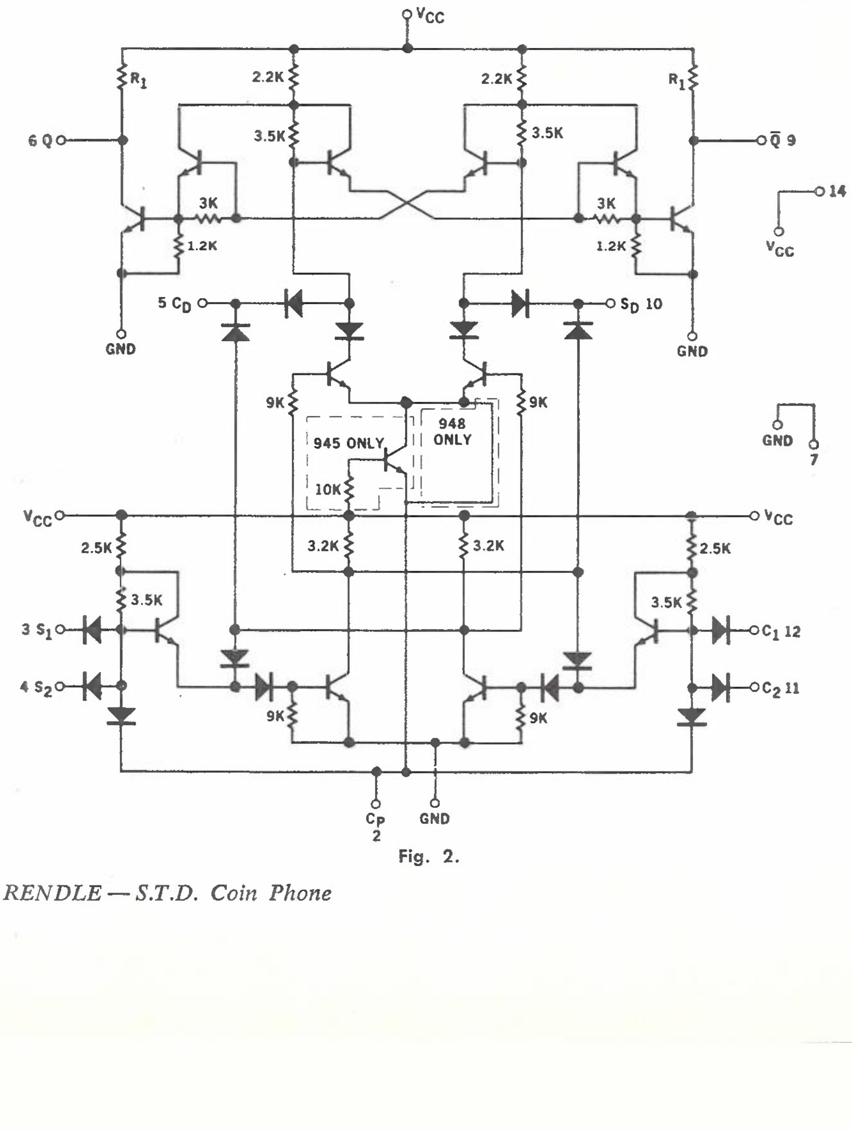


Fig. 2.

An advantage of the 930 DTL series used in the laboratory model is that it can be obtained from at least four different sources in Australia. A new generation of circuits more suitable for the telephone switching field is now beginning to emerge, having a higher switching threshold (4 to 5 volts) and slower speed: it will be possible to use these safely in closer proximity to relay circuits. An example of this type is shown in Fig 3. Silicon planar transistors are used

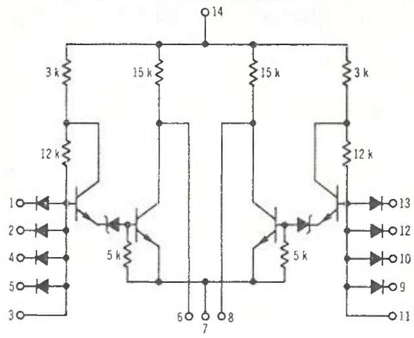


Fig. 3.

for switching solenoids and lamps and various timing circuits. Wherever possible, electrolytic capacitors have been avoided in preference for metallised plastic types. All components chosen have a working range of at least 0 to 75 degrees C.

CIRCUIT DESCRIPTION.

We can now turn to the operation of the circuit (Fig. 4). The easiest way to do this is to consider it function by function.

Operator Assistance Facilities.

Coin Identification Tones: Stepping switch contacts, located in each coin chute, close momentarily as the coin passes. When this happens a low going pulse will be produced, which will set one of three flip-flops (depending on the coin value) and turn on a 10 Hz astable multi-vibrator (transistors SC45 and SC46). The 50 mS pulses from this multi-vibrator control, via gates 5N1 and 4N1, a 900 Hz astable tone generator (SC37 and SC38). The 50 mS pulses are counted by flip-flops B7 and B6. The outputs of B7 and B6 are decoded by gates 16N3 and 16N4 and used to reset the three RS flip-flops and thus turn off the 10 Hz multi-vibrator, after the correct number of pulses for the particular coin size have been produced. The effect of this will be to produce the following series of tone signals:—

5c coin: 1 pulse; 50 mS duration.

10c coin: 2 pulses } at 50 mS
20c coin: 4 pulses } intervals.

After a chargeable call has been answered ie. (when one meter pulse has been received), the flip-flop formed by gates 8N2 and 8N3 will have been changed over and one input of 4N3 will be held low. This will inhibit the production of coin tones, preventing annoyance, when additional coins are inserted during a S.T.D. call.

Refund Tone: In case a dispute over coins arises with the operator, the subscriber can momentarily depress the gravity switch and return the coins to the refund chute, without dropping out the connection. At the same time a two-second burst of 900 Hz refund tone will be returned to the operator. This is possible because the gravity switch functions are performed by a slave relay (GSR), which has a two-second release time, achieved by a simple capacitor discharge timing circuit (C14, R33, and SC28). After the receipt of an answer signal transistor SC24 will be biassed to conduct and C14 will discharge through R31, reducing the delayed release of GSR to about 10mS. This provides a quick drop out when the gravity switch is operated to terminate a call. The refund tone is produced as follows:—Capacitor C10 charges through a gravity switch contact, when it is depressed. It discharges through R20, causing transistor SC15 to conduct for two seconds, and thus, via gates 5N1 and 4N1, producing a burst of tone from the 900 Hz astable multivibrator.

Bulk Coin Collection: Coin collection for operator assisted calls is achieved by pushing PB1. This causes C13 to charge through SC22. SC19 conducts for approximately two seconds, while C13 discharges, and in turn keeps SC20 and SC18 conducting. SC20 operates the bulk collection magnet and SC18 turns on the 250 Hz astable multivibrator. After the receipt of an answer signal, SC22 and SC23 will not be biassed to conduct and therefore PB1 will be inoperative. This prevents collection of coins during a S.T.D. call due to accidental operation of the button.

S.T.D. and Local Calls.

The principle of coin collection could be described as sequential prepayment. On answer, a single coin is seized from the intermediate suspense position and transferred to the coin tin. This coin will buy a certain length of call time; after this has been exhausted, a second coin will be seized. This sequential collection of coins will continue until there are no coins waiting in the suspense position, when, after appropriate warning, the call will be cut off.

Meter Pulse Detector: The cost of the call will be indicated by periodic meter pulses generated in the exchange and transmitted to the telephone as 45V a.c. 50 Hz longitudinal pulses superimposed over both legs of the line to earth. Each pulse is approximately 300 mS long. The a.c. pulses are detected in the telephone and shaped into square wave pulses about 500 mS long. The detection circuit is protected against spurious operation in three ways. The primary of TR1 is tuned to 50 Hz by C1 and C2 (effectively in parallel), the integrating action of C16 and R36 will reject pulses of less than 50mS and the switching threshold of the circuit will ignore pulses of less than about 30v. Also, of course, due to the balanced arrangement, signals on the telephone line will not affect the circuit.

Meter Pulse Counter: The heart of the coin collection circuit is a three-stage binary counter, B1, B2, and B3. This is decoded by 7N2 in such a way that every time a count of 6 is reached a coin will be collected. The counter is stepped forward by the leading edge of each metering pulse. Initially, when the handset is lifted, the counter is set to a count of 5. The first metering pulse, received on answer, will step the counter to 6 and thus initiate the collection of the first coin. The circuit is arranged so that the smallest coin available will be collected first, primarily to minimise the loss if a wrong number is obtained. The collection pulse is steered to collect the correct coin by gates 9N4, 10N2 and 10N3, which are each connected via a pair of transistors to operate the three coin collection solenoids. On a local call, only one metering pulse will be received, on answer this will cause the collection of a single coin, of the lowest value deposited.

TABLE 1.

Coin	4c Fee	5c Fee
5c	1¼	1
10c	2½	2
20c	5	4

Pre-Setting Circuit: Table 1 shows the value, in metering periods, of the three coin sizes for two different unit fee charges.

The correct value for each coin is recorded by pre-setting the counter, at the time the coin is collected, to an appropriate count below 6. For example, taking the fee of 4c the counter will be pre-set to 1 when a 20c piece is collected; therefore 5 meter pulses will be needed to regain a count of 6 and initiate the collection of the next coin. The correct pre-setting condition is set up on 14N1, 14N2 and 14N3 at the beginning of the collection period, but not transferred to the asynchronous inputs of the counter until the end of the collection period. The sequence is as follows. Before the start of the collection period the output of 9N1 is held high by the low state on the output of 8N4. The leading edge of the meter pulse will maintain the high on the output of 9N1 by making the second input go low. At the end of the meter pulse, both inputs of 9N1 will be high, causing the output to fall. The output of 13N3 will consequently rise, allowing the pre-setting condition established on 14N1, 14N2 and 14N3 to be transferred to the counter. As soon as presetting has been accomplished, the collection pulse will disappear and the output of 9N1 will return to a high state, causing 14N1, 14N2 and 14N3 to be inhibited once again. It will be seen from Table 1 that coins do not in all cases buy discreet numbers of units. Where a fraction is involved, the coin is given the nearest whole number of units below its actual value, the remainder being stored in the two flip-flops B4 and B5. Whenever the accumulated fractions add up to one the coin being collected is given an extra unit. Thus, for the 4c fee, each 5c coin is given a value of one unit, but every four 5c piece collected is allowed 2 units so that the correct value is given in the long run. Adjustment for different fee rates is made by altering a number of quick-connect links.

'Last Coin in Use' Lamp: To give the user a chance to extend the call by depositing more coins, he is given various warning signals as the time approaches for him to be cut off. The first warning will be an illuminated sign on the telephone reading **Last Coin in Use** or wording to that effect. When the last coin is collected from the suspense position, the output of 10N1 will fall and via 11N3, 3N4 and 2N3 cause SC14 to conduct and turn on the illuminated sign. To prevent the sign being alight continuously during a local call, it will be held off until the flip-flop formed by 3N2 and 3N3 is changed over on receipt of the second meter pulse. It will not be affected by the first meter pulse because the output of 3N1 is held high until the flip-flop formed by 8N2 and 8N3 has changed over. This will not happen until after the short pulse (approx. 200nS) from 1N4, occurring at the beginning of the meter pulse, has passed, because the operation of 7N2 is delayed about 0.05 mS by C24.

Pay Tones: A 500mS pulse of 900Hz, known as the warning pay tone, is given when there is only one paid meter period remaining. This is generated in the following way: if the counter reaches a count of 5 at a time when there are no coins held in suspense, the output of 7N1 will fall. This will initiate a 500mS non-regenerative monostable circuit (C23, R48 and SC42), which, via 4N2, will turn on the 900Hz tone generator for 500mS. At the same time, a second monostable circuit (C22, R46, SC40 and SC39), with a period of 6.5 seconds, will be started. If the next meter pulse arrives during this 6.5 second period, it will be prevented from stepping forward the meter pulse counter because the output of 6N2 will be held high. Instead, the flip-flop formed by 5N2 and 6N4 will be changed over, turning on the 900Hz tone generator. This will remain on until reset by the following meter pulse. The effect of this will be as follows:—for those metering periods less than 6.5 seconds (i.e., the 4, 5 and 6 second periods), the user will be given warning pay tone when he has one paid period remaining, but if he fails to deposit

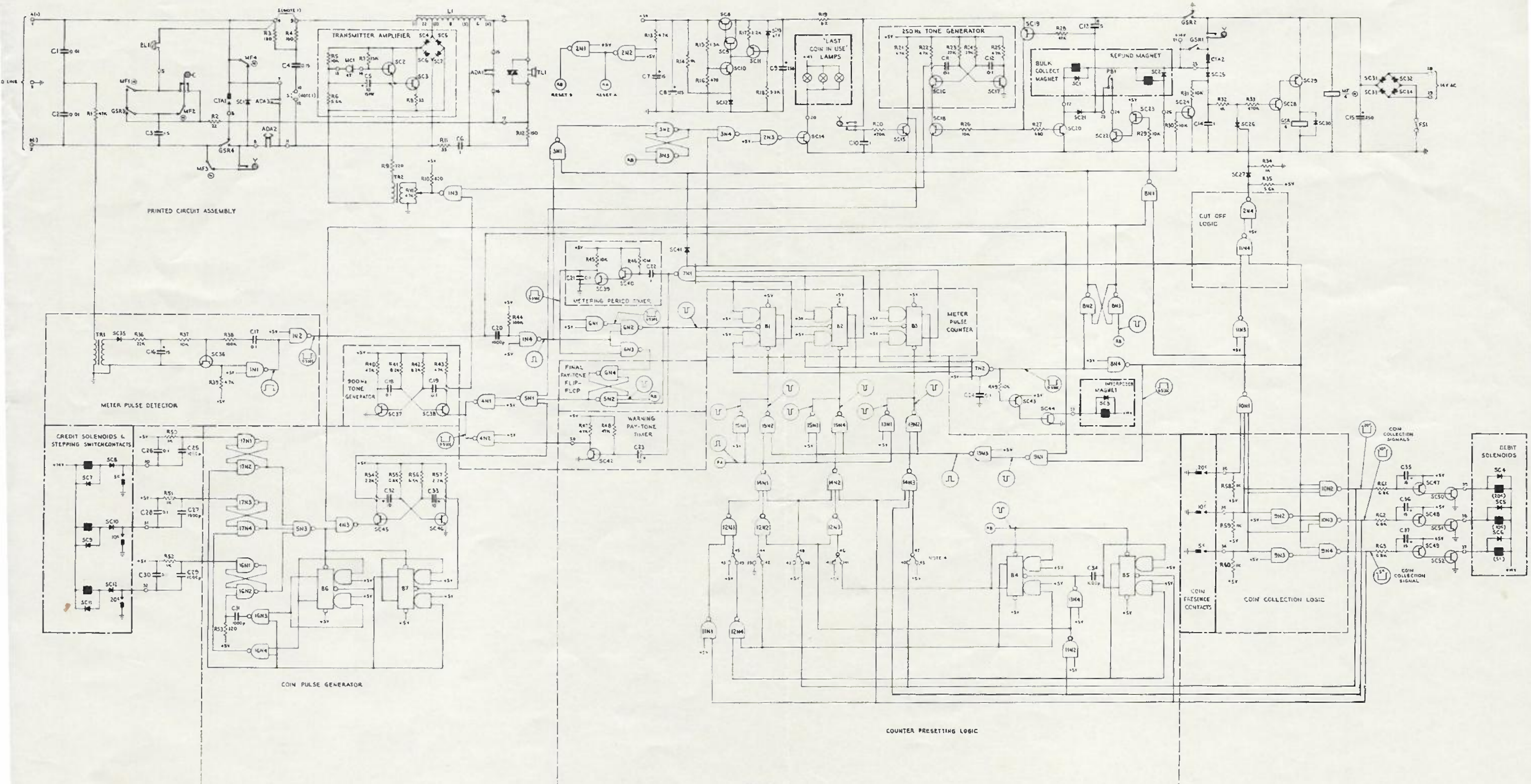


Fig. 4.

Notes:—

1. For line resistance below 300 ohm remove strap from 9-4 to 10-12.
2. Logic gates are designated by a number (the number of the package) + the letter N (Nand Gate) + another number (the number of the element within the same package). Typical example: 2N4; meaning the 4th Nand Gate in the 2nd package.
3. Clocked flip-flop (binary counter) is designated by the letter B (binary) + a number (the number of the flip-flop such as B3 or B7).
4. Strapping shown thus — is for 4c unit charge. To change to 5c unit charge, strap thus - - -.

a coin before the arrival of the next meter pulse 4, 5 or 6 seconds later), instead of being cut off, he will be given a final pay tone persisting for the duration of the next metering period. If he deposits a coin during the final pay tone, the tone will be switched off at the end of the metering period and the coin collected, allowing the call to continue normally. If he does not deposit a coin during the final pay tone the call will be cut off at the end of the period. The purpose of this procedure is to allow a minimum time of 8 seconds to deposit a coin, between the warning pay tone and cut off. In the case of metering periods longer than 6.5 seconds, the user will be given warning pay tone at the beginning of the last paid period and cut off at the end of this period, if he fails to deposit an additional coin. Extra coins may, of course, be deposited at any time during a call.

Cut Off Circuit: If the meter pulse counter reaches a count of 6 without a coin being present in suspense, the ouptut of 11N4 will fall, causing the output of 2N4 to rise and trigger SCR SC26. This will cause relay GSR to fall out, opening the loop on the line and dropping out the call. SC26 will continue to conduct until the circuit is broken by operating the gravity switch.

Telephone Transmission Circuit: The only oddity in this part of the circuit is that a rocking armature microphone (a 4-T receiver) is used instead of the usual carbon type. A two-stage transistor amplifier, operated from line current, is used to provide adequate send level into the line. There are several reasons for adopting this approach. There is a discernible world trend away from carbon microphones, as attempts are made to improve the transmission quality and reliability of telephone instruments; this new coin telephone will provide useful experience in a new technique as a guide to its more general application. Also in the development of this instrument the accent has been on reliability, and it was felt that avoiding the carbon microphone would make a useful contribution in this regard. From a circuit point of view the send amplifier provides a convenient point to inject tone signals into the line.

Power Supply Fail Procedure: When the power supply fails, the two relays, MF and GSR, will not operate and the gravity switch functions will be performed directly by contacts on the gravity switch. The instrument will now work as an ordinary telephone except that, if a line polarity reversal is received, which will happen when a chargeable call is answered, a diode across the line will conduct, shunting the telephone with a low impedance and preventing transmission. The effect of this will be to allow the telephone to be used only for non-chargeable (emergency) calls.

Power Supply: 15 volts a.c. is supplied to the instrument. This is rectified to provide a d.c. supply to operate the various solenoids and magnets in the coin mechanism. A conventional series regulator provides a stable 5v. supply for the logic circuits. The average consumption of the telephone while in use is about 600mA.

CONCLUSION.

Before large scale production and installation of this new telephone is begun, a sample group of about twelve instruments will be field tested. The field trials will probably begin about the middle of 1968, and, if successful, production should begin later in the year.

The circuit design has been carried out by the Headquarters Subscribers' Equipment, Telegraphs and Power Section, with advice from the P.M.G. Research Laboratories, who were also responsible for the layout and manufacture of the elegant printed wiring board which can be seen on the cover of this issue.

TECHNICAL NEWS ITEM

HOBART - LAUNCESTON BROADBAND RADIO SYSTEM.

The first microwave broadband radio relay system to be installed in Australia with a capacity of 1800 telephone channels was recently placed in service between Hobart and Launceston. The new radio system comprises the two terminals and two repeaters at Mt. Seymour and Cleveland. The equipment was manufactured by the Telettra Company, Italy, and was installed by Australian Post Office staff.

The equipment, which uses fully solid-state circuitry with a travelling wave tube amplifier (TWT), operates in the 4GHz band. The facilities provided are an 1800 channel bearer for telephony, a one-way (Hobart to Launceston) bearer for the regular relay of the national television programme, and a both-way protection bearer, which can be used to provide additional television relay facilities between Launceston and Hobart when required. Of the 1800 channels provided on the 'through' bearer, 60 channels are available for 'wayside' traffic, and these circuits are extracted at the Cleveland repeater to serve between Launceston and Campbelltown.

Supervisory and switching facilities are incorporated in the system to indicate fault or non-standard operating conditions to the control terminal and to automatically switch traffic to the protection bearer when the main bearer fails.

The completion of the radio system will permit the introduction of S.T.D. circuits between Hobart and the mainland when the associated channel multiplexing and exchange equipment has been commissioned.

DEVELOPMENTS IN SUBSCRIBERS' TELEPHONE INSTRUMENTS

*M. F. SAGE, B.E.**

INTRODUCTION

When the 800 series telephone was introduced in 1963, most other telephone instruments were still of obsolescent design; still housed in bulky unattractive cases, they offered a range of facilities, unsatisfactory to many telephone users. A joint Australian Post Office-Industry Telephone Instrument Development Committee was formed in 1964 to stimulate the development of new equipment and to extend the range of facilities. The work of the Committee on the more complex Intercommunication and Business telephone systems is continuing, but several improved designs, providing other facilities, have already been introduced.

The new instruments already in production are based on the 801 telephone with push-button keys and some circuitry added to provide the required facilities; this hardware will provide a basis for further system development. However, the major telephone project now under way will use only the speech circuit, dial and handset from the standard telephone and will be housed in a larger case of new design. It is expected that this latter project will provide a suitable basic instrument case for custom-built non-switching units as well as for a standard range of equipment which could include one or more sizes of Executive-Secretarial and Intercommunication Telephone Systems.

DESIGN TARGETS

The general aims of all these projects have been similar and are summarised below:—

(a) Exchange line transmission and signalling limits should be at least equal to the crossbar limit of 1500 ohm excluding the telephone. Where possible, these limits will be extended to 4000 ohm for new equipment so that the use of lighter gauge cable conductors will be facilitated.

(b) The equipment should be of modern and attractive appearance.

(c) The facilities offered by existing equipment should be improved on if possible, and flexibility to enable restrapping for a range of facilities should also be incorporated.

(d) Installation of the new equipment should be simplified as far as practicable, in keeping with the possibility of modifying the facilities by re-strapping. Connection at the subscriber's premises by screw terminals, soldered connections or wire-wrapped connections should be avoided.

(e) Power supplies should be tailored to meet the needs of each particular system type, although existing general purpose power supplies should be used if they meet all requirements. 24V d.c. is used for

* Mr. Sage is Engineer Class 3, Subscribers Equipment, Telegraphs and Power Section, Headquarters.

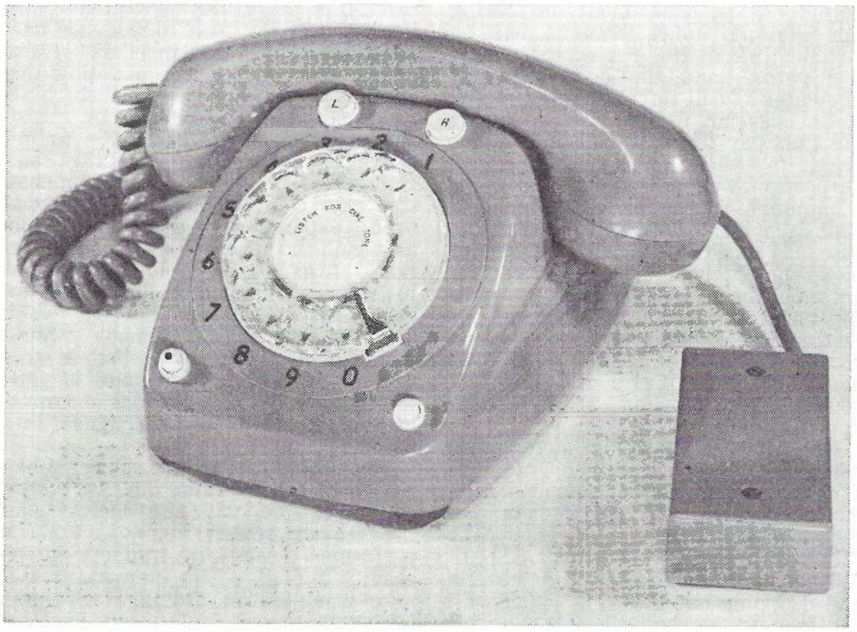


Fig. 2. — 8202/8203 Telephone.

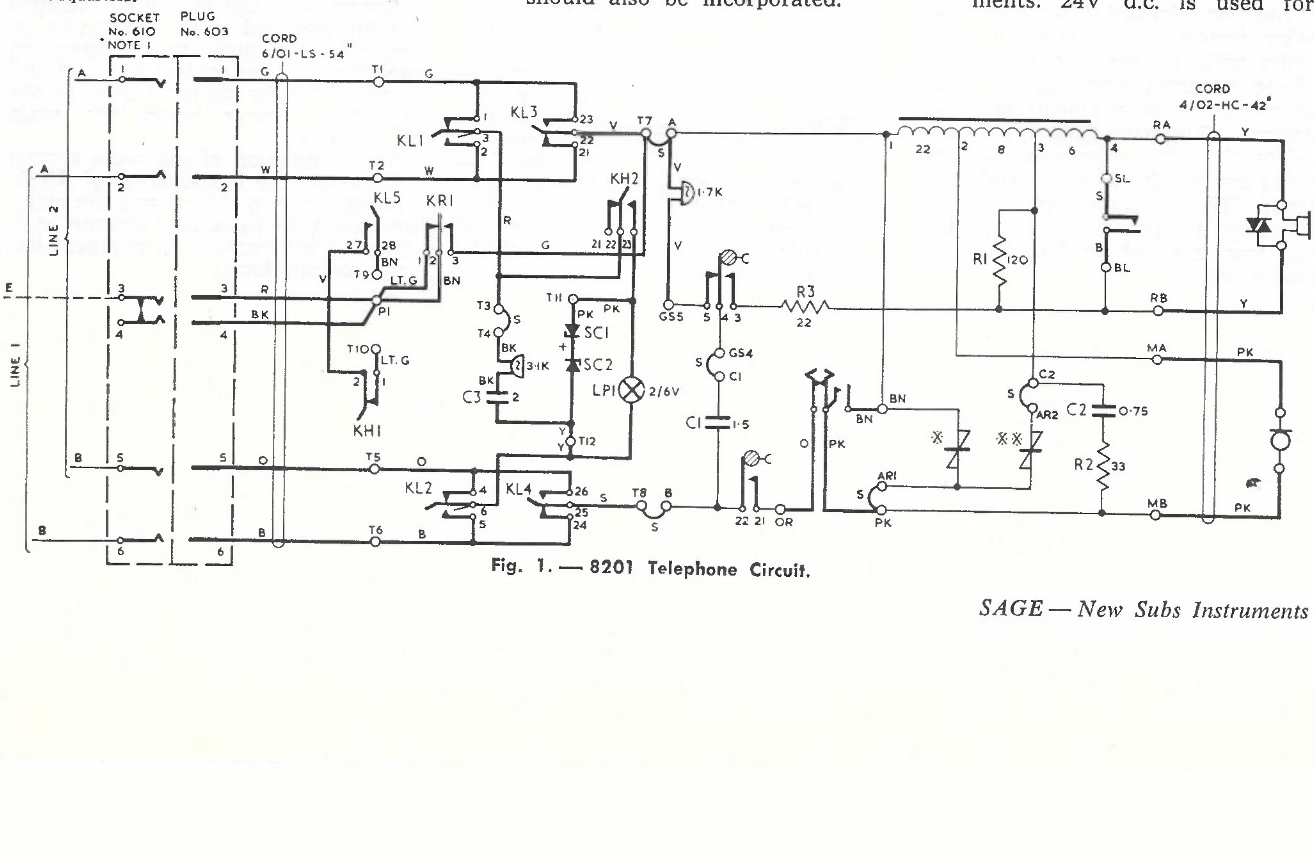


Fig. 1. — 8201 Telephone Circuit.

transmission battery feed and 24V d.c. and 75V a.c. (50Hz) used for signalling, and where a number of lamps are used, the supply should be voltage regulated.

(f) Visual supervision of exchange line conditions should be provided by lamps and a hold facility is required for each exchange line.

(g) New hardware should be introduced to improve reliability, performance appearance and to reduce size and cost.

(h) Maintenance should be facilitated by provision for easy and rapid replacement of component sub-assemblies.

(j) Printed wiring techniques should be used as far as practicable to increase reliability and to reduce cost.

(k) Only facilities which can be economically justified should be provided.

TWO LINE TELEPHONE

The type 8201 telephone has been developed to provide direct access to two lines without the need for a separate switching unit. A manual hold facility is provided and the lines may be auto or C.B. exchange lines, or P.B.X. lines, or any combination except that only one 4-wire line may be connected.

Two locking push-button keys are fitted above the dial and are used for line selection and holding respectively. A lamp is fitted in the hold key and together with a parallel zener diode this forms the line termination in the hold condition. Recall or hold and call facilities on P.B.X. lines can be controlled by a non-locking push-button key fitted in the lower right corner of the instrument. The telephone circuit is shown in Fig. 1; the appearance of the instrument is similar to the type 8202/8203 telephone illustrated in Fig. 2 but with the lower left hand key omitted.

The locking push-button keys are supported by a bracket which replaces the gong strap and also acts as a heat sink for the Zener diodes. Other components which are mounted on the bracket are an auxiliary terminal board fitted with 12 quick connect lugs, and a capacitor and a.c. buzzer which terminate the idle line; the normal telephone bell and capacitor terminates the switched line. A 6-conductor cord and the standard 603/610 plug and socket are used for connection to the lines and no power supply is required.

INTERCOM SYSTEM 1/2

A natural development of the two-line telephone concept is the use of one line for intercommunication between two points which share access to the same exchange or 2-wire P.B.X. line. The Intercom System 1/2 provides this basic executive-secretarial system with a filtered exchange line for the executive. The circuit is shown in Fig. 3.

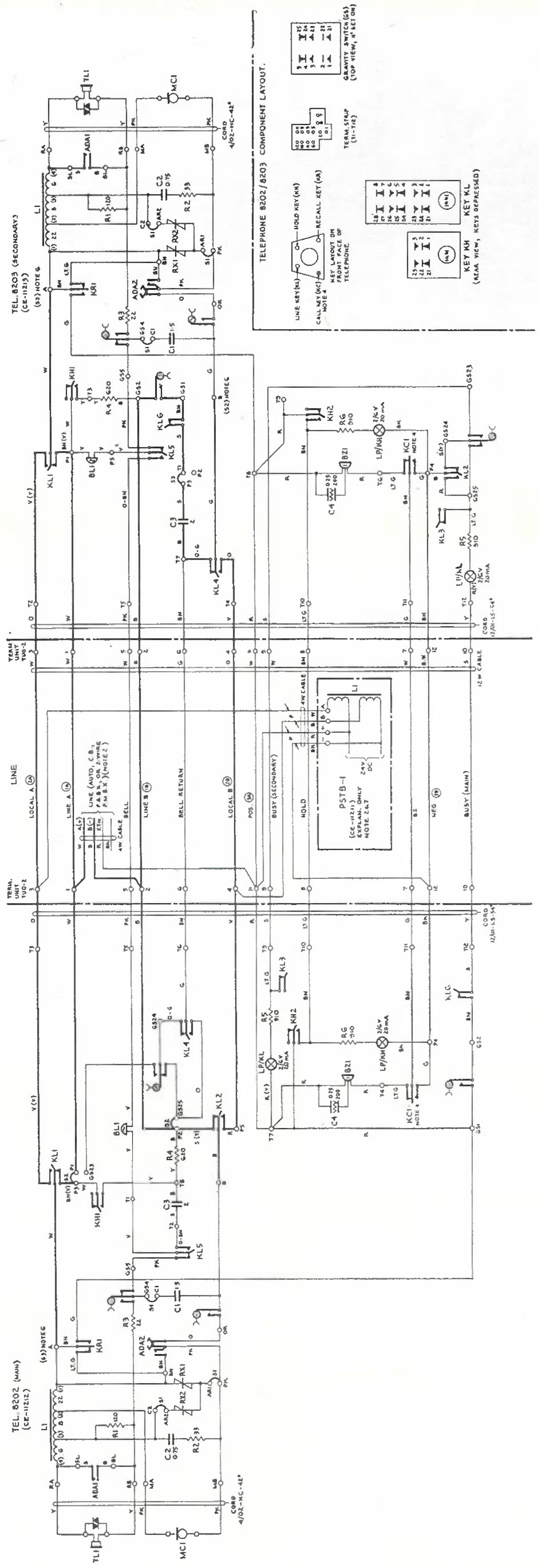


Fig. 3. — Intercom. System 1/2 Circuit. (Transmission Path Shown in Heavy Line.)

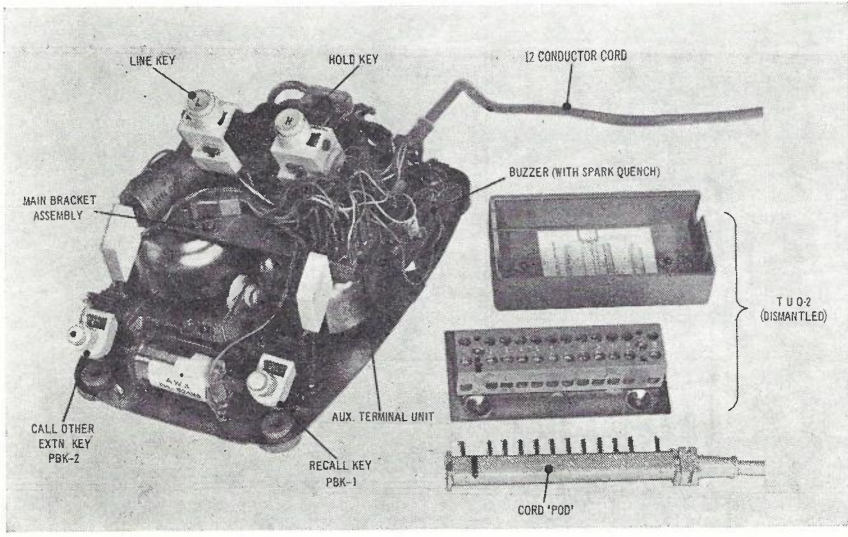


Fig. 4. — 8202 Telephone Construction.

Standard Facilities

The two telephones which are shown as type 8202 (executive) and type 8203 (secretary) are identical (see Fig. 2) except for their internal strapping arrangements and provide the following standard facilities:—

(a) Incoming exchange calls are normally signalled and answered at the 8203 telephone but by operation of the line key in the 8203 telephone, as would occur during a local intercom call, the signalling is extended to the 8202 telephone as well.

(b) The 8202 instrument has priority in access to the exchange line, but monitoring at the 8203 telephone is possible; both telephones have lamp supervision to indicate whether the other party is using the exchange line. An exchange call may be held by either point while an intercom call is made and transfer of an exchange call between the points is possible.

(c) Intercom signalling is provided by a push-button (marked with black dot, see Fig. 2) which operates a buzzer in the other telephone (see Fig. 4).

Optional Facilities

Other facilities which can be readily provided by restrapping of the standard telephone are:—

(a) Incoming exchange calls sound the bells in both telephones and the executive (8202) can silence his bell by operation of the line key.

(b) The executive may have complete secrecy on exchange calls or alternatively, parallel operation is possible; the latter arrangement is restricted to exchange line loops of less than 400 ohm so that sufficient transmitter current is fed to both telephones.

Equipment

The type 8202 and 8203 telephones differ from the type 8201 telephones in the following respects:—

(a) A 620 ohm hold resistor is used instead of the hold key lamp and zener diode combination. This provides an acceptable return loss figure although for line holding a termination of 300 ohm or less would be preferred.

(b) Exchange line supervision is provided by a lamp in the line key.

(c) 6V, 20mA lamps are used with a 910 ohm series resistor to operate from the standard 24V supply but for 50V working, the only modification required in the instrument is to change to 36V, 20mA lamps.

(d) A 24V d.c. buzzer is used for intercom signalling instead of the a.c. buzzer in the type 8201 telephone which is required for exchange line signalling.

(e) Mounting arrangements for the keys and components have been improved so that removal of individual units from the instrument is simplified. Similarly changes will be introduced in the type 8201.

Normally, a special power supply and transmission bridge unit (PSTB-1) is provided to supply 24V d.c. for intercom speech signalling and lamp supervision but as mentioned above 50V operation is also possible if some modifications are carried out.

The power supply is regulated and the rectifier diodes, transmission bridge and regulator circuit are mounted on a printed circuit board except for the output transistor of the regulator, which is mounted on the chassis together with fuses, transformer and a terminal strip. The circuit is shown in Fig. 5.

Cabling

A 12-wire connection between the telephones is required and a loop limit of 100 ohm applies. Special instrument cords and a screw-type terminating unit have been developed. The 4-wire cable from the power supply and the exchange line may be connected to either terminating unit.

ALTERNATIVE SYSTEMS

The 8202 and 8203 instruments use identical hardware with different internal strapping. Other variants of the hardware could provide:—

(a) A 6-wire extension of an Intercom System 1/3 with a direct exchange line.

(b) Three speaking points with access to a common exchange line and intercommunication between all points.

(c) As for (a) but with each point having an individual line instead of sharing with the other two points.

The PSTB-1 unit would be used with systems (b) and (c).

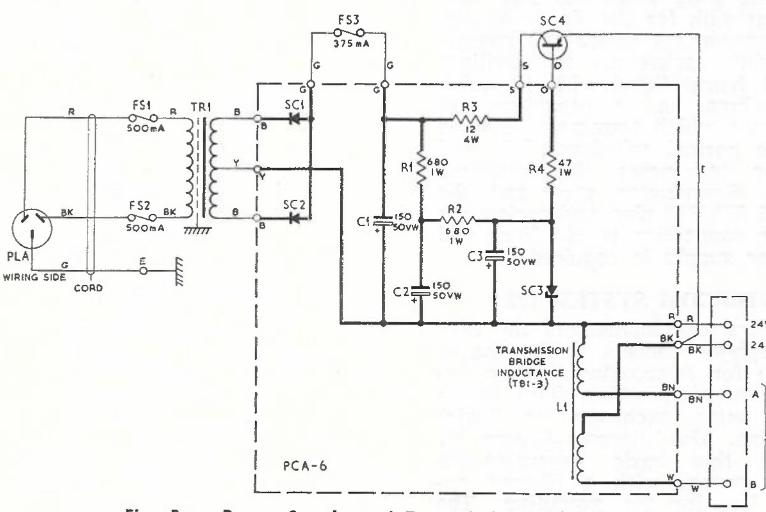


Fig. 5. — Power Supply and Transmission Bridge No. 1, Circuit

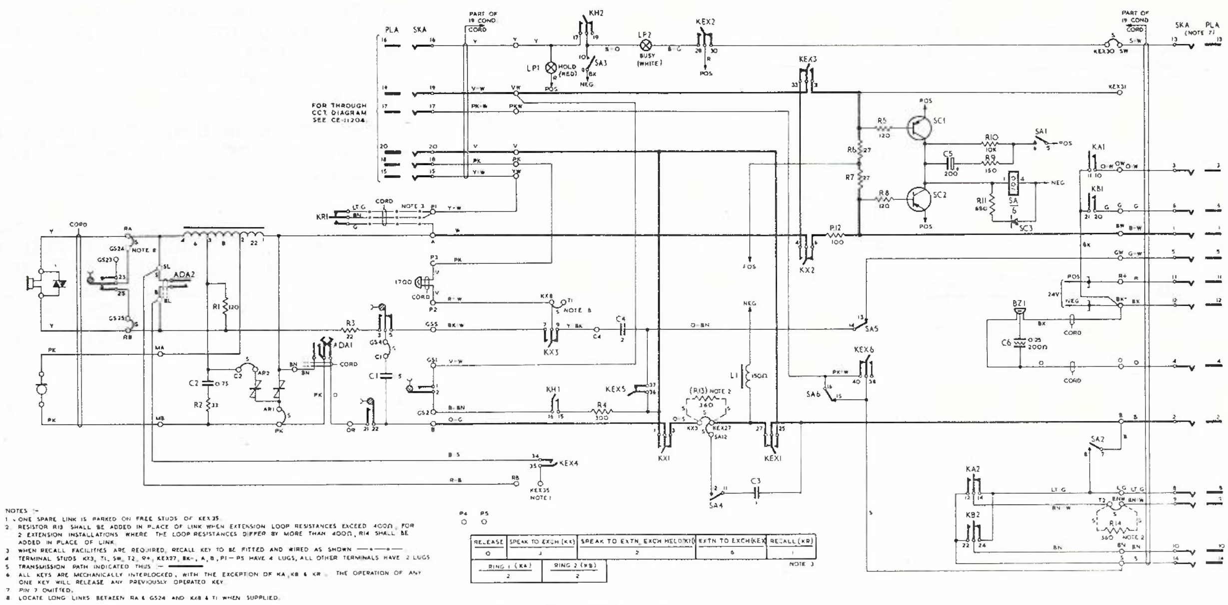


Fig. 6. — 8501 Telephone Circuit.

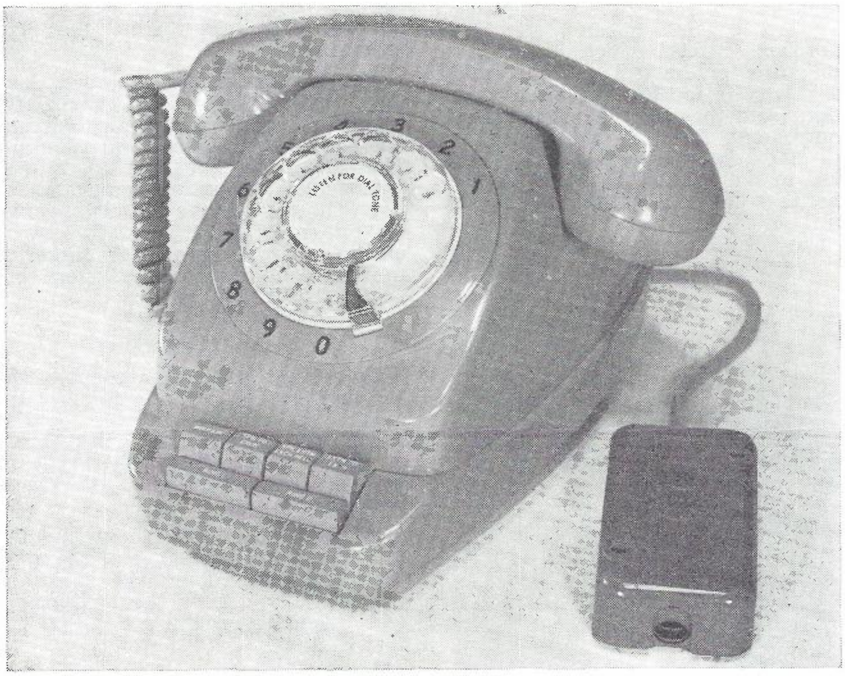


Fig. 7. — 8501 Telephone.

INTERCOM SYSTEMS 1/3

The Intermediate Telephone which was a development of the Interswitch has itself been superseded by the Intercom System 1/3. The main telephone in this system is the type 8501 (see Figs. 6 and 7) and two extension telephones may be connected. Either extension may be a 2-wire type using a modified type 8011 instrument or a 6-wire type using a type 8014 instrument. The circuit of the type 8014 instrument is shown in Fig. 8.

Standard Facilities

Intercommunication between the main and extension telephones is provided with selective calling from the main. Direct calling between 6-wire extensions is possible but when 2-wire extensions are connected, calls between extensions must be set up via the main point.

The exchange line is controlled by the main who may hold an exchange call while calling an extension or switch the exchange line direct to the extensions in parallel. Lamp supervision of the exchange line is provided in the 8501 telephone for the 'exchange line held', and 'exchange line to extension' conditions.

System Limits

The transmission and signalling limits of the Intercom System 1/3 are:—

(a) Main to Exchange — Normal 801 telephone limits apply; 1500 ohm for ARF crossbar parent exchange.

(b) Main to Extension (6-wire).
   - (i) Transmission limit is controlled by extension to exchange working (see (d)).
   - (ii) Signalling limit is 200 ohm from the power supply.

(c) Main to extension (2-wire) — Limited by extension to exchange working (see (d)).

(d) Extension (6 or 2-wire) to Exchange.
   - (i) Transmission limit is 1500 ohm of 6½ lb. cable or equivalent.
   - (ii) Signalling limit is 1500 ohm.

(e) Extension to Extension.
   - (i) Transmission limit is 2000 ohm of 6½ lb. cable or equivalent provided that the main telephone does not participate in the connection.
   - (ii) Signalling limit for 6-wire extensions is 50 ohm.

Transmitter current feed balance can be controlled by replacing a link in the 8501 telephone with a fixed resistor.

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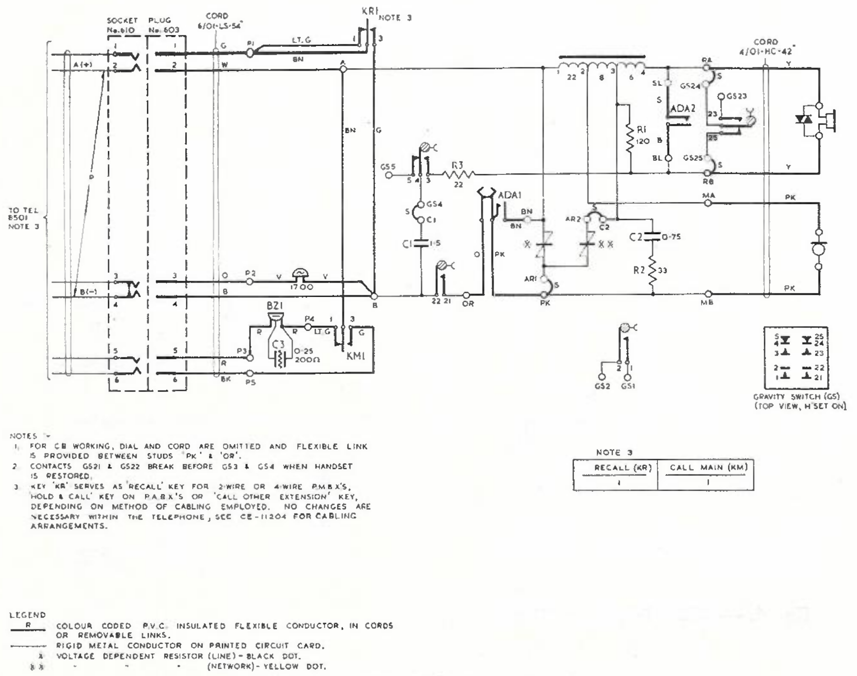

Fig. 8. — 8014 Telephone Circuit.

Design Features

The 8501 telephone consists of an 801 telephone mounted on a plinth unit. All additional signalling and supervisory circuitry is mounted on a printed circuit board in the plinth together with the key switching unit. (See Fig. 9).

Exchange line supervision is performed by a transistorised current detection circuit which controls a miniature cradle relay. The relay sensitivity is too low for direct operation from the line. Other miniature components fitted in the plinth are the 24V d.c. buzzer which is also used in the 8014, 8202 and 8203 telephones and L.E.S. lamps in the key unit.

The 8501 line cord has 19 conductors and terminates on a partially equipped 40-way connector and is then cabled to the power supply and switching unit (Fig. 10); exchange lines and extension lines are also terminated in this unit.

Both extension telephone types are basically 801 instruments which have additional components fitted:—

(a) 8014 (6-wire extension).
A miniature d.c. buzzer and two non-locking push-button keys are added: the L.H.S. key is to 'Call Main' and the R.H.S. key to 'Call Other Extension', or 'Recall', depending on the installation.

(b) 8011 (2-wire extension).
A non-locking push-button is fitted to 'Call Main'. NOTE: The standard 8011 instrument must be restrapped for use as an extension of an Intercom System 1/3. When two 2-wire extensions are connected, fitting of a thermistor is required in each telephone to prevent the bells tinkling during dialling.

An 8201 (2-line) telephone can also be used as a 2-wire extension to provide a direct line as well as the normal filtered line from the 8501 telephone.

The power supply and switching unit (PSSU-1) provides 24V d.c. for intercom speech, supervisory circuits and signalling to 6-wire extension and 75V 50Hz for signalling to 2 wire extensions. Mounting brackets for two 3000 type relays are also provided; one relay is required for 2-wire extension working and the other if the line connected to the system is a 4-wire P.M.B.X. type.

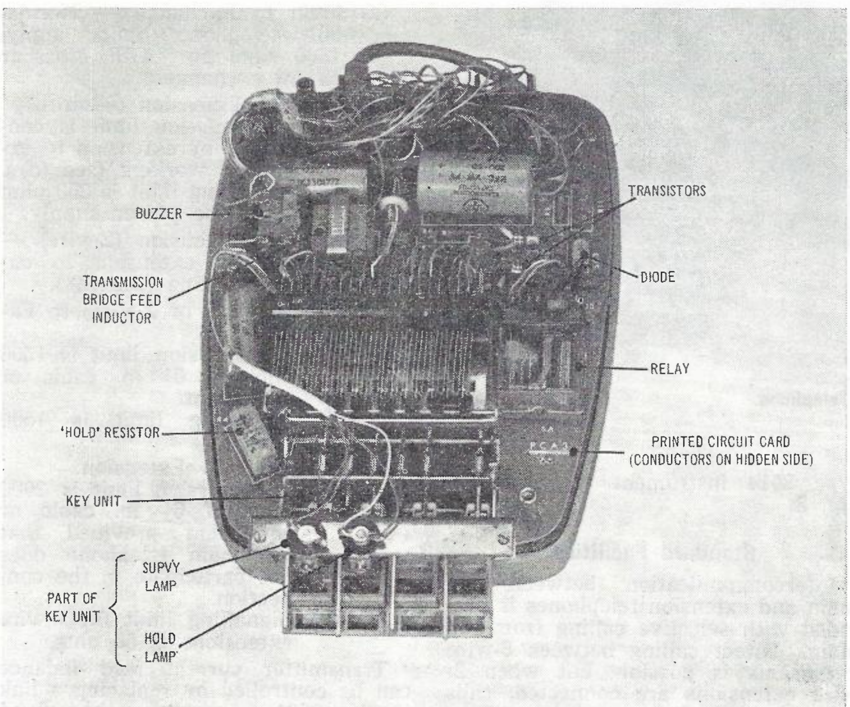

Fig. 9. — 8501 Plinth Unit.

Design Limitations

Unfortunately, the limitations of the key unit selected for this system have resulted in some undesirable features which will be eliminated if redesign of the system with another type of key unit becomes feasible. The drawbacks are:—

(a) Reversed lines between the main and exchange or the main and extensions will partly or wholly disable the system, depending on the type of installation.

(b) The unbalanced transmission feed bridge makes the system sensitive to noise interference. Some modifications have been introduced to partially overcome this problem.

(c) Earth return signalling is used for the 2-wire extensions and this causes interference because of (b).

(d) Ringing must be on the negative leg and this system is not used in some P.A.B.Xs and exchanges. Consequently, an additional relay may be required to transfer the ring to the opposite leg.

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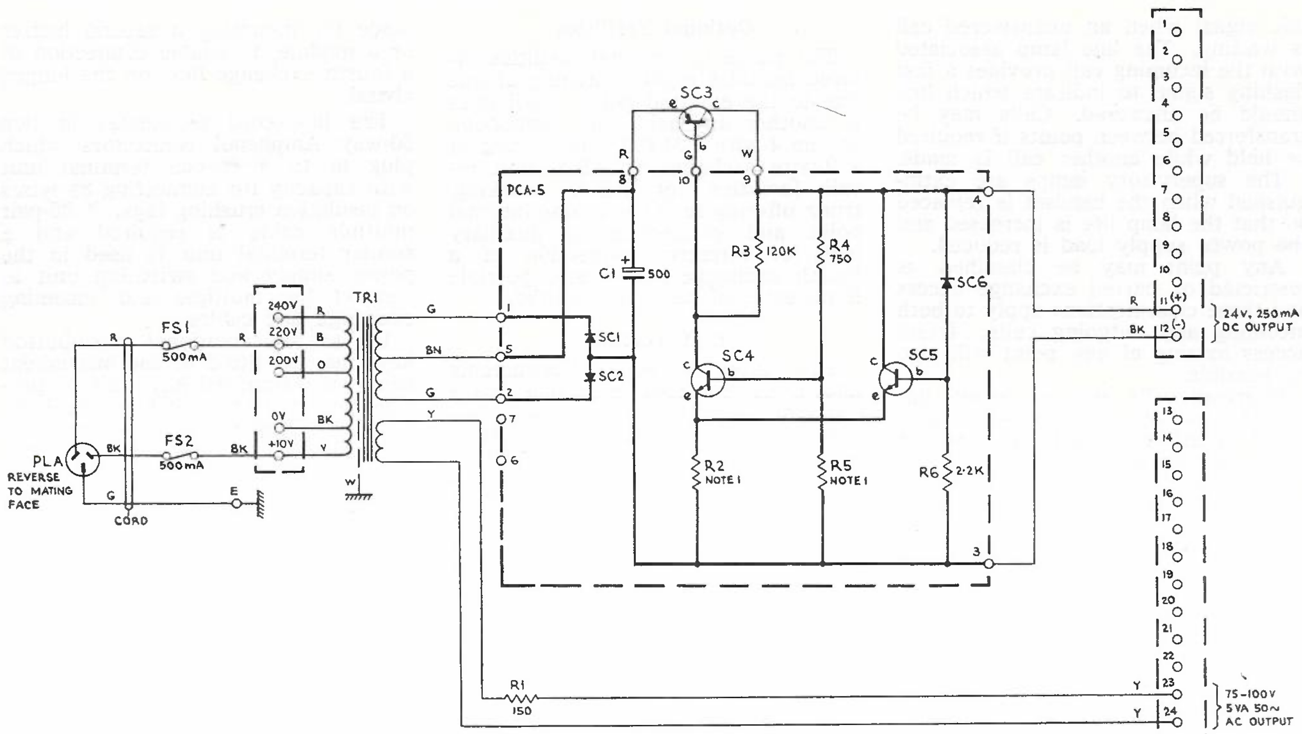

Fig. 10. — Power Supply and Switching Unit No. 1, Circuit.

(e) Use of standard 2-wire repeaters is not possible because of (c), and the method of supervising exchange to extension connections.

Future Variants

Possible future developments of the Intercom System 1/3 include the use of an 8201 telephone instead of an 801 telephone in construction of the 8502 instrument (Fig. 11) to provide the main point with an exclusive line and as previously mentioned, modified 8202/8203 telephones could be used as extensions with direct line access in addition to the normal filtered line from the 8501.

INTERCOM SYSTEM 3/11

Development of the Intercom System 3/11 to replace the Intercommunication Telephone A10 has been entrusted to Telephone and Electrical Industries Pty. Ltd. It was hoped to have this system in service by the end of 1968 but design problems now seem likely to delay production until 1969.

The system provides direct access to three exchange lines from up to 11 speaking points with communication between the points. A smaller system catering for two exchange lines and up to seven speaking points will also be introduced but as all other features are similar to the Intercom System 3/11, no further reference will be made to the smaller version known as the Intercom System 2/7.

The facilities offered are basically similar to the A5/A10 systems with improved exchange line/extension ratio, the addition of night switching and power fail facilities, direct exchange line access for an external (2-wire) point, improved signalling and supervision, and replacement of the transfer unit by a wall mounted power supply and switching unit. A brief description of the system is given below and further detail will be included in a future article when the design is finalised.

Facilities

Outgoing exchange calls may be established directly from any point. Lamp supervision is provided on the internal telephones, known as Type 8601, to indicate whether an exchange line is busy (steady glow) or held (slow flash) and in addition, a guard circuit prevents seizure of a busy line and provides complete secrecy for exchange calls.

Incoming calls may be answered at any internal point but normally, only two points would receive the aud-

Fig. 11. — 8502 Telephone.

ible signal when an unanswered call is waiting. The line lamp associated with the incoming call provides a fast flashing signal to indicate which line should be answered. Calls may be transferred between points if required or held while another call is made.

The supervisory lamps are extinguished when the handset is replaced so that the lamp life is increased and the power supply load is reduced.

Any point may be classified as restricted or barred exchange access and these classifications apply to both incoming and outgoing calls. Trunk access barring of any point will also be possible.

Intercom calls are not secret, but selective calling of extensions is provided. Conference calls may be set up by calling a common point.

When an external point is connected, all internal points can call it direct, but the external point can call only one nominated internal point. When making an outgoing exchange call the external point automatically seizes the first free line and during any call the line may be held while an enquiry call is made.

Under power fail conditions, each line is switched to a selected point to provide emergency service but all other system facilities are inoperative during the power failure. A call set up under power fail conditions is not interrupted when the power is restored.

System Limits

The system limits are:—

(a) Exchange calls: Normal 801 telephone limits apply; 1500 ohm for ARF crossbar parent exchange.

(b) Intercom calls (internal points): 50 ohm loop to the power supply and switching unit.

(c) External point: 500 ohm loop to the power supply and switching unit.

Optional Facilities

The range of optional facilities offered includes night switching of one line to the external point or all lines to another internal point, connection of one 4-wire P.M.B.X. line in lieu of a 2-wire exchange or P.B.X. line, recall facilities for P.B.X. working, trunk offering facilities at one internal point and connection of auxiliary bells or buzzers; connection of a fourth exchange line is also possible if no external point is required.

Construction

The internal point instruments known as the 8601 telephone use a standard handset, cord, dial and 801 speech circuit but the equipment is housed in a case of new design (see Fig. 12). Intercom and exchange line switching is performed by a mechanically interlocked key unit; lamps for exchange line supervision and external point signalling are mounted in the key unit adjacent to the associated key. All speech components, auxiliary exchange line relays and associated circuitry, and most of the circuit connection and strapping points are mounted in a common printed circuit cord in the base of the instrument. The gravity switch which is mounted on the circuit board and the key unit release are operated sequentially via a parallelogram linkage which supports the handset plungers; loading of the handset is unnecessary.

Connection to the 72-way line cord and the key unit is made via quick connect lugs on the printed circuit board and on an auxiliary board, vertically mounted on the left hand side of the unit. A miniature a.c. buzzer is used instead of a bell for both intercom and exchange calls and is mounted on a hinged chassis which also supports the dial. Provision is made for mounting a second buzzer or a module, to enable connection of a fourth exchange line, on the hinged chassis.

Fig. 12. — 8601 Telephone.

The line cord terminates in two 50-way Amphenol connectors which plug in to a special terminal unit with capacity for connecting 84 wires on insulation crushing tags. A 35-pair multiple cable is required and a similar terminal unit is used in the power supply and switching unit to connect the multiple and incoming exchange line cables.

Up to six additional push-button keys may be fitted to the instrument below the standard key unit to provide the optional switching facilities.

The external point telephone is an 801 telephone fitted with two non-locking push-buttons to provide for 'Call Exchange' and 'Call Main' facilities and is similar in appearance to the 8014 telephone.

Five major units are mounted in the central relay set unit known as Power Supply and Switching Unit No. 2 (PSSU-2).

(a) Regulated and self protecting 24V d.c. power supply and 75V 50Hz ring supply.

(b) Common services plug in module, which provides ring start, lamp flashing and timed throw-out facilities.

(c) Exchange line plug in modules which provide ring detect, guard, and hold facilities.

(d) 84-way insulation crushing terminal unit for termination of the multiple exchange lines and external point cables.

(e) 60-way socket for connection to the optional facilities switching unit (see below).

The PSSU-2 provides all equipment for the standard facilities and also can accommodate a fourth exchange line module, but if an external point, trunk barring, or any other special features are required, a second relay set, the optional facilities switching unit (OFSU-1) must be installed. This approach was adopted to avoid loading the standard system with the extra cost and space of the external point module which is connected to only 10% of installations of this type of equipment. The OFSU-1 is identical in size and external appearance to the PSSU-2 except that the ventilation louvres in the cover are eliminated. Some of the metal work is common to both units but the internal layouts are quite different. Mounting of the OFSU-1 to the right or below the PSSU-2 is possible and the OFSU-1 is fitted with a flexible cable and plug to connect to a socket in the PSSU-2. All modules in both the PSSU-2 and OFSU-1 are of the plug-in type so that replacement is facilitated.

All 8601 telephones and all PSSU-2 units are supplied with standard circuit strappings and for a basic system the only alterations on installation would be fitting of power fail relays and associated restrapping in selected instruments and selection of two answering points for incoming exchange calls, by strapping in the associated terminal unit. Connection of an external point and variation of the standard facilities can also be arranged by appropriate restrapping in the instruments or the relay unit and for most purposes the only extra equipment required is a suitable key unit for night switching or recall.

Case Design

The case for the 8601 telephone will also be used to accommodate other instrument designs which are unsuitable for the standard 801 case and will be available for systems custom built by the State Administrations of the A.P.O. These other possible uses have been considered in designing the case and one feature is that a standard 801 telephone circuit assembly can be fitted into the case without modification.

CONCLUSION

The equipment described above represents a range of telephone subscribers instruments which have been improved in appearance, flexibility, and sensitivity by the introduction of modern circuit components and by the further use of techniques introduced with the 801 telephone. Future developments are expected to make extensive use of these established techniques and to introduce other readily available components such as magnetic cores, FET's and integrated circuits.

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2. R. B. Cullen, 'Executive-Secretarial Telephone Systems'; Telecommunication Journal of Aust., Vol. 16, No. 2, June, 1966, page 124.

TECHNICAL NEWS ITEM

TOWNSVILLE - MT. ISA BROADBAND RADIO SYSTEM

The rapid development of Northern Australia has presented the Postmaster-General's Department with an accelerated demand for telecommunication facilities in this area.

To meet this requirement, a broadband system is being planned between Townsville and Mt. Isa, as the first stage in providing broadband facilities to Darwin.

A solid state radio system of 600 circuit (or greater) capacity per bearer has been selected as the most practical and economical method for the Townsville - Mt. Isa route, which is at present served by an open-wire carrier system. Tenders have been invited for the micro-wave system in a schedule which closes on 29th February, 1968.

The alternative coaxial cable scheme presented two particular problems, namely, the opening of extensive earth fissures in the dry season, which could damage a lead and polythene sheathed coaxial cable and the danger of termite attack on the cable.

The radio bearer system will have one main telephony bearer and one protection bearer, with branching facilities catering for local requirements at a number of intermediate centres. A television transmitter has been approved in principle for Mt. Isa, and if a television programme relay facility between Townsville and Mt. Isa is required, it could be provided by means of an additional one-way bearer on the micro-wave system. If necessary, this television bearer could be equipped with drop-out facilities so that the television relay could also be used to provide programme material for possible low-powered television stations along the route.

This broadband system is scheduled for completion in 1970/71. It will connect at Townsville with the east coast broadband network and will form an integral part of the national broadband facilities.

SAGE — New Subs Instruments

SUPERVISION OF PLANT CONGESTION

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

INTRODUCTION.

Every telephone administration wants to know whether its network is giving a satisfactory service. To be more precise, the operating authority needs to know whether the network performance is within the specified design limits in regard to plant congestion, transmission loss, crosstalk, incidence of faults, delay in establishing a connection, etc. Reliable information on all these aspects of service quality is required continuously, so that any deterioration in service can be promptly detected and remedied. This article outlines techniques used, or under development, by the Australian Post Office to supervise plant congestion.

Some information about the actual service provided can be deduced from subscribers' complaints. However, such information is rarely specific enough, and at best gives only a very incomplete picture about the performance of the network. Also, when the service has deteriorated to such an extent that the subscriber is driven to complain, corrective action can be quite costly. Therefore, most telephone operating authorities employ automatic indicating devices, as well as direct manual supervision of selected circuits, to acquire the required system performance data on a regular basis.

The A.P.O. uses both manual service sampling and various automatic and semi-automatic devices to supervise the performance of our telephone network. Some of these equipments are multi-purpose devices and are used to observe several aspects of network performance (e.g., traffic route testers). Others, such as direct reading traffic recorders, although designed primarily to acquire planning data, can be used also for spot checks of the traffic load, from which the adequacy of circuit provision can be deduced.

CONGESTION AND ITS EFFECTS.

Congestion occurs at any switching stage, when the number of available circuits is insufficient to carry the traffic offered to it. The degree of congestion is usually described by the proportion (or percentage) of traffic (or calls) that cannot be carried during a specified period of time. Traffic engineers prefer to call this proportion the effective grade of service, or the probability of loss. Equipment engineers call it plant congestion to distinguish it from traffic loss caused by equipment faults, the latter being referred to as the technical loss. In many cases however, these two kinds of losses cannot be separated, as a busied out faulty switch causes increased congestion by reducing the number of circuits available to traffic.

From the subscriber's point of view all kinds of call obstruction have the same effect: they prevent him from establishing a connection to the wanted party. The subscriber does not stop to analyse whether he lost his call because of insufficient common plant, equipment fault or his own mistake—often he cannot even distinguish when the called party is engaged. When he does not get through at the first attempt the subscriber usually tries again, either immediately or after a short pause.

The repeated attempts, if they amount to a considerable proportion of all calls, can lead to a sharp deterioration in the grade of service. If the cause of a repeated attempt is an engaged call party, it affects only one subscriber, and has no significant effect on the grade of service. If, however, for some reason the number of available circuits at some stage is grossly inadequate, many calls are blocked and most of them are repeated. The repeated attempts add to fresh first attempt calls and inflate the offered traffic load, which, in turn, makes congestion worse and generates more repeated attempts. This kind of regenerative overload spreads to other parts of the network and in some common control systems can cause complete paralysis.

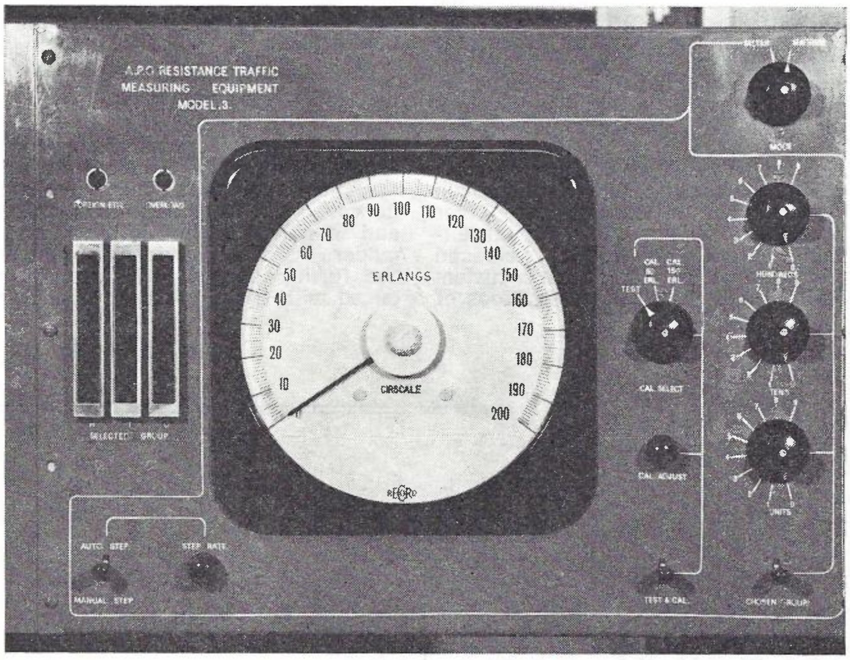

Fig. 1 — Circuit Occupancy Meter. Control Switches for selecting required circuit group are on the right and Lamp Display to indicate selected group is on the left.

TYPES OF SUPERVISION EQUIPMENT.

Several different types of supervision equipment are used by the A.P.O. Some of these are simple counting meters, provided as an integral part of the exchange and permanently wired to particular groups of circuits. To this class belong the overflow meters provided at step-by-step exchanges and the statistical meters in crossbar exchanges. Erlang-hour meters, now being installed to supervise subscriber trunk dialling routes, can be also placed in this group, as they are permanently associated with a particular group of circuits.

Other supervision equipments are designed for multiple access, so that they can be connected to any circuit group in the exchange, as required. Some of these units are permanently installed, others are portable, catering for smaller exchanges, where a permanently installed unit cannot be eco-

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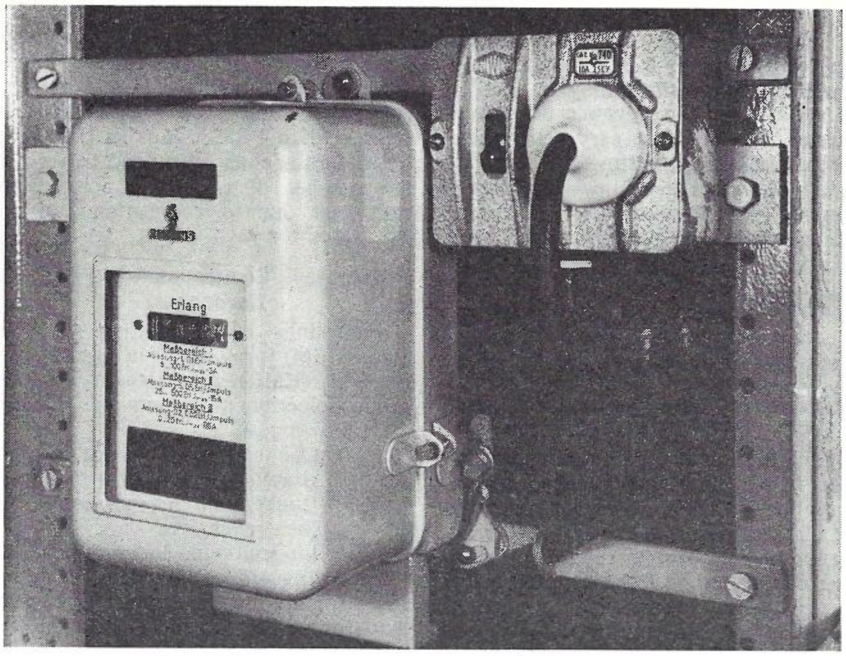

Fig. 2 — Erlangmeter.

nomically justified. Examples of this type are the traffic route testers and direct-reading group occupancy indicators.

Overflow Meters in Step Exchanges.

The simplest type of congestion supervision device is the overflow meter. It is of the same construction as the subscriber's meter, i.e., it is a ratchet-driven 4 or 5-wheel counter. One such meter is connected to the last step of each equipped level of the switching stages in step-by-step exchanges. Whenever a bimotional selector drives to the 11th step of the bank, the overflow meter connected to this particular level is energised and advances the count by one unit.

Operated in this way, overflow meters keep the progressive total of overflowed calls for each group of circuits. At regular intervals they are read and their count recorded. Subtraction of the previous reading then gives the number of overflowed calls during the interval between readings. (Actually, the true number of overflowed calls is higher, because while a switch is standing on the 11th step other overflows on this level are not recorded).

Since offered calls are not counted at the same time, overflow meter readings cannot be used to calculate plant congestion. Overflow meters are primarily intended to be first warning devices, indicating when a check on trunking adequacy should be made with more accurate equipment (e.g., a traffic recorder). However, overflow meter readings can give a rough guide to plant congestion, if the approximate level of the busy-hour traffic load is known. The following example will explain how this can be done.

Assume the average traffic load on a selector level is known to be about 100 erlangs. If during one week the overflow meter associated with this level has increased its total by 300, what is the approximate level of plant congestion? Assuming an average holding time of three minutes per call, each erlang of traffic is equivalent to 20 calls per hour. If the busy period in this exchange lasts about three hours each working day, the average number of calls handled during this time is 60 for each erlang of traffic. The traffic load usually drops considerably outside the busy period of the day and we do not normally expect calls to be blocked during the slack period. Hence, we can reasonably assume that the observed overflows occurred during the aggregate busy period of 15 hours. Now, during 15 hours some 30,000 calls were offered to the route in question; therefore we estimate plant congestion during the busy period to be about 0.01 (1 per cent.) or higher (we do not know the number of unrecorded multiple overflows).

Direct Reading Occupancy Indicators.

Route occupancy indicators are based on the resistor recorder principle and are calibrated to indicate the instantaneous carried traffic in erlangs (or the number of simultaneously occupied circuits). They are, essentially, direct reading milliamp-meters, indicating the total current flowing through the grounded recording resistors. Only those recording resistors are grounded, which are associated with busy circuits. Since all recording resistors are connected at one end to the meter, which has exchange battery behind it, the current flowing through the meter is directly proportional to the number of occupied circuits.

A large face meter is normally installed for this purpose, so that the route occupancy can be read off with an accuracy of plus or minus one circuit. The complete unit includes also an access switch and keys, or push buttons, to control it. The occupancy indicator can, therefore, be connected in turn to every circuit group in the exchange. In local exchanges they are known as resistor traffic recorders and are, indeed, still used for this purpose when a manual traffic recording is carried out. At other times they serve as congestion supervision devices, to be used at the discretion of the service supervising technician.

These meters do not measure congestion—they indicate the traffic load on the route. However, by reference to suitable traffic capacity tables, it is possible to see, whether the actual traffic load exceeds the design value or not. Naturally, since the traffic load continually fluctuates, one can only make a rough estimate of the average load after a reasonable period of observation. Therefore, as in the case of overflow meters, observation of route occupancy gives only a rough indication of trunk shortages.

Currently trunk exchanges are also being equipped with route occupancy indicators to observe traffic on S.T.D. routes. These observations permit a more efficient management of trunk routes by regulating trunk operator access to S.T.D. circuits.

Erlang Hour Meters.

The erlang-hour meter, more commonly known by its trade name of Erlangmeter, is essentially a current intergrating device. It consists of an ampere-hour meter, a decimal counter, and a pulsing contact to generate pulses for telemetering purposes. The unit is built into a sealed metal case and is usually rack-mounted.

The principle of operation is very similar to that of a domestic watt-hour meter. In the Siemens and Halske Erlangmeter, the current to be measured drives a small d.c. motor, which is geared to a six-digit counter. A mercury pulsing switch is triggered each time the d.c. motor has done a set number of revolutions. Thus, the number of pulses emitted and the increase of the counter reading are both proportional to the average intensity of the measuring current during the interval of observation.

Erlangmeters have been used for many years by several overseas administrations for the measurement of telephone traffic flow. In the A.P.O. they are primarily being used for the traffic supervision of important S.T.D. routes. The measuring current flowing through the meters is a direct analogue of the traffic flowing in the supervised group of trunks. It is derived in the same way as described in the previous section; that is, it is the combined current flowing through traffic recording resistors of the busy circuits.

To ensure that supervision is confined only to the busy period of the day, the Erlangmeters are controlled by time switches. They are switched on for one or two busiest hours each day, five days a week. It is the responsibility of exchange maintenance staff to record each day's readings of all supervised routes and forward summaries every two or four weeks to their State's Traffic Engineering Division.

It will be noted that, like the direct reading circuit occupancy indicator, the Erlangmeter is a traffic measuring device. However, since it is connected to a particular circuit group throughout the busy period of the day, it gives an accurate indication of the average traffic carried by the group (to convert the reading into erlangs it is only necessary to divide the increment in reading by the measurement period in hours). By plotting its indications day by day (or weekly) against the design load for the observed circuit group selection stage may be due to be spotted well in advance of serious trouble and the necessary relief measures taken in good time.

It is intended to equip with Erlangmeters all final routes in the Australian automatic trunk network. Some of the more important high usage S.T.D. routes may also be supervised by Erlangmeters, particularly where no other continuous traffic or congestion supervision devices are provided.

Supervision of Common Control Equipment in ARF102 Exchanges.

Each item of common control equipment in the ARF102 system is equipped with inbuilt supervisory aids which continuously check the performance of the plant in regard to faults and congestion. This information is recorded on permanently connected statistical meters, and, in cases where the effect on service is serious, a service alarm will operate. A service alarm is a device which counts the number of times an item of common control equipment cannot complete its switching functions within a preset time. Normally these 'time-outs' are caused by fault conditions, but in some cases they can be caused by plant congestion. When the incidence of time-outs exceeds a predetermined limit within a fixed time interval, or within a fixed number of calls, an alarm will operate.

In general, meters provided for the purpose of indicating congestion incidence are shown in Table 1.

TABLE 1.

Equipment.	Meter	
Subscribers' Line Marker SLM and SLM/S	SUM*	Indicates congestion on outgoing calls. It includes Register and SR congestion.
	SIM*	Indicates congestion on incoming calls.
PBX Supervision (Individual Subscriber)	SMT*	Calls to a particular PBX Subscriber
	SML*	Calls connected to a particular Subscriber.
	SMT-SML	Congestion on a particular PBX Group.
Code Sender Finders	SM	Indicates the number of time releases due to no free KSR being available.
Group Selection Stages 1GV-KMR GIV-KMR	SM) SM)	Indicates the number of times congestion is encountered in the stage.

*Not permanently connected.

Metering leads SUM and SIM can be connected to resettable meters on the service control rack for analysis purposes, when service alarms are in evidence. Meters SMT and SML are connected to PBX groups as required. As meters are also provided to record the number of calls, the percentage calls lost due to congestion can be calculated for each stage.

Route Congestion—ARF102 Exchanges.

Recordings of congestion on the meter (SM) provided for each code receiver (KMR) associated with the group selection stage may be due to the following:—

(a) Congestion on the last choice route;
(b) Congestion on routes to the local exchange;
(c) Internal link congestion.

Recordings for each group selector stage should be compared to ensure that congestion is not due to faulty testing circuits in the marker. It is also necessary to check that all outlets are being taken into use, as fault conditions may exist which remove the availability of a circuit, yet will not be detected by an alarm condition. The circuit occupancy on individual routes may be determined by observing the occupation lamps on the junction relay sets, or by the use of the direct reading occupancy indicator, which is provided at all larger exchanges and tandem switching centres.

Particular attention must be given to congestion supervision at tandem exchanges, as their performance affects many other exchanges. The behaviour of the tandems is influenced by the overall network configuration and the congestion patterns in a tandem may vary unexpectedly during the course of a day.

Inbuilt Link and Route Congestion Indicators in ARM Exchanges.

Apart from the Erlang Hour Meters, which are connected to all final choice routes and to some important high usage routes, permanently connected meters are provided to record time congestion on each outgoing route. When all outlets on a particular route are in use, these meters are operated from a one second pulse source. This provides a measurement of the total time a route is congested and serves as a more reliable indicator of the degree of congestion than 'call congestion' meters.

In order to reduce the possibility of route congestion it is essential that any blocked trunk circuits are restored to service with a minimum of delay. To facilitate supervision of these circuits the occupation and blocking lamp on each outgoing trunk is extended to the maintenance control room.

In ARM exchanges 10 metering leads are provided from each marker and 17 metering leads from each route marker. These metering leads are wired out to an i.d.f., where they are cross-connected to cables which terminate on fixed 80-point programming blocks mounted on the statistical meter rack. A panel of 80 resettable meters terminated on a similar 80-point block, is also provided By suitable selection and connection of the programming of blocks, readings can be obtained to determine the average link, and route congestion experienced by traffic switched over two and four stages and the congestion experienced in individual switching stages. Register congestion is supervised from the register finder marker. Two meters are provided. Meter SM1 records the total number of time-outs after inlet identification, and meter SM2 records the time-outs after a register has been selected. The difference between the readings (SM1-SM2) could be due to register congestion or faults.

ARK Exchanges.

In the ARK 511 type exchange ten meters are permanently connected to record the number of calls and time-outs experienced by the marker, register finder and registers. Facilities are provided to record the period registers are in congestion if this is required. Where the ARK is parented on a manual exchange, congestion will be recorded on the meter TKB, but in the case of an automatic parent this meter will only indicate register and SNR congestion. Meter TKR will indicate junction congestion. As these meter readings will reflect actual equipment faults, internal congestion, and external abnormalities such as swinging loops and subscriber dialling habits, it is necessary to take these aspects into consideration when analysing the cause of any excessively high readings. Should no fault conditions exist, the readings will be due to congestion.

In the ARK 521 type exchange a more elaborate meter set-up is provided to permit a more detailed analysis to be made. The following meters are provided to indicate congestion:—

Meter SM records congestion on incoming calls.

Meters SUM1 and SUM2 indicate congeston during stages of an outgoing call.

Meter SM indicates register time congestion.

Meters SRG1, 2 and 3 indicate congestion on various register groups.

NETWORK CONGESTION SUPERVISION.

Centralised Service Assessment.

Prior to the introduction of crossbar equipment, statistics on plant congestion were extracted from the service assessments results of live traffic. However, in a mixed crossbar and step network it is not possible to obtain this information. In the step case the operator could monitor the setting up of the call and detect at what stage busy tone was received, but with crossbar equipment the observer cannot monitor the setting up of the call and when busy tone is heard the operator cannot differentiate between 'wanted subscriber busy' and 'congestion.' Furthermore, in the case of calls routed by crossbar equipment, busy tone is returned to the caller when certain fault conditions are encountered. Figures on plant congestion can still be obtained for calls switched exclusively through step exchanges, provided some form of card analysis is used.

In analysing service assessment figures for plant congestion it must be realised that the results give a broad indication only as the readings are taken over the whole day. A more accurate figure could be obtained if the observations were performed during busy periods only.

New Congestion Signal.

At present a field trial is being carried out in Victoria of a new signal to indicate plant congestion. As the introduction of an entirely new signal would cause confusion to the subscribers, the tone selected in the trial is similar to the standard busy tone, but with alternate pulses attenuated by 10db. Whilst this tone has proved satisfactory from a service assessment viewpoint, it may not be entirely suitable for detection by automatic service assessment equipment. These matters must be resolved before a final decision. is made on the exact nature of the tone.

The new congestion tone will also be applied to the eleventh step of group selectors at step exchanges. In the case of crossbar exchanges, the tone will be supplied from the register on receipt of the MFC congestion signal (B4). Under congestion conditions the release of the register is under the control of the subscriber and the overall register time supervision, should the caller fail to release the call. From an analysis of the incidence of congestion and the holding times for calls encountering service tones, this modification will have a negligible effect on register provision.

Wanted Subscriber Busy.

The purpose of analysing overall service assessment figures from an engineering viewpoint is to improve the performance of the switching plant by reducing the percentage of calls lost due to plant failure and congestion. In a good network this could be as low as 2 to 3 per cent., whereas calls abandoned before completion or lost due to the subscriber being busy, or absent, could represent 25 per cent. of the total calls, and, as all these calls contribute to plant deterioration and congestion, it is necessary to seriously consider any means possible to reduce

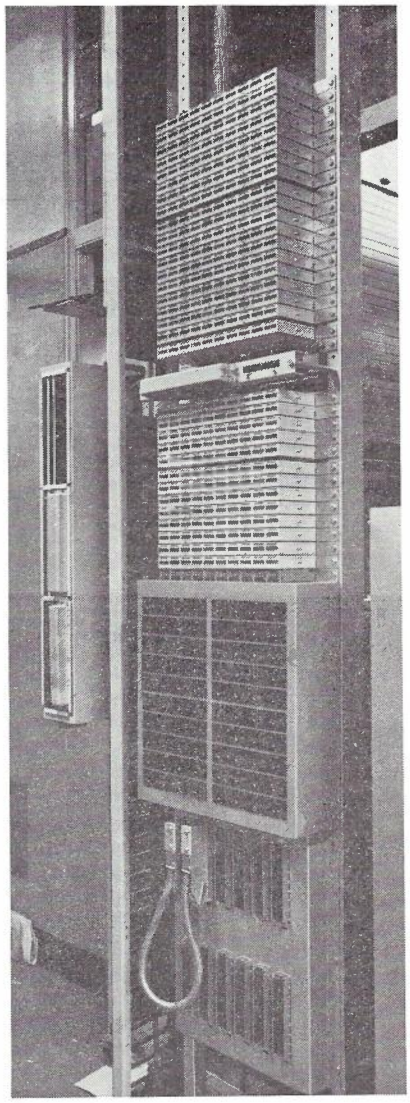

Fig. 3—Permanently connected Statistical Meters and Panel of 80 Resettable Meters, together with Programming Blocks at ARM Exchange.

this figure. Whilst a customer education programme could greatly assist in this regard, it is possible to reduce the 10 to 12 per cent. 'wanted subscriber busy' component by making an analysis of all lines frequently tested for this condition by service centres. As mentioned previously, facilities are available in crossbar exchanges to indicate the number of calls which cannot be connected to PBX groups due to all lines being in use. Where it is evident that additional lines are required the matter is followed up with the subscriber.

Traffic Route Testing.

During the past twelve years considerable use has been made of traffic route testers in order to obtain statistics on plant performance and to aid fault location. Prior to the introduction of crossbar equipment it was possible to indicate the incidence of call failure due to plant congestion on these test calls by testing for busy tone prior to the last two digits being sent to line. As it is not possible to detect plant congestion in this manner in a mixed step and crossbar network, it is proposed to modify the standard TRT to detect the new congestion signal when it is introduced. It will then be possible to indicate the percentage call loss due to congestion on test call programmes. To determine the grade of service, it is necessary to generate test calls during periods of both heavy and light traffic. In planning these test call programmes it is necessary to consider the effect that this additional traffic will have on plant congestion. During periods of heavy loading, addition of TRT generated traffic may seriously inflate the proportion of blocked calls and lead to an incorrect congestion reading.

The Analysis of Subscriber Reports of 'Busy During Dialling.'

In capital cities reports of 'Busy During Dialling' are forwarded from the service centres to the network service co-ordination centre (CARGO), for plotting on a network basis. Although it has been possible to plot only step-to-step calls, and up to the third digit on step-to-crossbar calls, this analysis has proved effective in pinpointing congestion in the network.

CONCLUSION.

This article has described the facilities available in A.P.O. exchanges for the supervision of plant congestion. The information provided should assist staff to effectively and intelligently use all available congestion supervision facilities and so help to maintain a good grade of service in the telephone network.

FURTHER READING.

Ormond, D. J.: 'An Introduction to the Analysis of Subscribers' Complaints'; Telecommunication Journal of Aust., Feb. 1963, Vol. 13, No. 6, Page 446.

A.P.O. Engineering Instructions, TELEPHONE EXCHANGES:

- M 7020 — 'Inbuilt Supervisory Limits for ARF 102 Equipment.'
- M 7021 — 'Description of Alarms and Recording Devices Associated with Inbuilt Supervisory Units for ARF 102 Equipment.'
- M 7451 — 'ARM 20 Crossbar Trunk Exchanges, Statistical Meters, Description and Comments.'
- M 7251 — 'Fault and Traffic Meters in ARK 511 Exchanges with REG-D Working.'
- M 7253 — 'Fault and Traffic Meters in ARK 521 Exchanges with REG-D Working.'

ERRATUM

In Vol. 17, No. 3 a horizontal line across Table 3 on Page 208 was omitted. The absence of this line gives the incorrect impression that the words 'Resistance To' on the left of the table apply to the data on 'Material Transfer'.

A LINE SIGNALLING SCHEME FOR PULSE CODE MODULATION (P.C.M.) TELEPHONE SYSTEMS

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

INTRODUCTION.

The Australian Post Office has noted with interest the development and increasing use of pulse code modulated (P.C.M.) transmission systems for use on telephone junction circuits overseas. These systems can be used to increase the number of speech circuits available in V.F. cables from seven to twelve times the number of physical pairs under ideal conditions, and are thus particularly valuable in metropolitan areas where ducts are fully utilised and the cost of further underground work is high. To investigate the application of P.C.M. systems in the Australian network, a 48-channel system on a radio bearer will be provided between Windsor and Kurrajong, N.S.W., in 1968, and a more extensive field trial of a number of 24-channel systems will be conducted in 1969.

At present frequency division multiplexed carrier telephone systems provide at most a single out-of-band signalling path in each direction per circuit, which can be used to transfer the necessary line signals between exchanges. Line signalling schemes used over such circuits have of necessity been designed within this limitation. P.C.M. transmission systems are time division multiplexed and by an extension of the multiplexing process the number of out-of-band signalling paths per circuit can be increased for relatively small cost increase. With more than one signalling path available the signalling scheme can be simplified in the sense that different line signals can be identified on a non-sequential basis, which results in a simpler and thus less expensive line signalling relay set.

A line signalling scheme using two out-of-band signalling paths in each direction per circuit has been developed for use in the A.P.O. network. The signalling scheme and associated signalling relay sets designed for use with the initial P.C.M. systems to be introduced in Australia are described in this article.

P.C.M. TRANSMISSION SYSTEMS.

It is not intended to give here a full description of the principles of P.C.M., as this is readily available from other sources (Refs. 1 and 2), but to explain how P.C.M. systems make an improved signalling scheme possible some basic features will be described.

The basic form of pulse modulation is pulse amplitude modulation (P.A.M.). This is achieved by sampling a speech signal wave-form at regular intervals and producing a pulse of amplitude proportional to the average amplitude of the continuous signal during the sampling period. This is illustrated in Fig. 1.

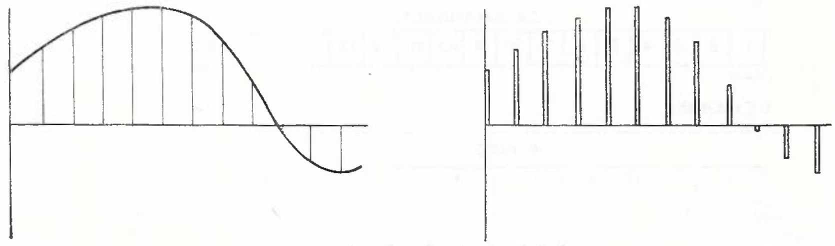

Fig. 1 — Pulse Amplitude Modulation.

It is a well-known theorem of information theory that if the sampling frequency is a little more than twice the maximum frequency contained in the signal to be transmitted by P.A.M., no information is lost by this process. Thus to faithfully represent a V.F. signal with a maximum frequency of 3400 Hz a sampling rate of 8 kHz may be used.

There is little point in replacing a continuous signal with a series of pulses for the transmission of one signal, but if other signals are translated into pulse form and transmitted in the gaps between the pulses representing the first signal, a number of different signals can be simultaneously transmitted over one channel. This process is illustrated in Fig. 2 and is called time division multiplexing (T.D.M.).

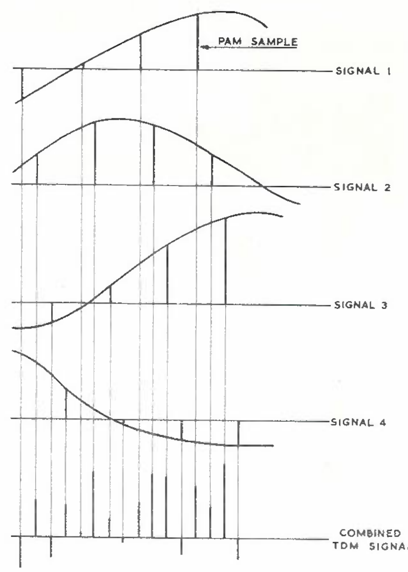

Fig. 2 — Time Division Multiplexing.

P.A.M. is unsuitable for transmission in a noisy environment, such as V.F. cable, because of its high noise susceptibility. If the individual pulses of the P.A.M. signals are themselves replaced by a series of equal amplitude pulses, which represent, in coded form, the amplitude of the original pulse, a signal is produced which has a high noise immunity and is therefore suitable for transmission over V.F. cable pairs. This process is called pulse code modulation, P.C.M., and is illustrated in Fig. 3.

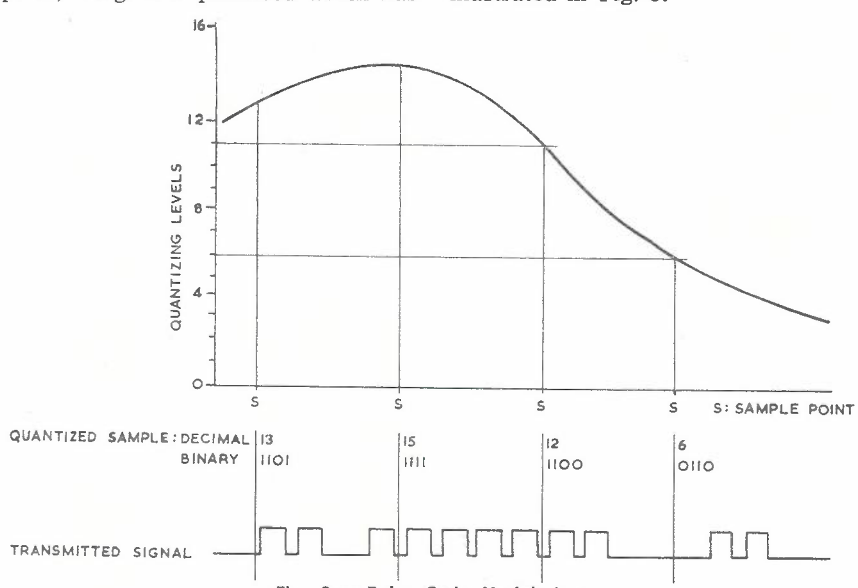

Fig. 3 — Pulse Code Modulation.

* Mr. Crew is Engineer Class 3, Crossbar Development, P.M.G. Research Laboratories. See Vol. 17, No. 1, Page 77.

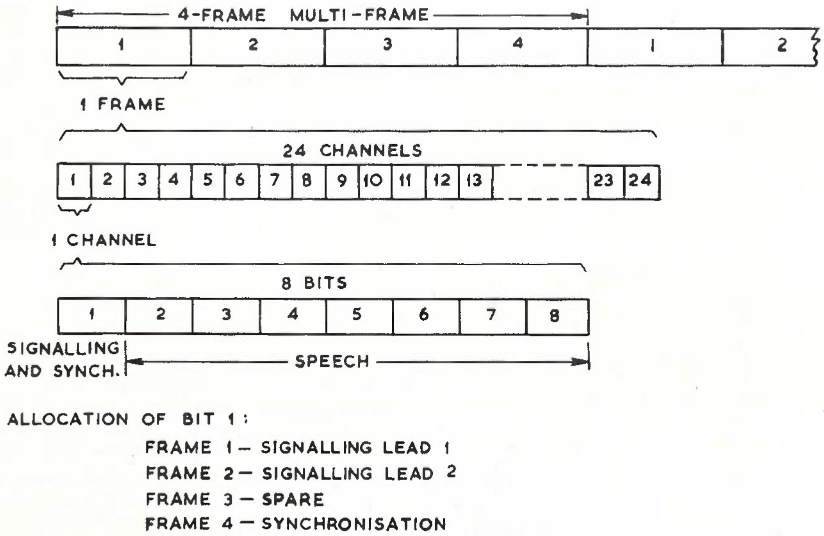

Fig. 4 — P.C.M. Multiframe Structure.

We now have a series of pulses of equal amplitude, representing in T.D.M. form a number of different speech signals. It is necessary to provide synchronising information to enable the receiving end to distinguish between the groups of pulses representing different signals. Typically, P.C.M. systems provide for 24 individual speech channels and use eight pulses (called "bits" because of their binary nature), to represent the information pertaining to each individual sample of a single speech channel. Each channel is sampled once every 125 microseconds (8 kHz sampling rate). The group of 192 pulses representing one sample of each of the 24 channels is called a frame. Of the eight pulses used to transmit individual channel information, only seven are used to represent the magnitude of the sampled speech signal. The remaining pulse or bit is used for line signalling and sometimes for synchronisation purposes as well. When this is the case it is necessary to develop a multiframe structure for the P.C.M. signal within which the 'meaning' of the signalling bit of each speech channel can be changed by a sub-multiplexing process to represent line signalling in one frame and synchronisation information in another frame. A multiframe structure, which may be used by a P.C.M. system is shown in Fig. 4, which illustrates these concepts.

Once multiframing is introduced to develop synchronisation information with the channel line signalling bits, it is convenient to extend the degree of sub-multiplexing and thereby use the single line signalling bit of each channel to represent a number of signalling wire conditions at the channel terminals. This process, if carried too far, results in increased cost of the P.C.M. equipment and can also cause excessive distortion of the line signalling conditions being transmitted due to the increasing period between samples.

Signalling conditions may be distributed over a multiframe structure in two ways, either represented by independent binary choice signalling bits or by a pattern developed by the signalling bits over a number of frames. For example, if two frames are available for signalling purposes the independent bit method may generate the four conditions: 11, 10, 01, 00 on the signalling bits by identifying the odd and even frames to distinguish between the 10 and 01 conditions. On the other hand, the same multiframe structure could only develop the three conditions: 11111, 101010, 0000 on a pattern coding principle, but it would no longer be necessary to distinguish odd and even frames, as patterns 01 and 10 are combined.

The A.P.O. has decided to adopt the independent bit signalling method for P.C.M. systems, because of its greater capacity. This also allows the use of a standard E and M signalling technique, and any available E and M signalling relay set may then be used to signal over P.C.M. circuits. The number of E and M signalling leads will be limited to two in each direction, as studies have indicated that the provision of additional signalling leads does not appreciably reduce the cost of line signalling equipment under that required for two signalling leads.

THE SIGNALLING SCHEME.

Line signals are required on circuits between exchanges to provide supervisory functions, both on idle lines and on established connections. Currently used A.P.O. line signalling schemes have been described in Ref. 3.

The signalling scheme using two signalling leads in each direction (called send, SL or M and receive, RL or E leads), which has been developed for use over P.C.M. circuits in the A.P.O. network, has been given the designation T5.

In Table 1, 1 represents the condition of earth applied to the M-Lead (and received at the corresponding E-lead), and 0 represents earth removed from the M-lead. Fig. 5 shows in schematic form the signalling leads over a P.C.M. circuit.

There is a strong analogy between the T5 signalling scheme and loop-disconnect signalling over physical circuits. In the forward direction the condition of the FUR M1-lead indicates seized or idle condition, which correspond to loop and open circuit conditions in the loop-disconnect case. In the backward direction the two FUR E-leads combine to give the four conditions—idle (junction guard loop with normal line polarity in the loop-disconnect case); B-party switch-hook normal, or meter (normal line polarity); answer (reversed line polarity); and force release or blocking (absence of line polarity).

The idle condition, in having one signalling lead on and one off, provides the main advantage of tone-on-idle systems without the disadvantages. The advantage of tone-on-idle systems derives from the fact that a

TABLE 1: ALLOCATION OF SIGNALS IN T5 SCHEME.

Forward Signals.			Backward Signals.		
Outgoing Relay Set. (FUR) Lead. M1	M2	Meaning.	Outgoing. Relay Set. (FUR) Lead. E1	E2	Meaning.
0	0	Channel fault	0	0	Channel fault, blocking, force release.
0	1	Idle	0	1	Idle condition
1	0	Spare (Seize forward on bothway circuits)	1	0	Answer.
1	1	Seize forward	1	1	Seize acknowledge, meter, B-party clear (depending on signal mode in use—switch hook or modified Karlsson signals).

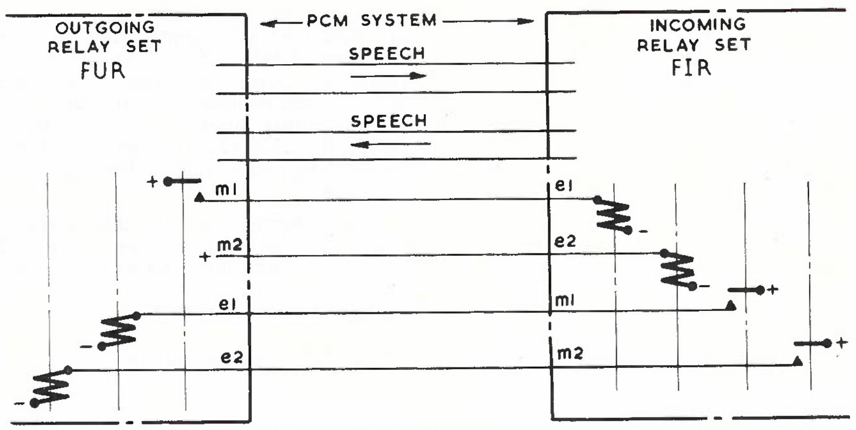

Fig. 5 — P.C.M. Signalling Leads.

fault condition, by removing the normally on signal, causes immediate blocking of idle circuits at the outgoing relay set. On the other hand, the seizure signal is also represented by turning a signal off, so that fault conditions may result in false seizure signals at the incoming end of the circuit unless a compelled sequence seizure signal is used.

During the course of a normal call, only one signal lead will change state at any one time, thus eliminating the problems of transition states encountered when two conditions change together. The sequence of events on a normal call are shown in Fig. 6.

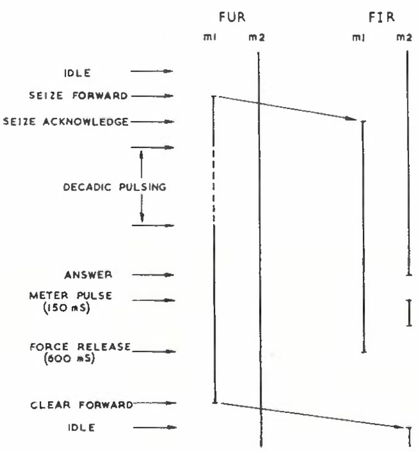

Fig. 6 — Typical S.T.D. Call.

Under fault conditions a change in state of both signalling leads may be experienced, such as when a fault occurs after seizure of a circuit, but before answer. In this case the backward signals will change from 11 to 00, and the E-lead relays in the FUR may momentarily adopt the configurations 01 or 10, depending on their relative release times. The associated circuitry must be designed to ensure that a false answer condition is not recognised due to this cause.

On bothway circuits, the initial seize forward signal has been allocated the condition 10. The seize forward signal for unidirectional circuits, 11, is the same as the backward seize acknowledge signal, and this does not allow the detection of dual seizures on bothway circuits. The seizure sequence followed by bothway circuits is shown in Fig. 7. After initial seize forward a bothway relay set FDR can distinguish between seize acknowlege (11), denoting a successful seizure, and a seize forward signal being sent from the other FDR (10), denoting dual seizure of the bothway junction.

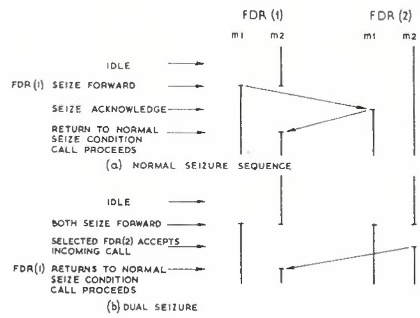

Fig. 7 — Bothway Circuits.

With the exception of the use of the forward signal, 10 for initial seizure on bothway circuits, this signalling condition is spare and may be used for any additional forward signals that may be required, such as forward transfer (recall of operators), in special circumstances.

It will be noted that the condition 00 denotes a fault condition in both the forward and backward directions of signalling. A common feature of P.C.M. transmission systems is that under fault conditions or if synchronisation of the received P.C.M. bit stream is lost, the E-leads are opened regardless of the signalling condition being transmitted. This condition corresponds to the force release signal in the backward direction, but the condition must persist for from 300 to 450 msec. before an FUR will accept it as forced release. This ensures that spurious faults or noise on P.C.M. system bearers will be unlikely to cause the release of established calls.

SIGNALLING EQUIPMENT.

A number of relay sets have been specified, using the T5 signalling scheme, to meet the requirements of the A.P.O. network. The design of the step-by-step and ARF relay sets required for the Windsor-Kurrajong installation and the P.C.M. field trials has been completed. Fig. 8 is a trunking scheme, indicating the location of the step-by-step exchange relay sets in

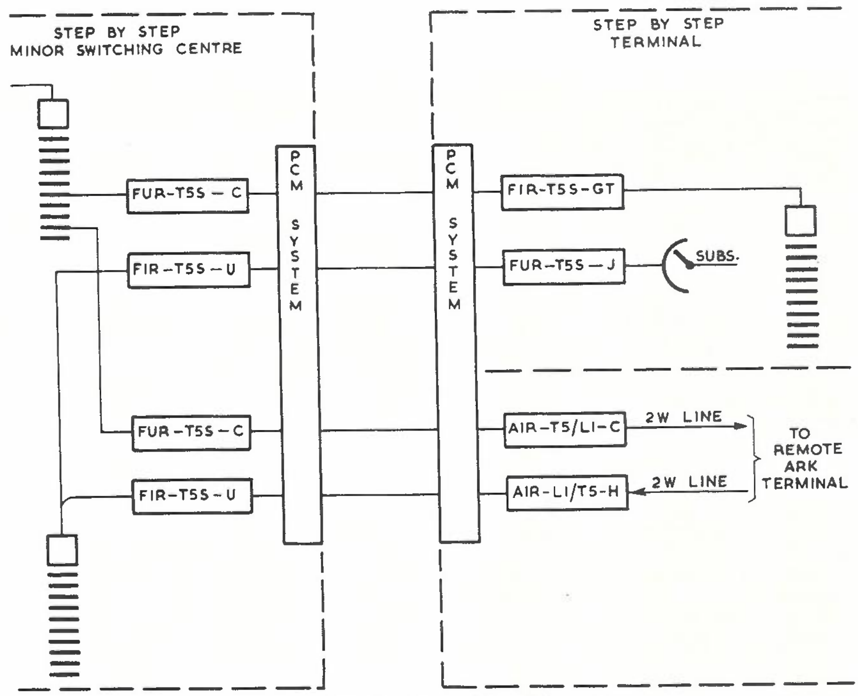

Fig. 8 — Step by Step P.C.M. Relay Sets.

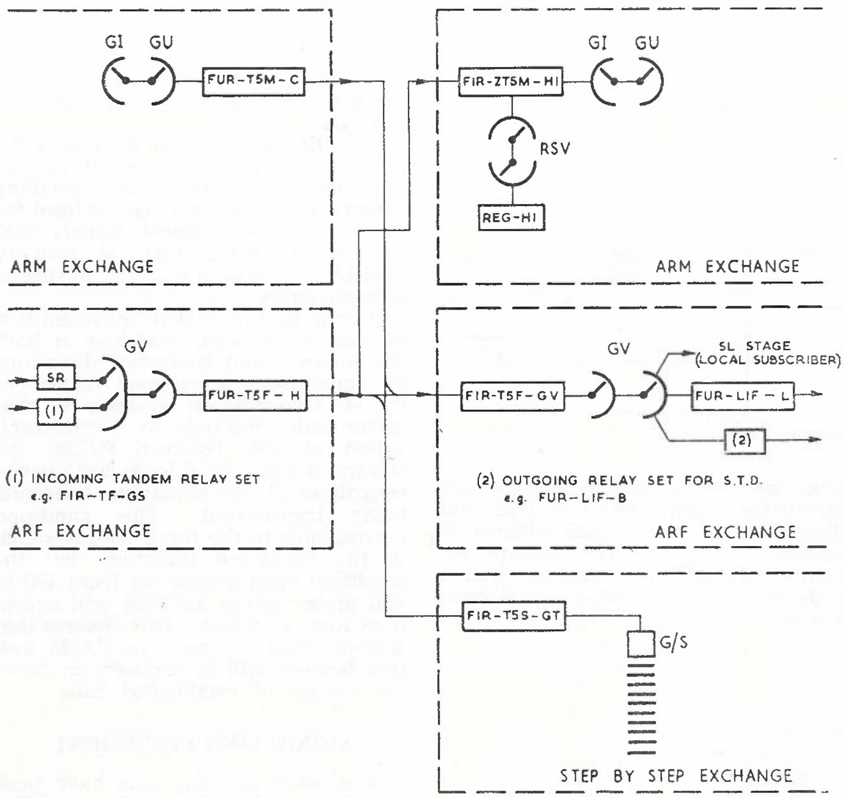

Fig. 9 — ARF and ARM Relay Sets.

a typical network, and also the use of intermediate relay sets for converting from loop disconnect signals (L1) into T5 signals and vice versa. Fig. 9 shows typical locations of the ARF and ARM P.C.M. signalling relay sets.

The step-by-step relay sets include designs for S.T.D. traffic, as well as for normal unit fee applications and intermediate signalling conversion. Two ARF relay sets have been designed which will allow for all requirements of incoming and outgoing traffic cases except those requiring coupling to an ARF register. The FUR can be used on unit fee or S.T.D. calls and can repeat decadic pulses if required, and the FIR can act as a tandem exchange repeater or provide B-party ring and battery feed conditions in a terminal exchange.

The P.C.M. signalling relay sets so far designed are comparable in size (number of relays used), to the corresponding loop disconnect relay sets and are appreciably smaller than the corresponding single E and M carrier signalling relay sets, particularly when those relay sets use pulse (T type) signalling.

The designations of the various relay sets shown in Figs. 8 and 9 follow the standard A.P.O. switching equipment designation scheme, as set out in Drawing CP-2040.

CONCLUSION.

The development of a new signalling scheme, with its attendant family of relay sets, is justified by the reduced size of 'T5' relay sets in regard to 'T' relay sets. Considerable cost savings can be gained by using T5 relay sets on P.C.M. circuits in lieu of T relay sets, even when the additional cost of the second signalling lead in the P.C.M. system is taken into account. The full value of the T5 signalling scheme depends on the use made of P.C.M. transmission systems in the network, and if current overseas trends are followed in Australia this value can be expected to increase rapidly in the next decade.

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2. Chandler, T. W. 'An Introduction to Pulse Code Modulation'; G.E.C. Telecommunications, No. 35, 1967.

3. Crew, G. L. 'Line Signalling in the Australian Post Office'; Telecommunication Journal of Aust., Feb., 1967, Vol. 17, No. 1, Page 23.

EXPO 67 SOUND CHAIR SYSTEM

S. H. McCLIMONT*

INTRODUCTION.

Towards the end of 1965 the Australian Government accepted an invitation from its Canadian counterpart to participate in a Universal and International Exhibition, to be held in Montreal to celebrate the centenary of Canadian Confederation. The exhibition became known as Expo '67, and has recently concluded after a sucessful run of six months, from April 28 to October 29, 1967, and visits by over 50,000 persons. Expo 67 was the first occasion that Australia has participated in such an international exhibition, and every endeavour was made to present this country to the world in a fitting manner. Australia joined with 58 nations and various Canadian and international sponsors to present 80 pavilions, which together with numerous restaurants, boutiques and entertainment areas, made up the 1000 acres of Expo 67.

The now much-publicised sound chairs were a major feature of the presentation in the Australian Pavilion and this article describes the A.P.O.'s contribution to the design, manufacture, installation and maintenance of the chairs and the associated control system.

AUSTRALIAN PAVILION.

Australia's Pavilion was situated on Ile Notre-Dame, one of the man-made Expo islands in the St. Lawrence river, and was adjacent to the pavilions of West Germany, India and Ceylon. It was arranged in a typically Australian environment of trees and shrubs, the background contained a pit occupied by a number of kangaroos and wallabies. A display of coral from the Great Barrier Reef was also featured at the rear of the building. Fig. 1 gives a general view of the pavilion.

The pavilion was a floating box structure with walls which sloped outwards to the top. Two facing walls were of reinforced concrete, while the remaining two were fully glazed. The ground floor area was open except for the circular foyer and the relatively small inquiry and service areas. Four large murals in the entrance depicted aspects of Australia's role in the story of 'Man and His World,' the Expo theme.

Visitors to the pavilion proceeded up a spiral ramp to the 140 foot square main exhibition area, viewing en route large colour transparencies of Australian life and scenery. On entering the first floor area, it was impossible not to be impressed by the atmosphere of comfortable elegance engendered by the thick, white, wool carpet and the modern styling of the 240 sound chairs. As a matter of interest, this carpet, which was extended up both concrete walls to the ceiling for acoustical reasons, produced a unique and attractive decorative effect.

The exhibition area was divided into four sections, each devoted to a particular subject theme, and each containing 60 stereo sound chairs arranged around the exhibits in a carefully determined but apparently random manner. In each section 45 chairs were provided for English - Speaking visitors, and 15 for those who preferred to listen to French translations of the various programmes. It was possible to distinguish between English and French speaking chairs by the colour of the seat cushions, green for English and orange for French. In all, 34 programmes were provided in English and 31 in French. The four subject themes were 'The Arts,' 'National Development,' 'Science in Australia,' and 'Our Way of Life,' a total of eight or nine programmes in each section. The layout of the exhibition floor area is shown in Fig. 2, and a general view of the interior is shown in Fig. 3.

Equipment to provide programmes to the chairs was contained in a basement below one of the service areas on the ground floor. The equipment room was annular in shape, with an inner diameter of 11 feet and an outer diameter of 20 feet.

SOUND CHAIRS.

The concept of utilising sound chairs to tell the Australian story at Expo 67 was initially proposed by the exhibit architect for the Australian pavilion, Mr. Robin Boyd, in December, 1965. At the time, Mr. Boyd's idea was based on a simple installation with a tape recorder fitted in the base

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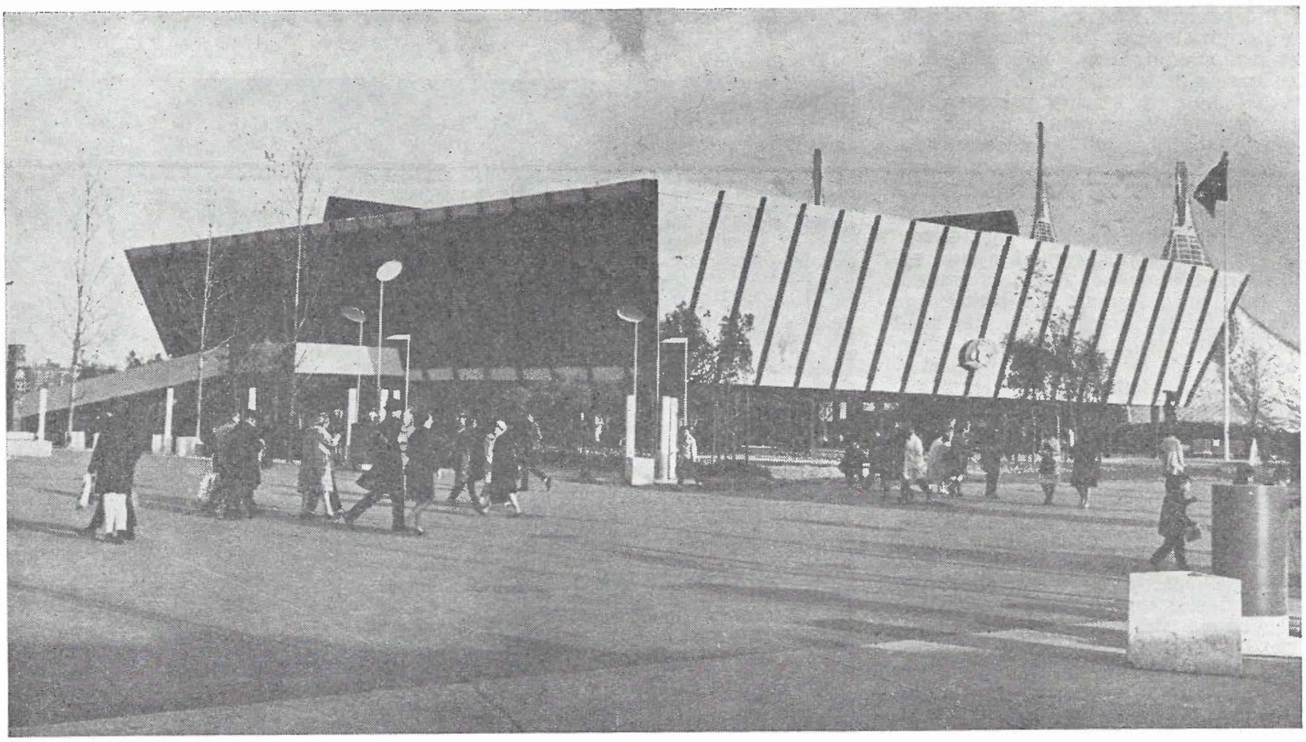
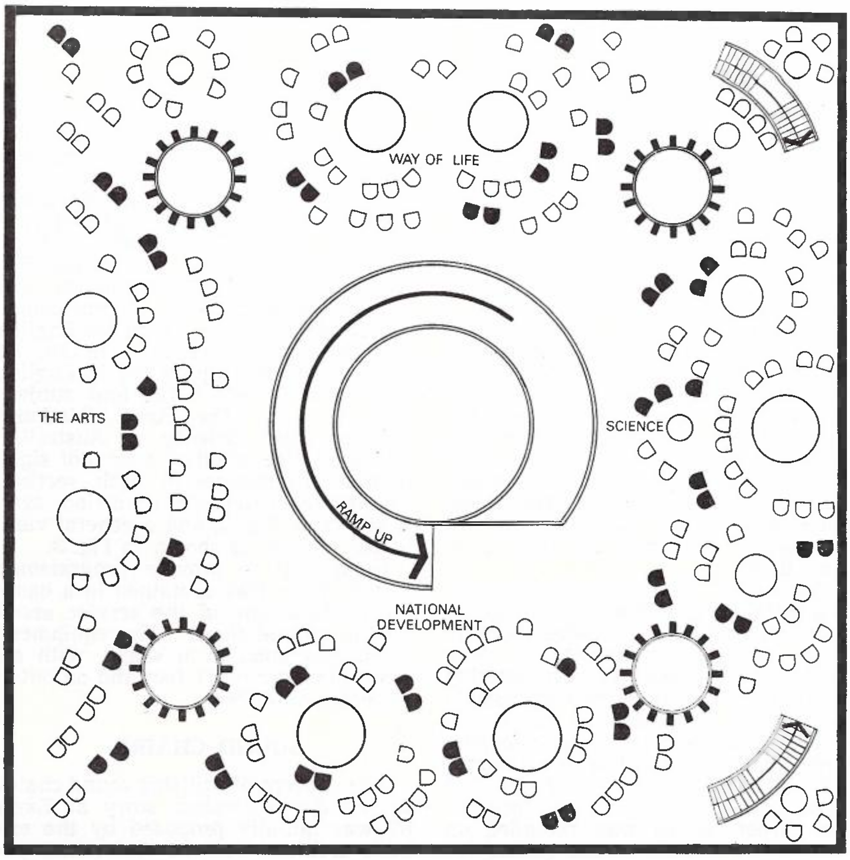


Fig. 1 — General View of the Australian Pavilion at Expo 67 (News and Information Bureau Photo).



FRENCH SPEAKING CHAIRS ENGLISH SPEAKING CHAIRS

Fig. 2 — Layout of Sound Chairs and Exhibits.

of each chair. A.P.O. participation in the project was requested during the design stage of the chairs and the sound tape equipment. Following discussions with Mr. Boyd, the designer of the chair, and other participating Government departments, it became apparent that it would be necessary to establish a separate equipment room for the tape play equipment.

The actual design of the sound chairs was entrusted to Mr. Grant Featherstone, a furniture designer, of Melbourne, and the A.P.O. accepted the task of designing the switching, wiring, cabling, and loud speaker system for the chairs. The chairs were manufactured by Aristoc Industries Pty. Ltd., in Melbourne. Each chair consisted of a polystyrene foam shell, coated with a layer of polyurethane foam padding, the whole being covered with wool fabric. The speakers were mounted in an acoustically designed headrest, which was formed in plastic reinforced fibre glass, padded with polyurethane foam, and covered with the same material as the chair. Both the head rest and seat cushion were attached to the chair by strips of Velcro. This is a nylon material provided in two forms, on one of these the face surface is covered by a large number of small hooks, while the face of the other is covered with an equivalent number of loops. When the two surfaces are pushed together the pieces of material are held by the intertwining action of the hooks in the loops. The strips can be released by a firm tearing action.

Bracket plates of 12 B.G. mild steel were fixed to the exhibition floor at each chair location. Rubberised webbing straps extended from the chair seat ring and clipped on to a large hole in the top of the brackets, so that the chairs, although in a fixed position, were free to turn and move within a restricted area. A six-way telephone socket, type 610, was attached to the bracket and the signal and control circuits were extended to the chair via a type 603 plug and six-way coiled cord.

Two speaker matching transformers were mounted on a fibre board within the base of the chair. A micro-switch was fitted on a rubberised mounting strap, which was stretched across the seat so that a minimum weight of 50 pounds applied to the centre of the cushion would operate the switch. All connections were made by cords terminating on Utilux push-on type quick connect tags. The headrest was connected to the main chair wiring form by a plug and socket.

After installation, access to the base of the chair was obtained by lifting the cushion and inserting an arm through a hole in the cushion support. The chair could then be unplugged and released from the floor bracket. As the chairs were extremely light, the mounting arrangements made it simple to replace a chair which developed a fault, and several spare chairs and headrests were kept in the equipment room as replacements. It was therefore possible to avoid clearing chair faults in the exhibition area while the pavilion was open to the

Fig. 3 — Interior View of Pavilion (News and Information Bureau Photo).

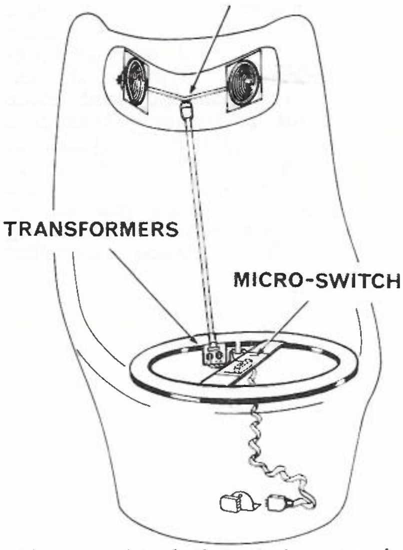


Fig. 4 — Sound Chair Equipment and Wiring.

public. Fig. 4 illustrates the location of wiring and components within the sound chairs.

SWITCHING SYSTEM.

For reasons of reliability, it had been decided to provide a tape play machine for every chair rather than risk the adverse visitor reaction which could be expected if groups of chairs were out of order due to the failure of a common programme source. At this stage, the A.P.O. were called on for technical assistance in relation to the wiring of the sound chairs, their installation and the associated cabling to the racks of play machines. However, it was immediately obvious that a simple arrangement of sound chairs, connected permanently to individual tape relay machines, was not in fact what was required to meet the demands of the exhibit designer.

The problem was that, while most people were expected to listen to complete programmes, there would be those who would sit in a chair, start a programme, listen for a while and then leave the chair before the endless tape cartridge in the recorder had completed its programme. Another visitor using this chair before the tape was ready for a new cycle would hear the end of a programme, or if this was masked there would be a pause of varying duration up to the length of the programme before the commencement of the next cycle.

To overcome this, and so that each chair would have access to a selection of suitable programmes, the A.P.O. suggested that a special switching system be inserted between the chairs and the tape machines. Headquarters, Telephone Exchange Equipment Section, was called on to design this switching system, basing their design on items of equipment which would in the main be re-usable in the A.P.O. network at the conclusion of Expo and providing the following facilities:

(a) Identification of an occupied chair.
(b) Selection of a suitable free tape play machine for connection to the chair.
(c) Connection of the chair to the tape machine.
(d) Release of the connection if the chair became unoccupied for a period of five seconds or longer.
(e) Busying of any machine released under the conditions of (d) until it had completed its cycle and was ready to play again from the beginning of its programme.
(f) Provision of an alarm if a machine commenced a cycle of operation but did not complete it within six to twelve minutes (maximum programme time 4 minutes).

The use of uniselector equipment was considered, but as this was difficult to get quickly, it was decided to use crossbar equipment as the finder and connecting device. The equipment actually used was a modified ARF incoming register finder stage (RS-I) with specially designed chair access relay sets providing the connection into the RS switch and further special tape access relay sets to which the RS stage switched.

To avoid congestion, the switching stage was lightly loaded, an RS-I stage consisting of two switches and a marker being provided for each group of 15 chairs. Thus four RS stages were required for each section of 60 chairs. Three stages with some outlets commoned provided connections between the section's 45 English chairs and 45 tape machines supplying English programmes. The 15 French chairs in the section were connected by the remaining stage to an equivalent number of machines which were supplied with French tapes. A trunking diagram of the complete sound chair system is shown in Fig. 5.

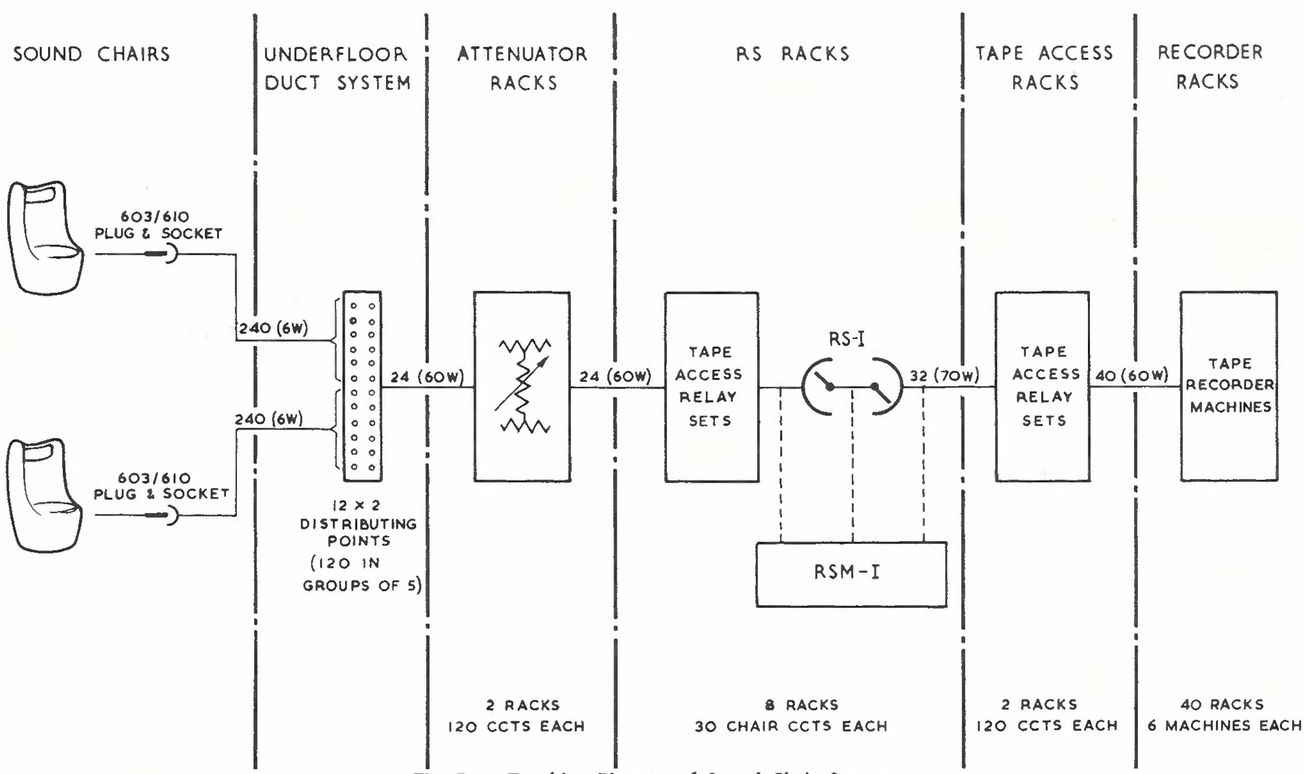


Fig. 5 — Trunking Diagram of Sound Chair System

On account of the low ceiling in the equipment room, the equipment was mounted on specially manufactured 2178 mm BDH type racks. Each RS rack was equipped with two RS stages and associated chair access relay sets, and provided equipment for 30 chairs. A total of eight of these racks were required for the complete installation. Tape access relay sets were mounted on separate racks, each with equipment for connection to 120 tape play machines. Jack boxes were provided on the RS racks with jacks to monitor programmes, keys for testing and blocking, keys for individual selection of particular recorders from predetermined chairs, and lamps to indicate chair occupation conditions. Call meters were provided for statistical purposes. The jack boxes on the tape access racks had a lamp display to indicate the occupation of tape machines and to assist in location of faulty machines. Tape play machine blocking keys and their associated lamps were also provided.

The ten crossbar racks were manufactured by the Postal Workshops, Sydney, using components supplied by Telephone and Electrical Industries Pty. Ltd. It was the workshops maiden venture into this field. They also assisted by manufacturing a number of other items of hardware for the Expo 67 installation at very short notice to meet early shipment dates made essential by the state of the ice in the St. Lawrence River. Thirty-four chair access and 34 tape access relay sets were made by Centre Industries of Sydney, the remaining items being obtained from store stock.

During the month of September, 1966, the first racks of the switching system were tested in Sydney by setting up the equipment for one group of 45 chairs. No difficulties were encountered and the remaining racks were wired and the equipment packed and despatched early in October. The whole task, from design through manufacturing, to despatch was handled in less than five months.

TAPE RECORDERS.

The tape recorded equipment was developed and manufactured in Melbourne by the Rola Division of the Plessey Components Group to specifications provided by the Department of Supply. A quantity of 250 machines was purchased. Two hundred and thirty of these, being simply play machines, were given the type name *Producermatic*. The remaining 20 machines had facilities to record as well as play and were known as *Recordermatics*. The machines were designed to use endless tape cartridges. The tape ran at a speed of 7.5 inches per second. Three tracks were used, the outer tracks for the stereo programme, whilst the centre track was used for cueing purposes.

A length of tape just long enough to give the desired recording time was inserted in the cartridge. An 800 Hz tone was used for cueing and this was automatically inserted on the cue track whenever a recordermatic machine was switched to record. On playback, after the whole loop of tape had passed the play head, this tone operated a relay to stop the tape just before the recommencement of its programme.

Siemens and Halske relays were used for remote operation of the machines. These commenced the play function on receipt of the start signal from the switching system and indicated the various operational conditions of the machine to the tape access relay sets. These conditions were busy, end of programme, and ready to play.

The machines were mounted on forty-two 7 ft. by 20¼ in. racks. Forty-one racks each housed six machines, while the forty-second rack was equipped with four recordermatic machines, two Leak amplifiers, and control and patching facilities for bulk recording tape cartridges on the 20 recordermatic machines. The racks were assembled and wired by Zepher Products Pty. Ltd., of Melbourne, this work also being organised by the Department of Supply, with assistance from the A.P.O. at the testing stage.

ATTENUATOR RACKS.

Two racks of variable attenuators were also made up by Zepher Products. Each rack was equipped to control the programme level to 120 chairs in groups of six. These racks were provided to adjust the signal level in the sound chairs in relation to the ambient noise in various parts of the pavilion from time to time during the day. In practice, it was not necessary to vary the attenuator settings from the mid-range point selected during pre-cutover testing.

POWER.

A standard 50-volt 50-amp. rectifier, modified for 60 Hz operation, together with a 45 Ah continuously floated battery were used as the power source for the switching system. The maximum load of the system was in the order of 65 amps and the 45 Ah battery was installed to compensate for the peaks. The tape recorders were mains operated units, designed for 240 volts, 60 Hz operation and together with the rectifier were connected to the local 208 volts three-phase mains via a 35 kVA transformer unit on which were also mounted the 400/240 volt a.c. distribution fuses and circuit breakers.

PROGRAMMES AND TAPES.

The 34 English and 31 French programmes were presented as conversations between two people and were arranged to give a person using a sound chair the impression that they were sitting at a table listening to a conversation. Some of the participating parties were prominent Australian personalities, while other recordings were produced by well-known actors.

As indicated previously, eight or nine different programmes were used in each of the exhibition sections. Because of the random selection provided by the register finder equipment, chair users had no control over the programme received. However, the exhibit architect had indicated some priorities for particular programmes and also the number of repeats of each programme which was to be used. As far as the English chairs were concerned, it was possible to meet his requirements by allocating tapes to machines in such a way that chairs around nominated exhibits would, in the main, receive the priority programme for that area.

The master tapes were produced by Hector Crawford Productions. Masters in endless loop cartridge form were produced from these in the Melbourne laboratories of the Department of Civil Aviation. They were then used by the A.B.C. in Sydney to produce bulk copies for Montreal. During the exhibition, tape machines were in almost constant use for 12 hours a day, seven days a week, and, because of expected tape wear and deterioration, it was anticipated that approximately 2000 tapes would be required for the period of Expo. This estimate proved to be correct in practice.

Unfortunately the playing time of the majority of programmes produced was in excess of the three to four minutes for which the switching system was designed. This was particularly so with the French translations, which in several cases were over seven minutes. These long programmes were a cause of traffic congestion, as visitors tended to leave their chair and release the chair to recorder connection before hearing the whole message. As the recorder then tested busy until the tape was ready to re-start, there were periods when no free recorders were available and new traffic offering could not be switched. To alleviate this problem, it was necessary to edit the tapes to reduce the playing time and then re-record bulk copies of the edited programme. This was a most tedious task and had to be carried out on top of normal maintenance activities throughout the period of Expo 67.

INSTALLATION.

To handle the installation and maintenance of the sound chair system in Montreal, it was decided to send a team consisting of a project engineer and three supervising technicians or senior technical officers (S.T.O.s) from Australia. A Department of Supply engineer, Mr.W.Wells, was responsible for preparation of the tape recorder specification and follow-up of their purchase and production. He continued as project engineer. The A.P.O. provided an S.T.O. from the Subscribers' Equipment, Telegraphs and Power Section at Headquarters to handle aspects of the installation for which the Department was responsible. This included installation of the chairs and switching system and the system cabling.

To handle the installation and quality testing of the tape recorder racks, the Department of Civil Aviation made available a supervising technician from their laboratory in Melbourne. The remaining member of the party was an S.T.O. from the A.B.C. in Sydney; he was responsible for the acoustical testing of the chairs and maintenance during the whole period of the exhibition. At the time he arrived, cabling to the chairs had been completed, but the carpet had not been laid and he took over the final installation of the sound chairs.

To avoid delays on site, as much installation planning as possible was done prior to departure from Australia. A floor layout plan was prepared and all cables and terminations were charted. In all, the number of installation terminations involved was just under 18,000. All equipment and material requirements except minor items of hardware such as screws, etc., were accumulated in Australia and despatched to Montreal so as not to delay the installation programme. Special short forming boards were made up for use with the shorter than normal BDH racks and all the necessary tools and jigs for use with these racks were also forwarded from Australia. Sheet metal troughing for use over the BDH racks was made up by the Postal Workshops, Sydney, and a case of 4 in. x 4 in. PVC commercial troughing was despatched to hold the cables over the recorder racks.

Cables to the sound chairs were accommodated in a limited, 8 in. x $1\frac{1}{4}$ in. trough type duct system on the main exhibition floor. This consisted of three parallel runs of duct on 12 ft. centres along each side of the exhibition floor, fed by a riser from the equipment room. There was no provision for running cables out from the duct system to the individual chairs and as six wires were required per chair, it was initially intended to use two parallel runs of four-wire adhesive backed flat cable, stuck together, and run under the carpet. However, for reasons of economy, and also because it was most difficult to feed the flat cables into round grommetted holes in the removable duct covers, it was decided to use normal three-pair PVC cable for these final runs.

To locate the chairs, a grid system was first marked out on the floor and they were positioned in accordance with the exhibit architect's requirements. Threaded studs were shot into the concrete floor at each location. The 3-pair cables were run out from the duct directly to these studs and fixed to the floor along the entire length of the runs by 2 in. wide strips of adhesive backed heavy kraft paper. As the carpet layers positioned their underfelt, they cut grooves in the felt along each cable run so that after the carpet was laid there would be no likelihood of ridge formation. As the carpet was run the cables were fed through by the carpet layer. The chair brackets were then fitted over the carpet and the 3-pair cables were terminated.

All work in the duct system had to be completed before the carpet was laid and no access was then available to this wiring. Twenty-four 60-wire cables were used to feed the chair circuits from the equipment room to distributing points in the ducts on the exhibition floor. These cables were connected to the 3-pair chair cables via a number of commercial 12 x 2 screw-type terminal strips, which after termination were stuck to the duct wall with 'Scotchmount' double-sided adhesive foam.

Lack of access to the underfloor wiring and the distributing points was a real worry, so that immediately after the duct covers were replaced and prior to laying carpet, all chair cables were tested. Although the method of cabling was somewhat unorthodox, it proved to be reliable during the exhibition.

As far as the installation of equipment was concerned, the basement area was just large enough to house the necessary apparatus in two rows, facing inwards around the inner and outer walls of the annular shaped room, and this was the basis of the floor layout. The narrow circular room provided some difficulties for the installation of BDH racks, as it was not possible to install suites in the normal manner with adjacent racks using common vertical members. Therefore, each rack had to be made up to form an independent unit, the front corners butting together around the outer wall and the rear corners butting together on the inner wall. The troughing over the crossbar racks was made up so that the ends could be bent on site to interleave at the rack junctions.

Before the engineering team left for Montreal it was found that the L.M. Ericsson organisation had a strong representation in that city, and arrangements were made for some trained installers to be available to assist with the on site installation of the switching system. Four L.M. Ericsson installers were employed for periods varying from three to four weeks, and a tester assisted with the pre-cutover testing for one week. The L.M. Ericsson staff did all the terminations on the switching system, attenuator and recorder racks. The association proved to be very satisfactory and helped to expedite completion of the work in time to permit four weeks' acoustical testing before the opening of Expo 67.

A party of radio tradesmen from the RCA Victa Company in Montreal were to have run and terminated the chair cables and to have worked on the tape recorder equipment. However, this arrangement ended suddenly, after they had worked for two days, as they belonged to a union which did not have a franchise for its members to work on the Expo 67 site. The same problem restricted L.M. Ericsson staff to work only in the area of that company's equipment. As a consequence, the Australian technical team found themselves in a position of personally completing this work as a sideline to their other duties, assisted by one lone French-speaking electrical tradesman who was given a short course on telecommunication cabling methods.

There were numerous problems associated with the installation. Some of these related to matters of personal comfort, the most active part of the work being in progress during February, a very cold month in Montreal. Temperatures were sub-zero and ice and snow were plentiful. On-site amenities were poor and transport arrangements were difficult. The building air-condition system did not extend to the equipment basement, and it was necessary to install a special unit in that area, taking up space, which was at a premium.

The chief difficulty was caused by 6 in. sewer pipes, which protruded through the equipment room ceiling and ran around most of the inner wall before crossing the room en route for the main. The pipes, which served the public and staff toilet block on the ground floor immediately above the equipment room, were not shown on the working drawings of the building. They frequently extended below rack height and made a complete rearrangement of floor plans necessary. The crossbar racks ran round the walls according to plan, although along the inner wall the cable trough was shared by a pipe for some distance. Location of the tape recorder racks was more difficult and they were set out radially around the room in suites of three, the area under the pipes becoming the aisle. Suites were reduced to two racks or moved off their normal centres where the presence of pipes or other obstructions made this necessary.

Incidentally, one Sunday afternoon in the early stages of the exhibition, this pipe system became blocked, pressure built up and water commenced to drip from most of the pipe joints in the equipment room. It was a most busy time, catching drips and diverting water from various racks of equipment. A frying pan from the VIP kitchen was pressed into service for use in the trough over the crossbar equipment.

Portion of the switching system is shown in Fig. 6, and a group of recorder racks in Fig. 7, some of the pipes mentioned above being in the top right-hand corner of the photograph.

MAINTENANCE.

For the first month of the exhibition the maintenance of the system was carried out by the technical staff from Australia, with the assistance of a Canadian university student on summer vacation. Crowds were heavy, with up to 27,000 visitors on some days, and the chairs and equipment were really given a thorough workout.

There were some chair faults during the first week due to a certain amount of sag in the chair cushion supports, causing the micro switches to remain permanently operated. After adjustment, no further difficulty was experienced in this area.

The switching system was heavily loaded, and, in the first week or so, congestion conditions frequently occurred due to the enthusiasm of some visitors, particularly small boys, who moved from chair to chair without listening to more than a few words of programme. The situation improved gradually as the tapes with overlong programmes were replaced The incidence of faults in the switching equipment was not high and followed the pattern for similar equipment in normal service. One spare marker and a spare RS switch were available for emergency use.

Heat was the main problem as far as the tape recorder equipment was concerned. Two hundred and fifty continuously running motors put considerable pressure on the air conditioning system, and, although this worked reasonably well, there were pockets of heat among the racks. As the tapes were running almost continuously, the bulk of the maintenance efforts consisted of replacing worn, broken or seized tapes, cleaning play heads and cleaning and adjusting puck wheels. A number of seized motors was also encountered.

Towards the end of the first month of Expo 67 two Canadian technicians were engaged and trained to permit the return to Australia of the A.P.O. and D.C.A. staff. The S.T.O. from the A.B.C., with a staff of three, then carried on the maintenance of the system until the conclusion of the exhibition. The project engineer remained on site for the whole period of the exhibition, with overall responsibility for the sound chair system, the general exhibits and various other engineering aspects associated with running the Australian pavilion.

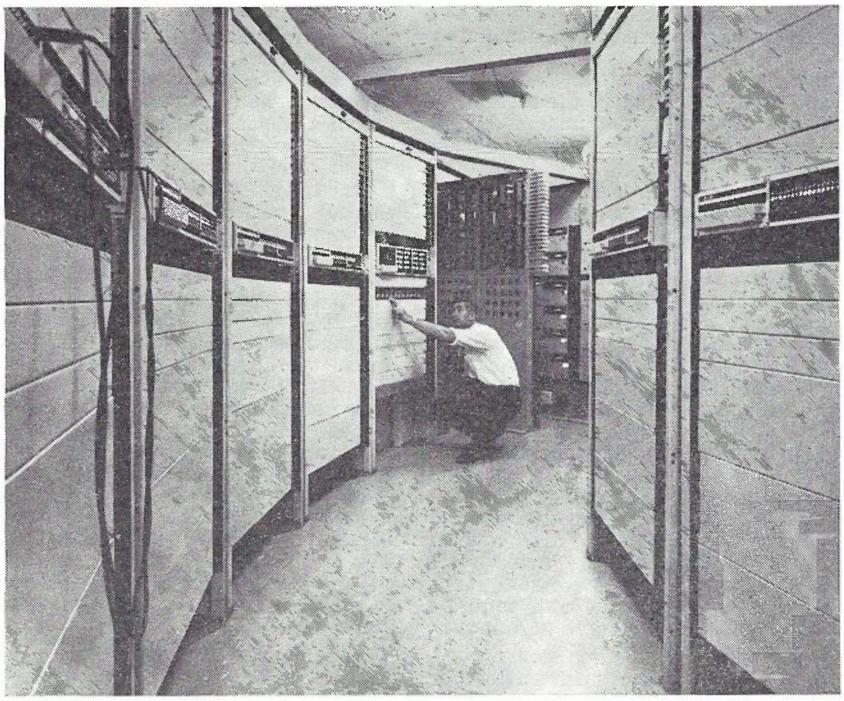


Fig. 6 — Section of the Switching System (News and Information Bureau Photo).

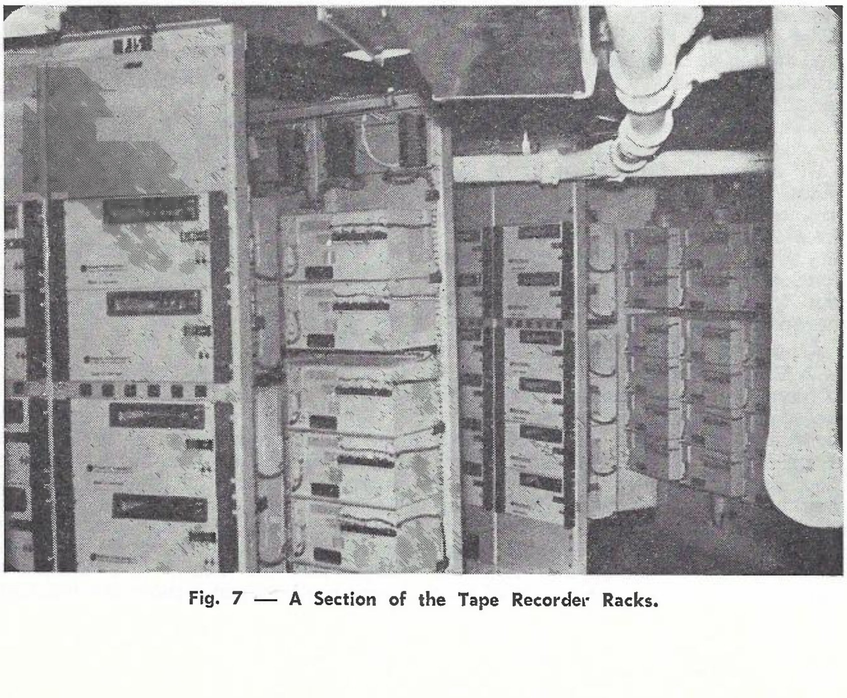


Fig. 7 — A Section of the Tape Recorder Racks.

CONCLUSION.

Real interest was shown in Australia and the Australian pavilion during Expo 67. The total number of visitors passing through the exhibit during the six months period was 3,509,770, or almost 19,000 per day. Queues were maintained consistently at the entrance. An average visitor occupied from 3 to 4 sound chairs. However, early in the exhibition one consistent member of the public claimed to have heard 30 of the 34 available programmes.

A restricted number of visitors were able to view the equipment room. These were either people with an interest in the engineering aspect of the sound chair system, or special guests of the Australian Exhibit Organisation. They were impressed by the installation, and particularly by the fact that all of the equipment was manufactured in Australia.

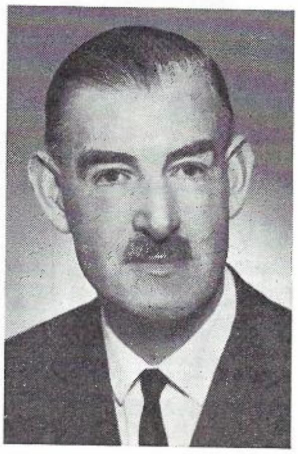
The equipment and sound chair system has been dismantled and the equipment returned to Australia, but the sound chair idea has proved so popular that there is a call for installation of limited numbers of chairs and recorders in the offices of various Australian overseas missions.

ACKNOWLEDGMENTS.

The presentation of the sound chair system was a team effort which drew on the resources of a number of Government departments and private firms. It was an excellent example of how such co-operative effort can be harnessed to present Australia to the world.

Concerning the Australian Post Office effort, the work of Mr. K. B. Smith in relation to the electrical aspects of the chair design and his conception of the switching system should be acknowledged, as also should the resulting developmental work of the design group in the Telephone Exchange Equipment Section at Headquarters and the staff of the Postal Workshops, Sydney.

OUR CONTRIBUTORS



R. G. KITCHENN

E. J. KOOP

R. G. McCARTHY

R. G. KITCHENN, author of the article 'Transmission Objectives', joined the British Post Office as a Youth-in-Training in 1936, leaving in 1951 to join the Australian Post Office. His service with the B.P.O. covered all fields of communications and included seven years with the Engineer-in-Chief's Office in the Telegraphs, Training (as Lecturer in Transmission) and Local Lines and Wire Broadcasting Branches. While in the latter Branch, as Executive Engineer, he was awarded the British Institution of Radio Engineers' (now the Institution of Electronic and Radio Engineers) 1951 premium for "the most outstanding paper in the field of broadcasting" published in that Institution's Journal. He was Secretary for an I.E.E. Sub-Section, a member of the Brit. I.R.E. Programmes and Papers Committee and a member of that Institution's General Council.

In 1951 he joined the N.S.W. Radio Section and was associated with National and commercial broadcasting stations and studios until 1955 when after a period as Divisional Engineer, Engineering Studies, N.S.W., he took up duty as Divisional Engineer, Planning and Standards, Radio Section, Central Office, moving to Systems Planning Section as Sectional Engineer, Trunk Networks in January, 1958.

Since the formation of the Headquarters Planning Branch, he has been responsible for the determination of transmission performance objectives and planning rules for the public and private telecommunication networks provided by the A.P.O. Mr. Kitchenn has been General Secretary of the Postal Electrical Society of Victoria (later Telecommunication Society of Australia) since 1958. He holds the London degree of Bachelor of Science (Engineering), is a Member of the I.E.E. and an Associate Member of the I.E.R.E.

E. J. KOOP, author of the article 'The Transmission Performance Preferences and Tolerances of Telephone Users', is an Engineer Class 3 in the P.M.G. Research Laboratories. After graduating as an electrical engineer in 1948 from the University of Adelaide, he commenced work with the Department in the Engineering Division, Adelaide, on long line equipment maintenance. He transferred to the Research Laboratories, Laboratory Equipment Division in 1950 where he became associated with laboratory instrumentation calibration, maintenance, procurement and development. In 1964, he was transferred as Engineer Class 3 in charge of the Telephone Standards Division and has since been concerned with Telephone Transmission Standards, measurements of transmission performance and electro-acoustics. During 1966 Mr. Koop made an overseas study tour to investigate techniques and trends in these fields.

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A. A. RENDLE

R. G. McCARTHY, author of the article 'The Establishment of an A.R.M. Network in N.S.W.', joined the Postmaster-General's Department as a Cadet Engineer in 1952. After graduation in 1956 as Bachelor of Engineering (1st Class Honours) at the University of N.S.W., he spent eight years with the Trunk Service and Telegraphs Section, Sydney, oversighting service aspects of trunk signalling and switching equipment and controlling major trunk exchanges at Dalley Street and the G.P.O.

In 1964 he transferred as Engineer Class 2 to Long Line and Country Installation, No. 4 Sub-Section, to start the Haymarket A.R.M. Project and in 1967 was placed in charge of a temporary division set up for the establishment of the initial A.R.M. telephone network, with control of A.R.M. projects at Haymarket, Canberra, Newcastle and Goulburn.

★

A. A. RENDLE, author of the article 'An S.T.D. Coin Telephone', graduated Bachelor of Arts in 1958 with honours in Mechanical Sciences from Cambridge University. He spent three years with Standard Telephone and Cables in London, mainly working on test equipment for aircraft aerial systems. He joined the P.M.G. Research Laboratories in 1962 and transferred to the Subscribers' Equipment Section in 1964, where he is employed as an Engineer Class 2, mostly concerned with coin telephone design.

I. H. MAGGS

I. H. MAGGS, author of the article 'The New National Automatic Trunk Network', is an Engineer Class 3 in the Switching and Facilities Section of the Headquarters Planning Branch. Mr. Maggs joined the Postmaster-General's Department at Sydney as a Cadet Engineer in 1954. After graduating from the University of New South Wales in 1957 he was appointed Engineer Class 1 with the Long Line and Country Installation Section in New South Wales. After 1960, as an Engineer Class 2 in that section, he was actively engaged in the installation of switching and transmission equipment in the Canberra and Wollongong regions.

In 1964 he was promoted to the position of Engineer Class 3, Metropolitan Networks, Switching and Facilities Section, Headquarters and was engaged on the formation of forward plans related to the development of metropolitan networks. In 1967 he was transferred to the Trunk Network Administration Division in the Switching and Facilities Section and is currently associated with the planning and implementation of the national automatic trunk network. Mr. Maggs is also editor of the National S.T.D. Newsletter and an Associate Member of the Institution of Electrical Engineers.

M. F. SAGE

M. F. SAGE, author of the article 'Developments in Subscribers' Telephone Instruments', joined the Postmaster-General's Department in 1957 as a Cadet Engineer. He completed the degree of B.E. at Melbourne University in 1960 and in 1961 commenced duty as an Engineer Class 1 in the Postal Workshops, South Melbourne.

In 1963, he transferred to the Radio Section as operations and maintenance engineer for the Victorian studios of the National Broadcasting Service and continued in this position for six months after transfer of the studio technical staff to the Australian Broadcasting Commission.

After returning to the Postmaster-General's Department in June, 1965, he was appointed Engineer Class 2 in the Subscribers' Equipment Design Sub-section of the Headquarters Engineering Division where he has been concerned with type approval examination of telephone and private line attachments, formulation of trunk access barring policy and examination of P.A.B.X. barring equipment and more recently with the design of intercom telephone equipment. He is currently in charge of a Sub-section concerned with P.A.B.X. and Unstandard Facilities.

S. H. McCLIMONT

S. H. McCLIMONT, author of the article 'Expo 67 Sound Chair System', who is at present a Senior Technical Officer Grade 2 in the Subscribers' Equipment, Telegraphs and Power Section at Headquarters, has for some years been engaged in development of subscribers' equipment installation and service standards in that Section. He commenced duty with the Department as a junior mechanic in 1940 and completed his training and qualified as a senior technician in 1948 after a period of four years service with Army Signals. After completing a further two years as an instructor in the Technicians Training School, Melbourne, he undertook supervising technician responsibilities in turn in the Materials Section, Postal Workshops and Country Installations Sections in Victoria, his work being mainly concerned with long line equipment and small automatic exchanges. In the latter half of 1966, Mr. McClimont was selected to supervise the installation of the switching equipment, cabling and sound chairs in the Australian pavilion at Expo 67. He assisted with the design and testing of the sound chair system, planned and prepared the drawings of the cabling, and organised the supply of material for this part of the work before travelling to Montreal in January, 1967, to carry out the installation work.

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SPECIAL EXAMINATION SUPPLEMENT

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CONTENTS

FOREWORD

In 1967 candidates for the Department's Senior Technician Examination sat for a new series of papers in Section 2 of the examination. In addition to a pass in Section 1 (Telecommunication Principles), candidates are required to pass in at least one paper in Section 2. Previously this section offered a choice of four 'plant' papers; in the new series a choice of seven papers is available.

To mark this change in a manner attractive to examinees, the Board of Editors sought the co-operation of the Department's Headquarters Technical Training Section. The production of this special examination supplement in which each of the new 'plant' papers has been given special coverage, is an indication of the excellent way this request for assistance was answered.

On behalf of readers, particularly those who are students of the Examination Section of the Journal, the Board of Editors expresses its sincere appreciation for the efforts of all persons who have contributed to the production of this supplement.

ANSWERS TO EXAMINATION QUESTIONS

Examination No. 5632, July 1967, to gain part of the qualifications for promotion or transfer as Senior Technician (Telecommunications), Postmaster-General's Department.

TELEPHONE EXCHANGE EQUIPMENT.

QUESTION 1.

(a) With the aid of suitable sketches show the magnetic flux paths for a relay fitted with a HEEL END SLUG when:
(i) The relay is operating.
(ii) The relay is releasing.

(b) List four (4) other methods which give the same effect on the operation of a relay as a heel end slug.

ANSWER 1.

(a) Fig. 1a shows the flux paths when the relay is operating and Fig. 1b shows the flux paths when the relay is releasing.

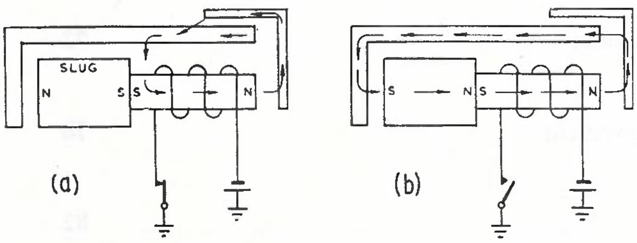


Fig. 1

(b) The characteristic of a heel end slug is for the relay to operate normally and to have a slow release. Other methods of providing the same effect are:—
(i) A resistor connected in parallel with the relay coil.
(ii) A capacitor connected across the relay coil.
(iii) A rectifier connected in parallel with the relay coil.
(iv) A two-winding relay having one coil short-circuited after operating by its own or another relay's make contact.
(v) A single-winding relay in which the coil is short-circuited by the contact breaking the circuit. (Examples of (iv) and (v) are the CD and B relays in the final selector circuit supplied with the examination paper.)

QUESTION 2.

(a) State the three (3) main requirements for a signalling scheme in an automatic exchange equipment network.

(b) Explain briefly what is meant by the term 'multi-frequency compelled sequence signalling' as used in ARF102 crossbar equipment.

(c) The ARF102 crossbar system uses a control signal to denote the condition—WAITING PLACE, NEXT DIGIT. Explain briefly:
(i) The effect of this signal on the setting up of a connection.
(ii) Why such a signal is necessary.

ANSWER 2.

(a) (i) The transmission of number or digital information and revertive signals to control the routing of a call.
(ii) The supervision of the progress of a call.
(iii) The transmission of information relating to the charging of a call.

(b) Multi-frequency signalling uses voice frequency signals coded in the form of either 2 out of 5 or 2 out of 6 frequencies which are used as information signals. Compelled sequence means that the duration of a signal is not determined by any timing arrangements but controlled by signals in the opposite direction.

(c) (i) This signal informs the register not to seize a distant code receiver until the complete number is received and stored in the register.
(ii) To prevent the distant code receiver from being held until the subscriber has finished dialling.

QUESTION 3.

(a) Briefly explain what is meant by PROMPT and DEFERRED alarm classifications in a 2000 type exchange.

(b) Classify the following alarms as either prompt or deferred, giving the corresponding delay period:
Fuse, High or Low Volts, C.S.H. Supervisory, N.U. Tone Supervisory, Release, N.U. Tone overload.

(c) Name and briefly describe the function of each of the three rack and shelf relays which together form the release alarm circuit in a 2000 type exchange.

(d) Explain briefly the main purpose of—
(i) The sub-section classification block in an alarm system.
(ii) The blue number panel light in a main display floor panel.

ANSWER 3.

(a) A prompt alarm is one which indicates that a failure of an urgent nature has occurred and requires immediate attention.
The deferred classification is used for faults which may be temporarily neglected without affecting the service of a group of subscribers.

(b)

Alarm.	Classification.	Delay Period
Fuse	Prompt	Nil
High or Low Volts	Prompt	Nil
C.S.H. Supervisory	Deferred	3 mins.
N.U. Tone Supervisory	Deferred	9 secs.
Release	Prompt	9 secs.
N.U. Tone Overload	Deferred	Nil

(c) The three relays are: RA, AR, BR.
The RA relay is a shelf relay (1 per 2 shelves), which operates in series with the rotary magnet of one of the 20 selectors concerned. The relay operates a rack relay and also indicates the group of 20 switches in which the fault has occurred.
AR is a rack relay. It is operated by a shelf relay and signals the delay set to commence the timing function.
BR is also a rack relay. It is operated from the delay set at the completion of the 9 to 18 second interval and when operated brings in the alarm and identifies the rack in which the fault has occurred.

(d) (i) It is a commoning point for alarms from the various divisions within that sub-section and also serves as a point where the alarms are classified as prompt or deferred.
(ii) This indicates a failure in the power room.

QUESTION 4.

(*a*) *Explain briefly the meaning of any three (3) of the following terms when used in conjunction with Trunk Line Switching:—*
- (*i*) *Demand Working.*
- (*ii*) *Automatic transit switching.*
- (*iii*) *Pad switching.*
- (*iv*) *Delay working.*

(*b*) *By means of a suitable sketch show the principles of a trunk circuit using 'True' 4-wire switching.*

(*c*) *State briefly what function is performed by the TT lead in 2VF switching equipment.*

ANSWER 4.

(a) (i) With demand working the telephonist who answers the subscriber sets up the call while the calling subscriber holds the line.

(ii) Automatic transit switching is the switching through of trunk calls at intermediate stations by means of automatic trunk selectors controlled by the originating telephonist.

(iii) On trunk calls, where pad switching is employed, pads are automatically switched in or out of circuit to maintain overall transmission equivalents within satisfactory limits.

(iv) When working in delay the connection cannot be completed immediately the call is booked. The trunk operator recalls the calling subscriber when the trunk circuit becomes available.

(b) A suitable answer to the question can be found in the Course of Technical Instruction, Telephony 5, Trunk Line Switching, Appendix 4 and Fig. 34.

(c) On 2VF to 2VF trunk calls, the TT lead causes the trunk line circuits to remain in a condition which allows the 2VF signals to pass through the line circuits without splitting occurring.

QUESTION 5.

The block diagram (Fig. 2) shows the trunking between four exchanges in a closed 6 digit directory number multi-exchange area.

Sketch the trunking paths showing the switching stages used for the following calls:—
- (*i*) *Any exchange B subscriber calling an exchange D subscriber.*
- (*ii*) *Any exchange A subscriber calling an exchange B number on the direct route.*
- (*iii*) *Any exchange D subscriber calling an exchange B subscriber via the direct route.*
- (*iv*) *Any exchange A subscriber calling a local number when all junctions are busy to the main (tandem) exchange.*

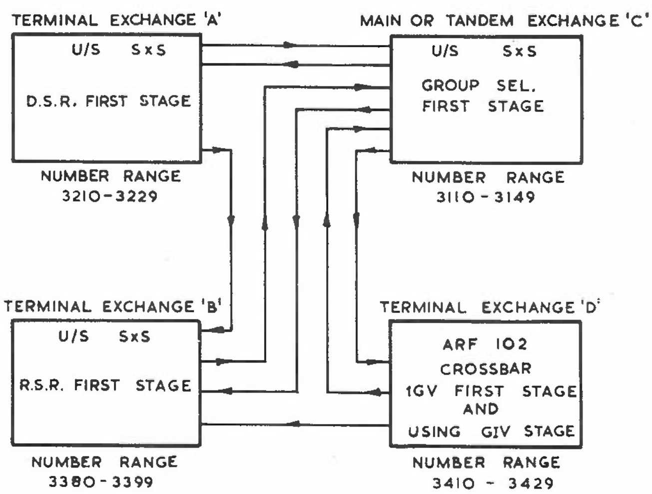


Fig. 2

ANSWER 5.

(i) See Fig. 3.

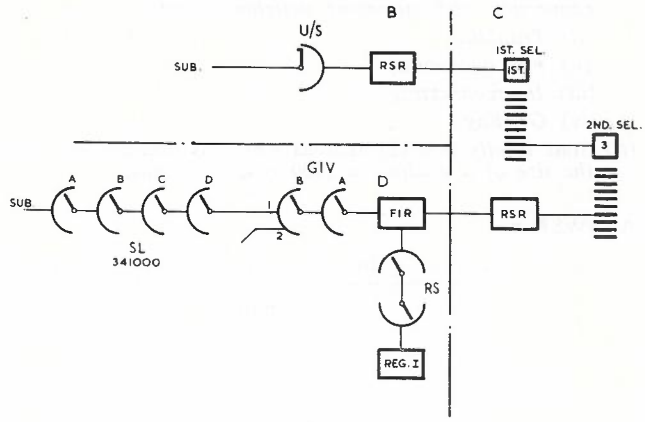


Fig. 3

(i) See Fig. 4.

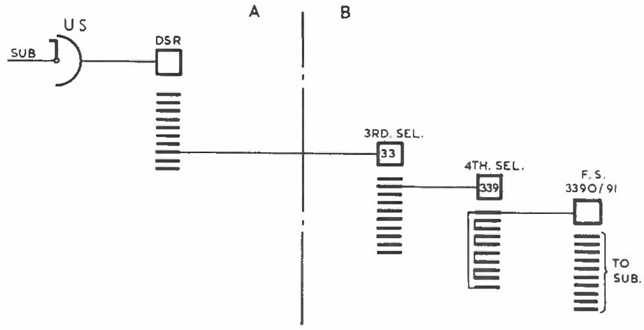


Fig. 4

(iii) See Fig. 5.

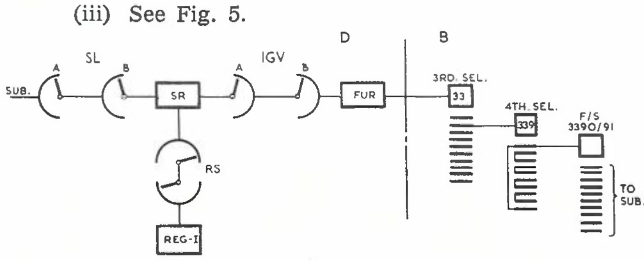


Fig. 5

(iv.) See Fig. 6.

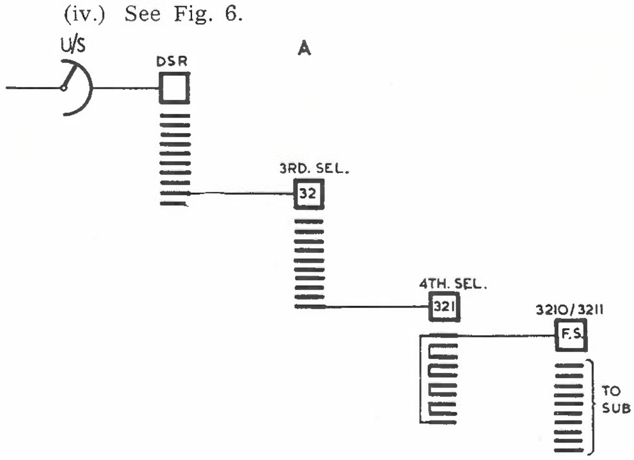


Fig. 6

QUESTION 6.

(*a*) *Explain briefly what is meant by the following terms, in connection with automatic switching plant—*
- (*i*) *Trunking.*
- (*ii*) *Full availability.*
- (*iii*) *Interconnecting.*
- (*iv*) *Grading.*

(*b*) *State briefly two (2) reasons why it is necessary to limit the size of a grading in 2000 type apparatus.*

ANSWER 6.

(a) (i) Trunking is the determination of the amount of plant required in an automatic exchange, its arrangement and cabling. It also concerns the method of rearranging and adding to that plant as circumstances require.

(ii) Full availability exists where all the sources of traffic at one stage have access to every trunk to the next stage.

(iii) Interconnecting is the name given to any method of connecting level multiples together when the availability is limited, so that sets of trunks available from different shelves are partly common to each other.

(iv) Grading is a method of interconnecting in which the outlets are always searched in an invariable order.

(b) The answer should contain any two of the following:
- (i) To facilitate the tracing of calls.
- (ii) To reduce congestion of tie cable circuits.
- (iii) To minimise crosstalk due to the capacity between bank contacts.

QUESTION 7.

(*a*) *The symbols in Fig. 7 are used in crossbar circuits. Briefly state their meaning.*

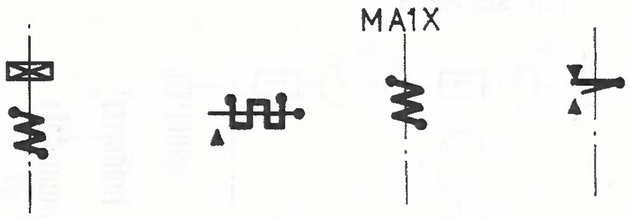


Fig. 7

(*b*) *Explain briefly the use of the following types of diagrams in crossbar circuitry —*
- (*i*) *Block diagrams.*
- (*ii*) *Survey diagrams.*
- (*iii*) *Grouping plans.*

ANSWER 7.

(a) Reference Fig. 7 (left to right):
- (i) Slow operate (or armature end slugged) relay.
- (ii) Thermal relay.
- (iii) Miniature relay mounted in place of the right-hand springset on the MA1 relay.
- (iv) Make before break contact.

(b) (i) To indicate the relationship between groups of apparatus.

(ii) To give an overall appreciation of the operation of a complete phase or stage.

(iii) A type of trunking diagram to show the connections between crossbar switches and devices or between partial switching stages.

QUESTION 8.

(*a*) *The trunking diagram for an ARK511 type exchange is given in Fig. 8.*

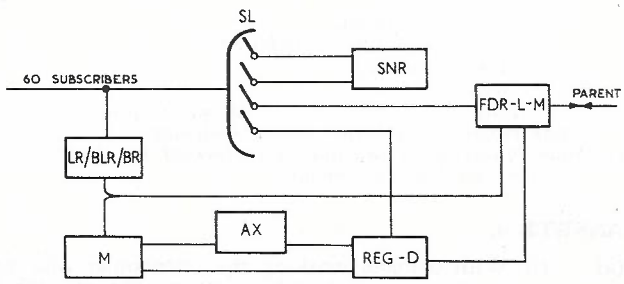


Fig. 8

Use the diagram to answer the following questions:—
- (*i*) *Which relay set provides battery feed to the A and B parties on a call between two local subscribers?*
- (*ii*) *How many SL switches are provided for a capacity of 60 subscribers?*
- (*iii*) *What is the function of the AX relay set?*
- (*iv*) *State the type of parent which uses an FDR-L-M relay set.*
- (*v*) *Which piece of apparatus provides dial tone to a local subscriber making an outgoing call?*
- (*vi*) *What type of metering is employed in ARK511 type exchanges?*

(*b*) *Explain briefly what is meant by the term 'vertical jump' in connection with the operation of an ARK511 type exchange.*

(*c*) *Give an example of a national number for a subscriber situated in a 5 digit local closed numbering scheme. Which is the 'B' digit in your example?*

(*d*) *Define the terms—*
- (*i*) *Minor trunk switching centre.*
- (*ii*) *Terminal switching centre.*

ANSWER 8.

(a)
- (i) SNR.
- (ii) 3.
- (iii) To determine and record the subscribers' classification.
- (iv) Manual parent.
- (v) Reg-D.
- (vi) Positive battery OR discharge of capacitor.

(b) The transfer of a connection from one device (for example, a connection to Reg-D) to another device (for example, an SNR relay set).

(c) Example: 05934 — 3021. Digit 9 is the B digit.

(d) (i) A Minor trunk switching centre switches the final routes for terminal exchanges only.

(ii) A Terminal switching centre is one which performs no through switching of inter-exchange circuits.

QUESTION 9.

(*a*) *List six (6) safety precautions you would take to prevent fire damage in a telephone exchange.*

(*b*) *What important features should be watched to reduce the fire risk due to incorrect connection of number unobtainable (N.U.) tone to a subscriber's line?*

(*c*) *Number unobtainable tone is connected to cancelled subscribers' services upon removal from changed number facilities. List two other cases in 2,000 type exchanges where N.U. tone is used.*

ANSWER 9.

(a) The answer should contain any six of the following points:—

(i) An adequate number of fire extinguishers in working order should be situated in good locations.

(ii) A check should be made each day to ensure that personnel are not smoking in the last hour before ceasing duty.

(iii) All electrical fuses in use should be of the correct rating for the circuit concerned.

(iv) A check should be made each day before ceasing duty to ensure that all electrical appliances, such as soldering irons, radiators and lamps, are disconnected.

(v) The use of flammable liquids should be carefully controlled and they should be clear of the installation.

(vi) An adequate sign should be displayed in the battery room indicating the precautions necessary to prevent explosions and these precautions should be supervised.

(vii) All equipment alarms, such as release alarm, indicating conditions which might result in fire, should be checked immediately power is connected to the equipment, and at reasonable intervals thereafter.

(viii) Accumulations of rubbish should be avoided, as they may be ignited by the careless disposal of matches and cigarettes, or by spontaneous combustion.

(b) (i) The possibility of a low resistance battery feed due to the excessive paralleling of relay coils should be avoided.

(ii) Care should be taken to see that the cords which connect N.U. tone battery feeds to particular lines are not left in a position where an accidental earth connection can initiate a heavy current flow.

(c) Any two of the following:—

(i) Unallotted lines.

(ii) Unallotted levels of switch ranks.

(iii) Faulty lines when the fault duration will be very long.

(iv) Cancelled lines when no redirection of the call is required.

QUESTION 10.

(a) Sketch the simplified diagram for each of the following testing conditions performed from a test desk in an automatic exchange. Include in your diagrams the keys operated for each of the tests.

(i) Insulation resistance test.

(ii) Capacity test.

(iii) Test for earth on the positive (+) line.

(b) Explain briefly the test procedure and test desk operations for testing the percentage make ratio (weight) of impulses received from a subscribers' dial.

(c) Explain the principle of the impulse speed test on a standard test desk.

ANSWER 10.

(a) Suitable diagrams of the testing conditions concerned will be found in the Course of Technical Instruction, Telephony 4, paper 8, page 20, Figs. 16(c), 16(d), and 16(f). However, the value of the test battery shown in Fig. 16(c) should be changed to 250v.

(b) The following points should be contained in the answer:—

(i) The telephone under test is connected to the test circuit and the Impulse Weight key (KIW) is operated.

(ii) The dial is held off-normal for a short period while the test desk controls, RI and RX, are adjusted to obtain a voltmeter deflection of 100 per cent.

(iii) The reset key (KWR) is momentarily operated when the dial restores to normal to reset the voltmeter to the 30 per cent. mark.

(iv) A large number digit (0) is dialled while the voltmeter deflection is observed. The deflection obtained while the pulse train is in progress represents the make ratio of the dial.

(v) The reset key is again operated momentarily at the end of the pulse train when a further test is required.

(c) The impulse speed test depends on the discharge pulses of current from two capacitors through the heavily damped voltmeter. The capacitors are alternately charged and discharged under the control of the dial pulse springs; one capacitor charging while the other is discharging through the voltmeter.

As the charge and discharge times of the capacitors are fast enough to be independent of the make-to-break ratio of the dial pulse springs, the current pulse through the voltmeter is the same for each discharge. Because the voltmeter is heavily damped it records the average value of the voltage drop due to this current, and the average depends on the proportion that each current pulse bears to the time of no current; that is, the time elapsing before the next pulse is received. When, for example, the speed of pulsing is slow, the discharge pulses are separated by comparatively long intervals and the voltmeter needle tends to restore to zero after each discharge

QUESTION 11.

Use the circuit of a large group P.B.X. final selector (100 line) Drawing CE11315 to answer this question. (A copy of this circuit was attached to the question.)

(a) Draw the symbols in the circuit which represent:

(i) 11th contact bank wires.

(ii) 1st set of 11th step contact springs.

(iii) The first to make contact on the 5th contact set of relay F.

(iv) Positive battery.

(b) Describe in detail the electrical circuit operation from the time a free line is reached during the hunting operation, and up to and including the connection of ring current to the selected line.

(c) When are large group P.B.X. final selectors provided for subscribers?

ANSWER 11.

(a) See Fig. 9 (Left to Right).

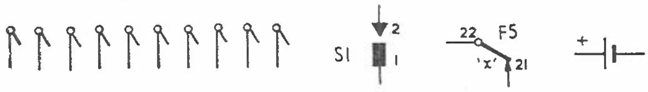


Fig. 9

Examiner's Note: Question a (iii) incorrectly asked for 'the first to make.' All candidates who attempted this question were given marks for this section.

(b) G is operated by the rotary interrupter contacts at the end of the rotary step and when the P1 wiper reaches a free line, G holds in series with H over the P1 wire to battery via 1300 ohms. H operates; H3 locks H on its 400 ohm winding to earth at B6, H1 and H4 connect the circuit through to the negative and positive wipers, and H6 opens the rotary magnet circuit to prevent further stepping. H5 earths the P1 wire to busy the line and also to operate the cut-off relay in the line circuit when this is a two-way line. This earth also short-circuits the 900 ohm winding of H and the d-e winding of G; H holds on its 400 ohm winding, but G releases slowly. G2 opens the circuit of HS, which releases slowly. HS6 completes the circuit to operate J via HS6, H2, E6, HS3, NR2, N2 to earth at B6.

J1 connects ringing current to the negative side of the called line via the 300 ohm winding of F and J2 completes the ringing circuit by connecting ring return battery to the positive side of the line. J4 connects ring tone via F3, J4 and G3 to the 570 ohm winding of A relay.

(c) Large group final selectors are provided when the subscriber requires many more than 10 lines in one group and does not want more than one rotary group. Borderline cases with between 10 and 16 lines are often connected to 2-10 P.B.X. final selectors, but groups of lines of approximately 16 or more are normally connected to large group final selectors.

QUESTION 12.

Fig. 10 is a typical grouping plan for a GV unit in an ARF crossbar exchange. The diagram should be used where applicable in answering the question.

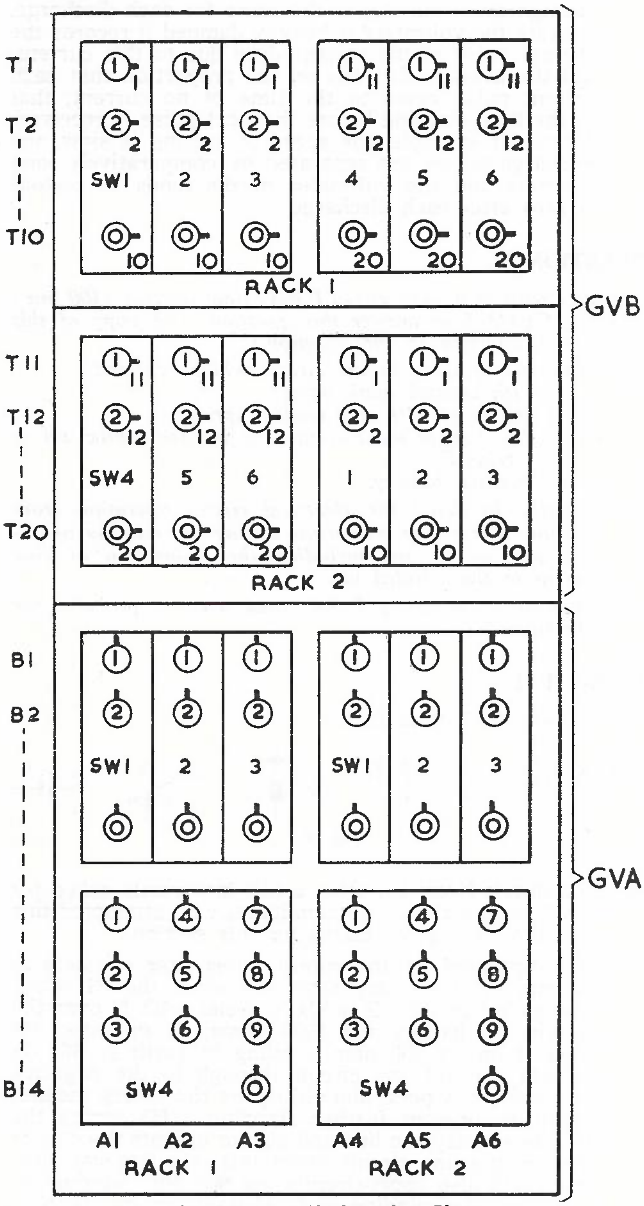


Fig. 10 — GV Grouping Plan

(a) State the number of:—
(i) Inlets to the GV unit.
(ii) Outlets available from the GV unit.
(iii) GVA switches on each GV rack.

(b) How many wires form:—
(i) An outlet circuit.
(ii) An inlet circuit.
State the function of each wire.

(c) The symbols T1 to T20 on the diagram refer to relays in the GV marker. Give the main function of these relays.

(d) The switch magnets used to switch a call within a GV stage having 20 routes each with an availability of 20 were:—
H1, HB and V2 of GVA switch 3 on rack 1.
HO, HA and one of the verticals of a GVB switch.
State
(i) The vertical and switch used in the GVB stage.
(ii) The circuit number and route number used for the call.

ANSWER 12.

(a) (i) 80. (ii) 400. (iii) 4.

(b) (i) 4: a and b are speaking wires.
c is for guarding.
d is for testing, identifying and holding.
(ii) 6: a and b are speaking wires.
c is for guarding.
d is for testing, identifying and holding.
e and f wires are for by-path testing from the SL stage via SR to the GV inlet.

(c) The T relays are test relays and indicate free outlets within a particular route.

(d) (i) V1, GVB6, Rack 2.
(ii) Circuit 11 of route 10.

QUESTION 13.

(a) Explain briefly the symbols in Fig. 11 when used in grouping plans for crossbar equipment.

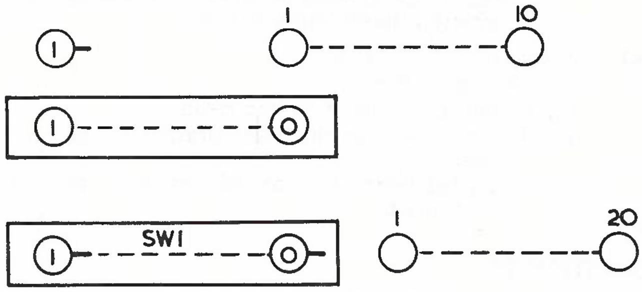


Fig. 11

(b) List four (4) main functions of an ARF102 SL stage marker when used for incoming traffic.

(c) In an ARF102 crossbar exchange (capacity M = 8), how many SLA crossbar switches are provided to serve a 1,000 line fully equipped group?

(d) Explain briefly why the multiple is transposed between the odd and even SLA switches.

ANSWER 13.

(a) Reference Fig. 11, from top to bottom:
(i) One vertical (vertical 1) with 10 outlets.
(ii) One switch with 10 verticals.
(iii) No. 1 switch with 10 verticals and with all 20 outlets multipled.

(b) (i) To identify the calling inlet.
(ii) To receive information about the required number.
(iii) To test the condition of the required subscriber's line (busy or free).
(iv) To connect the calling circuit to the desired number.
(v) To return information regarding the called number to the originating register.

(c) 40.

(d) To distribute the traffic evenly over available devices and decrease the possibility of internal congestion.

QUESTION 14.

(*a*) *Sketch the trunking diagram for a 50/200 line A.P.O. type C rural automatic exchange.*
(*b*) *What indication is given to a manual operator at the parent exchange of a 50/200 A.P.O. type R.A.X., when answering a call from a public telephone connected to the R.A.X.?*
(*c*) *State four (4) methods which have been used to supply power to R.A.X.'s when local commercial power is not available at the exchange location.*

ANSWER 14.

(a) A suitable diagram is given in the Course of Technical Instruction, Telephony 5, Paper 8, Fig. 7.
Auxiliary relay sets, start leads and the figures showing the provision of each item of equipment are not required.
(b) When the call is answered the operator receives ring tone for 12-15 seconds.
(c) (i) Charge over trunk lines.
(ii) A wind driven generator.
(iii) A petrol or diesel electric generator set.
(iv) Transporting charged batteries from a station with charging facilities.
Examiner's Comment: Marks were also given for answers which clearly indicated P.T. tone conditions as used in some States.

QUESTION 15.

(*a*) *List four (4) advantages claimed for the use of enclosed type cells over open cells as secondary batteries associated with telecommunication power plant.*
(*b*) *Explain briefly the difference between the terms 'charge-discharge' and 'floating' when applied to the operation of batteries.*
(*c*) *Explain briefly why the 'floating' method of operating batteries is preferred.*

ANSWER 15.

(a) The answer should contain any four of the advantages listed in the Course of Technical Instruction, Telephony 5, Paper 1, Page 2, Para. 2.5.
(b) In charge-discharge working duplicate batteries are provided and one battery is charging while the other battery is discharging and supplying the load.
With floating, the battery and the conversion plant are connected in parallel across the load and operated continuously at a constant voltage.
(c) The answer to this question is contained in the Course of Technical Instruction, Telephony 5, Paper 2, Page 16, Para. 6.1.

QUESTION 16.

(*a*) *What is the purpose of a service alarm in an ARF exchange? List the items of equipment supervised by this alarm.*
(*b*) *What information is obtained from the analysis of the permanently connected statistical meters associated with the 1GV stage of an ARF exchange?*
(*c*) *A service alarm has operated in the GIV stage in an ARF exchange. The cause of the alarm is assumed to be an open circuit W relay on Rack 1 of the GIV stage. Describe briefly the steps you would take to locate this fault and the use you would make of:—*
(i) The resettable meters on the Maintenance Control Rack.
(ii) A lamp set.
(iii) The exchange tester.

ANSWER 16.

(a) The service alarm is normally the most immediate indicator of any serious malfunctioning of the common control equipment, and permits service staff to initiate corrective action at the earliest possible time, usually before subscribers' complaints are received. The following equipment is supervised by this alarm—SL markers, GV markers, CD code receivers, code sender finders, KSRs and registers.
(b) The permanently connected meters associated with the 1GV stage provide the following information:—
(i) Calls handled by each marker, i.e., traffic balance.
(ii) 'Time outs' in each marker. This enables the performance of the marker to be checked against other similar markers on the expected performance figure. It also enables the effect of corrective action re fault repair to be assessed.
(iii) It indicates the incidence of congestion. This could be associated with local routes, links or the last choice routes. To be effective, congestion readings should be taken at half-hourly intervals during the busy hour over at least three days.
(c) This question was initially set with reference to the GIV survey diagram CE14371. In this diagram the 'WK3' relay, which calls in the marker, is shown as operated from the contacts of the route ('W') relays on GVA/B rack 1.
In practice, however, it is the W relay contacts on rack 2 which operate the WK3 relay to call in the marker. Under these conditions the effect of an open W relay coil on rack 1 would result in no-progress calls to that particular route. This fault condition will be detected by subscribers' complaints or test calls. It will not cause the operation of a service alarm at the GIV stage.
Should the faulty relay be on rack 2 the marker is not called in, as WK3 relay will not operate and the KMR will time out. Repeated calls to this route will cause the operation of a service alarm.
As the question indicated that a service alarm had operated, the following action would be taken.
(i) Connect the resettable meters associated with the service alarm group. These meters are mounted on the service control rack. The readings will indicate:
(a) The particular GV stage which is faulty.
(b) That 'time-outs' are equal and high on both KMRs (assume two KMRs used).
(c) The incidence of time-outs to calls could indicate a fault in the marker, a faulty route, or a faulty inlet.
(ii) If available, connect a lamp set to the GIV marker. This will indicate:
(a) Inlet identification complete.
(b) Routing information stored in KMR.
(c) WK3 relay is not operating to call in the marker.
As the WK3 relay is operated by contacts of the W relays on rack 2, observe the W relays under traffic or by making test calls to determine the faulty relay (assumed fault).
(iii) If a lamp set is not available, use the Automatic Exchange Tester to set up test calls and observe the operation of relays in the KMR. It will be noted that WK3 fails to operate and as this relay is operated from the W relays on rack 2, observe the relays to detect the faulty relay.

Examiner's Comment.

Candidates who were aware of the fact that a service alarm would not result from a faulty W relay on rack 1, would, on receipt of a complaint of no progress on the particular route, use the Automatic Exchange Tester to originate calls on this route from each GIV stage, to determine the location of the fault. In this case the marker would complete its function, but the horizontal bars on the GVB switches which, are operated by the W relay contacts on rack 1, would not be operated. A lamp set would not assist in the location of the fault.

Examination No. 5631, July 1967, to gain part of the qualifications for promotion or transfer as Senior Technician (Telecommunications), Postmaster-General's Department.

TELEPHONE SUBSCRIBERS' EQUIPMENT.

QUESTION 1.

CE-11201 is a diagram of an 801 telephone. Briefly describe, with the aid of simple schematic sketches, the current flow in the induction coil windings and the transformer action that takes place at a particular instant when:

(*a*) *Speaking on the telephone.*

(*b*) *Receiving (listening) on the telephone.*

ANSWER 1.

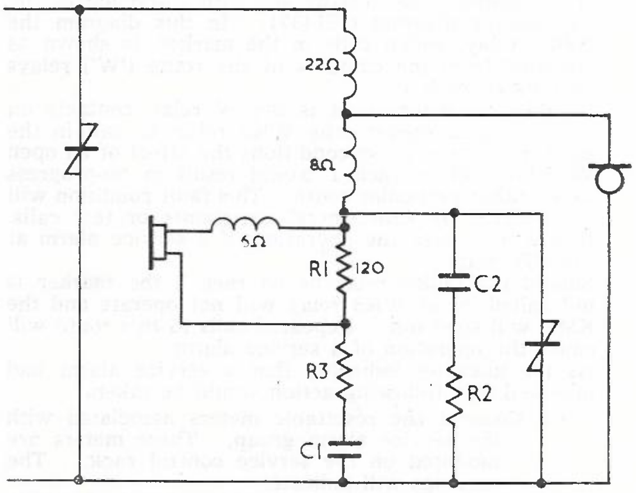


Fig. 1 — Transmission Circuit.

(a) When the handset is lifted, d.c. from the exchange passes through the loop circuit comprising the 22 ohm winding of the induction coil and the transmitter. The a.c. speech component from the transmitter divides so that part flows through the local network via the 8 ohm winding of the induction coil and part to line via the 22 ohm winding. The varying current through the 8 ohm winding produces the greater flux and a step-up transformer action takes place, with the 8 ohm winding acting as the primary on the transformer.

The flux variations in the 8 ohm and 22 ohm windings induce an e.m.f. in the 6 ohm winding, which tends to produce a sidetone current in the receiver. The voltage across the 120 ohm resistor opposes the induced e.m.f. and produces a degree of sidetone suppression.

(b) The major part of the received speech passes through the 22 ohm winding and the transmitter. Transformer action between the 22 ohm and 6 ohm windings causes current to flow in the local receiver circuit. Any current flowing in the 8 ohm winding results in a transformer action which assists the receiver current.

QUESTION 2.

(*a*) *A subscriber has a 400 ADT telephone connected as an extension to a P.A.B.X. The extension in question is located in a workshop with a high level of room noise. The subscriber has complained that the high level of sidetone is making it difficult to use the extension.*

Suggest a more suitable telephone for this location, giving brief reasons for your choice.

(*b*) *Following a report from a subscriber, his dial and line have been tested. The dial has indicated that the subscriber's dial has an incorrect ratio. You know that the dial in this telephone is one of the original BTM dials and the only replacement dials available are BPO type No. 21. Under these circumstances, what additional spare parts must the fault technician take to the fault? Briefly give the reasons for your choice.*

ANSWER 2.

(a) An 801 series telephone would be more suitable for this location. Two voltage dependent resistors (V.D.R.) are used in the 801 series telephone, the line V.D.R. acting as a shunt across the line and the network V.D.R. acting as a shunt across the balance network. The network V.D.R. helps to produce an improved sidetone suppression by shunting the network so that a balance is achieved with the combined impedance of the line and the line V.D.R. This effect gives an improved sidetone suppression on short loops and results in an improved performance in noisy locations.

(b) The technician must not attempt to correct the ratio in the field and therefore the dial must be changed. In addition to the replacement dial, the technician would need either a complete set of mouldings or a replacement number ring, as the BPO type No. 21 dial and the original number ring do not match.

Note. — In the past, replacement number rings have not been purchased, so that generally a complete set of mouldings would be required. At many locations the complete telephone is changed.

QUESTION 3.

CE-11040, Sheet 1, is a circuit drawing for a two button type Multicoin Public Telephone. Describe briefly the functions of:

(*a*) *Relay A.*

(*b*) *Relay B.*

(*c*) *Refund springsets (RF).*

(*d*) *Coin tin alarm springsets (CTA).*

(*e*) *The bridge network MR3 around Relay A.*

ANSWER 3.

(a) Relay A. Operates when the correct coin has been inserted and prepares to release relay B after button A is operated.

(b) Relay B. Operates to a reversal of line polarity or when the coin slot springs are operated. When relay B is operated it prevents any conversation by shunting the receiver and part of the A.S.T.I.C. network. It is released by the insertion of the correct coin and the restoration of the coin slot springsets when button A is operated.

(c) Refund Springset RF. Operates when button B is pressed and remains operated by an escapement mechanism for 3 - 5 seconds after button B is released. It introduces a warning tone circuit and maintains a holding loop, which prevents the caller from masking the tone by replacing the handset.

(d) Coin Tin Alarm Springset (CTA). This springset is normally operated while the coin tin is in position. When the coin tin is removed, the springset releases, preventing the telephone from being used by placing a loop across the line.

(e) The Bridge Network MR3 around relay A. This network ensures that relay A will remain operated on reversal of normal line polarity.

QUESTION 4.

Explain briefly the following features of telephone dials used in the A.P.O. network:
(a) What standards are adopted with regard to speed and ratio?
(b) Why is it necessary to maintain the speed and ratio standard?
(c) How is the speed of a dial maintained constant?
(d) Why are off normal springsets associated with a dial?

ANSWER 4.

(a) The nominal speed is 10 p.p.s. and the impulse ratio is 33-1/3 per cent. make, 66-2/3 per cent. break.
The permissible speed range is from 9 - 11 p.p.s.
The make ratio may vary between 31 per cent. - 36 per cent. for an unquenched dial and 34 - 39 per cent. for a quenched dial.

(b) Because the impulsing circuits controlled by the dial are designed and maintained to operate at standards which provide a margin of safety for the operation of selectors. The margin for ratio is reduced by distortion.

(c) By the action of a governor which is geared to the main spindle.

(d) These springsets short-circuit the receiver and transmitter when the dial is off normal. They prevent clicks in the ear while dialling and provide a dialling loop free of variable resistance.

QUESTION 5.

(a) CE-11244, Sheet 1, is a circuit diagram of the two line telephone (telephone 8201). List the service facilities that can be provided with this telephone.
(b) The telephone 8201 is delivered into the field to the drawing CE-11244, Sheet 1. The installation requires an extension bell to be fitted. This bell must not be wired in series with the existing bell, but must be in series with the buzzer. To which terminals of socket 610 is the extension bell connected and what circuit strapping changes are required?

ANSWER 5.

(a) Two lines are connected to the telephone.
They can be exchange or extension lines or a combination of both for C.B. or auto.
One of the lines may be a 4-wire extension.
The two lines cannot be interconnected.
A hold facility allows one line to be held while a call is made or received on the other line. On completion of the second call the original conversation can be resumed.
The push button key can be used as:
(i) Recall on a P.M.B.X. extension.
(ii) Hold and call on a P.A.B.X. extension.
An extension bell can be fitted in series with the buzzer, making it available to only one line at a time.

(b) (i) Wire the extension bell to terminals 3 and 4 of the socket 610.
(ii) Remove the flexible link between T3 and T4.
(iii) Transfer the R conductor of the line cord from P1 to T3.
(iv) Transfer the BK conductor of the line cord from P1 to T4.
(v) Park the 3 conductors of key KR1 together on P1.
(vi) Park spare flexible links between P2 and P3.
(Connections (v) and (vi) are not essential to the circuit operation.)

QUESTION 6.

(a) List the components required for an intercommunication service to provide for 2 exchange lines, 6 internal extensions and one external extension.
(b) Draw a block schematic diagram showing the layout of the equipment to provide the service in (a).

ANSWER 6.

(a) 6 Intercommunication Telephones No. 2 (A10) with terminal boxes.
Transfer Unit No. 3A.
Handset telephone for external extension.
Power supply (battery eliminator or equivalent).
Cable, cable clips, etc.

(b) Fig. 2 shows a typical layout.

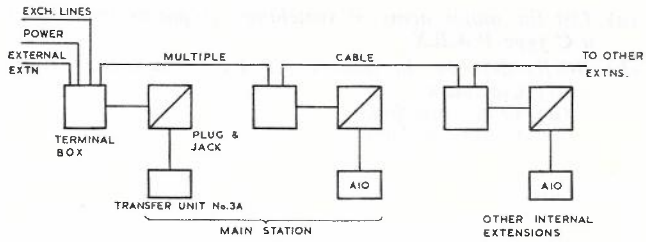


Fig. 2 — Layout of Typical Intercommunication Service

QUESTION 7.

(a) You are inspecting a new installation of an ARD520 type P.A.B.X. This requires an inspection of the crossbar switch selecting fingers. List the three checks that you would make of the crossbar selecting fingers.
(b) During the inspection of (a) you find that a crossbar selecting finger is deformed. What action should be taken to correct the condition?
(c) List three traffic facilities that may be provided on an ARD 520 P.A.B.X. by suitable strappings.

ANSWER 7.

(a) (i) Check that fingers are straight.
(ii) Check that each finger is central between the vertical lifting springs.
(iii) Check that a thinnest possible beam of light is visible between the holding bar and finger when the horizontal is brought axially up against the left-hand end position.

(b) Any deformed finger must be replaced. No adjustment must be made on the actual selecting fingers.

(c) The following traffic facilities may be provided:—
(i) Barred for outgoing traffic.
(ii) Open for outgoing traffic.
(iii) No priority.
(iv) Priority for internal traffic.
(v) Priority for enquiry.
(vi) Barred for S.T.D. (Additional equipment required.)

QUESTION 8.

CE-11240, Sheet 1, is a simplified circuit diagram for a cordless lamp signalling P.M.B.X. type 2/3A, and should be used where applicable in answering this question.
(a) What is the purpose of the automatic call trap facility?
(b) Briefly describe the principle of the 4 wire extension signalling.

ANSWER 8.

(a) The automatic call trap intercepts an incoming exchange call on a line switched to an idle extension. The signal is directed to the exchange line call lamp and not to the extension telephone bell.
On the completion of a call to an extension, the call trap circuit is connected across the exchange line when the extension handset is replaced. The extension loop is broken, relay SA releases and at SA1 releases relay SB. SB1 reoperates relay CT. CT1, 2 disconnect the connecting circuit and the extension line from the exchange line, CT3 prepares a holding circuit for relay CT, and CT4 places the AC relay across the exchange line. An incoming ring operates

relay AC, which at AC1 lights the call lamp. (Fig. 7 in the E.1 TELEPHONE, Substation C5021 shows the call trap principle.)

(b) The 4-wire extension principle is adequately described in para. 5.4 and Fig. 22 of the Miscellaneous Note MSO62 'Cordless Type P.M.B.Xs.'

QUESTION 9.

(a) List the major items of switching equipment included in a C type P.A.B.X.

(b) Briefly describe the following P.A.B.X. facilities:
(i) Call back.
(ii) Trunk offering.
(iii) Camp on busy.

ANSWER 9.

(a) (i) All relays are of the 3000 type except for the line relays, which are 600 type.
(ii) Extension to extension calls are established via link circuits (4 link selectors are provided).
(iii) Each link circuit is associated with a 25-point uniselector acting as a line finder.
(iv) Four bothway exchange lines are provided, each associated with a 50-point uniselector.
(v) Call back and transfer circuit.
(vi) Level 9 circuit and uniselector type linefinder.
(vii) Ring and tone equipment.

A description of the equipment provided in a C type P.A.B.X. is given in Section 6 of Telephony 5, Paper 7.

(b) P.A.B.X. facilities are briefly described in Course of Technical Instruction, Telephony 5, Paper 7, Section 3.

QUESTION 10.

(a) Fig. 3 shows the switching circuit for a basic 200 line capacity Pentaconta P.A.B.X., using a line multiselector which comprises a total of 19 selectors in three groups. List these three groups and briefly detail the type of traffic carried by each group.

(b) A number (31) is enclosed by circle A in Fig. 3. What does this number represent?

(c) What tones are supplied by the local link (LL) on a local call?

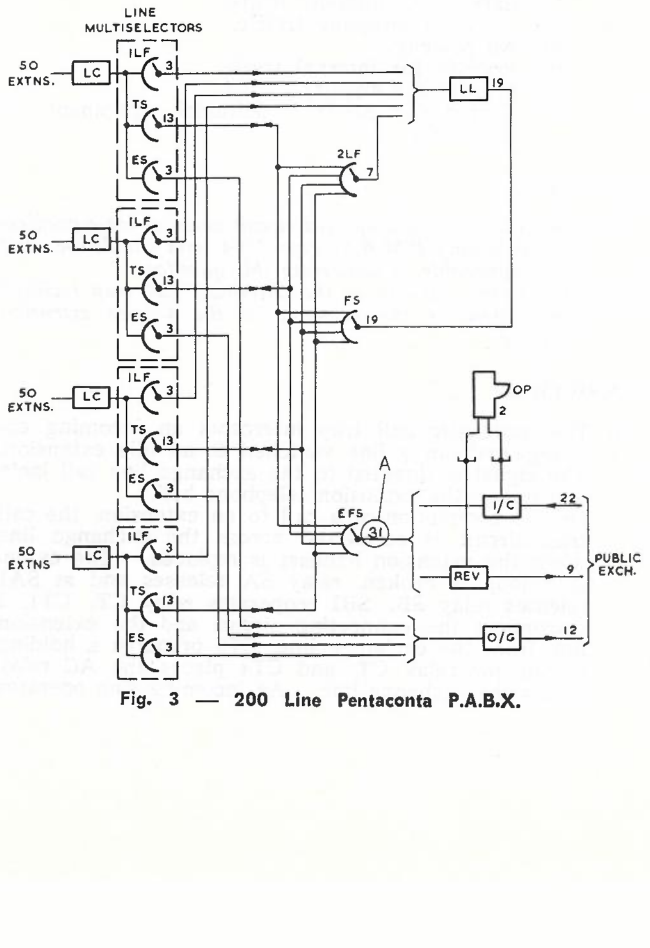


Fig. 3 — 200 Line Pentaconta P.A.B.X.

ANSWER 10.

(a) (i) 1st Line Finders (1LF), connected directly to Local Links and carrying the basic internal traffic originated within the 50 group. Up to three direct local links are provided per 50 group.
(ii) Terminal Selectors (TS). Thirteen TS are provided in each 50 group and carry all terminating traffic for the 50 group, as well as the overflow component of originated traffic.
(iii) Exchange selectors (ES). Up to three ES are provided per 50 group. They carry the basic originating exchange traffic and are connected to direct outgoing exchange line circuits.

(b) The number 31 indicates that 31 Exchange Fifty Selectors (EFS) are available for association with incoming and revertive exchange line circuits.

(c) (i) Dial tone.
(ii) Busy tone.
(iii) Interrupted ring tone.

QUESTION 11.

An earth fault exists on a cable pair between two pits approximately 50 yards apart. You have available a multimeter, a number of dry cells, earth stakes, a coil of jumper wire and a knife.
Describe how you would locate the fault using the slide wire bridge principle, and complete the circuit sketch to show your connections.

ANSWER 11.

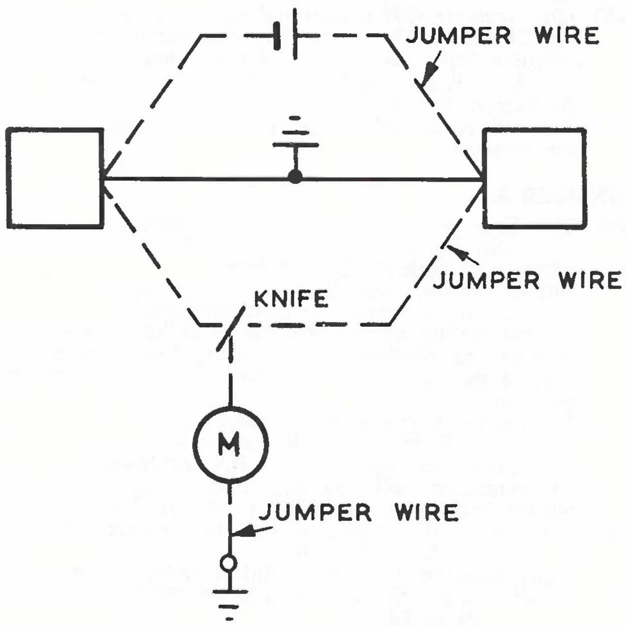


Fig. 4 — Typical Connections

The main points to be considered when proceeding to locate the fault using the connections shown in Fig. 4 are:—

(i) Disconnect the faulty line from the exchange.
(ii) Connect a battery of dry cells to the two ends of the faulty wire.
(iii) Run a separate lead of jumper wire approximately parallel to the faulty wire and connect to each end of the faulty wire.
(iv) Connect one terminal of the meter to earth via a flexible lead and the other terminal via a flexible lead to the knife.

(v) Move along the parallel lead of jumper wire, cutting the insulation at intervals with the knife so that contact is made between the lead and the meter.

(vi) When contact is made at a point opposite to the earth fault, the meter should show zero deflection, as at this point there is no difference in potential between the earth fault and the earthed meter.

QUESTION 12.

(a) The standard test desk provides circuits to enable the testing officer to test or speak to a subscriber, junction or other line connected to the exchange.
List four (4) circuits that are provided.

(b) List the tests which may be carried out on a subscriber's LINE from the test desk.

ANSWER 12.

(a) Four connecting circuits are:—
- (i) Test selector trunks.
- (ii) Trunks to M.D.F. exchange side.
- (iii) Trunks to M.D.F. line side.
- (iv) Test and plugging up lines.

(b)
- (i) Capacity test.
- (ii) Insulation Resistance test.
- (iii) Resistance test—high scale.
  —low scale.
- (iv) Earth test on either side.
- (v) Foreign battery—positive plate earthed.
  —negative plate earthed.

QUESTION 13.

(a) List the tests performed by the Line Test Robot (APR).

(b) List the complete procedure necessary in performing a dial speed test with the Line Test Robot (APR). (Include reference to tones).

ANSWER 13.

(a) The tests as listed in the E.I. TELEPHONE, Exchanges C7040, are:—
- (i) Test dial speed 10 p.p.s. nominal.
- (ii) Test dial speed 20 p.p.s. nominal.
- (iii) Test bell on full voltage.
- (iv) Test bell on half voltage.
- (v) Test leakage resistance from 'a' leg to earth.
- (vi) Test leakage resistance from 'b' leg to earth.
- (vii) Test leakage resistance between 'a' and 'b' leg.
- (viii) Test line loop resistance.
- (iv) Test control of APR.

(b) Access to the APR in a crossbar exchange is gained by lifting the receiver and dialling 199. When ring tone is heard, the receiver is replaced and a ring is received on the telephone from the APR.
To test the speed of a dial having a nominal speed of 10 p.p.s., the digit 1 followed by digit 0 is dialled.
If the dial speed is within tolerance limits of 12.5 - 8.5 p.p.s., N.U. tone will be heard. A fast dial (over 12.5) is indicated by dial tone and a slow dial is indicated by ring tone.

Examiner's Comment.

Full marks were given to candidates who gave the above tones or alternatively correctly quoted tones for the earlier model described in the article, 'Robot Test Desk,' in the Feb. 1965 (Vol. 15, No. 1), issue of this Journal.

QUESTION 14.

You are required to inspect an installation in a subscriber's premises. Detail briefly the important points you would look for while inspecting:
- *(a) Cabling.*
- *(b) Location of apparatus.*
- *(c) Records.*

ANSWER 14.

(a) See Page 5 of the E.I. TELEPHONE Substation I 0004.

(b) The main points regarding location of apparatus are listed in sections 5, 6, and 7 of the E.I. TELEPHONE Substation I 0004.

(c) See section 15 of the E.I. TELEPHONE Substation I 0004.

QUESTION 15.

Special precautions are taken to prevent the use of A.P.O. facilities for illegal purposes.

(a) List four cases where an installation should not proceed because of the likelihood of the service being used for illegal purposes.

(b) List four cases where the installation may proceed but where it is necessary to make a prompt report of the matter.

(c) What reporting procedure should the technicians follow in (a) and (b) above.

ANSWER 15.

Answers to this question may be found in Section 7 of the E.I. TELEPHONE General A 0521.

QUESTION 16.

Wall mounted P.A.B.X.'s of approved design may be installed by the A.P.O. or by private contractor.

(a) What are the accommodation standards designed to ensure?

(b) List six (6) locations which you would consider unsuitable for wall mounted P.A.B.X. equipment.

(c) If the P.A.B.X. obtains its power supply from a battery eliminator:
- *(i) What is the minimum number of mains power points that must be provided?*
- *(ii) What is the maximum length of the eliminator power cord?*

ANSWER 16.

(a) The standard of accommodation should ensure that reasonable maintenance conditions exist and that hazards are minimised. There should be no possibility of damage or deterioration as a result of the location.

(b) Some unsuitable locations are listed below:—
- (i) A riser shaft.
- (ii) A passage way or entrance hall.
- (iii) A boiler room.
- (iv) A storage room.
- (v) A garage.
- (vi) A workshop.
- (vii) A bathroom or toilet.
- (viii) A kitchen.

(c) One power point is provided for the sole purpose of supplying the battery eliminator, and at least one other outlet will be required for portable tools, etc.
- (ii) The eliminator power cord must not exceed six feet in length.

Examination No. 5633, 1st July, 1967, and subsequent dates to gain part of the qualification for promotion or transfer as Senior Technician (Telecommunications), Transmission Equipment, Postmaster-General's Department.

PART A. — LINE TRANSMISSION EQUIPMENT.

QUESTION 1.

(*a*) *The curves shown on Fig. 1 illustrate the velocity of propagation versus frequency characteristics for the following transmission lines:*
- (*i*) *200 lb./mile open wire.*
- (*ii*) *Balanced pair cable.*
- (*iii*) *Loaded cable.*

Label each curve with the type of line to which it applies.

(*b*) *What is the nominal value of the characteristic impedance of the following lines:*
- (*i*) *Open wire line at voice frequencies?*
- (*ii*) *Open wire line at carrier frequencies?*
- (*iii*) *20 lb./mile balanced cable pair at carrier frequencies?*
- (*iv*) *Coaxial cable pair?*

(*c*) *With respect to voice frequency loaded cable pairs, what are the values for the following:*
- (*i*) *Loading coil inductance?*
- (*ii*) *Nominal loading coil spacing?*
- (*iii*) *Cut-off frequency?*

(*d*) *What is the frequency bandwidth required for:*
- (*i*) *A 960 channel broadband telephone system?*
- (*ii*) *A video frequency channel to Australian TV standards?*
- (*iii*) *A high quality audio broadcast programme channel?*

ANSWER 1.

(a) See Fig. 1.

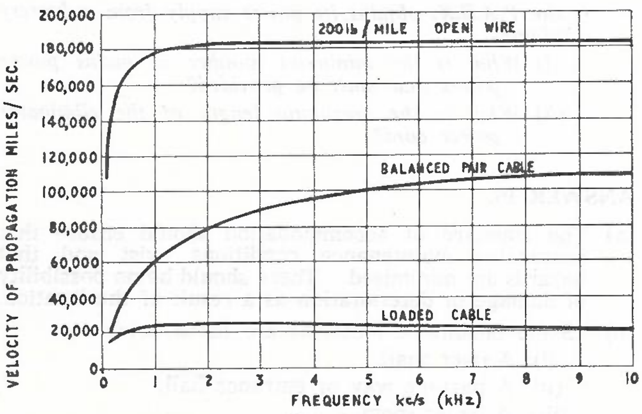


Fig. 1

(b) (i) 600 ohms.
(ii) 600 ohms.
(iii) 135 or 150 ohms.
(iv) 75 ohms.

(c) (i) 88mH.
(ii) 6000 feet.
(iii) 3.4 - 4kHz.

(d) (i) 60kHz to 4028kHz.
(ii) 30Hz to 5MHz or d.c. to 5MHz.
(iii) 50Hz to 10kHz or 50Hz to 15kHz.

QUESTION 2.

(*a*) *In the block schematic of a Pulse Echo tester for the location of line faults, label each of the blocks.*

(*b*) *Describe briefly, with the aid of a diagram if necessary, the pulse which is transmitted. What effect would variation of the pulse width have on the test results?*

ANSWER 2.

(a) A suitable answer to this question is Fig. 3 of the Miscellaneous Note, MLR 036, Pulse Echo Testing.

(b) Because of its shape, the pulse transmitted to line is known as a Sine Squared or Raised Cosine pulse. (See Fig. 2.) An important characteristic of this pulse is its limited frequency spectrum. The narrower the pulse width the greater the frequency bandwidth and vice versa.

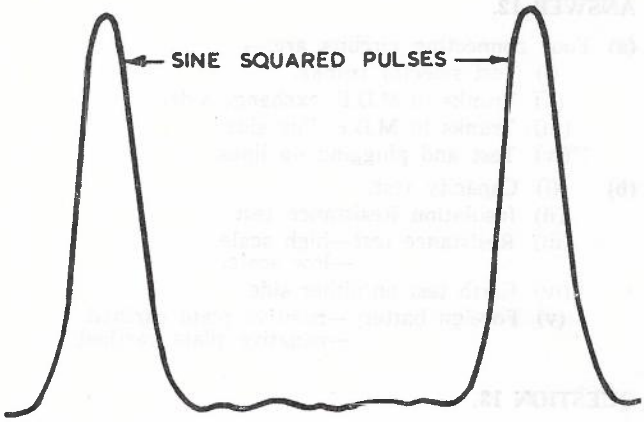


Fig. 2

Greater accuracy can be obtained with a narrow pulse width, but this requires a wide frequency bandwidth which may be greater than that of the line to be tested. When the pulse bandwith is greater than that of the line under test, 'ringing' occurs which can obscure the test trace. The pulse bandwidth is sometimes limited to reduce pulse loss and interference into other circuits. In general, as narrow a pulse as possible is used within the frequency limits of the line to be tested.

QUESTION 3.

(*a*) *Show with the help of a diagram, the method of direct connection of supergroups between two broadband systems. Explain clearly the purpose of any special equipment which might be necessary. (Show, on your diagram, the levels and frequency range at the connecting points.)*

(*b*) *What type of wiring is used for the cross connections on the S.G.D.F.?*

ANSWER 3.

(a) Fig. 28 in the Course Paper, CP 225, Broadband Terminal Equipment, is a suitable diagram for this answer.
Through supergroup filters and pads or amplifiers are added as shown in the diagram. The through supergroup filters restrict the frequency range passed to 312 - 552kHz to prevent frequencies beyond this range from causing interference to channels in the adjacent supergroups. The pads or amplifiers are required to give suitable level adjustment.

(b) Solid dielectric coaxial jumpers.

QUESTION 4.

Draw a block diagram of 12 channel modem equipment using two modulation stages and including inbuilt out-of-band signalling. Show frequencies at all main points of the circuit and test levels and impedances at MOD. OUT (Group) and DEMOD. IN (Group).

ANSWER 4.

A suitable diagram is Fig. 6 of the Course Paper, CP 222, Twelve Channel Modem Equipment. The frequencies at the main points in this circuit are:

MOD. IN — Voice frequencies (300Hz - 3.4kHz).

Input to Sub-Group Mod. — 12kHz - 24kHz.

MOD. OUT (Group) — 96kHz - 108kHz (Sub-Group 1 assumed).

DEM. IN (Group) — 96kHz - 108kHz (Sub-group 1 assumed).

Output of Sub-Group Dem. — 12kHz - 24kHz.

DEM. OUT — 300 Hz - 3.4kHz.

The impedances and test levels at MOD. IN (Group), and DEM. OUT (Group) are as follows:

MOD. OUT (Group) 135 ohms, —42dBr or 150 ohms, —36.5dBr.

DEM. IN (Group) 135 ohms, —5dBr or 150 ohms, —30.5dBr.

QUESTION 5.

All 3 channels of a three channel open wire carrier system are reported as noisy simultaneously. Give typical causes of this fault condition and describe the methods of locating and correcting them.

ANSWER 5.

Possible Causes: As the trouble affects all three channels, the fault would be in the bearer, or in equipment common to all channels.

A bearer fault could be an intermittent contact, a faulty joint, or a severe unbalance of the line. It could possibly be crosstalk from a system, which is 'howling' on the same route.

An equipment fault could be in any of the equipment from the M.B.F.'s to the bearer and from the bearer to the D.B.F.'s at the terminals, or in any of the system equipment at a repeater station. Equipment troubles which could cause noise in the channels are dry joints, faulty valves and transistors, oscillating amplifiers, dirty jack contacts, contacts due to loose wires, faulty capacitors, and disconnected earths. A noisy power supply, for example due to a disconnected filter capacitor, at either terminal or at any repeater station could also cause the fault.

Location and Correction: Listening tests on the channels and on the physical bearer would give a preliminary indication as to whether the physical is faulty or whether the fault is confined to the channels. In certain cases some bearer sections do not appear at the terminals, and it would then be necessary for a check of the bearers to be made at the intermediate stations.

If the bearer were found to be faulty by listening tests, the system would be patched to a spare bearer, if available, and the line fault located in the normal way. Long distance systems with repeaters are usually equipped with A.G.C. and most bearer troubles would be indicated by this equipment; the faulty physical section being the one before the first station at which a received A.G.C. pilot is abnormal.

If it is doubtful whether the trouble is due to a bearer, the system would be checked by terminating at Mod. In of a channel at each terminal in turn and listening at the Demod. Out or Hyb. Line at the other terminal to see whether the noise exists in one or both directions. The faulty station (or bearer section if still in doubt) is located by opening or terminating the bearer at the line filter jacks at a terminal while listening on a noisy channel. If the noise disappears when the bearer is opened or terminated at the terminal station, it is not in the receive equipment at the station. This form of location can be continued by opening or terminating the line at successive intermediate stations and at the distant terminal.

After localisation to a station, the fault is passed to that station for attention and the faulty equipment would be located in a similar manner, for example, by listening to a channel at a receive terminal station and opening or short-circuiting equipment items working away from the listening point. At a repeater station or sending terminal a T.M.S. connected to the system output in the direction concerned would be used as a detector instead of listening on a channel. Faulty jacks, wiring or dry joints found by this method would be repaired. Use should be made of any spare equipment panels available for substitution. If the trouble is in an amplifier the components should be checked for dry joints or loose connections. Valves or transistors should be checked. Wiring and joints would be inspected carefully and wires moved near the joints to see if this makes the noise vary in level. If the trouble is still not located and appears to be due to a dry joint, a test tone would be applied at the input to the amplifier and observed on a meter at the output. All components should be tapped, for example, with a pencil, and wiring moved until a variation is observed. If the trouble is due to the failure of components, the faulty item could be located by observation of power supply voltages at valve sockets, at transistors, across resistors and transformers, etc., and by testing individual components for open circuits or by substitution.

QUESTION 6.

(*a*) *Draw a simplified diagram illustrating a negative impedance repeater. Give a brief description of each major item of equipment.*

(*b*) *Give the reasons for the use of combined series/shunt repeaters in preference to series or shunt units only.*

ANSWER 6.

(a) See Fig. 3.

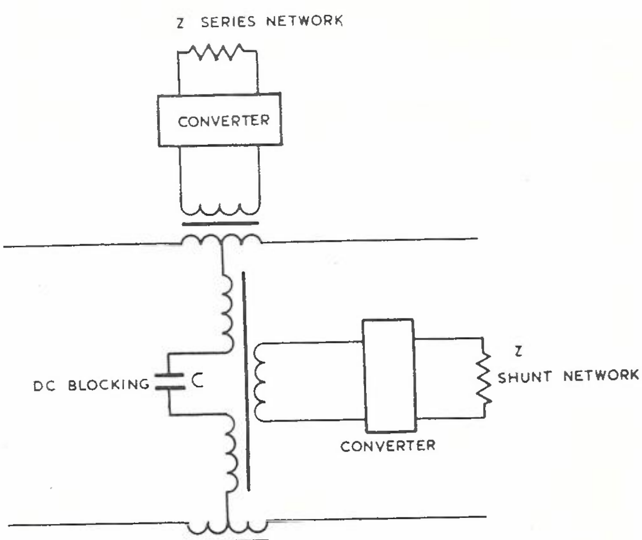


Fig. 3

The basic negative impedance repeater consists of four main parts. These are:

The transformers, which couple the series and shunt converters and networks to the telephone line. The series transformer allows a d.c. signalling path.

The converters, which use electron tube or transistor amplifiers with controlled positive feedback to provide gain without circuit oscillation or 'singing.'

The networks, which contain inductance, capacitance and resistance of selected values such that when they are connected to one pair of terminals of the converters, the negative impedance produced at the other pair of terminals of the converters provides the required gain and matches the line impedance.

The d.c. blocking capacitor, which prevents the shunt transformer from 'looping' the signalling circuit.

(b) A series or shunt negative impedance introduces an impedance mismatch in the line (the extent of this is proportional to the gain), and can only be used to obtain low gain while still providing good return losses. The combined series/shunt repeater can provide good return losses and relatively high gain. The unit can be made to have an image impedance matching the mean curve of the line impedance and also independent of gain.

QUESTION 7.

(a) The diagram below is a block schematic of a single channel of a rural carrier telephone system terminal suitable for multimetering. Clearly designate each block with symbols or words and label any other parts of the diagram (inputs, outputs, etc.) necessary for clarification.

(b) Assuming the channel shown is required to be compatible with standard 3 channel and 12 channel systems on other wires of the route, what are the upper and lower frequency limits of the SEND and RECEIVE CHAN B.P.F.'s?

(c) Describe briefly the purpose and principle of operation of the compressor and expandor.

ANSWER 7.

(a) Fig. 7 in the Miscellaneous Note, MLR 031, Rural Carrier Telephone Systems, is a suitable answer to the question.

(b) When rural, three and twelve circuit systems are operated on the same pole route it is normal to avoid the use of channels of the rural system having the same frequency range as the three-channel system for the opposite directions of transmission. It is also necessary to use rural channels falling in the same frequency ranges, A - B and B - A, as the twelve channel system; for this reason a 'grouped' rural system must be used. Although a nominal channel frequency allocation is made, it is possible for any frequency allocation to be allotted to any channel. The explanation is not required in the answer. Any of the following frequency allocations are satisfactory:

A-B Direction: 92 - 100kHz, 100 -108kHz, etc., to 164 - 172 kHz; or 96 - 104 kHz, 104 - 112kHz, etc., to 168 - 176kHz.

B-A Direction: 20 - 28kHz, 28 - 36kHz, etc., to 76 - 84kHz; or 20 - 28kHz, 28 - 36kHz, etc., to 80 - 88kHz. (36 - 40 kHz not allotted.)

(c) A compandor is a combination of a volume range compressor and a volume range expandor and its purpose is to improve signal to noise ratio on a telephone circuit. The compressor is connected in the voice input circuit to compress the volume range of speech signals by offering loss to high level signals and gain to low level signals. The expandor is connected in the voice output circuit and performs the opposite functions to the compressor to restore the volume range of the voice signals back to their original range, and in so doing reduces the level of noise received.

QUESTION 8.

(a) What value of crosstalk is considered the minimum for the station cabling of the more common types of long line equipment?

(b) Name two methods by which satisfactory crosstalk can be achieved between screened pair cables carrying frequencies up to 150kHz (kc/s) at different power levels.

(c) What practices are applied to d.c. power distribution systems from which long line equipment is to be supplied in order to ensure a satisfactory noise and interaction crosstalk performance?

(d) What is the standard method of designating row and rack positions in a long line equipment installation?

ANSWER 8.

(a) 70 db.

(b) Satisfactory crosstalk can be achieved by physical separation of screened cables. This separation concerns frequency groups and levels and can be brought about by the uses of ducting or separation on runways.

(c) Noise and interaction crosstalk is reduced by the connection of decoupling units at selected points in the power distribution system. A main decoupling unit is provided at the power distribution panel and a local decoupling unit is provided at the input to each lateral feed. In addition the earth busbars of all lateral feeds are interconnected at the lateral row ends.

(d) All rows are designated numerically starting from the front left-hand side of the installation. When a centre aisle is provided each half row is given a separate number. The racks are designated alphabetically from left to right viewed from the front. When a centre aisle is provided the racks for each side are designated separately. Fig. 4 illustrates simple row and rack designations for a station with a centre aisle.

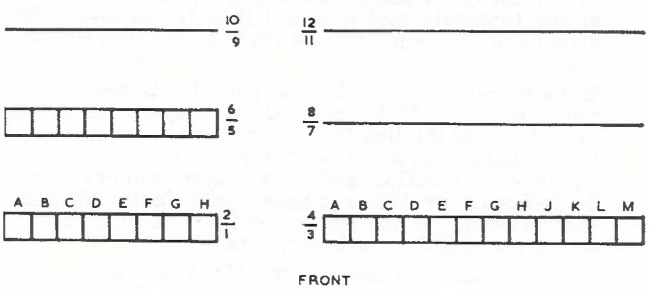


Fig. 4

PART B — RADIO COMMUNICATION EQUIPMENT

QUESTION 13.

Describe the construction of a corner reflector aerial, a two-element yagi aerial and a rhombic aerial. Give the approximate gain and 'front-to-back' ratio of each aerial system.

ANSWER 13.

(i) A corner reflector aerial (see Fig. 5) comprises a nominal ½ wave-length dipole in front of a reflector. The reflector is two metallic planes forming an angle usually 90°, but may be 360°/N where N is an integer. It may be either metal sheet or formed by close spaced rods parallel to the dipole element. The leg length of the reflector is not critical but should be 2 wave-lengths or longer. The width should be about 0.6 wave-length and the spacing between the dipole and the apex of the reflector should be between 0.1 and 0.25 wave-lengths. The gain is approximately 12dB reference a dipole in free space, and the front to back ratio is about 20dB.

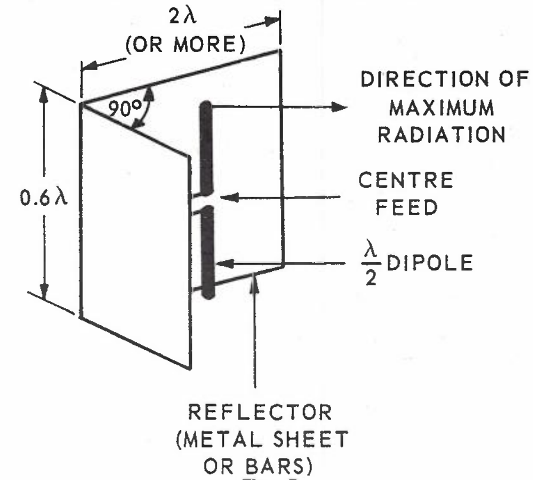


Fig. 5.

(ii) A typical two-element yagi aerial comprises a nominal ½ wave-length dipole spaced approximately 0.2 wave-length in front of a passive reflector element. The reflector element may be a self-supporting continuous tube attached to the main support. The electrical length of the reflector is approximately ½ wave-length plus 5%, that is, it is inductive in reactance (see Fig. 6). (Alternatively, a passive director element which is electrically shorter than ½ wave-length may be mounted in front of the dipole, and used instead of the reflector).

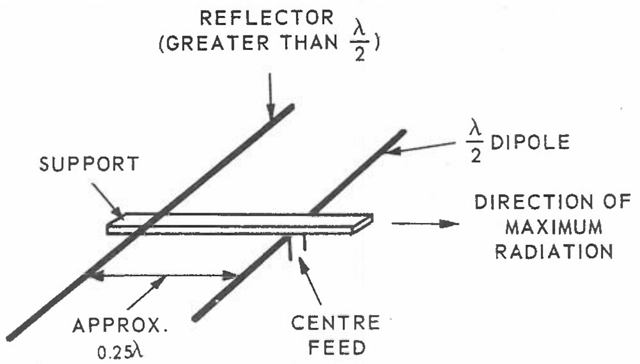


Fig. 6

The dipole may be either a simple dipole split at the centre to provide a current feed point, or a folded dipole formed from tubing insulated from the support. The impedance of the aerial is approximately 50 ohms using a simple dipole or 200 ohms using a folded dipole, as the reflector reduces a dipole's normal impedance. The forward gain is approximately 2½dB reference a dipole in free space when mounted several wave-lengths above the ground. The front to back ratio is approximately 6dB.

(iii) A rhombic aerial comprises four copper wires forming a rhombus suspended by four supporting poles (see Fig. 7). Each of the four copper wires, or legs, is at least 2 wave-lengths long at the lowest frequency and the height above ground is approximately ½ wave-length at the centre frequency of the range over which the aerial is used. A terminating resistance is connected at the end opposite to the feed connections in order to make the aerial directional. The input impedance is approximately 600 ohms over the frequency range of use. The forward gain is approximately 15dB reference a dipole in free space and the front to back ratio is approximately 12dB.

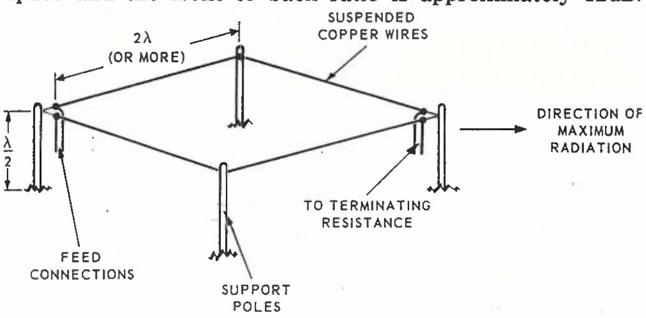


Fig. 7

QUESTION 14. (a)

Show the voltage and current distribution along a transmission line when the load impedance is a resistance, R = 2Zo. Give the standing wave ratio in terms of current.

ANSWER 14. (a)

See Fig. 8. As R is greater than Zo, the voltage standing wave is a maximum and the current standing wave is a minimum at the termination. The ratio of the reflected wave to the incident wave is—

$$\text{the incident wave is } \frac{Zt - Zo}{Zt + Zo} = \tfrac{1}{3} \therefore \text{SWR} = \frac{I\,max}{I\,min} = 2.0$$

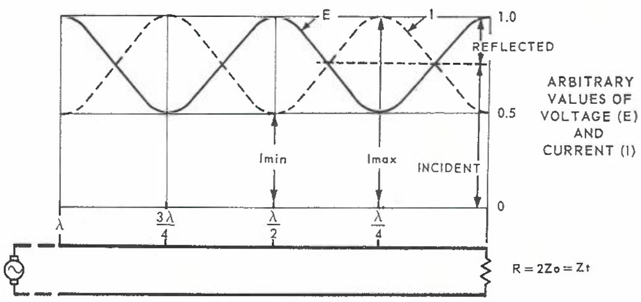


Fig. 8

QUESTION 14. (b)

Describe two different methods of impedance matching such a transmission line.

ANSWER 14. (b)

(i) A quarter-wave transformer may be used between the load and the transmission line to achieve matching (see Fig. 9).

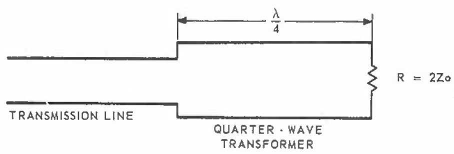


Fig. 9

The characteristic impedance of the transmission line stub comprising the quarter-wave transformer, will be equal to:—

$$\sqrt{R \times Zo}$$

where R is resistance of termination, and Zo is characteristic impedance of line.

$$= \sqrt{2Zo \times Zo} = \sqrt{2Zo^2} = Zo\sqrt{2}$$

Therefore, characteristic impedance of the quarter-wave section will be $\sqrt{2}$ times the Zo of the line.

(ii) A matching stub with the same physical dimensions as the main transmission line is connected across the line (see Fig. 10). The position of the stub connection and the length of the stub are varied until matching is achieved.

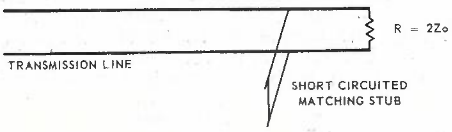


Fig. 10

The impedance looking along the unmatched line to the load varies above and below the Zo of the line. The stub is attached at an intermediate point where the resistive component of this impedance equals the Zo of the line. The stub, which is reactive, is then adjusted (by moving the short circuit) to an equal and opposite reactance which cancels the remaining reactive component of the line impedance at the point of connection.

QUESTION 15. (a)

Describe with the aid of a circuit diagram a voltage doubling rectifier suitable for providing H.T. to a receiver. Give typical values of components.

ANSWER 15. (a)

A power transformer of 100V output is used to isolate the rectifier circuit from the mains supply, and is connected to two rectifiers and two 8uF capacitors as shown in Fig. 11. A smoothing circuit comprising a 30 Henry choke followed by a 16uF capacitor is connected to provide a smoothed H.T. voltage output suitable for a receiver.

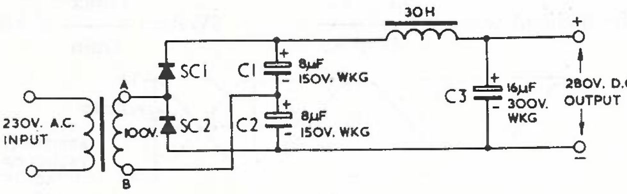


Fig. 11

QUESTION 15. (b)

Explain how the voltage doubling is achieved, and the precautions necessary when thermionic diodes are used in this circuit.

ANSWER 15. (b)

In Fig. 11, when point A is positive with respect to point B, capacitor C1 is charged through diode SC1. When B is positive with respect to A, capacitor C2 is charged through diode SC2. The polarity of the charges on the capacitors are as shown and are in series and additive. As each capacitor is charged to the peak voltage during each half cycle, a voltage of approximately 140V appears across each. The maximum output voltage is the sum of these, that is, 280V, and voltage doubling is achieved.

When directly heated thermionic diodes are used in this circuit, the power transformer must have separate filament windings capable of withstanding a working voltage equal to the peak voltage of the secondary voltage. When indirectly heated thermionic diodes are used, the heater-cathode insulation must be capable of withstanding a similar working voltage when connected to a common heater winding. With certain indirectly heated diodes, it is necessary to delay connection of the transformer secondary until the heaters have warmed thoroughly.

QUESTION 16. (a)

Describe the physical and electrical features of the following power rectifiers:—

(i) Semiconductor diode type.
(ii) Thermionic diode type.
(iii) Mercury vapour type.

ANSWER 16. (a)

(i) Semiconductor diodes are physically small, robust and constructed for permanent connection into a circuit. The outer body is often one connection point and may be used with a heat sink to prevent over-heating. The rectifier element is either silicon or germanium, and is formed by growing crystals with certain impurities or by an alloy technique of introducing the impurities.

They are electrically very efficient and the large type is capable of carrying several amperes, but can be instantaneously destroyed by high voltage punch through or excessively large current. Under normal working conditions, they have an extremely long life.

(ii) A thermionic diode physically comprises a cathode of either a directly heated filament or indirectly heated tube coated with electron free material, surrounded by a metallic anode and mounted in a sealed high vacuum. In some types, two or more diodes are included in one envelope. Pins are used for connection so that replacement may be made easily.

Electrically, the diode requires a secondary power for the heater or filament. A fairly large voltage drop exists across the diode when conducting and, therefore, it is not very efficient. It can withstand short term overloads due to its thermal capacity, forced cooling is not normally required and heat is dissipated by convection and radiation. The life is finite, with continuous deterioration occurring under normal working conditions. The end of the useful life is reached when the forward voltage drop reaches an excessive amount.

(iii) The mercury vapour rectifier physically comprises a directly heated oxide coated filament as the cathode together with a metal anode sealed in a glass envelope in which there is a vacuum and a small quantity of mercury. Pins are used for connection so that replacement of the tube may be easily made.

Electrically, this rectifier requires a secondary power for the cathode. The voltage drop across the tube is constant at approximately 15 volts over the working current range. Ionisation of the mercury vapour allows a large current to be conducted in the forward direction.

QUESTION 16. (b)

Compare their forward and backward resistance and voltage ratings.

ANSWERS 16. (b)

Forward resistance:
(i) Very low — fraction of an ohm.
(ii) Moderately high — several ohms.
(iii) Varies with the current, constant voltage drop about 15 volts.

Backward resistance:
(i) Moderately high — several hundred kilohms.
(ii) Infinite.
(iii) Very high.

Voltage Rating:
(i) Moderately high — several hundred volts.
(ii) High — up to 1kV.
(iii) Very high — up to 10kV.

QUESTION 16. (c)

Explain what safety precautions, necessary to prevent damage, are incorporated in the circuit for each type when used to provide the power supplies of a 10kW transmitter.

ANSWER 16. (c)

(i) Semiconductor. As these are used in series, equalising resistances are put across each section. Surge limiting resistors are put in series with the chain and fast acting fuses are used.

(ii) Thermionic. Heaters to be warmed up before power is switched on to anodes. Overload relays are used.

(iii) Mercury Vapour. Heaters to be thoroughly warmed up before power switched on to anodes. Arc back cut-outs are used. Location of mercury is controlled by air cooling a spot near the base of the valve; the mercury condenses at this spot.

Examination No. 5634 — 1st July, 1967 and subsequent dates. To gain part of the qualification for promotion or transfer as Senior Technician (Telecommunications), Radio and Broadcasting Equipment, Postmaster-General's Department.

PART A — BROADCASTING EQUIPMENT

QUESTION 1. (a)

Briefly describe those characteristics of medium frequency radio wave propagation which influence the construction of broadcast transmitting aerials.

ANSWER 1. (a)

At medium frequencies, radio wave propagation is by means of:—

(i) Ground wave, which can be propagated only as a vertically polarised wave. Its intensity decreases with frequency and increases with ground conductivity.

(ii) Sky wave, which is a high angle space wave reflected from the ionosphere. At M.F., it is negligible during daytime, but strong at night, fluctuating in intensity with ionospheric variations. Its intensity increases with frequency.

(The space wave component can be neglected at M.F. since the aerials are near the earth and the direct space wave is cancelled by ground reflection.)

The ground wave intensity determines the daytime or primary service area and the sky wave intensity determines the effective limit of the night-time service area (limited by the possibility of interference to other M.F. stations). Interference between ground wave and sky wave causes selective fading which is severe where the intensities of the two component waves are approximately equal.

It is therefore essential to construct an M.F. transmitting aerial which produces maximum ground wave and minimum sky wave intensity. It is particularly important to reduce high angle radiation as much as possible, otherwise the resulting sky wave will fall within the primary service area, restricting the night-time range of the transmitted signal due to fading.

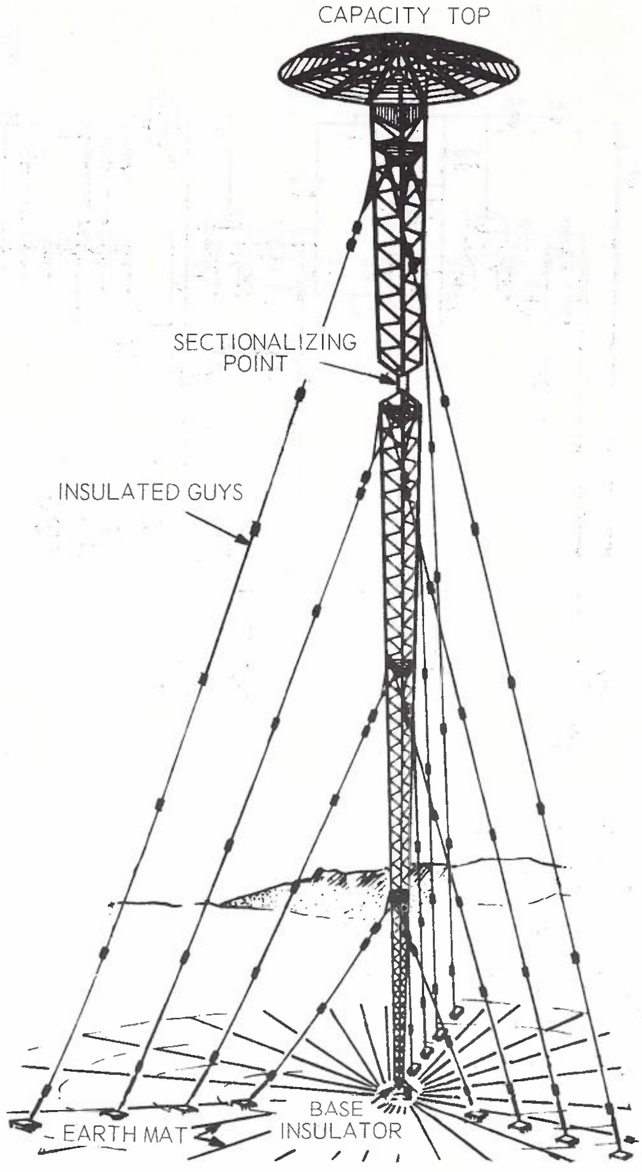


Fig. 1

QUESTION 1. (b)

Show with the aid of a sketch or sketches, those constructional features of a modern medium-frequency vertical mast-radiator which are essential to its performance as a broadcasting transmitting aerial. Give, very briefly, a reason for each of these factors.

ANSWER 1. (b)

Refer Fig. 1.

(i) Length of aerial approximately 190° electrical (0.55 wave-length) to give maximum ground wave efficiency.

(ii) Capacity top to decrease high angle radiation and, therefore, reduce sky wave.

(iii) Base insulator to insulate radiator from earth.

(iv) Sectionalizing point (series inductor connecting insulated section of mast) to increase the electrical height of a short radiator.

(v) Guy insulators to insulate the mast and break up the guys into non-resonant lengths.

(vi) Earth mat to improve effective ground conductivity and therefore increase low angle (ground wave) radiation.

(vii) Cross-section of mast adequate to provide necessary bandwidth. (This is normally greatly exceeded to provide the required rigidity.)

QUESTION 2. (a)

The circuit diagram (Fig. 2) is of portion of a medium-frequency broadcast transmitter. Label each of the external connections A to H inclusive.

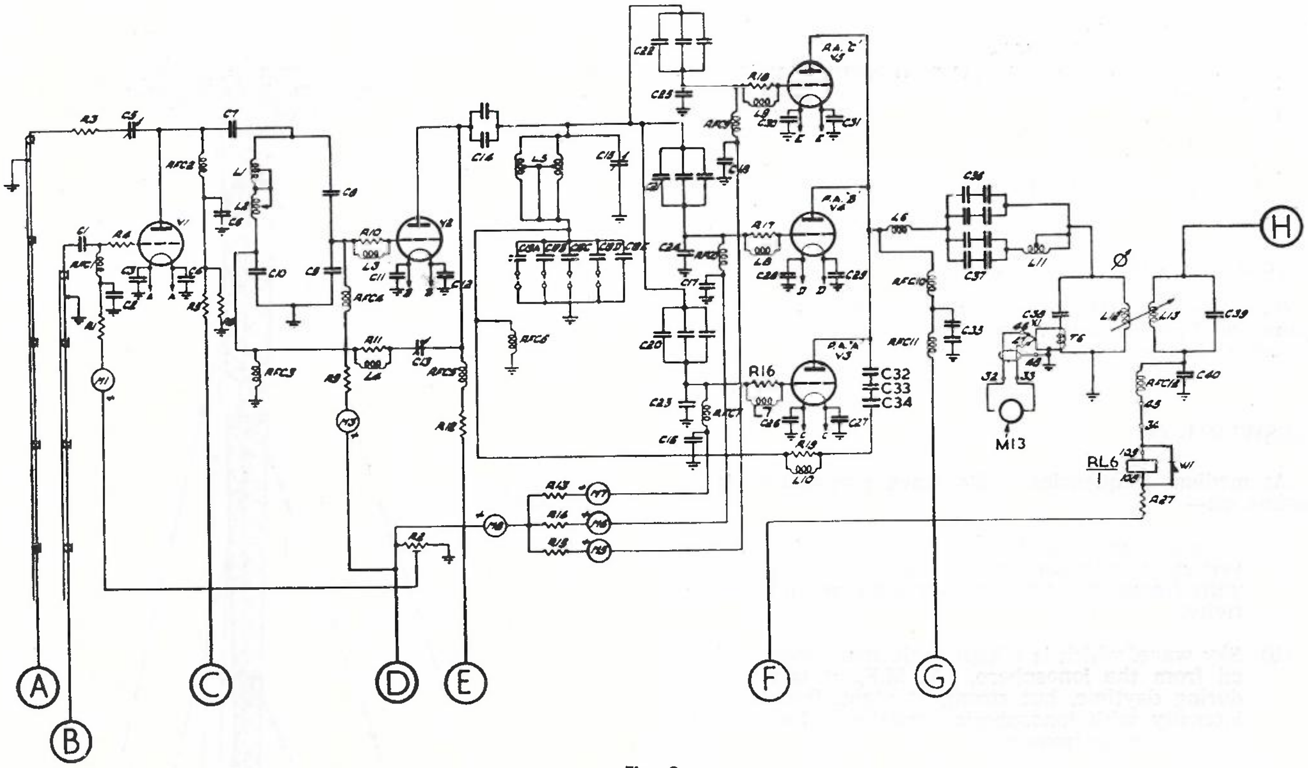


Fig. 2

ANSWER 2. (a)

A. Negative feedback (to preceding stage).
B. Radio frequency input.
C. V1 high tension supply.
D. V2 and P.A. bias supply.
E. V2 high tension supply.
F. Relay operating voltage.
G. Modulation and P.A. high tension supply.
H. Transmission line to aerial.

QUESTION 2. (b)

Answer briefly the following questions:
(i) What function is performed by C32, C33 and C34?
(ii) Why are R16 and L7 necessary in the grid circuit of V3?
(iii) What does M13 indicate?
(iv) Under what condition will RL6 operate?

ANSWER 2. (b)

(i) They feed back an out-of-phase voltage to neutralize the P.A. tubes.
(ii) This is a 'grid stopper' to prevent parasitic oscillation in the grid circuit of V3.
(iii) The output tank circulating current. (This current is proportional to the power output, but is very much greater than the aerial or anode current.)
(iv) When there is an overload on the transmitter output due to a short on the transmission line, aerial coupling, etc., or a line arc. (d.c. flows along this feeder and through the low impedance of the arc or short to earth, operating the relay to cut off the transmitter.)

QUESTION 3. (a)

It is sometimes necessary to receive broadcast programmes, transmitted in the high-frequency band, for direct rebroadcast over a local medium-frequency transmitter. What conditions are required of the received signal to ensure that it is satisfactory for rebroadcast?

ANSWER 3. (a)

(i) High signal-to-noise ratio.
(ii) Minimum possible level of interference.
(iii) Signal must not fade noticeably.
(iv) Good fidelity over an adequate audio bandwidth (without selective fading).

QUESTION 3. (b)

List those characteristics of the receiving equipment in which special care must be taken to ensure that the requirements of (a) are met.

ANSWER 3. (b)

(i) Adequate sensitivity (high-gain, low-noise R.F. stage).
(ii) Adequate selectivity to avoid adjacent channel interference (properly aligned I.F. stages to give sharp skirts).
(iii) Sensitive automatic gain control to compensate for fading.
(iv) Adequate I.F. and audio bandwidth.
(v) Directional aerial to improve input signal level and reject interference.
(vi) Adequate frequency stability.

QUESTION 3. (c)

Although high-frequency broadcast transmitters employ double sideband amplitude modulation, under some circumstances it may be necessary to use single-sideband reception for rebroadcast of the high-frequency transmission. What advantages will this technique have over the normal double-sideband reception?

ANSWER 3. (c)

(i) Higher signal-to-noise ratio (about 3dB).
(ii) By choice of upper or lower sideband, adjacent channel interference can be minimised.
(iii) Because the carrier is provided by the receiver, the effect of selective fading is reduced.

QUESTION 4.

The output stage of an audio-frequency amplifier uses a triode valve which has an anode a.c. resistance of 5,000 ohms and an amplification factor of 20. The output transformer has a turns ratio of 25:1.

Calculate the signal voltage which must be applied to the grid of the valve in order to deliver one watt of power to a 15ohm loudspeaker. (Assume perfect components).

ANSWER 4.

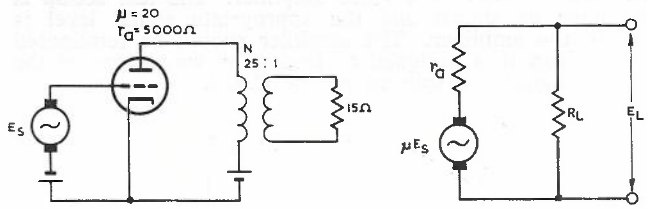


Fig. 3

$$R_L = 15N^2 = 15(25)^2$$
$$= 9{,}375\Omega.$$

$$\text{Power into speaker} = \frac{E_L^2}{R_L} = 1 \text{ watt.}$$

$$E_L = \sqrt{1 \times 9{,}375} = 96.5\text{V.}$$

$$E_L = \frac{\mu E_s R_L}{r_a + R_L}$$

$$\therefore E_s = \frac{E_L(r_a + R_L)}{\mu R_L}$$

$$= \frac{96.5\,(5{,}000 + 9{,}375)}{20 \times 9{,}375} = 7.4\text{V.}$$

Answer: 7.4 Volts.

QUESTION 5. (a)

A coaxial cable, which had a loss of 6dB when feeding a matched load, is connected to an aerial having a reflection coefficient of 0.1, i.e. 10 per cent, with respect to the characteristic impedance of the cable.

(i) What is the return loss at the input to the aerial?
(ii) What is the return loss at the input to the coaxial cable (sending end)?

ANSWER 5. (a)

(i) Return loss (in dB) at the input to the aerial.

$$= 20 \log \frac{1}{\rho}$$

Reflection coefficient (ρ) is the ratio of the magnitudes of the reflected voltage (or current) wave to the incident voltage (or current) wave.

$$\therefore \text{Return loss} = 20 \log \frac{1}{0.1}$$

$$= 20 \log 10 = \mathbf{20dB.}$$

(ii) The 6dB (2 : 1 voltage) cable loss attenuates both the incident and reflected waves. Thus an incident wave of unit amplitude is attenuated to one-half by the cable loss. At the aerial, one-tenth of this incident wave is reflected and before reaching the sending end, is again attenuated. The reflected wave arriving back at the sending end is therefore:—

$\frac{1}{2} \times 1/10 \times \frac{1}{2} = 1/40$ or 0.025 times the incident wave at that point; and the reflection coefficient at the input to the cable = 0.025.

Return loss (in dB) at the input to the cable

$$= 20 \log \frac{1}{\rho}$$

$$= 20 \log 40 = \mathbf{32dB.}$$

QUESTION 5. (b)

What is the Voltage Standing Wave Ratio (V.S.W.R.) in the cable:

(i) Near the input end?
(ii) Near the output end?

ANSWER 5. (b)

(i) $$\text{V.S.W.R.} = \frac{1 + \rho}{1 - \rho}$$

Near the input end of the cable, $\rho = 0.025$.

$$\therefore \text{V.S.W.R.} = \frac{1 + 0.025}{1 - 0.025}$$

$$= \frac{1.025}{0.975} = \mathbf{1.05}$$

(ii) Near the output end of the cable, $\rho = 0.1$.

$$\therefore \text{V.S.W.R.} = \frac{1 + 0.1}{1 - 0.1}$$

$$= \frac{1.1}{0.9} = \mathbf{1.22}$$

QUESTION 6. (a)

The relative amplitude versus frequency response shown in Fig. 4 is produced by the capacitor-resistor networks A, B and C connected between the isolating ideal amplifiers.

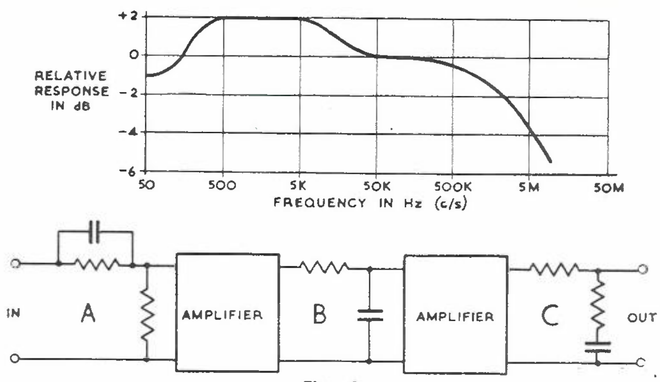


Fig. 4

Draw individual frequency response curves for each of the networks A, B, and C.

ANSWER 6. (a)

Frequency response curves for networks A, B and C are shown in Fig. 5.

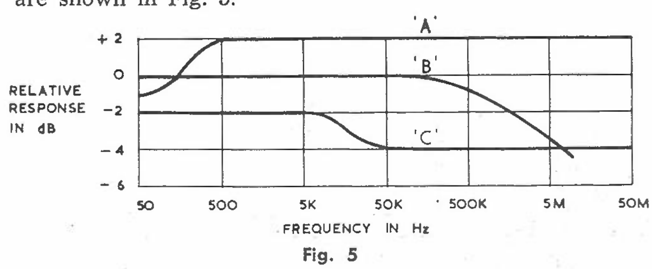


Fig. 5

(Examiner's Comment. The relative positions of the three response curves are not important. They have been displaced to show clearly their shapes.)

QUESTION 6. (b)

Select a test signal which would best show the waveform distortion caused by each network and sketch the wave shape of the test signal before and after passing through the network.

ANSWER 6. (b)

The waveform distorting effect of network A may be shown with a 100Hz or lower frequency square wave (Fig. 6).

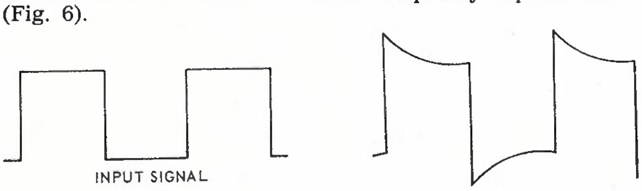


Fig. 6

For network B, any test signal having a fast rise time or the ability to detect high frequency loss may be used; for example, a T.V. line rate square wave, pulse and bar, or a higher frequency square wave. In Fig. 7, note that the pulse height is reduced in the pulse and bar test signal, and the diagonal corners of the square wave output are rounded due to high frequency loss and phase distortion.

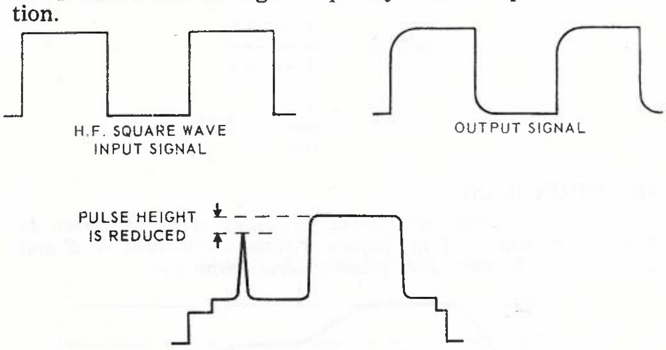


Fig. 7

Network C distortion may be shown by using a square wave having a rate of between 1kHz and 15kHz approximately. A T.V. line rate (15,625Hz) square wave or the bar of the pulse and bar signal would be suitable. In Fig. 8, note the slow rise to the final value of the output signal compared with that shown in Fig. 7.

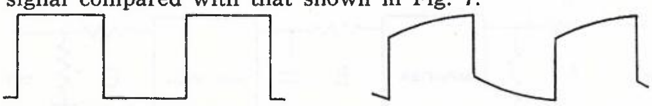


Fig. 8

QUESTION 7. (a)

A radio frequency envelope monitor is fed from the output of a television transmitter modulated with a pulse and bar test signal, including synchronising signals. Draw the pattern which would be displayed on the screen.

ANSWER 7. (a)

Fig. 9 shows the R.F. envelope (two lines displayed) with pulse and bar modulation.

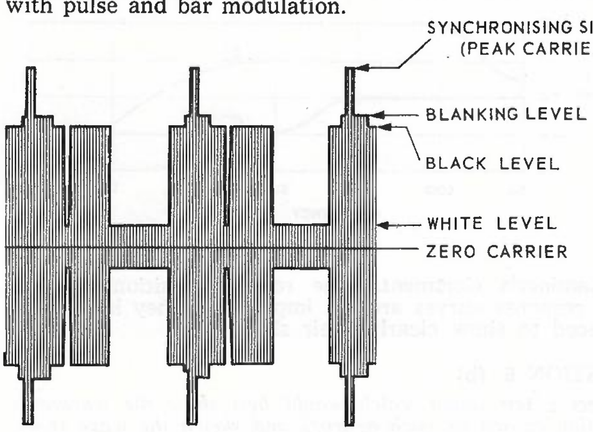


Fig. 9

QUESTION 7. (b)

Describe two methods of testing the linearity of a video amplifier. Sketch all test signals and show clearly how non-linearity can be detected.

ANSWER 7. (b)

A saw-tooth signal as shown in Fig. 10 may be used to test the linearity of a video amplifier. The test set-up is arranged as shown and the appropriate signal level is fed to the amplifier. The amplifier should be terminated in the load it is designed to feed. The waveshape of the output signal is displayed on the C.R.O.

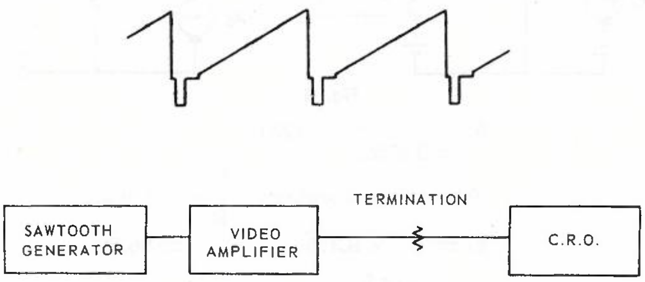


Fig. 10

A non-linear amplifier will cause a change in the shape of the signal, which is most noticeable in the sloping edge of the saw-tooth as shown in Fig. 11.

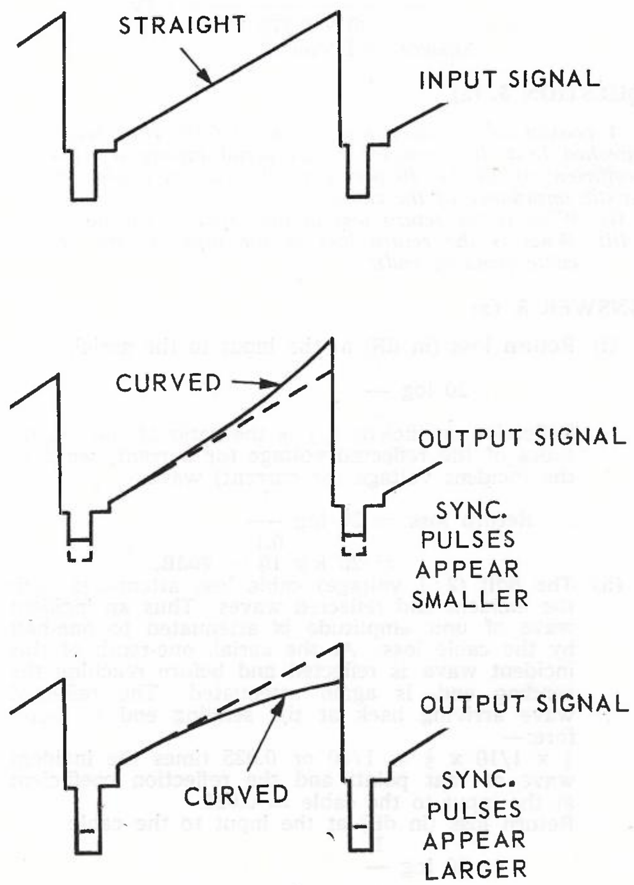


Fig. 11

Note: The non-linearity of amplifiers having a.c. coupled stages may depend upon the average picture level (A.P.L.). The A.P.L. may be altered by having one line of sawtooth signal followed by several lines at black level (that is, low A.P.L.) or several lines at white level (that is, high A.P.L.). Certain faults may be found only by using a small group of lines of sawtooth signal with the remainder of the field at either black or white level.

Alternative test signals are the 'stair step' having about 10 steps and a sawtooth plus sine wave signal (see Fig. 12).

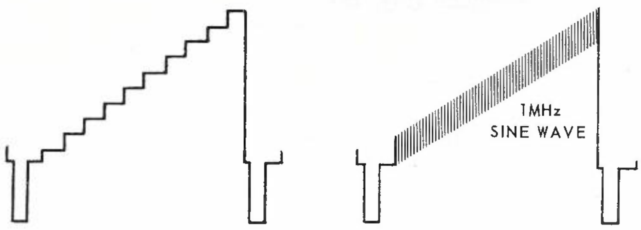


Fig. 12

Non-linearity in the 'stair step' signal may be assessed on the C.R.O. by comparing the relative heights of the steps (see Fig. 13).

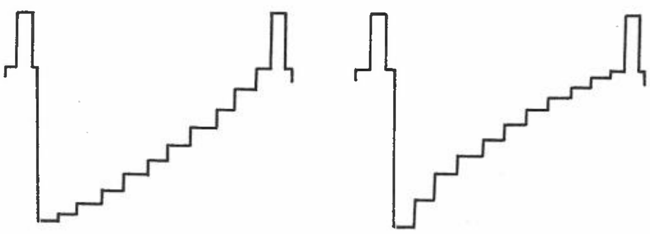


Fig. 13

Changes caused by non-linear amplifiers to the sawtooth and sine wave signal may be shown by passing the output signal through a high pass filter to separate the sine wave (1MHz) from the sawtooth. The envelope of the sine wave displayed on the C.R.O. may be used to assess the non-linearity of the amplifier as shown in Fig. 14.

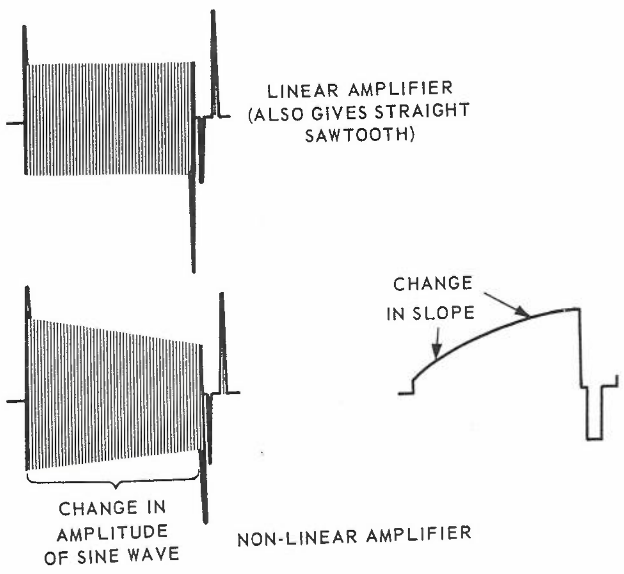


Fig. 14

The result of a linearity (or differential gain) test, using the sawtooth plus sine wave, may be expressed by a factor called 'G'.

$$G = 100 \left(1 - \frac{\text{minimum of sine wave}}{\text{maximum of sine wave}}\right)$$

, that is, the percentage drop from the maximum to the minimum.

(Examiner's Comment. Answers to this question giving a brief description or explanation and two input and output waveform sketches were given full marks. The 'G' factor explanation was not required.)

QUESTION 8. (a)

Sketch the relative response as a function of frequency for the intermediate frequency amplifier of an Australian television receiver. Explain the purpose of, and mark the position and frequency of, three minimum response points caused by 'trap' circuits in the amplifier.

ANSWER 8. (a)

See Fig. 15.

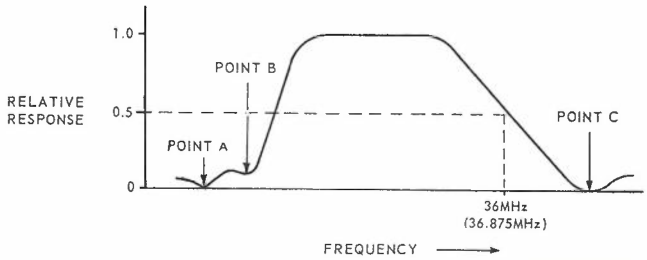


Fig. 15

In the following legend, the figures in brackets are the recommended alternative intermediate frequencies for Australian T.V. channels.

Point A. Trap tuned to 29MHz (or 29.875MHz) to reduce I.F. response to adjacent channel vision carrier.

Point B. Trap tuned to 30.5MHz (or 31.375MHz) to give optimum vision/sound carrier ratio at vision detector. (Sound inter-carrier generation.)

Point C. Trap tuned to 37.5MHz (or 38.375MHz) to reduce I.F. response to adjacent channel sound carrier.

QUESTION 8. (b)

The circuit of a video amplifier using silicon transistors is shown in Fig. 16.

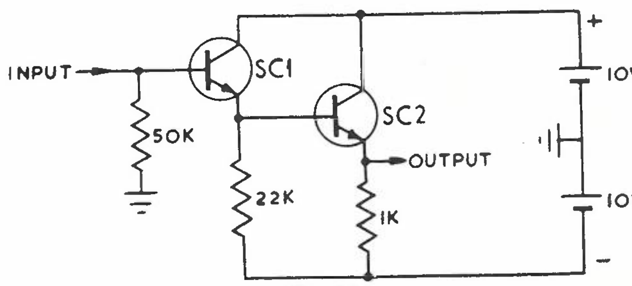


Fig. 16

(i) State the approximate voltage gain of the amplifier.

(ii) What is the approximate d.c. voltage between the emitter of transistor SC2 and ground?

ANSWER 8. (b)

(i) The approximate voltage gain of the amplifier is one. The circuit shows two directly coupled emitter follower stages; each stage has a gain of slightly less than one.

(ii) The emitter of SC2 is negative with respect to ground by the sum of the base-emitter 'knee' voltages of SC1 and SC2 plus the base current of SC1 times 50 kilohms. Assuming, for SC1 and SC2, that beta is approximately equal to 40 and a 'knee' voltage of about 0.5 volt, the emitter of SC2 would be at approximately —2 volts with respect to ground.

(**Examiner's Comment.** Candidates were expected only to recognise that the stages were emitter followers and that the base and emitter, as in most quiescent linear-transistor amplifiers, would be at nearly the same potential. Answers discussing the question in this way or giving a voltage of between 0 and —5 volts were accepted.)

QUESTION 9. (a)

Briefly describe the mechanical and electrical features of feeders used to connect the transmitters to the aerials of systems operating in the H.F., and V.H.F. and S.H.F. frequency bands. Give reasons for the difference in feeder arrangements in each case.

ANSWER 9. (a)

Typical feeders used between H.F., V.H.F. and S.H.F. transmitters and aerials are the two-wire line, the coaxial cable and the waveguide. The choice of feeder is normally dependent upon the frequency concerned and selection is made to provide a suitable low attenuation medium with economy as a second consideration.

(i) Two wire line (Fig. 17).

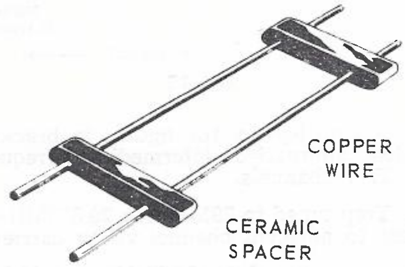


Fig. 17

Two copper wires about 0.1 inch radius are spaced by ceramic insulators at a constant separation of about 10 inches or supported by insulators on poles about 11 feet above the ground. The wires are tensioned to prevent excessive movement in the wind.

Both wires are balanced with respect to earth and the characteristic impedance of the line is about 600 ohms with a power rating up to about 50kW. This type of line is used at H.F. At frequencies higher than H.F., losses due to radiation become excessive.

(ii) Coaxial cable (Fig. 18).

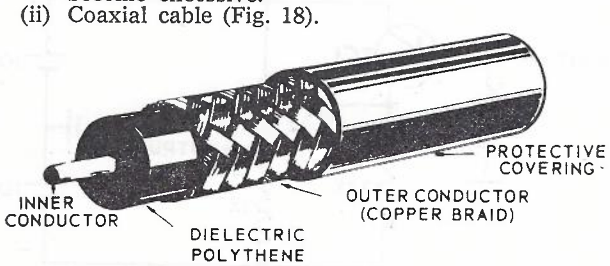


Fig. 18

This consists of an inner conductor centrally located within, but insulated from, an outer conducting tube. The insulation may be solid, in the form of disc spacers at regular intervals or in the form of a continuous spiral (helix). Coaxial cables may be either rigid or flexible, with a diameter of about 0.25 inch for low power working to several inches for high power. Rigid cables are often pressurised with dry air to prevent the ingress of moisture.

Coaxial cables are used at H.F. and V.H.F. The cable is unbalanced, the outer conductor being earthed. Due to the shielding effect of the outer conductor, losses due to radiation are negligible. The characteristic impedance is typically between 50 and 100 ohms and the power rating, with large diameter cable, up to about 50kW. The attenuation is a fraction of a dB at H.F. varying up to about 1dB per 100 feet at V.H.F.

(iii) Waveguide (Fig. 19).

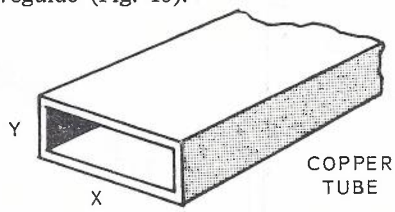


Fig. 19

A typical waveguide consists of a hollow rectangular copper conductor with plated inner surfaces. It is constructed in lengths which are bolted together so as to provide no discontinuity of the inner surfaces, and is pressurized to prevent the ingress of moisture. The cross-sectional dimensions determine the minimum frequency the waveguide will propagate. In practice, the ratio of the sides X : Y is of the order of 2.1.

Electrical energy is propagated by electromagnetic fields along the waveguide. Waveguides have lower conduction, dielectric and radiation losses than two wire and coaxial lines. However, their use is restricted to frequencies above about 1GHz because of practical dimension considerations.

QUESTION 9. (b)

A transmission line comprises two wires of 0.2 inch diameter spaced 10 inches to their centres in air. Calculate the characteristic impedance of the line assuming that the height above ground is much greater than the wire spacing ($Zo = 276 \log b/a$).

ANSWER 9. (b)

b = spacing of conductors = 10 ins.
a = radius of conductor = 0.1 in.

Substituting these values in the formula gives a characteristic impedance (Zo) of **552 ohms.**

QUESTION 10. (a)

Draw the simplified circuit of a full wave three phase rectifier and show the output voltage waveform.

ANSWER 10. (a)

A typical circuit is shown in Course of Technical Instruction, Radio 2, Paper 9, Fig. 9.

The output voltage waveform is shown by the solid line in Fig. 20.

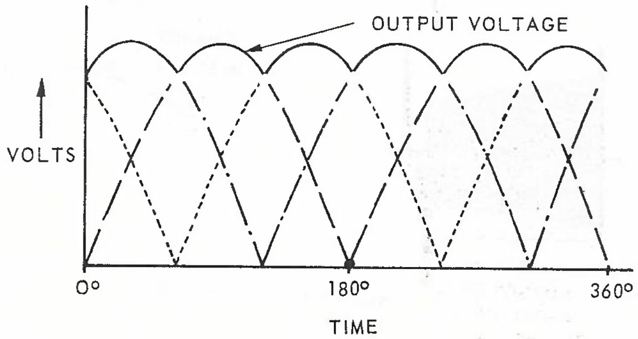


Fig. 20

The frequency of the output ripple is six times the supply frequency, that is, 300Hz for a supply frequency of 50Hz.

QUESTION 10. (b)

Explain how the voltage ripple may be minimised and indicate how good regulation may be obtained.

ANSWER 10. (b)

A filter circuit comprising a large inductance in series and a large capacitance in parallel, may be used to minimise the ripple voltage. The inductance opposes a change in current by producing a counter e.m.f. to oppose these changes and the capacitance opposes a change in voltage. Two filters may be used in cascade to improve the effectiveness of the filter.

Good regulation may be obtained by the use of regulation circuits such as a neon regulator, a series/shunt valve regulator, saturable reactor, etc. (Refer Radio 2, Paper 9, para. 7.4.)

QUESTION 11. (a)

Describe the ionised layers of the upper atmosphere giving their identification letter, approximate heights and variation from day to night.

ANSWER 11. (a)

The upper parts of the earth's atmosphere have ionised layers of rarefied air containing a large proportion of charged molecules. This is called the ionosphere. If conditions are favourable, these layers bend (refract) the paths of radio waves of certain frequencies back to earth.

Approximate heights of these layers are:—

D layer — 50-90km (30-55 miles);
E layer — 110km (70 miles);
F1 layer — 220km (140 miles);
F2 layer — 250-350km (155-220 miles).

The D layer is effective during daylight only.

The E layer is governed by the amount of ultraviolet light from the sun and, at night, tends to decay uniformly with time.

The F1 and F2 layers merge at night to form a single F2 layer.

A sporadic E layer, the occurrence of which is unpredictable, is often present in the E region. It usually occurs in the form of thin layers of clouds of varying diameters 1km to several hundred km in the height range 90-130km (55-80 miles).

QUESTION 11. (b)

Describe how the layers assist in the transmission of long distance high frequency radiations and give reasons why a number of frequencies are often used in a H.F. radio system.

ANSWER 11. (b)

At H.F., the ground wave is attenuated rapidly and long distance radio transmission is achieved by refraction of the sky wave from the ionised layers and subsequent reflection from the earth in a series of 'hops'. The lower frequencies in the H.F. range penetrate the D layer and are refracted by the E layer; as the frequency is increased, the signal penetrates this layer and is refracted by the F layer. For each mode of transmission to a desired reception point, therefore, a particular angle of radiation will be the optimum.

Different frequencies are required in a H.F. system, particularly a change from day to night. Attempt is made to use the highest frequency at all times to avoid the atmospheric noise at the low end of the H.F. band. During the night-time, the frequency used must be lowered to avoid penetration of the layers and to provide reliable refraction. Different frequencies are also required due to changes in effective layer heights from summer to winter. Also, as the degree of sunspot activity changes over an eleven year cycle, a change occurs in the critical frequency owing to the increase in ultraviolet radiation with high sunspot activity.

(A description of the ionosphere and its effect on radio waves is given in the Course of Technical Instruction, Radio 2, Paper 10.)

QUESTION 12.

Describe the mechanical and electrical differences between a dipole aerial and a two element yagi array. Show the radiation pattern of each, indicating their relative amplitudes.

ANSWER 12.

A typical dipole aerial (see Fig. 21) consists of a length of wire or thin tube with an electrical length of ½ wave-length at the frequency of operation. In practice, the physical length of the element is usually cut to about 95% of ½ wave-length in free space, owing to 'end effect'. The dipole is split at the centre to provide a current feed point. The impedance at the centre is a minimum (about 72 ohms) increasing to a maximum at the ends.

Another arrangement is the folded dipole which consists of two ½ wave-length conductors in parallel. For two identical conductors, the aerial impedance at the feed point is about 300 ohms. Other values of impedance may be achieved by making the diameters of the two conductors unequal or by using more than two conductors in parallel.

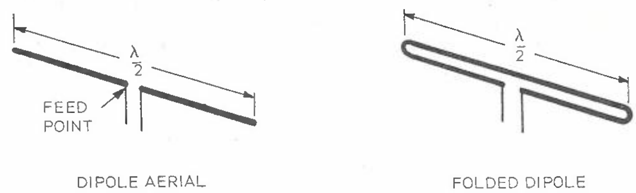


Fig. 21

When the aerial is in free space, the radiation pattern of a dipole is in the form of a doughnut with the dipole passing through the centre. When the dipole is close to the ground, reflection from the ground plane changes this pattern; for example, Fig. 22 shows the directivity patterns for a height of ½ wave-length above ground.

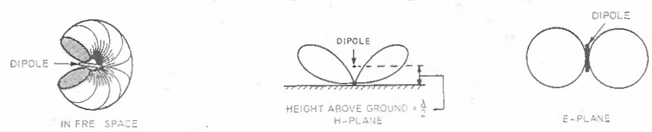


Fig. 22

A two element yagi is a dipole with a passive reflector or director element added (see Fig. 23). The passive reflector is an unbroken element electrically longer than ½ wave-length, while the director element is less than ½ wave-length. The effect of the additional element is to reduce the impedance at the centre of the dipole aerial.

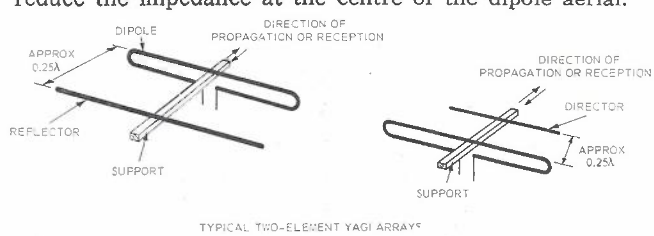


Fig. 23

In a two-element yagi, the additional element changes the radiation pattern to provide greater directivity (see Fig. 24). When used at a height of several wave-lengths above ground, free space pattern is obtained. The increase in gain is approximately 2½dB, that is, 2½dB reference a dipole in free space.

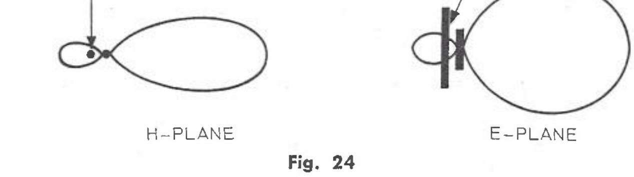


Fig. 24

Examination No. 5635 — July, 1967, to gain part of the qualifications for promotion or transfer as Senior Technician (Telecommunications), Telegraphs, Postmaster-General's Department.

TELEGRAPH EQUIPMENT.

QUESTION 1.

(a) *A source of double-current 50 Baud reversals is in correct adjustment but has 54 volts negative for marking potential and 46 volts positive for spacing potential. Sketch the Start-Stop display you would expect to see on a B.A.T.E. T.D.M.S. Type 6 ABV with the Signal 1 switch set to POLAR —M, the Display switch set to M.S. and S.M., the unit code switch set to 7 units and the speed switch set to 50 bauds:*
   - *(i) On the tongue of the send relay.*
   - *(ii) On line at the receive relay end some miles distant.*

(b) *A B.A.T.E. T.D.M.S. type 6 ABV monitors double-current signals from a distant source firstly on the line side of a receiver relay and registers 2 per cent Marking bias distortion and secondly on the tongue of the receive relay and registers 6 per cent Marking bias distortion. The receive relay is known to be neutral. How could you check whether the T.D.M.S. input circuit was neutral?*

(c) *If in (b) the T.D.M.S. was found to be neutral what feature of the T.D.M.S. input switching circuits could explain the difference in these readings?*

ANSWER 1.

(a) (i) See Fig. 1.

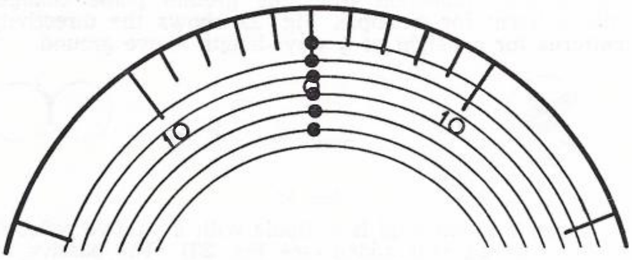


Fig. 1

(ii) See Fig. 2.

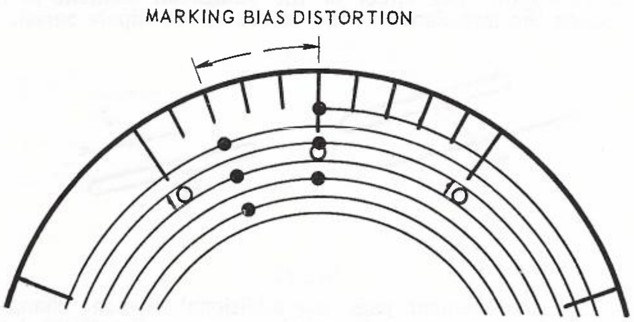


Fig. 2

(b) Approximately 10 volts r.m.s. of 50Hz a.c. should be applied to the T.D.M.S. input. Evenly balanced input triggering points will cause a zero distortion display, and unbalance will cause a reading of distortion. Unbalance tends to be masked by the short rise time of reversals type signals and these are not suitable.

(c) If neutral, the input switch triggers when +2.5 volts and — 2.5 volts appear at the output of a voltage divider connected between it and the input. The readings may be different if the T.D.M.S. and the receive relay operate at different voltage levels on a badly shaped line signal.

QUESTION 2.

(a) *Describe with reference to Fig. 9 of E.I. Siemens & Halske E 1001, the selection process of the Siemens & Halske Model 100 teleprinter. Commence with the receiver shaft just starting its rotation and conclude with the setting of the transfer bars (omit the actual starting and stopping of the receiver shaft).*

(b) *Explain how adjustment of the rangefinder mechanism varies the timing of instants of selection with respect to the start of the receiver shaft rotation.*

ANSWER 2.

(a) The first peak of the selector cam 46 offers the selector armature 45 to the receive magnet 44. Meanwhile, the first code lever 42 rides to the peak of its cam 43, while the selector lever 48 is still on the long high portion of cam 47. Assuming the first element is a space, the armature 45 falls following the face of cam 46. The selector lever 48 begins to follow its cam surface to the lower level, but the adjuster plate 48a is stopped by the fallen selector armature. The bail 48b does not tilt the lowered sword 50, which is then raised to storage level on the right side of locating pin 49. The selector lever cam then depresses the bail and retracts the adjuster plate. At this point code lever 2 passes code lever 1 as it is being positioned ready for selection of the second element. Assuming it is a mark, the armature, which has been offered while the code lever is riding to its peak, is held by marking condition in the receive magnet. When the selector lever rides toward the valley of its cam, the adjuster plate passes under the armature extension and the bail tilts the sword. The bail and sword then rise together to storage level of the code cam before the bail restores, leaving the sword on the left of the locating pin.
Three, four and five are selected similarly. Swords 1, 2, 3, 4 leave storage level together to position their transfer bars down for marking or up for spacing as 5 is drawn down for selection. Sword 4 is stored for only a short time. while sword 5 is not stored at all, but proceeds directly from the tilting position to the transfer bar setting position.

(b) A stop cam on the receiver shaft runs up against a locking lever at the end of the revolution and arrests the shaft. The position of the locking lever and therefore the rest position of the shaft is qualified by the rangefinder mechanism. When tripped, the receiver shaft has less rotation (low readings on plate) or more rotation (high readings on plate) before the commencement of sampling. The instants of selection are thereby advanced or retarded.

QUESTION 3.

A page printer for 7½ unit 50 Baud start-stop telegraph signals is found to be mutilating received traffic.

(a) *What type of mutilations would cause you to suspect speed error? Why?*

(b) *Illustrate with diagrams the relationship of instants of selection to significant instants if the receive machine is slow by the maximum amount that will just not cause errors in undistorted signals. (Assume that a selecting period of 4 milliseconds is necessary for correct selection.)*

(c) *Illustrate with diagrams the relationship of instants of selection to significant instants if the incoming signal was generated by a transmitter with a cam speed 2 per cent. fast and the receive machine was running at its correct speed.*

(d) *In 3 (c) above what is the maximum distortion due to speed error?*

ANSWER 3.

(a) Speed distortion accumulates over the character and reduces the margin for distortion most significantly at the end of the character. Mutilations involving predominantly 4th and 5th code elements will result.

(b) See Fig 3.

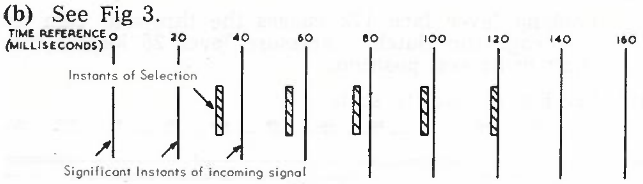


Fig. 3

(c) See Fig. 4.

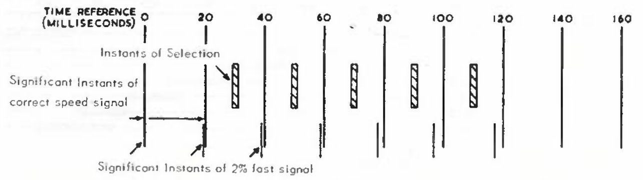


Fig. 4

(d) The maximum distortion is on the transition at the end of the 5th element (120mS).
The shift is 2 per cent. of 120mS = 2.4mS.

$$\text{The distortion is } \frac{2.4}{20} \times 100 = 12 \text{ per cent.}$$

QUESTION 4.

(*a*) *List the features of the Clare HGS5071 polarised telegraph relay used extensively in the automatic telex system that make it superior to the Carpenter type 4H39.*

(*b*) *What other differences exist between these relays? Give values where appropriate.*

(*c*) *Sketch a circuit suitable for testing a polarised telegraph relay for neutrality. Indicate the type of drive and why you consider it most suitable for this purpose.*

ANSWER 4.

(a) Reed armature eliminates need for pivot.
Mercury wetting eliminates or greatly minimises contact bounce and wear.
Low mass of reed permits higher signalling speeds.
Stable performance over a long life without adjustments.
Smaller physically.

(b) The Clare HGS5071 has lower sensitivity than the Carpenter 4H39 (22 ampere turns against 4.5 ampere turns), has higher coil resistance (130 ohm against 55 ohm) and is restricted to mounting within 30 deg. of vertical.

(c) See Fig. 5.

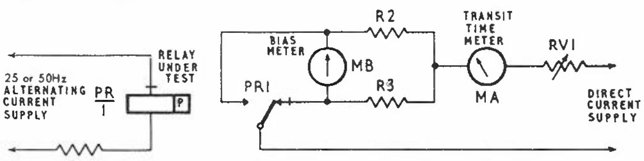


Fig. 5

An a.c. drive is necessary to ensure that small differences in the operate point for positive and negative polarity applied will register on the meter. The time difference (and therefore the unbalance indication) on a rapidly rising square signal such as reversals is insufficient to register small unbalance.

QUESTION 5.

(*a*) *Explain with reference to Drawing CG 1004, Sheet 1, the operation of the sequential start relay set serving a line-finder suite. Begin from the receipt of = from the automatic number programme switch on to the PRN relay. Finish your description at the operation of the release relay NR.*

(*b*) *How does this sequence differ if the relay set is serving C.T.O. send positions?*

(*c*) *Explain briefly any other function of relay PC not dealt with in (a).*

ANSWER 5.

(a) 'Figs. V,' auto NBP operates NBV.
NBV operates FV, which locks and connects 'D' to the B wire.
D releases to earth on the B wire.
D connects cadence pulses to PA, which operates to first cadence.
PB operates at end of first cadence and connects reperf identification.
PC operates to second cadence.
PB releases at end of second cadence and operates XM 'Figs. V.' on tape operates NBV again.
NBV operates NR.

(b) No reperf identification is needed for C.T.O. send positions. A strap is laid so that the release of D energises the transmitter clutch.

(c) On interstate and urgent channels the state letter absorbed in switching has to be re-inserted in the routing code by the programme switch.
The programme switch sends positive on the B wire after the state letter is sent to line. PC operates, then releases and energises the transmitter clutch so that two routing characters from the tape are transmitted to line at the right time.

QUESTION 6.

(*a*) *List with reference to Drawing CG 1004, Sheet 2, the relay sequence involved in the Register when registering the necessary codes for intrastate messages. Commence with the operation of CA and conclude when a call for the marker is initiated.*

(*b*) *State briefly the variations in functions involved in registering:*
(*i*) *Interstate messages.*
(*ii*) *Urgent messages.*

ANSWER 6.

(a) CA operates, CE releases, DV-DZ register the state letter.
SC operates, operating SCA and XM. DV-DZ release the state letter.
CB and DV-DZ operate. DV-DZ lock for first routing character.
CC operates. CB releases slowly.
CD operates and operates UV-UZ and CDA.
UV-UZ lock for second routing character and CDA calls for the marker.

(b) (i) Following DV-DZ registering the state letter, SC does not operate.
SCB therefore releases and operates CDA to call marker.
The state letter and blank are stored on D and U relays.
(ii) Following the first letter registration (Z), both SC and SCA operate.
CB operates and holds Z stored.
CC and CD operate and UV-UZ store state letter.
CDA operates and calls marker.
The register stores Z and the state letter.

QUESTION 7.

(*a*) *Explain the scanning principles in the receivers of:*
(*i*) *The fixed receiver of the picturegram service.*
(*ii*) *The receiver of a message or weather facsimile service.*

(*b*) *In message and weather facsimile services it is possible for the receiver sometimes to produce a copy exhibiting greater contrast than the original document in the transmitter. Describe how the contrast circuit of the transmitter can produce this effect.*

ANSWER 7.

(a) (i) A fixed intensity light beam is modulated by a mirror oscillograph and shaped aperture under the control of a signal derived from the line signal. The modulated beam is focussed on to a revolving drum which has a sensitised film wrapped around it. The drum traverses past the focal point of the beam on a lead screw which feeds during the period following the end of a line before the start of the next. The lead screw and drum are driven at precisely the correct speed by a phonic motor controlled from a fork-controlled oscillator whose frequency matches that of the transmitter fork-controlled oscillator.

(ii) Moist electrosensitive paper is drawn between a fixed stainless steel writing edge and a revolving helix. The point of contact of the writing edge and helix moves across the paper, and when current is passed between them, chemical action colours the paper. Signals from the line are amplified and applied between writing edge and helix.

(b) The modulator of the transmitter requires a signal swing of 1 volt to produce the 25db difference in transmitted line levels (corresponding to black and white). Full white to black transitions on the document generate a 5-volt swing at the photomultiplier output. Much less contrast will generate the 1-volt swing necessary for full 25db contrast on the outgoing levels.

QUESTION 8.

Drawing CG758, sheet 1, shows one application of a circuit of a terminal unit developed to permit point to point working of Siemens and Halske Model 100 teleprinters.

(a) A service employing the application shown is in local run condition. Describe the circuit operation following a call from the distant terminal up to the extinguishing of the local run lamp.

(b) If this circuit is in the "on line" condition, what is the sequence of operator actions and related relay sequence to arrange for the TD only to be on line and the teleprinter available for local tape preparation?

(c) Why is LR4 an "x" springset?

ANSWER 8.

(a) DL, LR and B are operated in Local Run condition.
On call from distant end (open) B releases. Spring 4 of B2 breaks earth from local hold circuit and DL.
Springs 3 and 5 of B2 re-apply local hold circuit earth.
Contact B3 shorts line coil of B relay.
B1 sounds buzzer.
If motor is running, DL releases after discharge of C1 (adjusted for 2 to 3 seconds).
If motor not running, DL releases immediately.
DL1 released extinguishes local run lamp and releases LR.

(b) Operator operates OFF LINE Key.
If no tape in TD gate (S released) earth from 'off line' contact operates DL and B.
DL1 operates LR and lights Local Run lamp.
LR establishes local run condition.
Now operator operates SWA (TD on line) and TL operates. TL connects tape transmitter contacts into line circuit while maintaining local circuit.

(c) Off line Key operates B, which must be held during the operation of LR after LR5 has operated. LR4 being an 'x' contact ensures B is held before LR5 operates.

QUESTION 9.

(a) Describe with reference to Fig. 63 of E. I. Siemens & Halske E 1400, the tripping of the T lock 15a distributor shaft and its subsequent return to the rest position. (Contact operations may be omitted.)

(b) Illustrate in a timing diagram using ½ inch = 20mS, the timing of XD, DC6, DC1-5 contacts with respect to the start of the Transmitter shaft rotation.

(c) How is the timing relationship between the contacts XD and XA physically arranged?

ANSWER 9.

(a) XD contact closes the distributor magnet circuit. Armature 23 is attracted, releasing locking lever 17. Pressure spring 16 engages the clutch and the camshaft 13 rotates.
When DM is released to disengage the drive, lobe 18a restores projection 17b behind armature extension 23a.
Locking lever face 17a causes the throwout cam to disengage the clutch. Pressure lever 25 locates the shaft in its rest position.

(b) See Fig. 6. (Not to scale).

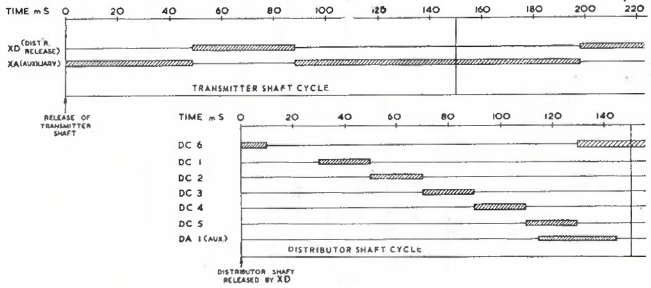


Fig. 6

(c) XD and XA are parts of the same spring pile operated by a single cam. XD is made only during the time XA is open.

QUESTION 10.

(a) List the variations in functions of a standard Model 100 teleprinter that are effected by the fitting of an automatic carriage return and line feed attachment.

(b) What are the functions of the magnetic two colour printing attachment for the Model 100 teleprinter?

(c) Describe the means by which non-printing function signals are arranged to suppress type basket carriage feed in the standard Model 100 teleprinter.

ANSWER 10.

(a) The receipt of either a CR or LF will result in both operating.
If neither is received by the 69th character both will be operated.
If both are received and the line is longer than 15 characters, only one line feed is permitted. On shorter lines, two line feeds occur.

(b) The magnetic two-colour printing attachment extends the control of the mechanical two-colour printing attachment to include a tape transmitter.
With this facility, traffic transmitted from an attached or associated TD appears in the 'outgoing' colour.
Without this facility, traffic transmitted from tape appears in the 'incoming' colour.

(c) Carriage feed is suppressed by disengaging the feed pawl from the feed ratchet. The forward movement of a pullbar for a non-printing function causes an extension to engage a tine in a comb, causing it to pivot and disengage the feed pawl.

QUESTION 11.

(a) List the functions of the relay set MIR-A in setting up a local call in an ARB111 automatic telex exchange.

(b) In Fig. 1 of E.I. Switching RS 1705, 1MC1 is the seizure and connect relay for AM1, and 1MC2 is the seizure and connect relay for AM2. What provisions are made to ensure that only one marker can seize and connect to a particular MIR-A? (Answer by stating the relay conditions appropriate to each possible combination of calls.)

ANSWER 11.

(a) Provides strapping field for ABS, ABS-U and K digit for the 40 subscribers associated with it.
Selects the SLA switches for calling or called sub. and operates horizontal magnets.
Extends by-path testing circuits to AM.
Extends a, b and c wires to AM.
On outgoing calls assists marker in identification of calling subscriber.

(b) Outgoing in AM1: AN in AM1 operates 1MC1 in MIR-A, which blocks 1MC2.
Outgoing in AM2: AN in AM2 operates 1MC2 in MIR-A, which blocks 1MC1.
Incoming in AM1: SV in AM1 operates 1MC1 in MIR-A, which blocks 1MC2.
Incoming in AM2: SV in AM2 operates 1MC2 in MIR-A, which blocks 1MC1.
On simultaneous calls the incoming call has preference:
Incoming in AM1: SV in AM1 energises one winding of 1MC1 and disconnects the counter-acting winding so 1MC1 operates and blocks 1MC2.
Incoming in AM2: SV in AM2 energises one winding of 1MC2 and disconnects the counter-acting winding so 1MC2 operates and blocks 1MC1.

QUESTION 12.

(*a*) *Draw a block diagram of an ARB111 automatic telex exchange. (Relay set quantities may be omitted.)*

(*b*) *The ZR relay set in ARB111 is an auxiliary code sender. What indications would you expect to have in a telex exchange if a fault developed in one ZR relay set which caused it to mutilate its sent characters.*

(*c*) *Faced with the indications in 12 (b), you decide to check to see if you have a faulty ZR. State briefly how you would do this.*

ANSWER 12.

(a) See Fig. 7.

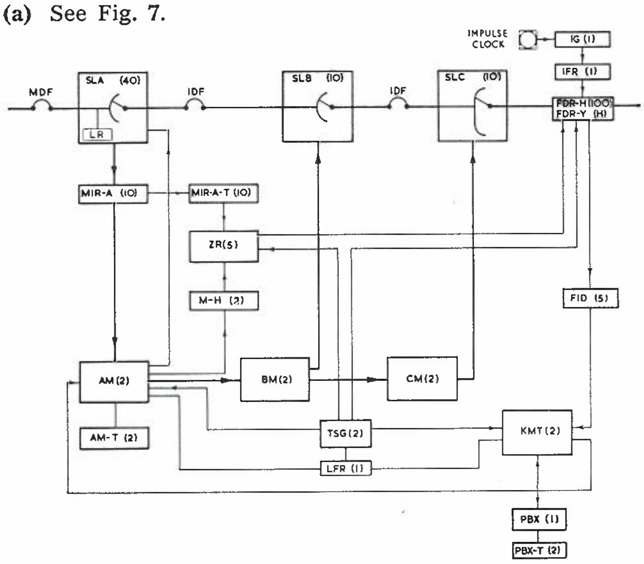


Fig. 7

(b) GA to subscribers from this ZR will be faulty and this should be indicated by subscriber fault reports and perhaps service sampling. TK to Registers will be faulty and route markers will generate centrallograph printouts and NC conditions to subscribers.

(c) Test calls can be made while observing the allotting chain in M-H to identify the ZR in use for each call. The faulty ZR is the one in use when a mutilated GA is received.

QUESTION 13.

(*a*) *Add to Fig. 8 components and connections to show in principle how you could employ Clare HGS5071 relays in a polarential telegraph circuit.*

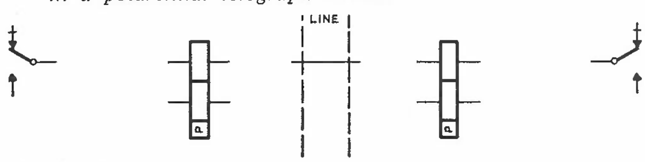


Fig. 8

(*b*) *Is there any electrical characteristic which could make it an advantage to use the carpenter type 4H39 relay instead of the relay nominated in 13 (a) for long polarential lines?*

(*c*) *How does the artificial line at the end of the circuit wired for 'differential send' signals operate to prevent signalling troubles?*

(*d*) *If the bias current to achieve neutrality in the differential receive relay was appreciably less than the midpoint between the mark and space currents, sketch the line current waveform you would expect to see at this end of the circuit.*

ANSWER 13.

(a) See Fig. 9.

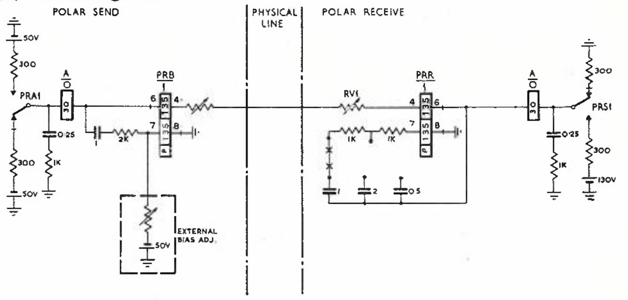


Fig. 9

(b) No. Carpenter Type 4H relay is more sensitive, but it requires approximately the same minimum current (10mA) when fitted with coil No. 39 (1400 turns), as does HGS5071 (3400T). The small difference in winding resistance would not be significant.

(c) Discharge from line through the line winding of the receive relay on the space to mark transition of PRS would lift the receive relay off mark if it was not balanced by a corresponding discharge from the artificial line.

(d) See Fig. 10.

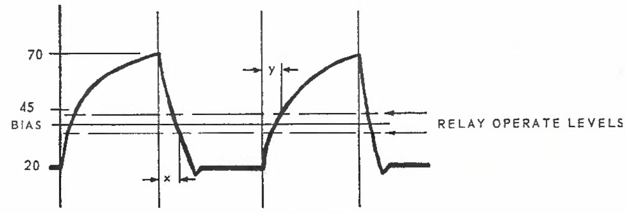


Fig. 10

For zero distortion, x = y.

QUESTION 14.

A telegraph order has been issued to provide a telex service without tape or local run facilities in a central city building.

(*a*) *What equipment is required in the subscriber's premises and what checks and tests would you make before you considered the installation was complete?*

(*b*) *If a call alarm had been requested as an additional facility how would the material requirement differ?*

(*c*) *What are the special conditions regulating the location of call alarm equipment?*

ANSWER 14.

(a) Equipment: 1 Siemens and Halske Model 100 KR teleprinter.
1 CG492 Sub's Terminal Unit (with power and machine plugs and line test switch).

Line Test: With co-operation of Exchange Staff, line should be tested for foreign battery, earth, insulation resistance, loop resistance, reversal, and line and bias current adjustment made.

Machine Test: Range and orientation on undistorted ADS. Receive margin on distorted ADS. Send distortion on ADM.
Check calls should be made to confirm that correct subscribers' category and originating tariff zone have been connected.

(b) In addition to the call alarm relay set and the alarm device, the CG492 Sub's Terminal Unit would be replaced by one with local battery, say CG494 or CG484.

(c) The switchbox must be adjacent to the machine. The remote alarm must be in the same premises, though not necessarily the same building.
Loop resistance to the remote alarm must not be more than 100 ohms.

QUESTION 15.

A subscriber desires to establish a semi-automatic tape relay centre with 50 Baud channels and machines and with Broadcast and Automatic numbering facilities. The detailed requirements are:

(1) Ten two-path outstations. 5 Simplex and 5 Duplex.
(2) Automatic numbering on all outgoing lines.
(3) Tape monitoring on 2 outgoing duplex lines (on H.F. Radio Links).
(4) Incoming reperforators on all receive lines.
(5) Incoming page printers monitoring duplex lines.
(6) Broadcast available on all lines.
(7) Capacity to originate traffic to any combination of outgoing lines from either of two tape transmitters with associated Send-Receive page printers.

(a) *Draw a block diagram for the proposed centre showing standard machine types.*

(b) *Sketch in simplified form, but with sufficient detail to demonstrate the principles involved, the means of obtaining the broadcast facility from a conventional single current machine.*

(c) *If the traffic offering from the outstations was more than could be handled in the tape relay centre, state two distinct methods by which the tape relay centre traffic capacity could be increased.*

ANSWER 15.

(a) See Fig. 11.

(b) See Fig. 12.

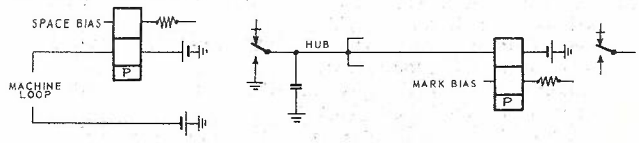


Fig. 12

(c) The tape centre could handle more traffic if speeds were increased to 75 bauds or if a third connecting circuit was added.

QUESTION 16.

(a) Regenerative repeaters and conventional telegraph repeaters each can be said to 'repeat telegraph signals'. Give more precise examples of particular functions of these classes of repeaters to distinguish between them.

(b) A 50-Baud telegraph channel on a voice frequency telegraph system is subject to electrical interference causing random disturbances of short duration. Under what conditions would you expect a modern electronic regenerator to fail to guard against them?

(c) Why are restrictions placed on the general use of regenerative repeaters as a means of meeting the telex transmission plan?

ANSWER 16.

(a) A regenerative repeater corrects incoming distortion up to its margin (typically 48 per cent.) due to bias, speed or interference, etc., and retransmits a new signal at low distortion. It may have special features such as short-start rejection, etc. It functions on a mid-element sampling principle.
Conventional repeaters are typically used to convert from one signalling mode to another. They may also be used to extend the signalling range on long circuits. The operating principle involves repeating each transition as it occurs, as faithfully as possible. Its ability to correct distortion is limited to bias distortion.

(b) If the circuit is idle, only disturbances greater than 10mS in duration will cause the regenerator to cycle and generate an output character. If traffic is passing, errors will be recorded each time a disturbance causes a change of signal state on the channel during the sampling period for an element, except in the case of stop elements if automatic stop insertion is operating.

(c) Regenerators would restrict signalling during calls to the five-unit start-stop code of the telex machine. At present, the restriction applies only during setting up time, and attachments using other codes may be approved.

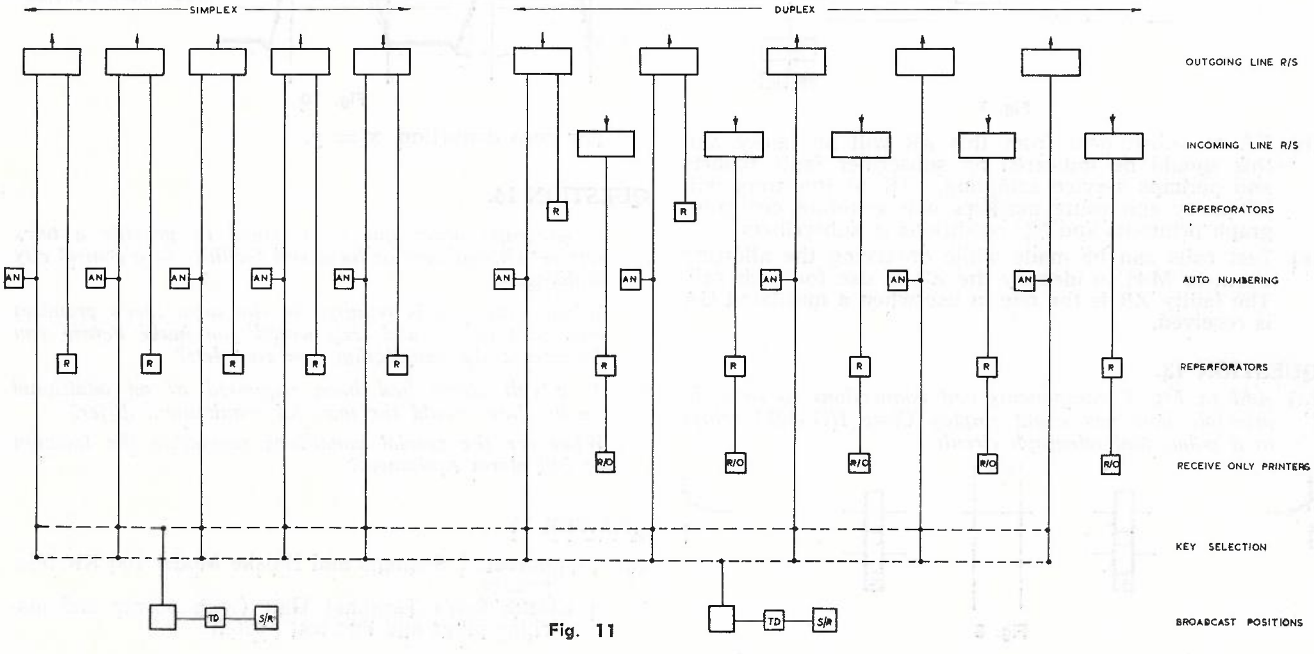


Fig. 11

Examination No. 5637 — 1st July, 1967 and subsequent dates, to gain part of the qualification for promotion or transfer as Senior Technician (Telecommunications), Research, Postmaster-General's Department.

TELECOMMUNICATION PRACTICE AND MEASUREMENTS

QUESTION 1.

(a) Daily measurement (over a period of 328 days) were made of the terminal voltage of a solar battery by means of a remote reading digital indicator reading to the nearest volt.

Indicated Voltage (Volts)	No. of Times Indicated	No. of Times Voltage is Equal to or Less than Given Value
36 (or less)	0	0
37	1	1
38	4	5
39	8	13
40	16	(*See* part (*b*) of question)
41	25	. .
42	32	. .
43	47	. .
44	52	. .
45	47	. .
46	36	. .
47	26	. .
48	19	. .
49	10	. .
50	4	. .
51	1	. .
52 (or more)	0	. .

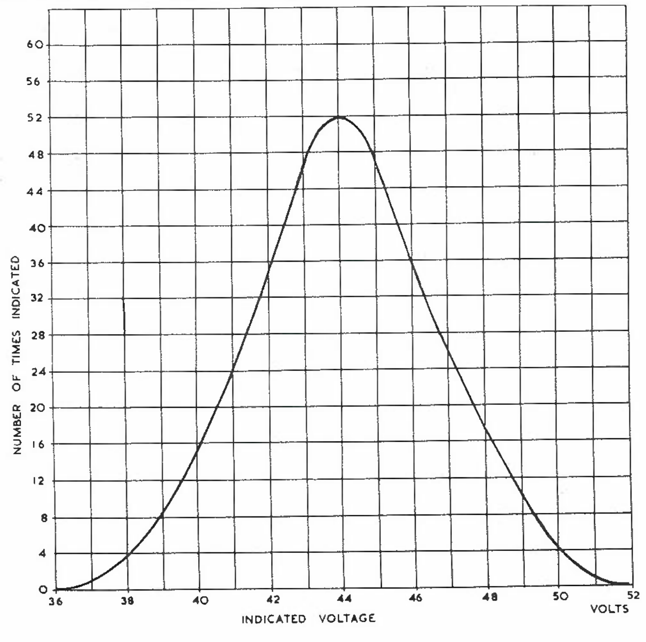
On the graph paper provided, draw a smooth curve showing the frequency distribution of voltage as suggested by the tops of lines the lengths of which indicate the number of times each value was indicated during the testing period.

(b) Draw up a table (as suggested by columns 1 and 3 of the above table) showing at each indicated voltage the number of times that voltage or a lower voltage had been indicated during these tests.

(c) On a separate sheet of graph paper, plot the values from table (b), and draw a smooth curve through the plotted points.

(d) From graph (c) estimate the actual battery voltage which was not exceeded for half of the total number of measurements.

ANSWER 1. (a) See Fig. 1.



(b)

Indicated Voltage (Volts)	No. of Times Indicated	No. of Times Voltage is Equal to or Less than Given Value
36 (or less)	0	0
37	1	1
38	4	5
39	8	13
40	16	29
41	25	54
42	32	86
43	47	133
44	52	185
45	47	232
46	36	268
47	26	294
48	19	313
49	10	323
50	4	327
51	1	328
52 (or more)	0	328

(c) See Fig. 2.

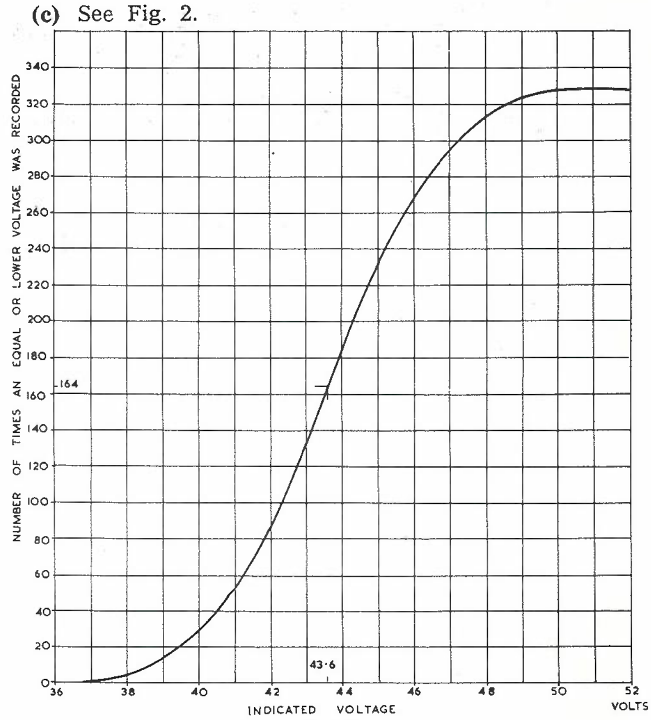


Fig. 2

(d) Total number of measurements is 328 (one on each day of test). Half of the number of measurements

$$= \frac{328}{2} = 164$$

From graph 2, a voltage of 43.6 volts was not exceeded for half the number of measurements.

QUESTION 2.

Answer any THREE of the following four parts to this question.

(a) The energy (E) stored in a capacitor is given by the relationship:

$$E = \tfrac{1}{2}CV^2$$

where C = capacitance, V = voltage.

One of two identical capacitors is charged and then connected in parallel with the second uncharged one. Compare the total stored energy in the two capacitors before and after the connection. If they are different give a reason.

(b) A television receiver with a line frequency of 18,600 Hz, has negligible horizontal flyback time and a picture width of 20 in. The horizontal scan is made from left to right.
In one location the antenna receives two signals, one directly from the transmitter and the second via a reflection from a large building.
Calculate the difference in length between the direct and reflection paths if the ghost (due to the reflected signal) appears one inch to the right of the main image.
(Velocity of light = 186,000 mile/sec.)

(c) List the requirements for a room to have good acoustics for sound recording purposes.
Define the term 'Reverberation Time'.

(d) What is meant by the following terms?
(i) Percentage Modulation.
(ii) Regenerative Action.
(iii) Anode Bend.

ANSWER 2.

(a) Before connection, stored energy $E_1 = \frac{1}{2}CV^2$

After connection, stored energy $E_2 = \frac{1}{2}(2C)\left(\frac{V}{2}\right)^2$

(the total capacitance is doubled, and the final voltage is halved because the electric charge which remains constant is shared equally between the capacitors)

Hence $E_2 = \frac{1}{2}E_1$

The difference is energy lost in the form of heat, light, sound and R.F. energy, in the connecting wires and the spark which occurs when the connection is made.

(b) Time for one 20 inch horizontal line scan $= \frac{1}{18{,}600}$ sec.

Time for 1 inch of scan $= \frac{1}{20 \times 18{,}600}$ sec.

In this time R.F. waves travelling at 186,000 miles per sec., cover a distance of $\frac{186{,}000}{20 \times 18{,}600}$ mile.

Ans. = 0.5 mile.

(c) Requirements of a room for good acoustics.

(i) The signal sound intensity should be sufficiently loud.
(ii) The background noise should be low.
(iii) There should be no significant echoes.
(iv) The sound energy should be uniformly distributed.
(v) The reverberation time should be optimum. (Too long a reverberation time causes lack of clarity, and too short a time results in a reduction of both the intensity and the quality of the sound.)

The reverberation time is the time required for the average sound energy, initially at a steady state, to decrease to one millionth (−60dB) of its initial value after the source is stopped.

(d) (i) In an A.M. wave the signal level varies about the carrier amplitude. The variation expressed as a percentage of the carrier amplitude is known as the percentage modulation.

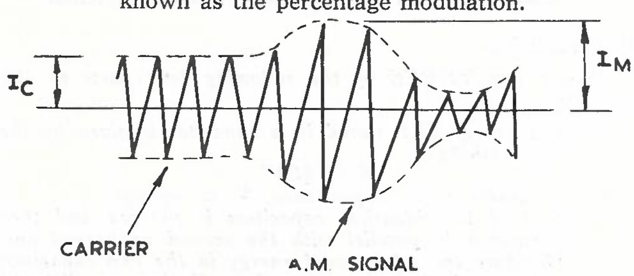


Fig. 3

$$\text{Percentage Mod.} = \frac{Im - Ic}{Ic} \times 100$$

Examiners Note.

Full marks would be given for EITHER the written definitions OR Fig. 3 and formula.

(ii) Regenerative action is the effect of applying positive feedback in an amplifying circuit. That is, the amplification of a component of the output signal which has been fed back in a manner which enhances the output signal.

(iii) Anode Bend describes a type of detection in which a thermionic valve is operated on the lower end of its anode characteristic, i.e. at a grid bias approaching anode current cut off. (See Fig. 4).

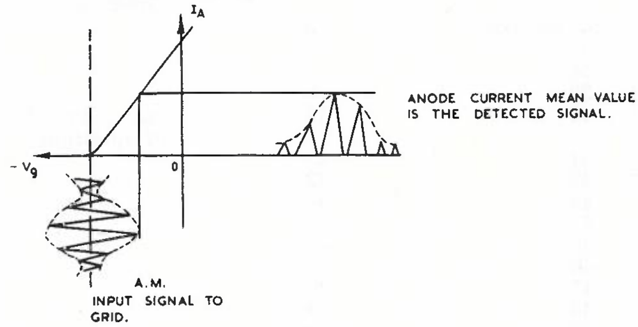


Fig. 4

QUESTION 3.

Answer any THREE of the following four parts to this question.

(a) Express in dB, the ratio of the output signal level with respect to the input level, for the matched piece of equipment shown in Fig. 5.

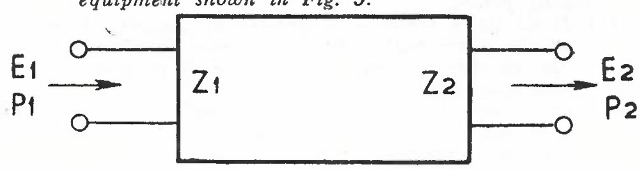


Fig. 5

(i) In terms of the power levels P_1 and P_2.
(ii) In terms of the voltage levels E_1 and E_2 and impedances Z_1 and Z_2.
(iii) In terms of E_1 and E_2 when $Z_1 = Z_2$.

(b) What is the 'characteristic impedance' of a transmission line?
Briefly describe a method of measuring the characteristic impedance of a short length of line.

(c) What is meant by 'singing'? How is it caused? How may it be overcome?

(d) What is meant by the terms 'frequency staggering' and 'frequency inversion'? Where are these processes used and why are they effective?

ANSWER 3.

(a) (i) $\text{dB} = 10 \log \left(\frac{P_2}{P_1}\right)$

(ii) $\text{dB} = 10 \log \left(\frac{E_2^2 Z_1}{Z_2 E_1^2}\right)$

(iii) $\text{dB} = 20 \log \left(\frac{E_2}{E_1}\right)$

(b) The characteristic impedance of a line is that impedance which would be measured at the input terminals if the line were of infinite length.

(Alternative definitions are:—

(i) The impedance in which a line must be terminated to prevent any energy from being reflected back along the line.

(ii) The impedance in which a line must be terminated to render the input impedance independent of line length).
Measure the short and open circuit impedances respectively and calculate the characteristic impedance from $Zo = \sqrt{Zsc\ Zoc}$
(Alternatively, terminate the line with an adjustable known impedance and vary this until the measured input impedance and the terminating impedance are the same. These will then both equal the characteristic impedance. The line should not be an integral number of half wave-lengths long for this method).

(c) Singing is a term used to describe the self oscillation of a two wire V.F. repeater. It is caused by a net gain around the amplifier hybrid loop.

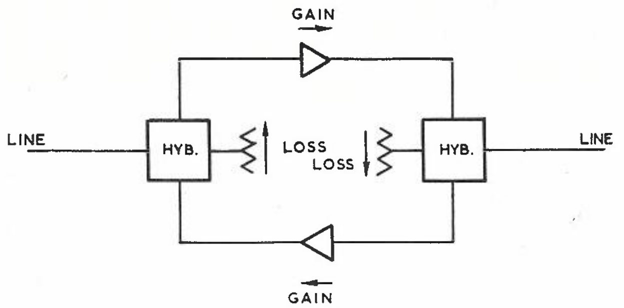


Fig. 6

The factors which may contribute to the net gain are:

(i) Lack of match between the hybrid line and balancing network impedances.

(ii) Excessive amplifier gains.

Singing may be overcome by correctly balancing the hybrid coil circuits and by keeping the amplifier gains down to a safe level.

(d) Two carrier systems on the same route are said to be frequency staggered when the side bands of one system are all shifted in frequency with respect to the side bands of the other system.
The frequency shift is usually chosen so that the mid-channel frequencies of one system fall in between the channels of the other system (see Fig. 7).

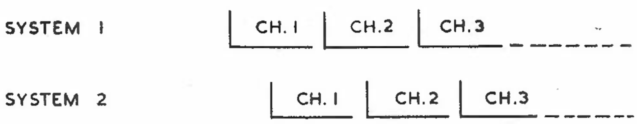


Fig. 7

Frequency inversion is the reversing of the order of the audio frequency range represented in each side band of one carrier system with respect to that in a second system on the same route (see Fig. 8).

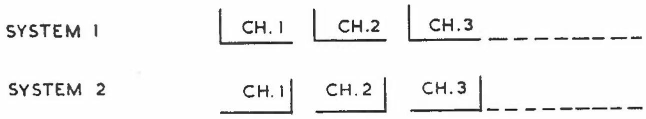


Fig. 8

Both techniques are used to reduce the effects of cross talk on open wire carrier systems. They are effective because they make cross talk less distracting to a telephone user by making it unintelligible.

QUESTION 4.

(a) For a 3,000 type relay, explain what is meant by the terms:
(i) Armature air-gap?
(ii) Residual air-gap?

(b) What are the effects on the operate and release times of increasing:
(i) Armature travel?
(ii) Residual air-gap?

(c) In addition to the plain core used for general purpose relays, a number of alternatives are available and include:
(i) Nickel iron core.
(ii) Copper slugged core (heel-end).
(iii) Nickel iron sleeved core.
Discuss briefly the special characteristics of relays using such cores and suggest an application for any one of these three types.

(d) With the aid of a simple sketch, describe the basic operation of a bimotional selector (2,000 type). Indicate the function of the usual three banks of contacts and how 200 outlets are provided.

(e) What is the basic function in a step-by-step exchange of:
(i) A group selector?
(ii) A final selector?

ANSWER 4.

(a) (i) The armature air gap is the distance between the relay pole face and the near surface of the armature, measured along axis of coil, when the relay is unoperated. (See Fig. 9).

(ii) The residual air gap is the height of the residual stud, which is the armature air gap when the relay is operated. (See Fig. 9).

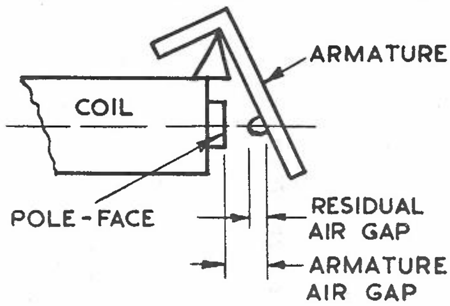


Fig. 9

(b) (i) Increasing the armature travel increases the operate time and may decrease the release time due to extra spring pressure when operated, caused by the longer armature travel.

(ii) Increasing the residual air gap has no effect on the operate time, but will reduce the release time.

(c) (i) A nickel iron core because of its higher resistivity, reduces eddy currents and provides quicker operation and release. It is used in high speed relays and impulsing relays.

(ii) A copper slugged core (heel end) gives a relay with a slow release characteristic. Such a core is used in a holding relay where a delayed release is required so that other relays will have operated (or released) before it releases.

(iii) A nickel iron sleeved core is used in a relay to provide a high winding impedance at voice frequencies. The nickel iron sleeves have a relatively low eddy current loss compared to a solid soft iron core at high audio frequencies, and the Q of the winding and hence its impedance is thus kept high at these frequencies. Such cores are used for line bridging relays such as battery feed relays.

(d) A bimotional selector switch (2,000 type) has three banks of contacts similar to the single bank illustrated in Fig. 10. Each bank has 10 rows or levels and the wiper is stepped vertically under the control of dialled impulses by means of the vertical magnet, to the required level. The rotary drive magnet then steps the wiper along the row of contacts, one contact at a time. The rotary drive can be either controlled by dialled impulses to the

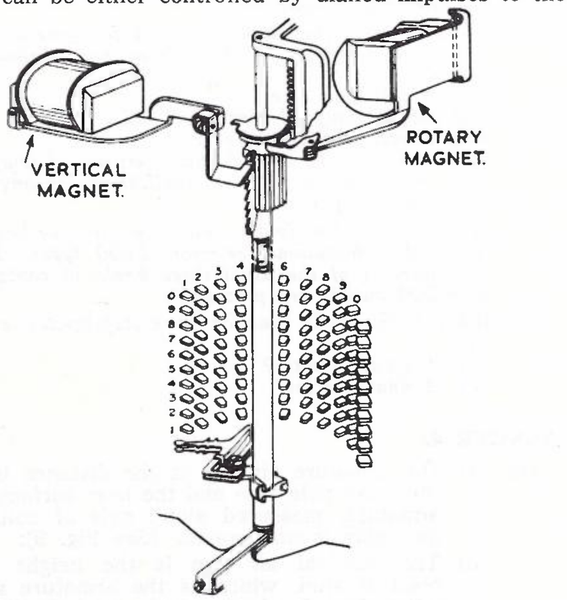


Fig. 10

required contact or by its own stepping circuit in a search for a free line (i.e. line with private not earthed). The wiper for each bank is split into upper and lower units, and each contact has insulated upper and lower contact surfaces. Each wiper therefore makes two simultaneous connections on each contact. Normally there are three banks and 200 outlets are possible.

Bottom Bank: + and — line contacts for 100 outlets

Middle Bank: + and — line contacts for second 100 outlets

Upper Bank: P contacts for 200 lines (100 each for lower and upper wiper).

The selection of the first or second 100 lines is controlled by a relay in the switch relay set, which switches the respective wipers to the appropriate line bank and in the case of the P bank to the lower or upper contact surface, thus enabling a selection of any of the 200 available outlets, each with a + wire, a — wire, and a P wire.

(e) The basic function of a group selector is to make a selection of a group of subscribers, e.g. one of the 'hundreds' group or perhaps a 'thousands' group. Under the control of the dialled digit, the vertical magnet selects the required level in that group. e.g. steps 4 to get to the 4th hundreds group. The horizontal magnet then steps, searching for a free outlet in that 4th hundred group.

The basic function of the final selector is to select the required subscribers line in a group of 100, e.g. number 47 in the 4th hundred group. It does this by selecting under the control of the last two digits dialled, the tens and units of the subscribers number; e.g. steps up 4 under vertical magnet control and rotates 7 steps.

The bi-motional selector meets both requirements. In both cases the vertical magnet is stepped under the control of dial impulses. For the group selector the rotary magnet self drives until a free outlet is obtained (absence of P wire earth stops self drive), while in the final selector the rotary magnet is controlled by the final set of dial impulses.

QUESTION 5.

(a) Draw a labelled block diagram of a basic superheterodyne receiver with automatic gain control. Show the frequencies present in the various stages when a 1,200 kc/s carrier modulated by a 500 c/s single tone is received, the I.F. frequency being 455 kc/s.

(b) Explain the advantages and disadvantages of a superheterodyne receiver as compared to a tuned radio frequency receiver.

(c) Draw a basic schematic circuit of one of the following, using labels to show all prominent features:
(i) A converter stage, OR
(ii) A detector and delayed gain control circuit.

ANSWER 5.

(a) See Fig. 11.

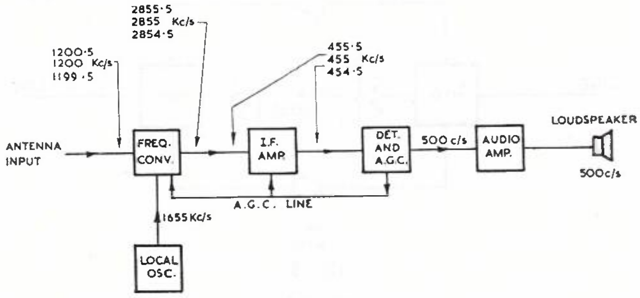


Fig. 11

(b) Advantages.

(i) The use of the relatively low I.F. frequency causes the selectivity to be high, and both the selectivity and sensitivity to be more nearly constant over the wave band.

(ii) Because the I.F. amplifier employs fixed tuned circuits, the receiver tuning mechanism is less complicated. In addition a high I.F. gain may be readily achieved without fear of instability as the tuned circuits may be well shielded and stray coupling is less at the lower frequency. This enables the sensitivity to be high.

Disadvantages.

(i) There are a number of possible interfering signals which may be received besides the derived frequency. These include the image frequency, separated from the wanted signal by twice the I.F. frequency, and various combinations of oscillator and signal harmonics.

(ii) The I.F. resonant circuits seldom have sufficient bandwidth to pass all sidebands of the incoming signal. Hence the higher audio frequencies are attenuated and the fidelity is reduced.

(c) (i) See Fig. 12.

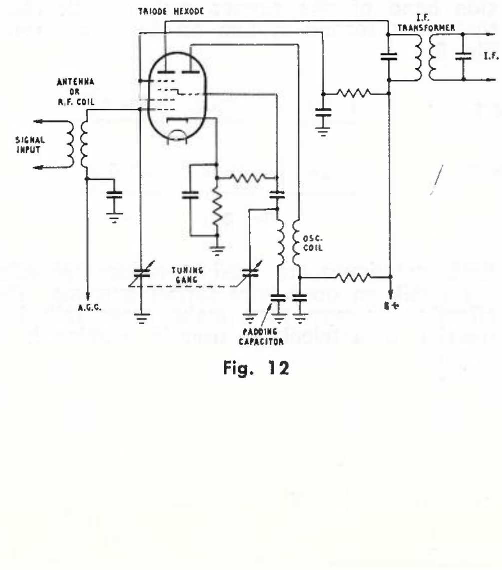


Fig. 12

(ii) See Fig. 13.

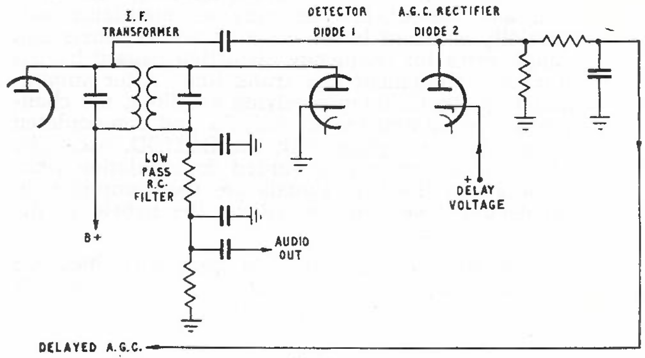


Fig. 13

(Note: there are many other acceptable alternative circuits including those using semiconductor devices).

QUESTION 6.

(a) *Draw basic schematic circuits of the following, indicating typical input and output impedances and current gains:*

(i) *A common base amplifier.*

(ii) *A common emitter amplifier.*

(iii) *An emitter follower.*

(b) *Show a BASIC circuit for measuring the small signal current amplification factor of a grounded emitter transistor. Explain the method of measurement you have chosen.*

ANSWER 6.

(a) See Fig. 14.

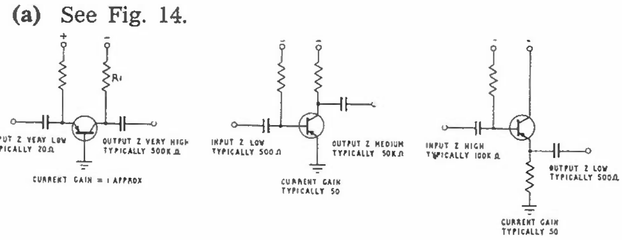


Fig. 14

(b) See Fig.15.

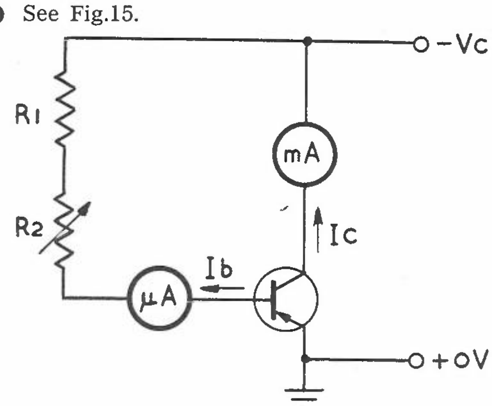


Fig. 15

The desired operating conditions are set by choosing Vc and R_1 and R_2.

Let the operating base current $= I_{bo}$.

R_2 is varied so that the base current is first increased and then decreased by equal small amounts above and below I_{bo}. These base currents and the corresponding collector currents are read.

Let the increased currents $= I_{b1}$ and I_{c1}

Let the decreased currents $= I_{b2}$ and I_{c2}

$$\text{Then } \beta_{AC} = \frac{I_{C1} - I_{C2}}{I_{b1} - I_{b2}}$$

QUESTION 7.

Answer EITHER part A OR part B

A. *Write factual notes on some aspects of a Microwave Radio system. Give EITHER general information about the whole system OR more detailed descriptions of some of its components.*

B. (a) *Draw a basic circuit of an anode modulator for use in a broadcast or H.F. transmitter. Show the class C modulated amplifier and the modulating amplifier. Explain the operation of the circuit.*

(b) *Show how you would connect the deflection plates of a cathode ray tube to the above modulator in order to measure the percentage modulation. Assume there is more than enough signal to provide full deflection. Sketch the cathode ray tube display for 50 per cent, 100 per cent and over-modulated signals.*

ANSWER 7.

A. Part A of this question is not taken from the prescribed course, which is partly why the alternative choice part B was given.

Part A covers microwave radio systems which are important because of their ever growing numbers throughout Australia and the rest of the world.

No typical answer has been given as the question gives scope for many possible answers. The length of the answer should be about 200 to 250 words.

Suitable references are:—

1. Yonezawa S. and Tanaka N., 'Microwave Communication' (1965 2nd Edition); Maruzen Co. Ltd., Tokyo — General Information Chapt. 1.
2. Molloy E. and Pannett W. E., 'Radio and Television Engineers Handbook'; (1956 2nd Edition) Newnes, London. Chapt. 17.

B. (a) See Fig. 16.

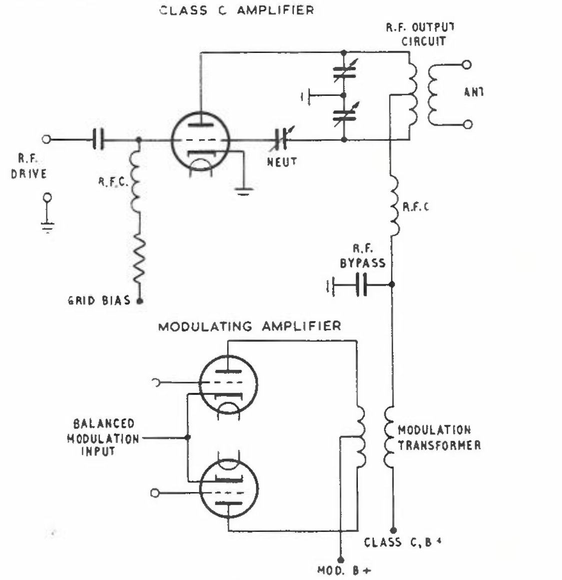


Fig. 16

The class C amplifier is operated with a constant R.F. drive signal, and an anode supply voltage which is equal to the sum of the modulating voltage and the class C B+ voltage. The addition of these latter voltages is achieved by connecting the modulation transformer secondary in series with the class C supply line.

The R.F. output voltage of the class C stage is proportional to its supply voltage. Hence the output signal is modulated in accordance with the modulating signal.

(b) See Fig. 17. Both voltage dividers are of sufficiently high impedance to prevent them from significantly loading the circuits to which they are connected.

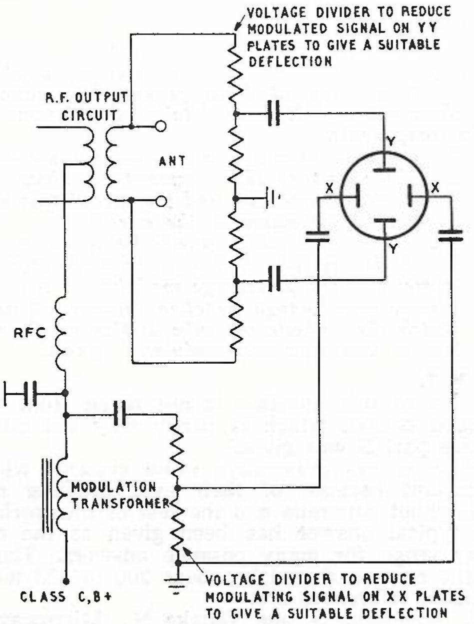


Fig. 17

Cathode ray tube displays are shown in Fig. 18.

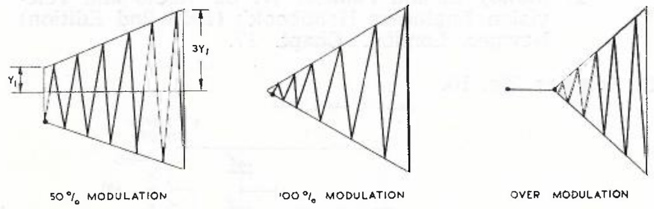


Fig. 18

QUESTION 8.

(a) Draw a labelled block diagram of a basic 3-channel open wire line carrier telephone system terminal. Show the input from the trunk switchboard and the output to the trunk line. You may use standard abbreviations when labelling the diagram.
Explain the operation of the terminal when receiving.

(b) Why is Pilot Regulating Equipment used in open wire carrier telephone systems?

ANSWER 8.

(a) See Fig. 19.

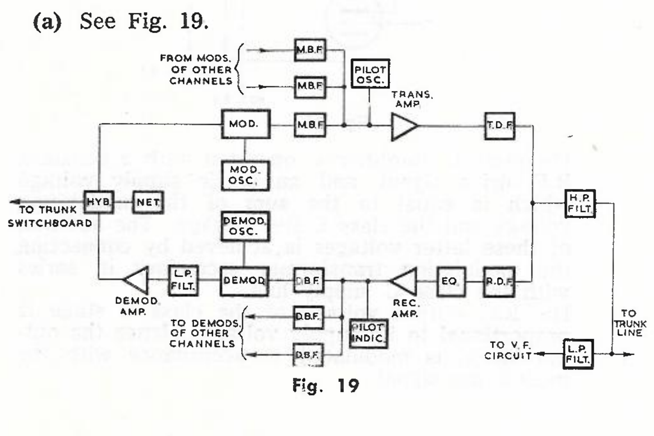


Fig. 19

Incoming carrier signals are passed by the H.P. filter and the R.D.F. The equaliser maintains substantially constant levels for all three channels and compensates for frequency distortion caused by the preceding equipment and trunk line. After amplification by the common receiving amplifier, the channels are separated by the D.B.F.s and demodulated by mixing the signals with the DEMOD. osc. The L.P. filter suppresses unwanted demodulation components and the V.F. signals are then amplified to the desired level and passed via the hybrid to the trunk switchboard.

(b) The variation in attenuation of open wire lines due to changing weather conditions is considerably greater at carrier frequencies than at V.F. For this reason it is necessary to adjust the levels of a carrier system from time to time at the receiving terminal both to ensure that the overall transmission loss between switchboards does not vary to more than a tolerable amount, and to keep the overall system gain below the instability point when line attenuation is low.
Furthermore, when repeaters are involved it is necessary to ensure that their input levels are neither too low nor too high. Too low a level causes noise to be noticeable while too high a level overloads the repeater amplifiers and produces distortion and interchannel crosstalk.
Pilot regulating equipment enables the above conditions to be met by either the manual or automatic adjustment of amplifier gains throughout a system to maintain a pilot signal close to its correct level, these adjustments being made with the system in service.

QUESTION 9.

(a) For the L.M. Ericsson crossbar systems adopted for use in the Australian telephone network, indicate briefly the four main characteristics in regard to:
(i) Control of calls.
(ii) Control of switching stage.
(iii) The basic switching stage.
(iv) Signalling between exchanges.

(b) List the three main types of crossbar exchange systems in use in the Australian telephone network and indicate the special applications for each type.

(c) Describe with the aid of a simple sketch the construction and operation of a typical crossbar switch having 10 vertical magnets and 5 horizontal operating bars to provide a connection capacity of 100 lines. (To simplify the description, assume a single wire switching circuit).

(d) What is the maximum number of calls which can be held switched through this crossbar switch at any time?

(e) Indicate briefly how the switch described in (c) above can have its capacity increased from 100 to 200 connections by adding a sixth horizontal bar and increasing the number of vertical contacts.

ANSWER 9.

(a) (i) Central register control.
(ii) Common marker control of switch relay magnets.
(iii) Crossbar switch with 10 vertical magnets and 6 horizontal magnets to provide 10 inlets and 20 outlets.
(iv) High speed multi-voice-frequency signalling for both transmitted digits and control signals between crossbar exchanges.

(b) (i) ARF: Metropolitan and large country exchanges.
(ii) ARK: Smaller country exchanges (30 to 2000 Subs).
(iii) ARM: Trunk switching exchanges.

(c) See Fig. 20. The switch comprises 10 vertical magnets and 5 two-way horizontal magnets. Each horizontal magnet operates a finger which sets either the upper or lower contacts in all verticals such that the appropriate vertical contact is made when a vertical magnet is operated. The connection is held by the vertical magnet and the horizontal magnet can then be released. A separate connection can be set up with each vertical magnet allowing 10 connections among a possible 100 outlets.

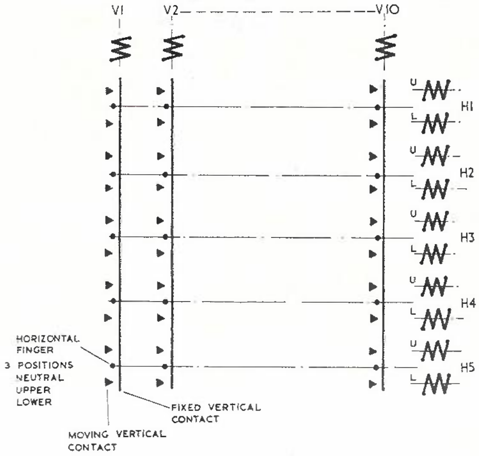


Fig. 20

(d) Ten calls is the maximum which can be held switched at any time.

(e) See Fig. 21. To increase the capacity to 200 outlets, each vertical magnet operates two sets of moving contacts and a sixth horizontal magnet is set to connect to the first or second group of contacts as required through contacts making onto the fixed vertical contacts. Each vertical magnet can therefore switch to any of 20 outlets and the switch can connect 10 calls out of the 200 available outlets.

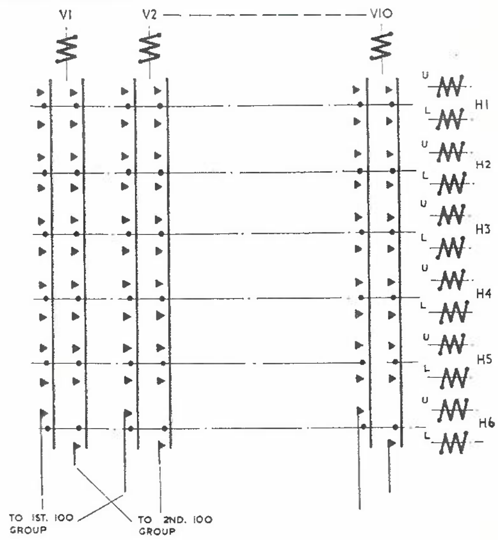


Fig. 21

QUESTION 10.

(a) What is a blocking oscillator? What general characteristic distinguishes the output voltage of a free-running blocking oscillator from other common types of free-running oscillators?

(b) Fig. 22 shows the circuit of a transistor blocking oscillator employing collector to emitter feedback and using a general purpose medium gain germanium pnp transistor.

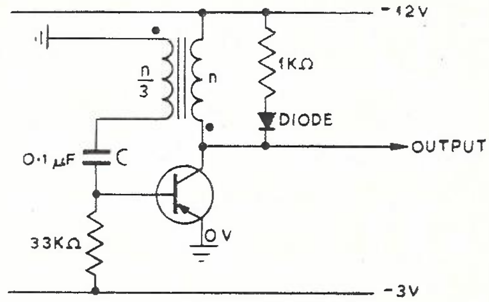


Fig. 22

Describe the operation of the above circuit and show the collector and base voltage waveforms and appropriate voltage levels. What is the function of the diode-resistor shunt across the collector winding?

(c) Indicate which time constants exercise the main control over the 'on' and 'off' periods of collector current. What is the approximate pulse repetition rate of this oscillator?

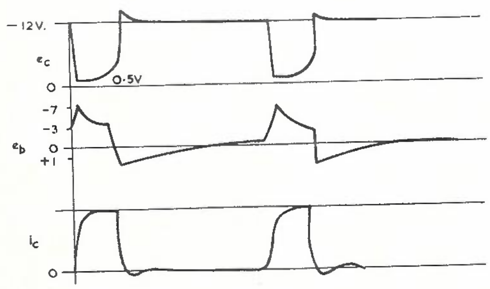
(d) Explain how this circuit can be operated as a synchronised oscillator. What are the requirements for the synchronising signal?

ANSWER 10.

(a) A blocking oscillator is a form of relaxation oscillator which employs heavy positive feedback via a transformer, to ensure switching between the two extremes of saturation and cut-off of the amplifier stage. Generally its output voltage has a pulse waveform which has a lower on-off ratio (duty cycle) compared to other common types of free running oscillators.

(b) Operation of the blocking oscillator circuit is as follows: When the collector voltage is first applied, the collector is momentarily at the supply voltage of —9V. The base is biased at —3V relative to the emitter, so that the transistor is heavily forwarded biased and tends to conduct strongly. As conduction commences, the collector voltage falls rapidly but the rate of current increase is limited by the effective inductance of the collector winding, which is affected by the current drawn from the secondary winding. The primary voltage transformed to the secondary winding charges capacitor C and increases the negative forward bias on the base. The collector current continues to increase until either the saturation current of the transistor is reached, or until the resistance of the collector winding causes a sufficient drop in available collector voltage. The current then stops increasing and the feed back voltage to the base drops, and the resulting further reduction in collector current causes a reversed polarity feed back which now causes a rapid reduction of collector current until completely cut off. At this stage capacitor C has a large positive charge and holds the transistor cut off for a relatively long period until C has discharged through the 33k ohm base resistor. Conduction commences again when the base becomes slightly negative with respect to the emitter. As soon as collector current flows, the transformer feed back rapidly increases the current to saturation and the cycle repeats itself.

When the collector current is rapidly cut off, a high reverse voltage is developed across the collector winding which can result in a voltage break down of the collector to base or emitter. The diode across the collector winding absorbs the reverse voltage by allowing some current to flow through the winding after the transistor is cut off. The series resistor prevents excessive diode current flow and the possibility of excessive transformer damping which could upset the oscillator timing. The circuit waveforms are shown in Fig. 23.



CIRCUIT WAVEFORMS

Fig. 23

(c) The 'on' period is determined chiefly by the time constant CR where R is the sum of the saturated base to emitter resistance which is low (order of 100 ohms) and the transformer secondary winding resistance. The 'off' period is determined chiefly by the time constant CR where R is the base circuit resistor (= 33k ohms).
Neglecting the short 'on' period, the time constant CR = 3.3mS.
The oscillator repetition rate is approximately

$$\frac{1}{CR} = \frac{1000}{3.3} = 300\text{Hz}.$$

(d) The oscillator can be synchronised by feeding into the base circuit a negative going pulse just before the transistor recommences conduction. In order to be synchronised, the synchronising signal must have a slightly faster repetition rate than that of the free running oscillator. Its pulse amplitude would need to be of the order of 50 to 500mV, depending on how close the free running frequency is to the synchronising signal.

QUESTION 11.

(a) List two basic types of oscillator circuits with a nominally sinusoidal output which employ R/C networks for frequency determination.

(b) With the aid of a sketch describe the operation of one only of the types in part (a). (Either a transistor or valve circuit can be used for the illustration).

(c) What limits the practical frequency range of an R/C oscillator and why is such a circuit more often used for an audio frequency range oscillator than an L/C type of oscillator circuit?

ANSWER 11.

(a) Phase shift, Wien Bridge, Bridged-T — only 2 required to be stated, and only 1 to be described in (b).

(b) (i) In the phase shift oscillator (Fig. 24) the 3 stage phase shift network comprising series 0.1 microfarad capacitors and shunt 10k ohm resistors connects the output with the out-of-phase input. Each stage attenuates the signal and changes its phase. At some frequency the total phase shift becomes 180 degrees resulting in positive feedback from collector to the base. If the current gain of the transistor at the frequency is sufficient to overcome the loss in the phase shift network, the overall gain exceeds unity and the circuit will oscillate. The gain of the transistor can be adjusted for optimum oscillation by either varying the base bias or by varying the collector load. Excessive circuit gain will cause the output waveform to be distorted.

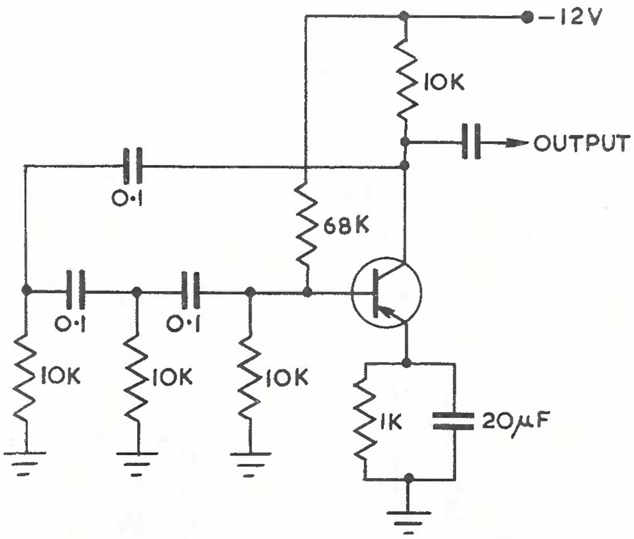


Fig. 24

(ii) In the wien bridge oscillator (Fig. 25), an amplifier with output in phase with its input (usually a 2-stage amplifier) has a wien bridge phase shift circuit. At some frequency the series CR and the parallel CR circuits have an equal phase shift and form a 2 : 1 ratio voltage divider. The oscillator voltage is also divided into a similar ratio by the 10k ohm resistor and the thermistor. The voltage difference between the two dividers, which together make a bridge, is applied between the input terminals of the amplifier (i.e. grid and cathode) and is amplified and so again fed to the wien bridge. The thermistor is so chosen that when the oscillator has normal output level, the voltage difference across the dividers of the bridge and as applied to the amplifier input, is just sufficient to drive the amplifier output. Any tendency for the oscillation level to increase or decrease will be offset by the action of the thermistor in increasing or decreasing the balance of the wien bridge. This circuit is widely used for variable frequency oscillators. Both C values, or alternatively both B values, have to be varied simultaneously to tune the oscillator.

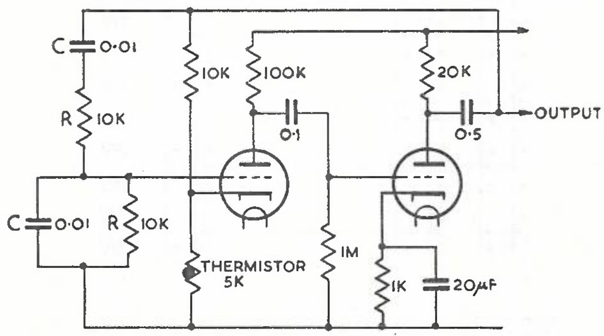


Fig. 25

(iii) The bridged-T oscillator (Fig. 26) is a modification of the selective amplifier in which the bridged-T network is placed between the output and input to provide negative feedback. The amplifier has least feedback and hence maximum gain at the null frequency of the bridged-T network. By applying as well, a non-frequency selective positive feedback loop of sufficient gain to make the net loop gain of the amplifier just exceed unity, the circuit will oscillate at the bridged-T null frequency. At all other frequencies, the negative feedback via the bridged-T network over-rides the positive feedback and keeps the loop gain to less than unity. Hence the frequency of oscillation is determined by the null frequency of the bridged-T network. The oscillator can be tuned over a limited range by varying the shunt leg resistor of the bridged-T network.

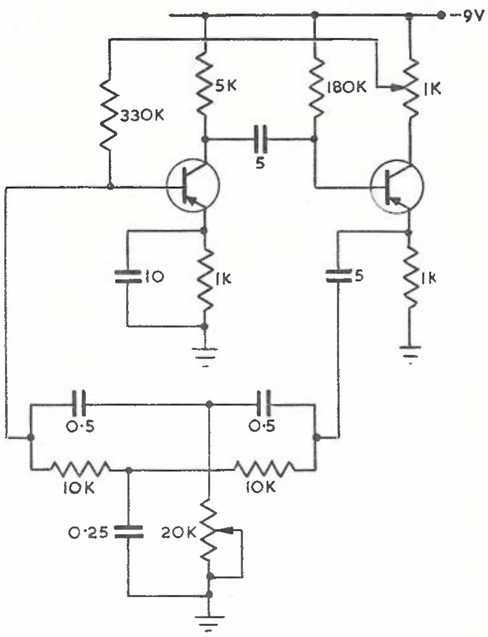


Fig. 26

(c) As the frequency is increased, the C elements of RC oscillators must be small and stray wiring and circuit capacitances, as well as amplifier phase shifts, affect the oscillator performance. At low frequencies, to avoid the use of large and expensive capacitors, high values of R need to be used. Leakage resistances and limitations of amplifier input impedances restrict the upper limit of R. At audio frequencies, large values of L and C are required to tune an LC oscillator. It is both difficult and expensive to make either one variable. In an RC circuit, at audio frequencies, the required values of R and C are more readily available and in particular, it is fairly simple to provide variable resistors to tune the oscillator.

QUESTION 12.

(a) What is the basic function of the magnet system of a moving coil meter?

(b) Describe with the aid of a sketch how this requirement is achieved in a core-magnet type of moving coil meter, similar to that used in the A.P.O. Multimeter.

(c) What advantage does a core-magnet type of meter have over a conventional magnet type of moving coil meter?

(d) A moving coil meter has a full-scale current sensitivity of 1mA d.c. It is fitted with a series and a shunt rectifier as shown in Fig. 27.

What RMS current from a sinusoidal alternating current source will produce full-scale deflection of this meter?

(Given: For a sinusoidal waveform

$$RMS = \frac{PEAK}{1.414} = AVERAGE \times 1.11)$$

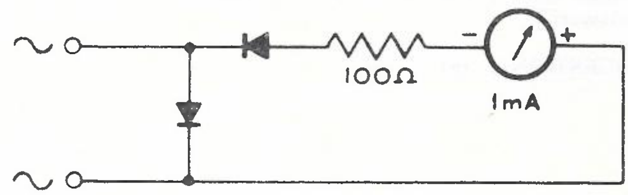


Fig. 27

ANSWER 12.

(a) The basic function of the magnet system of a moving coil meter is to generate an intense, stable and uniform magnetic field in an annular gap in which the moving coil can rotate. To ensure that the rotational deflection of the coil is proportional to the current, the magnetic field across the gap must be uniform and constant, so that at any angular position the coil torque is proportional to the current and is opposed by an equal spring torque which is proportional to the deflection angle.

(b) In the core-magnet meter, the highly efficient magnet bar, transversely magnetised, takes the place of the usual soft iron core. (Fig. 28.) This magnet has especially shaped soft iron pole tips. The annular gap in which the coil moves is surrounded by a soft iron annular ring which ensures a uniform field in the air gap and provides a return path for the magnetic flux.

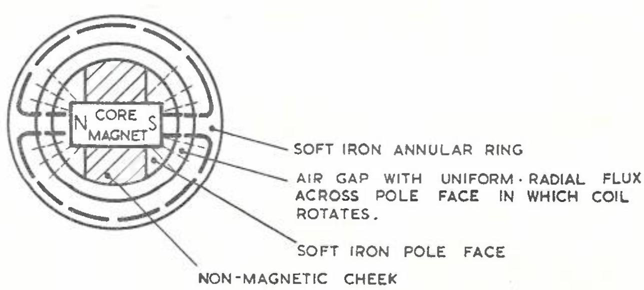


Fig. 28

(c) A core-magnet type meter has less external magnetic field and is less affected by external fields than the conventional meter. A core-magnet movement is also lighter and more compact.

(d) Although two rectifiers are used, only current pulses of one polarity will be directed through the meter circuit, which responds to the average current flowing through it. The meter current will be half of the input current.

i.e. $Im = \frac{1}{2}$ Average of input RMS.

$$= \frac{1}{2} \times \frac{\text{RMS value of input}}{1.11}$$

or RMS value of input $= 2 \times 1.11 \times Im$, where $Im = 1mA$.

$\therefore$ RMS input current $= 2.22mA$.

Examination No. 5599, 26th November, 1966, and subsequent dates to gain part of the qualifications for promotion or transfer as Senior Technician (Telecommunications), Control Systems, Postmaster-General's Department.

PART A — ELECTRONIC CONTROL TECHNOLOGY.

(Reasons appearing with the answers are given for clarification only. They were not required in the examination answers.)

QUESTION 1. (a)

Fig. 1 represents a 5 bit binary counter:—

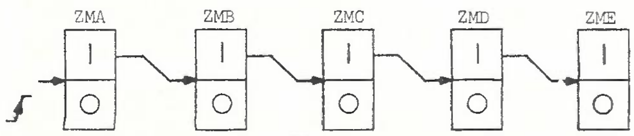


Fig. 1

(i) *Which element represents the least significant digit?*
(ii) *Which of ZMD and ZMB changes state more frequently?*
(iii) *How many times more frequently?*
(iv) *What is the decimal weighting of ZMC?*

ANSWER 1. (a)

(i) ZMA.
(ii) ZMB. Reason: It represents a less significant digit.
(iii) 4 times. Reason: Each element changes state twice as frequently as the next element on its right.
(iv) Four. Reason: Decimal weighting of the elements from left to right is, 2^0, 2^1, 2^2, 2^3, 2^4, therefore ZMC represents $2^2 = 4$.

QUESTION 1. (b)

In Fig. 2 are two gatings constructed to extract given counts from the counter in 1 (a). G1 is a simple AND gate and you are given that its output is count 12. XV1 is a load sharing inverter.

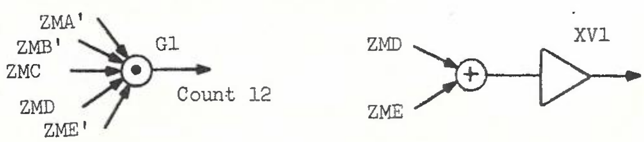


Fig. 2

(i) *What count(s) does the output of XV1 represent?*
(ii) *If the ZMA' input to G1 was open circuit what count(s) would G1 represent?*

ANSWER 1. (b)

(i) Counts 0 - 7. Reason:
XV1 = (ZMD + ZME)'
= ZMD'. ZME'
The output of XVI is logical 1 for all counts for which both ZMD and ZME are logical 0. This gives all counts less than 8, i.e., counts 0-7.

(ii) Counts 12 - 13.
Reason: With ZMA' input open circuit, the output of the gate G1 is G1 = ZMB'. ZMC. ZMD. Z.M.E'.
and this is logical 1 when ZMC and ZMD are logical 1 and ZMB and ZME are logical zero. The two binary numbers which comply with this condition are 01100 and 01101, i.e., the decimal numbers 12 and 13.

QUESTION 1. (c)

From information on the relay tree in Fig. 3, determine what count Test Point 'X' represents.

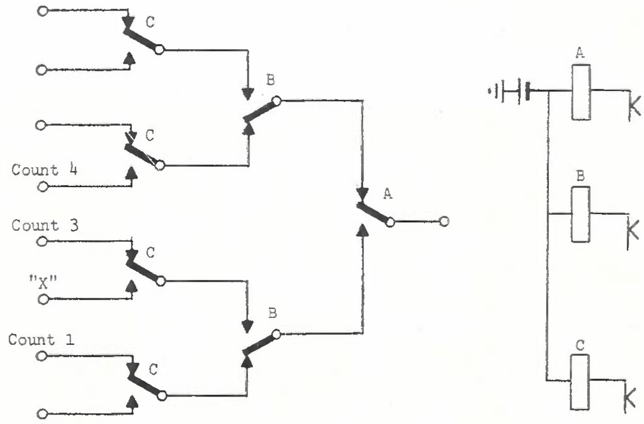


Fig. 3

ANSWER 1. (c)

Count 7.

Reason: From the three given counts.
Count 1 = A op. B rel. C rel, therefore A has decimal weighting 1.
Count 3 = A op. B op. C rel, therefore B has decimal weighting 2.
Count 4 = A rel. B rel. C op., therefore C has decimal weighting 4.
(This last piece of information is not necessary if it is assumed that the three relays in fact represent decimal weightings 1, 2 and 4.)
Now count X = A op. B op. C op., i.e., the binary number 111, which gives count 7.

QUESTION 2. (a)

Draw the circuit of a two input diode AND gate connected into a two input OR gate, using negative logic. Show suitable values and polarities for the power supplies.

ANSWER 2. (a)

See Fig. 4.

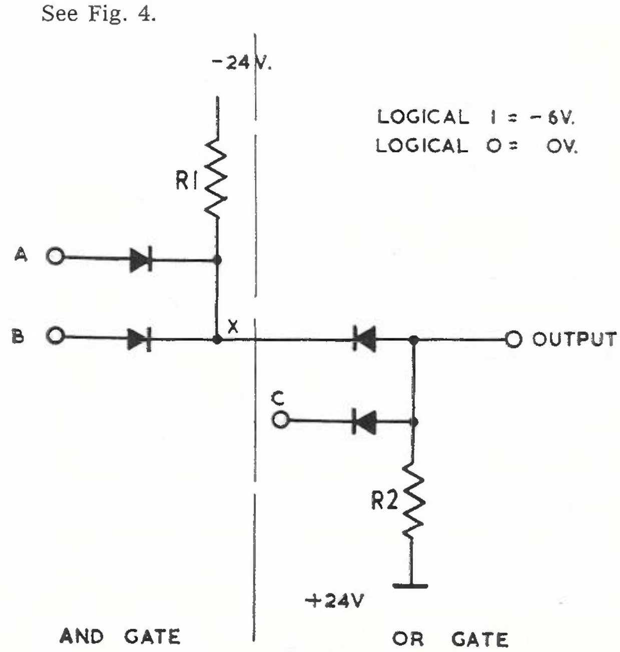


Fig. 4

QUESTION 2. (b)

Complete the following truth tables for the gates in Fig. 4, showing all possible input conditions.

ANSWER 2. (b)

(b)

Inputs		Outputs
A	B	A.B
1	1	1
1	0	0
0	1	0
0	0	0

Inputs		Outputs
A.B	C	A.B+C
1	1	1
1	0	1
0	1	1
0	0	0

QUESTION 2. (c)

Explain how the AND gate functions.

ANSWER 2. (c)

The AND gate diodes D1 and D2 are connected through R1 to a backing voltage more negative than logical 1, tending to bias the diodes conducting. The output of the AND gate, point X, is then clamped to that input voltage which is furthest away from the backing voltage, neglecting the forward drop across the diodes. Any input diode which is connected to a less positive voltage is then reverse biassed. Therefore, for the two possible input voltage levels, —6 volts and 0 volts in this case, whenever 0 volts is present at either input the output will be also clamped to 0 volts, and only —6 volts at both inputs will give a —6 volt output.

QUESTION 2. (d)

Explain how the OR gate functions.

ANSWER 2. (d)

The OR gate diodes D3 and D4 are connected through R2 to a voltage more positive than logical O. Again the diodes are in the conducting direction and the output is clamped to the voltage furthest away from the backing voltage, reverse biassing any input diodes which are connected to a more positive voltage. Thus whenever —6 volts is present at either input the output will be —6 volts and only if both inputs are at earth will the output be 0 volts.

QUESTION 3. (a)

Draw the circuit of a typical common emitter saturating inverter, of the type used in the automatic letter handling plant at Sydney Mail Exchange and,

(i) Show suitable values and polarities (where applicable) for resistors, power supplies and for logical 1 and logical 0.

(ii) Show on the circuit how it can be made to limit the logical 1 output voltage level to its specified value.

ANSWER 3. (a)

See Fig. 5.

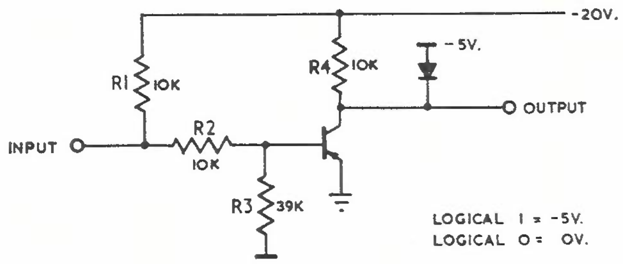


Fig. 5

(NOTE: The above are typical values, many other combinations are suitable.)

QUESTION 3. (b)

Explain with the aid of simple calculations how both states of the input logic can cause the transistor to switch.

ANSWER 3. (b)

R2 and R3 form a voltage divider between the INPUT and the positive supply so that $\frac{R2}{R2 + R3} = \frac{10}{10 + 39}$ = 1/5 (approximately) of the voltage difference between the INPUT and +10 volts will be dropped across R2.

With logical 1, i.e., —5 volts, at the INPUT, the total voltage across the divider is 15 volts. 3 volts will be dropped across R2, so that the base voltage tends to —2 volts. This causes the transistor to switch on and saturate. The actual base voltage will be about —0.5 volts, the extra voltage being dropped across R2 by the base current passing through it.

With logical 0, i.e., 0 volts, at the INPUT, the total voltage across the divider is 10 volts. 2 volts will be dropped across R2, making the base voltage +2 volts. This causes the transistor to switch off.

QUESTION 4.

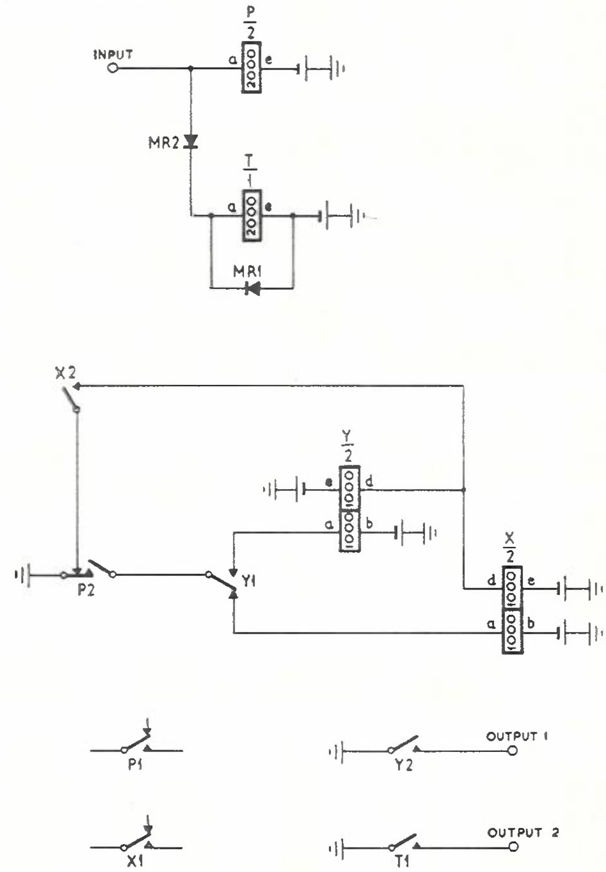


Fig. 6

In the relay circuit provided (Fig. 6), the INPUT is normally open circuit. The only signal ever applied to the input is a series of 10 earth pulses which are each 130mS long with a pause of 50mS between each pulse. Relays P, X and Y have operate and release times of 20mS each.

QUESTION 4. (a)

What is the purpose of MR1?

ANSWER 4. (a)

MR1 is to increase the release time of relay T.

QUESTION 4. (b)

What is the purpose of MR2?

ANSWER 4. (b)

MR2 is to prevent MR1 affecting the release time of relay P.

QUESTION 4. (c)

What is the signal at OUTPUT 1 due to the pulse train at the INPUT?

ANSWER 4. (c)

The signal at OUTPUT 1 will be 5 earth pulses, each of 180/mS duration with 180/mS spacing between the pulses. The first pulse appears 170/mS after the first pulse at the INPUT.
Reason: See Fig. 7.

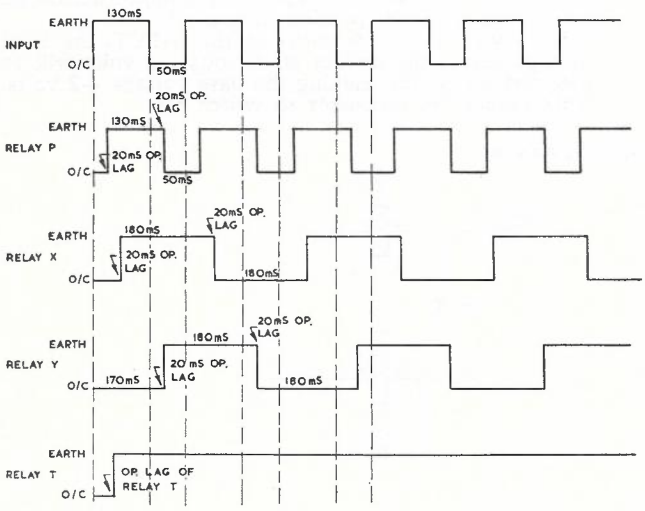


Fig. 7

QUESTION 4. (d)

What is the signal at OUTPUT 2 due to the pulse train at the INPUT? (State when it begins relative to the beginning of the signal at OUTPUT 1).

ANSWER 4. (d)

The signal at OUTPUT 2 will be a continuous earth pulse for a period longer than the duration of the input pulse train, as relay T will not have time to release during the 50mS space between pulses. The pulse will begin (170 — op. lag of T)/mS before the first earth pulse at OUTPUT 1, that is about 150/mS before, assuming 20/mS op. lag for T.

QUESTION 5.

The System Logic given below is typical of that used in connection with the Register Translator in an automatic letter handling plant.

UB1 = MA1 . MA3
UB1 = MA2 . MA3
UB2 = MA1 . MA2
UB2 = MA1' . MA2'
NB1 = VB1
NB2 = MB1
NB2 = VB2
NB1' = MB2
NB2' = MB2
EB1 = MB1'
EB1 = MB2'

Note:— MA1, MA2 and MA3 are normally SET.

QUESTION 5. (a)

Given that MA1, MA2 and MA3 are all normally SET, what is the normal state (or output) of:—

(i) *MB1?*
(ii) *MB2?*
(iii) *FB1?*

ANSWER 5. (a)

(i) MB1 is reset.
(ii) MB2 is reset.
(iii) FB1 is logical 1.

Reason: MA1, MA2 and MA3 normally set, i.e., logical 1,
therefore UB1 = 1 + 1 = 1.
therefore VB1 = 0.
ALSO UB2 = 1 + 0 = 1.
Therefore VB2 = 0.

Now as NB1' = MB2 and NB2' = MB2, both MB1 and MB2 always reset one bit after MB2 has set, so that the only way either of them can be maintained in the set state is if UB1 or UB2 at their set input is logical 1.

Thus assume both MB1 and MB2 reset.
This gives NB1 = VB1 = 0.

and NB1' = MB2 = 0, which is a stable input condition and will not change the state of MB1.
and NB2' = MB2 = 0, which is also a stable input
and NB2' = MB2 = 0, which is also a stable input condition and will not change the state of MB2.
Then EB1 = MB1' + MB2 = 1 + 1 + 1.
Therefore FB1 is logical 1.

In your answer to parts 5 (b) and 5 (c) it may be helpful to draw timing waveforms or sequence charts.

QUESTION 5. (b)

MA1 is RESET for 1 bit, then returns to normal. Determine the duration and timing, relative to MA1 resetting, of the output at:—

(i) *MB1*
(ii) *MB2*
(iii) *FB1*

ANSWER 5. (b)

MA1 is reset for 1 bit.

VB1 will not change, as MA2 . MA3 is still logical 1.

VB2 will go to logical 1 for one bit, as both its inputs will be logical 0.

Therefore, the sequence chart in Fig. 8 will be applicable, and the answer is:—

(i) MB1 remains reset.

(iii) MB2 sets for 1 bit period, 1 bit after MA1 resets.

(iii) FB1 remains logical 1.

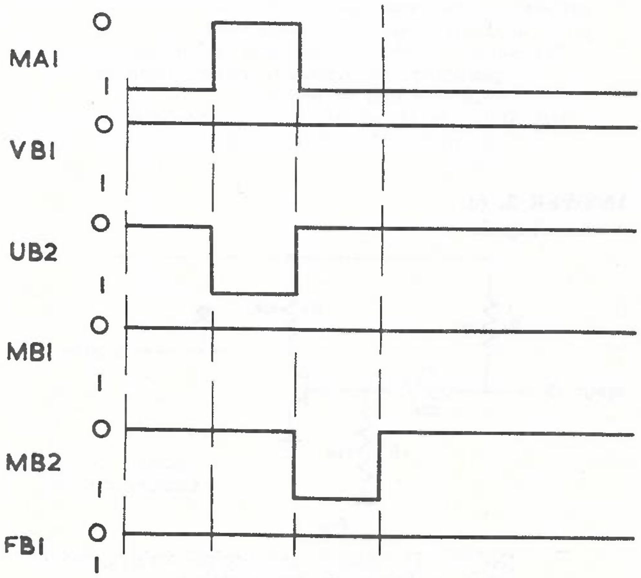


Fig. 8

QUESTION 5. (c)

MA3 is RESET for 1 bit, then returns to normal. Determine the duration and timing, relative to MA3 resetting of the output at:—

(i) MB1
(ii) MB2
(iii) FB1

ANSWER 5. (c)

MA3 resets for 1 bit.

Therefore VB1 becomes logical 1 for 1 bit, but VB2 will not change. The sequence chart in Fig. 9 will apply and the answer is:

(i) MB1 sets for 2 bits, one bit after MA3 resets.
(ii) MB2 sets for 1 bit, two bits after MA3 resets.
(iii) FB1 becomes logical 0 for 1 bit, two bits after MA3 resets.

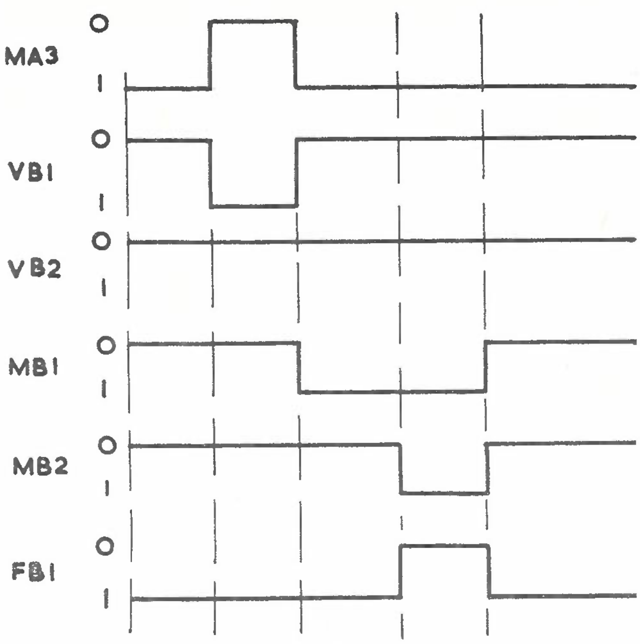


Fig. 9

QUESTION 6. (a)

From the circuit in Fig. 10, determine the output of XV1 for each of the four cases. (The numbers 1 and 0 refer to logic levels. If the output depends on inputs other than those specified, write "Unknown" for your answer.)

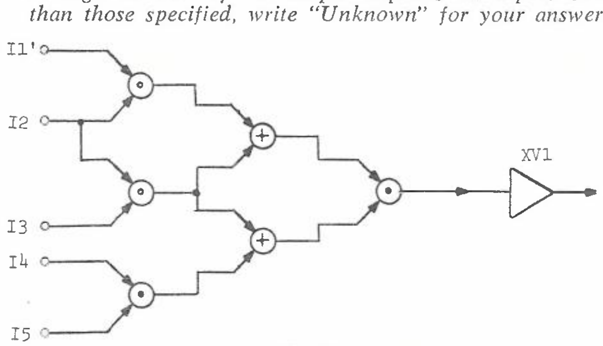


Fig. 10

(i) I2 = 0
(ii) I3 = 0
(iii) I1 = 1 and I3 = 0
(iv) I4 = 1 and I5 = 1

ANSWER 6. (a)

(i) Logical 1.

Reason: I2 = 0 makes output of both AND gates it feeds logical zero. Therefore, the OR gate into which these feed also has logical zero output, which in turn makes the final AND gate output logical 0. Therefore the inverter output is logical 1.

(ii) Unknown.
Reason: I3 = 0 makes the output of the AND gate it feeds logical 0. This is fed to both OR gates, but each of these has another input, so that their output is unknown.

(iii) Logical 1.
Reason: I1 = 1 means I1' = 0 and hence this case is similar to (i).

(iv) Unknown.
Reason: I4 = 1 and I5 = 1 makes the output of the AND gate they feed logical 1. This feeds into an OR gate whose other input is unknown, hence its output is unknown.

QUESTION 6. (b)

The 3 bit binary counter circuit below is required to stop on count 3 whenever a certain inhibit signal, FC, becomes 1. (FC is normally 0.)

Draw the additional circuitry required.

ANSWER 6. (b)

Here it is required to gate in with the counter stepping signal a signal which makes the input to the first toggle zero when FC is 1 and the counter is on count 3. Two possible circuits are shown in Fig. 11.

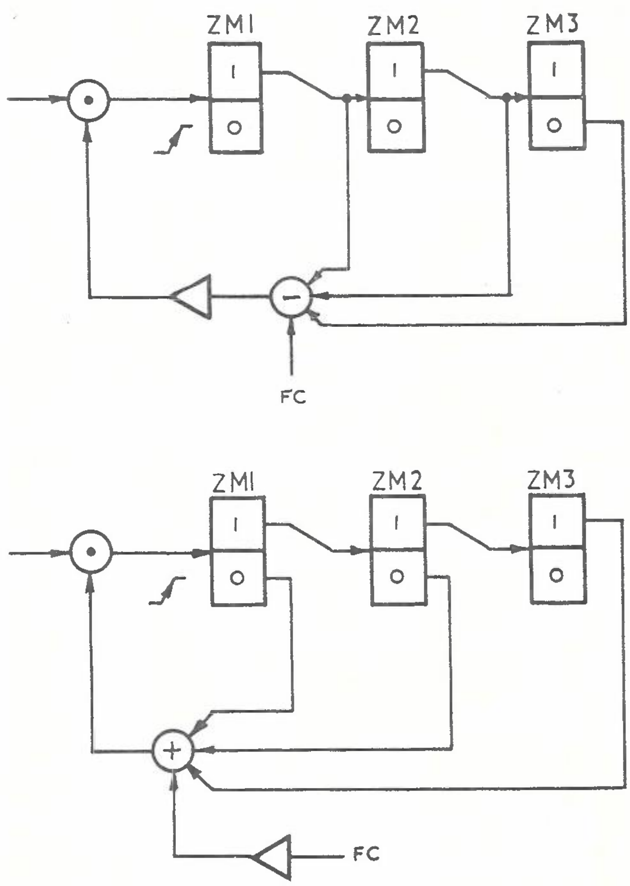


Fig. 11

QUESTION 6. (c)

Fig. 12 is a gated counter output circuit. Complete Fig. 13 so that it gives the same count output, using as few elements as possible.

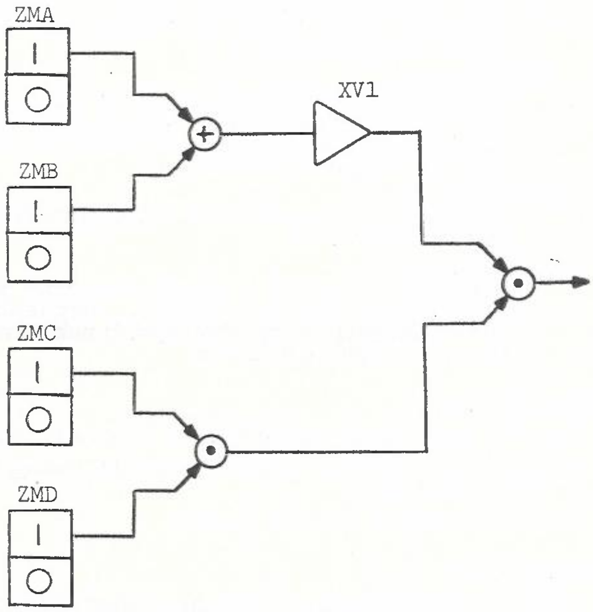


Fig. 12

ANSWER 6. (c)

See Fig. 13.

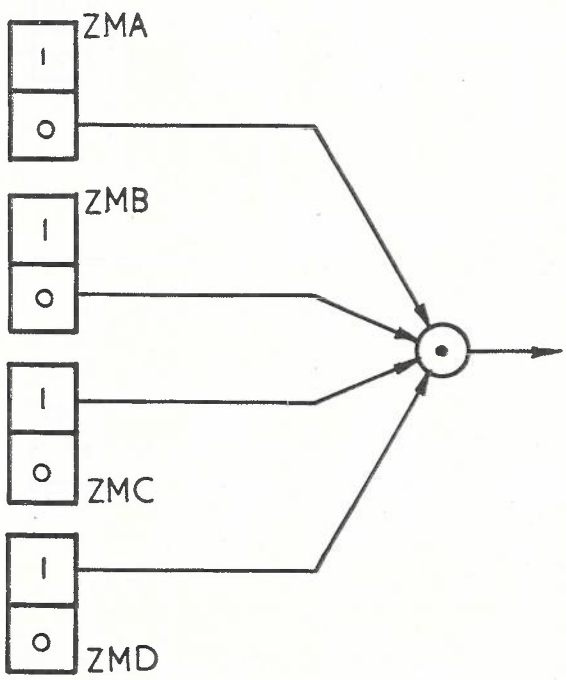


Fig. 13

Reason: Use de Morgan's theorem for the OR gate and inverter. (ZMA + ZMB)' = ZMA' . ZMB'

Then have (ZMA' . ZMB') . (ZMC . ZMD)

Combine all AND gates to get the answer.

PART B — AUTOMATIC MAIL HANDLING EQUIPMENT.

(Reasons appearing with the answers are given for clarification only. They were not required in the examination answers.)

QUESTION 1.

The circuit of a regulated power supply, as used for example in the Pitney Bowes Facer-Canceller, is shown in Fig. 14.

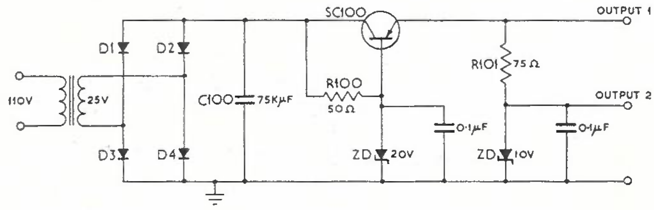


Fig. 14

QUESTION 1. (a)

Indicate in the table below the value of voltage and polarity, with respect to earth, at OUTPUT 1 and OUTPUT 2.

ANSWER 1. (a)

Output	Voltage	Polarity
1	20 volts	Negative
2	10 volts	Negative

QUESTION 1. (b)

Briefly explain what effect an INCREASE in alternating voltage input will have upon the circuit and its output voltage.

ANSWER 1. (b)

An increase in a.c. voltage input will cause an increase in d.c. output from the full wave rectifier, raising the voltage applied to the series regulator transistor and the 20V zener diode circuit.

The zener diode maintains the base of the transistor at a constant voltage of —20V, the extra voltage being dropped across R100, and by emitter follower action the output at the emitter of the transistor remains at a constant —20V. The increase in voltage is thus dropped across the high impedance base-collector junction.

Output 2 is maintained at 10V by the 10V zener diode, the excess voltage being dropped across R101.

QUESTION 1. (c)

Briefly state why OUTPUT 1 uses a different type of regulator circuit to OUTPUT 2.

ANSWER 1. (c)

OUTPUT 1 has to supply a greater current than OUTput 2. If a large current is to be drawn from OUTPUT 2, the value of the series resistor R101 needs to be small. However, a lower value series resistor decreases the regulation and necessitates the use of a zene diode with higher power dissipation capabilities. In the series regulator the impedance of the collector-base junction of the transistor changes with the current, so that good regulation is obtained for a large range of loads. Also, the power dissipation of the zener diode in the base circuit is kept low.

QUESTION 1. (d)

What effect would a short circuit to ground on OUTPUT 1 have upon the regulator and briefly explain how the short circuit causes this effect.

ANSWER 1. (d)

The transistor would burn out due to the high current it would attempt to pass, as there would be —20V directly across the base emitter junction and no limiting impedance in series.

QUESTION 2. (a)

State two of the main functions of the Register Translator.

ANSWER 2. (a)

(i) To accept and store an address or place name in a suitable form.
(ii) To obtain a translation corresponding to the stored address, giving routing information.

QUESTION 2. (b)

The transfer system feeding a particular Decoder shuts down due to a fault condition.
What happens to letters being coded by the operators for that particular Decoder?

ANSWER 2. (b)

The letters are sorted automatically into the reject channel of the Coder and no code is printed on the envelope except for the printer identification mark.

QUESTION 2. (c)

State the principal use to which the following forms of logic would be put by the maintenance staff:—
(i) System logic.
(ii) Practical logic.
(iii) Frame logic.

ANSWER 2. (c)

(i) System logic is used principally for understanding the system. The condensed glossary associated with system logic enables the maintenance staff to follow the operation of a section of the logic circuitry with which he is not fully conversant.
(ii) Practical logic enables testing to be carried out at the test points without removing the frames from the rack. By this means a fault is located to a particular active element or gate.
(iii) Frame logic is used to localise faults within the frame after it has been removed from the rack. It is used to identify each component and interconnecting wire.

QUESTION 3. (a)

Indicate by a tick (✓) in the appropriate column, whether a translation is always required before a letter leaves the Coder viewing window under the conditions listed.

ANSWER 3. (a)

Condition	Yes	No
Alpha or Numeric Code	✓	
Reject key pressed	✓	
Repeat key pressed	✓	

Reason: A translation is always required for the machine to cycle.

QUESTION 3. (b)

Using letters or numerals as examples, complete the following table.

ANSWER 3. (b)

Type of Code	Code Stored in Address Store
Alpha Code	REFRN
Numeric Code	7 — — 01
Short Code	A A A A A

Reason: A numeric code consists of a number between 0 and 9 stored in each of the first, fourth and fifth digit stores and nothing stored in the second and third digit stores. A short code consists of the same character (any letter or numeral) stored in all five digit stores.

QUESTION 3. (c)

Referring to the Register Translator and Coder, under what conditions, if at all, do the following stores RESET?
(i) Address store.
(ii) Diverter store.
(iii) Printer store.

ANSWER 3. (c)

(i) The address store resets on the first valid key stroke after a translation has been obtained or when the cancel key is pressed.
(ii) The diverter store resets when the Z relay in that store releases after the back e.m.f. of the diverter solenoid has decayed.
(iii) The printer store never resets.

QUESTION 3. (d)

What is the function of the State Code Generator?

ANSWER 3. (d)

The state code generator is to generate and store the state code for each block of addresses in the one state and thereby save tracks on the magnetic drum.

QUESTION 3. (e)

With the aid of Fig. 15, briefly describe the operation of the State Code Generator.

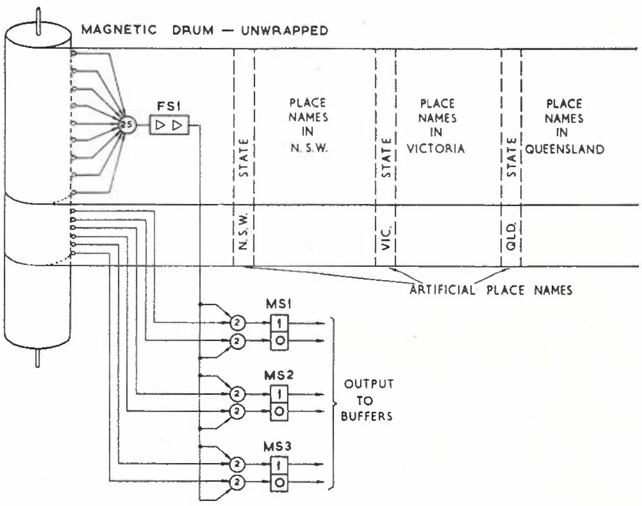


Fig. 15

ANSWER 3. (e)

The state code generator toggles MS1, MS2 and MS3, set or reset according to the information read off the translation tracks to which they are connected, in the time slot when the FS1 control signal becomes logical 1.

This occurs when the appropriate control code (STATE) is read from the address tracks, making all 25 inputs of the AND gate preceding FS1 logical 1. The control code and state code are recorded on the drum for each state in the time slot before the first address in that state. Once the state code generator has assumed a certain condition it will remain unchanged while FS1 is logical 0. This is the case until the beginning of the next state block of addresses where a new state code is generated.

QUESTION 4. (a)

Complete the table of keyboard wires below, indicating which wires are involved when the given key in column 1 is pressed.

ANSWER 4. (a)

Coder Key	Wires which are normally Earth	Wires which are normally Open Circuit.
Zone	L1, L2	L6
Field	L3, L4, L5	L7
Reject	L1, L2, L3, L4, L5	L8, L10
Cancel	L11	—

QUESTION 4. (b)

Briefly describe, with the aid of a sketch, the operation of the comparator. Include only those elements from the reading amplifiers to the comparison bistable MC1 which are found in the System Logic. Neglect inputs to MC1 which are not relevant to the comparison.

ANSWER 4. (b)

See Fig. 16. The address store signals XMA01 — XMA28, and their complements, are compared with the pairs of complementary signals from the address tracks of the drum and the state code generator. The address track signals are read by the reading amplifiers RAO1 — RA25 and the state code is stored on the toggles MS1 — MS3.

When all the corresponding signals into the comparator are identical, i.e., XMA01 and RA01 are either both logical 0 or both logical 1, and so on up to XMA28 and MS3, the outputs of all two-input AND gates into VC1 and VC2 will be zero. This is because each AND gate looks into a normal and a complementary signal of a corresponding pair, one of which must be logical 0. Then, and only then, will the inverter input, UC1 and UC2, both be logical 0, so that VC1 and VC2 both become logical 1. Therefore MC1 will set, indicating that a comparison has been obtained.

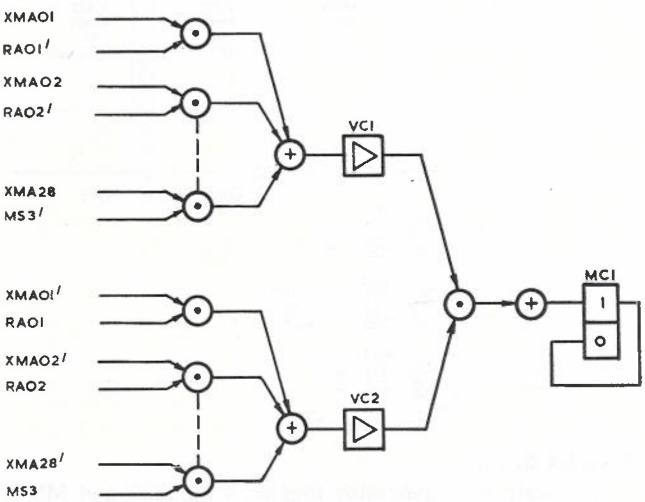


Fig. 16

QUESTION 5. (a)

Draw a circuit for diverter blockage detection of the type used in either the Coders or the Decoders.

ANSWER 5. (a)

See Fig. 17.

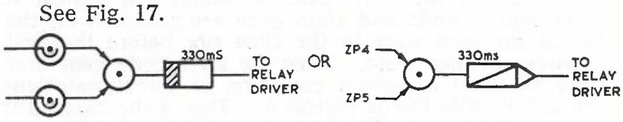


Fig. 17

QUESTION 5. (b)

The translation programmed for Randwick, N.S.W., is:—
R A D C K = 26 11 30 30

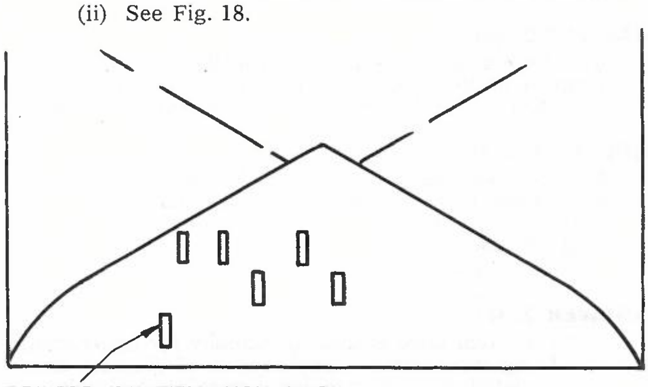
(i) *How would you interpret the four groups of numbers*

(ii) *Sketch the phosphorescent code mark layout you would expect to find on a letter to Randwick which was posted in Sydney.*

ANSWER 5. (b)

(i) 26 — The channel into which a letter for Randwick will be sorted in the Coder.
11 — The channel into which the letter will be sorted in the Decoder. This number will also be printed in binary form on the back of the envelope.
30 — No print, as no further sorting in the Decoders is required. 30 — No print, as no further sorting in the Decoders is required.

(ii) See Fig. 18.



PRINTER IDENTIFICATION MARK

Fig. 18

QUESTION 5. (c)

In relation to the 'R' relay in the Coder Intermediate Store:—

(i) *When does it not operate on count 0 - 1?*

(ii) *When does it operate in the above case?*

ANSWER 5. (c)

(i) When the other operator's first counter is between 0 and 19.

(ii) During counts 20 - 21 of the other operator's first counter.

QUESTION 5. (d)

In certain cases a ZMO or ZMO' pulse is gated with the output of a counter chain in the Coder Presentation Sequence Control.
State when and why this is necessary and give ONE example illustrating the need for it.

ANSWER 5. (d)

This is necessary when the outputs of the counter chain are gated into sensitive electronic bistable circuits.

It is necessary because the bistable may falsely trigger on a transition state between two unwanted counts unless inhibited by the ZMO or ZMO' signal, which allow the input to change only after the counter has settled down.

Example: Change from count 15 to count 16 involves 3 transition states:

Count 15	0 1 1 1 1	
1st transition	0 1 1 1 0	(Count 14)
2nd transition	0 1 1 0 0	(Count 12)
3rd transition	0 1 0 0 0	(Count 8)
Count 16	1 0 0 0 0	

QUESTION 6. (a)

What are the functions of the following relays in the Coder Intermediate Relay Store?

(i) 'R' relay.
(ii) 'P' relay.
(iii) 'M' relay.

ANSWER 6. (a)

(i) The R relay shifts the information from the translation store into the first intermediate store and it resets the translation store.
(ii) The P relay shifts the information from the first to the second intermediate store and it initiates printing.
(iii) The M relay recognises check codes.

QUESTION 6. (b)

Fig. 19 is a section of the Coder Intermediate Relay Store.

(i) What is the function of the 6D3 contact?
(ii) What is the function of the S2 contact?

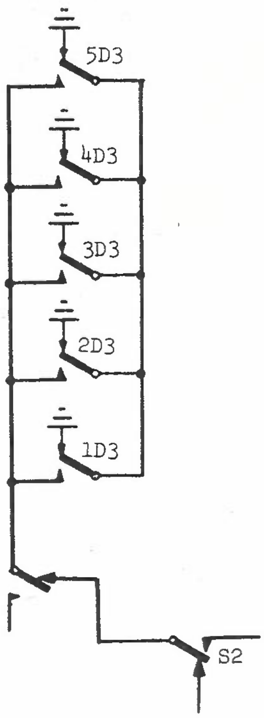


Fig. 19

ANSWER 6. (b)

(i) The 6D3 contact open circuits the alarm path on normal codes.
(ii) The S2 contact prevents transient alarms when the D relays are switching by open circuiting the alarm path during the shift of information into the fourth intermediate store.

QUESTION 6. (c)

Fig. 20 is a section of the Diverter Relay Store, Coder and Decoder.

(i) What is the function of Z relay?
(ii) What is the function of diode D5?
(iii) What is the function of contact Z2?

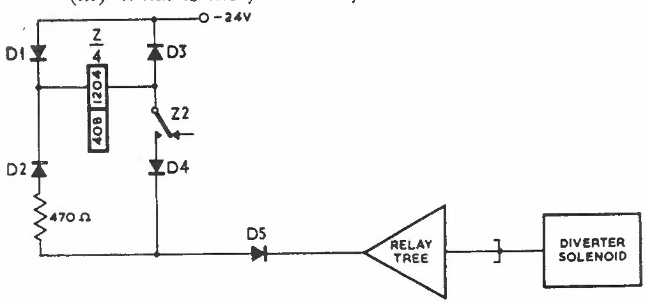


Fig. 20

ANSWER 6. (c)

(i) The Z relay ensures that the relays in the tree do not release while they are carrying heavy current.
(ii) D5 prevents false operation of the Z relay when two diverter stores are connected to the same diverter solenoid and the solenoid driver of the first store switches on.
(iii) Z2 prevents false operation of the Z relay due to the back e.m.f. of the solenoid in similar circumstances to (ii).

QUESTION 6. (d)

It is found that a Coding machine repeatedly shuts down on the fifth letter (piece of mail) after it is switched on. Give an example of a fault that would produce such a stoppage and briefly describe HOW the fault causes this symptom.

ANSWER 6. (d)

A likely fault is that the diverter stores are not being cleared. One reason for this would be a failure to receive output pulses from ZP6, the P.E. cells behind the slotted disc, so that the diverter counters are not counting.

The diverter stores are selected one after the other by the allotter counter. On the fifth letter the first diverter store is being selected for the second time, and because it is full, the alarm relay will be operated and the machine will shut down.

QUESTION 7.

In relation to the Pitney Bowes Facer-Canceller, detail the detection of an Australian stamp and the associated electrical adjustments, under the following headings:—

QUESTION 7. (a)

The types of stamp that can be detected by this machine.

ANSWER 7. (a)

The Pitney Bowes Facer-Canceller is capable of detecting both fluorescent and phosphorescent stamps.

QUESTION 7. (b)

The type of stamp selected for Australian use and the reason why.

ANSWER 7. (b)

Phosphorescent stamps have been selected for Australian use because some envelopes use paper with fluorescent content to give a brighter appearance, thus making it difficult to detect fluorescent stamps on these envelopes.

QUESTION 7. (c)

How the machine irradiates the stamp and determines the presence of the current Australian type.

ANSWER 7. (c)

The stamps are irradiated by ultra-violet lamps, which are flashed on and off at 3kHz and the output of the sensor is sampled during the off period of the lamps for light emission from the stamp. During this off-period fluorescent output drops to zero, but phosphorescent emission remains high.

QUESTION 7. (d)

Colour of light emitted by the stamp, also the type and purpose of the filters used in the light guide.

ANSWER 7. (d)

The emitted light is in the orange-red region of the spectrum. An orange filter is used to further reject blue light due to fluorescence and yet pass the orange light from the stamp.

An almost clear glass filter is used to prevent the ultra-violet light from saturating the sensor.

QUESTION 7. (e)
Type of light sensor that is used.

ANSWER 7. (e)
Photomultiplier tubes are used as sensors.

QUESTION 7. (f)
How the varying electrical signal developed in the output of the sensor is converted to binary (or digital) form compatible with the remainder of the logic circuitry.

ANSWER 7. (f)
The voltage across the anode resistor of the photomultiplier is directly coupled into the photomultiplier Special Amplifier. This is a comparator, using a present reference (or trigger) level. When this level is exceeded the comparator changes state.

QUESTION 7. (g)
How the sensitivity of the sensor is adjusted.

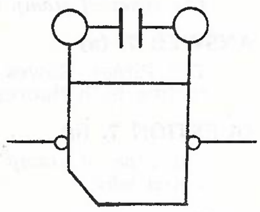
ANSWER 7. (g)
The sensitivity of the photomultiplier tube is adjusted by varying the —ve H.T. voltage applied to its cathode. Increasing this voltage increases the sensitivity.

QUESTION 7. (h)
The value of the recommended trigger level voltage for detecting Australian stamps.

ANSWER 7. (h)
The recommended trigger level for phosphorescent stamps is 0.6V.

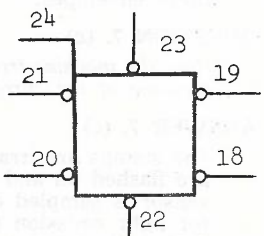
QUESTION 8.
The symbols in this question are those used in the Pitney Bowes Facer-Canceller logic schematic circuit.

QUESTION 8. (a)
(*i*) *What does this symbol represent?*
(*ii*) *State the function of this device.*



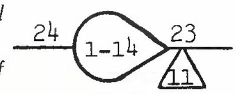
QUESTION 8. (b)
(i) A one-shot.
(ii) To give a logical 1 output pulse of a fixed duration.

ANSWER 8. (a)
(*i*) *What does this symbol represent?*
(*ii*) *Name the input and output leads as listed below by the pin connections.*
Pin 18, Pin 19, Pin 20, Pin 21, Pin 22, Pin 23 and Pin 24.
(*iii*) *State two methods of SETTING this device.*



ANSWER 8. (b)
(i) A flip-flop.
(ii) Pin 18 Reset output.
Pin 19 Set output.
Pin 20 Reset sampled input.
Pin 21 Set sampled input.
Pin 22 Reset d.c. input.
Pin 23 Set d.c. input.
Pin 24 Clock input.
(iii) 1—Logical 0 on the set sampled input for at least 30 micro-secs before receiving a positive going transition on the clock input.
2—Logical 0 on the d.c. set input.

QUESTION 8. (c)
(*i*) *What does this symbol represent?*
(*ii*) *State the function of this device.*
(*iii*) *What is the significance of the following numbers on this symbol?*

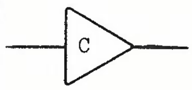


1 - 14, 

ANSWER 8. (c)
(i) An inverter.
(ii) To give an output signal whose logic value is the inverse of that of the input.
(iii) 1 - 14. : The inverter is on a card in position 14 of shelf 1.

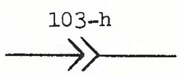

The output of the inverter is extended to test point 11.

QUESTION 8. (d)
(*i*) *What does this symbol represent?*
(*ii*) *State the function of this device.*



ANSWER 8. (d)
(i) A clock-amplifier.
(ii) To provide a fast risetime pulse at the clock input of the flip-flop.

QUESTION 8. (e)
(*i*) *What does this symbol represent?*
(*ii*) *What is the significance of the designation 103-h?*



ANSWER 8. (e)
(i) A plug or jack point.
(ii) 103 h means pin h in plug or socket 3 of the A machine.

QUESTION 9. (a)
An oscilloscope with a two trace vertical amplifier is to be used to display two 50Hz (cycles per second) signals simultaneously.
(*i*) *Indicate by a tick (✓) in the table below the most suitable mode of operation for the vertical amplifier.*
(*ii*) *Give brief reasons why the other modes were not selected.*

ANSWER 9. (a)
(i)

Channel 1 only	
Alternate	
Chopped	✓
Added	
Channel 2 only	

(ii) Channel 1 only, Channel 2 only, and added would not give two displays.
The two displays on the alternate mode would flicker at such a low frequency of triggering.

QUESTION 9. ((b)

You observe one of your staff reading a square wave signal using a C.R.O. fitted with a 10x probe. It is displaying overshoot on the transients.

(i) *What is the first thing you would have him check?*
(ii) *List two reasons why 10x probes are used.*

ANSWER 9. (b)

(i) Check the calibration of the probe for correct frequency compensation.
(ii) Raise the input impedance of the C.R.O. to reduce loading on the circuit being observed, and attenuate the input signal and thus increase the maximum voltage range of the instrument.

QUESTION 9. (c)

When using a trigger timebase C.R.O. it is observed that the sweep stops as it is moved upwards on the face of the cathode ray tube by the position control.

(i) *What method of trigger coupling is indicated by this condition?*
(ii) *What method of trigger coupling can be used to ensure that the timebase will continue to operate as the position control is varied?*

ANSWER 9. (c)

(i) d.c. trigger coupling.
(ii) a.c. trigger coupling.

QUESTION 9. (d)

In relation to Storage oscilloscopes:—

(i) *How do they differ from other oscilloscopes?*
(ii) *Can Storage oscilloscopes be used as normal oscilloscopes?*
(iii) *When using a Storage oscilloscope certain precautions must be observed to prolong tube life. List two of these precautions.*

ANSWER 9. (d)

(i) Storage C.R.O.'s can store or hold a display for periods up to 1 hour. The displays can be erased at will. Storing is done electronically without recourse to a high persistence cathode ray tube.
(ii) Yes, storage is just an additional facility.
(iii) Two of the following:—
1. Store on single sweep only.
2. Never use excessive intensity.
3. Do not leave C.R.O. in the storage mode for periods longer than necessary.
4. Do not store repeatedly on the same area of the screen.

QUESTION 10. (a)

What action is taken by a Decoder under the following UNSTANDARD conditions?

(i) *A letter is blocking the Decoder brush station P.E. cell.*
(ii) *A letter is blocking a diverter entry P.E. cell.*
(iii) *The LL relay releases.*

ANSWER 10. (a)

(i) The motor associated with the pick-off will be switched off.
(ii) The pick-off and the thirty channel diverter motors will be switched off and an alarm will be indicated.
(iii) The pick-off and the thirty channel diverter motors will be switched off, provided that the LL relay releases for a sufficiently long time (about 2 seconds).

QUESTION 10. (b)

What is the function of the Code Staticiser in the Decoder?

ANSWER 10. (b)

The function of the Coder Staticiser is to convert the serial sorting information sensed by the reading head photomultipliers and amplifiers into parallel form to be fed into the relay stores, and to check that the code is of the correct 5 bit complementary form.

QUESTION 10. (c)

The circuit in Fig. 21 is of a type found in the Decoders. The D relay is normally released and receives a 50mS operate pulse when a letter passes through the system.

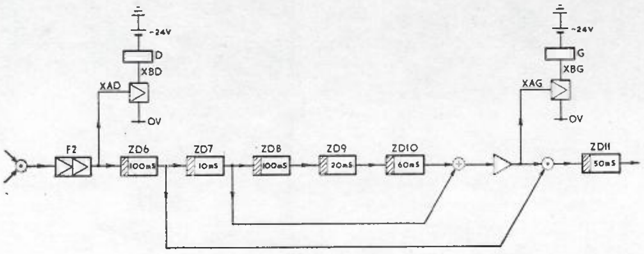


Fig. 21

(i) *What is the normal condition of the G relay?*
(ii) *How long after the BEGINNING of the D operate pulse does the G relay receive a pulse?*
(iii) *What is the duration of the pulse into XAG.*

ANSWER 10. (c)

(i) The G relay is normally released.

Reason: As the D relay is normally released, XBD is normally logical 1, and XAD is logical 0. Therefore ZD6, ZD8 and ZD10 are normally logical 1 and ZD7 and ZD9 are logical 0. Thus the OR gate output ZD7 + ZD10 = 0 + 1 = 1, and the inverter output, i.e., XAG, is normally logical 0. Hence XBG is logical 1 and relay G is normally released.

(ii) 150 milliseconds.
(iii) 160 milliseconds.

Reason for (ii) and (iii): The ZD elements are inverters whose change in output from logical 0 to logical 1 is delayed by the time indicated.

A sequence chart for the 50mS input pulse is shown in Fig. 22. Now XBG is the same as the OR gate output (as there are two stages of inversion in between), so that the operate pulse to the relay G is a 160mS earth pulse, 150mS after the beginning of the input pulse.

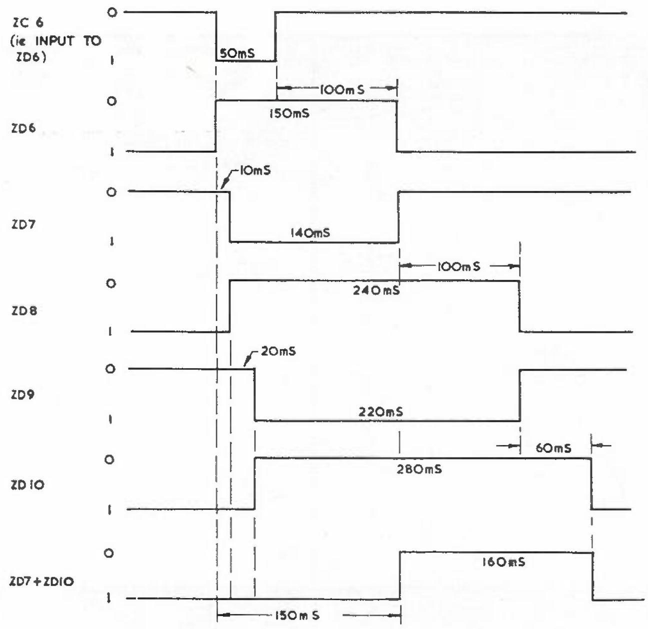
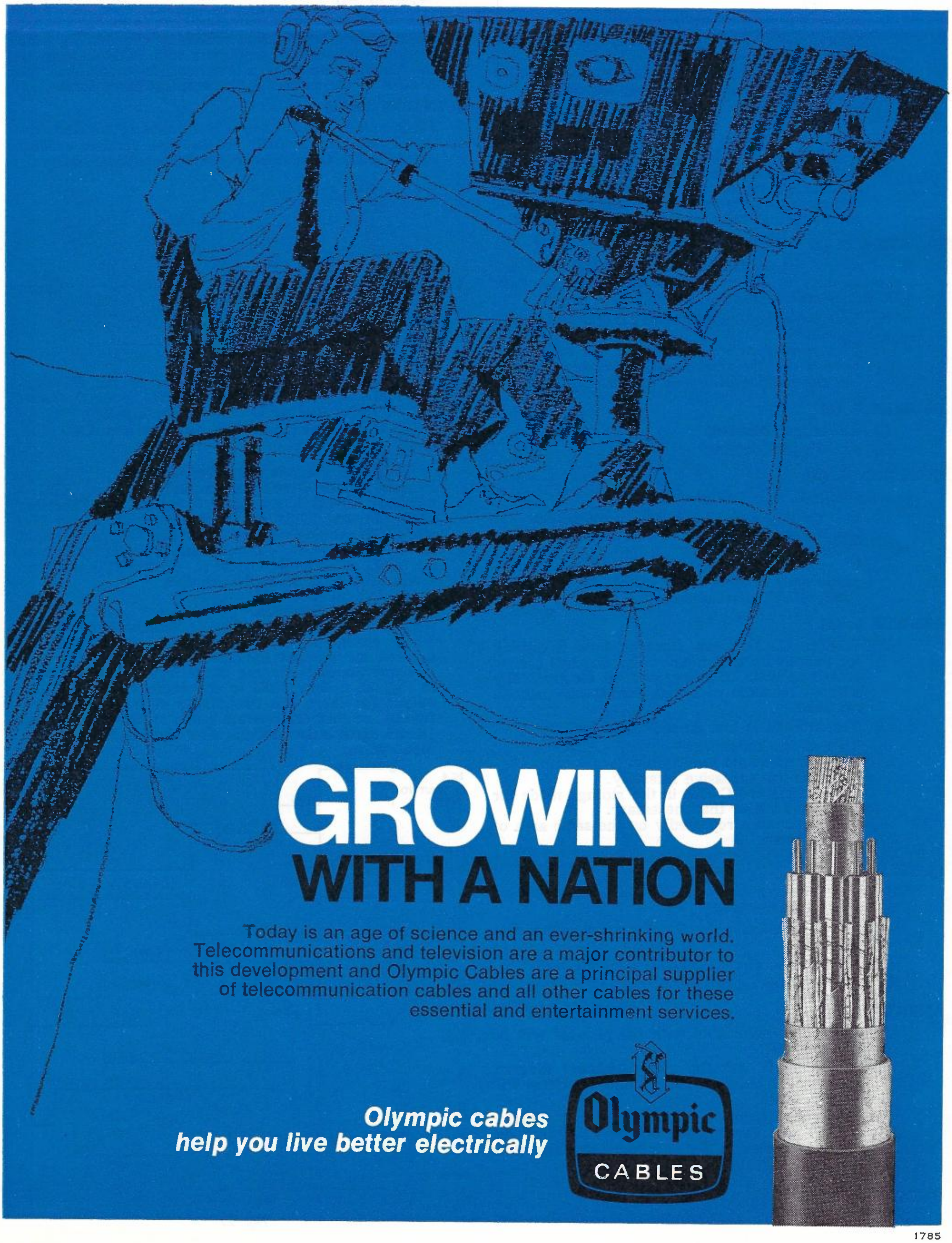


Fig. 22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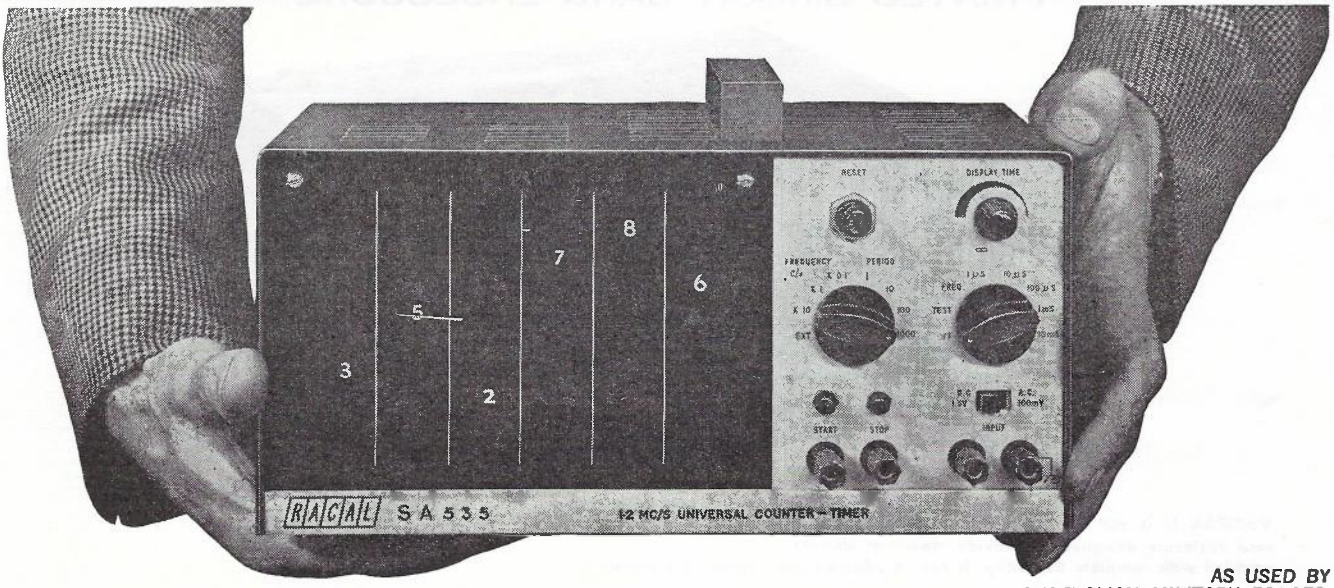
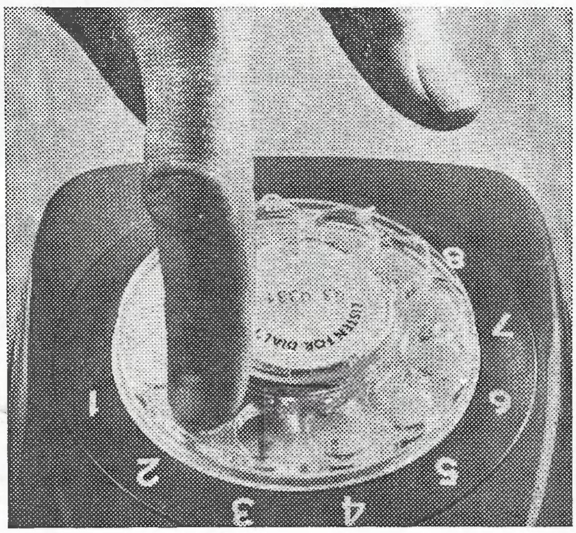

RESET
DISPLAY TIME
START
STOP
INPUT
RACAL SA 535
1·2 MC/S UNIVERSAL COUNTER—TIMER


PAX
LIMIT
4 MILES
PER HOUR

Calling Carnarvon



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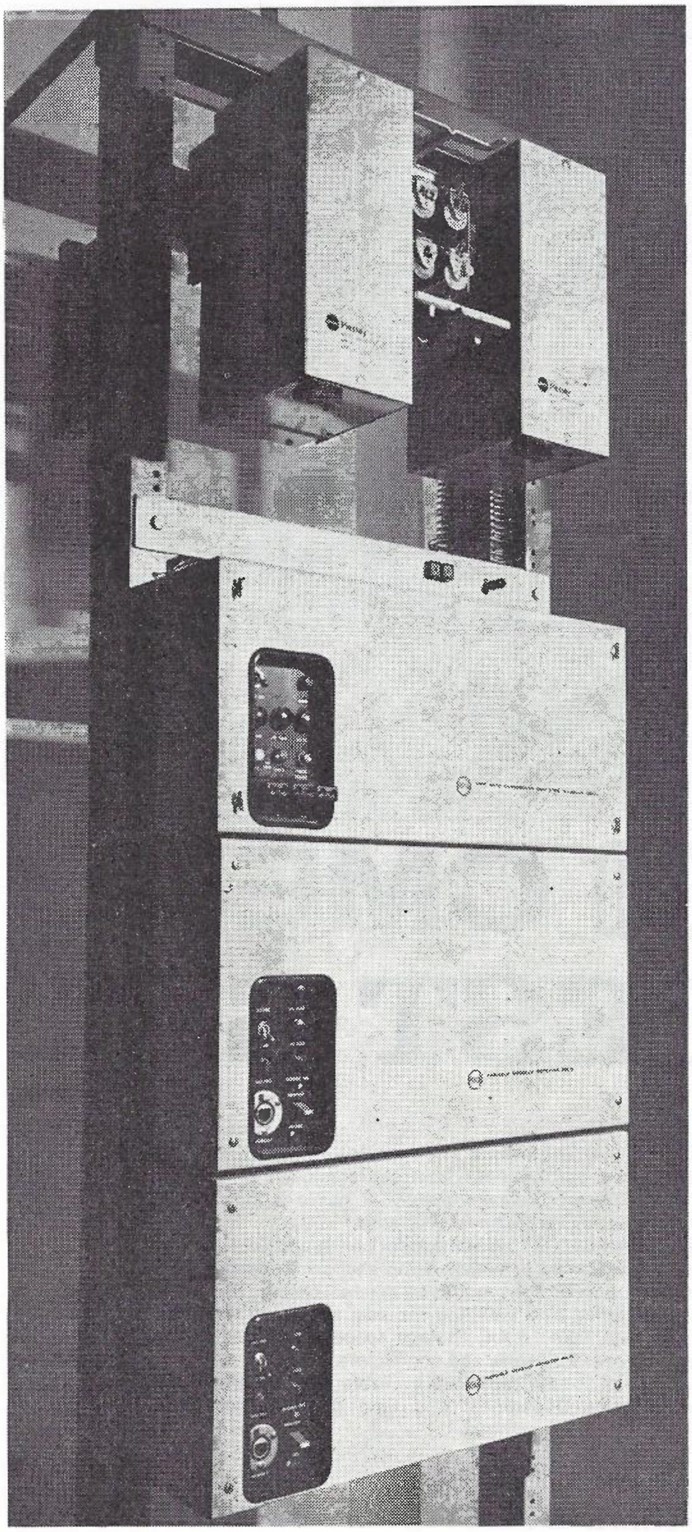

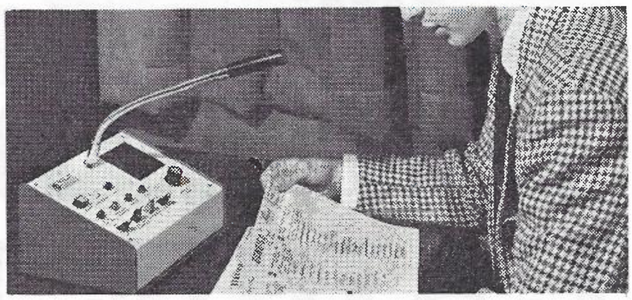

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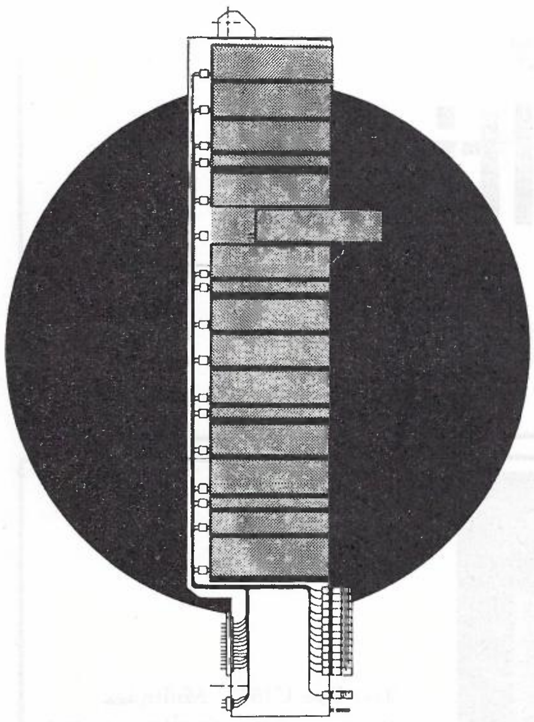

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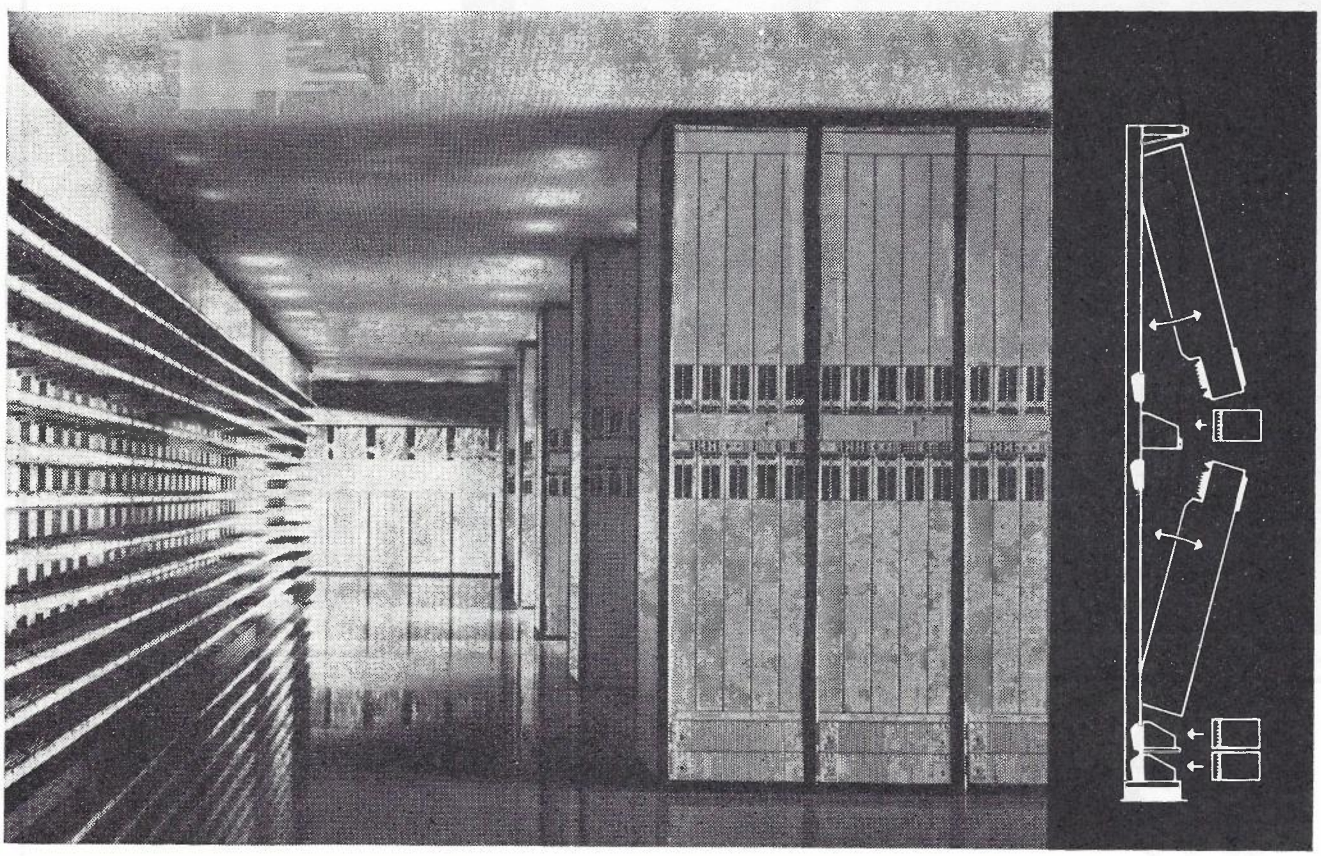

M4

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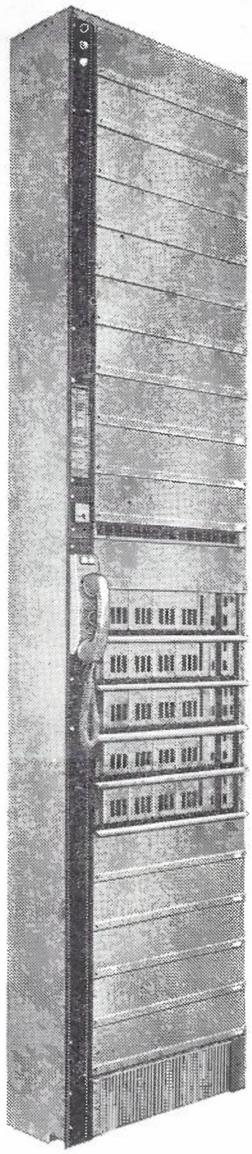

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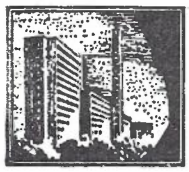

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THE TELECOMMUNICATION JOURNAL OF AUSTRALIA

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FEBRUARY 1968

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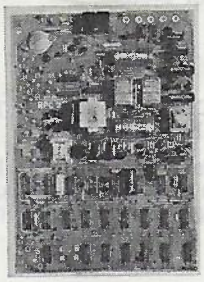

COVER
Printed wiring board developed by the P.M.G. Research Laboratories for the new S.T.D. Coin Telephone

The TELECOMMUNICATION JOURNAL of Australia

ABSTRACTS: Vol. 18, No. 1

CARROLL, B. J., and RUBAS, J., 'Supervision of Plant Congestion'; Telecom. Journal of Aust., Feb. 1968, Page 54.

The A.P.O. uses both manual service sampling and various automatic and semi-automatic devices to supervise network performance. This article outlines techniques and equipment used or under development for supervision of plant congestion.

CREW, G. L., 'A Line Signalling Scheme for Pulse Code Modulation Telephone Systems'; Telecom. Journal of Aust., Feb. 1968, Page 59.

A line signalling scheme for telephone networks has been developed which utilises two out-of-band signalling paths in each direction of transmission. This scheme is specifically intended for use over P.C.M. transmission systems which provide the double signalling facilities required. An appreciable saving in the cost of signalling equipment for this signalling system can be realised when compared with the cost of signalling equipment utilising only one signalling path in each direction of transmission.

KITCHENN, R. G., 'Telephone Transmission Objectives'; Telecom. Journal of Aust., Feb. 1968, Page 15.

This paper traces the history of the development of transmission objectives in the A.P.O. for both subscribers and inter-exchange networks as a preliminary to detailed description of existing objectives and an indication of future trends. Current subs network as well inter-exchange network objectives are discussed and the trend toward use of subjective ratings is reviewed.

KOOP, E. J., 'The Transmission Performance Preferences and Tolerances of Telephone Users'; Telecom. Journal of Aust., Feb. 1968, Page 28.

This paper discusses transmission performance aspects of the Australian public telephone network in terms of the requirements of the overall connection between any two subscribers. A detailed description is given of transmission opinion tests carried out in the P.M.G. Research Laboratories, Melbourne, for the purpose of ascertaining telephone users' preferences and tolerances. The results obtained are of fundamental importance for the determination of the best compromise between the preferred technical standard of performance of a telephone circuit and the cost of providing a telephone network capable of providing this performance.

MAGGS, I. H., 'The New National Automatic Trunk Network'; Telecom. Journal of Aust., Feb. 1968, Page 3.

This article outlines the scope and magnitude of the task undertaken by the Australian Post Office in creating a new national automatic subscriber trunk dialling network. The basic planning which led to the establishment of a national Subscriber Trunk Dialling (S.T.D.) objective is discussed, together with the reasons why an inter-connected automatic trunk network will be needed to be established as quickly as possible if the S.T.D. objectives are to be achieved. The proposed national ARM switching network is described in detail and a summary of the ARM implementation programme up to 1975 is given, with an indication of the funds necessary to meet the planned national trunk switching programme.

McCARTHY, R. G., 'The Establishment of an ARM Network in New South Wales'; Telecom. Journal of Aust., Feb. 1968, Page 8.

The scope of the work involved in commissioning ARM exchanges at Sydney, Canberra and Newcastle as part of the ARM grid in N.S.W. is described, together with a discussion of the network problems encountered, the co-ordination aspects, the technical developments, the cutover staging and the directory publication aspects.

McLIMONT, S. H., 'Expo 67 Sound Chair System'; Telecom. Journal of Aust., Feb. 1968, Page 63.

The article provides details of the sound chair system installed in the Australian pavilion at Expo 67 in Montreal. It describes, in particular, the A.P.O.'s contribution to the design, manufacture, installation and maintenance of the chairs and the associated control system.

RENDLE, A. A., 'An S.T.D. Coin Telephone'; Telecom. Journal of Aust., Feb. 1968, Page 40.

A general description of the facilities and overall design of the A.P.O.'s new S.T.D. coin telephone is followed by a detailed description of the design of the electronic control circuit.

SAGE, M. F., 'Developments in Subscriber Telephone Instruments'; Telecom. Journal of Aust., Feb. 1968, Page 46.

Facilities offered by new subscribers' equipment, based on the 801 telephone, are described. The Two-line Telephone, Intercom 1/2, Intercom 1/3 and Intercom 3/11 systems are referred to in some detail.

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