The

Telecommunication Journal of Australia

No. 1 JUNE, 1935

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THE POSTAL ELECTRICAL SOCIETY OF VICTORIA

FOREWORD

THE purpose of a foreword in a venture of this kind is, I suppose, to send it forth with every initial good wish—a sort of literary breaking of a champagne bottle on the prow of this our Victorian Technical Argosy as she takes the water for her maiden voyage. If that be so, then very sincerely do I contribute my word of Good Luck and Bon Voyage.

I well remember, as Secretary of the Institution of Post Office Electrical Engineers, helping to launch a Journal which, at its inception, was equally modest, and which we sent forth with equal trepidation. Its first issue was on All Fools' Day, 1908, and there were some who facetiously connected the date with the venture; but to-day the Journal is probably the premier Telecommunication Journal of the World—"The Post Office Electrical Engineers' Journal." It also started from small beginnings and from a sense of the need which British Post Office Engineers were then feeling of some vehicle by which they could pool and share their engineering knowledge and experience. For the true Scientist and Engineer is never selfish or exclusive. He is glad to bring his contribution into the common hive of knowledge and place his observed data at the disposal of his fellow-workers, whether they be workers in the realm of inductive thought, research or practical engineering. The value of a Journal of this kind to our Engineers is emphasised in another article in these pages, but may I stress one vital truth—it is only possible to achieve success in a Journal of this kind by widespread and consistent support!

So, just as 64 years ago the Society of Telegraph Engineers in London founded the great Institution of Electrical Engineers with its world-wide membership and authoritative Journal, and 27 years ago the Engineers of the British Post Office founded the Post Office Electrical Engineers' Journal, which to-day has also a world-wide circulation, so may our Victorian venture be a prelude to an All-Australian Communication Journal, which in due time will increase in value and become the authoritative record of the steady progress of Communication Engineering in Australia.

J. M. Crawford

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No. 1. *JUNE, 1935.*

TELECOMMUNICATION.

S. H. Witt, A.M.I.E.E., A.M.I.E. (Aust.) M.I. Rad.E. (Aust.)

In days gone by it was the custom to speak of "Telegraphy," "Telephony," "Radio" as though they were separate arts, doubtless having mutual points of contact, but generally not a great deal in common; indeed, public utilities and commercial organisations were built up on one or the other of those apparently distinct divisions. Yet underlying the development and utilisation in such specialised spheres there always has been a common theory, the basic science, namely, that of the Transmission of Electric Currents of Varying Frequency.

It is not disparaging to say that a great deal of earlier development—and it has been enormous—occurred empirically, that is, by trial and error and painstaking visual observation of mechanisms. That is not at all an unusual phenomenon in human progress; other useful arts have progressed in the same way and there is much that excites our admiration in the tale of ingenuity and perseverance thereby told. But it is always interesting to try to find the reasons why an art should develop empirically rather than by scientific, and therefore logical, progression from fundamentals. Such reasons are generally obscure, often lost in the mists of antiquity, usually quite complex. To say that real knowledge accrues only when precise measurement can be made is a truism. Lord Kelvin made a statement to this effect which has now become famous, and the longer we live the more apt does his dictum prove to be.

In the case of the arts of which we are writing, it would not be far wrong to say that the main reason was the extreme difficulty of measuring the minute and rapidly varying electrical quantities that are involved. It was a difficult matter to obtain even an indirect indication of the magnitude of electric currents carrying, for example, speech impulses in a telephone circuit. A direct reading instrument was out of the question, for to give a readable indication more power was required by the instrument than the total amount available in the circuit. It is not surprising, therefore, that the earlier advances in the art of electrical communication were made on an empirical basis; rather, when we contemplate the difficulties, it is truly marvellous that so much has been accomplished.

During the last 20 years a profound change has been occurring: a change evolutionary in nature, but owing to the rapidity of its action, revolutionary when viewed in retrospect. It is due to the discovery and development of the electron tube, or thermionic valve, as it is sometimes called. In the short space of this article the genesis and development of the electron tube cannot be traversed; moreover, its history is so recent that it is common knowledge to present-day engineers, and there is also abundant literature to consult.

We are accustomed, however, to think of the electron tube in terms of the many valuable and ingenious devices that have been built upon it for its direct utilisation, as in amplifiers, telephone repeaters, radio receiving sets and the like. Some of these applications have been spectacular, having come directly under the notice of the public, even in the homes of the people, as, for example, radio receiving sets. One is inclined to believe, however, that the transcending importance of the electron tube and its derivatives lies in its application to the measurement of those electrical quantities that had hitherto been most elusive.

With the powerful tool so provided, it became practicable to verify by direct experiment the theorems in electrical transmission, so confirming and extending knowledge in the scientific side of the field and simultaneously enabling the engineer, who wished to make use of the knowledge for some practical end, to proceed to an application by methods that gave him confidence and satisfaction. These are basic matters, they lie at the foundations.

What have been the outstanding results of this buttressing of the foundations, so to speak? Without reference to chronological order, but rather taking a cursory glance over the superstructure that has become erected on those foundations, we see that there has been a great deal of stimulation of theoretical analysis into circuital arrangements of the elements of generalised networks, namely, the elements possessing the properties of resistance, leakance, inductance and capacitance. Combinations of these elements, both without a continued electro-motive force—*passive* networks—or with an internally associated source of energy—*active* networks—have been, and are being, the subject of intense investigation.

Many practical devices have been the direct outcome and there is space here to name but a few: The electric wave-filter, which is the key to the carrier-current system of telephony and telegraphy and certain of the more highly developed forms of long-distance point-to-point radio telephone systems; inductance *loading*, by which the properties of long telegraph and telephone lines may be modified in certain advantageous directions; equalisers, devices for making the response of lines and amplifiers independent of frequency over almost any desired range; phase correctors for making substantially equal the propagation time of different frequencies over long circuits. These devices are embodiments of the *passive* network.

Besides the more commonly known forms of amplifiers and repeaters, notable examples of derivations from the *active* network are: echo-suppressors for very long telephone circuits, to prevent confusion of the speaker by the return to his ear, after an appreciable interval of time, of his own voice electrically reflected from a distance point in the circuit; voice-operated switching systems, another key development which has made possible the operation of a radio-telephone circuit as a link between the trunk telephone systems of two countries. Some of the forms of the devices just named embody a third type of network which has been given much attention in recent years, the *non-linear* network. Such a network is characterised by a response having magnitude not directly proportional to the magnitude of the input to the network.

Not only has the study of transmission networks been prolific in their own development, but also the processes of their theoretical analysis have shed light in other directions. For example, it has been possible to apply them to the study of mechanical systems in their dynamic state. This has been done by making an electrical analogue of the mechanical system wherein the property of mechanical mass is represented by the property of electrical inductance, friction and viscosity by electrical resistance, the reciprocal of stiffness by electrical capacitance, and so forth. One of the outstanding results of study by this process has been the revolutionary change made a few years ago in the processes of phonograph recording and reproduction.

The advances in fundamental transmission knowledge, together with those in sister sciences, have been applied indiscriminately to the benefit of telegraphy, telephony, picture transmission and television, carried over wire systems and by radio. One result has been that whatever lines of demarcation may have existed between these fields of application have been made indistinct, and the terms have contracted upon a more specialised meaning, namely, that which connotes a particular use to which the ends of a transmission circuit may be put.

Thus it has become the habit, when speaking of the art as a whole, to use the term *electrical communication*. Now even that term has itself been the subject—or victim—of study. At the International Congress at Madrid in 1932 it was decided that the art warranted an all-embracing term and so the word *telecommunication* was evolved. Henceforth that Congress, which meets once in five years, will become known as the "International Telecommunication Congress." Since the new term has received general recognition because of its satisfactorily wide basis, it has been deemed a good one to apply to this new Journal.

Stress has been laid on the development of transmission theory for three reasons: firstly, because of its fundamental nature; secondly, because the intricacies of the transmission circuit, being electrical, are not directly visible; thirdly, because the manner of its development has been a powerful unifying influence in the telecommunication arts. There have yet to be mentioned the equally important developments in those devices of which the main purpose and functions can be appreciated by visual inspection, namely, the devices of utilisation applied to the ends of a transmission system; the units which furnish electrical power for operation; and the physical constructions that support, protect and insulate the electrical conductors of a complete telecommunication system.

But here, such things can be no more than just mentioned. The pages of this Journal will disclose the intricacies and almost uncanny accomplishments of automatic telephone switching mechanisms; the ingenuity of the mechanism of printing telegraph apparatus; the care which is taken both in the selection of material for, and in the development of novel methods of line construction, to meet economically the conditions of the Australian environment; the modern developments in power supply equipment; and interesting features of radio systems. Indeed, in the present issue of the Journal there are articles on some of these subjects. Finally, the functioning of telecommunication systems produces problems of finance, of traffic flow and adjustment of operating staff that call for specialised study by skilled people.

It is the hope of the sponsors of this Journal that it will provide a forum for those engaged in the art of Telecommunication in Australia to describe their works and express their views. Herein will be found, in convenient form, information upon the Telecommunication Services that are provided for the benefit of the people of Australia.

THE MURRAY CORRECTION SIGNAL.

B. Edwards.

(With Special Reference to Multiplex Working over Carrier Channels.)

One of the best-known features of the Murray Multiplex system of telegraphy is the synchronisation that must exist between the rotating brushes at the two ends of the circuit. It is also well known that this synchronisation is maintained within very close limits by the use of driving motors of the phonic type, driven from the contacts of tuned vibrating reeds.

Because of the difficulty of maintaining two reeds, of the type used with the multiplex, at exactly the same speed of vibration over long periods of time, the reeds are arranged to run at slightly different speeds and means are employed to nullify the effects of the speed difference by retarding the brushes at the faster motor whenever the gain in phase at that station approaches an amount sufficient to upset the working of the system.

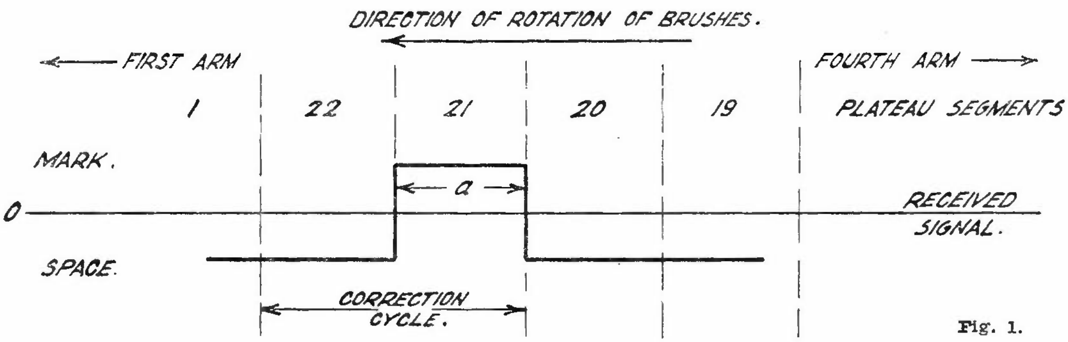


Fig. 1.

This "correction," as it is called, is effected by the transmission from the slow-running station of a "correction" signal cycle, which consists of one element of Marking current followed immediately by one element of Spacing current. This transmission takes place once per revolution, even though no message transmissions are taking place, and corresponds to a fixed phase position on the plateau from which it is sent; it will be recognised, then, that should the arrival of this correction cycle, at the receiving end, be retarded or accelerated due to signal distortion on the channel, the phase correction between the two ends of the circuit will be interfered with and bad working will result.

The effect of this distortion of the correction impulse may best be understood by a consideration of the correction process at the "corrected" station, i.e., at the station at which the correction impulse is received and made use of.

Figure 1 shows a curve of the ideal correction signal as received over a carrier channel when no message transmissions are being made on any of the "arms" of the multiplex set. It will be seen that the only marking element is that corresponding to the plateau segment No. 21, and that that element is exactly the same length as the spacing element that follows for the second half of the correction cycle. Under these conditions correction takes place as follows:

In Figure 2 CM is the correction magnet connected to the correction segment CS. When energised, CM acts mechanically on the driving mechanism so as to retard the forward movement of the rotating brushes and thus bring them back into phase with the brushes at the distant end from which the correction signal has been sent. B and B-1 represent different positions of the same "receiving" brush which makes contact with the segments Z-5, CS, and the others of the plateau and so, in revolving, transfers the receiving line signal to the particular segment on which the brush is resting at the moment. It will be seen from Fig. 2 that single current only is passed on to the receiving brushes, and that this current is put on during the reception of the marking impulses. When spacing impulses are being received there is no potential on the receiving brushes. The magnets connected to the receiving segments of the plateau are, therefore, simple unpolarised electro-magnets. R is a point on the correction segment called the repere or action point. If there is a potential on the brush when it encounters the leading edge of the correction segment, and

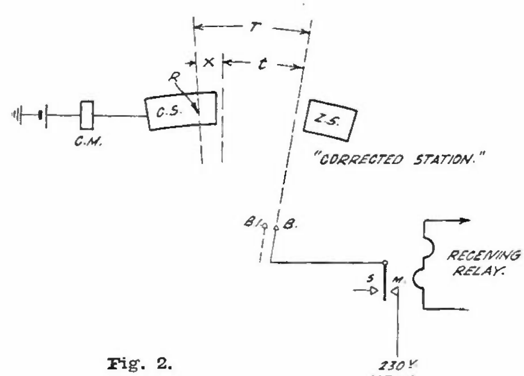


Fig. 2.

if that potential is maintained until the brush arrives at the point R, then the correction magnet will operate. If the potential is withdrawn before the point R is reached, the magnet CM will not operate.

Considering a revolution up to the point where the brushes have gained sufficiently to warrant correction taking place, we may assume that the impulse 21 (Fig. 1) commences when the brush is in the position B (Fig. 2) and continues for a time T—equivalent to time (a) Fig. 1—up to the repere point. The correction magnet CM will now operate the mechanism which will step the brushes back 1½ degrees into phase with those at the far end. While the signal shown in Fig. 1 continued to arrive at regular intervals the brushes would always be set back to their proper phase position whenever they had gained enough to carry the correction signal up to the repere point R on CS. The left-hand edge of 21 in Fig. 1 is sometimes called the active edge of the signal, because, as will be seen, it is the changing over of the signal from marking to spacing (potential to no potential on the brush) which determines whether the magnet CM is to be energised during any given revolution of the brushes, or not. Obviously, if this left-hand edge of the signal does not fall either on or beyond the repere point, correction will not take place during that revolution.

In working multiplex systems over carrier channels it is found that distortion to the correction signal takes place whenever the sending of marking impulses precedes the sending of the signal 21 (Fig. 1). Apparently a marking impulse sent from any segment of the plateau causes some distortion to the correction signal, but in practice serious distortion results only when marking impulses are sent from the segments corresponding to the last arm of the system. The distortion takes the form of a shortening of the duration of the signal 21, so that the conditions corresponding to Fig. 1 now become as shown in Fig. 3. In the figure marking impulses are shown incoming on segments 18, 19 and 20 of the last arm. As a result of this the potential on the grid of the rectifier valve in the carrier terminal is very greatly depressed, and this abnormal depression of the grid voltage results in a premature cutting off of the marking signal 21. The conditions, so far as the multiplex is concerned, are shown in Fig. 3, where the received 21 signal is now only of length (b), having been reduced by an amount equal to (c).

Referring back now to Fig. 2—although commencing as before at position B, the correction signal continues only for a time "t," equivalent to "b" in Fig. 3, and is not applied to the segment CS up to the repere point.

Since the correction magnet would not operate under these circumstances the "corrected" station brushes would continue to gain in phase beyond the small allowable limit, on the "correcting" station brushes, and a movement of orientation would take place between them.

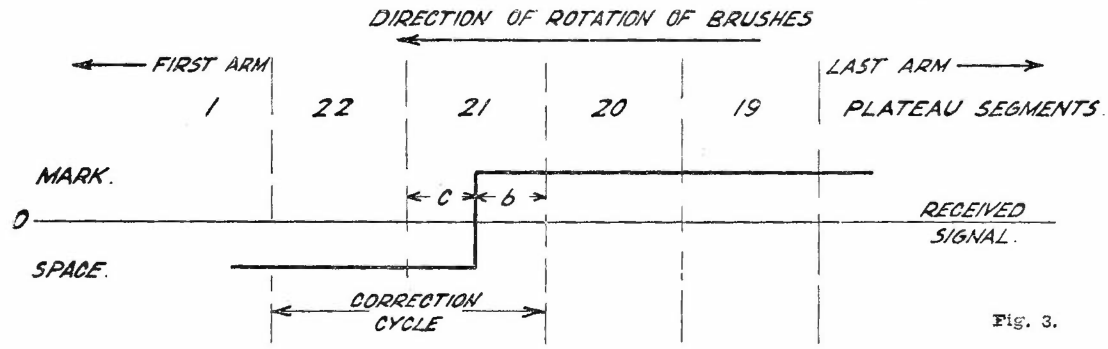


Fig. 3.

The state of affairs last described continuing, correction eventually again takes place; the correction impulse commencing when the brush is at "B1," Fig. 2, and continuing for a time t = b (as before), but this time up to the repere point R; but obviously the orientation between the two stations has moved by a time space equivalent to "c," Fig. 3, which in actual shift may vary for different carrier conditions up to a value of perhaps ¼ inch as measured at the plateau circumference.

If, now, the "marking" impulses antecedent to the correcting impulse should cease, the now lengthened correcting impulse will extend beyond the repere point by the distance it previously fell behind it at the instant the extra impulses commenced.

Violent correction quickly steps the "corrected" brushes back to the original phase position; and so, while this distortion remains unchecked, swinging orientation between the stations results.

It is fortunate, so far as mitigation of the evil effects is concerned, that the working margins of the multiplex system are so wide that it is essential to consider only the distortion introduced by the transmission, from the "correcting" station, of a "marking" impulse from the 5th segment of the last arm of the system.

Adverting, now, to Fig. 2, and the considering always a revolution in which correction is due to take place—if, on those occasions, when the correcting impulse is preceded by a "marking" impulse on Z5 (i.e., the 5th of the last arm of the system) the correcting segment could be moved or extended to the right by an amount x; equal to the equivalent distance, at the receiving ring, by which the distorted correcting impulse is shorter than the undistorted; the repere point would also be moved and consideration will reveal that the correcting signal will be applied to the segment for a sufficient time to operate the correcting magnet, thereby stepping the brushes back the requisite amount to keep the phasing of the two stations unaltered. Thus, by arranging for the correction segment to be virtually moved to the right or to the left, as a marking signal is receiving on Z5 or not, the correcting segment and repere point would be made to follow the shifting imposed upon the left-hand edge of the 21 impulse, and so bring about the correcting operation when the "corrected" station brushes had gained sufficiently on the "correcting" station brushes. The correction would then take place in whichever condition the correcting impulse might be, i.e., distorted or undistorted.

This movement of the correcting segment may be effected by an arrangement which will now be described. Fig. 4 indicates schematically the addition of a short extension ES, permanently fixed in relation to, but insulated from, the main correction segment.

The leading edge of the extension has a ramp formed of insulating material, and the lagging edge is cut obliquely, as shown, to form an air gap between the two portions, across which the brush may travel with a make before break action.

In Fig. 4, ES is the extension to the correction segment, referred to above. CS, CM and B are as before in Fig. 2. R-1 is the repere point (corresponding to R in Fig. 2) when distortion is absent. R-2 is the repere point when distortion is present—it corresponds with the junction of the time periods t and x in Fig. 2. Z-5 is the last receiving segment on the plateau and immediately precedes the reception of the correction cycle. ZP is the cadence segment of the last arm printer; current is applied to it shortly after the correction signal has been received. The means of applying current to ZP are, however, merely local, and have nothing to do with the received signals. CR is a polarised relay with its windings connected as shown. When operated CR joins CS and ES together through the switch shown.

In series with the 5th printer-magnet on the last arm, then, is placed CR, a polarised relay of low resistance. The contacts of CR, when closed, as the result of the passage of current through the printer-magnet and relay coils, electrically connect the extension piece to the main portion of the segment. These contacts remain closed until the tongue is thrown to the opposite side by the passage of the cadence brush over the segment forming part of a restoring circuit. (See Fig. 4.)

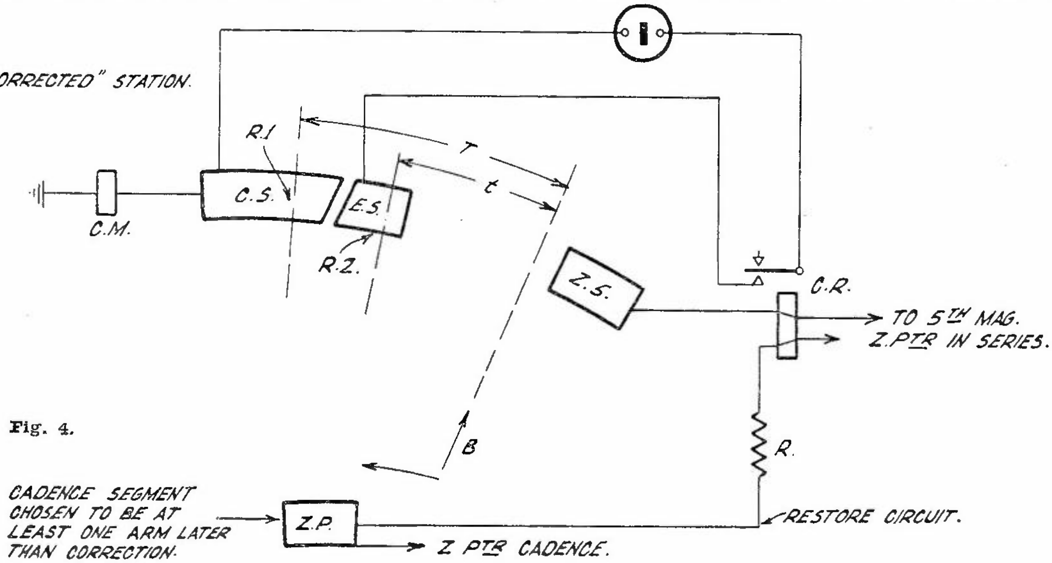


Fig. 4.

Let it now be assumed that, for a particular carrier circuit, the length of ES is chosen to equal the amount of orientation shift due to the distortion of the correction signal introduced by the carrier channel. It will be seen that whenever the correction signal is preceded by a "marking" element on Z-5, the correction segment will be elongated against the direction of rotation, the amount of elongation thus compensating for the foreshortening of the correction impulse. The foreshortening of the signal and elongation of the segment have both resulted from the transmission of the marking signal antecedent to the correction impulse.

By referring to Fig. 4, and considering a revolution of the brushes in which correction is due to take place, it will be seen that should "marking" current from Z-5 not have been transmitted prior to the sending of the correction signal from segment 21 (quad. mux considered), the correction signal will, at the receiving end, be impressed on the brushes while they are at, say, position "B" and will continue for a time "T" up to the normal repere point "R1." Correction will take place and the brushes will be stepped back in the usual way. Had the correction signal, above considered, been preceded by the transmission over the carrier system of a marking element from Z-5 segment at the sending end, the result at the receiving end would have been that the correction signal commenced, as before, while the brush was at position "B," but continued only for a time "t" up to the position R2. Now clearly, since this is a revolution in which correction should take place (the uncorrected gain in brush position at the "corrected" station being governed entirely by vibrator speed, and not by any transmissions or maltransmissions over the circuit), correction from this signal would, under the usual conditions, be entirely lost.

In the arrangement depicted, however, the circumstance of the reception of an impulse on Z5 has elongated the correction segment sufficiently to allow of the utilisation of the shortened distorted signal for the purpose of stepping the brushes back in **this** revolution, up to which revolution they have gained in phase sufficiently to warrant such correction.

This method of rectifying, at the plateau, the effects of signal distortion introduced in the carrier channel, was suggested by Mr. S. T. Webster, of the Melbourne staff, and has proved of the greatest value, especially where multiplex systems have to be operated over two or more carrier channels in tandem, e.g., on the Sydney-Adelaide and Sydney-Perth systems. The device is so good, in fact, that it can stand having some of its shortcomings pointed out.

It will be noticed that the extension segment is of a fixed length, and therefore any given extension would, ideally, compensate for only one amount of signal distortion. As pointed out, the distortion actually varies for the different arrangements of coded signals that precede the correction signal; in practice, however, it is found to be sufficient if the extension segment compensates for the amount of distortion introduced by the conditions when five marking elements are being transmitted immediately prior to the correction cycle—that is, when the erase signal is being sent on the last arm of the system—and the segment is extended only when marking current is received on the single segment immediately preceding the correction cycle. It will be seen that, no matter what the distortion may be, due to other marking elements, no correction takes place unless the Z-5 segment happens to receive a marking impulse on it.

Again, the amount of distortion experienced for the same received arrangements of signal elements may vary over the same carrier channel from day to day, and over different channels on the same day. It is not an easy operation to change the extension segment at a moment's notice to meet the new conditions if the working channel is changed, or the amount of the distortion suddenly varies.

The scheme works out very well in practice, even with these minor deficiencies, and it is found that, if a switch is provided for the cutting out of the extension segment when it is not required, an intelligent choice of the length of ES, together with a judicious use of the switch, will allow all except extreme conditions to be met on any given system working over the same route daily.

TRANSMISSION PLANNING.

R. J. Attkins, A.M.I.E.E., A.M.I.E. (Aust.).

In a short sketch of this description it will not be possible to attempt any complete or detailed survey of the wide field comprehended by the term "Transmission Planning." The best that can be done is to bring out a few points which are worthy of attention, either because they are so outstanding that they form the frame around which any plan must be built, or are amongst those relatively obscure considerations which are easily overlooked, but which have an unpleasant habit of growing in importance until they threaten the whole structure.

Although it is only proposed to examine the skeleton of telephone transmission planning, it will be desirable to consider the different parts in their logical sequence. The following order will, therefore, be followed in the discussion, i.e.:

The general objective.
The transmission plan.
The application of the plan.

Obviously an objective is as essential to transmission planning as to any other sort of planning, and it is worth while spending time in acquiring as thorough a knowledge and mastery of this objective as possible. Such a knowledge not only simplifies the preparation of the plan and ensures that it is free from dangerous omissions, but it facilitates its application after it has been formed. In other words, it helps not only to make the plan, but to "keep it on the rails." To obtain this grasp of the objective it is necessary to study both the broad fundamental base upon which it rests and its details, by which are conveyed in concrete terms the requirements which must be met.

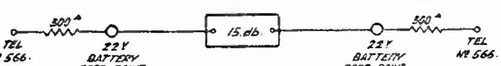


Fig. 1.
Standard Transmission Circuit.

The fundamental objective of telephone transmission planning might be stated as the provision of facilities of such quality that any existing or future subscriber in this country will be able to converse with any other subscriber in the country, or with any subscriber in any other country provided the telephone link between the two countries and the telephone plant in the distant country meet certain requirements.

This definition may at first appear simple and obvious, but in fact it contains a number of important implications and provisos which will soon become apparent to anyone who considers the possible effects of omitting, say, the words "or future" or the proviso that the telephone links to other countries and the plant in those countries should meet certain requirements.

Having stated the objective in a fundamental fashion it is necessary to translate it into a more specific form, so that it may be used in the design and provision of telephone plant. In other words, included in the complete statement of the objective must be an answer to the question, "What is the 'quality' of telephone plant which will enable subscribers to 'converse satisfactorily'?"

The answer to the question as propounded is that a conversation, to be regarded as satisfactory, must not be worse than that obtained between two telephones No. 566 (22V. C.B. Handset Type) with 300-ohm non-reactive resistance in place of the ordinary subscribers' lines and a 600-ohm non-reactive network with an attenuation of 15 db, connecting them as in Fig. 1.

This is a perfectly practical and satisfactory standard from certain points of view, especially when a direct comparison between it and any circuit under consideration can be made, and possibly in the future the technique of making such comparisons will be simplified and brought into general use; but in the meantime the application of the standard for planning and designing purposes is greatly simplified by assuming that the 300-ohm non-reactive resistances can be replaced by subscribers' lines in cable with 300-ohm loops (or their equivalent in the case of systems other than 22-volt C.B.), and that the 15 db. non-reactive network can be replaced by trunk lines or junctions having a total attenuation of 15 db. We really assume, therefore, that if the sum of the attenuations due to trunk and junction lines in any connection does not exceed 15 db., the requirements of the standard have been met.

At first glance there might not appear to be much difference between the two circuits, i.e., the specified standard with its non-reactive elements and the secondary standard with actual lines. In many cases this will be so, but it all depends on the lines. Departure from the specified standard is most likely to arise in the trunk or junction lines which are specified to have an attenuation not in excess of 15 db., and to simplify our discussion on planning it will be confined to dealing with these lines and very largely to the methods to be followed in order to meet the attenuation requirement, i.e., the 15 db. limit, as applied to trunk connections. The problem of meeting this limit in the case of calls within the same multi exchange (metropolitan) area is a separate—although in some respects inter-related—problem. Before proceeding further, however, it is necessary to point out that while in the case of an actual connection the attenuation of the trunk and junction lines may not exceed the 15 db. limit, the quality or intelligibility may fall much below standard. If the band of frequencies transmitted is too narrow, as may be the case in a line on which inductive loading has been badly arranged or on which defective filters are in circuit; or the time of propagation is too long, as may be the case on very long heavily loaded circuits; or for any reason distortion is occurring in the circuit, then a speaker comparing the circuit with the standard may conclude that it is much worse, although the attenuation of the trunk and junction lines in it may not exceed the 15 db. limit.

It might be mentioned that the effective transmission of the frequency band from 300 cycles/sec. to about 2,800 cycles/sec. is considered to be sufficient for good commercial telephone speech. The maximum permissible time of propagation between one subscriber and another is generally accepted as 0.25 sec. This means that a speaker cannot get a reply in less than 0.5 sec. Any longer period produces difficulties in conversation. On circuits of considerable length consideration has also to be given to echo effects and to phase distortion due to different speeds of propagation of different frequencies in the voice range. These are amongst a number of factors of which the Transmission Engineer must not lose sight when preparing and applying his plans to meet the attenuation requirement imposed by the 15 db. limit.

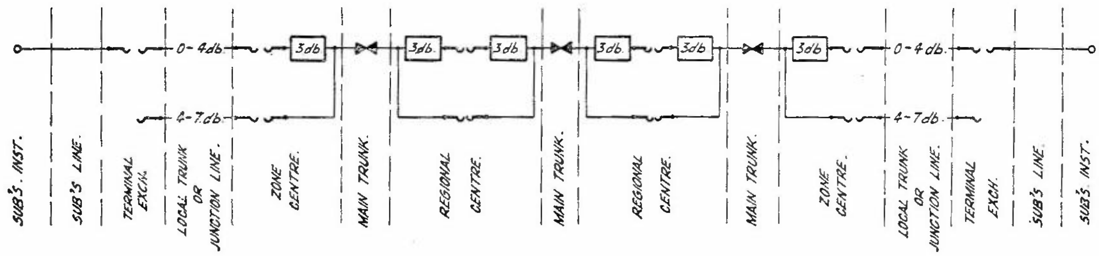


Fig. 2.

⧓ = INSERTED GAIN.

Interstate Connection. Trunk Switching Plan.

Dealing now with the actual plans which might be employed to provide for a 15 db. limit between terminal subscribers' exchanges, it is considered that the one most likely to prove satisfactory is that based fundamentally on a system of "pad" switching. It is illustrated schematically in Fig. 2.

In this scheme a "Terminal Exchange" is the exchange to which any subscriber is connected. It may be a main or branch exchange in a metropolitan area or a country exchange.

A "Zone Centre" is an exchange which is provided with local trunks or junctions to the terminal exchanges in its particular zone and with main trunks to its particular Regional Centre.

"Regional Centres"—which in this country for a considerable time will probably be at capital cities only—are major trunk exchanges connected by means of main trunks to all zone centres in their areas and to all other regional centres.

The local trunks or junctions connecting subscribers' terminal exchanges with the zone centres will not normally require repeaters, as they may have a maximum attenuation of 7 db. This value of 7 db. was determined by first assuming that ultimately—if not immediately—it would be practicable under suitable conditions to operate all main trunks with zero attenuation, so that the whole of the available allowance of 15 db. could be used up in the local trunks or junctions. Then, as any local trunk or junction might at some time be switched via one or more main trunks to any other local trunk or junction, it was apparent that no one of them could be permitted to exceed 7.5 db., i.e., half of 15 db. This value was reduced to 7 db. to take care to some extent of the small switching losses which would be introduced by trunk exchange cord circuits.

It will be noted from Fig. 2 that local trunks or junctions are shown as graded into two classes, one class having attenuations between zero and 4 db. and the other having attenuations from 4 db. to 7 db. The pad switching devices incorporated in the circuits at zone centres are designed to remove the 3 db. pad included in each main trunk only when a local trunk from the second group (4 to 7 db.) is connected to it. (To simplify the diagram in Fig. 2 main trunks have been shown with two jacks at each terminal—one including and one excluding the 3 db. pad. In practice, only the first jack would be provided, the switching out of the circuit of the pad, when required, being accomplished by relays.) In this way a main trunk line when in use will always be terminated by a 3 db. pad or by a local trunk having an attenuation of at least 4 db., a condition which it is expected will ensure adequate stability.

Each main trunk will be seen to have a 3 db. pad at each end, and to include a repeater or amplifier giving a transmission gain which it is intended should be equal to the total attenuation of the line itself—so that when not in use the total attenuation of the trunk between its terminals would be 6 db., i.e., the sum of the two terminal pads. Improved stability will also be secured by the provision of terminating resistances, which will only be removed when the line is switched through to some other line or termination.

One reason—amongst others—which makes it essential that 3 db. pads should be provided at each end of main trunk lines is that both regional centres and zone centres will function also of probable technical development. Predicting as terminal exchanges for their own local subscribers, who will require connection to the trunk lines. Regional centres will also function as zone centres for exchanges in the metropolitan and sub-metropolitan areas. When main trunks are switched together at any point it is intended that the two pads—one in each trunk—at that point shall be switched out of circuit.

Such, in brief outline, is the plan by means of which it is hoped that the objective of enabling subscribers to "converse satisfactorily" will be achieved in the case of trunk conversations.

One feature worthy of note is that which proposes a maximum of four intermediate trunk switching points. This is important, as experience, including that of the Bell System in U.S.A., indicates that any material increase in the number of switching points introduces delay and increases the possibility of error in trunk switching.

We now have to consider the application of the plan.

Conceivably an attempt might be made to apply this or any other plan to meet our previously stated objective in the shortest time possible by reviewing the present arrangement of plant, and setting out to alter it almost at once. While having the advantage of early compliance with the standard, this would be an extremely uneconomical procedure since it neglects a very vital consideration associated with the provision of adequate transmission in a country such as Australia, where there is considerable growth and extension of telephone traffic and plant. This is the manner in which the provision of new plant to meet development frequently tends in itself to improve transmission, and the opportunities which it offers to combine that provision with the rearrangement of existing plant for the same purpose. This is well illustrated by the manner in which the creation of new exchanges in an existing area reduces the lengths of subscribers' lines, and the necessity for new direct trunks between centres required to meet traffic increases enables carrier circuits with low equivalents to be provided.

A logical attack on the problem of effecting ultimate compliance with the plan could very well be combined with a design of a plant layout to meet estimated requirements up to the most distant date for which such estimates are normally prepared. In most cases this is 20 years ahead. In the majority of cases a layout which resulted in the minimum total investment at the 20-year period might be expected to prove the most economical from the fundamental viewpoint of the total present value of annual charges over that period. In doubtful cases a complete cost analysis could be made.

The first step, therefore, would be to obtain estimates of trunk channels based on traffic requirements at various periods up to 20 years ahead. An examination of these estimates would first be made to select present and future zone centres. This selection of zone centres should be made by plant and transmission engineers and traffic experts working together. Many of the centres will be definitely fixed by geographic and other considerations, and their fixation will in turn tend to determine other centres.

When completed this selection of zone centres may involve adjustments to the estimates of channel requirements, and when these have been made the next step in the process should be to determine for the estimated conditions at the end of the 20-year period, the manner in which the various channels required at that date are to be provided, and the characteristics which they should possess.

At this stage several important considerations related to transmission planning arise.

The first is the question of the degree of compliance with the transmission standard set out in our objective as necessary to give satisfactory conversation. It seems not unreasonable to base our plans on the proviso that all existing services —unless quite exceptional conditions exist in odd cases—should be brought into conformity with the standard in less than the 20-year period. Due, however, to the great area to be covered and the fact that much of it is still undeveloped from a telephone viewpoint, it is to be expected that for a long time extension and development will produce new cases where compliance with the standard may involve very considerable expenditure, and on that account a choice will rest between no service and a service less satisfactory than the standard until development shall present an opportunity to provide standard service. This choice is similar to the one which will have to be made for the plan generally at the present time in facing the large costs which would be involved in an attempt to reach the standard in a very short time. As against this method of relying on the future to provide a solution it is to be expected that in 20 years' time the demand for and expectation of satisfactory service on any telephone will have become general, and the public view that, if at all avoidable, the remoteness from centres of population should not be permitted to impose disabilities on individuals, will have become even more pronounced than at present. On the whole it seems best, therefore, to err on the side of generosity in providing for such cases in initial plant layouts, and to rely if possible upon adequate reconsideration to avoid wasteful expenditure when the time to provide the service arrives.

Another important factor which, while closely concerned with the question of costly services just discussed, is of even greater moment than the planning of large growths of trunks, is that the direction and extent of technical development is, no doubt, to a large extent an art based on a knowledge of the past, whether acquired by experience or study, but to quite a considerable extent it can be made a science based upon a consideration of technical and other aspects of particular fields in which development is possible. For instance, at the present time, the general type of commercial carrier telephone system provides three channels and utilises the frequency band between approximately 6 kc/sec. and 30 kc/-sec. being operated over lines and routes which were not fundamentally designed for carrier working. From this position development is possible in several directions. The frequency band from 30 kc/sec. to 50 kc/sec. and much beyond is available for use, given compliance with certain well-understood conditions. Six- and nine-channel systems must, therefore, be regarded not only as possibilities, but as probabilities of the future. In fact, a nine-channel system for operation over cable circuits has already been developed—a recent considerable advance in the technique of stabilising repeaters having made it possible to handle the large transmission gains involved. Co-axial cable capable of transmitting frequency bands of several megacycles are developments of the present, the use of which in the future must be considered in transmission planning.

It is unnecessary to further emphasise the importance and the eminently practical part which the intelligent forecasting of technical development should play in the field of transmission planning. Obviously the amount of line plant to be provided to meet any specified traffic requirements will depend largely on the number of carrier systems which can be accommodated on routes and the number of channels per system.

Having completed the plan for a layout of plant estimated to meet both transmission and development requirements at the 20-year period, the next step should be to utilise it as a guide in preparing a definite scheme of plant provision covering the present and immediate future and the intermediate periods—usually five to ten years—for which estimates of traffic requirements are made.

The plans and layouts resulting from this procedure would constitute a complete scheme for meeting anticipated development on every route, and at the same time complying with transmission requirements, and in its preparation the requirements at each period over the whole 20 years would have been given due weight so that our objective would have been achieved in an economical way.

Apart from the purpose for which it was primarily designed, such a plan when studied and summarised would provide a valuable means of estimating future requirements of equipment—such as carrier systems—and other plant.

Further, it could be used to ascertain fields for new systems—possibly not yet developed—and the directions in which the technical development should proceed. For instance, it might be ascertained from such a plan and the development data on which it was based, the extent of the field which existed for the use of, say, six-channel carrier telephone systems, and the time at which it would be desirable to have completed their development, effected any necessary alterations to line plant to enable them to be operated, and commenced to bring them into use in order to obtain the maximum benefit from them.

Features of Private Automatic Branch Exchange Installations.

L. Paddock

Although switching equipment similar to that provided in main automatic exchanges forms the basis of P.A.B.X.'s, consideration of space and cost have necessitated the development of distinctive standards for their installation. As each P.A.B.X. must meet the special requirements of a particular business undertaking, it is not possible to use self-contained equipment of the R.A.X. type, but development tends towards a standardised layout as being the most economical.

The layout plan shown in Fig. 1 has been used successfully at several installations, the most recent being that at the Victoria Police Headquarters. By its use cable lengths are reduced to a minimum, the racking is kept at one level, awkward bends are avoided and each group of cables is provided with a clear run on the racking, all crossing over being avoided. Apart from the resultant saving in material and labour, future growth is facilitated, as with an absence of cross-overs it only remain to provide racks of sufficient width to allow for the installation of the estimated ultimate cabling. The disposition of the equipment encourages efficient maintenance, as inter-related equipment is associated as closely as possible, while a further advantage of a standard layout both as regards installing and maintenance is that Mechanics who have previously worked on an installation of the type pick up the work far more quickly than they would otherwise do, thus making for greater general efficiency. As the ideal layout can only be contingent on the provision of suitable equipment, close attention has necessarily been given to the design of such apparatus and modifications have been made to meet the varied requirements of a P.A.B.X. This applies particularly to apparatus which is manufactured in local workshops.

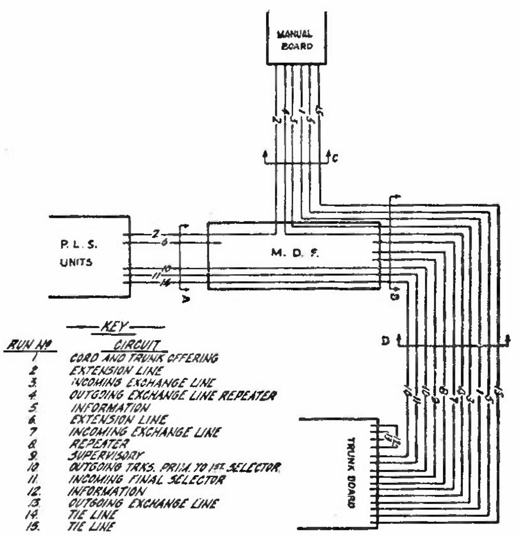


Fig. 1.—Private Automatic Branch Exchange Layout.

Main Distributing Frame.—The single-sided M.D.F. now used occupies little space, and is mounted in line with and adjacent to the line switch units. In this position the frame is simply supported by bolting it direct to the runway. A portion of such a frame is shown in Fig. 2. Full use is made of the available height, as on each vertical four strips of 20 fuses are fitted at the lower end, and at the upper end are six 20 x 2 terminal strips. As the distribution cables are connected to terminal strips and line switch unit cables to fuse strips, a ratio of 1.5 : 1 is maintained between distribution cable pairs and line switches. This ratio usually meets requirements and an additional vertical can be fitted easily to cover any exceptional case. As this M.D.F. has a distinct appeal owing to its simplicity, some further details of its construction may be of interest. Outer verticals, 8 ft. 7¼ ins. in height, span the distance from floor to upper edge of racking, which is drilled to form the upper support, while intermediate verticals 12 ins. shorter are supported at the upper end by a cross support between the outer members, and the lower support is bolted direct to the floor.

All main members are of mild steel 1½ x 1½ x 3-16ths angle section, but extension pieces of 1 in. x 1½ in. M.S. channel are welded to verticals for the mounting of fuse and terminal strips and are of such a length that the front edges of fuse mounts and terminal strips line up vertically. Small jumper rings are fitted in the usual position behind fanning strips and jumpers pass thence through one large ring at the rear of frame immediately behind the lowest terminal strip or approximately in a central position. This allows jumpers to be carried out at an angle to clear the ironwork, and those between verticals are brought to a central point for the horizontal run, thus maintaining a neat appearance. In practice only a small proportion of lines pass from one vertical to another, and if desired the numbering scheme can be so arranged to assist to this end, for once allotted very little change takes place in extension numbering.

Trunk Board.—By comparison with main exchange equipment, the number of any one class of switch at a P.A.B.X. is small, but conversely the number of types of switch or relay groups is large. As it is usual to have as many as nine types of relay groups, in addition to selectors, each requiring different treatment as regards jack wiring, care must be exercised to ensure that the initial provision of space permits growth of each class of equipment, otherwise costly alterations may subsequently be required. Detailed, the equipment to be mounted on the trunk board includes, apart from selector repeaters or selectors and repeaters, the following types of relay sets:—Cord circuit, Information line, In-

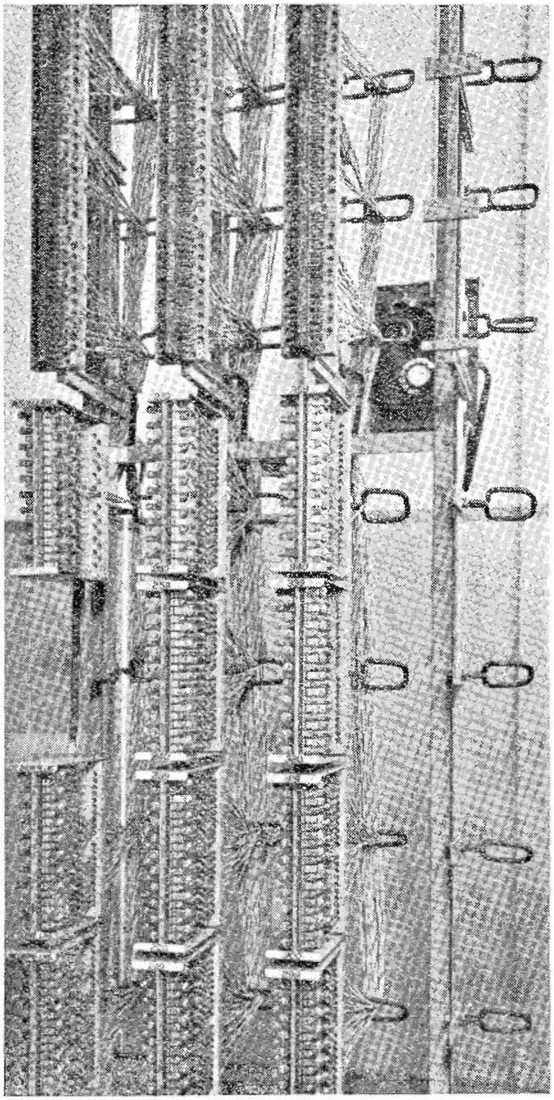


Fig. 2.—Private Automatic Branch Exchange, M.D.F.

coming exchange line, Trunk offering, Call back, Tie line, Phonogram or Trunk exchange line. Supervisory Relay groups are also conveniently mounted on the trunk board.

The main vertical members of the trunk board are of 3 in. x 2 in. x $\frac{1}{4}$ in. mild steel angle section, the intermediate shelf support 2 in. x 1 in. channel section, and the top rail and guard rail of $1\frac{1}{2}$ in. x $1\frac{1}{2}$ in. angle section M.S. The selector bank terminal assembly is mounted behind the selectors sufficiently high to prevent fouling the wiring of selector jacks. Standard right-hand banks are used, no alteration in lengths of tails being necessary. As the assembly extends five inches behind the board, additional space must be allowed between the rack and the wall for mechanics to work.

The general features of this type of trunk board are applicable to boards for either full-length or half-length shelves, the type used being decided on a consideration of the estimated ultimate capacity of the installation, but an advantage which tends to initial economy is that an additional trunk board could be built adjacent to the original should a half-length board prove insufficient after a period of years. As will be seen, provision is made for an ultimate of two shelves for selectors or selector repeaters and four shelves for relay groups. A board for half-length shelves has accommodation for sufficient bases for an installation with a maximum of 100 extension lines. Therefore, if it is anticipated that the ultimate will exceed this number a board for full-length shelves should be installed at the outset. It may be argued that as standard shelves may be used in the full-length trunk board, it is uneconomical to use half-length boards in any circumstances, but the fact remains that a considerable saving in floor space is effected by using half-length shelves and on small installations, particularly, this is an important matter. As maintenance is simplified by installing Bi-motional switches near eye-level, it is probable that at future installations selectors will be placed on the second and third shelves, leaving the top and lower shelves for relay sets.

Manual Switchboard.—As Manual Switchboard relay equipment is mounted on the trunk board, ample space is available in the cabinet for the placement of cables without congestion. Terminal strips cord terminations, etc., are fully accessible so that maintenance is carried out with ease. As far as possible cables from other racks and frames are terminated directly on the jacks, etc., in the cabinet, but as cord circuits pick up at several points, i.e., R. and L. keys, answering and calling cords, etc., it is considered good practice to form the complete circuits at the Workshop, carrying the wiring to terminal strips mounted in the switchboard to which the exterior cables can be connected by the installing staff.

Power Plant.—The close attention lately given to a revision of P.A.B.X. power plant practice is fully justified by results. After passing through various stages now wherever possible single batteries of 24 cells in lieu of duplicate 25-cell batteries are installed, and in place of costly switch gear automatic battery voltage control charging is provided.

The selection of the type of equipment to be installed is governed by two factors—the main Power supply and the size of the installation. Where A.C. is available a single battery is provided and operated either on the full float or partial float principle. A rectifier is used for small installations, and a voltage controlled motor generator set for larger installations. At those installations where only a D.C. power supply is available a single battery can be used with the larger installation charged by a voltage controlled motor generator set. In the smaller installations where charging must be done from the main through dropping resistances duplicate 25-cell batteries are necessary, but even under these circumstances automatic control, charge and change-over circuits have been arranged.

As control of charging and change-over by means of marginal adjustments relays has so far been of limited application, the equipment used is of interest and therefore justifies a somewhat detailed description. Battery voltage must be maintained between the limits of 48 and 52 volts, and as repeated cutting in and out at short intervals is undesirable, it is essential that control relays should have a narrow margin of adjustment. Strowger switch type relays are therefore fitted with an extra spring of flat steel insulated from but bearing against the outer contact spring for about one-half of its length. It is then flared out to a forked end so that the legs of the fork pass on either side of a 4 BA threaded stud 1 in. in length. A milled nut bearing on the spring renders the relay capable of micrometer adjustment. The relays are used in conjunction with resistances controlling the marginal current, so that the magnetic condition is most sensitive to slight changes in voltage. On operating they effect circuit changes involving other relays and causing the application or disconnection of the charging current.

Where a rectifier is used it is usual to control it by means of a mercury switch, which is tilted by the armature of a control relay. Mercury switches consists of a small gas-filled glass tube in which a small quantity of mercury is imprisoned, and if caused to run by tilting the tube a pair of contacts at one end may be opened or closed at will. Argon, an inert gas, is used to quench arcing in the tube. Such tubes are used to switch power to the primary of the rectifier transformer, and for this purpose the 5-amp tube is quite suitable. The size of this tube is 1¼ in. long x 5-16ths in. diameter approximately. It is usual to mount the tubes on Strowger relay chassis.

Switches are available to break heavier currents, as also are a type designed for the operation of change-over circuits. In this type a common point may be connected by the mercury to either one of two other contacts, depending on the position in which the tube is tilted. These tubes are used where full automatic control is applied to duplicate batteries charged direct from D.C. mains.

At larger installations a motor generator set is installed, together with an automatic motor starter. These are available for both A.C. and D.C. motors. In this equipment a relay mounted in the starter switches current to the motor through the starting equipment. This relay in turn is controlled by voltage control relays. Where a motor generator is used it is necessary to instal a cut-in-cut-out switch of the Salford type, but when using a rectifier it is not necessary to open the charging leads. The advantages of automatic charging will be readily appreciated when it is considered in relation to a system requiring the services of a mechanic both to start and stop the charge.

Cabling.—As previously mentioned, the ease with which P.A.B.X. equipment is cabled is dependent on a layout which provides close relationship of equipment and cable runs without cross-overs. This is necessary as apart from facilitating the original installation, the probable growth of a P.A.B.X., depending on the expansion of a particular firm cannot be so accurately forecast as that of a main exchange. Space must, therefore, be left for possible abnormal growth. As instances, one P.A.B.X. in Melbourne has developed most rapidly from the aspect of extension lines connected, while extensions at another installation have developed a calling rate so high that the maximum provision of trunking contemplated when the equipment was manufactured has proved to be totally inadequate.

More time is spent on forming and terminating cables than on any other phase of installing work, and is accordingly deserving of close attention. Means of reducing labour have been found by reducing terminations to a minimum and by butting cables as close as is reasonable to the point of the first termination. The time spent on both forming and terminating has been reduced by eliminating junction points wherever possible, and to this end cables are run direct from point to point wherever possible without intermediate jumpering or commoning points, any necessary commoning being done at switch jacks or terminal assemblies.

On several of the smaller installations even the I.D.F. has been dispensed with, but it is open to argument whether this economy is fully justified. Where the I.D.F. is omitted it is necessary to provide separate cables for each class of service, i.e., information trunks, tie lines, etc., where there is any possibility of subsequent rearrangement to permit growth. Until comparatively recently it was usual in cabling work on trunk boards to butt all cables together before the first branching point and form out the whole of the wiring together. Much time was spent in making a uniform and neat job of the butts and lacing. This practice has, therefore, been abandoned in favor of one in which the cable braiding is carried as close as possible to the first terminal point. An instance of this is seen in the handling of cables which provide for an appearance at the Manual Board of each extension line and which extend, therefore, the negative, positive and private normals from line switch unit terminals to the multiple jacks. It is interesting to note that for this purpose we have reverted to the use of 63-wire flat cable in lieu of the 63-wire oval. The advantages of the flat cable are that it can be laid on the rack one wide and five high if necessary, so permitting each cable at the jack strip end to come out in its correct position and allow the braiding to be butted right at the jack strip. This provides a neat, efficient job at the least expenditure in man hours. A point worthy of note is that the use of flat cable for this purpose demands that bends in the racking must be of at least 6-in. radius, as flat cables cannot be bent so sharply as those of oval or round section.

Equipment.—Some comments on equipment are justified, as some types of switches are used exclusively at P.A.B.X. installations.

Selector repeaters, as their name implies, perform the combined functions of a selector and a repeater. Apart from a saving in shelf space, these switches are in general cheaper than selectors and repeaters.

A very useful switch used on two-figure systems is the final selector repeater. This switch operates as a normal final selector on levels 1 to 9 covering extensions 10 to 99. On the 10th level the switch has an automatic search, this level being allotted to outgoing exchange lines. On this level the switch functions as an impulse repeater.

Special Services.—Special services available on all P.A.B.X. installations are:—

(i) The call back facility.
(ii) Prevention of access to exchange lines.
(iii) Conference facilities.
(iv) P.B.X. services.

The call back facility enables selected extensions to originate a call while holding an incoming call and is arranged by disconnecting the line switch from the final selector bank and providing two pairs of wires to the extension telephone. When calls are originated from lines thus equipped the incoming line is guarded by earthing the final selector bank private normal at the contacts of a series relay in the outgoing line circuit. This relay when operated also connects a holding coil across the incoming line terminals at the final selector bank.

The facility whereby access to outgoing exchange lines is prevented on extensions selected by the subscriber is provided by a discriminat-
is so good, in fact, that it can stand having some of its shortcomings pointed out.

It will be noticed that the extension segment
ing relay in the selector or its equivalent. Once installed the bar is placed on any extension merely by connecting a non-inductive resistance spool across the line switch B relay.

Conference facilities may be extended to a limited number of extensions and permits a predetermined number of extension users to conduct a conference by telephone.

P.B.X. services may be catered for by the installation of P.B.X. type final selectors.

Facilities applied to the manual switchboard provide the operator with automatic ringing on cord circuits, trunk offering facilities and an easy means of reverting calls.

Tie lines are connected to the manual switchboard for the handling of incoming calls, but the tie line is also provided with an extension number so that extensions may obtain access to the tie line by dial operation.

THE 200-LINE FINAL SELECTOR.
(STRAIGHT LINES)

F. J. Ryan, B.Sc.

One of the recent major developments in automatic equipment of the Strowger type is the use of final selectors designed to serve groups of 200 lines. The main advantage of the 200-line final selector is that a higher average traffic occupancy is attained. This increase in efficiency from a traffic-carrying viewpoint results from the fact that final selectors grouped to serve 200 lines operate in larger traffic groups than final selectors grouped to serve 100 lines.

The higher average traffic occupancy of the 200-line final selectors means that in an average case a reduction in final selectors to the extent of 15 per cent. to 20 per cent. can be attained. This saving in switches is achieved at the expense of providing 600-point banks instead of the usual 300-point banks and installing an additional relay—the wiper steering relay—per final.

The 300-point banks used with the 100-line final selectors consist of 100-point private banks on which the private wires terminate assembled above 200-point line banks, to which the positive and negative wires connect. The 600-point banks used with 200-line final selectors consist of three 200-point banks assembled in a similar manner to the usual test distributor banks. The upper 200-point banks take the private wires for the 200 lines in the group. The negative and positive wires of subscribers' lines in the odd hundred connect to the middle banks; and the negative and positive wires of the subscribers' lines in the even hundred connect to the lower banks.

Normally, the wiper springs—positive, negative and private—passing over the bank contacts of subscribers' lines in the odd hundred are in circuit, but when the wiper steering relay is operated wiper springs appropriate to the lines in the even hundred are switched into circuit.

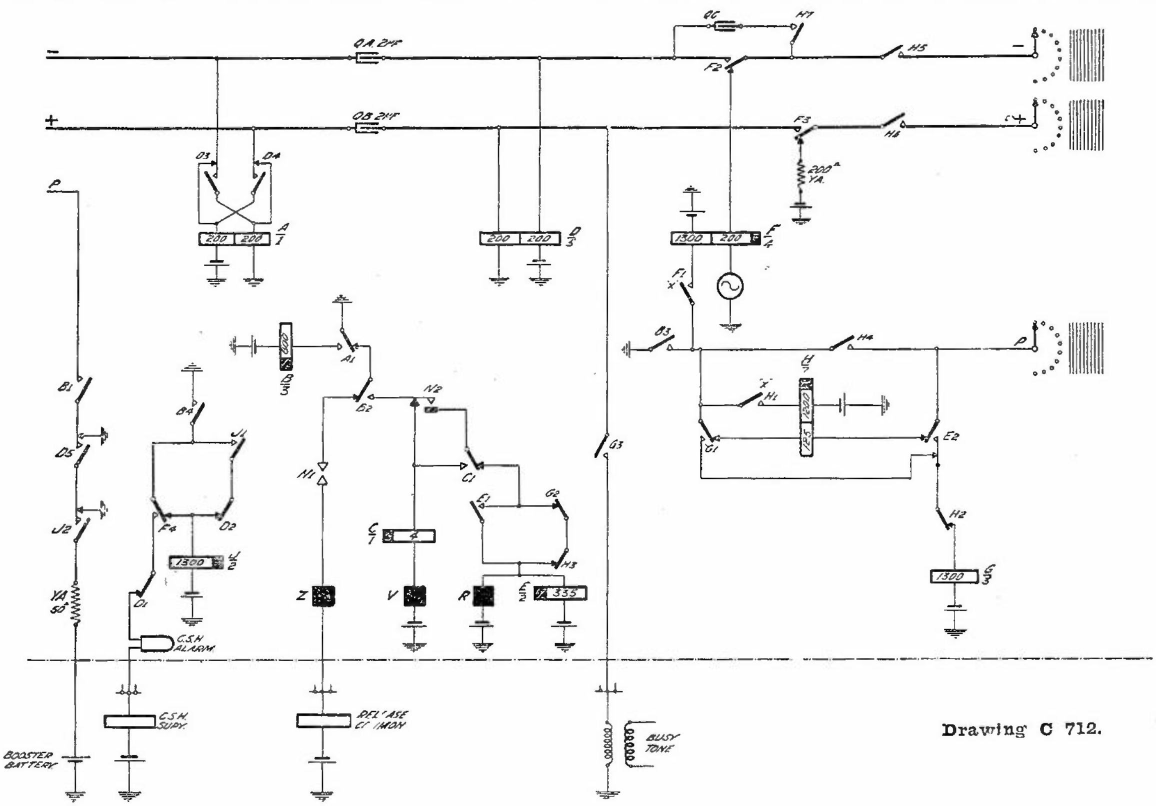
The circuit of a typical 200-line final selector is shown on Drawing C.1033, while C.712 is typical of the 100-line final selectors at present in use. A comparison of these circuits will be of interest, and in this connection it will be observed that the following points are incorporated in the circuit shown on C.1033:—

(1) A wiper steering relay WS is provided to switch from the upper to the lower set of wiper springs.

(2) A pre-operated C relay is used during vertical stepping and rotary stepping.

(3) Contacts on the C relay disconnect the D relay during impulsing.

(4) The F relay locks up on the break of its own contacts.



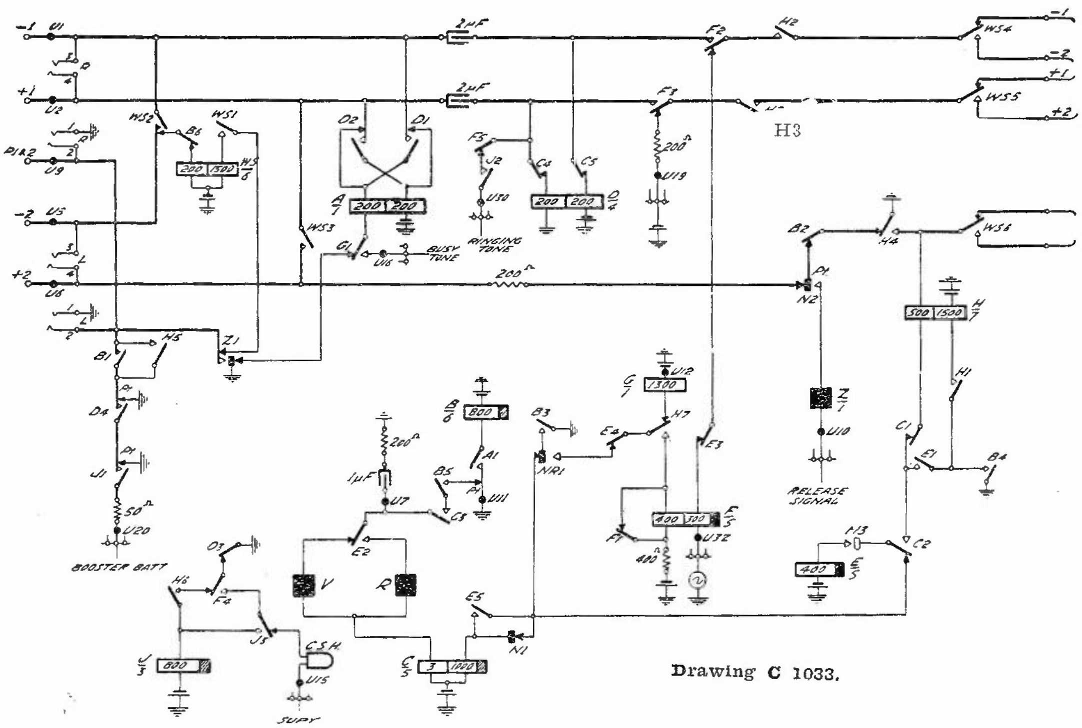
Drawing C 712.

(5) A quick-acting H relay is used and the premature operation of this relay is prevented by means of the circuit arrangements.

(6) When an engaged subscriber is called, busy tone is supplied from the centre point of the A relay, thus securing a balanced circuit for the transmission of the busy tone.

(7) Ringing tone and ringing current are definitely segregated at the ringing panel, and are supplied separately to final selectors.

(8) Provision is made for guarding the switch against seizure during release by providing a contact Z1 which is operated by the release magnet.



Drawing C 1033.

To enable final selectors to serve two 100-line groups, it is necessary to interconnect two levels of the banks of the penultimate switches. In the case of a five-figure system, this interconnection is made at the third selectors. The usual method is to associate the following levels:—

First and tenth;
Second and third;
Fourth and fifth;
Sixth and seventh;
Eighth and ninth.

Where two levels are associated at the third selectors in this manner, the private wires for these levels are multiplied and connected to the P1 and 2 terminal shown on the left of C.1033. The outlets from the line contacts of these levels, however, are cabled separately to the final selectors, the odd level being cabled to —1 and +1, and the even level to —2 and +2. The effect of this interconnection is that when a final selector is in use it will test busy on both the odd and the even levels, as its private wire is common to both levels. However, a final selector reached from the odd level will be entered through the input terminals marked —1 and +1, whereas a final selector reached from the even level will be entered from contacts —2 and +2. Therefore a call on an even level loops the —2 and +2 terminals, thus operating WS relay, which locks up through WS1 and switches —2 and +2 input terminals through to the impulsing relay (relay A). At the same time, contacts WS4, WS5 and WS6 switch the lower set of wiper springs into use.

The C relay used in circuit C.712 is a 4-ohm slow-acting series relay, and because of its low resistance it is necessary to limit its spring sets to a minimum. In the circuit shown on Drawing C.1033 the C relay is provided with a high resistance winding of 1,000 ohms. As soon as the switch is taken into use A and B relays operate and B3 closes the circuit of the 1,000-ohm winding of relay C which then operates. At the first vertical step this winding of the relay is opened at the vertical off-normal contacts N1. Relay C, owing to its slow release action, is now held during the vertical impulses which pass through its 3-ohm winding. On the completion of this train of impulses, C relay releases, and the circuit of E relay is closed, via N3, C2, NR1 and B3. Relay E operates and again closes the circuit of the 1,000-ohm winding of C relay at E.5. At the first rotary step the rotary off-normal contacts NR1 open the circuit of the 1,000-ohm winding of C relay, and this relay is now retained during the rotary impulses which pass through its 3-ohm winding.

It will be observed that prior to the vertical and the rotary impulses, relay C is operated; it is only necessary for the impulses through the low resistance winding to maintain the relay in the operated position. In these circumstances C relay is more reliable in operation, and advantage is taken of this fact to provide extra contacts C4 and C5, which open the circuit of D relay. This ensures that during impulsing relay A is not affected by the two 2-microfarad condensers and the D relay being connected in shunt across A relay. The final selector A relay, therefore, functions during impulsing under similar circuit conditions to the A relay in a group selector.

In comparing the ringing circuit on C.1033 with the ringing circuit on Drawing C.712, it will be observed that in each case the ringing current is tripped by the operation of relay F. When F operates it pulls through and locks up by means of an auxiliary winding. In circuit C.712 it is necessary for contacts F1 to make before the auxiliary winding comes into operation, whereas in circuit C.1033 the auxiliary winding is brought into circuit on the break of these contacts. The latter is a more reliable circuit arrangement, and a ringing circuit of this type is being introduced generally as the opportunity presents itself.

In final selector circuits of the type shown on Drawing C.712 the H relay is provided with a copper slug to ensure that this relay does not operate and cut through before K relay in the called subscriber's rotary line switch circuit operates and clears the line of the called subscriber's line relay. This ensures that the ringing current is not tripped via called subscriber's line relay. In the circuit shown in Drawing C.1033 the H relay is a quick-acting one, but the correct operating sequence is ensured by the manner in which the circuit is arranged. During the rotary impulses both C and E relays are operated and the circuit of the 500-ohm winding of H relay is, therefore, opened at C1. E relay is held operated during the rotary impulses through N3, C2, E1 and B4. On the completion of the rotary impulse train C releases and the circuit for H relay is completed by C1. In the event of the line called being disengaged relay H operates over the earth connection via B4, E1, C1, 500-ohm winding of H, WS6, the private wiper to K relay connected to the private wire of the called subscriber's line and negative battery. Relay H cuts through, but there is no danger of the ringing current being tripped if a slight delay occurs in the operation of the K relay, because the ringing circuit is disconnected from the negative wiper at E3, and E relay, due to its slow release action, does not release until a slight interval after the operation of H.

In circuits of the C.712 type the busy tone is connected, when necessary, to the positive line via G3, and while this circuit is in general satisfactory, the busy tone feed cannot be regarded as a balanced one. In circuit C.1033, the busy tone is introduced at the centre point of A relay via G1, and therefore the circuit is balanced.

In C.712, the ringing tone is superposed on the ringing current and connected to the called subscriber's line. A small feed-back condenser QC is provided to feed back ringing tone to the calling subscriber. Under this arrangement ringing tone is supplied to the final selector at a suitable power level for transmission through the feed-back condenser to the calling subscriber. The power level of the ringing tone on the called subscriber's side of the feed-back condenser is fairly high, and in certain cases this caused inductive interference in neighbouring circuits. In C.1033 ringing current is supplied to the 300-ohm winding of the F relay, and any audio frequencies in the ringing circuit at this point which may cause interference can be eliminated. Ringing tone is supplied over the positive line via U30, J2, F5, back to the calling subscriber, and the power level of this tone is restricted to that required for the transmission of a satisfactory tone to the calling subscriber.

When the switch is released and the release magnet operated Z1 contacts will be operated, thus taking the earth off relay A and placing it on the private wire. This will render the switch busy during the release of the switch and will, therefore, prevent it being taken into use again until it is restored to normal.

It will be observed that in the developmental work associated with the introduction of a 200-line final, the final selector circuit elements have been modified. Individually, the modifications are of a minor nature, but in total the effect should be to ensure more reliable switch operation.

THE TRANSRECTER.

AN AUTOMATIC BATTERY CHARGE CONTROL EQUIPMENT.

J. A. Kline, B.Sc., A.M.I.E.E.

Special equipment has been installed for the automatic control of the batteries serving the Rural Automatic Exchanges at Somerville and Tyabb, in Victoria, and as it has proved satisfactory and economical, an extension of the use of this, or equipment giving similar facilities, may be expected. The purpose of this article is to give some information on the principles of operation and adjustment of this special equipment.

In an unattended exchange, the control of the charge of the batteries introduces difficulties not present where staff is available to determine when charge application is required, and then to perform the required switching.

To give a margin of safety against possible failure of the mains supply, it is usual to provide batteries in duplicate, each being charged and discharged in rotation. In the case of the Rural Automatic Exchanges, the change-over of the batteries may be performed by dialling from the parent exchange, the necessity for such action being indicated by a signal sent automatically to the parent exchange when the discharging battery operates the low voltage alarm. Arrangements have been devised whereby this change-over takes place automatically without the intervention of an officer at the parent exchange, but the relays, contact voltmeters or ampere hour meters used in such a scheme must be absolutely reliable, and even then require maintenance attention to ensure immunity from battery failure.

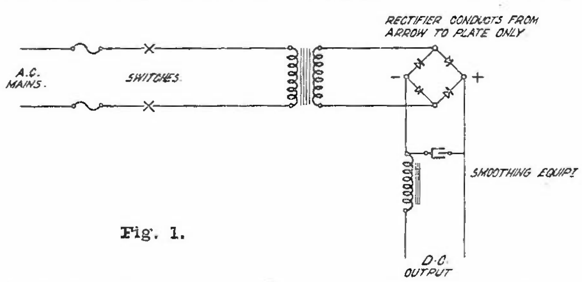


Fig. 1.

The provision of duplicate batteries with the attendant switching problems can be avoided by using a single battery connected on the "float" principle, if it is ensured that the battery will always be in a sufficiently charged condition to carry the load for any reasonable time of failure of the town main supply. This is not easily obtainable economically since a normal "trickle" charge is not sufficient to fully charge a battery once it has discharged more than about 30 per cent. of its full capacity.

To use the float scheme the charging rate must, therefore, be high enough to prevent the battery from ever being discharged beyond about 30 per cent. of its total capacity—a difficult condition to obtain if serious overcharging is to be avoided—or alternatively, the charging rate must be stepped up, when the battery is partially discharged, to a rate capable of fully charging the battery, and to avoid excessive charge the rate should be stepped down to the "trickle" value so soon as the battery is again fully charged.

This variation of the charging rate according to the condition of the battery is given by purely automatic means and without moving parts by the "Transrecter." This is the name which Messrs. Siemens Bros. use for their particular product, and it is desired to acknowledge the permission of that company to allow publication of the principle of control of the units supplied by them for the R.A.X. installations referred to above.

The simple essentials for battery charging from A.C. mains are shown in Fig. 1.

To give automatic regulation of the output a special double-wound choke is added to the circuit connected as shown in Fig. 2. The primary winding P of the choke coil A is connected in the A.C. circuit, while the secondary winding S is in the D.C. side.

The impedance of the primary winding of the choke depends on the extent of magnetisation of the core. The greater the magnetisation the less will be the impedance until magnetic saturation gives the minimum impedance.

The value of the current flowing in the D.C. circuit determines the extent of the magnetisation of the choke core, and hence the impedance of the primary winding is controlled by the D.C. output, being high when the D.C. output is low and vice versa.

If a battery and a load is placed across the D.C. output terminals the battery will be charged. Should the load increase or the battery gradually discharge, the battery voltage drops,

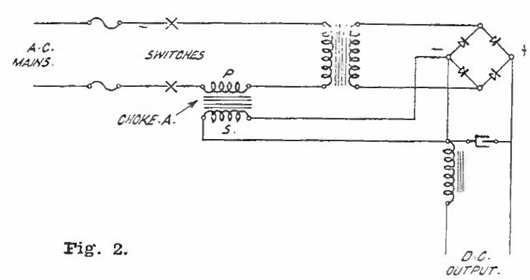


Fig. 2.

causing the rectifier output to increase, which increases the magnetisation of the core of choke A, thereby decreasing the impedance of the primary winding P, which causes the A.C. input through the transformer to increase to an extent sufficient to balance the increase in the output side. Further increases in the D.C. load cause the magnetisation of the choke "A" to rise until saturation of the core is reached and the maximum output of the transrecter is obtained. As the battery becomes fully charged the charging current will decrease, thereby reducing the magnetisation of the core of choke A, which in turn increases the impedance of the primary winding and reduces the A.C. input to the transformer, this continuing until finally the battery receives a trickle charge only.

The transrecter is designed for a fairly sudden change from full charge to trickle charge and vice versa. The voltage at which the change-over occurs is regulated by resistances shunting the choke coil windings, as shown in Fig. 3.

The effect of resistance YB is to regulate the proportion of D.C. current passing through the secondary winding of choke A, and consequently the extent of the magnetisation of the choke corresponding to any particular D.C. output. The voltage of the battery at which the full charge will be changed to trickle charge is regulated therefore by resistance YB, whilst resistance YA regulates the proportion of A.C. current, which can be controlled by the impedance of the primary winding of the choke, and therefore reducing resistance YA raises the trickle charge value.

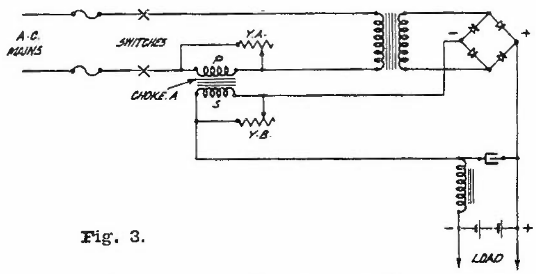


Fig. 3.

The two resistances are of the slide wire type, and are capable of controlling the rates within fine limits. Once set no further attention is required unless it is desired to alter the charging rates.

To eliminate A.C. ripple in the D.C. side through the transformer action of choke A, two chokes connected in series are used having equal transforming effect, but having secondaries connected in opposition to neutralise the induced ripple. Provision is made for an alarm being transmitted to the parent exchange in the event of A.C. power failure, and the manufacturers have also developed a means for giving compensation for mains' voltage variation.

The complete circuit is shown in Fig. 4.

The battery is kept in a practically fully charged condition and is, therefore, always able to carry the load should the mains' supply fail. In the R.A.X.'s, where these have been used, two or three days' supply is available from the battery alone, which gives an ample provision for reserve.

A comparison with the equipment required for duplicate battery working will indicate the savings in apparatus.

Transrecter Scheme.	Duplicate Battery Arrangement.
Transrecter. Battery 25 cells.	Rectifier. Battery 50 cells. Control equipment for changing over batteries.

Not only will there be savings in capital expenditure, but the absence of moving parts will reduce maintenance and increase the reliability of the installation, whilst the fewer cells will add to the economies to be effected.

Two sizes have been tried out; the smaller, having a maximum output of 2 amps., has proved very satisfactory with an adjustment to give a trickle charge of about $\frac{1}{4}$ amp. The larger has a maximum output of 5 amps., but with the apparatus as supplied by the Company the lowest trickle charging rate for which it can be adjusted is approximately $\frac{1}{2}$ amp., and this is higher than required for a 50- or 60-line R.A.X. with normal traffic, so that the automatic raising of the rate is seldom called into operation.

The battery controlled by the 2-amp. transrecter for six months is in a very satisfactory condition, and it would appear at this stage that the smaller unit will meet all requirements for

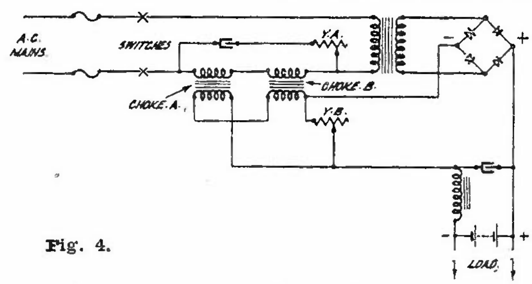


Fig. 4.

battery charge control at small exchanges where there is a reasonably reliable local A.C. supply.

FACTORS AFFECTING the FUTURE DEVELOPMENT of TRUNK SYSTEMS.

J. W. Read, B.Sc., Grad. I.E.E., A.M.I.E. (Aust.)

The development of long lines has been summarised many times from the general point of view. The use of earth circuits—the introduction of the pair—the successively increasing gauge of wire in an attempt to overcome distance; the loading of aerial lines—the reduction of gauge combined with repeaters and introduction of carrier; the use of cables with heavy loading, followed by the trend to lighter loading, the use of four-wire circuits and stabilised circuits may be called to mind. There is a trend to lighter and lighter loading and use of higher frequencies, and in some cases the abandonment of loading altogether. This is exemplified by the Bell System experiments in nine-channel four-wire carrier on unloaded pairs of ordinary cables, and the use of frequencies of the order of 1,000 Kc. on concentric cables. (Concentric cables consist of a single copper conductor totally surrounded by but insulated from a copper tube conductor. The outer conductor may be in contact with earth.) These methods require frequent repeaters, but the repeaters become simple in construction and one repeater amplifies many channels. Extensions of the items referred to above are all available in recent literature.

There are, however, a few points which must be borne in mind in connection with trunk-line work. The trunk circuits installed at any time remain in use for many years, and their characteristics affect profoundly future development. The line layout and design is based on the characteristics of the equipment to be used, and these characteristics must be studied accordingly. It is equally true that the equipment design is controlled by the line characteristics available and which can be provided. If lines suitable for a certain design of carrier can be produced, that design of carrier can and will be developed. An example of the co-design of Line and Equipment is given by the Tasmanian telephone cable.

The trunk-line characteristics now being provided are, therefore, going to form a big part of the specifications of carrier systems to be installed 10 and 20 years hence. It may be of interest, therefore, to consider the characteristics of lines and to look forward to possible future developments in carrier as determined by the line characteristics.

The demand for communication channels will include voice frequency channels of width 250-2,500 cycles, telegraph channels, programme channels, and possibly television relay channels. A few remarks will be given on each of these in the reverse order.

Television.—Television in its present form appears to require an upper frequency between 1,000 Kc. and about 5,000 Kc., although narrower bands may be useful. Such should be possible over concentric cables with very frequent repeaters, but it seems very doubtful whether these cables can be economically provided over great distances for many years. The possibility of using open wire, therefore, requires consideration. Satisfactory overall should be able to be obtained with repeaters at reasonable separation, provided uniform attenuation can be obtained. This requires that there shall be no absorption bands (as discussed below) in the range, a condition which it will probably be difficult to meet for the frequencies concerned. This will require some research measurements on the lines which are most likely to prove satisfactory. One point, however, must not be overlooked. It will probably never be considered desirable to use relatively long waves for television broadcasting (in the frequency range now used for programme broadcasting), because that frequency range is too valuable to give up the wide band necessary. It should, therefore, be equally true to say that television on an aerial route must not be allowed if it is going to prevent the use of a frequency range which is much more valuable for other channels. For example, if a television channel were to prevent the use of large numbers of carrier channels, it would not be desirable. Television channels will be left at this indefinite stage until measurements are made.

Programme Relay Lines.—The programme relay requirements in Australia can be grouped under three headings:—

(1) Unidirectional high quality channels for permanent relays to relay stations—for example, the Melbourne-Corowa line.

(2) High quality channels for intermittent relays. These should be reversible if possible. If it is not possible to provide them as reversible channels, they will have to be duplicated by unidirectional channels in each direction.

(3) Good quality channels providing about 5,500 cycle band width, but not unduly interfering with the utilisation of the line.

The present programme carriers will satisfactorily provide either (1) or (2) where nothing else exists on the pole line in the frequency range concerned. Voice frequency lines free of all equipment below 10 Kc. are also satisfactory; (3) can be provided by voice frequency lines with programme filters, carrier systems being used over the programme filters.

It does not seem feasible to try to work more than one programme carrier over a given aerial pole route, unless they all operate in the same direction. This is because of crosstalk. As the systems are reversible, this practically means that only one can be used. The simultaneous operation of such systems in opposite directions would require measured near-end crosstalk on the line to be about 100 db. at 42.5 Kc. Channels beyond one must, therefore, be voice frequency or fixed direction channels in another frequency range. For instance, they may be carrier channels working in the A to B direction between 5 Kc. and 16 Kc., and in the B to A direction between 18 Kc. and 28 Kc. It would be possible to provide any number of such systems on a well-designed pole route. It is, moreover, questionable whether it is economical to allow a reversible programme carrier at all, for it prevents the use of the frequency range concerned for anything else. It is, therefore, possible that in the future the only reversible channels will be voice frequency.

Telegraph Channels.—Telegraph channels do not require much comment, as their direction is fixed and they can be provided in sufficient numbers as carrier telegraph channels, or as voice frequency carrier telegraph systems over speech channels of a physical line or carrier telephone system.

Commercial Speech Channels.—Speech channels are the unit of channel, and can be provided over any frequency range which has satisfactory attenuation, and freedom from interference. Considering the future of such speech channels, the following points are worth tabulating:—

(1) Cable channels are freer from failure than aerial lines, but this can be largely overcome by provision of alternative routes.

(2) Short channels are required on most routes, and therefore all the channels on any route are not likely to be provided over a concentric cable. Moreover, there are several groups of channels required to the major centres on a route. A single concentric cable arrangement would involve a large amount of apparatus at these intermediate points.

It is unwise to assume blindly that cable or any other method will be used over any route in the future. There were aerial routes in existence some 10 years ago which were fully occupied. It was then assumed that these would be replaced by loaded cable in a few years' time. The advent of the three-channel carrier system has held this conversion in abeyance, and it is quite possible that carrier may develop in such a way that the now approaching crowding of three-channel carriers may be relieved. In any case, in a few years' time, it is somewhat unlikely that the loaded cable will be accepted without question. There is very much in favour of high velocity circuits, such as carrier channels either over aerial lines or over unloaded cable. Such circuits are much freer from echo troubles and similar distortion.

As far as aerial line carriers are concerned, it must be remembered that there are now a large number of three-channel carriers in existence, and the demolished asset cost of abandoning these will probably tend to keep the general frequency allocation below 30 Kc. as it is at present. In any case, three-channels are a useful unit for serving the inland towns, and 30 to 40 Kc. is probably about the highest frequency for which it will be economical to design aerial routes for satisfactory crosstalk between large numbers of pairs.

It is considered, however, that satisfactory transmission characteristics, including crosstalk, could be provided for a small number of pairs in selected positions on the pole, for considerably higher frequencies. As an example of this, on one route in the Commonwealth (Sydney-Melbourne) an attempt is being made to provide for frequencies of the order of 150 Kc. If the measurements of the characteristics confirm the anticipated results, it should be possible to use two systems, each working from 50 Kc. to 100 Kc. in one direction, and 100 Kc. to 150 Kc. in the other direction. These would require repeaters every 80-90 miles, and would be at least ten-channel systems with existing filter design. Research work on filter design and manufacture will probably allow channels to be closer together and these systems may have as many as 15 channels. Of course, one of these systems could be "staggered" with respect to the frequencies of the other. The attenuation at 150 Kc. should not be more than .5 db. per mile, and will probably be less. The Bell System have obtained attenuations of the order of 1 db. per mile at 1,000 Kc. over circuits of about 400 lb. copper. The characteristics which have to be considered at these higher frequencies are uniformity of attenuation and, if more than one system is used, crosstalk. There is also the possibility of interference from broadcasting stations, but these are not as low as 150 Kc. in this country.

The departure from uniformity in attenuation in the aerial line itself is caused by absorption bands, due to excessive crosstalk absorbing the power. Such crosstalk may be to all other pairs considered as a single circuit with earth return. There is an excellent example of such absorption in a 400-lb. copper trunk in New South Wales, occurring between 20 Kc. and 27 Kc., above which the attenuation is again normal.

It is anticipated that the attenuation will be satisfactory on the circuits referred to up to about 150 Kc., but beyond this the attenuation will probably be somewhat irregular. These circuits are about to be retransposed, after which measurements can be made in this frequency range and then steps taken to get a suitable system designed. If successful, each of these pairs will carry about as many channels as an arm of wires fully equipped with three-channel carrier, and probably at no higher cost per channel for equipment.

In considering the number of channels per system, it is worth remarking that with the most economical arrangement of three-channel systems and voice frequency channels for 20-year development figures on some routes, there are sections of route over which some of the physical wires are provided to accommodate the carrier only, the voice frequency channel not being required. An increase in the numbers of channels per carrier would therefore reduce the number of carriers required, and therefore avoid the necessity for these wires. Single-channel carriers should be purchased and used with reservation, as they occupy a line, and although lines are available for them now, in a few years they will not be able to be accommodated on main routes, on account of the extravagance of frequency spectrum available.

The foregoing does not consider the use of a combination of cable and aerial line. Such a transition stage is bound to occur if cable is used, and will undoubtedly affect the type of cable to be used. A loaded cable extended section by section would mean repeated moving outwards of carrier terminals. An unloaded cable with frequent repeaters (about every 25 miles) should allow the open wire type carriers to operate over the cable, and extension of the cable would simply mean the addition of 25 miles of cable and one group of intermediate repeaters, the cut-over in such cases being a very simple operation. This also has advantages in operation, as the demodulation is always in the centre of the main network. The consideration of such schemes is not within this paper, but it should be possible to work the carriers four-wire over the cable and thereby simplify the intermediate repeaters. This may be possible without increasing the numbers of cable pairs, for there may be more voice frequency pairs required than carrier systems.

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