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# Australian Carrier System.

## Description of the Perth-Adelaide Telephone and Telegraph Circuits.

*Introduction.*

IT is the intention to describe the telephone and telegraph channels which were provided recently between the Eastern and Western States of the Commonwealth of Australia. Before doing so, however, it might be desirable to set out briefly the settlement and character of the country and the necessity underlying the provision of the facilities.

The population of Australia has developed in two main settlements. The first and larger is that which originated in Sydney on the East coast, and which has extended North and South until at present practically the whole of the Eastern and South-Eastern portions of the Continent are covered. The second is that which originated around Perth in the South-West and which has since extended over an area about 400 miles square. Fig. 1 is a map of the Continent, showing the carrier systems in use prior to the provision of the system being described, and from this can be obtained an idea of where the bulk of the population exists. Between these two settlements there exists a stretch of country between Port Augusta and Kalgoorlie—approximately 1,000 miles —which is mostly desert country and practically uninhabited.

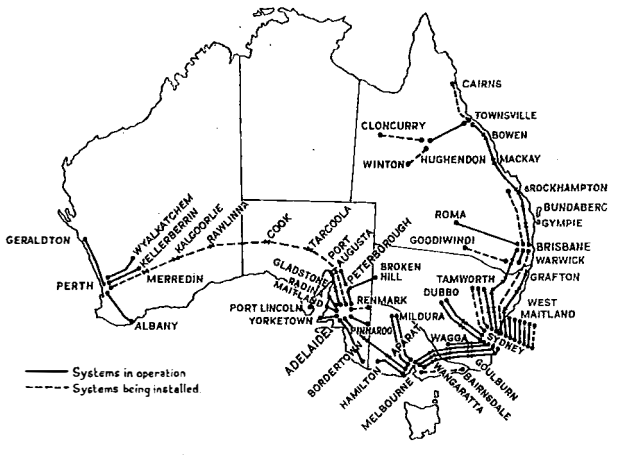


FIG. 1.—CARRIER TELEPHONE AND TELEGRAPH SYSTEMS IN AUSTRALIA.

The trans-continental railway bridges this desert country, and the only habitations are small settlements of railway employees, and here and there, where there is suitable country, graziers have established stations. For some three hundred and thirty miles in this area the railway follows a perfectly straight line over what is known as the Nullabor Plain and this section can best be visualised from its name " Nullabor " (Nullus-Arbor) or, " treeless." It is a fact that for some hundreds of miles in every direction from the centre of this plain there are no trees whatever; the tallest bush would not exceed two feet in height, while, generally speaking, the vegetation does not grow to a greater height than a few inches. It is also, incidentally, perfectly flat, and from the windows of the railway carriage one can see over the plain from horizon to horizon.

For a number of years prior to November, 1930, communication between the two settlements was obtained by means of three physical telegraph circuits. These were arranged to provide one duplex Wheatstone channel equipped with Creed printing apparatus between Perth and Adelaide, and another similar channel between Perth and Melbourne. These two channels normally worked duplex at approximately 95 and 85 words per minute respectively, but frequently line troubles and earth currents due to electrical storms reduced speeds considerably. The third circuit was rented by the Eastern Extension and China Telegraph Coy. and was used to connect its Adelaide office with its submarine cable,

which was brought to the shore at Cottesloe near Perth. These three lines were each equipped with duplex repeaters at Port Augusta, Cook, and Kalgoorlie, and the difficulties in maintaining sufficiently accurate duplex balances to permit maximum working speeds over the 24-hour cycle will, no doubt, be readily appreciated by the reader.

The degree of maintenance required to maintain an efficient service became more and more exacting as the traffic increased over the last few years; and, as commercial activities between the two settlements increased in volume, the need for telephonic facilities became a very real one. In consequence, to meet the public demand, it was decided to investigate the methods available for, and the economics of providing a telephone link.

The scheme decided upon as the most economical was to provide one voice-frequency channel operating over a band of 100-3,000 cycles per second, a carrier telegraph system operating over a band of 3,300-10,000 cycles, and two composite hand speed duplex telegraph channels operating over the remaining band of 0-100 cycles per second.

*Description of Line.*

In order to minimise interference it was necessary first to re-arrange the wires on the route. For nearly the whole distance between Perth and Adelaide the route followed the trans-continental railway. Between Adelaide and Port Augusta—259 miles—the three available wires were run on wooden poles and formed part of a normal trunk route. From Port Augusta to Kalgoorlie—across the desert area of 1,051 miles—they were run on iron poles (spaced 25 to the mile), the property of the Commonwealth Railway Department, which had on the same poles a number of telegraph and telephone wires; and from Kalgoorlie to Perth the wires again formed a portion of a normal 400-mile trunk route through country which is now largely under cultivation for the production of wheat.

Standard E, L, and X transposition sections were provided between Adelaide and Port Augusta, and between Kalgoorlie and Perth. The transpositions over the desert section between Port Augusta and Kalgoorlie were provided in the manner shown in Fig. 2, which is a photograph of a typical transposition pole. A plan of one section is shown in Fig. 3. It will be seen that, although there are only three wires actually in position, provision has been made for the erection of a fourth wire which, when it becomes necessary to do so, can be erected with minimum interference to the existing services.

*Repeater Station Location.*

The repeater stations at the Eastern and Western ends of the line were not difficult to locate because of the existence of small townships at suitable points. The Adelaide end of the circuit was perhaps slightly more difficult to decide upon than the Perth end, but it was finally decided to establish the stations at Gladstone and Port Augusta at the Adelaide end and

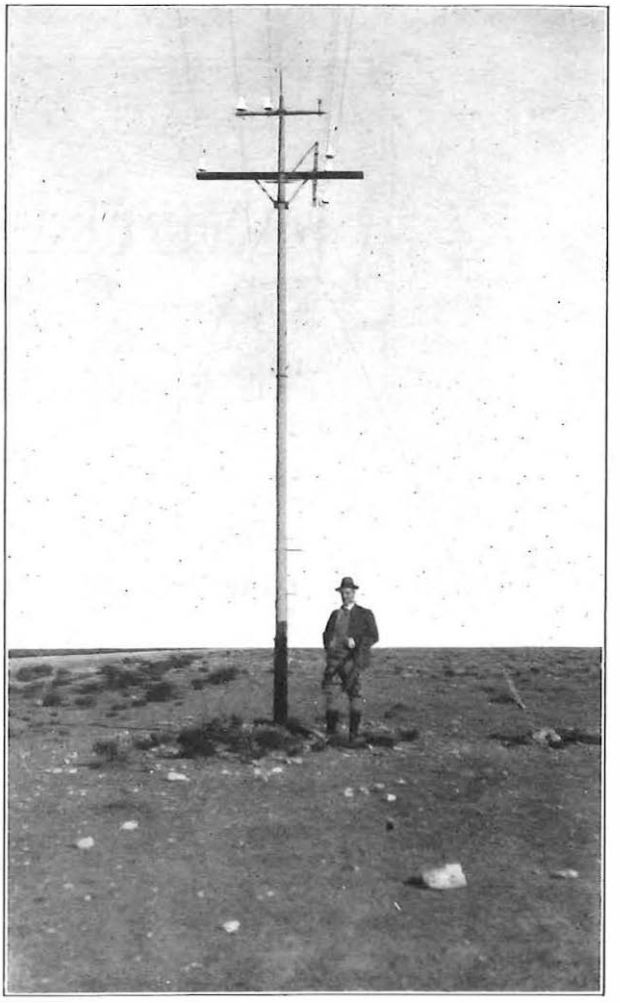

FIG. 2.—TYPICAL TRANSPOSITION POLE.

at Merredin and Kalgoorlie at the Perth end of the line. Small townships with populations ranging from 1,000 to 5,000 inhabitants existed at each of these points, and generally it was necessary only to add to the existing buildings under the control of the Postmaster-General's Department. This left a distance of approximately 1,000 miles to be bridged between Port Augusta and Kalgoorlie, and on this long section there were no townships existing although there were several small settlements of railway employees along the route. At one station —Cook—there was already in existence a building which was suitable for use and which had been erected in 1926 to house the duplex telegraph repeaters. Subsequently Tarcoola and Rawlinna were found to be the most suitable of the other railway settlements to choose as repeater stations, and the lay-out of the lines on the basis of these stations provided that the longest section between repeaters was—that between Cook and Rawlinna—a distance of 303 miles. The attenuation of this section at

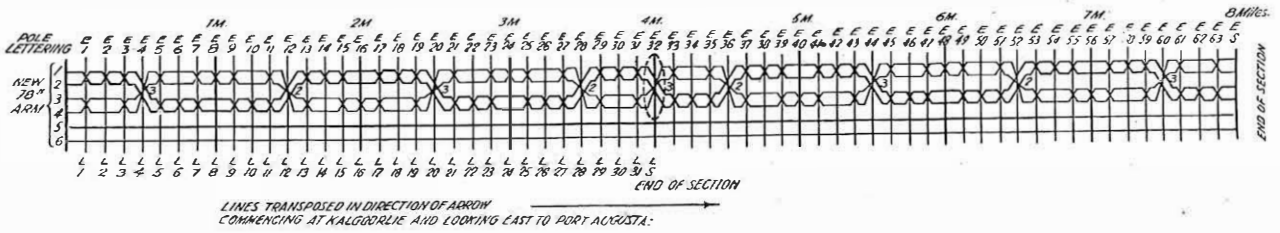


FIG. 3.—PLAN OF ONE TRANSPOSITION SECTION.

1,000 cycles is within the limits of the voice frequency repeater, and also at 10,000 cycles of the repeater on the carrier telegraph system. It was necessary both at Tarcoola and Rawlinna to erect repeater buildings and cottages for the staff which was to be employed. It was necessary also, at the repeater stations, to provide for the postal and telegraphic business originating at these centres. Fig. 4 is a photograph of a repeater station building.

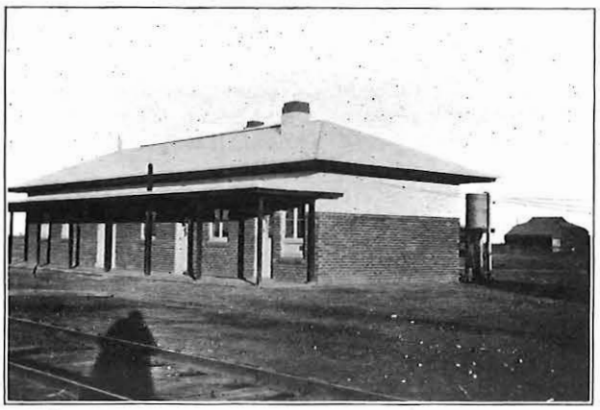

FIG. 4.—REPEATER STATION BUILDING: TRANSCONTINENTAL ROUTE.

*Line Measurements on Repeater Sections.*

When the repeater sections had definitely been decided upon, and prior to the installation of the equipment, the electrical characteristics of the line on each repeater section were measured at frequencies up to 10 Kc. The conditions existing over these lines vary widely from section to section. At the two ends of the line and for the two repeater sections from each end the wires are on heavily laden pole routes, and they are exposed to many types of interference. As frequent serious interruption had been caused to the telegraph services due to earth currents when these lines were working as earth return circuits it was anticipated, and has ultimately proved to be the case, that the electrical storms so common in this part of the country would cause serious interference to the channels provided on the carrier telegraph system should any unbalance be present on the pair now being used to provide service. It has been found, however, that over the carrier system the telegraph working is immeasurably superior to what it had been previously over the physical circuits.

Fig. 5 shows the impedance-frequency curve of the 256-mile section of line between Cook and

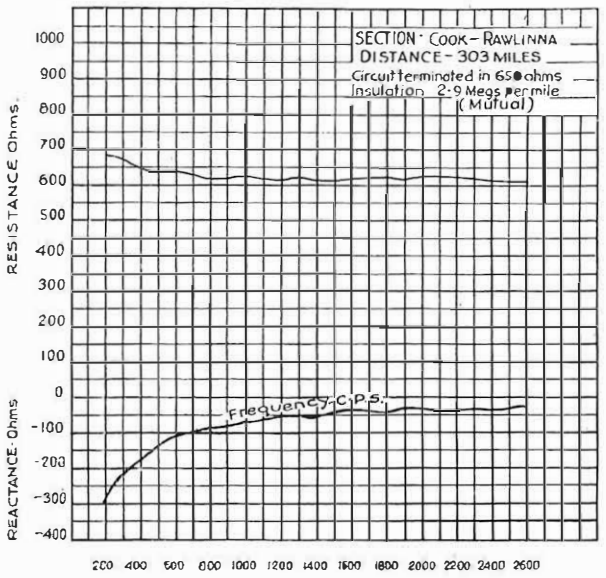


FIG. 5.—IMPEDANCE V. FREQUENCY.

Rawlinna. The attenuation characteristics of this section plotted against frequencies are also shown in Fig. 6. It was thought that the conditions on this line would be almost ideal because of the dry climate, but it has been found in practice that the insulation varies over wide limits and that the attenuation over the channels must be watched carefully during the day. The reasons for this wide variation are now the subject of investigation, but it would appear that mists which blow over the plains from the sea, a distance of perhaps 60 to 100 miles, and also the formation of heavy dews, seriously reduce the insulation resistance between wires to values as low as 0.7 megohms per mile.

*Power Supply.*

In carrier terminal offices and small repeater stations the battery voltages have been standardized and are :—

(*a*) For filament current supply ... 24 volts.
(*b*) For plate current supply ... 130 ,,

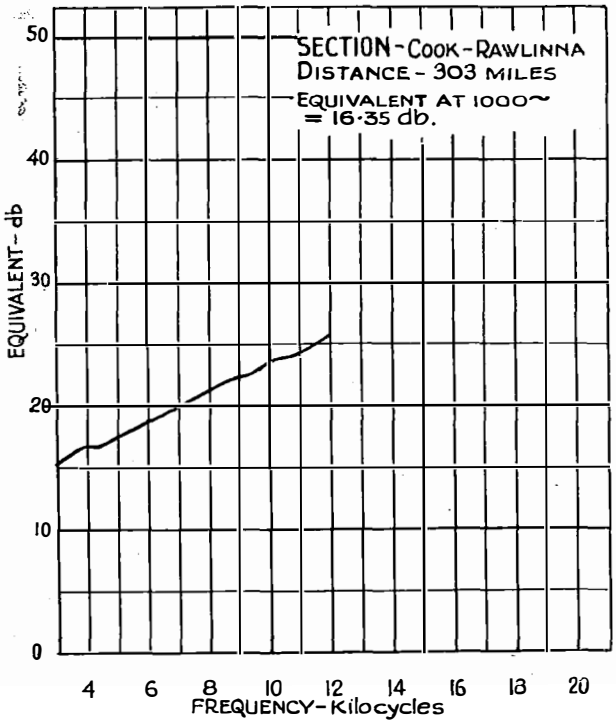


FIG. 6.—ATTENUATION V. FREQUENCY.

Generally speaking, two batteries of each voltage are installed in order that a regular charge and discharge routine may be arranged. The batteries are installed with sufficient capacity to provide some measure of insurance against breakdown in the service in the event of a failure in the main supply or in the battery charging plant.

Motor generators are installed at Gladstone, Port Augusta, Kalgoorlie and Merredin to convert the main supply for battery charging. At each of these towns there is a satisfactory supply available. At Tarcoola, Cook and Rawlinna, where there is no local power supply, prime movers direct coupled to generators were installed. These machines each consist of a petrol engine direct coupled to two generators, one supplying current up to 25 amps. at 35 volts and the other up to 10 amps. at 180 volts, and were supplied by the New Pelapone Engineering Company (England). This supply is also used to light the repeater station itself and the homes of the attendants. The 24 volt batteries have an initial capacity of 300 ampere hours at the 10 hour rate. The 130 volt batteries at Tarcoola, Cook and Rawlinna are Exide type (CZG 6) cells, while at the other stations the cells are the Exide DFG type. In the case of the open top cell there is considerable evaporation at the desert stations although the surface of the electrolyte is covered with battery oil. The cost of sending distilled water to these stations was estimated at 3/- per gallon, so, in order to avoid such high cost, small stills operated with kerosene heaters have been installed at these stations.

*Telegraph System.*

The carrier telegraph system provides at present for eight duplex channels and is capable of extension to ten channels. The system installed is that of Standard Telephones & Cables, Ltd., and was manufactured in England. In this system one group of frequencies from 3,330 cycles to 5,500 cycles is used in one direction, while another group from 6,500 cycles to 10,000 cycles is used in the opposite direction. At the sending end each of these carrier frequencies is controlled by a relay in the sending loop, so arranged that the carrier current flows for a marking signal but no current flows for a spacing signal. At the receiving end the carrier currents of different frequencies are separated from each other by selective tuned circuits. The received currents are then amplified and rectified and the

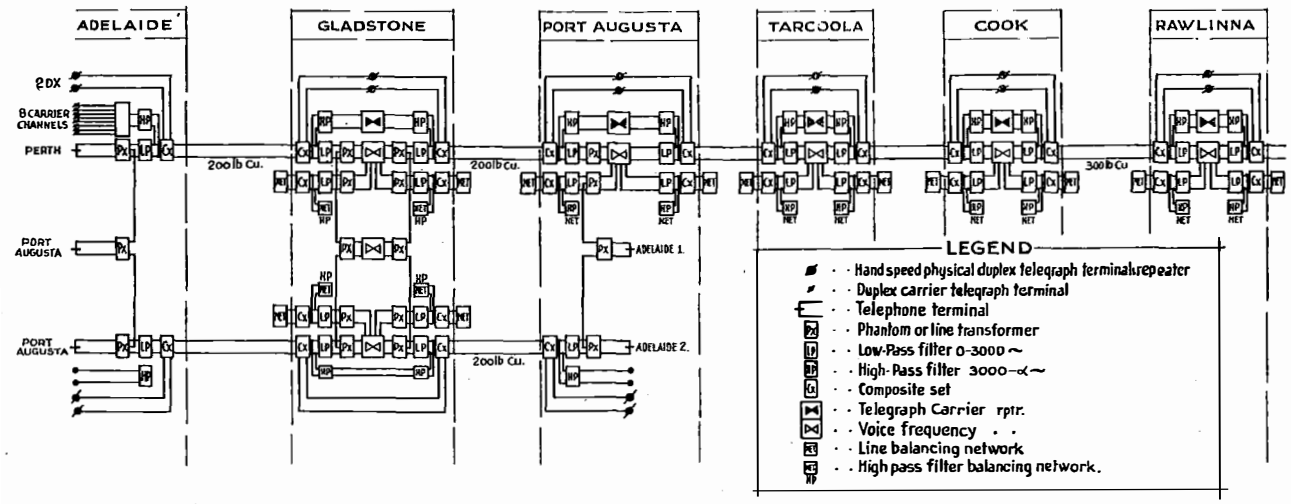


FIG. 7.—LINE

telegraph instrument in each receiving loop is controlled from a relay in the plate circuit of the rectifier valve.

At the repeater stations the group of carrier currents transmitted in one direction is separated from the group transmitted in the opposite direction by directional filters, and amplifiers are provided for each group of frequencies, *i.e.,* one amplifier for the east to west direction and one for the west to east direction. When the carrier system was first opened the telegraph channels were operated by Wheatstone Creed, the system which was previously used on the physical channels, but, subsequently, direct multiplex systems were provided between Perth and Adelaide, Perth and Melbourne, and Perth and Sydney. It will be appreciated that the introduction of these direct systems has meant a very considerable saving to the Department when it is considered that the need for re-transmission of Perth-Sydney traffic, which previously was required to be done at Adelaide, has now been entirely eliminated. The Perth-Adelaide multiplex link consists of a quadruple-duplex Murray system working at 270 revolutions per minute (45 words per minute per arm). The links between Perth and Melbourne and Perth and Sydney are Murray triple-duplex systems also working at 45 words per minute per arm, the latter working through rotary regenerative repeaters at Adelaide. These three systems are working quite satisfactorily and in the near future it is proposed to provide another Murray system between Perth and Brisbane after the carrier telegraph system, now being provided between Sydney and Brisbane, has been made available. This Brisbane to Perth system will operate over carrier channels for a distance of 3,500 miles.

One channel of the Perth-Adelaide carrier system is used by the Eastern Extension Cable Coy., who operate over it a Wheatstone Creed system, linking up with their submarine cable at Cottesloe, near Perth. The remaining channels are used for circuits between Perth and the other capital cities as the traffic justifies.

Composite telegraph equipment is fitted on the wires and duplex composite repeaters are installed at each repeater station. One of the composite channels is used to handle the telegraph business originating at the railway stations on the transcontinental railway line, and the second is equipped with selective "calling-in" equipment of local manufacture. This "calling-in" equipment is designed to enable the repeater station attendants to be recalled to their stations when required by either of the terminal stations. Normally, attendance is provided at these stations from 7 a.m. until 11 p.m., and should the necessity to have any testing carried out arise outside of those hours, the repeater attendants can be recalled from their homes by the attendant at either terminal station.

*Telephone Channel.*

The telephone channel is operated throughout at voice frequencies. The carrier frequency currents are separated from the voice frequency currents at repeater points and at the terminals by filter sets, each comprising a low and a high pass filter which are connected in parallel across the line and have nominal cut off frequencies of 3,000 cycles. The repeaters are the ordinary two-wire type of Standard Telephones and Cables' manufacture.

The line diagram is shown in Fig. **7**, from which it is seen that the circuit is part of a phantom group for two repeater sections at each end of the line and for the other sections is a single pair only.

This channel is normally worked at an equivalent of 12 db. between terminals, but when required for through traffic it is switched through cord circuit repeaters on to the remainder of the trunk line system to Melbourne, Sydney and Brisbane. The channel is equipped with 1,000 cycle signalling which has been standardized in Australia for use on repeatered lines and carrier channels.

Due to the long open wire circuit and the consequent variation in line conditions, it was found necessary to provide very accurate balancing networks at the repeaters, and all filter sets, line transformers and composite sets were balanced in pairs while four element networks closely simulating the lines were designed.

A third wire formerly used as one of the physical telegraph circuits is available and the question of its use to form, with the other two wires, a second telephone channel is being investigated. In the meantime, however, this spare wire

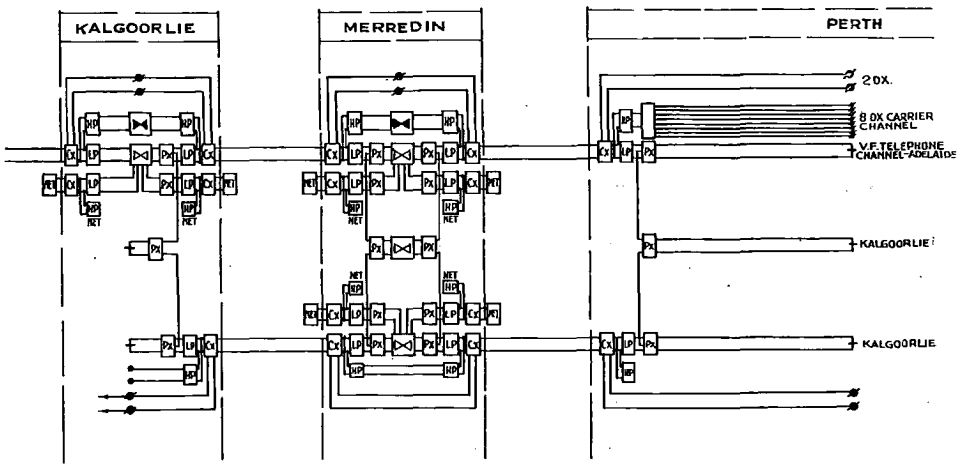


DIAGRAM.

is used as an emergency telegraph channel in the event of a carrier failure and also as a patching wire for use when a fault occurs on one wire only of the trunk line. Use has been made of this wire for patching purposes, and when in use it has been possible to operate the carrier system. The degree of unbalance, however, brought about by its use has prevented the voice frequency channel from being put into service, the noise induced from the Railway Department's circuits being too great to allow of commercial speech.

*Maintenance.*

Facilities for ordinary direct current measurements and for open circuit location are provided on trunk test boards designed and supplied by Standard Telephones & Cables, Ltd. The terminals at each repeater station are equipped with variable frequency oscillators and transmission measuring sets capable of measuring either equivalents or levels.

The maintenance routine provides for a complete line-up of the voice frequency channel and the carrier telegraph system between terminals at 7 a.m. daily. Fig. **8** shows the power level diagram for the carrier telegraph system and an endeavour is made each morning to return all stations to their normal setting and to have provided the levels laid down in that diagram.

It has been found necessary, in addition to the early morning line-up, to have an adjustment of repeater gains on the telephone channel occasionally during the day in order to maintain a constant equivalent. As an indication of the variations which occur in the equivalent on the voice frequency line, measurements made at 1,000 cycles over a test period during one day between Adelaide and Perth have been plotted and are shown in Fig. **9**. During the test period no alterations were made to the repeater gain settings. The variation in the line equivalent does not seriously affect the value of the rectified current on the telegraph channel due, generally, to the characteristics of the detector circuit. It is practicable to work through the variation met with on a normal day without alteration to the repeater gain and, generally speaking, with very little necessity to alter the gain at the terminal station.

It was anticipated that many difficulties would arise in the operation of these long channels, and perhaps the most interesting of these was encountered in operating the Murray multiplex systems. For some considerable time after multiplex working was introduced over the carrier systems in Australia difficulty was experienced in obtaining satisfactory operation. The difficulty was brought about by a certain type of distortion introduced mainly by the rectifier circuit of the carrier system. The effect on the multiplex signals could be described as positive characteristic distortion and was felt particularly by the synchronising or correcting impulse.

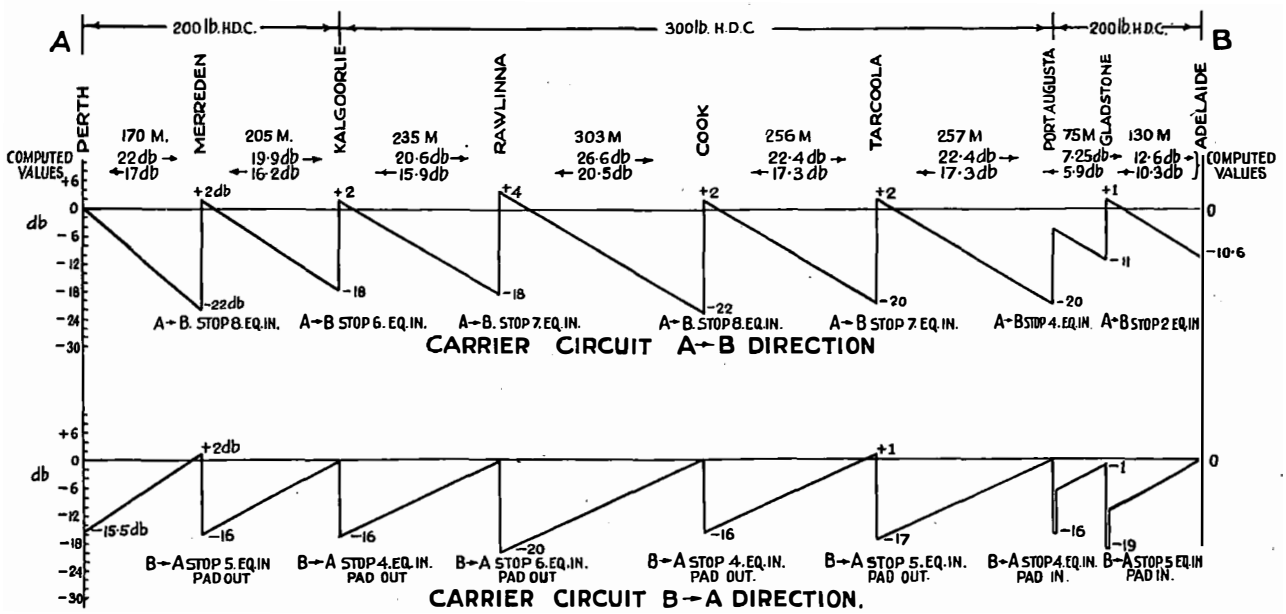


FIG. 8.—POWER LEVEL DIAGRAM.

On a triple Murray system the distributors used have on each of the sending and receiving rings 17 segments—five signalling segments for each of the three arms and two others, the 16th and 17th, which are employed in the synchronising system. Briefly the method of synchronisation employed is as follows :—

The distributor at one terminal is run at a speed approximately .3% faster than that at the other terminal. (For reference purposes the former will be called the " correcting " distributor and the latter the " corrected " distributor). The correcting dis-

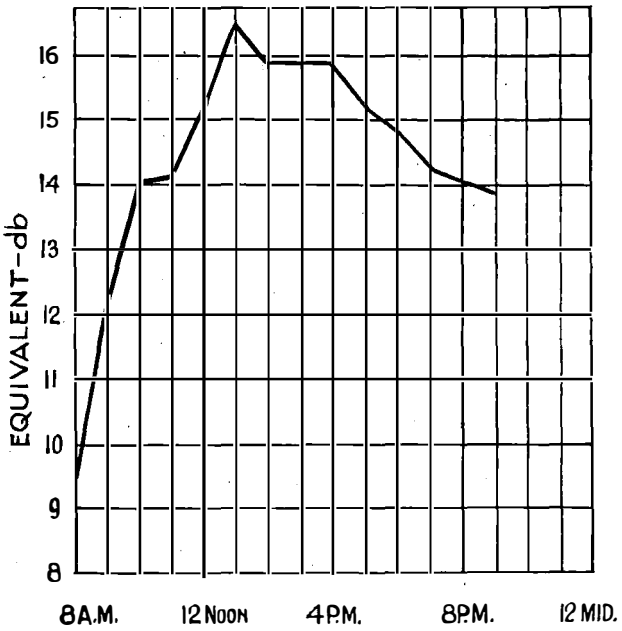


FIG. 9.—VARIATION IN ATTENUATION AT 1,000 C.P.S.

tributor transmits on each revolution of its brushes a correcting impulse from the 16th sending segment, and when the two distributors are in exact phase this impulse is received by the corrected distributor on its 16th receiving segment which is in fact a vacant space on the receiving ring. As the brushes of the corrected distributor advance in relation to those of the correcting distributor, however, this correcting impulse is impressed on the corrected distributor's 17th receiving segment. The latter is connected to a correcting magnet which, when it energises, operates an epi-cyclic gearing arrangement and steps the brushes back $1\frac{1}{2}°$ in relation to the brush spindle. It will be seen that should the tail-end of the correcting impulse be distorted, instability of synchronism would result.

In actual practice when operating the Murray system over carrier channels, it was found that the correcting impulse was on certain channels considerably distorted. When the correcting impulse was immediately preceded by a signalling impulse, the correcting impulse was foreshortened and instability of synchronism, combined with resultant phenomena, into which it is not proposed to enter in this article, was the result. Investigation into the cause of this distortion disclosed that the bulk of it occurred in the carrier rectifier circuit and was more evident on the lower frequency channels than on the higher. Two stages of amplification are employed and the rectifier is biassed back to 51 volts negative and is swung by the applied carrier to a point towards the upper flat portion of its curve. In effect the rectifier tube is overloaded and an appreciable value of grid current is caused to flow.

This grid current impresses a negative charge upon the grid condenser, but does not build up to a maximum during the time of one multiplex impulse. The charge does build up to a maximum, however, during the time of two impulses and the result is that when a double impulse is received the negative charge on the grid condenser reduces the magnitude of the positive potential applied to the grid by the incoming carrier current and consequently the rectified current value. The effect of this is that when the input is cut off the rectified current drops to zero more quickly and the signal is foreshortened. Between signals, of course, the charge on the condenser leaks away through the $\frac{1}{2}$ megohm grid battery resistance. It was found that, without doubt, it was this phenomenon which was causing the difficulty in operating the multiplex systems, and where two or more channels were operated in series the trouble, being cumulative, became more serious.

Several remedies were tried, among which were a reduction of the capacity of the grid condenser, and the use of transformer coupling, but so far the most satisfactory method of overcoming the trouble has been by making use of a device attached to the corrected distributor.

The average amount of phase displacement brought about by the distortion was determined in terms of millimeters measured on the receiving ring of the distributor. A small segment of the required length was attached to the leading edge of the 17th (correcting) segment but insulated from it. This extra segment could be connected to the correcting segment proper through the contacts of a polarized relay, the operating coil of which was placed in series between the fifth signalling segment of the third arm and the fifth magnet of the printer on this arm. When a fifth impulse is received (the impulse immediately preceding the correcting impulse) this relay operates and connects the extra piece of segment to the correcting segment proper. Thus when the tail-end is clipped from the correcting impulse, the correcting segment is actually brought back to meet the brush and so is not lost.

Although every effort had been made to provide for the more likely contingencies, occasional troubles have occurred which have caused serious inconvenience. Perhaps the most unfortunate instance occurred when drizzling rain set in along the line after a dust storm had been experienced. For some four or five hours until the dust had been washed away from the surface of the insulators by the rain, telegraph service was seriously interfered with and hand working only could be maintained. Speaking generally, however, it has been possible to maintain a high grade of service both on the telephone and the telegraph channels, and an analysis of the faults which occurred during the three months ended March 31st, 1931, showed that the average daily interruption to the circuit during this period was 37 mins.; 28 mins. being due to line troubles. So far indications are that this amount of interruption will be lower for the current quarter, and, as experience is accumulated, it is anticipated that methods will be devised to avoid the consequences of most of the troubles which may arise.