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# Telecommunication Journal OF AUSTRALIA

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# THE TELECOMMUNICATION JOURNAL OF AUSTRALIA

**VOL. 22, No. 3**
**OCTOBER 1972**


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COVER
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# A CENTURY OF TELECOMMUNICATIONS IN THE NORTHERN TERRITORY PART 1: THE OVERLAND TELEGRAPH

B. E. WOODROW*

## INTRODUCTION

On the 22nd August, 1872, a telegraph message was sent from Darwin to Adelaide. It was, historically, one of the most important telegrams ever transmitted in Australia, for it marked the completion of the overland line which linked the continent from North to South, and via other systems provided telegraphic communication with overseas countries. The construction of the overland line was a remarkable feat which ranks in the forefront of Australian pioneering achievements. The then Postmaster-General and Superintendent of Telegraphs, South Australia, Mr. Charles Todd, who was knighted in 1893, planned and supervised the work.

Of the early achievements of postal engineers and others in developing communications between the isolated communities of the continent which ultimately became the Commonwealth of Australia, none perhaps is more interesting and indicative of the tenacity and initiative displayed by the pioneers than that of the establishment of this telegraph line between Port Augusta and Port Darwin shortly after the continent had been crossed for the first time through central Australia by explorer Mr. McDouall-Stuart, and the following article, briefly describes its inception and completion. Before proceeding, however, it may be of interest to look back over the introduction of telegraph communication in Australia and some of the technical aspects of morse telegraph systems of the day.

Ten years after Professor Samuel F. B. Morse established telegraph communication between Baltimore and Washington, the first Australian telegraph line came into operation in 1854. It was between Melbourne and Williamstown, in Victoria. The fol-

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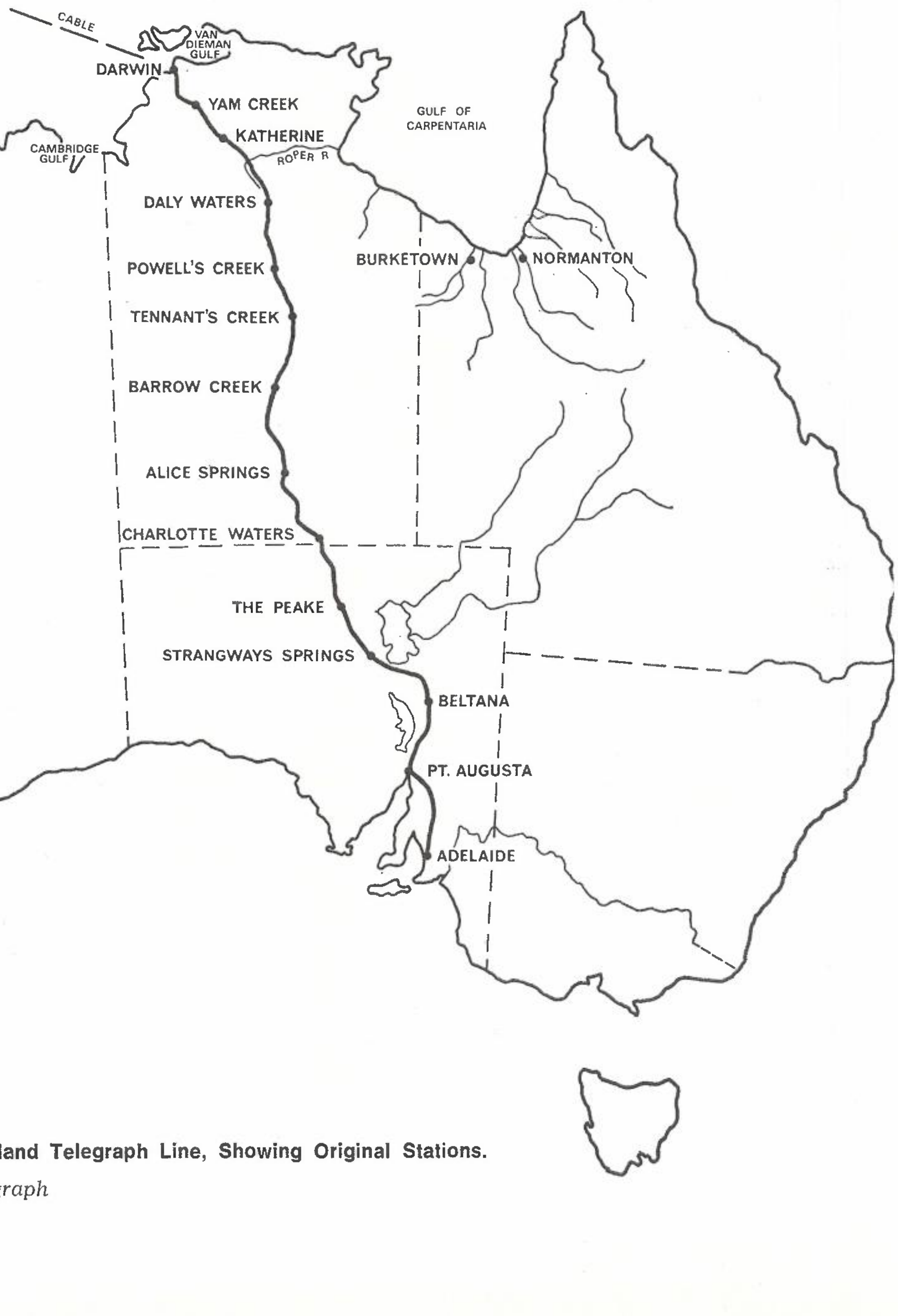


**Fig. 1.— Route of the Overland Telegraph Line, Showing Original Stations.**

lowing years saw telegraph services introduced in the other colonies and of these, South Australia was the first, with a line which employed the 'magneto electric' system and alphabetical needle instruments, between Adelaide and Port Adelaide in 1856. The first inter-colony telegraph communication was established between Melbourne and Adelaide in July 1858 and three months later a telegraph line was brought between Sydney and Melbourne.

## MORSE TELEGRAPH SYSTEMS

At the outset, morse telegraph channels in Australia employed the simplest form of telegraphy — single current simplex. The name 'simplex' was applied to the system which allowed transmission only in one direction, at any one time. Under normal line conditions, and if the distance was comparatively short, the signals could be received directly on a register. This was known as 'direct working'. In the case of long distances the signals were received first on a relay and thence, by means of a special local circuit, on the register. This was known as 'local working'. The line current required in either case was about 15 to 20 milliamperes. In local working each telegraph office employed a key, relay and register, a current from an electro-chemical battery being applied to the wire coils of the relays connected thereto. Signals were transmitted by sending impulses in a prearranged order by intervals of current and no current in accordance with the code invented by Morse, and were recorded by the electro magnet of the register attracting an armature to which was attached a small inking disc or embosser. A paper tape fed by the register was thereby marked. Later on it was found that the movements of the armature could be readily interpreted as audible 'dots and dashes', thus rendering it practicable to eliminate the apparatus for marking the paper tape. Thus the instrument known as the Morse sounder was evolved.

In the earliest telegraph circuits a metallic pair of wires was utilised but later it was discovered that the earth could be used as the return path for the current and therefore only one conductor wire was needed. This discovery meant that the cost of erecting telegraph lines could be substantially reduced. The most commonly used morse simplex circuit was known as the 'closed circuit' type, which meant that when the circuit was not in operation current passing through the line and relays thus held the relays and registers of sounders in the operated position. The key was normally closed by a switch incorporated in the construction, hence the name 'closed' circuit system. On short lines it was generally necessary to have only one main battery of the required voltage at one terminal office, but in the case of very long lines the main battery was subdivided into a number of groups of cells and located at different offices connected in the channel. In the system known as the 'open' circuit it was necessary for a main battery of the circuit voltage to be provided at each office connected to the channel. One advantage of the closed system was therefore the lower cost of provision and maintenance of batteries.

On long telegraph lines, repeating stations were necessary to enable working under poor conditions and hence repeating instruments were provided at certain points on the line which took messages from one section and transmitted them with greater strength into the next section. Two instrument sets were required at repeater stations and the principle was much the same as a relay in local circuit, but the action was carried one stage further to make the armature of the register act as a key so that all signals passing through it were transmitted to the next line circuit. The necessary switching of instrument connections was manually performed. This description can now be related to the Overland Telegraph Line.

## THE OVERLAND TELEGRAPH SYSTEM AND OPERATION

The system was closed circuit single current simplex, and the associated apparatus conformed to the best available in 1870. The system of duplex operation, which allowed faster traffic handling without the need for line duplication, was still in

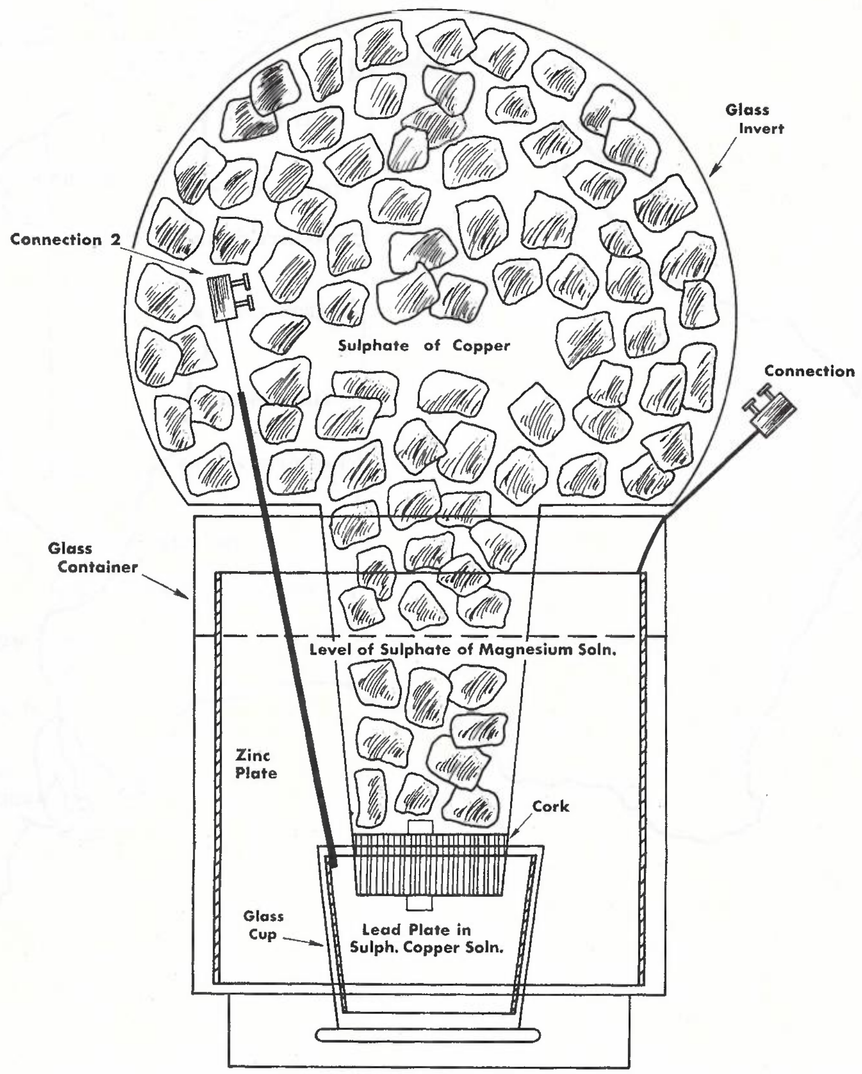


**Fig. 2. — Meidinger Cell used in Main Battery. The glass container was four inches in diameter and the assembled height ten inches.**

the development stage, but in any case, only one channel was provided for the expected traffic.

As the telegraph channel was to be a long line, nearly 2,000 miles, contemporary telegraph engineering dictated the need for about twelve intermediate stations serving as telegraph offices, battery stations and depots. (Fig. 1).

The wire No. 8 (400 lb.) solid iron, resistance between 14 and 16 ohms to the mile, was commonly used in telegraph lines. The main or 'line' batteries consisted of sulphate of copper cells known as 'Meidinger' cells (Fig. 2) each giving an e.m.f. of 1.08 volts. From the author's research it would appear that at least 600 of these cells were connected in circuit at the time of opening the line. With a total circuit resistance of some 40,000 ohms the circuit current would therefore have been about 16 milliampres, which was within the accepted limits. There were, however, two conditions which had to be met, primarily, signal strength, and secondly, economy in the application of batteries, resulting in frequent trial and error rearrangement of battery cells at the various stations and to the extent of the addition or subtraction of thirty cells at any number of stations, although at the terminal at Adelaide 100 to 110 cells were maintained in circuit. Eventually the battery required was to be in the order of 120-150 cells at repeating stations and 60 cells at intermediate stations, thus totalling at least 1000 cells. Batteries for local working of registers consisted each of five Daniell cells using zinc and copper as elements and giving an e.m.f. of one volt per cell.

Morse keys, relays, registers (Fig. 3) were standard, as previously mentioned, but it is perhaps the use of the register which evokes interest in the light of the wide use of coded information on paper tapes in more recent years. It was at this time when many first class sound operators had developed, and advocates for sound operating claimed several disadvantages in regard to tape operation, firstly, that the operator was ignorant of what was passing when he was not observing, secondly, should the register malfunction the message was lost, and so on to include factors such as speed and errors. The sound operator maintained that he could carry on the business by hearing the relay operation only. Therefore, although registers were equipped to all intermediate stations on the Overland Telegraph Line, it is probable that those operators who had developed the skill for sound reading made little use of this instrument for message reading.

At the time of the opening of the Overland Telegraph Line, Alice Springs was the only inland station equipped with repeating instruments, although shortly afterwards other stations were similarly equipped, to make up four main repeating sections, and two auxiliary sections. In unfavourable conditions, direct communication between Port Darwin and Adelaide was impossible and opera-

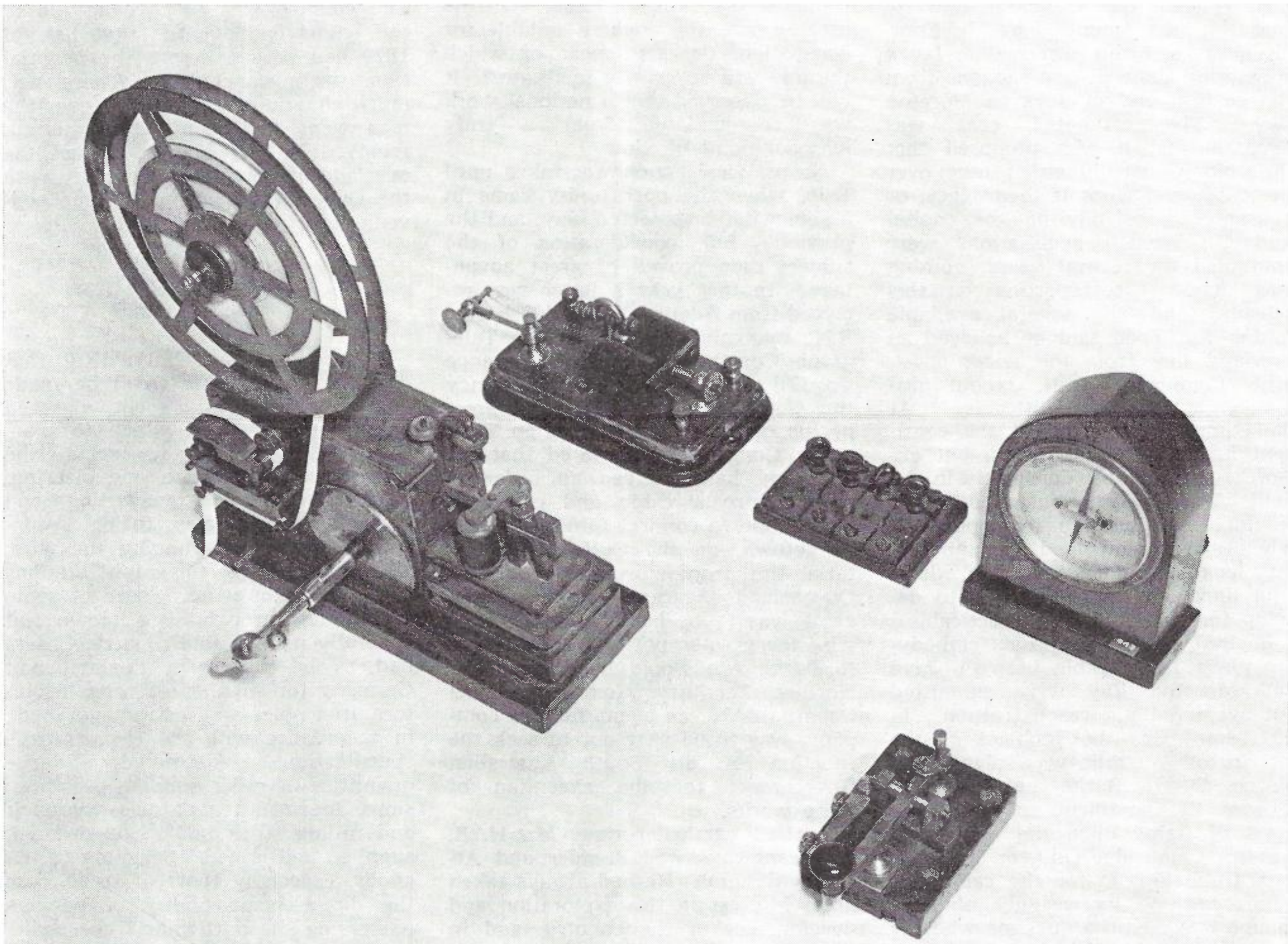

**Fig. 3. — Telegraph Instruments Typical of those used on the Overland Telegraph Line. Top: Relay, Plug-switch, Galvano meter. Bottom: Register, Closed-circuit Morse Key.**

tors at various stations had to repeat messages by hand operation. To facilitate operations, an order of business gave precedence to international traffic and allowed a geographical order of exchange between each station and Adelaide, for testing and normal business. A satisfactory explanation was to be demanded from any station operator breaking the sequence.

It is probably true to state, however, that in 1870 any concern that the engineers and others may have held for the future performance and operation of the circuit and equipment was minor in comparison with the deep concern regarding the task to construct the line and necessary buildings within the contract period laid down consequent to successful negotiations for the undertaking.

## BACKGROUND AND AGREEMENT TO CONSTRUCT THE LINE

Several schemes for the establishment of telegraph communication between England and Australia were mooted from the year 1859 onward. The first was submitted by Mr. Francis Gisborne, who proposed to lay a submarine cable in five sections from the eastern end of Java to Moreton Bay. The estimated cost was £800,000 and it was proposed that the colonies should either take over the cable and work it themselves, or guarantee a subsidy on the capital outlay. Though negotiations were continued for several years, nothing was done. In reporting on this scheme, and the several available routes, Mr. Todd said he believed an overland line from the north coast, near Cambridge Gulf, would ultimately be found practicable. At that time the crossing of the continent had not been effected, but explorers were almost constantly in the field. Their reports confirmed Todd's opinion, and led him to oppose all schemes which involved any unnecessary length of submarine cable, where land lines, which would tend to develop the country, were practicable.

In 1867 further proposals embodying plans for a cable between Java and Moreton Bay were submitted but again did not reach fruition. In the same year the problem of the interior of Australia was solved. Explorers Stuart, Burke and McKinlay crossed the continent. The advantages of fixing upon the neighbourhood of Cambridge Gulf, or Van Diemen Gulf (Fig. 1) for the cable terminus became increasingly obvious, though it was still a question whether the land line should be carried thence to Brisbane or to Adelaide.

Todd's report on the subject, which had much to do with influencing Government action, recognised that the project was of Australasian, and not merely South Australian, interest. He wrote: "The erection of an overland line of telegraph to the north coast should be regarded as a national work, in the carrying out of which all the colonies should unite. It is very improbable that an English company will undertake it; it will therefore devolve on ourselves, and have to be done either by a colonial company, with a guaranteed subsidy of 6 per cent. or by the colonies jointly — each colony contributing in some predetermined portion; or, as I think would be preferable, one Government to erect the line at its own cost, the other Governments agreeing to supplement the receipts up to 5 or 6 per cent. on the actual outlay. . . . In considering the question of route, we should not so much concern ourselves as to which colony will derive the greatest benefit, according as it started from this or that point, but be prepared to discuss the matter without local bias, selecting that route which will traverse, for the greater part, the country suitable for occupation, the settlement of which the line will so greatly facilitate." It will be observed that a national work was contemplated from a truly national point of view.

No practical action was taken until 1870, when the opportunity came in a somewhat unexpected way, and the previous full consideration of the subject then proved of great advantage. In that year a letter was received from Admiral Sherard Osborne, R.N., managing director of the Telegraph Construction and Maintenance Co. Ltd., addressed to His Excellency the Governor. It enclosed a prospectus of the British-Australian Telegraph Company, and stated that his Company had received an order to manufacture a cable and construct a land line to connect Singapore with Burketown, on the Gulf of Carpentaria, the proposed terminus of the Queensland telegraph system. As the cable was to be landed at Port Darwin, the greater portion of the route to Burketown would be through the Northern Territory. Commander Noel Osborne, R.N., as agent for the company, was to be sent out to seek the sanction of the South Australian Government for the execution of these works.

At that particular time, Mr. H. B. T. Strangways was Premier and Attorney-General. He had always taken great interest in the exploration and development of the country, and in the proposed transcontinental telegraph. The official reply to Admiral Osborne was that, while every facility would be afforded to the Company's agent, the Government would much prefer the construction of line from Port Darwin to Port Augusta, and was prepared to seek Parliamentary sanction for an agreement with the Company for a direct line across the continent to Port Darwin, either to be erected by the Company under Government guarantee, or constructed and worked by the Government.

Osborne arrived in April, and negotiations were immediately entered into, the result of which was that the South Australian Government proposed to undertake to construct and complete the land line by January 1, 1872; the Company on its part, agreeing to lay and complete by the same date a cable from Singapore to Batavia, and from Banjowangie to Port Darwin, the two sections of the cable to be connected by an intermediate land line through Java, to be constructed by the Government of the Netherlands. A Bill was accordingly introduced and passed through Parliament authorising a preliminary loan of £120,000 for the land line. The country was thus committed to the enterprise, but the first half of 1870 had passed before the negotiations were concluded. There was much chagrin in Queensland over the turn events had taken, which was not removed by the suggestion that the overland line might be connected with the Queensland system at some convenient point.

## CONSTRUCTION

### Planning

It was not until July, 1870 that detailed preparations could be made and therefore only about eighteen months remained in which to plan, recruit, supply for, and execute the task of route selection and clearing; selecting, felling, transporting and planting timber poles; fitting insulators to poles and running the wire; and establishing telegraph stations and depots for a new route of some 1800 miles through little known and generally inhospitable country. Orders had to be placed in England and Germany for supplies of wire, insulators, iron poles and instruments made in accordance with the Department's specifications. Additionally, large quantities of other supplies — provisions, medical, tents, tools, livestock and rolling stock had to be ordered, supplied and issued. Selection of the goods, especially tools of trade, was the direct responsibility of persons possessing the particular trade skills. For instance, the blacksmiths, saddlers, sawyers and linemen of each party personally saw that tools and materials were of the best quality and kind.

In the selection of horses assistance was given by the then Commissioner of Police. Every draught horse underwent an acceptance trial which involved pulling a load of sand up a steep incline, and the lighter stock had to exhibit their various paces under the keen scrutiny of the judges.

Recruitment of manpower presented no problem other than the need to open a special bureau to deal with the thousands of applications for employment in all grades.

The plan decided on in tackling the project, and presented to the Government by Mr. Todd, outlined the work to be undertaken in three sections:—

1st Section — Port Augusta to 500 miles North by contract (a line already existed between Adelaide and Port Augusta but required duplication).

2nd Section — From 500 miles north of Port Augusta to about Attack Creek, by Government parties supported by contractors for the cartage of materials and rations.

3rd Section — From near Attack Creek to Port Darwin by contract.

### Poling and Work Sections

The exploratory excursions undertaken by Stuart had indicated that the greater portion of the route could be poled from natural timber but a large quantity of iron poles had been ordered to be used where there was a scarcity of suitable timber.

Throughout the route the bulk of poles were from heavy gum saplings many twelve inches in diameter at the butt, none less than nine inches and pine poles of similar proportions. The effective height of the poles appears to have been between fifteen and sixteen feet. All timber poles had to be cut, trimmed, charred, hooped and bored directly into the top end for the fitting of insulator pin holders. The pin holders were made from $\frac{3}{4}$ in. gas piping with shrunk on collars and these were driven about 7 in. into the pole top. The insulator commonly used was called the 'double umbrella' type and in one form, designed by Charles Todd, the wire was held in a vertical slot provided in the top portion of the insulator. Lightning rods were fitted to alternate poles throughout the route. These rods terminated in a coil form under the pole butt to prevent easy removal of the rods.

**1st Section:** The Contractors' progress in this, the southern section, was hampered by a shortage of suitable timber and lateness in delivery of iron poles, but the difficulty was overcome by allowing the contractors to plant timber poles at a spacing of ten to the mile instead of twenty to the mile where natural timber was unsuitable. This resulted in the work being completed at the end of January 1871 for the purpose of advancing northwards the means of telegraphic communication. Shortly afterwards, however, iron poles were planted in conformity with the planned pole spacing.

**2nd Section:** The central and in every way the most difficult section was entrusted to Government parties, five in all, each with a responsibility for their parts of the section. Each party as a rule composed of one Inspector, one Sub-Inspector, one Cadet, and from twenty to twenty-five field hands, teamsters, etc. The Inspectors in each case were experienced Surveyors who had already seen service in the Northern Territory. The equipment of each party included 15 horse wagons, 17 bullock drays, one bullock wagon, five express wagons, 165 horses and 200 bullocks. A depot was established at the Finke River (about 830 miles from Adelaide) for the provision of fresh meat for the men working on the adjoining sections, and 2000 sheep were sent there. It must be remembered that all the material, provisions, etc., had to be hauled from either Port Augusta or Darwin, by horse, bullock vehicle, or camels and some idea of the difficulties experienced can be realised by the fact that the party, who constructed the northernmost part of the central section, travelled almost 1300 miles and took eight months to reach the starting point of this work. The central section was completed at the end of 1871 due to the determination the men displayed in a part of the country almost waterless, without roads or bridges and in many areas miles of sandhills and spinifex.

It should be mentioned also in regard to all sections of the route that considerable follow-up work of a repair nature was involved. Lightning caused wire damage, insulators were dislodged through wire strain, wire came adrift and contacted lightning conductors, poles became misaligned due to natural elements and were otherwise damaged by native tribesmen and termite attack.

**3rd Section:** It was in the northern (tropical) section, which encompassed that part of the route, 500 miles south of Port Darwin, that unexpected troubles and delays occurred. The contract broke down principally through transport inadequacies and the difficulties encountered in heavy clearing work after approximately 225 miles of poles and 156 miles of wire had been erected. The overseer of works, who was supervising the contract. returned to Adelaide and reported this disaster on his arrival in July, 1871. A departmental expedition was at once organised and sailed from Melbourne for Port Darwin in the S.S. 'Omeo' in August 1871, followed by a fleet of four vessels carrying material, horses and bullocks. In the meantime work was in progress in the main Central Section under five Departmental parties and despite the extraordinary difficulties in regard to transport, water supply and foodstuffs, steady progress was made and the work of that section as previously mentioned, was completed by the end of 1871. The wire was suspended throughout the whole length of the Southern contract by the same date, so that had it not been for the termination of the Northern end contract the communication by telegraph would have been possible with Port Darwin by the end of that year. It was hoped that with the large force of transport power sent to the Northern Territory, that although the Northern end would not be completed in 1871, it would be ready by March or April in 1872. During the interim it was proposed by means of a field operator at each end of the wire, and an estafette (horse express), to keep up communication between Adelaide and Port Darwin, but further misfortunes prevented this. The Northern Territory expedition arrived during the dry and hot months immediately preceding the setting in of the monsoonal season, the country was bare of feed and long stages had to be performed without water. The wet season then set in with great intensity and all work was stopped. 21 inches of rain fell in December and 10 inches during the first three weeks in January. Very severe losses of stock were sustained — about 30 to 40% of the bullocks died. A steamer was despatched from Darwin with stores and material to the Roper River and an officer was sent from the Roper by boat to Normanton and thence to the nearest telegraph station (Gilbert River) in Queensland to telegraph for further help. It was then decided that Mr. Todd should go to the Territory and he accordingly left Adelaide in the S.S. Omeo for the Roper with additional horses and stores, followed by the S.S. Tararua with more horses. As it was not expected that such large steamers as the Omeo and the Tararua would be able to navigate the Roper, a small paddle steamer, the Young Australian, was purchased and despatched from Port Adelaide with orders to proceed via

**Fig. 4. — Typical Temporary Camp of a Line Construction Party.**

the Western coast to meet Mr. Todd at the mouth of the Roper. As the Young Australian was not up to time and nothing had been heard of her, Mr. Todd decided to take the Omeo up the river as far as possible so as to land the horses safely. The captain of the Omeo naturally declined to take so great a risk and would not do so until a bond was signed making the Government responsible for the value of the vessel. After this was done the steamer crossed the bar safely and was able to proceed to a place called Three Island Reach about 50 miles from the mouth and put the horses ashore. Later, the Young Australian arrived at the Roper and assisted in taking the horses further up the river. Finally, after a delay of some weeks owing to organisation difficulties and the protracted wet season, teams were eventually fielded with full loads to enable construction work to be resumed.

After making these arrangements Mr. Todd travelled inland to inspect the work of the line parties and arrived at Daly Waters on 22nd June, 1872. There he received despatches which had been telegraphed to Tennant Creek, the north end of the line leading from Port Augusta. These messages informed him among other matters that the Government had hired 35 horses so that he was then in a position to establish the horse express (estafette) on a weekly basis, between the two ends of the wire — Tennant Creek and Daly Waters. Todd immediately sent a message via Darwin and the cable, which had been completed in November 1871, to the Agent-General in London, informing him of the state of the work and the establishment of the estafette.

On the following day (23rd June) a number of messages came through from London but before Mr. Todd could get the necessary replies from Adelaide, the cable between Port Darwin and Java broke down.

## COMPLETION OF THE LINE

The cable failure at this stage was of some advantage to the Government owing to penalties involved in the agreement and the four parties at that time engaged on the remaining construction work pressed more vigorously into the very heavy clearing work encountered over this portion of the route. Poling followed and then the wire, although it must be remembered that at this stage supplies now had to be carted from the emergency depot at the Roper River. Under these adverse conditions the gap of nearly 300 miles was gradually closed and finally the two ends of the wire were joined near Frews Ironstone Ponds on August 22nd.

This was a great day for the colony of South Australia and is perhaps best described by quoting from the 'Register', Adelaide, Friday, August 23rd, 1872. "Little more than two years have elapsed since the actual work of constructing the Overland Telegraph was entered upon, and we have now the gratification of announcing the completion of the line. At 1 o'clock on August 22nd the Government received a message direct from Port Darwin, intimating that the last length of wire had been stretched, and that uninterrupted communication across the Continent had been established. Immediately on receipt of the news the red ensign was hoisted on the Victoria Tower (G.P.O.), the Town Hall bells were rung, the Press flagstaffs were decked with bunting, and the Consular flags were hoisted. The Public Offices were also ordered to be closed, and the clerks were granted a holiday for the afternoon . . ."

When the lines were joined, Todd was at Central Mt. Stuart, and in the evening was inundated with messages of congratulations from friends in all parts of the colony. He reported that it was a bitterly cold night and

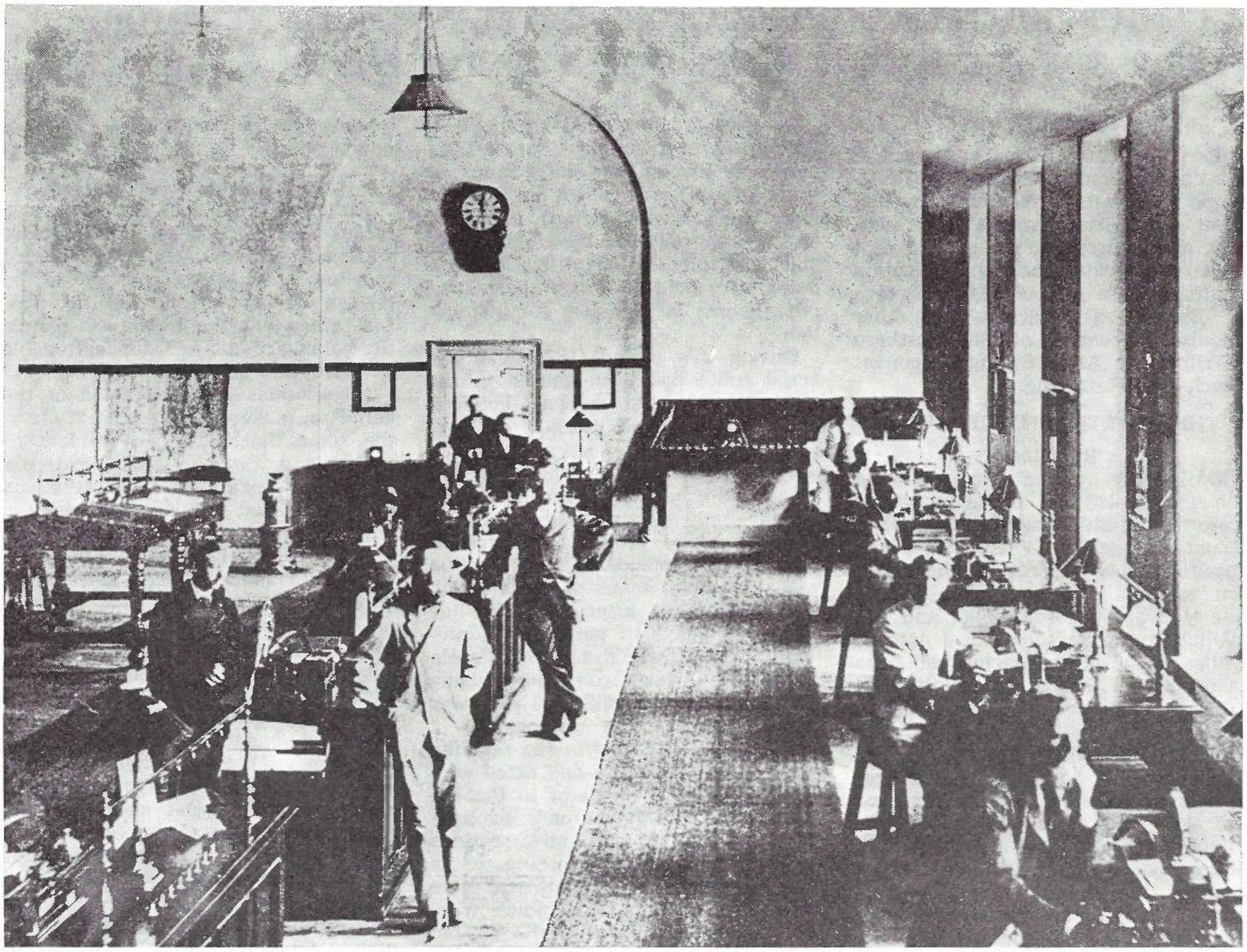

**Fig. 5.— The Chief Telegraph Office, Adelaide, in 1872. (The gentleman in the light coloured suit in the foreground is the late Sir Charles Todd.)**

seated on the ground with only a pocket relay instrument connected to the line at a shackle or joining point he received numerous messages from those who took an active interest in the work. He worked at the instrument until he was nearly frozen and completely fatigued.

It was to be two months before the submarine cable was restored, however, and the first direct message from London was received in Adelaide on October 22nd, 1872.

## COST OF CONSTRUCTION

The cost of the work amounted to £338,600, which included the cartage of about 36,000 telegraph poles weighing 5000 tons, carting them for a typical distance of eight to ten miles and a maximum distance of 350 miles, transport of some 2000 tons of other materials to the interior, driving several thousand sheep and cattle distances averaging 500 miles and extending to 1300 miles north from Port Augusta, the cartage of building materials, instruments, batteries and other stores for stations, building a stone station of 22 rooms at Port Darwin, stone stations of seven or eight rooms at the Peake, Charlotte Waters, Alice Springs and Barrow Creek, wooden buildings at Tennant Creek, Powells Springs, Daly Waters and Katherine; sinking wells and the establishment of and provisioning of depots.

For the sake of brevity this account does not include the numerous 'personal experiences' of sacrifice, privation and determination met among the many men engaged in this undertaking, however it cannot be closed without mention that five men employed on the construction of the line lost their lives through accident and other causes.

## CONCLUSION

The work which was undertaken proved far more costly than was anticipated, but the advantages gained from this telegraphic link gave impetus to commerce and development in the colonies and in particular, to the settlement of the Northern Territory.

# A CENTURY OF TELECOMMUNICATIONS IN THE NORTHERN TERRITORY PART 2: THE SUBSEQUENT DEVELOPMENT OF THE ROUTE

*R. M. TODD, B.Tech.**

## INTRODUCTION

Part 1 of this article has described the construction of the overland telegraph line. Part 2 traces the development of the route from a single simplex morse circuit to the present day, when it provides the communication facilities for a city of 32,000 persons at Darwin, as well as the other population centres of the Northern Territory at Alice Springs, Tennant Creek and Katherine.

## THE NINETEENTH CENTURY.

### Repoling.

During the original construction of the telegraph line, certain sections were built with poles spaced at 8 chains instead of 4 chains as the specifications required. In the southern sections this had been due to late delivery of iron poles and unavailability of suitable local timber, whilst in the north spacing had been increased to speed the work and minimise the penalties incurred by failure to meet the completion date prescribed by the cable companies. In addition it had been found that certain of the species of timber used for poles were subject to termite attacks which progressively increased in number as the line traversed the country from Tennant Creek to Darwin. In the heavy bush country of the north, fires initiated either by lightning or aborigines also took toll of the wooden poles. These factors made the early maintenance effort required much greater than that which could be provided by the staff located at the various stations on the route and arrangements were therefore made for extensive repoling, particularly in the northern sections.

The first section to be repoled was 450 miles in length and extended from the Elsey crossing (some 250 miles south of Darwin) to a point 30 miles south of Tennant Creek. This work was commenced in May, 1873, by a party of 60 men under the control of Mr. R. R. Knuckey.

The first 117 miles south of Elsey were poled entirely with iron poles. Subsequent sections to the south were poled with alternate iron and wooden poles; 5 mile sections on either side of stations were left poled entirely in the original wooden poles. In this manner the limited supply of iron poles and the available staff were used to give a maximum increase in route stability.

In a report presented to the S.A. Parliament in 1884, Sir Charles Todd indicated that in the 1569 miles of route from Darwin south to 'Government Gums' (near Marree), a total of 19,009 iron poles had been installed and that further quantities of iron poles were held at Port Augusta and other points in readiness for installation.

During this period (1872-1884) the aerial route had been shifted to the newly constructed railway between Port Augusta and Hergott Springs (Marree). In this section the route largely comprised iron poles and a second wire had been erected for use by the railway authorities. In all there remained some 11,500 wooden poles to be replaced. In conjunction with the replacement of poles which was carried out after 1884 the line was transferred to parallel the railway between Darwin and Pine Creek. This section was reconstructed using all iron poles and additional wire was provided for railway purposes.

The iron poles used in the repoling were 19 feet in length and fitted with a single pin and insulator in the top position. Poles were made of light tubes tapering to the upper sections and were fabricated according to the 'Oppenheimer patent'. Footplates were fitted for stability and poles were set 3 feet 6 inches into the ground giving clearance at the pole of 15-16 feet.

### Interference from Aborigines.

In addition to the natural hazards of lightning, fire, wind, termites, etc., the route was also subject to damage by aborigines, who found broken portions of insulators useful as tips for spears, binding wire as a suitable material for fish-hooks and footplates, unearthed and broken from the poles, satisfactory for use as 'primitive' tomahawks. In his report of 1884 Sir Charles Todd mentions that the distribution of fish-hooks and tomahawks to natives had been instrumental in lessening the incidence of wilful damage to the line. Aborigines were also responsible for the loss of livestock which were maintained and bred at several of the O.T. repeater stations and, on occasions, even attacked station personnel, causing injury and, in at least two encounters, death to station staff.

Details of these encounters have been reported elsewhere but needless to say, the presence of hostile aborigines was a factor which bore sharply on the organisation of maintenance effort in the early years of operation.

### Expansion of the Facilities.

Although failures of the submarine cable were infrequent, the difficulty with which repairs could be effected resulted in considerable delays in the restoration of service. For this reason rather than the inability to handle the volume of traffic a duplicate cable was provided in 1879.

Negotiations for duplication of the aerial route were commenced at about the same time. The government of Queensland, which had previously sought to have the cable terminus located in that State, again made a bid to secure a share in the telegraph traffic. The Queensland proposal was that a duplicate aerial line should leave the existing route at a point near Larrimah and thence proceed on new aerial route to link with the existing network north of Brisbane, a distance in excess of 1,000 miles through unpopulated country. The increased maintenance effort which would have been required to maintain the additional construction would have seemed a great enough deterrent to the proposal, but in addition the Queensland Government sought to place restrictions on the routing of traffic, which would have resulted in a significant reduction in the revenue to the South Australian Government. For these reasons the proposals were rejected.

In 1889 the volume of traffic being transmitted over the single iron wire warranted the installation of duplex equipment. Mr. C. Unbehaun, in an address to the South Australian Electrical Society in September of that year, described the differential system that was to be installed on the 'Port Darwin' line. The facility afforded by this equipment appears to have sufficed until 1898 when erection of an additional wire was commenced under the direction of Charles Todd. The new wire was 262 lb. per mile copper and was supported on insulators fitted to the existing poles. Whilst the construction teams were in the vicinity, the opportunity was taken to complete pole replacements and carry out clearing and other maintenance work. The first copper wire was completed between Adelaide and Darwin at the end of 1899.

## FROM 1900-1939

### Federation

In 1901 the federation of the Australian colonies placed the communi-

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cation networks of the various colonies under the unified control of the Postmaster General's Department. This brought to an end the need for division of revenue within Australia and permitted a more practical approach to the provision of submarine cables terminating in the eastern States (Ref. 1). The aerial route however, continued to be an important link in the Australian overseas communication network although alternative cable routes and, later, radio gradually eroded the absolute dependence which had earlier been placed upon this route.

### Maintenance

The main problem encountered in the years following the First World War appears to have been how to properly and adequately maintain the line in the most economic manner. Between Port Augusta and Darwin the country was gradually being used for cattle grazing and station staff were able in emergencies to seek the co-operation of station owners in maintenance of the route. In the sections where the pole route had been transferred to the newly constructed railways, agreements for maintenance by railway staffs were obtained but between rail heads the maintenance load continued to be borne by the P.M.G. Department.

The maintenance effort required can be divided into four main categories:

(a) Fault removal which was carried out on demand by station linemen.
(b) Routine pole, wire and insulator maintenance generally carried out by a patrolling line party.
(c) Clearing of grass and undergrowth and light maintenance carried out by station linemen with assistance provided by native labour.
(d) Instrument and battery maintenance carried out by station staff.

Each of these activities presented its own particular problem. For example before the linemen could depart to repair line faults it was necessary to round up the horses and prepare a party for an absence of several days. Delays in repair were also occasioned when linemen were absent on mustering duties either on the P.M.G. station or reciprocating by assisting on neighbouring stations. Many of the men employed as station linemen were ex-stockmen and the routine maintenance and clearing of the line on some occasions took second place of importance to matters of stock management. Generally it was considered a man was either a good stockman or a good lineman, but seldom both.

Equipment at the stations was comparatively simple but the power supply consisting of primary cells represented a significant maintenance load. The magnitude of the effort required in this direction can be realised when it is noted that in 1926 there were 1250 primary cells to be maintained at Alice Springs. Other repeater stations had comparable numbers of cells to maintain.

In a report of January, 1926, recommendations for staff rearrangements and replacements and modifications to maintenance arrangements were made to the State Engineer. The proposed rearrangements were designed to eliminate the unfavourable features mentioned and to ensure that qualified line staff were available to effect repairs of satisfactory standard. Some two years later it was apparent that no significant improvement in the maintenance position had been effected as the Department sought tenders from contractors who were willing to undertake line maintenance and fault clearance. No suitable tenders were received and the maintenance of the line was continued in the previous mode by the P.M.G. Department. By this time the majority of the international traffic was being routed via the copper wire which had far superior electrical characteristics to the original iron wire and therefore required less repeating. The original wire, which could transmit only hand speed morse, was relegated to the position of servicing local traffic needs and coping with overloads on the copper circuit.

### Voice Communication and Machine Telegraphy

Voice communication was first provided in the Northern Territory when trunk line facilities were furnished between Darwin and Pine Creek. In approximately 1925 the Overland Telegraph route was used to provide voice communication between Darwin and selected stations further to the south and subsequently between Adelaide and stations in the north of South Australia. The instrument used to provide this service was known as the 'phonophore' (Ref. 2).

The superior electrical characteristics of the copper wire permitted the introduction of mechanical telegraphy in the 'thirties. The Wheatstone system of machine telegraphy (not to be confused with the Wheatstone duplex telegraph system) was employed. This involved the preparation on coding machines of paper tapes which were fed into transmitting apparatus and the receiving of signals on recording devices which were subsequently decoded either by machines or acoustically. Successful operation of this equipment required that reliable automatic repeating equipment should be installed at intermediate repeater points. In 1938 teleprinters were installed at Alice Springs and Darwin. This represented the final advance in communication to the Northern Territory before the commencement of the second World War.

## THE SECOND WORLD WAR

### Initial Expansion

In 1939 the outbreak of war in Europe made it essential to consider by what means the capacity of the Overland Telegraph line could be expanded. The solution finally accepted as the most satisfactory was that a second copper wire should be added to the route to provide a pair of wires which would be capable of operation to 32 kHz. Before this plan could be implemented, however, the rapid deterioration of the military situation and the instability in the Pacific area made it necessary to seek a more rapid solution. It was resolved therefore that in the first place a service would be provided by radio.

In March, 1941, a party left Adelaide for Darwin to install the necessary radio equipment. A high frequency transmitter was installed some distance from Darwin and employed a rhombic antenna to achieve the directional characteristics required over the Darwin to Sydney link. The transmitting antenna was constructed using 29 wooden masts 70 ft. high and a number of smaller wooden poles to carry the serial feeder. The receiving equipment and apparatus for combining the transmitted and received signals were located in the Darwin Post Office. The single channel radio system became operational when the first connection to Sydney was made on April 21st, 1941. A month later the circuit was extended to Adelaide and in June of that year the circuit was made available for traffic.

The radio system certainly provided the first regular speech circuit into Darwin from the southern and eastern States, but it lacked the secrecy that was essential for wartime communication. The use of speech inversion equipment did not give the required degree of security and it was feared that the Japanese, who by 1942 were occupying the northern coast of New Guinea, were monitoring the radio transmission. In spite of this limitation, the radio system continued to be used until the Japanese air raid on Darwin in February, 1942, destroyed the equipment housed in the Darwin Post Office. The imminent completion of the second copper wire of the Overland Telegraph line and demands for equipment and manpower in other areas prevented recommissioning of the radio system.

### The First Carrier Bearer

The erection of the second copper wire had meanwhile commenced in July, 1941.

It was decided that the maintenance problem would be greatly reduced if the route were transferred to the railway poles between Oodnadatta and Alice Springs. This work, which had been the subject of previous negotiations in 1938, was now, because of the national emergency, included in the project to duplicate the wire. To provide adequate stability, a large number of stays were added to the route between Oodnadatta and Alice Springs. Between Larrimah and Pine Creek the route was also transferred to railway poles. The copper wires were transposed at intervals of approximately one mile which gave an insertion loss characteristic satisfactory for the operation of carrier systems up to 30 kHz. Where the route was transferred to the railway poles, 300 lb. hard drawn copper wire supported on conventional cross arms was used in lieu of 262 lb. conductor. The lower loss circuit resulting from this construction was designed to permit continued operation of the system in the event of one repeater failure. Between Alice Springs and Larrimah 262 lb. wire was used to match the existing circuit. Here the brackets used to support the original copper wire were used in pairs on alternate poles to minimise the number of additional crossarms to be fitted. South of Alice Springs the erection of the additional wire and the transfer of the circuits to the railway poles was carried out by staff of the P.M.G. Department who were formed into twelve parties. These parties were located at various points between Port Augusta and Alice Springs. Each party proceeded with the work in allotted sections. North of Alice Springs the wire was erected largely by army signal personnel under the direction of engineers of the P.M.G. Department.

Work on the erection of the second copper wire was completed on December 5, 1941, and a second high speed telegraph circuit became immediately available for traffic. The Adelaide 'Advertiser' of December 16th, 1941, reports the completion and states that because of the war situation 'both lines were operating at full pressure'.

Following the completion of the wire, two 3-circuit systems were installed between Adelaide and Alice Springs and between Alice Springs and Larrimah, which was the terminus of the Northern Territory railway and an important army staging camp. Initially, circuits were extended from Larrimah to Darwin by V.F. physical pairs and later by single channel and 3-channel carrier systems. Repeater stations were established at Newcastle Waters, Tennant Creek, Barrow Creek, Finke, Oodnadatta, Marree and Port Augusta. At points where suitable buildings were unavailable, the equipment was housed in specially constructed steel framed prefabricated buildings, many of which are still in use to this time. Thus in 1942, Darwin was placed in contact with Adelaide by carrier derived speech circuits. In addition to the speech circuits, telegraph facilities were also provided by 'R' Type 4-channel V.F. telegraph systems which were operated over one channel of the system between Adelaide and Alice Springs and one channel of the Alice Springs-Darwin system. The 'R' system between Adelaide and Alice Springs was subsequently replaced by a standard 12-circuit V.F.T. system and the Alice Springs-Darwin system was extended by installing a duplicate 'R' system with reversed poling (Ref. 3).

### Further Extensions of the Route

As the war continued, greater numbers of troops and increased quantities of equipment were deployed in the northern part of Australia and the need for telephone facilities increased. Additional wire was erected by army personnel on the existing route from Alice Springs to Darwin and a new route was built eastwards from Tennant Creek to Mt. Isa. In conjunction with the erection of additional wire south of Larrimah and north of Powell's Creek, sections of pole route carrying two additional pairs were built in a position adjacent to the newly constructed bitumen road. The original copper pair was subsequently transferred to these sections of the route. The poles used in the construction of these sections and the new route from Tennant Creek to Mt. Isa were 4 inch black iron pipe 20 ft. in length drilled to take arms and braces. In spite of the lack of protection against corrosion, these poles have proved to be most durable and very few failures have been reported. Thus by the end of the war the aerial routes in the Northern Territory had been increased from a single iron and a single copper wire to four copper pairs Darwin to Larrimah, three copper pairs Larrimah to Tennant Creek, and two copper pairs from Tennant Creek to Mt. Isa and from Tennant Creek to Alice Springs. The original iron wire by this time, whilst still in position on the centre pin of the Oppenheimer poles, was no longer continuous and had largely fallen into disuse. Additional wire was also provided for local circuits between Darwin and Adelaide River. 3-circuit systems were provided as previously described Adelaide-Alice and Alice-Darwin as well as a 3-circuit system Hughenden - Tennant Creek - Darwin and a local 3-circuit system Larrimah-Darwin (Ref. 4).

## POST-WAR DEVELOPMENT

### Installation of 3-Circuit Systems

The aerial bearers and 3-circuit systems provided during the war formed the foundation upon which the communication network of the Northern Territory was to be extended for the next 12 years. The first post-war increment was provided in 1948 when the southern terminal of the existing Darwin-Larrimah 3-circuit system was installed between Tennant Creek and Alice Springs.

In 1957-58 existing wire which had been erected for local circuit requirements between Marree and Port Augusta was extended to Alice Springs in order to provide an additional 3-circuit bearer. Between Marree and Oodnadatta the additional pair was composed of 262 lb. H.D.C. and from Oodnadatta to Alice Springs 300 lb. H.D.C. was used. An additional crossarm 108 in. in length was fitted to each pole 14 in. below the top arm and the new circuit was provided in pin position 3, 5-6. The existing 300 lb. pair which had been erected during the war years was transferred from the top arm to the new arm in pin position 3,1-2. Both pairs were heavily transposed to triple extra patterns in readiness for the eventual installation of a 12-circuit open wire carrier system. The work on the erection of this wire was completed in April, 1958 and line staff were then transferred to the Port Augusta-Kalgoorlie route where renovation and retransposing were carried out. The erection of this wire was the first major addition of external plant to the route since 1945 and enabled an additional 3-circuit system to be provided between Adelaide and Alice Springs in 1958.

### The First 12-Circuit System

In 1958 it became apparent that the continued relief of Northern Territory traffic by 3-circuit systems which would involve the erection of additional bearers was less economic than the provision of 12-circuit open wire systems on existing pairs and plans were therefore prepared for the initial installation of a 12-circuit system in 1961. The proposal was that a 12-circuit system should be installed between Adelaide and Alice Springs, with new standard 12-circuit system repeater stations to be established at William Creek and Hawker in addition to the existing 3-circuit system repeater stations. Between Alice Springs and Darwin it was also proposed that a 12-circuit system should be installed, but to minimise repeater requirements it was intended that only 6 of the 12 channels should be initially provided and to this end it was recommended that the amplification required to overcome the attenuation of the existing 32 kHz repeater sections at the higher frequencies should be provided by the provision of auxiliary pole mounted repeaters. These would amplify in the high frequency direction of transmission only. It was considered that additional auxiliary amplifiers for the low frequency direction would not be required until the additional 6 channels were required.

The design of the high frequency repeaters was undertaken by the Research Laboratories of the Central Office Administration of the P.M.G. Department. The result of the design was that a low cost (£600) transistorised repeater suitably enclosed for pole mounting was produced with a gain of 22.5 dB at 143 kHz tapering to 15.5 db at 90 kHz. Transmitting level of the repeater was +5 dBm. Because of this low level it was necessary that repeaters should be offset from the centre of main repeater sections by a distance of 25 miles in order that the high frequency signals should be received at all repeaters at comparable levels.

Each repeater was fitted with a relay held operated by the power feeding current. On release (due to repeater or power feed failure) this relay removed the repeater from circuit, thus permitting the system to continue in operation in a degraded mode.

Retransposing of the aerial route to an improved design was carried out between Alice Springs and Tennant Creek and between Adelaide River and Darwin in 1959 and 1960 and low level repeaters were installed on 'S' poles at Aileron, Banka Banka, Mataranka and Adelaide River. Standard 12-circuit repeaters were provided at existing repeater stations.

The Adelaide-Alice Springs system was commissioned in April, 1961 and the Darwin-Alice Springs system in August, 1961. The operation of this system exceeded the most hopeful expectations and eleven of the twelve circuits were accepted for traffic. The proposal to install additional low level repeaters on the Alice Springs to Darwin routes was therefore not pursued.

A 3-circuit system installed between Mount Isa and Tennant Creek in 1962 utilised the last bearer available on routes from Tennant Creek.

## EXPANSION OF THE ROUTE IN 1965-1967

### Preliminary Considerations

By 1963 it became apparent that the circuits provided by the route in its present state were no longer able to cope with the volume of traffic for all points in the Territory, but in particular for Darwin. Some minor relief was provided between Darwin and Katherine by the installation of a 3-circuit system in 1963. Elsewhere the capacity of the open wire route was already being taxed to the limit and alternative methods of relief were sought. The outcome of studies made at this time was that bulk provision of circuits by coaxial cable or microwave radio system was necessary to satisfy the long term demand for service to the Northern Territory. It was clear that unacceptable congestion would arise if the next relief waited upon the provision of a large facility not yet in the planning stage, and the only acceptable alternative was to increase the capacity of the open wire route by a major retransposition project. The proposed interim relief was scheduled to satisfy requirements to 1974. For this purpose the following bearers were required:

Darwin - Tennant Creek — four 12-circuit system bearers.

Tennant Creek - Mt. Isa — two 12-circuit system bearers.

Alice Springs - Tennant Creek — three 12-circuit system bearers.

Pt. Augusta - Alice Springs — two 12-circuit system bearers.

To achieve this capacity it was necessary to:

(a) upgrade existing wire from Adelaide River to Alice Springs to an improved transposition design of 200 lb. per mile copper spaced at 9 inches (C2,9 in.).
(b) Provide an additional pair (C2, 9 in.) from Daly Waters to Alice Springs transposed to the same pattern.
(c) Retranspose the two pairs from Tennant Creek to the Queensland border to a design suitable for the operation of 12-circuit systems.

The retransposing of the route from the border to Mt. Isa had already been put in hand by the Queensland administration and 143 kHz bearers were being made available between Mt. Isa and Townsville.

In addition a 12-circuit system bearer for local requirements from Darwin to Katherine was required and retransposing for this purpose was included in the project specifications. Between Tennant Creek and Larrimah, sections of the route (totalling some 180 miles) still followed the course of the original Overland Telegraph line. In those sections the cross-arms and additional wire that had been added during the Second World War were proving to be an excessive load for the iron poles which had been installed during the repoling of 1874-1900. An example of the type of pole failure resulting is shown in Fig. 1. The additional load which would be imposed by the addition of more wire made it desirable that these poles should be replaced. It was therefore resolved that in these areas the route should be relocated close to the highway to permit access by vehicles in wet weather.

For these reasons a new route was built adjacent to the Stuart Highway from Tennant Creek to Powell Creek (120 miles) and for a distance of 30 miles north and south of Daly Waters. In these sections of new route, poles were spaced at 4 chains and 'E' sections were 6.4 miles in length. In the sections where the route had been relocated adjacent to the road during the war, pole spacing was regular, the black iron poles were generally sound and 'E' sections of approximately 8 miles length were retained. Considerable maintenance work was carried out in conjunction with the retransposing of the route. Many defective and non-standard arms were replaced using 108/8/9 in. pressure treated hardwood arms and in the sections north of Larrimah wire was replaced which had been annealed by repeated grass and scrub fires. Pole replacements and respacing in the section between Pine Creek and Adelaide River were carried out using second hand 41 lb. rails 21 ft. in length and purchased in the area from the Commonwealth Railways. Calculations and practical tests showed that standing alone these rails had marginal capacity to resist the wind loading which may be expected (90 m.p.h.) and each pole was therefore fabricated using a complete 21 ft. rail with a 10 ft. 6 in. section of rail clamped to the lower section by four specially designed galvanised 'U' bolts. Below ground level these bolts served the double purpose of securing foot plates. In the southern sections near Daly Waters and Tennant Creek 21 ft. 50 lb. rails were obtained from the Commonwealth Railways at Port Augusta and these proved to be an economical and suitable pole for erection of the new route. South of Tennant Creek many of the original Oppenheimer poles were retained and route stability was improved by pro-

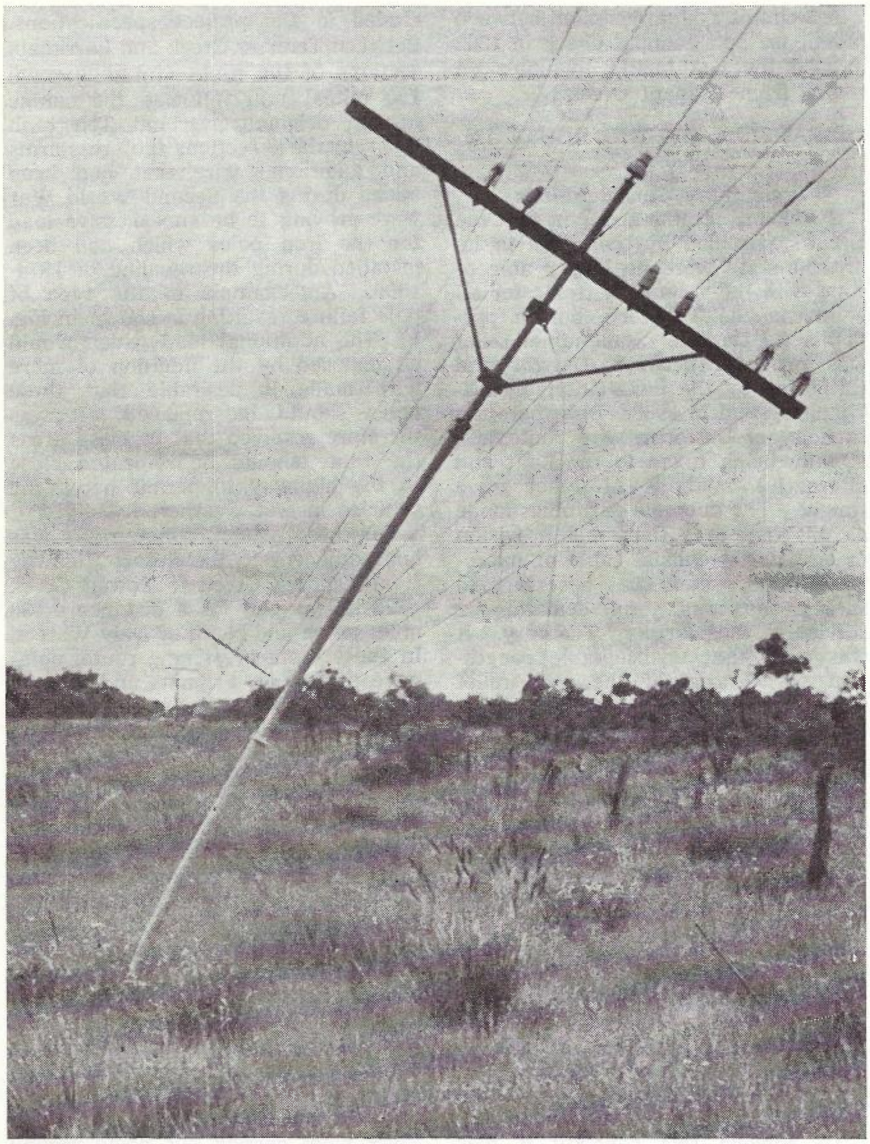

**Fig. 1. — The Iron Poles Installed between 1872 and 1899 had Inadequate Strength to Support the Increased Loading Applied During World War 2. A typical pole failure near Daly Waters is shown.**

vision of transverse stays at each alternate pole.

In addition to the retransposing it was planned that the route should be altered to permit the installation of repeaters at Adelaide River, Renner Springs, Daly Waters, Frewena, Aileron and Barrow Creek. At each of these points the layout of the terminal sections was adjusted to give a minimum of 80 ft. clearance between opposing terminal poles.

### The North-South Project

Work on the North-South Reconstruction Project commenced in April, 1965, when staff from the South Australian section of the East-West Aerial Reconstruction Project became available.

The techniques used in the retransposing work were similar to those employed on the East-West Project and some vehicles and equipment were transferred after refitting and maintenance direct to the North-South Project. Other items such as the tensioning truck, cable dispenser and wire running trucks which were still in use for the East-West Project, continued into Western Australia and therefore had to be obtained or built locally. The opportunity was taken at this time to improve the design of some items based on the experience obtained in the earlier project. Essentially, however, the technique was unchanged and the line was reconstructed and retransposed in successive sections which were rendered 'dead' by the use of bypass cables. By the end of June the reconstruction was completed from Katherine to Pine Creek and by end of September, 1965, the retransposing party completed the work as far north as Adelaide River. Portion of the work in the Pine Creek-Adelaide River section was in hilly country in which the main transposing party was unable to operate and this work was carried out by a separate smaller party which was also responsible for erection of poles and the installation of staypegs. In early October the main party returned to Katherine and commenced retransposing to the south. This work progressed at the same satisfactory rate and by November the retransposing of the section to Larrimah was complete to the point where the new route was to be commenced. Simultaneously the poling party had proceeded to Daly Waters where 60 miles of new route was to be constructed.

As the wet season closed in, the entire camp and equipment was moved to Daly Waters aerodrome and staff were flown south to Adelaide for recreation leave. In late January and early February as staff resumed from leave, operations recommenced. The country by this time had been inundated by the tropical rain and movement of vehicles 'off the bitumen' was greatly restricted. Additional and replacement vehicles dispatched from Adelaide reached Daly Waters only with great difficulty. The flooded conditions prevailing made the use of mechanical aids impossible and it was necessary to resort to manual methods of running wire as shown in Fig. 2. The conditions were similar to those encountered by Todd's men in 1871-2, but the advantage of motor transport and the facilities afforded by the bitumen and air transport enabled the work to proceed with some degree of efficiency. As the rain abated the country became accessible again and the previous satisfactory rates of progress were achieved. The erection of new route from Powell Creek to Tennant Creek with four pairs of 200 lb. per mile conductors was completed October 1966.

The retransposing of the route Tennant Creek to Mt. Isa was commenced in July, 1966. Again similar techniques were used except that instead of running out the multi-pair bypass cable which had been used previously, the alternative bearers were provided by trailing a 40-chain length of multi drop wire behind each of the tensioning and switching vehicles. Although initially some doubt was entertained regarding the durability of the

**Fig. 2. — The Difficult Conditions Met by the Original Construction Teams Recur Annually. Linemen are shown erecting wires in flooded country near Larrimah in February 1966.**

wire under these conditions, the failure rate was so low that replacement was a rarity. The eastern route was in extremely good condition and apart from the retransposing work very little maintenance was required. This permitted a most satisfactory rate of progress to be achieved and the transposing of the route between Tennant Creek and the Queensland border was completed by Christmas, 1966. The line parties then continued to the south of Tennant Creek erecting the new pair and transposing the existing circuits to the same pattern and using similar techniques to those which were employed in the northern sections. The entire project was completed late in 1967. Total expenditure on the project amounted to $1,300,000 and the work was carried out in the space of 30 months. During that time the following material was fitted to the route:

6,200 poles (41 lb. composite and 50 lb. rails).
2,500 single wire miles of 200 lb. H.D. copper.
16,000 108/8/9 in. pressure treated cross arms.
29,000 transposition plates.
164,000 trunk insulators.

From the abandoned sections of the route considerable quantities of scrap copper were obtained and returned for credit to the wire manufacturers.

In addition to the line reconstruction work carried out by the project, teams of local staff installed entrance cables and foundations for the prefabricated repeater stations which were to be installed at Adelaide River, Daly Waters, Renner Springs and Frewena. Where necessary entrance cables at existing repeaters were provided, replaced or extended.

**Testing of the Construction**

For satisfactory operation of 12-circuit systems the correct positioning of transpositions is of utmost importance.

The absence of one transposition at a critical point in the pattern can render the whole retransposing effort ineffective. Transmission tests of the northern portion of the route carried out by the staff of the Bearer Measurements Testing Laboratory revealed that despite the most rigorous visual inspection by party leaders, line inspectors and engineers, isolated errors had remained undetected. To further eliminate this possibility, from Katherine south each pair in each 'E' section was tested for polarity after physical checks of the transposition pattern were completed to determine if the number of transpositions was odd or even in accordance with the transposition pattern. It is obvious, of course, that two misplaced transpositions in the same pair will provide a 'correct' result but it was considered that after careful checking this condition was unlikely to exist. After removal of errors detected by this technique no further failures of the transposition pattern due to misplaced transpositions were reported by the transmission measurements testing team.

With some minor reservation between Pine Creek and Adelaide River, the retransposing achieved the desired results.

### Installation of Carrier Systems

In 1966 relief was provided between Katherine and Darwin by the installation of a 12-circuit carrier system and in 1967 the installation of the first Townsville-Darwin 12-circuit carrier system commenced. The equipment installed was manufactured by S.T.C. and where available, repeaters were accommodated in existing repeater stations. At other points in the Northern Territory where repeaters were required, transportable huts built and fitted with repeaters in Adelaide were conveyed to site on semi-trailers.

In conjunction with the installation of this system, the low level repeaters previously installed between Tennant Creek and Darwin were replaced by standard repeaters. Due to the fast reaction time of the solid state regulator circuit employed on the equipment, and the total length of the system to be regulated (in excess of 1500 miles), the initial operation of the system was unsatisfactory as the gain on the repeaters continually rose and fell as the various repeaters and terminals interacted together. Modification of the regulator circuit time constant was necessary to eliminate the interaction.

At Townsville the system was group connected to the broadband system to Brisbane and much needed circuits to Sydney and Adelaide were made available. This system was commissioned in August, 1967.

An additional 12-circuit system was also installed between Adelaide and Alice Springs at the same time and this was placed in service in June, 1967. Following the installation of these systems work was commenced on the installation of a second Darwin to Townsville 12-circuit system and this installation was completed in April, 1969. The addition of these three systems to the communication network of the Northern Territory permitted the normal flow of traffic to be met with demand service for a short time.

Further growth in traffic being offered in the latter part of 1969 made the installation of an additional Darwin-Alice Springs 12-circuit system necessary and this system was placed in service in July, 1970. Because of the unsatisfactory cross talk characteristics of the line between Adelaide River and Darwin, the initial usage of this system was limited to nine circuits. Noise and cross-talk on the unused circuits were measured after installation and although marginally below the standard required, in view of the increasing need, these circuits were subsequently admitted to traffic. With the installation of this system and a further system between Tennant Creek and Alice Springs all 12-circuit system bearers provided by the 1965-7 retransposing have been placed in service by 1972. With no patch circuits available, failure of any bearer now results in

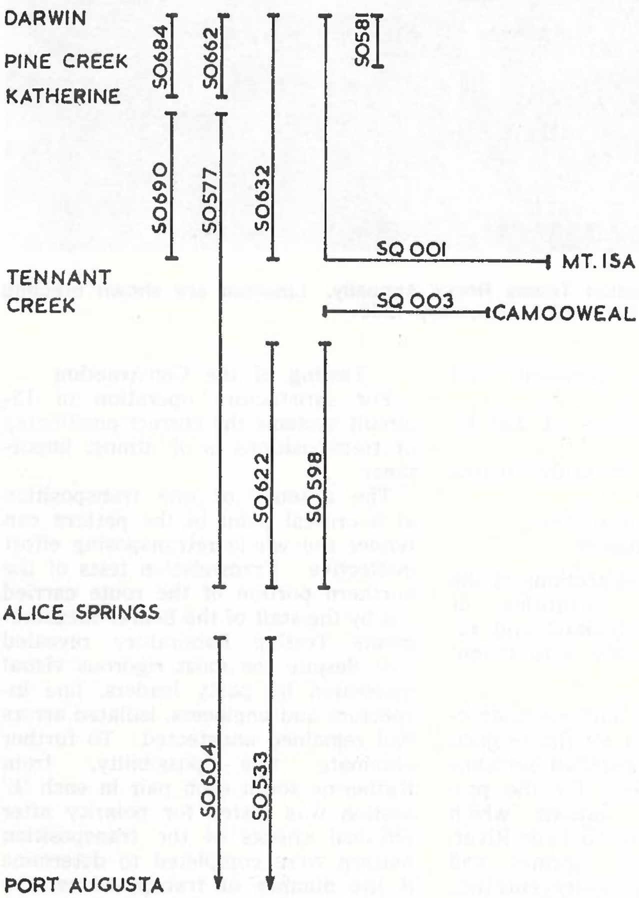


**Fig. 3. — Three Circuit Systems Installed in the Northern Territory, June 1972.**

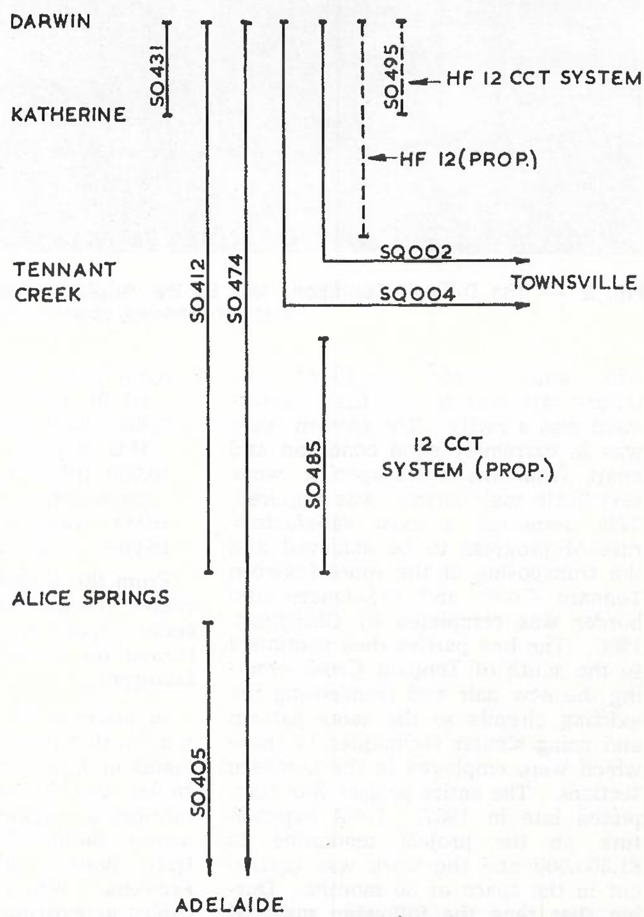


**Fig. 4. — Twelve Circuit Systems Installed in the Northern Territory, June 1972.**

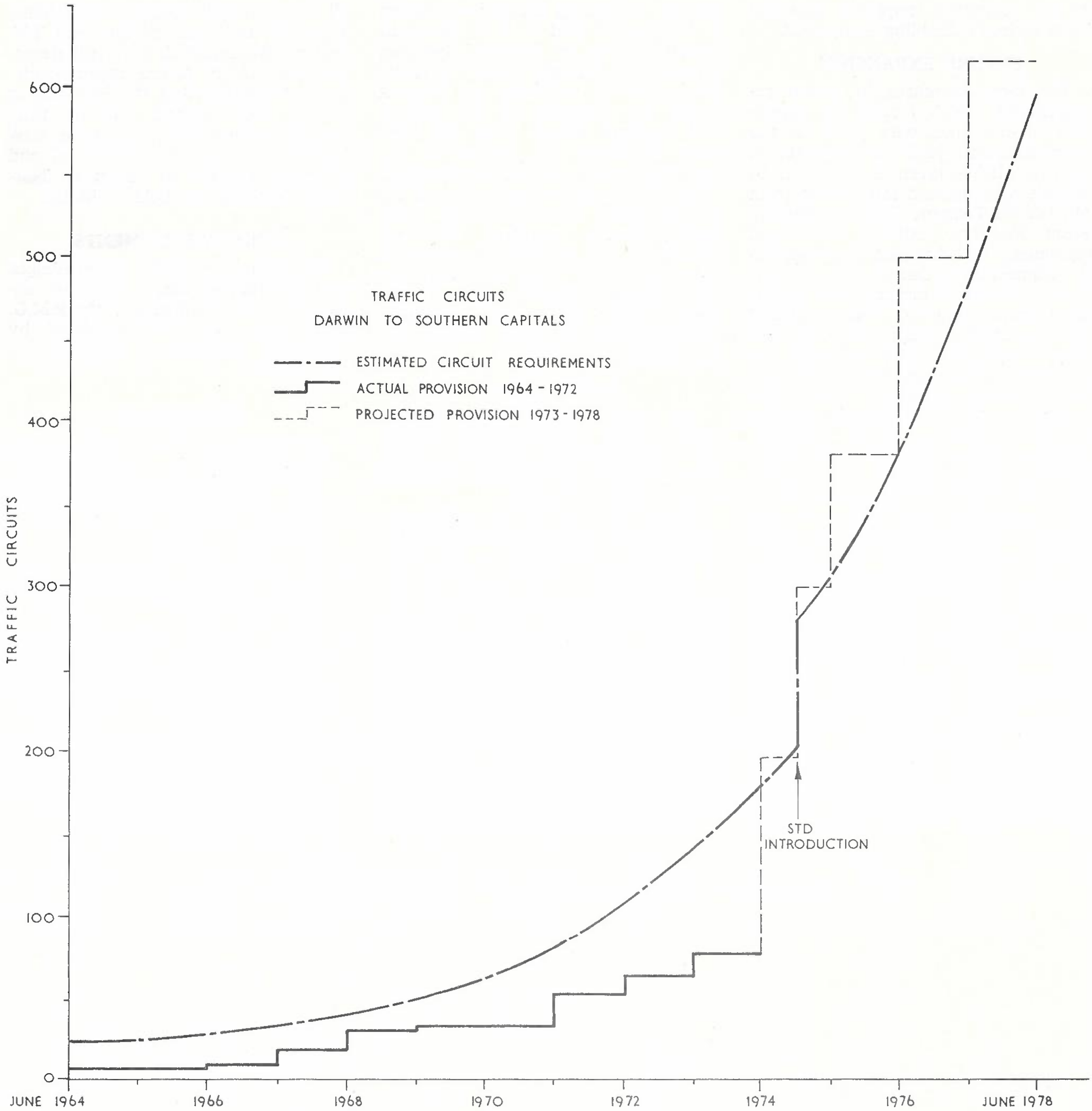


**Fig. 5. — Darwin Trunk Circuit Demand and Provisioning.**

the failure of at least one system until the repair of the circuit is effected. A system of priorities ensures that in this event the least important systems are withdrawn from traffic. A demand for additional circuits Darwin to Katherine was met in 1971 by the installation of a high frequency (H.F.) 12-circuit carrier system operating to 300 kHz in the spectrum above the normal 12-circuit system. Despite the large number of systems added in the last ten years, the growth of traffic offered has still outpaced the capacity of the route and with the promise of bulk provision of circuits on the broadband radio system by 1974-5 it was considered any further development of the route should involve a minimum of non-recoverable expenditure. To satisfy the additional need, circuit doubling equipment has been installed on circuits between Darwin and the eastern States and on circuits between Darwin and Adelaide. The reduction in bandwidth imposed by this technique is not generally objectionable for voice communication but is largely unacceptable for the operation of voice frequency telegraph equipment and some other special line purposes. Consequently the patching procedures which are employed in the event of failures must take account of the presence of circuits with restricted bandwidth. At the present time, 58 of the 64 circuits from Darwin to the southern capitals are operating on the restricted frequency provided by the circuit doubling equipment.

### FUTURE EXPANSION

The large increases in circuit requirements which forced the expansion of the open wire route in the years following 1965 have resulted in approval being given to the plan to provide a broadband radio route from Mt. Isa via Tennant Creek to Darwin. From Mt. Isa, existing broadband equipment will be used to complete the connection of Darwin and Tennant Creek into the Commonwealth broadband bearer network. There remains only one further avenue short of erection of additional wire by which the capacity of the open wire route may be effectively extended. This is the installation of H.F. 12-circuit systems to take advantage of the spectrum available above 143 kHz. The transposition pattern (Design 15) to which the route south of Adelaide River is now transposed has, subject to confirmation by measurement, two pairs which are suitable for this purpose. The route between Adelaide River and Darwin is therefore to be retransposed to this pattern to provide a bearer for such a system in addition to the high frequency Darwin-Katherine system already in operation. Secondary desirable effects of this retransposing will be that the noise and crosstalk performance of existing systems will be improved and limitations placed on the expansion of the rural carrier system to Bachelor (50 miles south of Darwin) may be removed. Following the retransposition it is planned that a H.F. 12-circuit system should be installed between Darwin and Tennant Creek. Circuits will then be available at Tennant Creek for extension to the eastern and southern States when the Tennant Creek-Mt. Isa section of the broadband radio system is completed.

Plans are also being prepared for the diversion of an existing Alice Springs-Darwin standard 12-circuit system to the broadband system at Tennant Creek, thus relieving the Alice Springs-Adelaide route of the need to carry Darwin traffic and providing circuits for Alice Springs via the broadband system.

### CONCLUSION

The aerial route built by Sir Charles Todd in 1872 established the route of the communication facilities which were to serve the Northern Territory for the next 100 years.

The second part of this article has described the successive modifications which have been made to the route in an attempt to cater for the increasing demand for service in the Northern Territory. Fig. 5 shows in graphical form the circuits which have been made available from Darwin to the southern capitals and relates this to the estimates of need. It is thus apparent that not until the full commissioning of the first bearer of the radio system can it be said that ample facilities will be available to satisfy all needs. Even when this satisfactory situation is achieved and all current requirements for telephone, telegraph and data circuits and T.V. bearers are satisfied, it is still necessary to look to future requirements. It is anticipated that the first bearer of the radio system will be fully utilised before 1980, but even now feasibility studies for additional and alternate systems to serve the Northern Territory are being initiated.

### ACKNOWLEDGMENTS

The author gratefully acknowledges the contribution made by many active and retired officers of the P.M.G. Department who have assisted by supplying information contained in this article.

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# A NEW WALL TELEPHONE

*M. J. MURNANE,* A.R.M.I.T., Grad.I.E. Aust.*

## INTRODUCTION

The 800 series colorfone was introduced in 1961 (Ref. 1), but a wall mounting version was not developed at the time, as none of the many suggested samples and designs were considered to be an adequate advance on the existing 400 type design.

In 1967, the A.P.O. decided to take advantage of the development in materials and techniques which had occurred since 1961, and the following design targets were established:

(a) The new telephone would have the same performance as the 800 series.

(b) The telephone would suit modern decors and be available in colours that would promote its use as a second telephone, particularly in domestic kitchens.

(c) Standard 800 series components would be used where practicable.

(d) The telephone would be made in Australia.

(e) Provision would be made for limited facilities so as not to prejudice the design.

(f) A 'park' position for the handset would be provided, as on most modern wall telephones.

(g) It would be easy to install and maintain.

## DESIGN CONCEPTS

The aid of a departmental Industrial Designer was enlisted. After preliminary discussions and investigations it was decided that the design would be based on the standard handset and dial, and that vertical cradling of the handset over the dial offered most potential for reducing the bulk of the instrument. In addition, this method ensured a simple direct gravity switch linkage and provided a 'park' position.

Several balsa wood and fibreglass models were constructed, with the earliest of these (Fig. 1) using an external dial number ring similar to the 801 table telephone. However, with this design a moving cradle was necessary to give adequate clearance when dialling and this caused prob-

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**Fig. 1. — Early Model.**

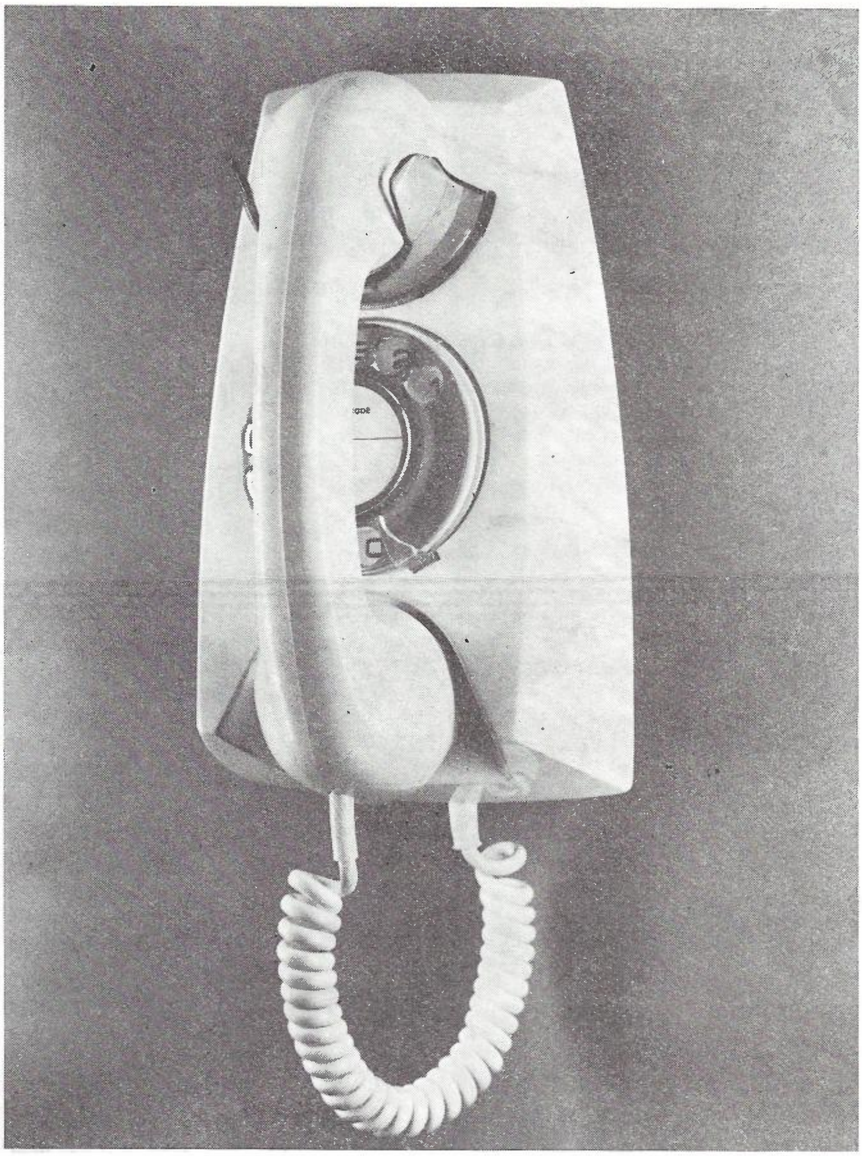

**Fig. 2. — General View of Wall Telephone.**

lems of rigidity. It was decided to used a fixed cradle without the dial number ring, as this was a more compact overall design and also lowered costs by eliminating a separate component.

The design was further refined and several non-working models were constructed and used for a customer survey by the Telecommunications Division in three States. A range of wall telephones was shown to new telephone applicants, who were asked to record their preference. Of 680 persons surveyed, 85 per cent. preferred the proposed design.

A development and supply contract was placed with A.W.A. Ltd. for the supply of the initial A.P.O. requirements. Although the external appearance and main component features of the telephone were specified by the A.P.O., it was left to the contractor to determine detailed layout and design of the internal components. The success of the final design is due to a large extent to the close co-operation between the A.P.O. and A.W.A. Ltd.

## GENERAL FEATURES

The new wall telephone (Fig. 2) uses the same basic components as the 801 table telephone, but the overall design has resulted in a slimmer telephone suitable for installation in a wide variety of situations. The cover and base of the case are moulded from acrylonitrile butadiene styrene (A.B.S.), which is the same material as used in the 801 telephone and has proven high impact strength together with good resistance to scuffing, marking, abrasion and scratching. Full advantage of the properties of this material is taken by designing the base moulding to accommodate all the major components without the need for a separate metal base plate. The base and cover interlock to give a mechanically strong assembly. With this method of construction the wall thickness has been reduced to 0.080 in., as part of the overall cost minimisation programme, without any significant reduction in strength of the assembled unit. Furthermore, being wall mounted, the telephone is not subject to accidental dropping from desks, etc.

Fig. 3. — Wall Telephone with Handset in the 'Park' Position.

The handset is normally cradled vertically over the dial by means of a cradle moulded from polycarbonate and welded to the cover moulding. Clear polycarbonate ensures that the cradle does not detract from the clean lines of the design, yet has adequate strength. The cradle accepts the handset horizontally to provide a 'park' position (Fig. 3), where the handset may be temporarily placed without operating the gravity switch. This eliminates the need to leave the handset hanging on the handset cord, and if the handset is dropped to the floor, the risk of damage is reduced by a shorter handset cord with a nominal 28 convolutions instead of the 48 used in the 801 telephone. Resulting from experience with the 801 telephone, small 'teardrops' are incorporated in the cover moulding to minimise scuffing, which tends to occur where the handset rests on the case.

The instrument is initially available in the following colours:

Appliance white.
Powder blue.
Black.

The appliance white version has a brown base moulding to accentuate the slim line. The appearance is further improved by a brown tinted handset cradle and dial number ring instead of clear plastic, as used on all other telephones .

In the future the telephone is expected to be available in additional colours yet to be determined.

## PRINTED CIRCUIT ASSEMBLY

Apart from the polarised bell, dial and handset, all electrical components are mounted and interconnected by means of a printed circuit card to form a circuit assembly (Fig. 4). The circuit assembly is located in the base

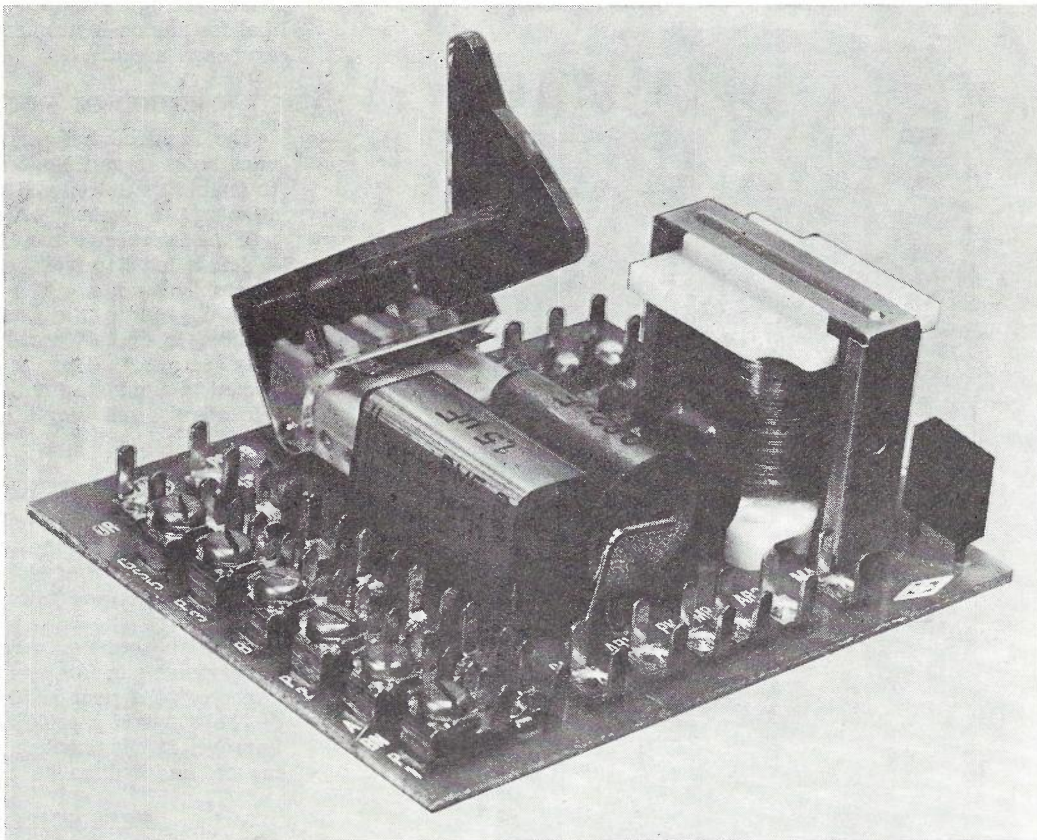

Fig. 4. — Printed Circuit Assembly.

of the telephone (Fig. 5) by moulded locating ribs, and is secured to the base by two screws which pass through the base of the induction coil. As this is the heaviest component, mechanical stressing of the circuit card is minimised.

### PRINTED CIRCUIT CARD

As in the 801 telephone, the circuit is etched on a base of copper clad, glass reinforced, epoxy bonded laminate. This material, although relatively expensive, ensures a stable base for the mounting of circuit components. The component side of the circuit board carries silk screened designations adjacent to all tags. Some tags carry dual designations to facilitate field replacement of component assemblies and to minimise the risk of incorrect replacement of interconnecting links.

### INDUCTION COIL

Although the turns ratio and electrical performance are equivalent to those of the 801 induction coil, a different grade of lamination steel is used and the moulding was redesigned to reduce cost. A redesigned clamp ensures firm attachment of the unit to the circuit board.

### GRAVITY SWITCH AND LEVER

The special micro-switch has precious metal contacts, and the contact sequencing necessary for correct functioning of the spark quench circuitry is built into the operating pins of the switch. Because of its small size, simplified operation and cost advantages, it is possible that this type of switch will be used in other 800 series telephones.

### CLICK SUPPRESSOR

Although electrically identical with the current standard unit, this item has solder pins instead of spade tags and is mounted on the printed circuit card.

### POLARISED BELL

The bell motor is the same as in the 801 telephone, but with a new bell base plate. The bell gongs are inverted to improve the sound output. Adjustment of the bell is improved by the use of more positive radial ribbing between the mating surfaces of the bell gongs and base. No external adjustment of the bell is provided.

### DIAL

The dial is mechanically identical to the standard (DMS) dial (Ref. 2) used in 801 table telephones manufactured by A.W.A. Ltd., but because there is no external dial number ring, the dial finger plate carries embossed numerals of Microgramma type face. Also, as the interchangeable external number ring previously served as an adaptor for a variety of dials, only the standard dial configuration can be used with the wall telephone.

To improve the appearance of the dial, particularly when installed in the powder blue or appliance white wall telephone, the finger plate and dial gasket ring are white instead of ivory. Both the above innovations have been introduced to 800 series table telephones because of the improved appearance and cost savings.

### HANDSET

The handset is identical to that used on the 801 telephone apart from a shorter cord and the absence of the click suppressor, which is now mounted in the printed circuit card.

### ADDITIONAL ASSEMBLIES

A bracket is being developed to accommodate a recall button and a key control unit.

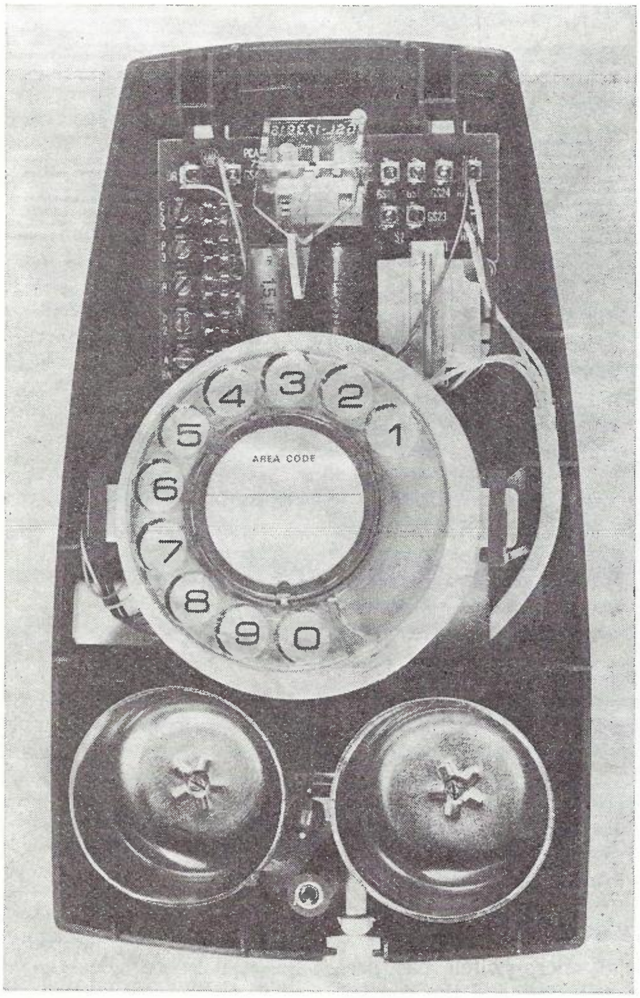


Fig. 5. — Interior View of Wall Telephone.

Also being developed is a dummy dial for use on instruments in manual exchange areas.

## METHOD OF MOUNTING

The moulded base has four clearance holes to suit No. 8 wood screws to enable the telephone to be directly attached to walls. Also available will be a special metal back plate which is fixed to walls by power fasteners, bolts, etc. The telephone is then clipped to the back plate and secured by metal thread or self tapping screws. This feature is expected to eliminate the use of wooden backboards and simplify installation in difficult locations.

## CONCLUSION

The new wall telephone incorporates many of the features and components of the 800 series range of instruments and fills a gap in the range of telephones available to Australian subscribers. Some of the developments in this telephone can be expected to appear in future versions of the 800 series table telephone, to improve its appearance and performance, and reduce its cost.

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# CABLE PROTECTION AND MAINTENANCE TESTING TECHNIQUES (Part 2)

*B. M. BYRNE, B.E.E., C.Engr., M.I.E.E.**

## CABLE TESTING

Modern cable testing is an activity that embraces a very wide range of electrical principles and equipment. In its earliest form it comprised the localisation of cable faults with a Wheatstone Bridge, using either Varley or Murray configurations. Today testing involves the technical capability to identify, categorise and isolate non-standard performance on any working cable (including coaxial). Also, the phases of provision of technical services related to working line plant are necessarily included. A fine but definite interface exists between this (fault testing) area and the technical acceptance of newly installed line plant.

Thus, the up-to-date cable testing technical officer must be equipped mentally and physically with the capacity to test for and/or localise:—

(i) Insulation faults on paper insulated cable.
(ii) Insulation faults on plastic insulated cable.
(iii) Crosstalk on any type of cable.
(iv) Noise on any type of cable.
(v) Extraneous sheath conditions (Alternating Current, etc.).
(vi) Power contacts.
(vii) Power induction — in particular to identify it, and its source.
(viii) Non-standard transmission — more particularly in V.F. circuits.
(ix) Faulty coaxial tubes.
(x) Lost (in the sense of unable to be topographically located) cables and conduit plant requiring cable finding.
(xi) Determination of route and identification of cable sheaths in multiple runs under rivers and estuaries, and in other difficult conditions — requiring high level tracers.
(xii) Location of buried manholes and pits.
(xiii) Repair, temporary or permanent, of equipment used in this area, and of equipment used by line staff on working cables.
(xiv) Measurement and safety checks on explosive gas concentrations underground.
(xv) Earth resistance and resistivity measurement.

In order to carry out functions such as the foregoing, it is necessary that each operative be relatively self contained. A 10 cwt. van will carry instruments to cover about 90% of the day-to-day testing needs. Where centralised control of testing exists (e.g. in Queensland), a back up supply of more elaborate equipment can be held to accommodate the occasional more involved tests. For this type of organisation, mobile radio-communication is provided.

Test instruments have become quite varied; these now include portable pulse echo test sets, direct reading open circuits locators, cable tracers, cable finders, box locators, inverter powered universal bridges, calibrated oscillators, transmission measuring sets and other items. Fig. 10 shows some of these.

Several of these instruments will be considered in relation to their development and use.

### D.C. Bridges

The Bridge Megger (Evershed and Vignoles Ltd.) has been the 'piece-de-resistance' in this area for some 30 years. As a robust d.c. bridge, it has stood the test of time but has never really been up-graded. It has demonstrated its effectiveness particularly on wet paper insulated cable. With newer cable types, especially plastic insulated, producing polarisable faults, and different jointing procedure, longer cables, coaxial cables (of high conductivity per unit length), aerial cables, and a variety of other plant, the inherent shortcomings of the traditional hand generator Varley bridge became more evident. The following needs existed:—

(i) Higher sensitivity, for faults not fully developed.
(ii) Resistance multipliers to be lower (i.e. 1/10 ohm per step).
(iii) Elimination of hand generator — for use in awkward locations.
(iv) Murray facilities (for high conductivity cables).
(v) Variable test voltage — to minimize polarisation.
(vi) Provision of 3-wire type bridge test on some 'universal' instrument.
(vii) A fault current meter, in addition to the galvanometer, to indicate polarisation progress.
(viii) Line reversal and open circuit switching.
(ix) Built in test voltmeter to observe foreign battery.
(x) Automatic Varley test (i.e. no computation).

During the last 10 years about half a dozen commercial instruments have become available, with some of the preceding improvements. One only has item (x), making it a useful instrument for cable jointers. No one instrument has all the improvements. A Queensland Departmental bridge incorporates (i) to (ix) inclusive, and probably represents the most effective combination to date.

It might be observed that the increase of sensitivity (Item (i) above) was tried early using semiconductors — in particular differential amplifiers. These were never wholly successful, partly because of self detecting properties, causing a.c. induction and noise on the wire under test to appear as a d.c. component in the bridge, and for other reasons.

### A.C. Bridges

Some development and small quantity production of a.c. resistance measuring bridges, in Varley configuration, operating at 3 or 4 Hz square wave, to obviate polarisation has occurred. The output is commutated synchronously by a reed relay, to deflect a semi-conductor amplified galvanometer. Results in operator complication and lack of stability are not encouraging.

### A.C. Induction Methods of Fault Localisation

There are two general methods — (a) apply tone to cable and search for the discontinuity, and (b) listen on the pair, and take a transportable source of tone and coupling inductor over the cable track. Either way, a steady frequency ($\pm$ 2 Hz between 1-2 kHz is optimum), relatively high transmitting power (in case (b) ) (15-500 watts), extremely high receive gain (100 dB) and high signal to noise ratio are required. Also, radiocommunication in the case of the inverse usage ( (b) i.e. receive on pair, transmitter portable) is necessary to stop the transmitting party when the fault is heard as it is passed over by the fixed end receiver. All of this equipment has been designed and used, but it is cumbersome, fairly expensive and requires reasonable experience to operate. It is thus more applicable to coaxial or trunk cables, where the complications can be tolerated. In return, the method offers speed of location.

The principle is not new, and has been used in various forms for 30 years or more, and is recorded here as an 'additional tool'.

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### Electro-Acoustic Methods of Fault Location

This method can also take the form of a transmit unit and a mobile search party. This latter party need not be technical staff. The principle used is the injection of low energy, extra high voltage pulses (10 kV) which discharge at the fault, producing local induction noise, detectable electrically within several yards of the fault. It is applicable almost solely to plastic cable, as a wet (paper) conducting path prevents the oscillatory discharge noise. The method has been treated experimentally in a southern state. Opinions differ on the merits and side effects of application of E.H.T. (low energy) to telecommunication cable.

### Cable Pulse Echo Tests for Fault Location

At least one type of portable, battery operated (rechargeable nickel cadmium type) pulse echo tester is in use in the Department. Two other types are available. The Cossor C.M.E. 110 is a small instrument (17 lb., about 16 in. x 8 in. x 8 in.) developed originally for naval purposes, which is very suitable for work on unloaded V.F. cable pairs up to 10,000 yards. It follows the general design and principles of more elaborate P.E.T.'s. but is a fully semi-conductor device, except for the cathode ray tube. Units in use by Queensland Cable Protection staff also include pulse amplifiers, with differential and superimposition display facilities.

Although the instrument is good, the application is limited. On an unloaded cable 'clear' pair, an informative trace is possible, showing opens, shorts, or crosses clearly and unambiguously. However, it cannot 'look' past a loading coil; it cannot 'see' insulation loss, unless below about 5,000 ohm. Lateral cables, terminal boxes, balancing capacitors, change of cable type at joints etc. all produce irregularities that make the instrument difficult to interpret on a distribution cable pair.

One application of a different nature of this type of test concerns its use on a run of plastic insulated cable, in which one or more sections are waterlogged. The extent of this condition or the individual lengths of several waterlogged sections in tandem can be observed without difficulty on the instrument. This is useful when a decision has to be made as to where the cable is to be cut to replace a section in which an excessive number of isolated conductor faults exist.

The portable P.E.T. is, of course, nearly indispensable on coaxial tubes, unloaded carrier cable, unloaded gas pressure alarm pairs and the like.

### Tracer Techniques of Fault Location

The use of a tracer system, for example Halide Gas Leak Detectors, for locating cable faults, or at least the sheath break, in cables not ordinarily pressurised has proved effective on a number of occasions. Where no good wire exists in a long run of buried cable, it is in fact economic, relatively fast and attractive. The two main disadvantages are, (i) the need to purge the cable of the tracer gas before repairing the leak — at least in lead sheathed cables, and (ii) the difficulties in driving F12 tracer gas past the various laterals, into the faulty section (i.e. the tracer gas is lost to atmosphere through some cable terminals before reaching the sheath perforation).

Other tracers could be used, but the Halide System exists and is applicable, so no others, as far as is known, have been used in this application.

### Ground Gradient Methods of Fault Location

This type of fault location is not new, but when it is discovered in some unusual form, it often receives considerable publicity. The method actually dates back to the 1890's when it was found effective in power cable work. Although the refinement and portability of semi-conductor test equipment have broadened the scope of its usage in recent years, it is not a 'cure-all' for the fault locator.

The principle is an application of Kirchoff's law, in three dimensions. The gradient, or 'pool of potential in earth' is formed by current leaving a perforation in a *non-conducting* sheath (note that no gradient is formed in the case of a conducting sheath), spreading into the ground, and likewise at the return end, forming a similar gradient around the return earth. The test current may be d.c., interrupted or commutated d.c., or sinusoidal or other wave-shaped a.c. The a.c. system lends itself to the use of amplifiers to improve gain, and selectivity (i.e. electrical noise rejection), and in consequence forms the basis of most modern systems.

The receiver end of the system, where tone is applied to the line, is normally a two spike probe, which may have from several inches to several feet spacing. This procedure, incidentally, is similar in principle and practice to the 'holiday' (hole) detectors used to find flaws in buried pipe coatings.

The limitations of the system are:

(i) It may only be used if the cable has a non-metallic sheath and is not in conductive ducting.

(ii) The sheath damage is located, not the conductor damage, if these are not coincident; and in plastic insulated cable, this is sometimes the case.

The receiver consists of an amplifier and phones or speaker. In a basic arrangement the spikes may be the operator's fingers, or spikes in the shoes (as the potential taps).

Several instruments based on this principle are in Departmental use. The simplest and most widely distributed would be the Departmentally developed 'Ampos'. The most sensitive would be the Delcon 4900A fault locator. The Queensland Type 1A Cable Tracer can also be used in this mode. The Philips Cable Detector is a further instrument of this type.

### A.C. Capacity Systems of Fault Location

The use of simple (or complex for greater accuracy) direct reading means of measuring mutual capacity of an open circuit pair is a convenient fast means of locating open circuits. The instrument may be either of a.c. bridge configuration, or more conveniently, and generally of no less accuracy, a suitably calibrated variable frequency a.c. ohmmeter. In the latter case, several designs have been produced Departmentally which are in fairly common usage. Commercial models are also available, generally at higher cost.

### Impedance Systems

Inherently, these require fairly elaborate and expensive equipment, and are most suited to submarine or long trunk cables, which are inaccessible over most of their length. The method is to plot impedance against frequency, and to compute the transmission irregularity accordingly. It is simplest to use a sweep frequency generator in the 'X' direction of an oscilloscope and display the impedance in the 'Y' direction. Again, this is a special tool, and not normally a first-in test. These can be used by relatively unskilled staff.

Other instruments used in the cable testing field include the several types of locators, for missing, unlocated, or unsuspected plant:

### Other Methods

*Pipe and Cable Finders*: These devices, operating in the 70-150 k4z range, resemble two boxes, usually about 8 in. x 10 in. x 3 in. on a 3 ft. 6 in. carrying handle. These are so positioned and adjusted as to be able to detect, by differential distortion of the transmitted field between the 'boxes', the presence of this conductor, due to the inductive coupling with a buried or adjacent *long conductor.*

*Cable Tracers*: As two separate entities, the foregoing transmitter and receiver of a Cable Finder can be used to some extent for tracing, placing the transmitter over, and aligning with the cable, thus inductively coupled to it. The receiver is carried along in maximum signal or minimum signal mode, as desired, over the cable (or pipe). Where the signal is poor, the cable deep, or in low resistivity strata, a cable tracer should be used. Several types, including three Departmentally developed battery powered models, are available. These range from 3 watts at 600 KHz (a widely distributed type) to a very high power 400 watt, 900 Hz model 'H.E.C.T.O.R.' (High Energy Cable Tracer; Oscillator and Receiver). This last type can trace coaxial and other cables laid 20 feet deep under salt water estuaries.

*Box Locators*: For the location of buried manhole covers, or reinforced pit lids, or other isolated metal objects, several types of excellent box locators are available. Operating on a principle similar to war-time mine detectors, although more refined in electronics and convenience, these instruments operate on the change in coupling factor due to metal proximity between two interwound large diameter coils. In general, their sensitivity is such that they can locate an object buried at a depth of up to their geometric mean diameter (i.e. a 2 ft. 6 in. x 2 ft. 0 in. manhole cover at up to about 2 ft. 6 in.).

One direction of follow-up to these various test methods has been to develop, both in the Cable Protection area and elsewhere, several less complex, less expensive instruments for use by line staff. Several instruments including insulation and continuity testers, 3 wire bridges, ground gradient testers and open circuit locators have been thus introduced.

Parallel directions of development concern the seeking of quicker or more effective fault localisation mechanisms or procedures. The introduction of any device for usage by cable jointers requires specific instructions and demonstrations of the usage and limitations of such test gear. It is remarkable how many devices have been received poorly at various levels due to one of the following:—

(i) Partially defective demonstration equipment, giving the impression that the limited performance of it is all that the operator should expect of it.

(ii) Lack of appreciation of the designer of the needs in the field with the result that the equipment does nothing very useful, even though it does what it was designed to do.

(iii) Overcomplicated written instructions, resulting in the equipment not being used.

(iv) Failure of the designer or distributor to indicate the range of application and specific function of the instrument, with the result that it is used for other applications, giving poor results, and is judged thereby.

The foregoing type of testing has been vested in the Cable Protection Division (now Section) for over two decades, in the Brisbane Metropolitan area. This centralised control has provided an almost unique facility for introducing, oversighting, developing or modifying new cable testing methods and equipment. It has also provided a useful central information point for hundreds of enquiries from country centres on problems in this area.

Fig. 10 indicates a range of test equipment that should be carried by, or be readily available to, any cable testing technical officer.

## OTHER FUNCTIONS

In this last section are brief descriptions of other engineering activities undertaken by Cable Protection staff. This staff undertakes projects and investigations for which a single specialist section is more appropriate than duplicated handling by several field sections.

### Fault Recording

For the foregoing reasons, in some states Fault Recording and Analysis has been a function of Cable Protection. This is fully documented in A.P.O. Engineering Instructions, and will not be further considered in this article.

### Chemical Technology

The control of the use of hazardous chemical substances is likewise vested in the Cable Protection Division. Typical projects encountered are:

(a) The best method consistent with safety to eradicate termites in poles, buildings etc.

(b) Eradication of ants, cockroaches, termites and other insects in departmental plant.

(c) Control of fungus growth on internal as well as external plant.

(d) Effect of various industrial effluents and solvents which have run into manholes.

(e) Toxicity of resins, hardeners, glues, adhesives, pipe jointing compounds, solvents, fuels and other industrial products.

(f) Safety precautions relating to flammability or toxicity of compressed gases, solvents, and highly volatile liquids used in departmental activities (this has bearing on the G.P.A. functions of the Division).

(g) Explosive nature of various gas/air mixtures, and significance of test equipment readings; recommendations for purchase of such equipment; maintenance tests on such equipment.

(h) Chemical analysis of unknown fluids, including suspected sewage found in manholes. Recommendation of preventive measures.

(i) Identification of origin of waters, suspected to be from broken drains, or main supply.

(j) Chemical activity of ground in which it is proposed to lay new plant.

(k) Deterioration of plastics of various kinds in various environments.

The author has never ceased to be amazed at the variety of queries that are directed to the Cable Protection Division, in the chemical technology area.

### Incipient Cable Fault Location

This is a dying art. Some 25 years ago, the anticipation of cable faults in major networks starting from insulation loss tests from the M.D.F. in exchanges was a very productive activity. About 16 staff were on this function in the Brisbane network in the 1940's. Sheath perforations in main cables located were of the order of several hundred per half year (the test frequency), together with many lesser 'wins'. Perhaps the most unusual academic discovery was the fact that of all sheath perforations so located, 50% were initially indicated by an insulation resistance reading in the 10 to 20 megohms range.

The complete gas pressurisation of the subscribers' network in the mid 1960's has now virtually eliminated this once vital activity.

### Preventive Maintenance Patrols on Major Cable Routes

This function applies almost wholly to coaxial cable patrols, and may be coupled to gas pressure maintenance, or may be a separate function. In actual practice, the latter is more common as the G.P.A. load is variable geographically and in time, whereas there is a need for regularity of the preventive maintenance patrol (e.g.

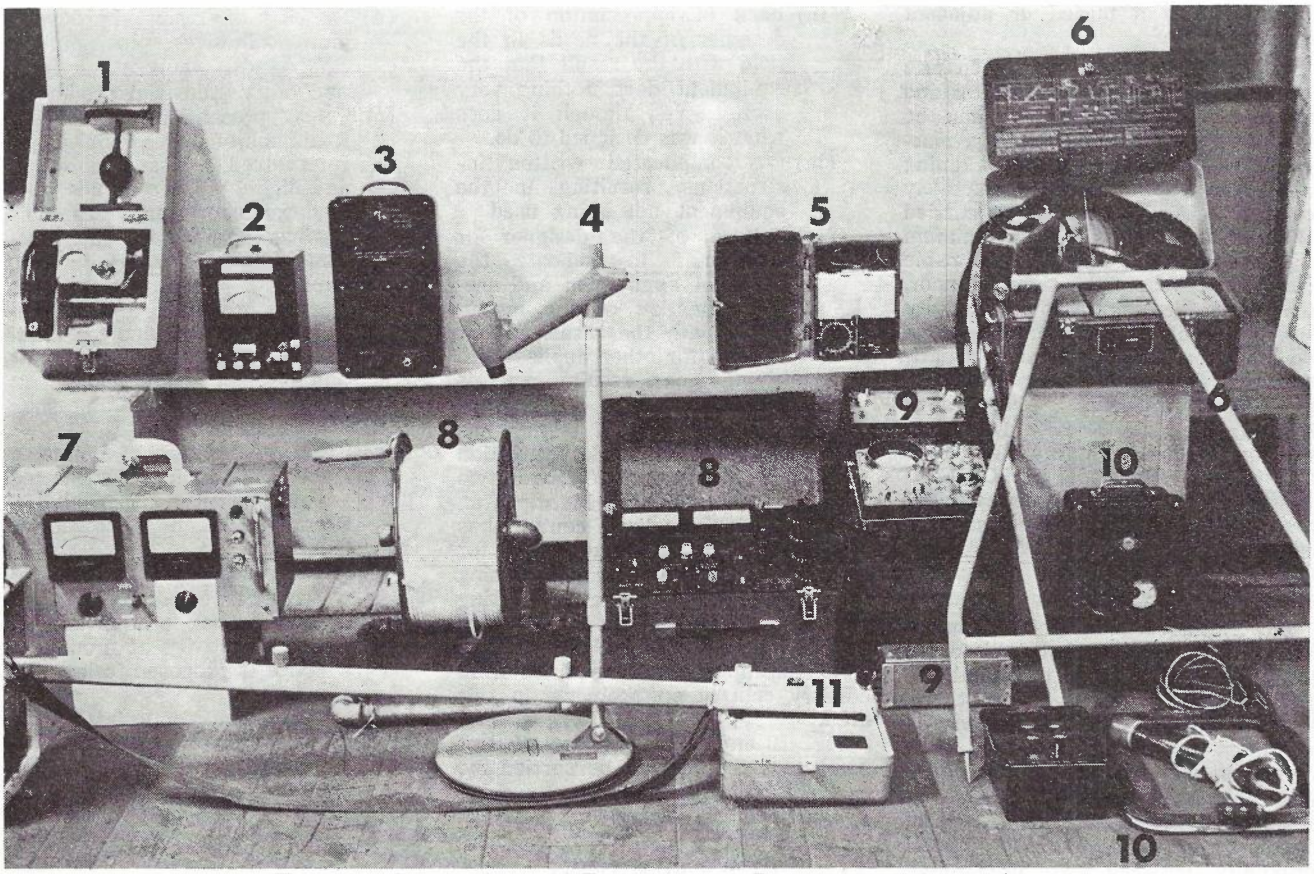



**Fig. 10. — Range of Typical Test Equipment Required for Cable Testing.**
1. Earlier type of explosive gas detector.
2. Three-wire bridge test set — protected travelling galvanometer.
3. Three-wire bridge test set — variable voltage power source.
4. Box locator.
5. A.P.O. No. 3 Multimeter.
6. Delecom 4900A fault locator (induction and/or gradient tester).
7. Cable pair open circuit locator (100,000 yd. model).
8. Bridge fault locator (variable voltage), with 500 yd. test lead and collapsible winder.
9. Cossor CME 110 cable test set (pulse echo tester) and spare rechargeable battery.
10. Type 2 cable tracer receiver, with power supply and alternative search cells.
11. Fisher TW5 pipe and cable locator.

checking on excavators, contractors, road works, etc.) which is usually a full time job, if the allocation of work has been so arranged. This latter patrol, involving restoration of civil works, is usually a district or area function.

### Cable Protection Professional Assistance to General and Planning Management

Provided sufficient engineering staffing is available in the Cable Protection area, both maintenance and development data can be fed back to the management, and in particular the planning management, areas.

It is possible to appraise the operational economics for any specific cable and conduit track (of main cables) from data accumulated in the Cable Protection area, especially when all the functions listed in this article are vested therein. A typical question posed is: "Is . . . junction cable worth retaining, or should we allow for its replacement in the next year or so?" Obviously, there is a limit to the number of cable and conduit routes on which data can be processed in the Cable Protection Organisation, but it is desirable to have this capacity to meet the demands of an expanding cable network.

### Cable Protection Equipment Rooms in Exchanges

It is not unusual in a large telephone exchange to find one or two air driers, one or two cathodic protection rectifiers, quite a massive array of flow distribution panels, gauge and valve control boards, and in a few but increasing number of sites, flow alarm equipment. In various exchanges and various states, this equipment is housed in the most extraordinary places — in air-conditioning rooms, cable tunnels, equipment and/or M.D.F. rooms, long line buildings, standby generator rooms, power suites, and, to the author's personal knowledge, in three separate cases, in disused (fortunately) toilets! Relatively recently, the need for specific housing and 24-hour access to this equipment has been recognised in the design of new or extended telephone exchange buildings. Known as Cable Protection Equipment Rooms, these provide suitable facilities in locations in the buildings where such after-hours access is available, without affecting the security of the whole building; they also provide the facility of Cable Protection control of installation and maintenance of future equipment, without the previously experienced likelihood of having to shift the lot for the main occupiers of other space in the exchange.

# CHANGE OF EDITORS

Subscribers to the Journal will be sorry to learn that Mr. E. J. (Jim) Wilkinson has resigned from the Board of Editors. Jim was recently promoted to the Australian Broadcasting Control Board as Director of Technical Services. We wish him well in his new position and extend our thanks for his many years of valuable service to the Journal.

Mr. P. H. Richards will take over from Mr. Wilkinson. Since joining the Post Office in 1949, Peter has worked in the Headquarters Radio Branch.

# TECHNICAL NEWS ITEM

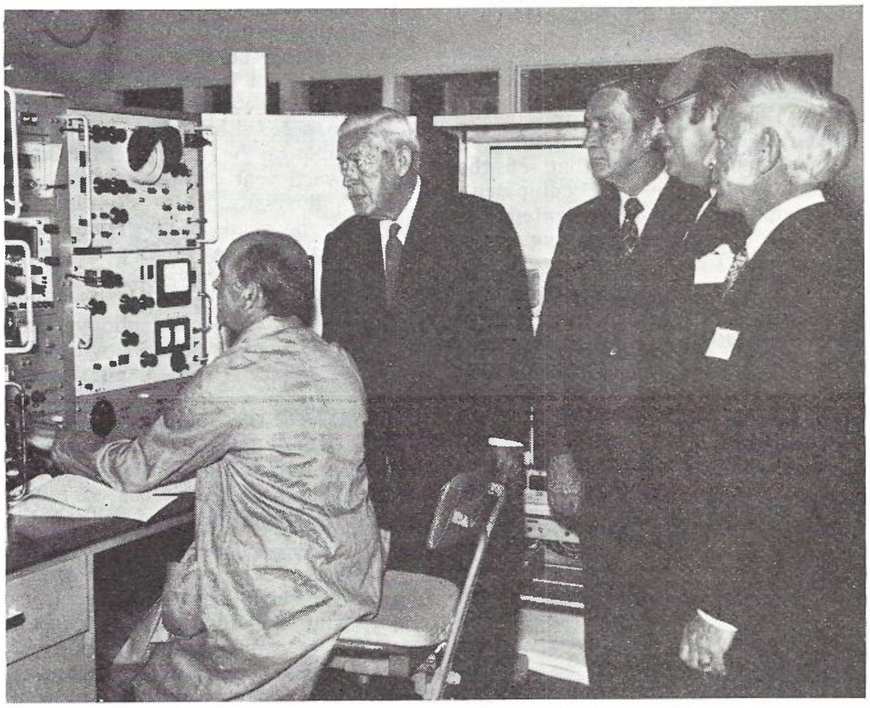
## NEW PHILIPS-TMC FACTORY

A new factory erected at Moorbank, N.S.W. for Philips Telecommunications Manufacturing Company Limited was officially opened by the Postmaster-General, Sir Alan Hulme, on 21st June, 1972. Speaking at the opening ceremony, Sir Alan said that Philips' new building was the most modern in Australia and that the company had set an example to other electronics companies who may be considering a re-building programme.

Sir Alan was guest of honour at the opening of the new $6 million building which houses the telephone division of Philips-TMC. Other guests included the Director-General of Posts and Telegraphs, Mr. E. F. Lane, the N.S.W. Minister for Health, Mr. A. H. Jago (representing the Premier, Sir Robert Askin), Mr. Van Doveren (from Philips world telecommunications headquarters at Hilversum, Holland) and representatives of O.T.C., A.T.D.A., Department of Supply, and other state and federal government officials.

Philips Telecommunications Manufacturing Company Limited is a major supplier of transmission equipment to the Australian Post Office. The main lines of manufacture include multiplex, voice frequency, telegraph and open wire carrier telephone equipment, data modems, filters, illuminated push-button keys and test instruments. As well as producing for local consumption, Philips-TMC also exports to New Zealand, New Guinea, Indonesia, Malaysia, Hong Kong, Pakistan, Canada and Ghana.

The new Philips-TMC building combines under one roof the activities the company previously carried out in separate antiquated buildings at Erskineville. Built by Civil and Civic Pty. Ltd. on 30 acres of land, the new factory offers 145,000 square feet — or 3.3 acres — of working space under one roof. All the working space is fully air conditioned to 72 degrees all year round. The air conditioning plant, which has a chiller capacity of 400 tons an hour, circulates 12,640 cubic feet of conditioned air an hour. Installed in the factory are 2,600 fluorescent lamps and thirty miles of electrical wiring. Staff amenities are in keeping with the modern design of the factory and include an air conditioned cafeteria which can seat 150 people at a time.



**A Technician checks Testing Equipment watched by (left to right) Sir Alan Hulme, Mr E. F. Lane, Mr H. D. Huyer (Chairman and Managing Director, Philips Industries Holdings Ltd) and Mr. T. E. Hodgkinson (Managing Director, Telephone Division, Philips-TMC)**

# TROPOSPHERIC SCATTER RADIO SYSTEMS IN AUSTRALIA

*A. G. ELLIS, B.Sc., A.R.M.I.T., M.I.R.E.E.**

## INTRODUCTION

Prior to 1959, radio communication links in Australia were largely confined to the roles of emergency services, short distance trunks and manually operated mobile systems. Even with these limited opportunities for providing service, the potential of radio communication was clearly apparent.

About this time the extensive New South Wales flood emergency network operating in the VHF range became operational with circuits which extended inland from Maitland to Armidale and along the coast to Lismore and Murwillumbah. In Queensland, a H.F. auxiliary network daily covered the entire State with a message passing system which operated throughout cyclones as a matter of course, whilst the Melbourne-Perth radio system, also operating in the H.F. band, a little later provided NASA with the only ground circuits across Australia throughout one of the early Mercury flights.

With these successes, the stage was set when at the end of the 1950-60 period, high capacity microwave radio systems became available at a price competitive with that of the minor 12/24 channel UHF equipment, which up till then represented the top limit of channel carrying capacity for Australian radio systems.

The period 1960-70 has seen the expansion in radio system technology and application from these early secondary roles to the present where some twenty thousand miles of T.V. program bearers have been installed to link Perth to Hobart to Cairns, and an almost equal distance of 960 channel telephony and data bearers provide the great bulk of the Departmental interstate telephony circuits. The stage has now been reached where all the capital cities have been linked with microwave television and telephony circuits and where each State has in addition, a backbone of microwave bearers serving their major regional cities.

Apart from the incredibly rapid increase in microwave technology since 1958, the major factor which existed to provide the essentials for this expansion has been the presence of established communal facilities—roads, railways, airports and a relatively dense population along most of the chosen routes. These facilities have combined to allow essential maintenance services to be provided with an acceptable mean time to repair (MTTR); in the most recent application of the East-West route, road transport has allowed first-in maintenance action to be achieved with an average MTTR of less than six hours.

At the present point in time, microwave line-of-sight systems have been used to connect distant centres of population whenever conditions along the entire length of the route permitted ready access to the radio sites spaced each 20 to 30 miles. With the further development of low-power high efficiency equipment, this need for ready access will disappear since the reliability of the equipment is expected to reach a level where an MTBF of five years for a 200 mile system could become an accepted standard.

However this type of operation still lies in the future so that even the highly reliable solid state equipment of 1969 has not been able to provide circuits in those areas where road or rail transport either does not exist or is liable to be unusable for long periods each year. An example which clearly illustrates this situation is given by the needs of the Nhulunbuy community, where mining interests have, in the last few years, opened up a township requiring reliable high performance trunk telephony and telegraphic communication with the rest of Australia on a continuous basis. The nearest trunk centre to Nhulunbuy is Darwin, with the intervening 600 kilometres of Northern Territory having no continuous road facilities and where access to much of the area can only be gained by ship or light aircraft.

With the impossibility of maintaining physical lines in this environment, and the maintenance incompatibility of a microwave line-of-sight system, the only available solution of a few years back would have been the small capacity H.F. system with its restricted hours of operation, interference and noise problems. Such distant communities are fortunate in that the technology of tropospheric scatter has developed to the extent where these radio solutions now yield a performance and reliability which is virtually indistinguishable from that provided by the high performance trunk systems operated in the more populated areas of Australia.

## GENERAL

Two tropospheric scatter systems have now been installed in Australia, Darwin to Nhulunbuy, and Roebourne to Mt. Tom Price. These systems have been designed to utilise the partial scattering properties of the troposphere to provide 120 telephone channels over 640 and 225 kilometres respectively. Each system will also carry a large number of low error rate telegraph channels.

The equipment uses a low noise parametric amplifier followed by quadruple diversity receivers operating into ratio squarer I.F. combiners. The extended threshold demodulators work into baseband combiners.

The transmitter power is 1 kilowatt obtained from a high gain klystron with a nominal drive input of 50 milliwatts. The transmitters radiate in the 2 GHz band through 12 metre dishes mounted on 30 foot shelf supporting towers. With the exception of the klystron in the power amplifier, the entire system is of solid state design, with plug-in units having controlled interface parameters. A high level of equipment redundancy ensures a very high reliability even though the MTTR will be of the order of one day.

Although such tropospheric radio systems have been manufactured for some years and in several countries, the usual design philosophy appeared to rely upon having staff readily available at each site to deal with both operational and maintenance problems as they arose. As this type of staffing was not practicable in Australia, the ultimate success of tropospheric systems in Australia was considered to be strongly dependent upon the following equipment design and production factors:

(i) Manufacture of the system in terms of compatible maintenance units, i.e. maintenance units which could be easily interchanged in the bearers without requiring adjustment to restore the original performance, and

(ii) The integration of the remote supervisory facilities with the operation of the system to ensure that the supervisory read-out permitted valid decisions to be made concerning the maintenance action needed to effect a restoration of service, and

(iii) Adequate inspection at the factory of the actual units being manufactured.

*Mr. Ellis is Supervising Engineer, Design (Mobile and Small Capacity Systems), Radio Section, Headquarters. See Vol. 21, No 1, Page 95.

In addition to the above 'hardware' factors, the overall success would of course also depend upon the installation planning, supervision and testing, but these aspects are described in another paper in this issue.

## MANUFACTURE OF MAINTENANCE UNITS

The manufacture of a system in terms of compatible maintenance units demands the equipment designer's attention to two major aspects, the first being to ensure that the unit tolerances of parameters such as input/output level, impedance, frequency and group delay responses are adequate, and secondly, to ensure that the unit can generate a unique alarm which would positively identify a faulty unit.

As an example of alarming without the positive identification, consider a common case where the modulator unit although carrying a pilot, is not protected by a pilot detector. Here a failure within the A.F.C. section of the modulator would pass undetected; this would be of little importance if the modulator frequency stability were sufficiently great to allow its continued operation for a period consistent with maintenance visits. Such stability is not likely however, the probability being that the modulator's natural frequency would in due course drift outside the frequency limit which the demodulator could tolerate. As a consequence, this frequency drift would be sensed by the receiver at the next site, giving rise to failure of the associated bearer. The situation would of course be intolerable in the Australian environment of unstaffed sites, since the system redundancy would be reduced to the extent of an entire bearer by a faulty modulator, whilst the level switched standby modulator which could have removed the problem, was standing idle without any switching information.

There are further implications of this lack of a pilot sensor in the modulator rack. Under the proposed operating method, the frequency drift at one site would only be detected as a receiver failure at the next site (since no output level changes have occurred), which would then incur a charter flight of several hundred miles so dissipating the available resources without removing the fault cause.

## SUPERVISORY

The purpose of the supervisory system is to provide the Radio Control Station with the necessary information to determine and affect in any given situation, the next line of action. Because of their importance in the everyday operation of the system, the following supervisory philosophy is basic to Australian tropospheric systems:

(i) **System Control:** The status of the system, i.e. the level of remaining redundancy, must be known and should be easily interpreted. Hence bearers and sites must be positively identified, and all switching operations within the bearer should be alarmed so that any one off-normal condition in a group of parallel sensors will operate to telesignal an alarm condition.

(ii) **Ease of Operation:** In the case of displays having alternative read-outs, all the site and bearer information needed to meet the objectives in (i) should appear on the 'normal' display to ensure that any change of state at remote sites becomes immediately apparent at the Control Site. Any alternative read-out (which might be obtained after deliberately operating a remote control function) should wherever practicable give only further itemised information which is directly related to the "normal" display.

The alarms should be grouped into operational functions, i.e. Tx, Rx, Power, site.

(iii) **Bit Conservation:** Redundancy in the telesignalling can be avoided if the bearer identification information is only signalled once. In the case of the Darwin-Nhulunbuy system, the transmitters and receivers at each site are alarmed separately so as to provide positive bearer identification; this allows individual units of the same type, e.g. Power Supply Unit, to be grouped onto one alarm whilst still retaining all the available information.

(iv) **Alarm Operating Levels:** All alarms of the same type, e.g. transmitter units from each of the bearers, should be set to operate at the same absolute power level. With respect to the alarm levels of tandem maintenance units, e.g. modulator, exciter and power amplifier units, the level of each alarm should be set so as to operate before the following alarm is operated. In this way the basic cause of each fault condition will be signalled without ambiguity.

## FACTORY TESTS

The factory tests which were carried out for the Darwin-Nhulunbuy equipment concentrated on the maintenance unit performance and their operation in the system as a whole.

The following comments are typical of actual results obtained.

### Supervisory Equipment

Because the 15 alarm conditions originally provided by the N.E.C. supervisory system were insufficient to remotely supervise the operation of the main system, N.E.C. readily agreed to incorporate a switching box (previously developed by the A.P.O.) in their equipment. This switching box effectively doubled the number of available alarms and has been incorporated into both Australian systems. An auxiliary switch was also associated with the site memory relays so as to telesignal to the control station the instant of time when any fault cleared.

### Modulator

The modulator tests were restricted to IF output, alarm testing and modulation sensitivity. The stability of the modulator sensitivity was checked over several days and found to be satisfactory, and pilot alarming of the units was arranged. The N.P.R. of a back to back modulator-demodulator was measured throughout the temperature and loading ranges, and proved that no significant change in thermal or intermodulation noise levels or IF output level was likely to occur under Australian conditions. The modulator centre frequency responded with a maximum cyclic change of 2 kHz.

### Exciter

In addition to the normal factory tests, an input-output measurement was taken to determine if the units could be alarmed to give a positive unit indication. The results of this test showed that a drop of input (modulator output) of 6dB resulted in less than a 3dB drop in exciter out-

**TABLE 1 — EXCITER ALARM LEVEL**

| Exciter Input | Exciter Output | |
|---|---|---|
| | Exciter 1 | Exciter 2 |
| —6dB | —2.5dB | —2.2dB |
| —4dB | —1.4dB | —1.3 dB |
| —2dB | —0.5dB | —0.5 dB |
| 0 (Nominal) | 0 (Nominal) | 0 (Nominal) |

put. Since a 3dB drop in exciter output did not result in a corresponding fall in P.A. output, all three units could be positively alarmed. These levels are demonstrated in Table 1.

**1 kW P.A. and Ageing Unit**

The P.A. operated to specification. One unit and exciter were heat cycled to 55 deg. C, where the P.A. response although slightly changed, recovered to the normal response at 45 deg. C.

**Receiver**

Following the usual tests of N.P.R., bandwidth and A.G.C., heat runs were taken for a modulator-exciter-receiver loop. The change in performance from 20 deg. C. to 45 deg. C represented only a few picowatts. At 45 deg. C., a cold demodulator panel could be substituted without significant change occurring in the N.P.R.

## CONCLUSION

Tropospheric scatter radio systems have been used in Australia to provide trunk circuits of high performance and reliability.

Their application in meeting the need for communication across large distances of inaccessible territory is expected to continue (particularly for over-water paths), although the low-power microwave equipment may in the next few years, also provide an acceptable solution.

## ACKNOWLEDGMENT

The ability and ready willingness of N.E.C. Ltd., which ensured the successful transition in operational facilities from a fully staffed system concept to a system suitable for the slender facilities available throughout the two Australian routes, is gratefully acknowledged.

# IMPORTANT ANNOUNCEMENT TO SUBSCRIBERS

NOW AVAILABLE — CONSOLIDATED INDEX to Vols 1 (1935) to 20 (1970) of the TELECOMMUNICATION JOURNAL of AUSTRALIA, providing reference to all articles and technical items published in these columns.

The objects of the Journal are to describe contributions by Australians to world telecommunications and to record the history of significant telecommunication developments in the Australian continent. Past issues of the Journal contain articles on all major works executed in the last 35 years, written by experts closely associated with them. Consequently the Journal provides an excellent reference to Australian telecommunications history. This new CONSOLIDATED INDEX is an INDISPENSABLE GUIDE to its contents.

The Index is issued free of charge to financial members of the Telecommunication Society in the year of issue. Other subscribers may obtain a copy of the index by applying to the General Secretary, Telecommunication Society of Australia (whose address appears beneath those of the State Secretaries in the front of this Journal) if you are an overseas subscriber, or to the appropriate State Secretary, if an Australian subscriber. The price, $2.00 per copy, includes postage by surface mail.

The price of the Index is quoted in Australian currency and proper conversion must be made for other currencies including U.S. and Canadian dollars.

# THE DARWIN-NHULUNBUY TROPOSPHERIC SCATTER SYSTEM (PART 1)

*M. J. KIMBER, B.E. (Hons.), M.I.R.E.E.* and V. W. LANGE, M.E., M.I.E.E.E.***

## INTRODUCTION

This article is presented in two parts. Part 1 contains the feasibility study and design of the system. Part 2 in the next issue contains the description of the equipment, including power plant and buildings, and its installation and maintenance.

Australia's first commercial tropospheric scatter system began operation between the city of Darwin and the mining town of Nhulunbuy in the Northern Territory on the 24th December, 1971. This three hop tropospheric scatter system provides 120 voice circuits to give the subscribers in Nhulunbuy access to the Australian Post Office's National Telecommunications Network for telephone, telex and data services.

Nhulunbuy is a new town being established by Nabalco, a consortium of Australian and Swiss companies interested in the mining and processing of bauxite ore. The town is located on the Gove Peninsula in the North-east of Arnhem Land in the Northern Territory (see Fig. 1).

The system was installed to provide trunk access to the network on the basis of the Australian Post Office's new Spur Line policy which was approved by the Postmaster-General in August, 1969. Broadly, this policy requires the company developing a particular town or area, which requires communication, to make an unconditional contribution towards the costs incurred by the A.P.O. in the provision of the initial trunk installation. This initial installation will also include sufficient capacity to allow for five years' growth. The A.P.O.'s contribution includes a public exchange and subscribers' reticulation to complete the telecommunication facility for the new town or area.

An agreement, based on this policy, was reached between the A.P.O. and Nabalco in October, 1969. Tenders were called for the design and installation of the tropospheric scatter system, and a contract was eventually let to NEC Australia Pty. Ltd. for the provision of such a system.

## ALTERNATIVES

Prior to the decision to use a tropospheric scatter system on this route, an economic study was carried out to find the best solution for the pro-

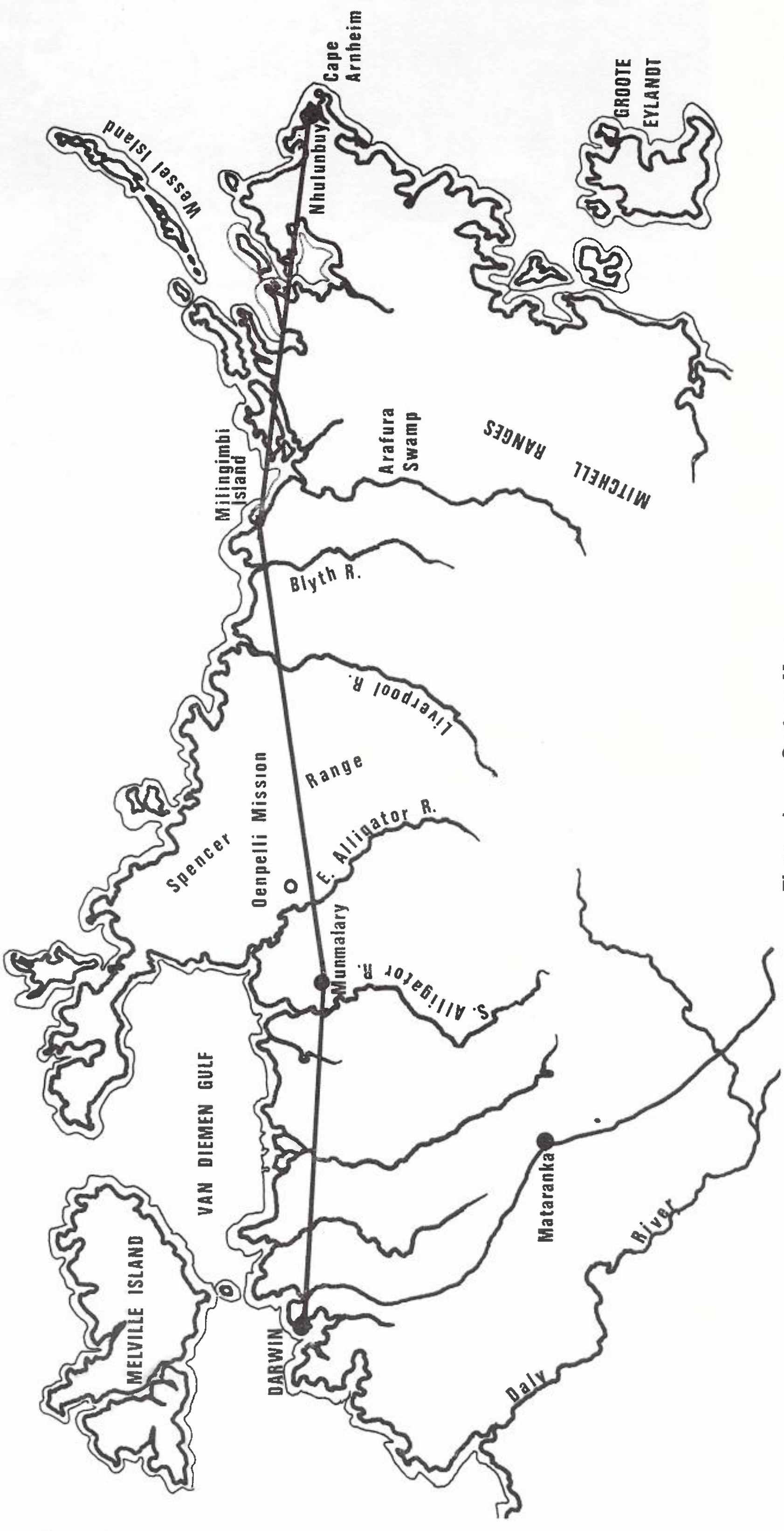



Figure 1. — System Map.

* Mr. Kimber is Engineer Class 3, and Mr. Lange is Engineer Class 2, Darwin-Mt. Isa Project, Darwin Area Management (Telecom.) Branch, Northern Territory.

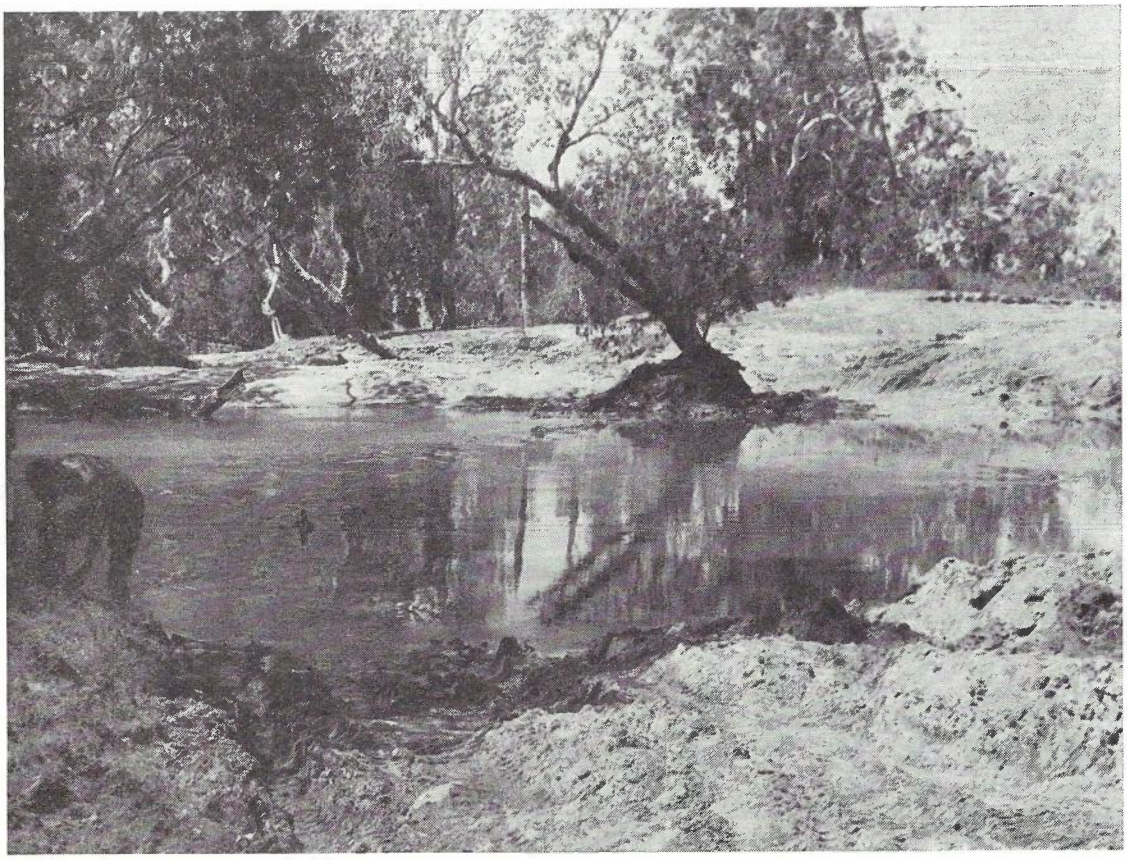


Fig. 2. — Creek Crossing on Munmalary Road.

vision of up to 120 voice circuits between the two centres of Darwin and Nhulunbuy. A number of alternative transmission systems were available to the A.P.O., namely:

(a) quad carrier cable
(b) coaxial cable
(c) medium capacity line of sight radio relay system
(d) tropospheric scatter system.

All of these had to be considered against the background of the environment in which they would have to operate and so studies were carried out to investigate possible routes and locations for alternative systems.

The 640 km route between Darwin and Nhulunbuy traverses extremely harsh and rugged terrain. There are no all-weather roads which link the two centres and access to Nhulunbuy can only be gained via aircraft or shipping. The creek crossing shown in Fig. 2 is typical of the hazards encountered on roads in the area. The rainfall in the area ranges from 50-60 in. per year, most of which falls in the months November-March. Consequently, for these months (known locally as 'the Wet') the inland areas are entirely inaccessible to land vehicles. During this time of the year, there is a high probability of tropical cyclones with wind velocities up to 110 m.p.h. During the dry season, the country is ravaged by forest fires which cause considerable damage to property.

These natural hazards almost immediately preclude the use of conventional systems, since for all of them access to the route and intermediate stations is necessary to maintain the systems. Apart from these problems, Arnhem Land is virtually divided by the rugged and precipitous Spencer Range where access can only be gained by means of aircraft.

After a study of the terrain and the possibilities for alternative systems, it became quite apparent that only a tropospheric scatter system could provide the service required and consequently work began on preliminary studies to prepare for the system's installation.

## TROPOSPHERIC SCATTER

Tropospheric scatter utilises the property of the lower atmosphere to bend and scatter U.H.F. radio energy over the radio horizon. Path lengths for such systems vary from 150-1000 km depending upon the particular system requirements. Tropospheric scatter systems are used to span inhospitable or inaccessible terrain and provide 1-300 voice channels.

A tropospheric scatter system operates in similar frequency bands to those used for conventional line of sight systems but because of the different propagation mechanism utilised the equipment configuration is somewhat different.

The scattering phenomenon is random and causes the path attenuation to vary over a range of 40-50dB in the short term. In addition, the median value of attenuation is very high and in order to accommodate these two conditions and provide good system signal to noise ratio, the equipment has to include high power amplifiers, high gain antennae and complex receiver chains. The transmitters which are used have output powers of the order of 1 kW and receivers have a noise factor of better than 3 dB. These receivers are associated with various diversity combining devices to overcome the short term fading phenomenon. The antennae which have to be used are usually parabolic with diameters from 5-30 metres. The photograph in Fig. 3

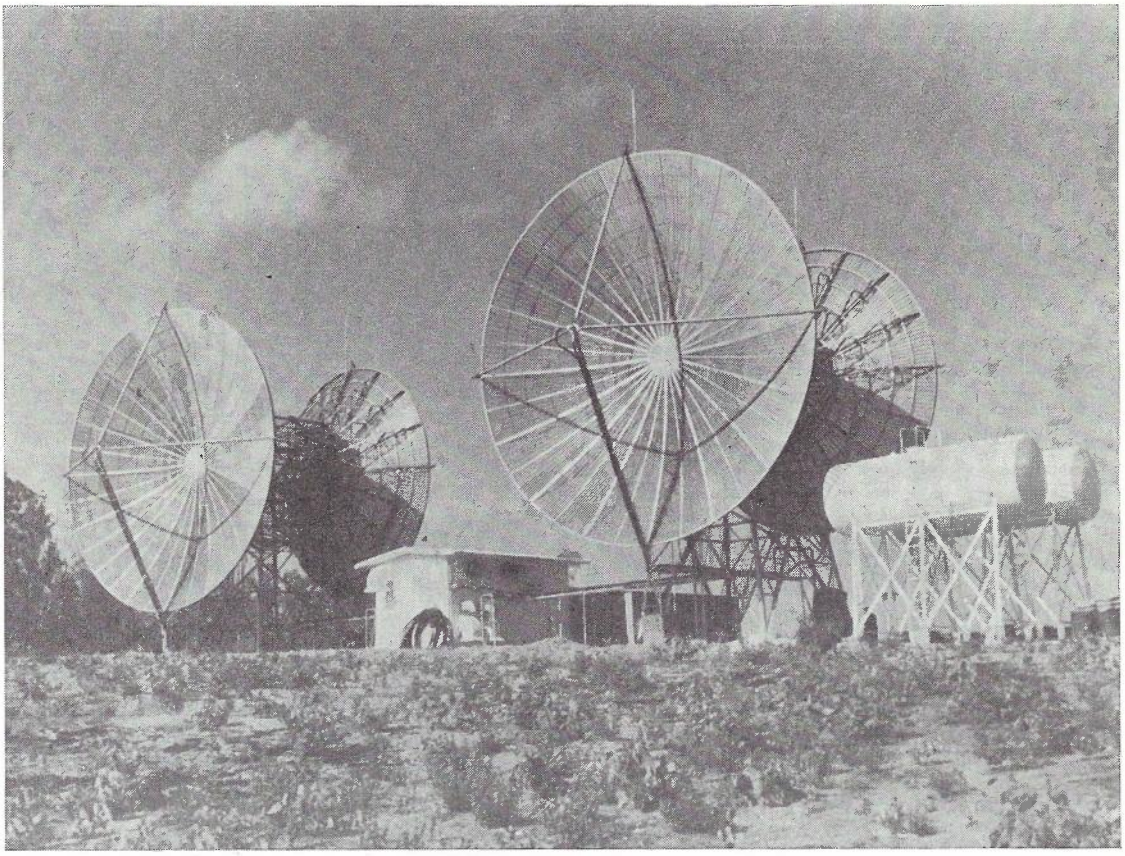


Fig. 3. — Munmalary Repeater Station.

shows typical 10 and 12 metre antennae which were used at Munmalary on this system.

The cost of this special equipment is high and the design of systems must incorporate a considerable amount of flexibility to allow the optimum use of this equipment. So, therefore, a considerable amount of work, including both field surveys and office design, was done by NEC and the A.P.O. before the system design was finalised.

## DESIGN

### Field Survey

The initial map studies indicated that there were a few possible locations for tropospheric scatter repeater stations between Darwin and Nhulunbuy. A preliminary feasibility study indicated that a three hop system offered the best solution. Based on this study, one terminal was located adjacent to the Cox Peninsula Radio Australia receiving station and the other terminal was to be located on either of two hilltops adjacent to Nhulunbuy. The repeater sites were to be situated in the general area of Munmalary station and on Milingimbi Island. (See Fig. 1.)

The final site selection was carried out by A.P.O. engineers and an engineer from NEC in February, 1970. As already outlined, access to all sites is difficult, the road to Cox Peninsula and Munmalary being impassable during the wet season and Milingimbi and Nhulumbuy being accessible only by sea and air. For this reason the complete survey was carried out utilising charter aircraft and relying on the local people to provide transport. Since permanent survey marks are rare in Arnhem Land, the determination of the exact latitudes and longitudes of the selected sites proved tedious involving sun shots and field calculations. The sites selected were in all cases compromise solutions to conflicting propagation requirements and such economic factors as site and ray-line clearing, access roads and general accessibility of the site from the nearest airport and/or barge landing. Being located in Arnhem Land, a major consideration was to ensure that the sites were not located on aboriginal sacred sites. To check on this, all sites were cleared with the respective tribal councils. Objections by the tribal council at Yirkala on Gove Peninsula to any structures being located on Mount Saunders, which to the local tribe is the sacred home of the Rainbow Snake, led to the location of the terminal for Nhulunbuy on Hill 1819 approximately 4 miles from Nhulunbuy. A photograph of the completed terminal station at Nhulunbuy is shown in Fig. 4. At Milingimbi the only feasible site was located on a sand ridge on the south side of the island which during the highest tides is completely surrounded by the sea. The initial site at Munmalary was selected only 1 mile from the air strip and homestead, but a more detailed survey which involved clearing a ray-line to determine the possible launch angles for the system found a ridge approximately 6.3 km towards Milingimbi which prevented a satisfactory system performance being obtained. After considering the alternatives of higher towers for the 10 metre and 12 metre antennae or re-locating the site, the latter course was selected. The site re-location involved the A.P.O. in the construction of a 700 ft. long causeway, including a 100 ft. wide spillway to cross a creek and approximately 4.2 miles of access roads.

The basic site information, including the amount of ray-line clearing, is shown in Table 1. From this basic

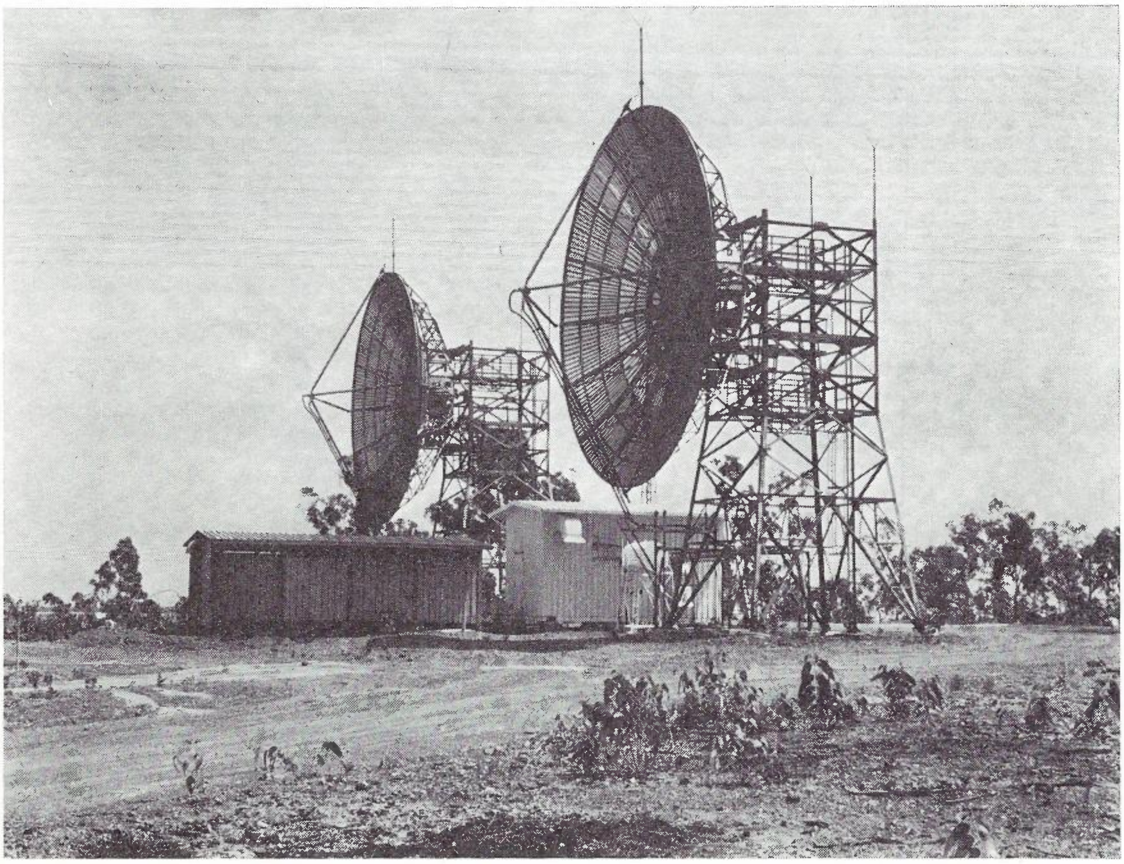


Fig. 4. — Nhulunbuy Terminal.

TABLE 1.—SITE INFORMATION

| Site | Lat. (S) | Long. (E) | Elevation (Metres) | Access Road Required | Site and Ray-line Area to be Cleared |
|---|---|---|---|---|---|
| Cox Peninsula ...... | 12° 28' 42" | 130° 44' 16" | 12 | Nil | 20 acres |
| Munmalary ...... ...... | 12° 28' 09" | 132° 33' 20" | 70 | 4.2 miles and causeway | 73 acres |
| Milingimbi ...... ...... | 12° 6' 50" | 134° 54' 8" | 8 | 1.8 miles | 43 acres |
| Nhulunbuy ...... ...... | 12° 12' 46" | 136° 48' 00" | 70 | 0.25 miles | 2 acres |

information the great circle distances between stations and ray-line bearings given in Table 2 were calculated. This data formed the basis for the system design.

TABLE 2.—PATH INFORMATION

| Path | Length | Bearing | Beam Angle |
|---|---|---|---|
| Cox Peninsula to Munmalary ........ ........ | 189.7 km | 89° 54' 01.7" | 0 |
| Munmalary to Milingimbi Island ...... ........ | 252.7 km | 81° 26' 35.6" | 0 |
| Milingimbi Island to Nhulunbuy ........ ........ | 207.0 km | 87° 08' 56.5" | 0 |

### System Design

The basic design criteria were the relevant C.C.I.R. recommendations regarding system noise performance. Since a tropospheric scatter system was the only economical solution for the Darwin-Nhulunbuy system, and since C.C.I.R. Recommendation 393.1 could not be met, the following general conditions for a hypothetical reference circuit of 2500 km as given in CCIR Rec 397.1 apply:

(a) The mean noise power during one minute must not exceed 25,000 pWOp for more than 20% of any month.

(b) The mean noise power during one minute must not exceed 63,000 pWOp for more than 0.5% of any month.

(c) The unweighted noise power (with an integration time of 5 msec) must not exceed 1,000,000 PWO for more than 0.05% of any month.

From the above figures the actual allowable system noise can be calculated once overall system length has been determined.

**Design Calculations:** As well as the location of terminal and repeater stations, the system capacity was selected at 120 circuits before detailed design commenced (Refs. 1 to 5). Based on the survey information and relevant C.C.I.R. recommendations the following system noise specification applied:

(a) the mean noise power during one minute must not exceed 6,760 pWOp (S/N = 51.7 dB) for more than 20% of any month.

(b) The mean noise power during one minute must not exceed 31,600 pWOp (S/N = 45 dB) for more than 0.5% of any month.

(c) The unweighted noise power (with an integration time of 5 msec.) must not exceed 250,000 pWO (S/N = 36 dB) for more than 0.05% of any month.

The basic equipment specifications considered necessary to achieve the above specifications are given in Table 3. Based on this data, it was necessary to determine the median received signal levels and their statistical variation on all paths to ensure that the design criteria were met. An important word of caution must be added at this stage, the theories and equations formulated for the design of troposcatter systems are mainly empirical, based on observed phenomena, rather than explicit analytic relationships.

**Mean Receiver Input Power:** The mean receiver input power is obtained from the following equation.

$$Pr = Pt + (Gt + Gr) - L(50) - Lf - Lc \qquad (1)$$

where

Pr = median input power level to receiver (dBm)

Pt = transmitter output power (dBm)

Gt, Gr = gain of transmitting and receiving antennae (dB)

L(50) = median transmission loss (dB)

Lf = fixed losses at transmitting and receiving end (dB)

Lc = Antenna to medium coupling loss (dB).

Since the received signal level and its statistical variation are of prime importance in determining system performance a more detailed consideration of equation (1) is warranted. The transmitted power Pt is purely a function of equipment type and within economic constraints is readily varied by the designer. Similarly the gain of transmitting and receiving antennae are variables directly under the designer's control. The gain selected, which is proportional to antenna size and operating frequency, is determined by the system noise objectives. Careful consideration to capital cost must also be given since any increase in size represents an almost exponential increase in cost. Another factor which effectively limits the size of antenna selected is the reduction in actual antenna gain below the theoretically available gain due to the phenomenon referred to as antenna to medium coupling loss (Lc). Opinions vary considerably on the magnitude of this additional loss factor. All authors (Refs. 2, 3, 4, 5) agree that it is directly dependent on antenna size but some later experimental studies (Ref. 4) have shown that path parameters such as distance and scatter angle also have considerable effect on the antenna to medium coupling loss. The calculations for antenna to medium coupling loss were based on the following empirical equations advanced by NEC engineers and have shown good agreement with experimental investigations.

The antenna to medium coupling loss:

$$Lc = Lch + Lcv \qquad (2)$$

where Lch: partial antenna to medium coupling loss associated with the horizontal antenna pattern.

Lcv: partial antenna to medium coupling loss for vertical pattern.

They are evaluated as

$$Lch = \sqrt{[1 + 0{\cdot}4\{(\alpha/\varphi_{th})^2 + (\beta/\varphi_{rh})^2\}]} \qquad (3)$$

and

$$Lcv = \exp\{(\theta_{tm}/\varphi_{tv})^2 + (\theta_{rm}/\varphi_{rv})^2\} \qquad (4)$$

where

$\theta_{tm}, \theta_{rm}$: Optimum elevation angles of transmitting and receiving antennas beam axis.

$\varphi_{th}, \varphi_{rh}$: 0·6 × (horizontal 3 dB beam width of antennae)

$\varphi_{tv}, \varphi_{rv}$: 0·6 × (vertical 3 dB beam width of antenna)

For the antenna sizes selected and the various path length of the system equations (2) to (4) yield values ranging from 4·9 to 8·1 dB.

The median transmission loss (L(50)) is a random quantity dependent upon frequency of operation, topographical and climatic conditions as well as the length and profile of the path. The behaviour of transmission loss can only be predicted by statistical means and this is further complicated since independent long and short term variations have been observed. The predictions made are based on actual propagation measurements where it was found that the long term variation of transmission loss followed a log-normal distribution, while in the short term variations followed a Rayleigh distribution. These variations exhibit seasonal and diurnal patterns with long term attenuation decreasing during the wet season on tropical paths since it is largely dependent on prevailing meteorological conditions. The short-term or Rayleigh fading is produced by multipathing effects. Hence to estimate the fading depth of a troposcatter path both the long and short term fading distribution must be combined into a composite distribution. The median transmission loss can be expressed as:

$$L(50) = F(d\theta) + 30 \log f - 20 \log d + A - Vde \qquad (5)$$

where

$F(d\theta)$ = Attenuation function

f = Frequency in MHz

d = Path distance in km (See Fig. 5)

$\theta$ = scatter angle in radians (See Fig. 5)

A = Atmospheric Absorbtion (dB)

Vde = Adjustment for climatic conditions (dB) (Ref. 2)

The attenuation function $F(d\theta)$ is dependent upon surface refractivity of the atmosphere, path length, scatter angle and path symmetry. It is an empirical function derived from observed phenomena and a number of authors have produced curves relating these parameters. The curves receiving most use are those published in

**TABLE 3.—BASIC EQUIPMENT SPECIFICATIONS**

| Item | Specification |
|---|---|
| Operating Frequency Range | 2450-2690 MHz. |
| RF Output Power | 1 kW |
| Receiver Noise Figure | 2.5 dB |
| Baseband Frequency | 60-552 kHz |
| Diversity Configuration | Quadruple |
| Combining Techniques | IF and Baseband non-linear combination |
| Frequency deviation | 245 kHz r.m.s. per channel |
| Antenna Gains: | |
| 10m | 45.7 dB at 2600 MHz |
| 12m | 47.2 dB at 2600 MHz |
| Antenna 3 dB Beam width: | |
| 10m | 13.6 milliradians |
| 12m | 11.4 milliradians |

Technical Note 101 of the National Bureau of Standards (Ref. 5).

The surface refractivity (Ns) varies with both height and geographical location and in the Darwin–Nhulunbuy area rises to a value of approximately 350. In general terms the median transmission loss decreases as the value of surface refractivity increases. Path length has a directly proportional effect on the attenuation function, and the function value also increases as the scatter angle increases. The attenuation function $F(d\theta)$ accounts for the difference between line of sight path loss over the same distance and actual encountered losses. Atmospheric absorbtion is due mainly to the presence of water vapour and oxygen (Ref. 5) and accounts for approximately 1 to 2 dB at 2·6 GHz and over path length varying 150 to 250 km. In addition to all losses mentioned above there are certain fixed losses (Lf) due to feeder and filters which must be taken into consideration.

## Statistical Variations of Receiver Input Power

To be able to effectively determine the behaviour of received signal strength and hence diversity requirements it is essential to determine the fading characteristics of each path. As stated earlier, fading on a transhorizon path is a combination of the long term log normally distributed fades due to meteorological conditions and the short-term fades due to multipathing, which exhibit a Rayleigh distribution.

The probability density function of the Rayleigh distribution $P(\gamma)$ is given by

$$P(\gamma) = (\gamma/\sigma^2).\exp(-\gamma^2/2\sigma^2) \text{ for } \gamma \geqslant 0 \qquad (6)$$

where

$\gamma$ = input level
$\sigma$ = standard deviation

The median value ($\gamma_0$) is given by:

$$\gamma_0 = (2\sigma^2 \log 2)^{\frac{1}{2}} \qquad (7)$$

The log-normal distribution is then considered about the median value ($\gamma_0$) of the Rayleigh distribution so that the log-normal density function $q(\gamma_0)$ becomes

$$q(\gamma_0) = [K/\{\sqrt{(2\pi)}\sigma^2] \exp [-\{K \log (\gamma_0/R)\}^2/2\sigma^2] \qquad (8)$$

where

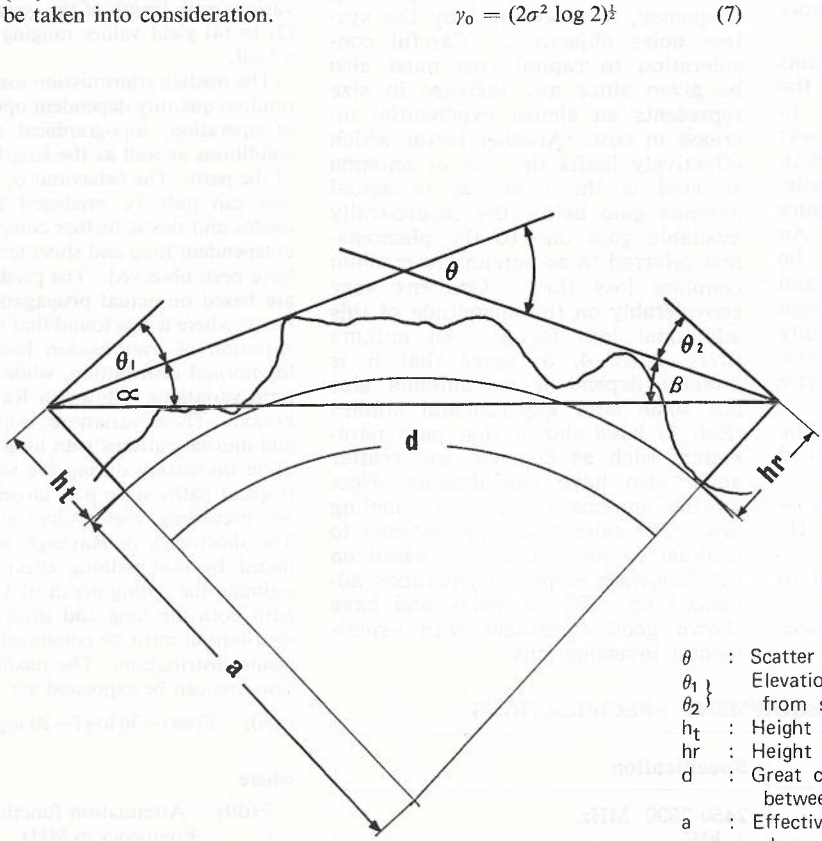
R = mean value of $\gamma_0$
K = transfer constant

Using the expression for median value given in equation (7) the probability density function for the Rayleigh distribution becomes

$$P(\gamma : \gamma_0) = \{(2\gamma \log 2)/\gamma_0\} \exp . \{-(\gamma/\gamma_0)^2 . \log 2\} \qquad (9)$$

Hence the density function $f(\gamma)$ of the composite Rayleigh–log normal distribution is obtained from

$$f(\gamma) = \int_0^\infty P(\gamma : \gamma_0) . q(\gamma_0) d\gamma_0 \qquad (10)$$




$$\alpha = \frac{d}{2a.10^{-3}} + \theta_1 + \frac{h_t - hr}{d.10^{-3}}$$

$$\beta = \frac{d}{2a.10^{-3}} + \theta_2 + \frac{hr - h_t}{d.10^{-3}}$$

$$\theta = \alpha + \beta$$

$$S = \frac{\alpha}{\beta}$$

**Fig. 5. — Tropospheric Scatter Path Configuration.**

with the distribution function $F(\gamma)$ given by

$$F(\gamma) = \int_0^\infty \gamma f(\gamma) d\gamma \qquad (11)$$

For design purposes, curves published in C.C.I.R. report 244·1 are usually used. These curves exhibit close agreement with above theoretical results. From these the fading depth of a troposcatter link can be determined. Once the fading distribution, and hence received signal distribution, has been determined, the effect of diversity reception on the received signal strength and hence system noise performance can be determined. By proper choice of antenna spacing and frequency spacing the correlation co-efficient for the Rayleigh distribution for the various received signals approaches zero. Experience has shown that for effective space diversity the antenna centres must be separated at a distance in excess of 100 wavelengths, while effective frequency diversity is obtained if the received frequencies differ by 1%.

There are various techniques available for combining received signals such as by switching, linear or non linear combining. The system selected for the Darwin–Nhulunbuy link utilises quadruple diversity with non linear signal combining techniques. From published curves (Refs. 2, 4) the standard deviation of each link was calculated and hence the fade depth for the various links, which are summarised in Table 4.

### System Noise Performance

There are three readily distinguishable components of system noise performance, they are:

(a) thermal noise
(b) path intermodulation noise
(c) basic equipment noise

Of these, the basic equipment noise is a fixed quantity but both thermal and path intermodulation noise must be determined for each path. Signal to thermal noise ratio is given by

$$S/N_T(p) = 10 \log (Pr/2kTF).(1/f_b).m_c^2 .W.U.(1/Fd(p)) \qquad (12)$$

where

$k$ = Boltzmann's Constant
$T$ = Temperature in degrees Kelvin (e.g. 300°K)
$F$ = receiver noise figure (2·5 dB)
$f_b$ = channel bandwidth (3·1 kHz)
$m_c$ = modulation index per channel (1 rad/channel)
$W$ = psophometric weighting factor (2·5 dB)
$U$ = diversity improvement (6 dB)
$Fd(p)$ = fade depth for p% of time

Equation 12 can be reduced to

$$S/N_T(p) = 142{\cdot}1 + P_r - Fd(p)(dB)$$

The calculation of the signal to path intermodulation ratio is less well defined and while a number of theories have been advanced, none gives the complete answer. All theories agree that under the usually prevailing conditions

$$S/N_I \propto \tau^{-4} m_c^2$$

where

$S/N_I$ = signal to intermodulation noise ratio
$\tau$ = relative time delay
$m_c$ = modulation index

The difference between the various theories arises in the calculation of $\tau$. The technique selected is based on the work of Beach and Trecker (Ref. 6) and NEC design report (Ref. 4). The median signal to path intermodulation ratio can be evaluated from

$$S/N_I(p\%) = 107{\cdot}8 - 40 \log(f_m.\tau) - 20 \log M_t + Z_n + W + U - FdI(p\%) \qquad (14)$$

where

$f_m$ = top modulating frequency
$M_t$ = total modulating index (radians)
$Z_n$ = combined loading factor
$FdI(p\%)$ = fading depth of intermodulation noise for p%
$\tau$ = delay time ($\mu$ sec)

$$M_t = 0{\cdot}41 m_c La \qquad (15)$$

where

$m_c$ = Modulating index (rad/channel)
$La$ = loading factor

$$\tau = 5{\cdot}6.10^{-7} d(\alpha + \theta_m)(\theta + \alpha + \theta_m) \qquad (16)$$

where $\theta_m$ = optimum beam elevation angle.

$$Zn = 10 \log N - La \qquad (17)$$

where

$N$ = number of channels
$La = -1 + 4 \log N$ if $60 < N < 240$ (18)

Hence for the Darwin–Nhulunbuy system equation (14) reduces to

$$S/N_I(p\%) = 130{\cdot}3 - 40 \log (f_m.\tau) - FdI(p\%) \qquad (19)$$

Path intermodulation noise also varies with time, but its distribution differs slightly from that of thermal noise. Assuming that $\sigma_1$ is the standard deviation of thermal noise and $\sigma_2$ that of path intermodulation noise then it has been found that

$$\sigma_2 \doteqdot 0{\cdot}7\sigma_1 \qquad (20)$$

By using the results of the foregoing discussion the total noise power for each hop can be obtained by adding thermal, intermodulation and basic equipment of noise power in tandem connected tran-horizon links. Statistical techniques and approximations must be utilised to obtain the overall noise distribution of the system. The basic assumption is that each path can be considered as an independent entity so that the mean and variance of the total distribution is the sum of the respective means and variances of the paths constituting the total system. Hence once the mean and variance of the noise distribution of each path is evaluated, the mean and variance of the distribution of the overall system can also be calculated. By approximating the mean and variance with a particular distribution the system noise power for any desired percentage of time can be determined. The distribution utilised is the log normal distribution and its probability density function (q(x)) from equation (8) becomes

$$q(x) = 4{\cdot}343/(\sqrt{2}n.\sigma.x) \exp[\{-4{\cdot}343 \log(x-m)\}^2/2.\sigma^2] \qquad (21)$$

where

$m$ = mean value
$x$ = probability
$\sigma^2$ = variance

Hence the true mean value and variance of each link is given by

$$M_i = \exp\left\{\left(\frac{m_i}{a} + \frac{\sigma_i^2}{2a^2}\right)\right\} \qquad (22)$$

$$S_i^2 = \exp\left\{\left(\frac{2m_i}{a} + \frac{\sigma_i^2}{2a^2}\right)\right\}.\left\{\exp\left(\frac{\sigma_i^2}{2}\right) - 1\right\} \qquad (23)$$

Where $m_i$ and $\sigma_i$ are in dB and a = 4·343. The mean and variance for the system become the sum of the individual paths.

$$M = \sum_{i=1}^{n} M_i \qquad (24)$$

$$S^2 = \sum_{i=1}^{n} S_i^2 \qquad (25)$$

So mean and variance of the overall system can be found from

$$m_0 = 10 \log M - 5 \log(1 + (S/M)^2) dBm \qquad (26)$$

$$\sigma_0^2 = (43{\cdot}43 \log(1 + (S/M)^2) dB \qquad (27)$$

**TABLE 4.—FADE DEPTH FOR PATHS OF DARWIN-NHULUNBUY SYSTEM WITH QUADRUPLE DIVERSITY.**

| Time | Darwin to Munmalary | Munmalary to Milingimbi | Milingimbi to Nhulunbuy |
|---|---|---|---|
| 80% | 4.5 dB | 4.2 dB | 4.5 dB |
| 95% | 9.2 dB | 8.5 dB | 9.0 dB |
| 99.5% | 15.5 dB | 13.5 dB | 15.0 dB |
| 99.95% | 20.5 dB | 19.0 dB | 20.0 dB |
| 99.99% | 24.0 dB | 22.0 dB | 23.0 dB |

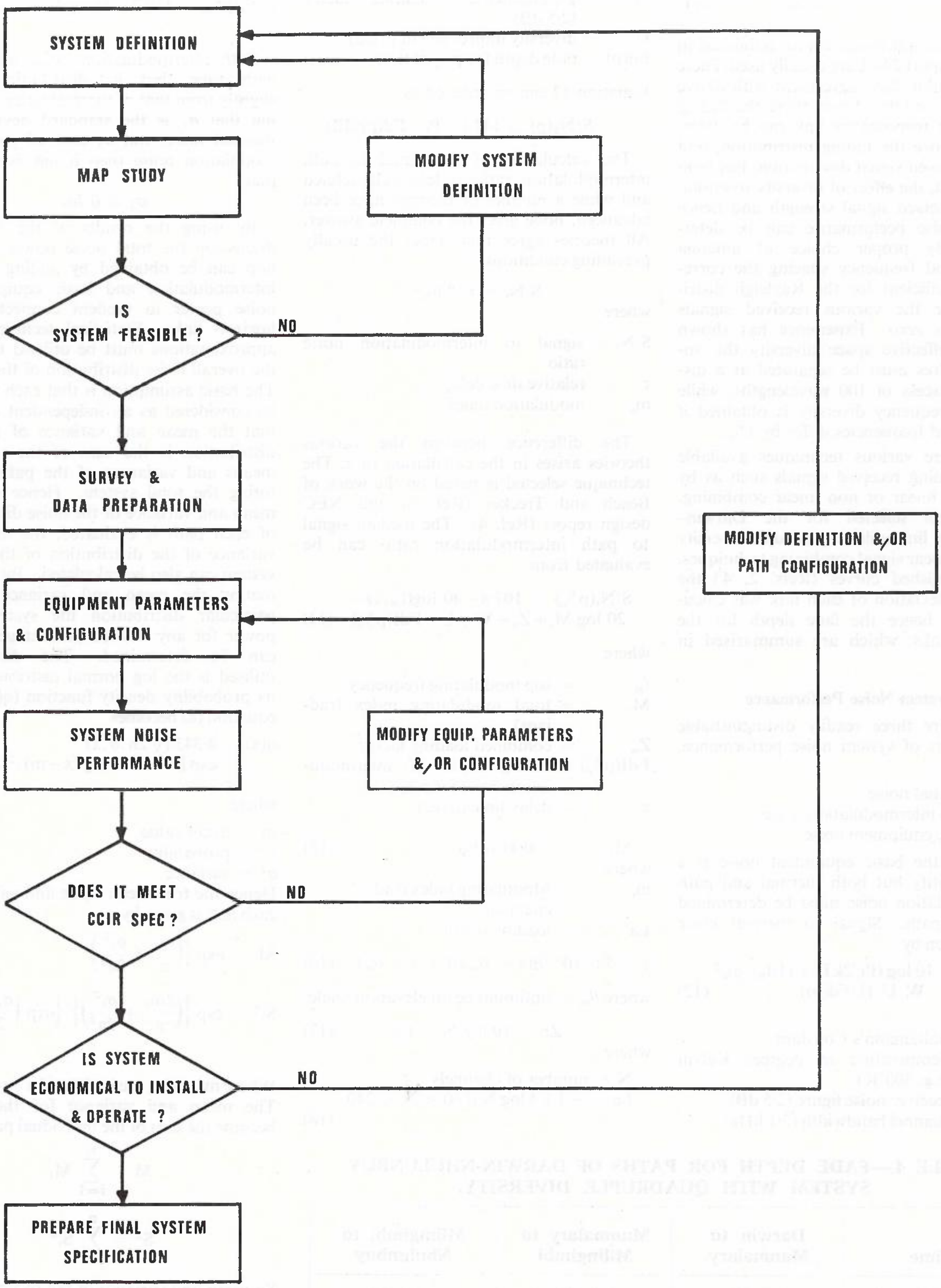



**Fig. 6. — Design Flow Chart.**

TABLE 5.—SUMMARY OF SYSTEM DESIGN

| Link Item | Path Length (km) | Scatter Angle (m rad.) | L(50) (dB) | Gt + Gr (dB) | Lc (dB) | Lf (dB) | Po (dBm) | Pr (dBm) | S/Nt 80% (dB) | S/Nt 99.5% (dB) | S/Nt 99.99% (dB) | S/Ni 80% (dB) | S/Ni 99.5% (dB) | S/Ni 99.99% (dB) | S/N Total 80% (dB) | S/N Total 99.5% (dB) | S/N Total 99.99% (dB) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cox Peninsula to Munmalary | 189.7 | 19.4 | 212.0 | 91.4 | 4.9 | 5 | 60 | —70.5 | 67.1 | 56.1 | 47.6 | 71.5 | 63.6 | 56.1 | 63.2 | 55.1 | 47.4 |
| Munmalary to Milingimbi Island | 252.7 | 31.7 | 220.8 | 94.4 | 8.1 | 5 | 60 | —79.5 | 58.4 | 49.1 | 40.6 | 60.4 | 53.4 | 46.9 | 55.9 | 47.7 | 39.0 |
| Milingimbi Island to Nhulunbuy | 207.0 | 24.4 | 215.2 | 91.4 | 5.8 | 5 | 60 | —74.6 | 63.0 | 52.5 | 44.5 | 65.7 | 57.8 | 50.3 | 60.1 | 51.3 | 45.0 |
| Overall | 649.4 | | | | | | | | 56.0 | 46.8 | | 58.0 | 51.8 | | 53.0 | 45.3 | 37.5 |

**Note: Basic Equipment Noise for each hop is 200pW.**

The mean and variance are calculated separately for the thermal and path intermodulation noise and the overall noise distribution for each is obtained by applying the log-normal law to each distribution. The total noise for the system is the sum of all component totals.

The methods outlined above were used in the design of the Darwin–Nhulunbuy system. The design approach is an iterative process and the basic flow chart is shown in Fig. 6. A summary of results is given in Table 5.

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# TYPE-72 MULTIPLEXING EQUIPMENT FOR THE APO NETWORK (PART 2)

*R. J. SPITHILL, B.Sc.(Eng.), G. van BAALEN, B.Sc.(Eng.) and L. R. GREGORY, M.I.E. (Aust.)**

## GROUP MODEMS

The new group modem equipment employs the standard C.C.I.T.T. modulation scheme for translating five basic groups (C.C.I.T.T. group B) into the basic supergroup and vice versa (Fig. 2b). A functional diagram of the equipment is shown in Fig. 7. Considerable improvements over earlier versions of this equipment have been effected, both in the electrical and the mechanical design.

In particular, the use of active modulators, as well as yielding the normal advantages of low carrier power, better impedance matching, and lower transmission loss, has allowed the use of a low-impedance, constant-voltage, 'bus-bar' carrier-distribution system within the rack. Pre-wired plug-in carrier links are used to build up a ring main similar to that used in the channel modem rack. In general, the tolerance and stability of transmission levels and responses have been improved by careful design and the use of proven, stable components. For example, modern loss-compensating filter design techniques have resulted in the attenuation distortion being reduced to half that of the previous equipment. Performance in other areas is in line with C.C.I.T.T. requirements as modified by the A.P.O., and is similar to the performance of the previous equipment.

The mechanical design of the group modem equipment has been refined to the point where the rack capacity is determined by the bulk of cabling which can be accommodated in the side cabling duct rather than the number of modems which can be mounted on the rack. Each group modem subrack occupies four rack units and contains 15 group modems together with common equipment for three basic supergroups. This represents a threefold increase over the previous equipment. On this basis a nominal rack capacity of 150 groups (30 basic supergroups) has been determined, leaving ample room for power-supply and carrier-supply equipment. Cabling to the group modem subracks is terminated on wire-wrap terminal blocks in the case

*Messrs Spithill, van Baalen and Gregory are S.T.C. Engineers engaged in the design and development of transmission equipment. See Vol. 22, No. 2, Page 164.

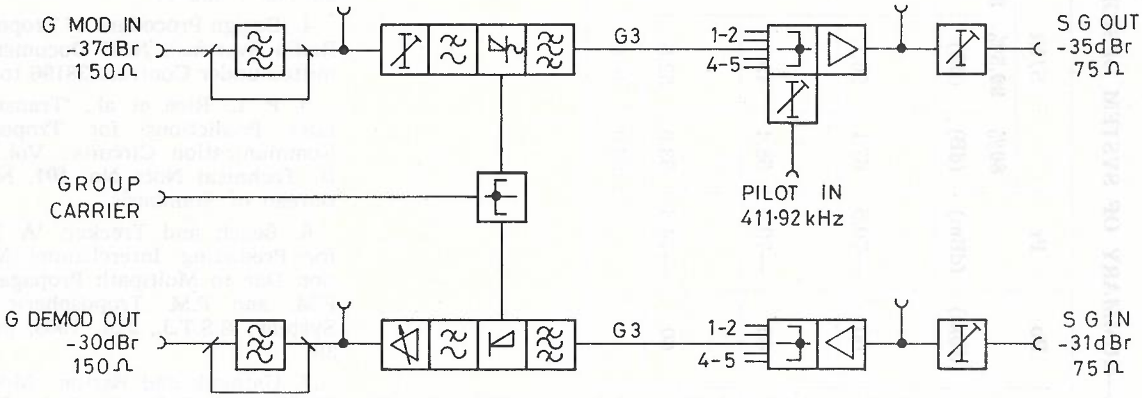


**Fig. 7. — Functional Diagram of Group Modem Equipment.**

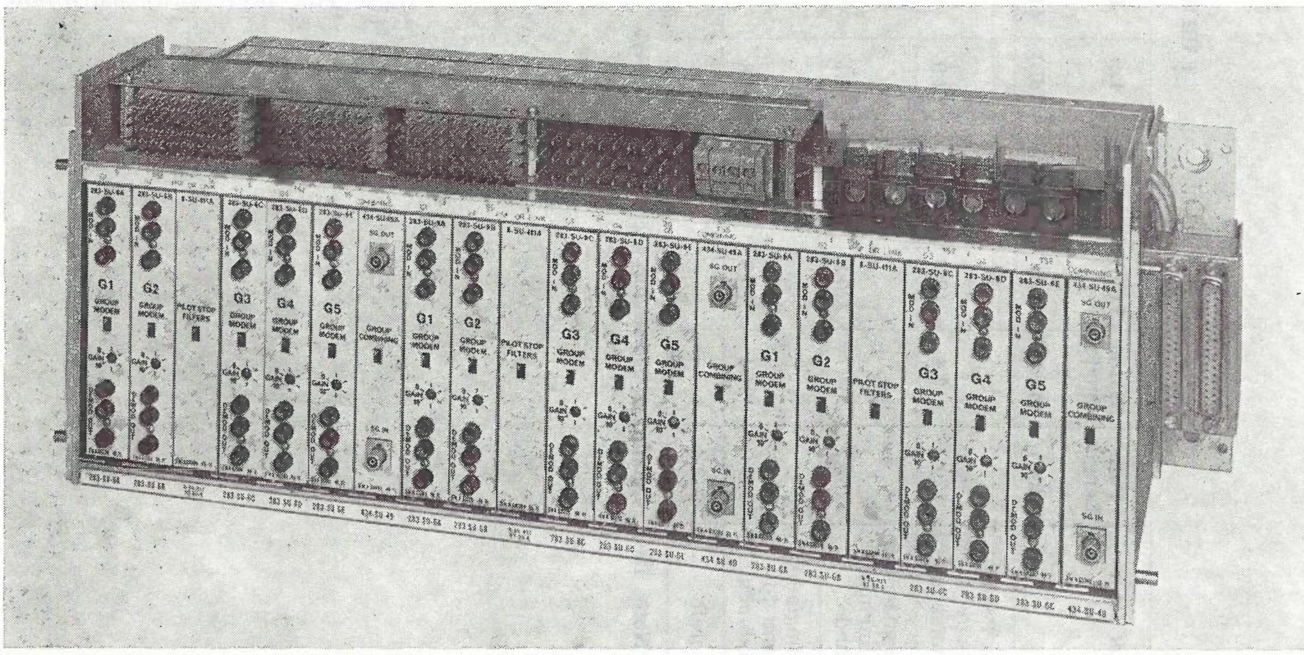

**Fig. 8. — Group Modem Subrack.**

of the basic group connections, and in snap-in coaxial connectors in the case of the basic supergroup connections. Fig. 8 shows a fully-equipped group modem subrack.

## GROUP CARRIER SUPPLY AND DISTRIBUTION

The group carrier supply generates, from the basic driving signal of 12 kHz, the five carriers, i.e., 420, 468, 516, 564 and 612 kHz required by the group modem equipment. In the new version of this equipment, a novel method of carrier generation is used, which involves a high-frequency local oscillator phase-locked to the station master 12-kHz supply. The group carriers are derived from the output of this oscillator by a process of division and modulation. Compared with the 12 kHz distortion method this results in greater output-level stability and eases the subsequent filtering requirements. The carrier supply may also be equipped with self-contained supergroup-reference-pilot oscillators, or with pilot-stabilising amplifiers where a station centralised pilot supply already exists.

The supply is fully duplicated with automatic changeover in the event of any malfunction which would affect the performance of the modem equipment. The automatic changeover facility has been considerably simplified; a single supervisory unit controlling all changeover relays which are mounted on the individual carrier-amplifier cards. This will result in an overall improvement in the reliability of the system.

The carrier-distribution subrack contains five buffer amplifiers for the group carriers and a stabilising amplifier for the supergroup reference pilot. The pilot output level is continuously monitored and an alarm is given should it deviate by more than a pre-determined amount from the nominal value. The capacities of the carrier supply and distribution amplifier subracks are such that a rack of group modems may be fed from either. In addition a carrier supply can feed ten racks of group modems via distribution subracks, or one rack of modems direct plus one rack via a distribution subrack. This means that the most economical arrangement to suit a particular station layout and ultimate capacity can be selected.

The mechanical design of the carrier supply and distribution subracks is similar to that of the group modems, the subracks being the same size. Fig. 9 shows the carrier supply subrack. Carrier output connectors are provided on the right-hand side of both subracks to match those on the group modem subrack. In addition, output connectors are provided on the left-hand side of the carrier-supply subrack for feeding to the input connectors on the left-hand side of distribution subracks. A second version of the carrier supply, for centralised hard-wired usage, has also been designed. This unit provides 10 outlets of each carrier and 10 outlets of pilot, but is larger (six rack units) than the standard carrier supply in order to accommodate the coaxial terminal strips involved.

## SUPERGROUP MODEMS AND CARRIER SUPPLY

The function of this equipment is to modulate basic supergroups into the line frequency band or radio baseband and vice-versa. Standard C.C.I.T.T. frequency allocations are used (Fig. 2c) and the electrical design follows established practice. Fig. 10 shows the functional diagram. The mechanical arrangement of the equipment has been rationalised to improve flexibility. The basic building block is a subrack containing any five supergroup modems together with common equipment for 300 channels. Thus the popular 300-channel system (SG 1-5) or the basic mastergroup (SG 4-8) may be accommodated in a single standard subrack. The basic 15-supergroup assembly (SG 2-16) consists of three 300-channel subracks fully equipped with supergroup modems and a combining subrack. This arrangement may be converted into a 960-channel system by the addition of SG 1 which is housed in the combining subrack. Station-cabling equalisers may be introduced at the 300-channel or 900/960-channel points, the levels at these points being adjustable over a wide range to cater for a variety of line and radio systems. The system frequency-comparison pilot (308 kHz) may be injected and picked off in the combining subrack. A supervisory receiver for this pilot may also be equipped.

A subrack mounting a number of passive, frequency-independent carrier distribution units is normally mounted on each rack. Each distributor has a single input and four identical out-

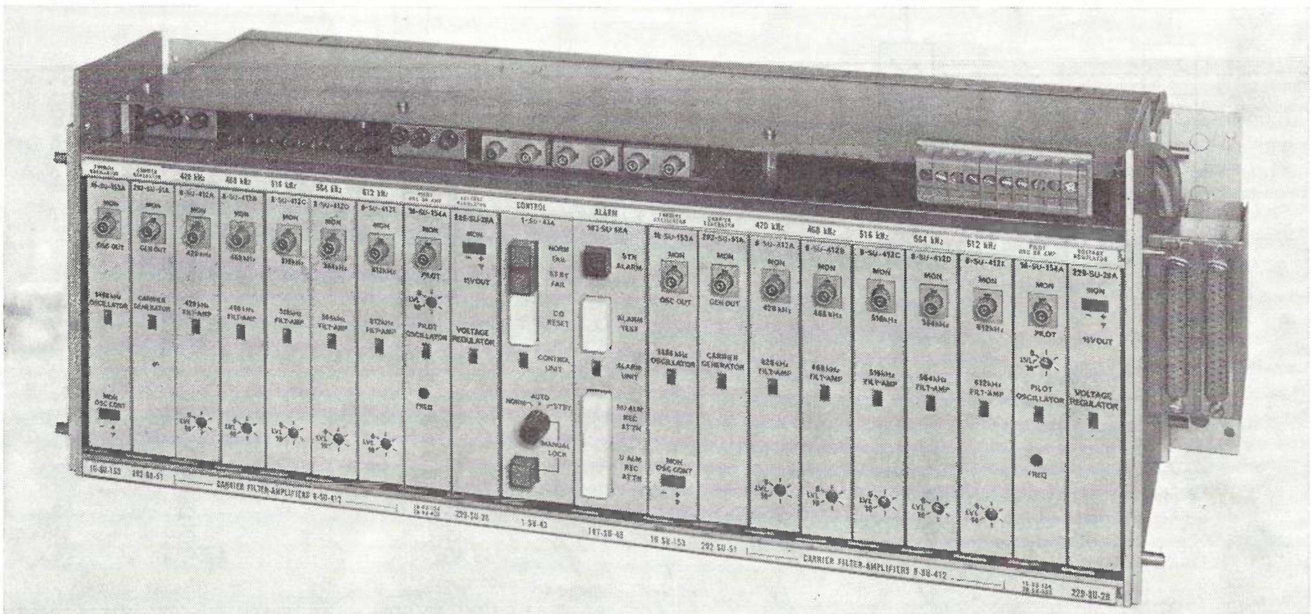


**Fig. 9. — Duplicated Group Carrier Supply.**

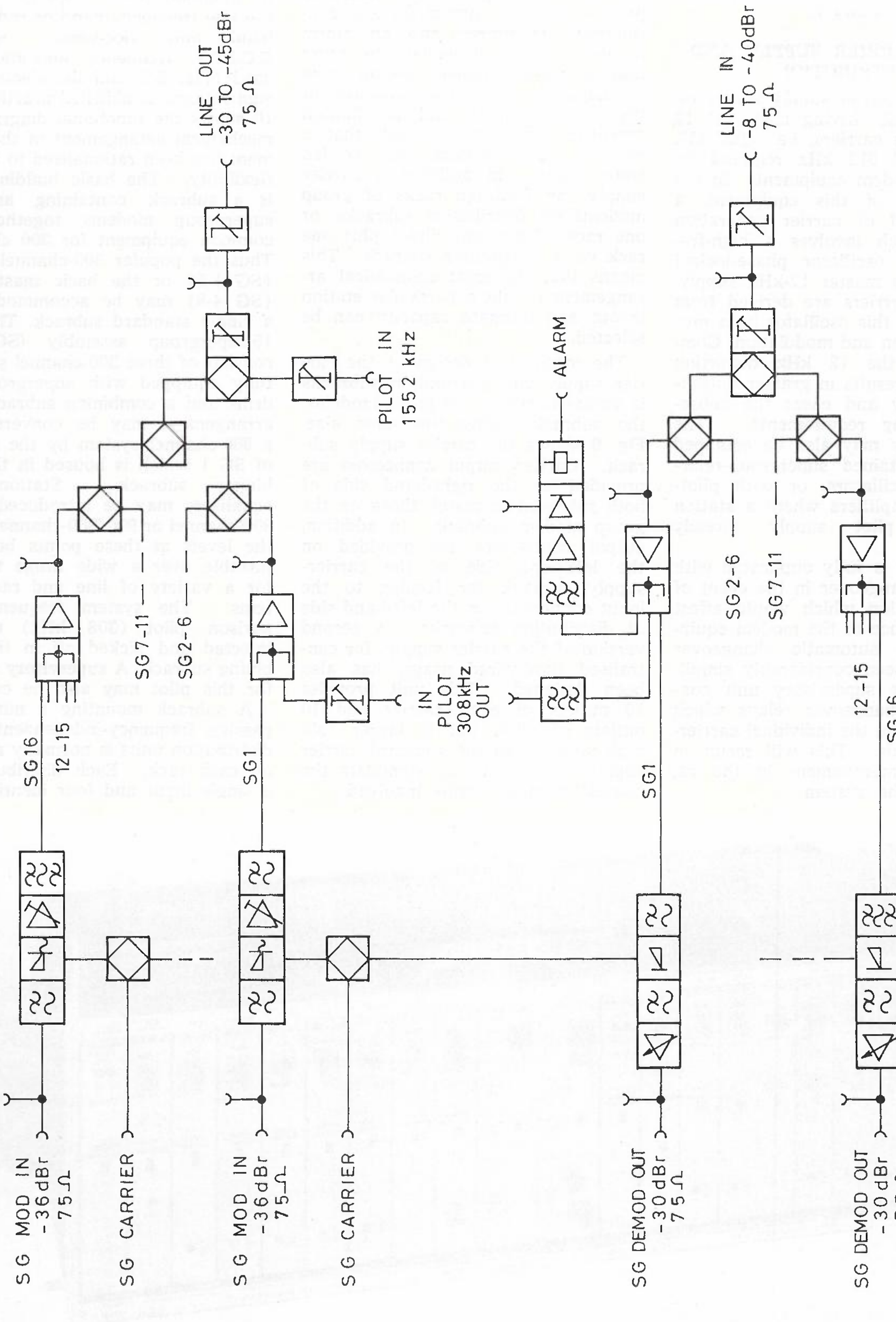


**Fig. 10. — Functional Diagram of the Supergroup Modem Equipment.**

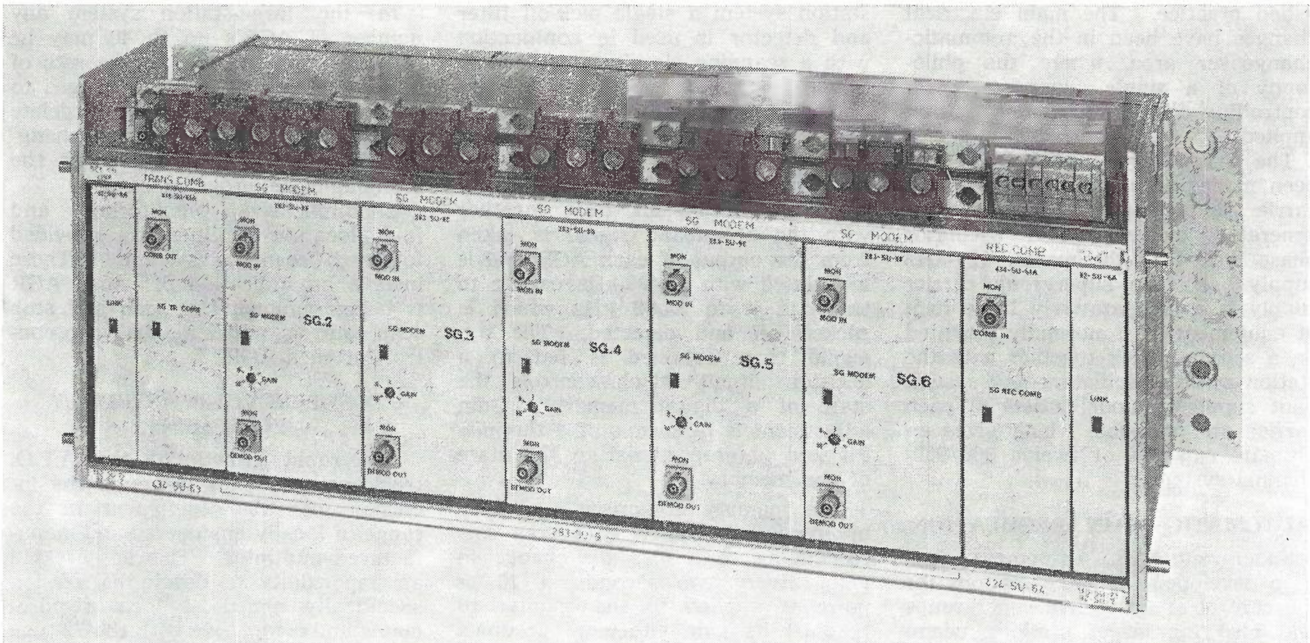


Fig. 11. — Supergroup Modem Subrack.

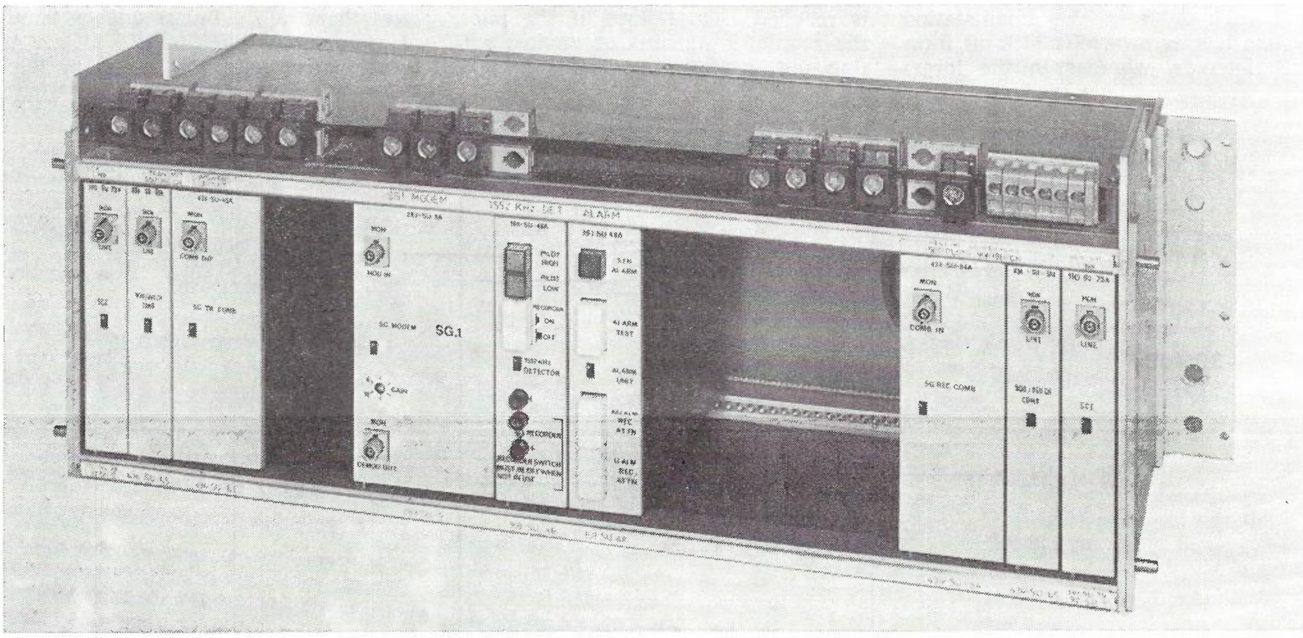


Fig. 12. — 900/960 Channel Combining Subrack.

puts. The size of the modem equipment is such that three 960-channel systems can be mounted on one rack, and the distribution subrack contains sufficient distributors to cater for the 15 carriers and two pilots used. With a single carrier feed at each frequency, up to four 300-channel systems may be equipped. However, 12 systems can be accommodated by utilising the spare distribution units and running more than one feed at each frequency to the rack.

All three subracks in the supergroup modem equipment are the same size (four rack units). The 300-channel supergroup modem subrack and the combining subrack are shown in Figures 11 and 12 respectively. The carrier distribution subrack is of a special design, while the other two subracks are similar to the group equipment subracks. Signal and carrier connections to the modem and combining subracks are made with snap-in coaxial connectors which mate via coaxial u-links to similar connectors joined to the subrack wiring. This method has the advantage of allowing the termination of cable ends away from the equipment, and provides break access at all interface points. All wiring between subracks is provided pre-terminated with the equipment.

The supergroup carrier supply, which supplies the 15 different carriers required by the modem equipment, again largely follows established practice. The main electrical changes have been in the automatic-changeover area, where the philosophy of a single supervisory unit controlling all changeovers has been applied.

The SG 1 carrier (612 kHz) has been made independent of the group carrier supply equipment and is now generated by a crystal oscillator phase locked to the master 124-kHz supply. As the supergroup carrier supply is a comparatively large item of equipment, it is normally mounted on a separate rack together with the station master oscillators and system pilot supplies. Four outlets of each carrier are provided, which gives an ultimate capacity of twelve 900/960-channel systems.

## AUTOMATIC GAIN REGULATION

Supergroup-AGR equipment has been developed for small stations for the control of up to five supergroups and also for larger stations where up to 40 supergroups can be controlled by a single system. The primary difference between the two systems is that each AGR in the small-station system has its own pilot pick-off filter and detector, whereas in the large-station system a single pick-off filter and detector is used in conjunction with a scanning circuit to control up to 40 AGR's. A functional diagram of the scanning system is shown in Fig. 13. With the exception of the scanning circuitry, the modes of operation of both systems are identical. The 411.92-kHz pilot together with the broadband signal is taken from the output of each AGR and is modulated with a 496-kHz carrier to translate it to 84.08 kHz which is picked off and detected. The d.c. signal thus obtained is fed to a decision circuit which controls the state of a digital memory. Gain adjustment is by means of a thermistor and is proportional to the state of the memory.

The memory comprises a 32-step bi-directional counter, each step corresponding to a 0.25 dB change in gain. Every two seconds, a 20 μs pulse is applied to the counter to readjust its gain either up or down one step if this is required. The range of regulation is ±4 dB and alarms are given if the end of range is reached. On failure of the pilot, the regulator remains at its last setting and an alarm is raised.

In the large-station system any number of AGR's up to 40 may be scanned and controlled at the rate of one every two seconds. Changes to the scanning cycle to include or delete any AGR are readily made by changing the position of a U-link on the scanning-cycle program card.

Comprehensive monitoring and fault location facilities are provided for each scanning system. These include an indication of which AGR is being scanned, fast scan and stop scan controls, and a manual gain control for each AGR.

## 15-SUPERGROUP ASSEMBLY EQUIPMENT

The rapid growth of the A.P.O. trunk network now warrants the inclusion of this equipment in the range of locally engineered and manufactured multiplex. This has created an opportunity to develop a version specifically aimed at local requirements and compatible with the 72-type equipment practice.

The equipment accepts three 900-channel systems (SG 2-16) and translates them into a line-frequency band of approximately 0.3 to 12.3 MHz. A functional diagram is shown in Fig.

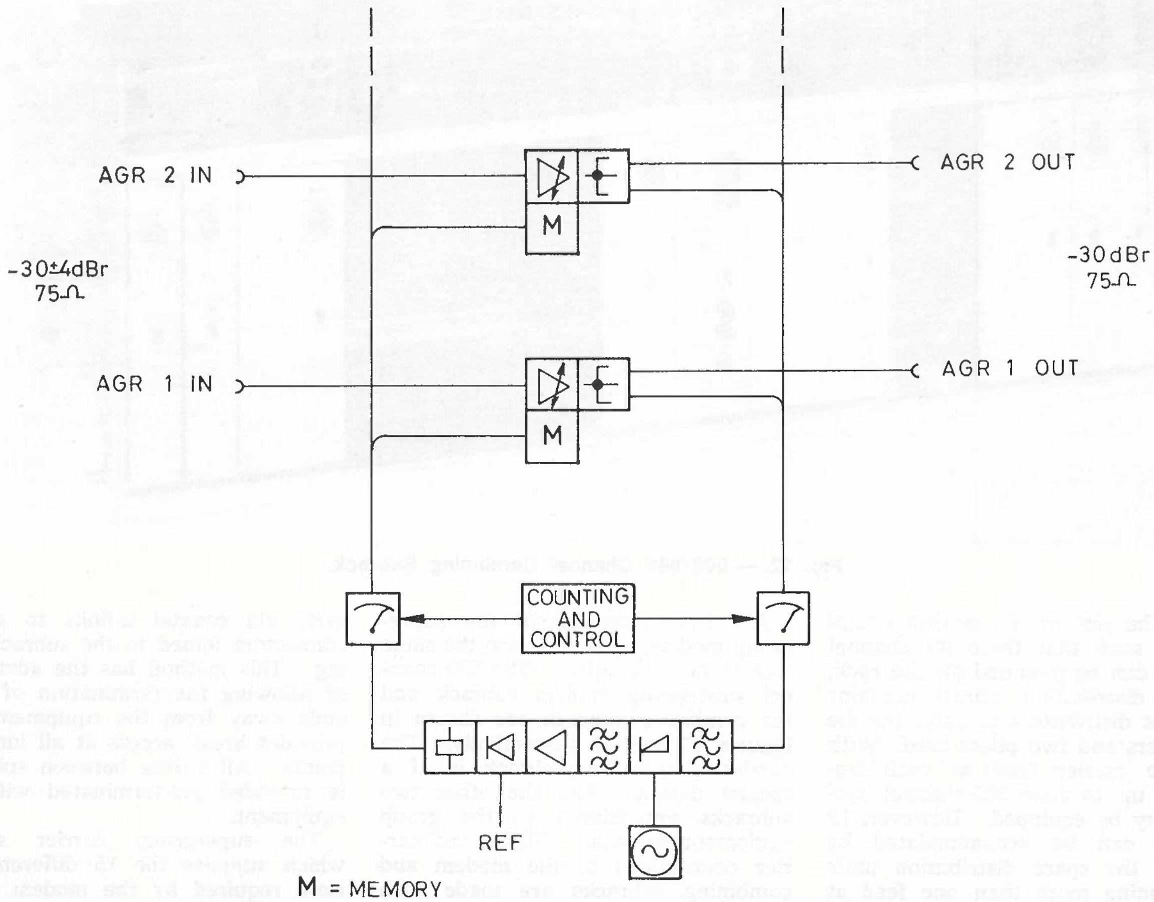


**Fig. 13. — Functional Diagram of Scanning Supergroup A.G.R. Equipment.**

14. The frequency allocations used are in accordance with C.C.I.T.T. Plan 2 (Fig. 2d). The carriers required, 8432 kHz and 12648 kHz, are multiples of the SG-7 carrier and are provided on the supergroup carrier rack. The subracks for this equipment are again in the 4-unit format, two such subracks being required for the modem equipment, and one each for the carrier supply and distribution equipments. The rack capacity is therefore five systems (2700 ch. each) assuming a carrier supply and distribution subrack mounted on the modem rack. The carrier supply has sufficient capacity to drive four racks of modems.

The equipment may be readily adapted for filter or leak dropping or for radio tail systems.

## MASTER OSCILLATOR EQUIPMENT

The master oscillator subrack provides the master driving signals of 4, 12 and 124 kHz, which are derived from a highly stable crystal oscillator operating at 2.48 MHz. Existing techniques have been refined to provide multiple outlets at each frequency, and to facilitate cabling on the new 72-type side-cabled rack. The equipment is fully-duplicated with separate feeds from the 'normal' and 'standby' sides to feed the normal and standby sides respectively of the channel, group, supergroup, etc., carrier supplies. The stability and purity are well within the requirements for systems up to 12 MHz. The capacity is such that only one such subrack is required even for very large stations, i.e., exceeding 20,000 channels. It is therefore mounted on a separate rack together with the supergroup carrier supply.

The system frequency-comparison pilot (308 kHz) and the basic 15-Supergroup assembly reference pilot (1552 kHz) are generated in another subrack normally mounted on the station master oscillator rack. The two pilots are produced by crystal oscillators, the 308 kHz one being phase-locked to the station master oscillator. A duplicated pilot supply is contained in a single 4-unit subrack. This has a capacity compatible with that of the other items of equipment described above.

## POWER SUPPLY AND DISTRIBUTION

Previous generations of equipment have been designed to operate from non-stabilised 24V batteries and it has been the usual practice to include voltage regulators in the equipment to give an actual circuit working voltage of 20V. With the change to 48V working of all equipment in stations, 48V - to - 24V converters are now mounted on carrier racks to provide the 24V supply required by the equipment.

The new 72-type 48V-to-24V converter has been designed both to meet the requirements of the Design Guide and for use as a general-purpose power supply. Its 7A capacity is sufficient to drive a complete rack of equipment, and two converters may be paralleled to give full redundancy working.

It is a switching-type converter operating outside the audible range and has a high efficiency (85% at 7A) and hence a low power dissipation. Like the other subracks mounting on the channel modem rack, it is 2½ rack units in height and uses a specially designed extruded heat-sink mounted on the front of the unit to keep the internal temperature rise to a minimum.

Careful consideration was given to the protection facilities both for the converter and for the equipment it operates. It is instantaneously rendered inoperative in the event of a voltage exceeding 30V appearing at its output, and is protected against reverse polarity connection at the input, and any current overload including a short circuit.

The converter automatically starts at full performance on restoration of the external power supply after a

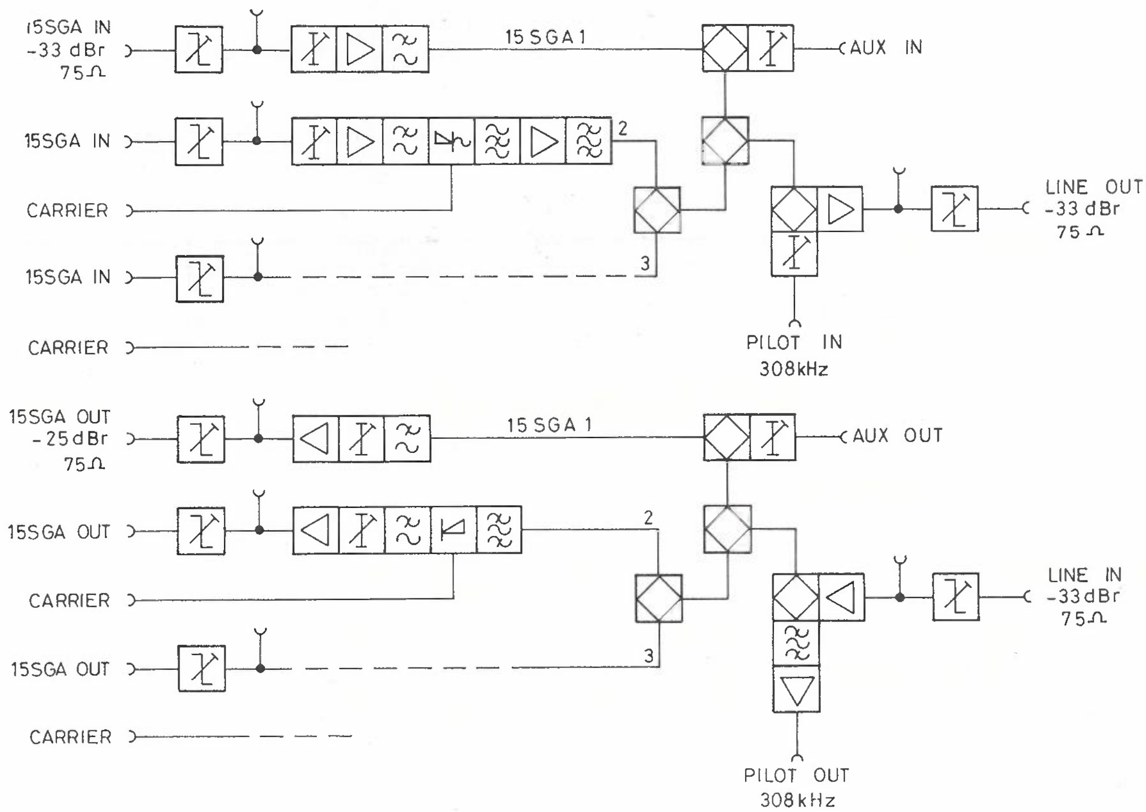


**Fig. 14. — Functional Diagram of 15 Supergroup Assembly Equipment.**

break. A significant advantage arising from the use of this unit is that a regulated and filtered d.c. supply is fed to the equipment. Novel control circuitry has been developed which maintains the output within ±0.5V of nominal for input variations from 35V to 55V, thus far exceeding the requirements of the specification. Normally mounted at the top of the rack, the converter is used in conjunction with a 2½ unit Alarm and Power Distribution Subrack mounted below it. This unit provides fusing and distribution facilities for all of the subracks on the rack and mounts the rack alarm lamp and associated facilities. In addition diodes are included for the paralleling of two converters to obtain a redundant supply.

## SUMMARY OF RACK CAPACITIES

The equipment densities achieved with the new family of multiplex equipment are summarised as rack capacities in Table 1.

These figures are, of course, for high-density stations. As the individual equipment descriptions show, the equipment may also be used to build up low and medium density stations with maximum flexibility and minimum initial outlay. As an example, a station terminating a 300-channel radio system, a 120-channel cable system and four or five 12-channel systems of the open wire or cable type would need two channel modem racks, one combined group and supergroup modem rack, and one master oscillator-supergroup carrier supply rack.

## MANUFACTURING AND TESTING

Sophisticated equipment of the type described in this article needs advanced manufacturing techniques for most economical production. These techniques must not in any way impair the inherent reliability of the equipment which has been derived from careful design and meticulous component selection, and should enhance these qualities.

Although an interesting account could be given of the manufacturing processes involved, it is beyond the scope of the present article. However, as an indication of advances in one area, Fig. 15 shows Channel Modem units being tested on a tape-controlled automatic test system. This is a general purpose tester which may be programmed for checking a wide range of units. Tests are performed at high speed and full results can be printed out if required. In addition, the unit can be programmed to stop should any parameter be out of limits. The printout obtained from this type of system is used as a valuable quality control adjunct.

Another important step in the quality control programme is the temperature cycling under power of all production for an extended period prior to final test and despatch. This practice eliminates almost all of the

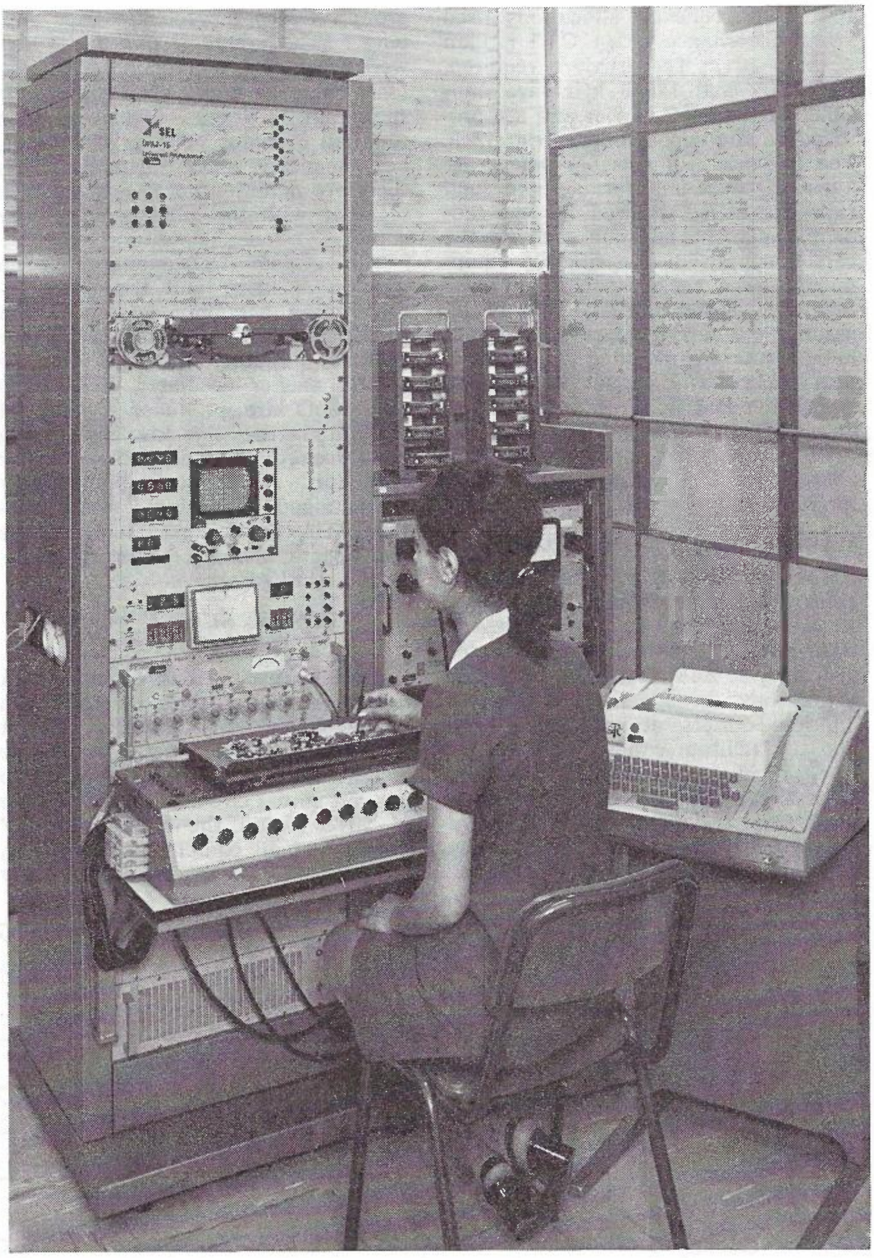

**Fig. 15. — Production Testing Channel Modems Using an Automatic Tape-Controlled Test Unit.**

**TABLE 1—EQUIPMENT DENSITIES**

| Rack | Capacity | Capacity in Channels |
|---|---|---|
| Chan. Modems | 240 | 240 |
| Group Modems | 150 | 1,800 |
| S.G. Modems | 3 x 960 Chan. Systems | 2,880 |
| 15 S.G. Assembly Modems | 5 x 2700 Chan. Systems | 13,500 |
| Master Oscillator/S.G. Carrier Supply. | Basic Capacity of Approx. 11,000 Channels. Ultimate Capacity in Excess of 50,000 Channels. | |

'burn-in' failures which otherwise would occur in the field.

**CONCLUSION**

This paper has described the approach by one manufacturer (S.T.C.) to fulfil the propositions of the A.P.O. Design Guide.

Every opportunity has been taken to ensure that possible economies are exploited to their best advantage, while at the same time minimising some of the problems inherent in a new design approach. The use of well-proven equipment practices and components has minimised the development costs; but opportunity has been taken to develop local techniques meeting A.P.O. requirements differing from overseas practices.

The 'building block' approach used has achieved maximum flexibility in system engineering design, and allowed logical development from the voice frequency channel to the 12 MHz line bandwidth and beyond.

These results have been achieved in a way that will not preclude the use of future developments which may be proved reliable and advantageous for transmission requirements within the Australian telecommunication network.

# TRANSMISSION TESTING ARTICLES

It has been suggested to the Editors of the Journal that a series of articles on the field applications of new items of transmission testing instruments would be appreciated by our readers.

The Editors believe that such a series would be of greatest value if they were written by members of the A.P.O. field staff who are most familiar with the problems associated with the use of transmission testing equipment.

Prospective authors should preferably contact the Editors through one of their local representatives.

# CABLING IN TELEPHONE EXCHANGES

E. J. MASON*

## INTRODUCTION

Over the last decade cable used by internal plant sections of the A.P.O. and the methods employed to support cable in telephone exchanges have undergone extensive investigations. As a result, more emphasis is now placed on the functional and economic aspects and less on aesthetics.

Prior to the mid-fifties, all cable used by exchange installation sections was constructed of annealed copper, enamelled, rayon and cotton covered and wax impregnated conductors with a sheath of cotton braiding which was treated with a flame-proof paint. Before cabling could commence, details such as position on runway, cross-sections of cable packs for each rack and frame, and cable 'drop off' points had to be prepared by the Drafting Section for each exchange, involving hundreds of man-hours of drafting time. Each cable in the packs was individually stitched into place with waxed linen thread and formed into bends of the correct radius, often assisted by heat and a plumber's maul. Fig. 1 shows a typical installation. The difficulty experienced in bending and forming bends was due to the amount of wax contained in the cable and to the coating of flame-proof paint applied to the sheath. Great care had to be exercised when positioning the cable packs on runways to ensure that sufficient space was provided between packs to accommodate future extensions to packs; often cable had to be run prematurely because its position in the pack made it impossible to be installed at a later date.

PVC sheathed PVC insulated cables were introduced into the internal plant sections of the A.P.O. early in 1960. These cables had the advantage of being easily formed into bends and eliminated the need for heating and blocking when forming bends. The added flexibility of PVC cable, however, created the problem of cable sag between runway slats which were spaced at approximately 9 inch centres.

## CABLING ON RUNWAY

An investigation into cable and cabling methods indicated that a high percentage of the total cabling man-hours used on an installation could be attributed to 'boxing bends' and 'stitching' cables into packs on runways. Erection of runways also contributed to the cost of cabling where special curves frequently had to be manufactured on the job and then assembled, using J bolts to fasten the slats to the side-members.

Early in the 1960's, when crossbar equipment was introduced into the A.P.O. network, the initial installations were cabled on a runway which was supplied by the equipment manufacturers and included various types of bends, joining pieces, etc., thus eliminating the need to fabricate bends on the job. The cables were glued into packs rather than stitched with lacing twine, which saved a considerable amount of time. However, care was necessary when using glue to ensure that the cable pack was in its correct location on the runway and that the cables contained within the pack were in their correct position. Any alteration to the cable pack was virtually impossible after the glue had set. Other disadvantages of the glue were the flammability and the toxic fumes.

## CABLE TRAY (ADMIRALTY PATTERN)

An alternative to runway was cable tray. In providing full support for

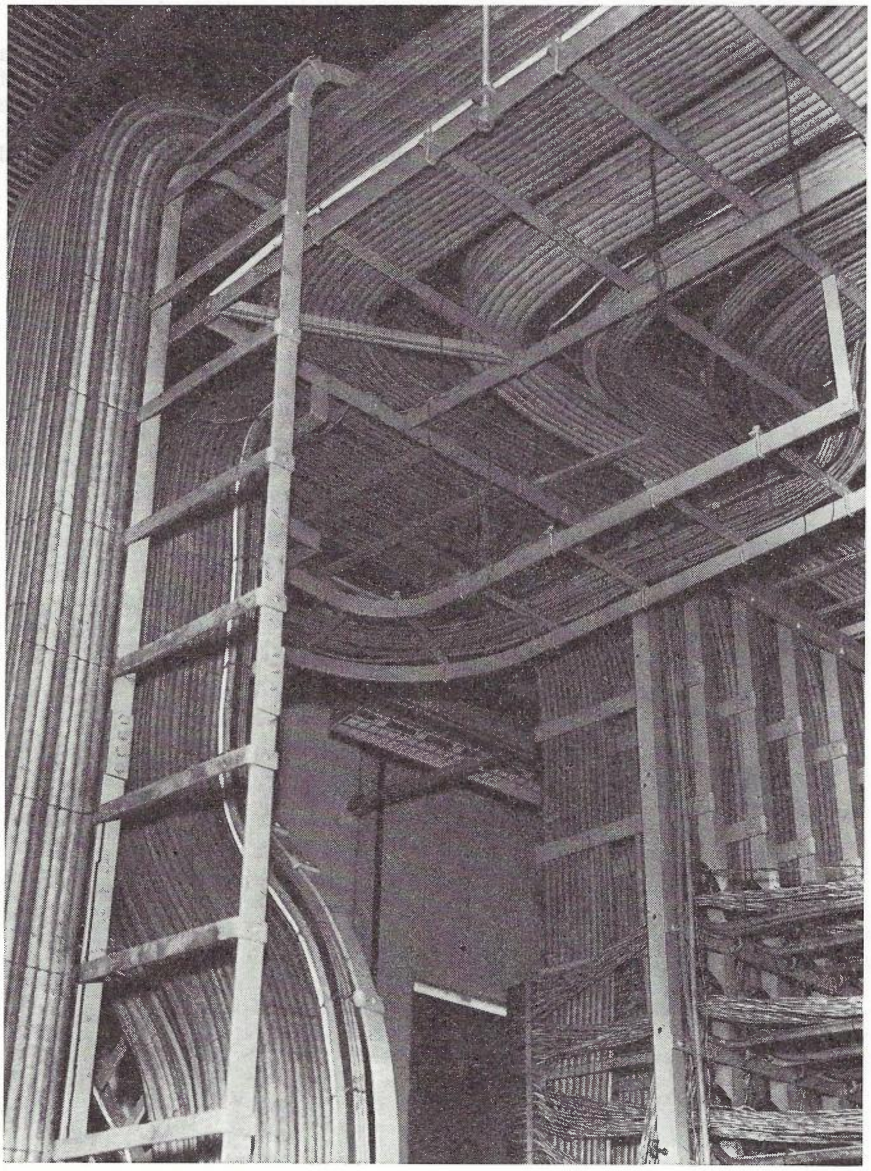

Fig. 1. — Cable Packs Stitched on Runway.

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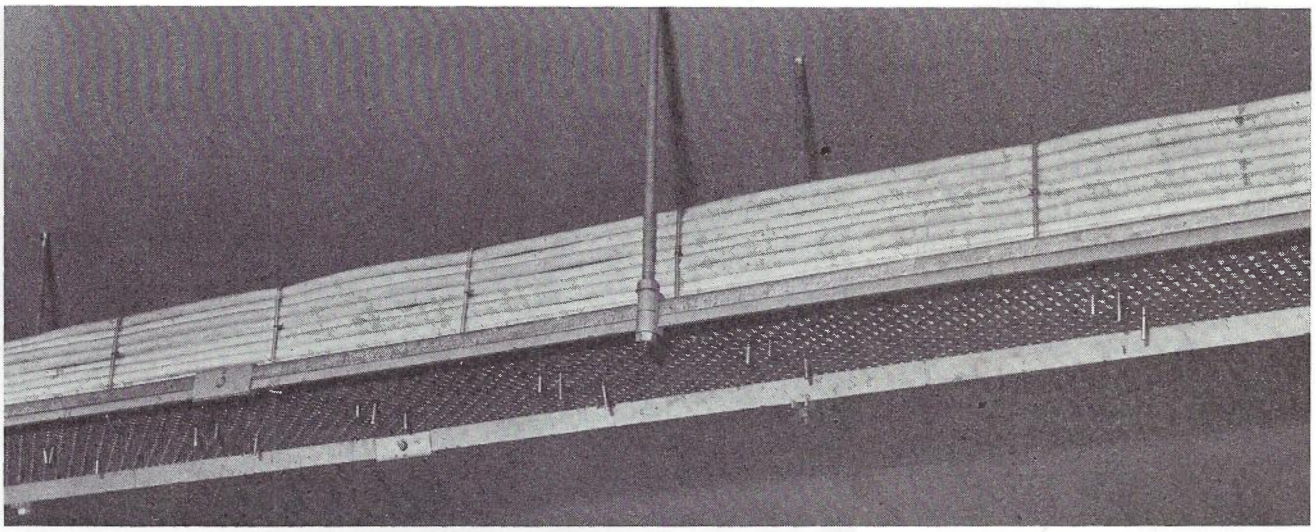

Fig. 2. — Cable Fixed to Cable Tray with Aluminium Stirrups and 'Quik' Nuts.

PVC cables, cable tray eliminated the sag experienced with runway and also the necessity to stitch cable packs. The stitching was replaced by a stirrup of soft aluminium rod placed over the cable pack and fastened to the cable tray with single-thread spring steel fasteners ('Quik' nuts). (See Fig. 2.) Cable trough was adopted in preference to the cable tray, which was expensive, both in material cost and in man-hours required to adapt it to the crossbar system.

### STEEL CABLE TROUGH

Several of the problems that were associated with runways were solved when cable trough was introduced for use with crossbar equipment. Cable trough removed the need for formed cable packs and stitching cables.

The cables are laid in the trough with only a rough tie placed around them where they leave the trough and enter the L. M. Ericsson BDH racks used by the A.P.O.

Steel trough did not overcome one of the main problems; that of access between suites. Several high level troughs running at right angles to, and approximately 18 in. above, the suite troughs, provide this access. The high level trough carries inter-suite cables and cables running between the MDF, IDF's and equipment.

An alternative method of gaining access between suites is to place a trough at the end of, and at right angles to, the equipment suites at the same level, and running the full length of the equipment room. This method is expensive in both cable and man-hours. Moreover, the trough

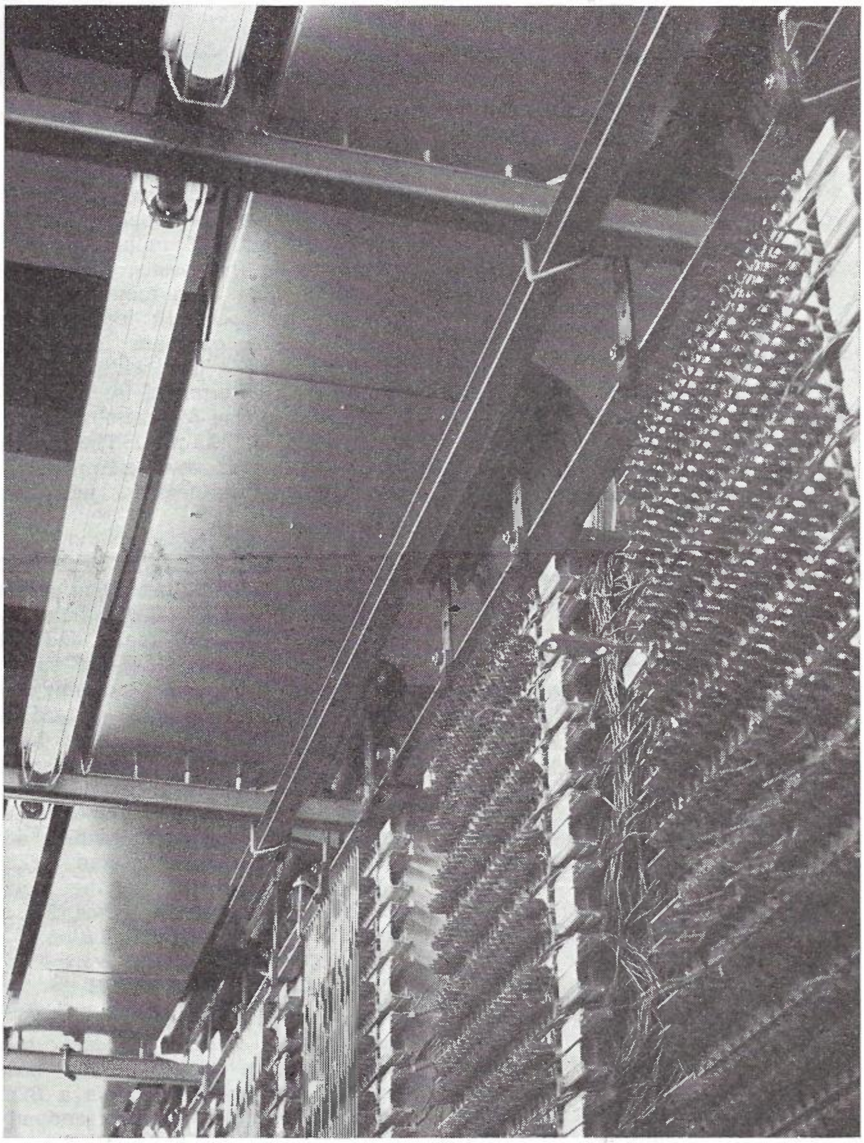

Fig. 3. — Cable Trough used to Carry Intra-Suite Cables.

usually requires modification where cables enter and leave the trough.

A variation of the above method designed to eliminate high level trough is to provide narrow troughs approximately 100 mm. wide between suites at rack height to carry inter suite cables. However, as in the previous case, considerable cost is incurred because of mounting difficulties and modifications necessary to gain access to other troughs.

## CABLE SUPPORT SPECIFICATION

An analysis of the two previous sections of this article reveal several areas where improvements could be made and also provide the basis of a specification for the ideal cable support for use with crossbar and long line equipment.

Ideally, the cable support should have the following facilities:

(i) All cables should be contained on the same level.

(ii) All cables should be supported every six inches or less.

(iii) All cables to be run direct from point to point.

(iv) Boxing and stitching of cables should be unnecessary.

(v) The cable support should be in modular form, easily erected, and designed to suit varying equipment layouts.

(vi) It should be so designed that re-working on the job is kept to a minimum.

(vii) The material and erection costs should be less than the costs for runway or trough.

(viii) The cable support should be readily available, preferably from more than one supplier.

## STEEL MESH

After study of the specifications and methods used overseas, the A.P.O. has adapted a concrete reinforcing mesh, which is electro-zinc plated and cut into modules, for use as a cabling support. The mesh selected is a stock item used by the building trade throughout Australia and manufactured from mild steel rod formed into a six-inch square grid. The mesh is formed from 5 gauge rod reinforced on the underside with a 3/0 gauge rod welded longitudinally to the mesh at 12 inch centres. The 3/0 gauge rod was added to the standard mesh to provide additional strength and also to ensure that the mesh would support the weight of staff engaged on cable running. The length of the mesh modules was determined by the standard commercial sizes in which the mesh is supplied, i.e., 10 feet by 20 feet. To minimise waste when cutting the sheets, the weight should be kept to a minimum. To facilitate transport, 10 feet was selected as the optimum length for each module. The width of the module was determined by the standard aisle spacing for crossbar equipment which is 1125 mm. The module width of 914 mm. was determined after making allowances for jack field erection.

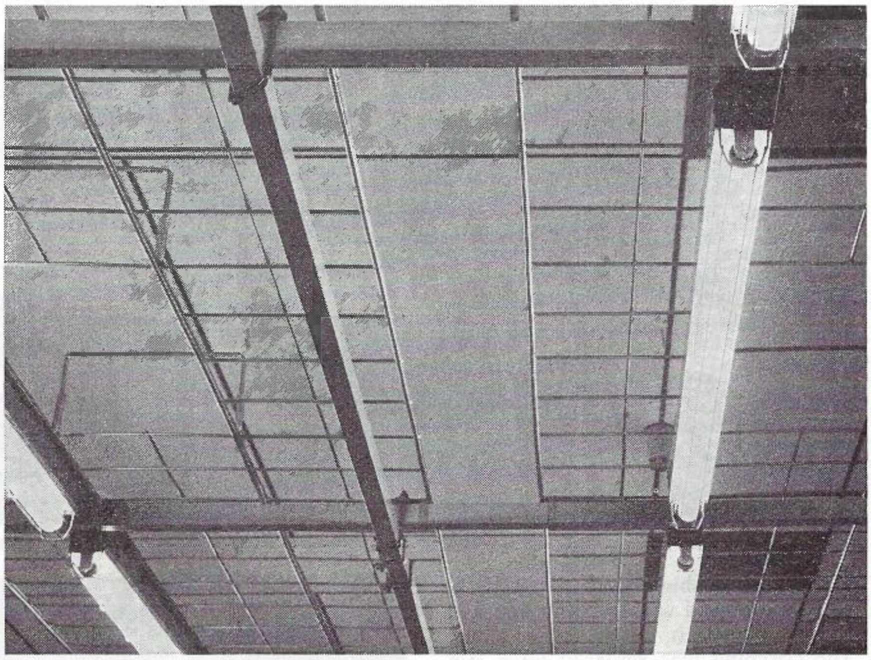

**Fig. 4. — General View of Mesh showing Access Holes and Cable Guards.**

Access for cabling, and to the jack fields of L. M. Ericsson's type BDD racks, is obtained by providing access holes on the basis of one hole between each two BDD racks; and one hole at each end of BDH-IDF suites. To prevent cables from crossing the access hole a removable guard is placed at each end of the access hole. The guard is removable for ease of transport. The mesh modules are placed on the tie bars and held in position with steel straps which are applied with a tensioner and locked with a sealer similar to the metal binding used on packing cases. Fig. 4 shows a typical mesh installation.

## CABLING ON MESH

Cables are run point to point, taking the shortest route. When cables have to be run inter suite, they pass between the jack fields if in a BDD suite. Cabling is placed randomly on the mesh. (See Fig. 5.) No special effort should be made to maintain packs. No ties should be used to fix cables to the mesh.

When a suite is partially equipped, running cables should be done carefully to ensure that they do not cover the area which will ultimately be occupied by a jack field. Temporary cable guides are erected to guide the cables around areas where jack fields will be erected.

## EXCHANGE LIGHTING

The lighting for equipment aisles is provided by a series of 40 watt fluorescent lights each fitted with a three pin outlet mounted in the side of the unit and a two feet cord with a plug attached. Power for each suite is supplied from a ceiling rose via a cord and three pin socket which is mounted at the end of each suite, and into which the first unit in each suite is plugged. Each unit in the suite is connected to the preceding unit by plugging the three pin plug into the outlet provided in the adjacent unit. The lights are suspended from the mesh on 'U' bolts which allow the light unit to pivot freely from the mesh and also facilitate removal of the light when access for racks is required in the suite. (Fig. 6.)

The type of light fitting found most suitable for mesh installations in crossbar exchanges is a 'Slim-Line' fitting not exceeding 4.5 in. from top to bottom. The 'Slim-Line' fitting is necessary to allow the gates on BDD type racks to clear the lights and also permits the upper relay sets of BDH racks to be removed without interference.

## TROUGH AND MESH COMPARISON

The results of an economic comparison based on a field trial conducted in N.S.W., where steel mesh was installed in an exchange with a capacity of 225 racks of crossbar equipment and 28 IDF racks, extended to cover the annual usage in that State, are given in Table 1.

**TABLE 1 — ECONOMIC COMPARISON OF TROUGH AND MESH IN N.S.W.**

**Erection time**

Mesh: 5216 racks at 21.3 minutes per rack = 1851 man-hours.

Trough: 5216 racks at 90 minutes per rack = 7824 man-hours.

Saving in erection time, 77%

**Cable cost**

Saving of 33% of cable.

**Cable running time**

Mesh: 3,595,000 yards at 1.98 minutes per yard = 237,270 man-hours.

Trough: 3,595,000 yards at 3.96 minutes per yard % 237,270 man-hours.

Saving of 50% of cable running time.

**Material cost**

Mesh: Cost per rack = \$3.70.

Trough: Cost per rack = \$2.94.

Loss of 20% of material cost.

## CONCLUSION

This paper has attempted to define both the reasons for and the nature of developments which have occurred over the past 10 to 15 years in cabling techniques for telephone exchanges.

The effects of escalating copper prices have been offset by utilising cables more effectively. Conductor gauges have been reduced from 0.020 inches to 0.0157 inches (0.4 mm). The length of cable runs has been reduced by using the direct cabling technique on steel mesh. Shortening the cable runs, eliminating stitching and boxing of cable packs, and reducing the time required to install the cabling medium, have significantly improved the economics of cabling.

Further cabling economies can be achieved by planning equipment layouts to take full advantage of the facilities offered by direct cabling.

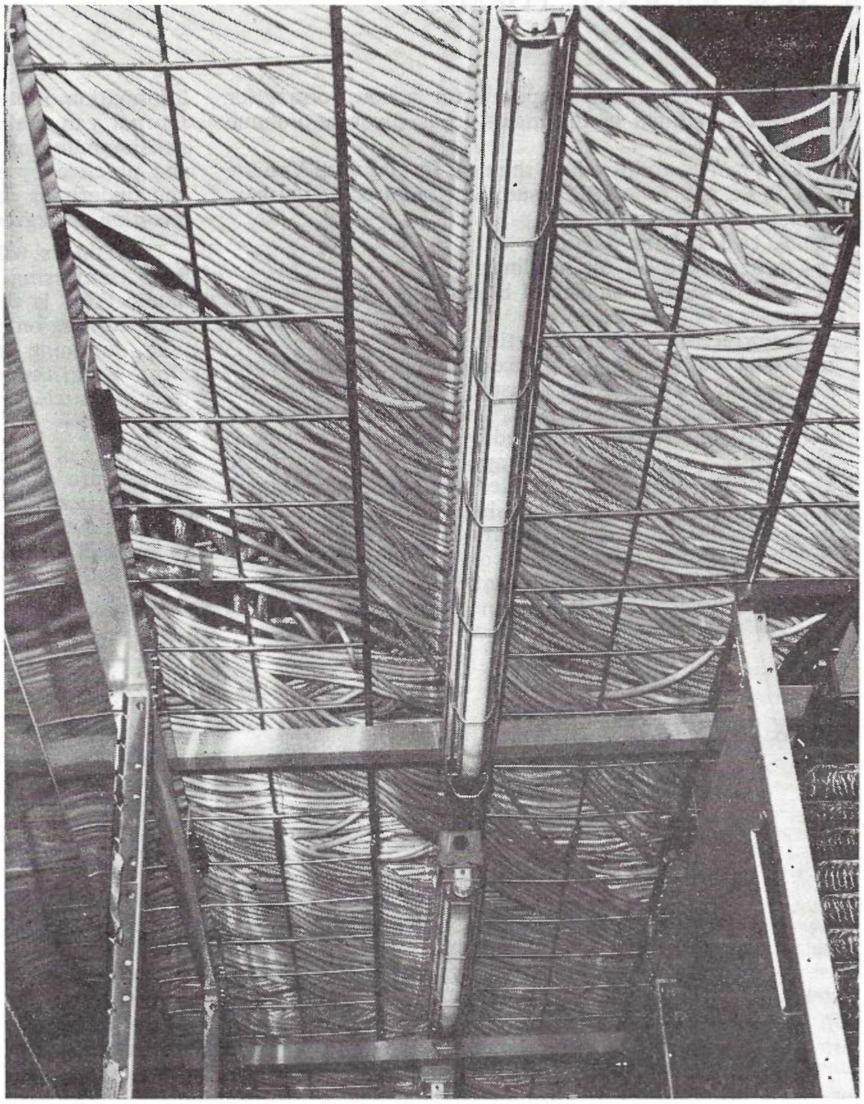

Fig. 5. — Cables Run Randomly on Mesh.

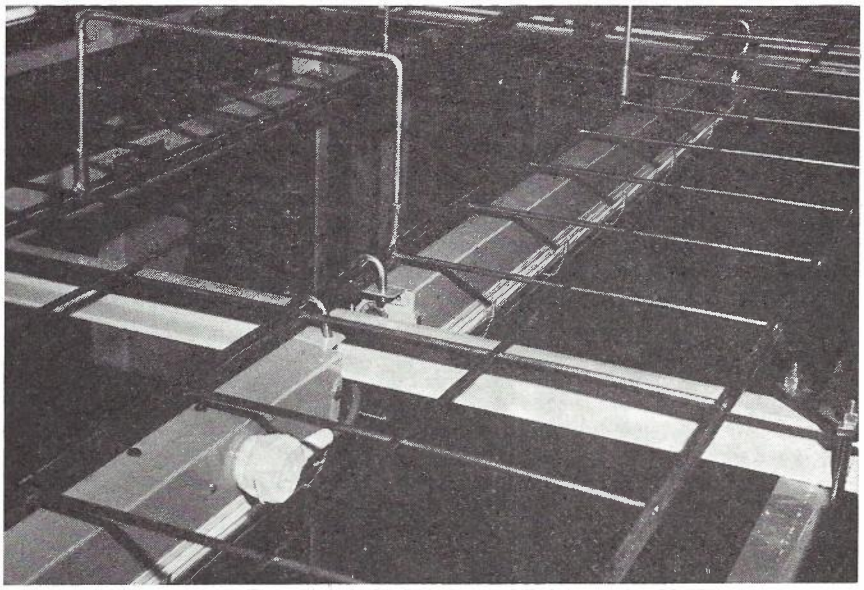

Fig. 6. — Fluorescent Lights Suspended from the Mesh.

# A NEW JOURNAL FORMAT

Readers will recall the proposals for a new format for this Journal outlined in the inside front cover of Volume 22 No. 1.

It is planned to introduce the new format with Volume 23 No. 2, i.e. the June 1973 issue. Key features of the new style Journal will be:—

- A two column layout.
- A new type set for headings.
- Use of various shades of blue to highlight key features of illustrations.
- Shorter, more concise articles.

Intending authors might please contact editorial representatives for a copy of the revised 'Notes for Editors and Authors' issued in October 1972. These notes describe the new format, and should be studied by all intending authors.

The Editors believe that the appeal and utility of the Journal will be enhanced if articles were generally shorter and more concise. The emphasis should be on fundamental and key issues, particularly on the 'why' of the subject in preference to a lot of detail on the 'how'. In earlier days the Journal was an important source of information that is now available in the Engineering Instructions and Information Bulletins of the Australian Post Office. The Journal can make a valuable contribution to the better understanding of this formal documentation of technology and practice by articles which highlight the fundamental and underlying issues of a topic, and which provide interesting background material.

The Editors will seek articles from the different disciplines comprising the Post Office's work force. Telecommunications is the business of installation and operations staff working on the plant itself, and those engaged in planning, designing and managing in the office and the laboratory. As in the past there will be room for the theoretical type of article as well as those on putting the theory into practice.

Articles of about 5000 words are appropriate but shorter articles are also welcome. Longer articles would be published in two or more parts. The essential requirement is that the author communicate effectively with the maximum number of readers who would have some interest in the topic.

Editor-in-Chief

# BOOK REVIEW

**TELEVISION MEASUREMENT TECHNIQUES**
**I.E.E. Monograph Series 9.**
**L. E. Weaver, 1971**
**Peter Peregrinus Ltd., p.p. 517, U.K. price £15**

**Chapter Headings:**
Measurement of level — Random noise — Interference — Non-linearity distortion — Linear waveform distortion — Insertion signals — Return loss — Miscellaneous measurements — Test patterns — Waveform monitors — Cameras — Videotape recorders — Telecine machines — Picture monitors — Appendixes — Index.

This work by Mr. L. E. Weaver, Head of the Measurements Laboratory, British Broadcasting Corporation, is a review of the techniques and equipment used in the field of video measurements and includes a considerable amount of material neither previously published nor readily available. It will be of particular interest to professional engineers and technicians engaged in television broadcasting and programme distribution.

It is a descriptive work, set out in a clear and logical sequence and, in addition to describing the techniques used in the author's organisation, gives comparisons with methods used by television authorities throughout the world. It assumes that the reader is already familiar with the principles of television operation and makes clear distinctions between tests carried out in normal operating situations and more precise measurements necessary as part of acceptance testing procedures.

The book includes an extensive treatment on waveform testing of colour television systems which is of particular relevance to the current Australian situation. In addition it includes a section detailing measurements employing insertion test signals (V.I.T.S.), enabling system performance to be assessed during normal programme transmissions.

The binding, paper, printing and illustrations are of very high quality and this presumably accounts for the high price of the book. It is unfortunate and surprising, however, to find that a simple diagram depicting the standard C.C.I.R. random-noise weighting network has been reproduced with component units transposed. This has apparently been overlooked during proof-reading.

This book clearly fills a gap in available television literature and will no doubt become a standard reference work in its field.

L. D. Sebire.

# TECHNICAL POSITIONS ESTIMATING PROCEDURE (PART 1)

*N. MATTHEWS**

## INTRODUCTION

The Australian Post Office has recently introduced a new system for determining the appropriate number and designations of staff required for Internal Plant Services Operations work. This article, in two parts, outlines the reasons for its development and its main features. Part 1 describes the background to the development of the new system and the methods and procedures used to make estimates of work load and staff required in an Engineering Section. Part 2 describes the procedures used by upper management to allocate labour resources to Engineering Sections in the light of their estimates.

The new Positions Estimating Procedure was designed just prior to the reorganisation of the Post Office for Area management as described in Volume 22, No. 1, of this Journal. This article, therefore, uses the new terminology appropriate to area management. The significant change is the replacement of the former field Division by an Engineering Section comprising two or more Divisions. A Supervising Engineer is the head of the Engineering Section.

## THE OLD "LOADING" SCHEME.

The 'Loading' scheme which was, at least nominally, in force until 1970 had been in existence since long before the second world war. There are still a few copies in existence of 'Engineering Administrative Circular No. 7 — Maintenance of Telephone Plant — Provision of Staff — Automatic Exchanges . . . ', which was issued in 1935. Earlier Circulars setting out uniform bases for the provision of staff for maintenance and installation of telephone plant are known to have been issued.

The version of the scheme with which most Engineering Branch staff are familiar was first issued in 1949, and re-issued in 1957, with a reduction of 15 per cent. in maintenance manhour requirements. The reduction was justified on the grounds that improvements in the equipment resulted in the need for less maintenance.

In 1958 an arrangement was introduced under which the States were authorised to approve allocation of staff in Divisional parcels up to 90 per cent. of the 1957 formula allowance. Requirements in excess of 90 per cent. were to be referred to Headquarters. The restriction was imposed as it was already clear that the 1957 formula allowed for more staff than necessary in some areas.

The 'Loading' scheme which had been in force for so long was theoretically based on a form of primitive work measurement analysis. The work that had to be done was broken down into its component tasks and an average duration for each of these tasks was determined. The tasks were then grouped in a way which associated them with particular items of equipment. The average number of manhours associated with the maintenance of each item of equipment for one year was thus obtained. In this way the total number of men needed to maintain a telephone exchange or any other type of telephone plant could be obtained by dividing the total manhours computed, by the hours a man would on average spent at work in a year. Fig. 1 shows a typical loading form then in use.

At the time the scheme was first designed there was limited experience in the Department in many fields of telephone plant which assumed major importance in latter years. There is little doubt that the various manhour values associated with items of equipment were adjusted so that the final answer gave the number of men that experienced Engineers and Supervising Technicians thought was 'right' for particular telephone districts.

From the above description it will be seen that the old 'Loading' scheme had a number of weaknesses built into it:

> The scheme seemed to imply an entitlement to the number of men given by the formula irrespective of whether or not there was a real work load for that number. The figures used were in fact based upon subjective judgments of the 'right' numbers of staff for particular districts at a particular time.
>
> The figures used were at best, average times and took no account of the wide variations in conditions in Australia.
>
> The scheme was based on maintenance techniques and equipment standards appropriate at the time. Changes in techniques and qualities of equipment cast doubt on its validity.
>
> Each new item of equipment had to be specifically added to the scheme, increasing its complexity, or regarded as equivalent to an item already included, further reducing its accuracy. In a time of rapid technological change it became impossible to amend the scheme frequently enough to keep up with new items which were introduced by the Department.
>
> The scheme assumed that the work associated with a piece of equipment was constant — which may have been more or less true under routine maintenance systems but was demonstrably false under qualitative maintenance systems.

On the other hand the scheme did have advantages. It was simple to operate, and, whilst few understood the basis of the scheme, everybody could see the effect of changes in the equipment installed in a district. The scheme gave clearcut decisions on the number of staff to which a district was 'entitled' which were widely accepted. There was therefore an 'objective' and uniform basis upon which top management could negotiate with the Public Service Board and staff Associations.

The Department had been for many years aware of the shortcomings of the scheme, but as long as the results of its operations were reasonably acceptable the Department's limited resources were better devoted to solving the many pressing post-war problems. However, by 1965 the old scheme was giving staff levels so much higher than needed that revision could not be deferred any longer. A number of factors had combined to make a thorough revision, not only of the factor values of the scheme, but of its basic design, obviously necessary:

> Staff levels as a percentage of the number 'justified' by the scheme varied widely. It was obvious that the variations were due to such factors as the policy of local managements, the availability of staff in particular areas, and special local conditions.
>
> The reductions in staff numbers below 'justified' had been largely obtained by reducing the numbers in lower level designations. Positions at Senior Technician and above were still provided at the 'justified' numbers.
>
> Because of the smaller number of lower designated staff it was common for high level staff to be employed on tasks more appropriate to lower level designations.

* Mr. Matthews was Engineer Class 3, A.P.O. Headquarters and is now Assistant Secretary, Rail and Special Projects, Department of Shipping and Transport, Canberra.

AUTOMATIC EXCHANGES—MECHANICAL STAFF.

E.M. 114,
Sheet 1.

## LOADING DETAILS.

| | | | No. Connected. |
|---|---|---|---|
| State: | | Subscribers' Lines .. | .......................... |
| | | Public Telephone Lines | .......................... |
| Exchange: | | Junction Lines .. | .......................... |
| | | Trunk Lines .. .. | .......................... |
| Type: | | Carrier Equivalent Lines | .......................... |
| Date........./.........../19....... | | | |
| | | Total .. .. | |

| | Exchange Maintenance. | | Substation Maintenance. | | Relief. | | Total. | | Actual Staff. |
|---|---|---|---|---|---|---|---|---|---|
| | Approved. | Proposed. | Approved. | Proposed. | Approved. | Proposed. | Approved. | Proposed. | |
| Super. Technicians .. .. | | | | | | | | | |
| Senior Technicians .. .. | | | | | | | | | |
| Technicians .. .. | | | | | | | | | |
| Technician's Assts. .. .. | | | | | | | | | |
| TOTAL .. .. | | | | | | | | | |

### EXCHANGE MAINTENANCE.

| Item | Equipment or Duty. | Units. | No. of Working Units in Situ. | Evaluation Man-hours per Unit per Annum. | Man-hours per Annum. |
|---|---|---|---|---|---|
| 1 | Uniselectors, Subscribers (Plunger) | Switches | | 0.15 | |
| 2 | Uniselectors, Subscribers (Rotary) | ,, | | 0.35 | |
| 3 | Uniselectors, Second or Junction (Plunger) | ,, | | 0.2 | |
| 4 | Uniselectors, Second or Junction (Rotary) | ,, | | 0.5 | |
| 5 | Allotters, Primary and Secondary | ,, | | 0.75 | |
| 6 | Secondary Finders | ,, | | 0.75 | |
| 7 | Master Switches | ,, | | 2.0 | |
| 8 | Group Selectors, First and Incoming (Pre-2000 Type) | ,, | | 2.5 | |
| 9 | Group Selectors, First and Incoming (2000 Type) | ,, | | *R2.0 T2.75 | |
| 10 | Group Selectors, Local or Intermediate (Pre-2000 Type) | ,, | | 2.0 | |
| 11 | Group Selectors, Local or Intermediate (2000 Type) | ,, | | R1.5 T2.1 | |
| 12 | Final Selectors, P.B.X. (Pre-2000 Type) | ,, | | 2.75 | |
| 13 | Final Selectors, P.B.X. (2000 Type) | ,, | | R1.1 T2.85 | |
| 14 | Final Selectors, Regular (Pre-2000 Type) | ,, | | 2.5 | |
| 15 | Final Selectors, Regular (2000 Type) | ,, | | R0.85 T2.6 | |
| 16 | Repeaters | ,, | | R1.25 T2.5 | |
| 17 | Selector Repeaters | ,, | | 3.0 | |
| 18 | Switching Selector Repeaters | ,, | | 5.0 | |
| 19 | Discriminating Selector Repeaters | ,, | | R2.5 T5.0 | |
| 20 | Discriminating Repeaters (Siemens) | ,, | | 3.0 | |
| 21 | Discriminating Selectors (Siemens) | ,, | | 3.5 | |
| 22 | Line Finders Bimotional | ,, | | 3.0 | |
| 23 | Miscellaneous Bimotional Switches | ,, | | 1.0 | |
| 24 | Line and Cut-off Relays | Pairs | | 0.1 | |
| 25 | Miscellaneous Relay-Sets | Relay-Sets | | 0.5 | |
| 26 | Subscribers Meters—Single Coil | Meters | | 0.05 | |
| 27 | Subscribers Meters—Double Coil | ,, | | 0.2 | |
| 28 | Power and Air Conditioning, City Exchanges | Fixed | | 4,000 | |
| | Power and Air Conditioning, Full Air Conditioning | ,, | | 1,000 | |
| | Power and Air Conditioning, Oil Filters | ,, | | 750 | |
| | Power Plant—No Air Conditioning | ,, | | 500 | |
| 29 | Main Distributing Frame | {Total Local 1st Select's or Equiv. Sws.} | | 3.0 | |
| 30 | Test Desk | | | 7.0 | |
| 31 | Fault Attention | Tot. Maj. Sws. | | 1.0 | |
| 32 | Total Items 1 to 31 | | | | |
| 33 | Miscellaneous 5% Item 32 | | | | |
| 34 | Special Allowance | | | {Show details Sheet 2} | |
| 35 | Complaints handled by Technicians | | | | |
| 36 | Total Items 32 to 35 | | | | |
| 37 | Supervision and Clerical | | | Fixed | |
| | | | | Total .. | |

* Prefix R—Exchanges with Automatic Routiners.
Prefix T—Exchanges with Manual Test Sets.

O/N. C3522/67....

**Fig. 1. — Typical Early Loading Form.**

There had been a significant change in the 'Functions' laid down as appropriate to the various designations of technical staff, and as a result of the change higher salaries had been awarded to all Technician designations.

The Qualitative Maintenance system was now Departmental policy, and this system, combined with the much improved reliability of modern telecommunications plant, was expected to result in both a significant reduction in the staff needs of telecommunication districts and in different proportions of the various designations, than had been appropriate to the Routine Maintenance system.

## WHY HAVE A POSITIONS AUTHORISING PROCEDURE?

The need for general rules of staffing the organisation is not peculiar to the A.P.O. or the Commonwealth Public Service; it applies equally to the Army, the Education Departments, and large commercial enterprises. In setting up these rules, it must be remembered that, whereas in a small organisation jobs can be fitted to people, the Public Service Act demands that positions be created only in accordance with work requirements and that the most appropriate people be appointed to them, i.e., we must load and grade positions.

In addition it is essential, for practical reasons, to have a set of general procedures for establishing positions. Each year the Public Service Board submits to Parliament a certificate stating that positions have been allocated to provide an efficient and effective Service. Without a system of Public Service Board procedures (Group Proposals scheme), individual staffing proposals would need to be prepared in the A.P.O. in their thousands each year and referred to the Public Service Board or its State Representatives. To reduce this 'paper war," the Public Service Board some years ago agreed to the provision of a total of Technical Staff positions to the A.P.O. annually on the basis of a general group proposal. This 'pool' of positions is held by the A.P.O., split up into State and Divisional pools, and allocated to various staff during the year by the A.P.O. as and when work demands justify. A necessary prerequisite of this system is that the Public Service Board has approved the procedures followed by the A.P.O. in allocating positions from the 'pool' so that the Public Service Board in turn can certify to Parliament that efficient staffing procedures are being followed.

Each year 'group proposals' for the following financial year are prepared by the A.P.O. State Administrations bearing in mind:

Likely need for staff in the coming 12 months to maintain existing plant in satisfactory condition;

Estimates of the labour force required to meet the programmed capital works;

Estimates of the trends in labour productivity in the maintenance area;

The likely numbers that will be regraded to different level positions due to the operation of the approved grading scheme.

The group proposals from all States are considered together in Headquarters in the light of:

Likely funds levels and staff ceilings set by the Federal Government;

The overall policy of the A.P.O. in regard to service versus cost;

The overall labour market.

In the end, a group proposal is forwarded to the Public Service Board, and if it agrees, Executive Council approval for the creation of the additional positions necessary is sought. The total number of positions available is allocated to the A.P.O. as a 'pool.' As the total number of positions allocated is recorded in Parliamentary statistics the 'pool' should be adequate for needs, but not bigger than necessary.

## THE CHARACTERISTICS OF A SUITABLE POSITIONS AUTHORISING PROCEDURE

In setting up general procedures or rules for authorising positions, there are two very important points to guard against. They are:

Over-emphasis on rules; hence the stereotype of a bureaucrat as a man who punctiliously keeps to formal procedures however inappropriate;

Rigidity; hence an inability to adapt fast enough to changing conditions. This is most likely where managers are used to stable conditions and now find, either because conditions have changed or because they have entered a new and different kind of situation, that their old methods are unsuitable.

With these problems in mind and recognising the need for a sound set of general procedures for authorising positions, a Joint Working Party from the A.P.O. and the Public Service Board during 1966/67, reviewed the whole question. Various possibilities were considered:

(i) Maintain the earlier approach of the Engineering Instruction L0001, but completely update;

(ii) Undertake Industrial Engineering studies of maintenance activities leading to activities lists and agreed times for each activity;

(iii) Use one or more in combination of the procedures used by Overseas Administrations.

A number of procedures used by overseas Administrations were investigated, but none of them was suitable for Australian conditions. It was finally decided that what was required was not a loading scheme which led to a 'justified' staff level for each and every Technician's District in Australia; the problems of staffing the maintenance operations of the A.P.O. are far too complex for any one or series of loading formulas to resolve. It was concluded that effective and efficient staffing and the inter-relation between staff, plant and practices can best be determined by the local management group (The engineering management and district O.I.C., comprising the telecommunication management area — previous field division). These are the people held responsible for telecommunications operations (in regard to both service and cost) in their areas.

## DEVELOPMENT OF THE POSITIONS ESTIMATING PROCEDURE

The Joint Working Party, after considerable study, recommended that the Department abandon its traditional 'loading' scheme, with its mechanical and simplistic application of fixed factors. It recommended the adoption of a procedure based upon a staff estimate prepared in each district. The estimate, because it would be prepared by local management,, including the O.I.C. of the district, could be expected to take account of all local conditions, quality of staff, and so on. But because it was prepared locally it would be difficult to ensure that policies laid down by top management were adhered to. It was therefore necessary to include in the procedure a means of checking local estimates against an independent yardstick—the Reference system. The Reference system would also be made to provide the Public Service Board with the information and assurances it needed in order that it could discharge its responsibilities to Parliament under the Public Service Act — to ensure that staff provided were, both in designations and numbers, appropriate for maximum efficiency and effectiveness in the Department's operations.

## THE POSITIONS ESTIMATING PROCEDURE.

P.E.P. applies to all Engineering Sections directly responsible for the maintenance of telecommunication plant and as such, the following procedures are undertaken annually by all these Sections. The procedures have been designed basically as a vehicle for preparing sound estimates of position requirements. Practically all the forms concerned remain in a Section and are meant to be used in the Section in the best manner to achieve the desired results. However for Sections above the reference level, or for Sections outside the referencing system, the P.E.P. studies will form the basis for discussion with Administration Branch and Personnel Branch officers prior to the preparation of staffing proposals to the State Public Service Inspector. It is therefore desirable to retain some uniformity of approach to recording the estimates, but at the same time ensuring that the 'rules' do not overshadow the need for real estimates.

Briefly P.E.P. involves the following:

The Sectional Manager (Supervising Engineer) determines detailed performance objectives for the operation of the telecommunication plant of the Section. The objectives must take account of overall performance objectives set by higher management.

The Telecommunication Technical Officers in charge of districts, in association with their controlling Engineers, estimate annually the work load involved, the organisation required, the changes in maintenance type plant facilities needed and the staff positions required to meet the above objectives;

The Supervising Engineer reviews the estimates from all districts in the Section and provided—

(i) He is satisfied the district estimates are soundly based and forward looking and, in total, are within the resources that will be available to the Section and

(ii) The existing technical staff positions for the Section are within reference;

he submits a proposal to the Authorising Officer controlling the State 'pool' of technical positions for the provision of appropriate positions as from specified dates in the coming calendar year. Alternatively he advises of the need to withdraw surplus positions.

If the existing or required technical staff positions for the Section exceed the reference, the Supervising Engineer refers his requirements to the higher management for prior approval to submit a proposal to the Authorising Officer, or for consideration by the Joint Review Team.

The procedure is designed to permit field management to participate actively in planning, implementing and controlling local maintenance and installation policies, and in determining the numbers and levels of staff needed to carry out those policies. The effectiveness of the procedures is dependent on close collaboration between the controlling engineer and the district O.I.C.'s during the preparation of the works programme and estimation of staff needs.

To initiate the annual P.E.P. estimates, by far the best arrangement is for the engineers and district O.I.C.'s to meet together and review the performance in regard to both service and cost of the Section as a whole and of that for each district, and reach agreement on targets and policies for the coming year.

Before tackling any estimation of work load for the coming year, and determining staffing patterns to meet it, it is desirable that the O.I.C. and the Section engineering management have a critical look at the existing pattern of organisation. It may be possible to improve the break up of work between groups of staff, and it may be possible to improve the lines of control.

Determining a maintenance works programme for the coming year and estimating the labour involved is the most crucial phase in P.E.P. There is no simple relationship between the objectives determined by management and the staff needed to achieve them. There are many answers depending on the state of the plant, the maintenance practices it is determined should be followed, the investment which shall be made in service aids, vehicles, training, etc. Many times it will occur that in preparing these estimates fresh and more efficient patterns of operation may come evident but that several years will be needed to implement the ideas. P.E.P. is an evolutionary process designed to produce a continuing improvement in operations. The following steps should be used in preparing the estimates:

The district O.I.C. prepares a programme of work for the main activities of his district for the coming year. The controlling engineer discusses the programme with him and gives it general approval before the district estimates are prepared.

The manhours required to carry out the work are estimated on a form E872 (see Fig. 2).

The designation of staff most appropriate to each task is determined, whether such staff are available or not.

Allowances are made for the training of staff, overtime, leave, staff control, district management, any special local circumstances, and finally the number and quality of the staff already available in the district.

The number of staff required in the district and the designations appropriate to them in the coming year is determined, and recorded on a form E873 (see Fig. 3).

The number and designations of additional staff required, or of existing staff surplus to requirements is found.

The district estimates are review and revised if necessary.

The district staffing estimates are discussed and critically examined by the Supervising Engineer and his staff to ensure that all work proposed is necessary, that the manhours estimated are reasonable, and that staff of the appropriate level is being sought. Earlier decisions on service or installation standards may need to be revised as a result of seeing the staff needed to achieve them. Similarly the policies regarding staff relief, overtime and work to be carried out by the Sectional pool may need to be revised.

It may be necessary to revise district works programmes and proposed district staff numbers and levels in accordance with the resources available to the Section. The procedure is designed to make the likely effects of such revisions accessible to the Supervising Engineer and through him to higher management.

The basic philosophy of the T.P.E.P. as finally developed could be summarised as follows:—

The Supervising Engineer should accept full responsibility for the efficient and effective performance of his Section and should be given authority commensurate with that responsibility.

Assessment of the Sectional performance and comparison with other Sections, is the responsibility and duty of higher management in the Engineering Division.

The Department's plant is maintained under a system of Quality Control (Qualitative Maintenance)

P.M.G'S DEPT.
E 872
(Sept. '71)

Technical Positions Estimating Procedure

ESTIMATING SHEET — (* MAINTENANCE/PROVIDING LOAD)

*Delete as necessary
**Based on future patterns of recruitment

| DISTRICT | Technical | | | | | Non-Technical | | | GRAND TOTAL (Manhours) |
|---|---|---|---|---|---|---|---|---|---|
| CELL | Estimated Technical Manhours | ** Functional Distribution of Manhours | | | | Functional Distribution of Manhours | | | |
| Proposed Work | | Telecom. Assistant | Telecom. Tradesman | T.T.O. 1 | T.T.O. 2 and above | | Clerical | Labourer/ Cleaner | |
| (A) | (B) | (C) | (D) | (E) | (F) | (G) | (H) | (J) | (K) |
| | | | | | | | | | |
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| | | | | | | | | | |
| TOTAL ESTIMATED LOAD | | | | | | | | | |

Fig. 2. — Manhours Estimating Form (E 872).

P.M.G.'S DEPT.
E 873
(Sept. '71)

**Technical Positions Estimating Procedure**

**DISTRICT SUMMARY SHEET – ..............................**
(District)

| LINE | Description (A) | Technical: Total Technical (B) | Technical: Telecom. Assistant (C) | Technical: Telecom. Tradesman (D) | Technical: T.T.O. 1 (E) | Technical: T.T.O. 2 and above (F) | Non-Technical: (G) | Non-Technical: Clerical (H) | Non-Technical: Labourer Cleaner (J) | GRAND TOTAL (K) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Estimated Maintenance Load in Hours (from E 872/s) | | | | | | | | | |
| 2 | Estimated Providing Load in Hours (from E 872/s) | | | | | | | | | |
| 3 | TOTAL Estimated District Load in Hours (lines (1) + (2) | | | | | | | | | |
| 4 | Trainee contribution in hours (from E 870) | | | | — | — | — | — | — | |
| 5 | Estimated overtime in hours | | | | | | | | | |
| 6 | Expected contribution from outside Districts in hours | | | | | | | | | |
| 7 | Sub-Total (4) + (5) + (6) | | | | | | | | | |
| 8 | District Load manhours requiring positions (line 3 minus line 7) | | | | | | | | | |
| 9 | District staff relief required in hours **(see instruction)** | | | | | — | | | | |
| 10 | Relief hours provided to other Districts | | | | | — | | | | |
| 11 | TOTAL District Staffing Hours lines (8) + (9) + (10) | | | | | | | | | |
| 12 | District Staffing Man-Year Equivalents line $\frac{11}{2000}$ | | | | | | | | | |

| LINE | Description | Technical: Total Technical | Technical: Telecom. Assistant | Technical: Telecom. Tradesman | Technical: Telecom. Technician | Technical: T.T.O. 1 | Technical: T.T.O. 2 and above | Non-Technical | Non-Technical: Clerical | Non-Technical: Labourer | GRAND TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 13 | Proposed number of staff for district (other than trainees) from proposed organisation chart E 871 | | | | | | | | | | |
| 14 | **Existing Positions (other than Trainees)** | | | | | | | | | | |
| 15 | Spare | | | | | | | | | | |

**Fig. 3. — District Summary Sheet (E873).**

administered by the local (Sectional) management team.

The local management team in each Section is best qualified to assess the effects of the complex inter-relationships between all of the following factors:

(a) The type (s) of equipment, and the practices appropriate to them;
(b) The condition of the equipment, and its place in the telecommunications system;
(c) Local conditions (climate, installation activities, distances, etc.);
(d) The quality of staff available (training, ability, experience), and the functions they are expected to perform;
(e) standards of service experienced by the customers;
(f) Restraints imposed by Departmental policies (e.g., availablity of resources) and Industrial Awards, etc.
(g) The application of modern information and control systems and management techniques in the local environment.

# TECHNICAL NEWS ITEM

## GRATIFYING PROGRESS IN METRIC CONVERSION

Householders by 1974 will be buying electric radiators still rated, for example, at 1000 watts (or 1 kw), but the flexible cables connecting to a power point may be a little smaller and lighter.

Their new refrigerators will be measured in cubic metres and the outside dimensions in millimetres or centimetres. This, and other consumer products, are likely to change little in appearance, but dimensions, weights and temperatures, for example, will be specified in millimetres, kilograms and degrees Celsius.

Gratifying progress has been made in planning for the conversion of the manufacturing industry to metric measurement, Mr. H. J. Brown said recently. Mr. Brown is Chairman of the Metric Conversion Board's electronics and electrical engineering sector committee and a councillor of the Australian Telecommunications Development Association.

He said that metrication would make little difference to TV sets. Many electronic components already were made in metric measurements and the picture sizes would remain much the same as now, though measured in centimetres instead of inches.

However, one important benefit which conversion to metric standards offered to all industries was a unique opportunity to rationalise and modernise industrial practices to avoid unnecessary diversity in manufacturing products, and to bring Australia's technical standards into accord with those adopted internationally, now almost entirely in metric terms.

"In reviewing standards throughout industry," Mr. Brown said, "committees not only have considered details of changing from imperial to metric units of measurement, but also have carefully studied what rationalisation of sizes may be obtained. In many cases this will lead to reduction in numbers of sizes and models required, with obvious benefits in simplification, longer production runs and reduction in store inventories."

In the electronics and electrical sector decisions had been made on nearly every question of adopting metric measures, though detailed work by the Standards Association was still in progress.

The hertz (Hz) would continue as the unit of frequency, and the watt (W) of power. The newton (N) would become the unit of force, the pascal (Pa) of pressure and the joule (j) of energy. In many cases the practical unit would be 1000 times larger, for example, the kilowatt, the kilojoule, and so on.

Like the watt, the other international system units mentioned are named after learned men who contributed importantly to scientific knowledge.

Mr. Brown said that it had been decided in preparing Australia's metric conversion not to replace the kilowatt-hour by the megajoule (one kilowatt-hour = 3.6 megajoules). The reason was the existence of great numbers of instruments measuring in kilowatt-hours, including all household electricity meters.

Mr. Brown said that preferred sizes of wires had been established by the Standards Association and referred to wiremakers for the necessary action. These included enamelled and uncoated magnet winding wires, quantities of which were consumed in making articles for telecommunications use.

Cablemakers were thoroughly considering standards for flexible cables of all kinds, including those used in domestic wiring, in telecommunications equipment and in telecom networks. They were doing so in association with user industries and with the Standards Association of Australia.

Existing standards would be revised in view of the great improvements in insulating materials which had occurred in recent years.

Broadly, the electronics and electrical committee has recommended that cablemakers should follow the International Electrotechnical Commission standards, instead of the present Australian standards, which require much thicker cables, now made unnecessary by improved methods and materials. After new cable standards have been adopted, wiring rules will be revised by the Standards Association for application throughout Australia.

Mr. Brown said that in the telecommunications industry few changes would occur in manufacturing processes or design. But many ATDA companies already were well advanced in planning for replacement or modification of tools, gauges and instruments.

Metal sheet and sections, fasteners and screws, and other materials and mechanical components, would all be available and produced almost exclusively in metric units from 1974 onwards to standards already converted. Manufacturers would have to take this into account in their planning and designs.

# OUR CONTRIBUTORS

*B. E. WOODROW*

*M. J. KIMBER*

*R. M. TODD*

B. E. WOODROW, author of the article 'A Century of Telecommunications in the Northern Territory,' Part 1, joined the Postmaster-General's Department in 1951. As a draftsman in the field of mechanical engineering, he served with the State Electricity Commission of Victoria from 1935 until 1947, when he joined the Department of Civil Aviation as aircraft draftsman. He became Chief Draftsman in South Australia in 1959.

★

M. J. KIMBER, co-author of the article 'Darwin to Nhulunbuy Tropospheric Scatter System', is an Engineer Class 3 engaged in the management of the installation of the Darwin to Mt. Isa Radio Relay System. Mr. Kimber was a cadet engineer during the last three years of an Engineering course at the University of Adelaide. He graduated in 1964 with an Honours Degree of Bachelor of Engineering and began work in the South Australian Radio Section of the Postmaster General's Department, where he was initially engaged in the installation of small capacity VHF Systems. Subsequently, he directed segments of the installation of the Adelaide-Broken Hill and Adelaide-Mt. Burr Television Bearer Systems. Following upon this, he supervised the installation, acceptance testing and maintenance of the South Australian portion of the Adelaide-Melbourne Radio Relay System. While associated with this latter aspect, he was a member of a working party established to improve its reliability. During this time he was also responsible for the installation of HF Subscribers' Radiotelephone Systems at Alice Springs and Katherine. In the years 1967 and 1968 Mr. Kimber was the Project Engineer concerned with the installation of the South Australian portion of the East-West System, and in 1969 was promoted to Divisional Engineer Darwin-Mt. Isa Project and since then has been responsible for that Project and for the Darwin to Nhulunbuy Tropospheric Scatter System.

Mr. Kimber is a member of the Institute of Radio and Electronic Engineers.

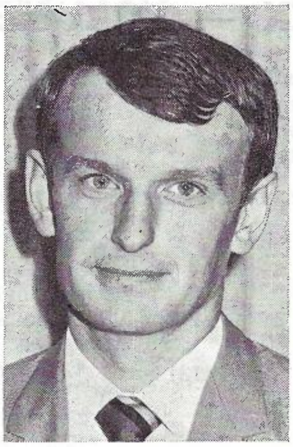
★

N. R. MATTHEWS, author of the article 'Technical Positions Estimating Procedure', joined the P.M.G.'s Department as a Cadet Engineer in 1950. After completion of the Cadetship, he commenced as an Engineer Grade 1 in the Telegraph Section, Victoria, later transferring to the Mildura Division as Group Engineer and later, Divisional (Class 3) Engineer. In July 1968, Mr. Matthews was transferred to A.P.O. Headquarters as a member of the Technical Positions Estimating Procedure Testing Team. After six months as a Controller in the Industrial Relations Division of A.P.O. Headquarters, he took up duty as the Controller, Rail, in the Department of Shipping and Transport and since March 1972 has been acting Assistant Secretary, Rail and Special Projects in that Department.

★

R. M. TODD, author of 'A Century of Telecommunications in the Northern Territory, Part 2', joined the Postmaster General's Department in 1946 as a Technician in Training. He was engaged in exchange and subscribers' maintenance and installation until 1961, when he was appointed as a Trainee Engineer. Following completion of the Bachelor of Technology Degree in 1963, Mr. Todd was posted to the Woomera Project Sub-section of the South Australian Administration. Here he was associated with the 1964 East-West Aerial Reconstruction Project and subsequently was responsible for the organisation and control of the 1965 North - South Reconstruction Project. In 1966 Mr. Todd transferred to the Bearer Provision subsection of the Planning Branch in Adelaide, and, in this section has anaIysed and planned extensions to the capacity of the aerial route between Darwin and Port Augusta. Mr. Todd is currently acting as Engineer Class 3 in the Transmission and Lines Planning Section, Sydney.

*E. J. MASON*



*V. W. LANGE*

*M. T. MURNANE*

E. J. MASON, author of the article 'Cabling in Telephone Exchanges', is at present a Senior Technical Officer, Grade 2, in the Telephone Switching Equipment Branch at Headquarters and has for some years been engaged in the development of methods and practices in the Installation Practices Section.

He commenced duty with the P.M.G.'s Department in 1947 after completing rehabilitation training at the R.M.I.T. as a radio technician. Prior to commencing duty at Headquarters he was employed on exchange installation as a supervising technician.

He is an Associate Member of the Institute of Industrial Engineers.

V. W. LANGE, co-author of the article 'The Darwin to Nhulunbuy Tropospheric Scatter System', joined the Australian Post Office in 1958 as a Technician-in-Training. In 1967 he completed a Bachelor of Engineering (1st Class Honours) at the University of Adelaide. He also obtained a Master of Engineering degree from the University of Adelaide for work carried out between 1967 and 1969 on active antennae. In 1969 he joined the Radio Communication Installation Sub-section, where he was engaged in installation and commissioning of broadband systems. Since 1970 he has been Engineer Class 2, Darwin-Mt. Isa Project Sub-section, and was engaged in all aspects of design, installation and commissioning of the Darwin-Nhulunbuy Troposcatter System.

Mr. Lange is a Member of the Institution of Electronics and Electrical Engineers (America).

★

M. T. MURNANE, author of the article 'A New Wall Telephone', joined the P.M.G.'s Department in 1951 as a Technician-in-Training and qualified as Engineer in 1959. After four years at Postal Workshops, Melbourne, he was promoted as Engineer Class 2, Subscribers' Equipment Design Section at Headquarters. He is at present acting Engineer Class 3 and is associated with the introduction of the new cordless P.M.B.X.'s.

## TECHNICAL NEWS ITEM

**STEP IN TIME.**

Standard Time was retarded by one second on Saturday, 1st July, 1972, at 10.00 a.m. Australian Eastern Standard Time. This adjustment was made to keep our clocks within approximately seven-tenths of a second of astronomical time (time given by the rotation of the earth).

It has long been known that the traditional method of keeping time, namely measuring the rotation of the Earth on its axis, does not produce a uniform scale of time; in fact the gradual slowing down of the Earth's rotation means that such a time scale is also slowing down or losing time.

Time-keepers have therefore introduced a very accurate and contant scale of time based on the behaviour of caesium atoms when subjected to carefully controlled magnetic fields. The time scale in this way is called Co-ordinated Universal Time (UTC) and it is this which is used to provide Standard Time around the world.

Since astronomical time is continually running slow it means that Standard Time gradually gains on astronomical time — at present by approximately one second per year. In order to keep these two times reasonably close together, it was decided by international agreement to retard UTC and thus Standard Time, by one second on 1st July.

This adjustment was made at the same instant around the world by causing the last minutes of 30th June at Greenwich to be 61 seconds long. In Eastern Australia this "long minute" commenced at 9.59 a.m. on Saturday, 1st July. The extra second in this minute is known as a leap second and started where 10.00 a.m. would have been and finished at the "new" 10.00 a.m.

All Standard Time in Australia underwent this adjustment. This included radio time signals, the Post Office telephone speaking clock services and the Post Office time signal broadcast from station VNG, Lyndhurst, Victoria, on short wave radio.

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| 3 | October | 1972 | 165-228 |


(T.N.I. refers to a Technical News Item or a Letter to the Editors.)

## TECHNICAL NEWS ITEM

### AUTOMATIC LINE FAULT ANALYSIS (ALFA)

A revised external plant line fault analysis system to be known as ALFA 2 was introduced throughout the Commonwealth on 1 July 1972, to cover aerial and cable faults on all types of external plant (subscriber, junction and trunk). It will replace the existing ALFA 1 system, which has been in operation since 1966 and was designed mainly for aerial plant.

The main features of ALFA 2 may be summarised as follows:—

(i) One composite fault docket will be used by the field staff to record all faults. Data will be collected on non-service affecting faults in addition to those which affect service.

(ii) Fault codes, except those for aerial plant, have been completely revised so that fault information can be obtained under the categories of 'in length', 'at joint', 'in external apparatus' and miscellaneous. (F.O.K. exchange equipment, etc.). Provision has been made so that fault codes can be amended as the need arises and new fault codes created to cater for new equipment and techniques.

(iii) Provision has been made on the fault docket for special surveys to be undertaken and a computer listing of theinformati on can be made available. This facility can be used either by the Section, the State or by Headquarters.

(iv) Two types of fault reports will be available:

(a) Operations reports on a quarterly basis covering:

- plant performance
- excessive faults*
- full listing of faults
- recurring faults on services*
- fault clearance times.
- (* Also available monthly if required)

(b) Analysis reports on a yearly basis covering:

- analysis of fault causes
- analysis of fault totals
- analysis of services affected

These reports have been designed to provide an information system for management and only one copy of each report will be forwarded to the area concerned.

## TELECOMMUNICATION JOURNAL OF AUSTRALIA
## AUSTRALIAN TELECOMMUNICATION RESEARCH

Increasing costs have forced an upward revision of subscription rates for the above journals with effect from 1972 calendar year, which is also the volume year. **The new annual subscription rates** and the first volume affected are shown below:

Telecommunication Journal of Australia : $2.50 ($1.80)* as from Vol. 22 Nos. 1-3 (1972).

Australian Telecommunication Research : $3.00 ($2.50)* as from Vol. 6 Nos. 1-2 (1972).

**Single copies** of the current subscription year are available:

Telecommunication Journal of Australia : $0.85 ($0.60)*

Australian Telecommunication Research : $1.50 ($1.25)*

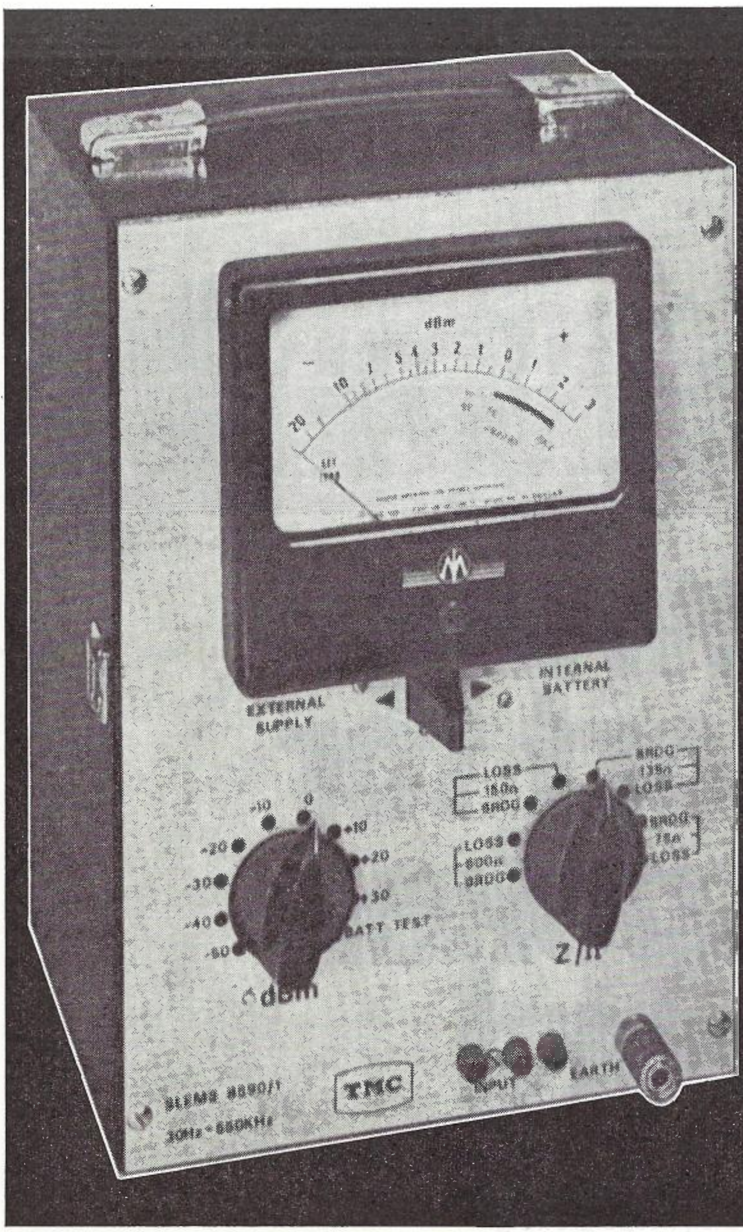
**Back numbers** (other than current subscription year), if available, are sold at the following rates:

Telecommunication Journal of Australia : $0.75 ($0.50)*

Australian Telecommunication Research : $1.25 ($1.00)*

(*The bracketed rates so marked apply only to residents of Australia (and Papua-New Guinea) who are also members of the Telecommunication Society of Australia.)

The subscriptions are quoted in Australian Currency, and proper conversion must be made from other currencies, including U.S. and Canadian dollars. All rates include surface mail postage.




# sensitive level measuring set for telecommunication systems

**PTMC Sensitive Level Measuring set, S.L.E.M.S. Type B590/1, is a portable level meter designed to cover a wide field of measurement in communication systems.**

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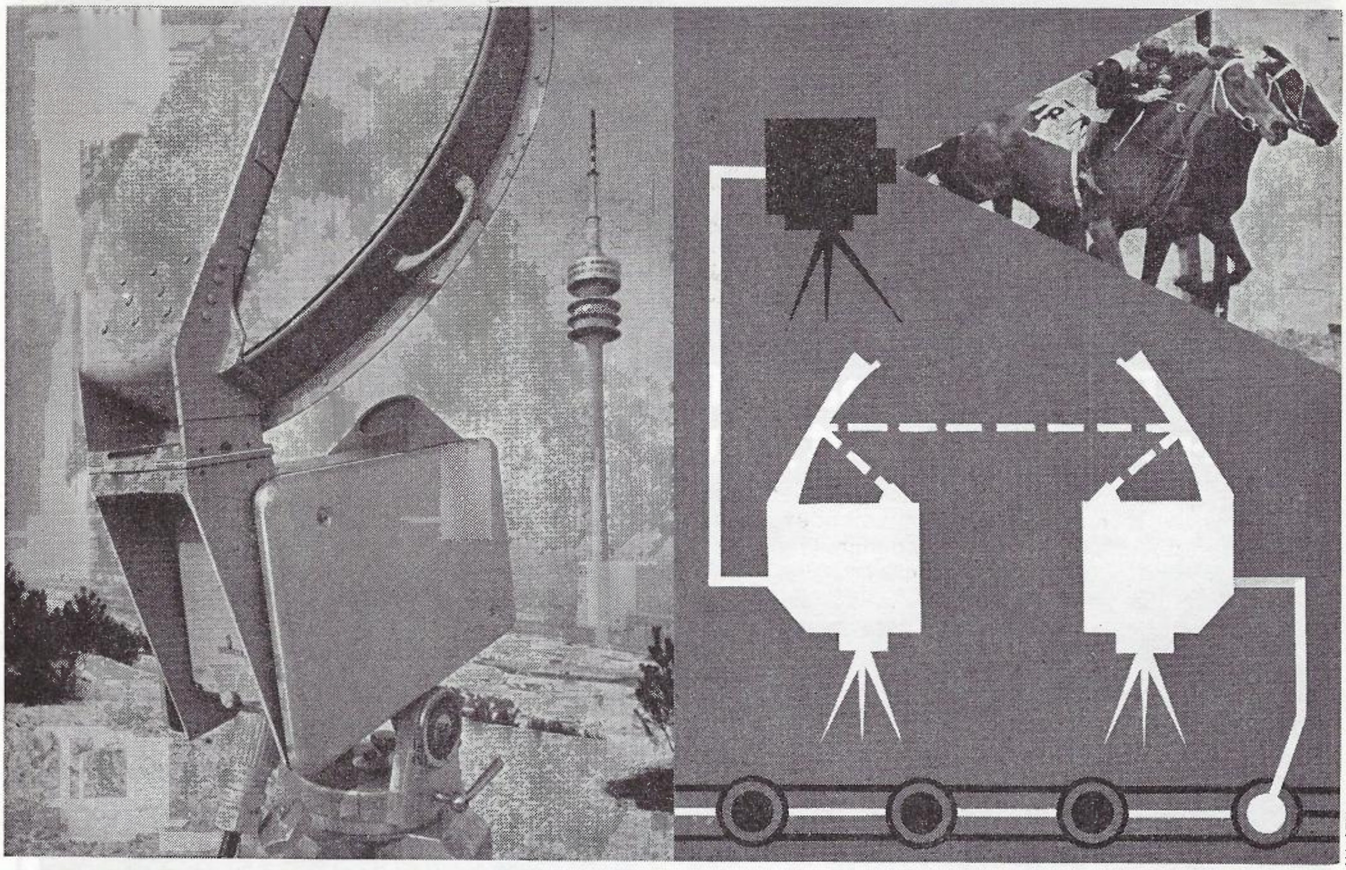
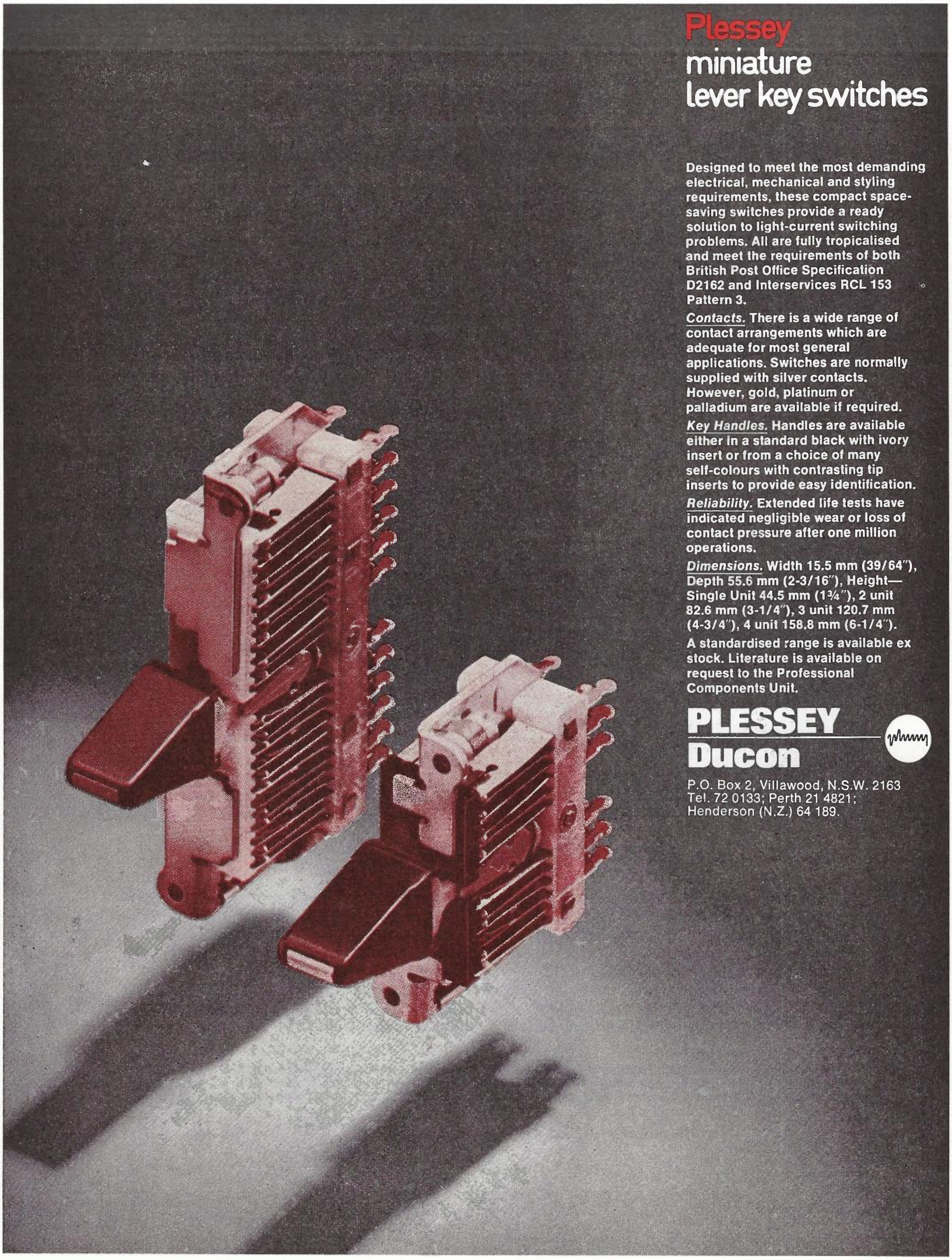


SH427N

# Siemens TV Transmission Equipment

Hy-Q
Hy-Q ELECTRONICS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# THE TELECOMMUNICATION JOURNAL OF AUSTRALIA

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OCTOBER 1972


CONTENTS



COVER
New Wall
Telephone

The TELECOMMUNICATION JOURNAL of Australia

# ABSTRACTS: Vol. 22, No. 3

**BYRNE, B.M.: 'Cable Protection and Maintenance Testing Technique, Part 2'; Telecom. Journal of Aust., October 1972, page 187.**

Part 1 of this article in the previous issue of the Journal describes various Cable Protection activities, largely as applied in the Queensland Administration of the Australian Post Office. Cathodic Protection in Corrosion Prevention is discussed briefly in design, anode materials and performance and results. Present investigations are noted. Gas Pressurisation is detailed briefly in application, performance and significance. Part 2 describes cable testing for faults and substandard performance. Miscellaneous cable protection activities are also described.

**ELLIS, A. G.: 'Tropospheric Scatter Radio Systems in Australia'; Telecom. Journal of Aust., October 1972, page 192.**

This brief article outlines the fundamental considerations underlying the introduction of Tropospheric Scatter radio systems to provide trunk circuits across larger distances of inaccesible territory in Australia. The need for an alternative to the conventional broadband system is outlined, and some of the main specification requirements are described.

**KIMBER, M. J. and LANGE, V. W.: 'The Darwin to Nhulunbuy Tropospheric Scatter System, Part 1'; Telecom. Journal of Aust., October 1972, page 195.**

This article in two parts describes the Darwin-Nhulunbuy radio Tropospheric Scatter sytem. Part 1 sets out the basic design considerations, whilst Part 2 in the next issue of this Journal describes the equipment, the associated power plant, installation aspects and the approach to maintenance.

**MASON, E. J.: 'Cabling in Telephone Exchanges'; Telecom. Journal of Aust., October 1972, page 212.**

The experience within the A.P.O. of the types of cables used in installation of exchange equipment is reviewed. The development of cabling practices using runway, tray, troughing and mesh is described. A description of the current practice in the provision of fluorescent lighting for equipment aisles is followed by an economic comparison of the costs of troughing and mesh for a crossbar exchange. This article on cabling techniques concludes by summarising the improvements and suggests how further economies can be achieved.

**MATTHEWS, P.: 'Technical Positions Estimating Procedure, Part 1'; Telecom. Journal of Aust., October 1972, page 215.**

Part I of this article describes the background to the development of a new system for determining the numbers and designations of staff required for Internal Plant service operations work in the Australian Post Office. It outlines the basis of the previous methods for determining staff numbers and describes the key features of the new procedures for making estimates of work load and the staff required in an Engineering Section. Part 2 of this article, which will be published in the next issue of the Journal, will describe the procedures used by upper management to allocate labour resources to Engineering Sections in the light of their estimates.

**MURNANE, M. J.: 'A New Wall Telephone'; Telecom. Journal of Aust., October 1972, page 183.**

A new wall telephone that incorporates many of the features and components of the 800 series table instruments is described. The new telephone was developed by the Australian Post Office and Amalgamated Wireless Australasia Ltd.

**SPITHILL, R. J., Van BAALEN, G. and GREGORY, L. R.: 'Type 72 Multiplexing Equipment for the A.P.O. Network, Part 2'; Telecom. Journal of Aust., October 1972, page 204.**

This article describes the development and production of the new range of channel multiplexing equipment by STC Pty. Ltd. (Australia) in accordance with the requirements of the Australian Post Office Design Guide for Long Line Equipment. It outlines the key features of the electrical and mechanical design of the equipment, with reference to such aspects as reliability, facility of installation, and operational needs. Part 1, in the previous issue of the Journal, describes the rack construction channel translating equipment and carrier supply arrangements. Part 2 describes the group and supergroup equipments, master oscillator and power supplies.

**TODD, R.M.: 'A Century of Telecommunications in the Northern Territory; Part 2, Subsequent Development of the Route'; Telecom. Journal of Aust., October 1972, page 174.**

This part of the article describes the development of the route from the first single simplex morse circuit to the present day. It includes the problems of maintaining the original line and equipment, the introduction of the first voice circuits, the development during 1939-45 war and the post-war years and outlines the proposed future expansion.

**WOODROW, B. E.: 'A Century of Telecommunications in the Northern Territory; Part 1, the Overland Telegraph Line'; Telecom. Journal of Aust., October 1972, page 167.**

This part deals briefly with some of the technical aspects of early morse systems and the Overland Telegraph Line circuit. It follows on to describe briefly events leading up to the construction of the line and then deals with some aspects of the construction, difficulties encountered and subsequent completion of the work.

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