THE

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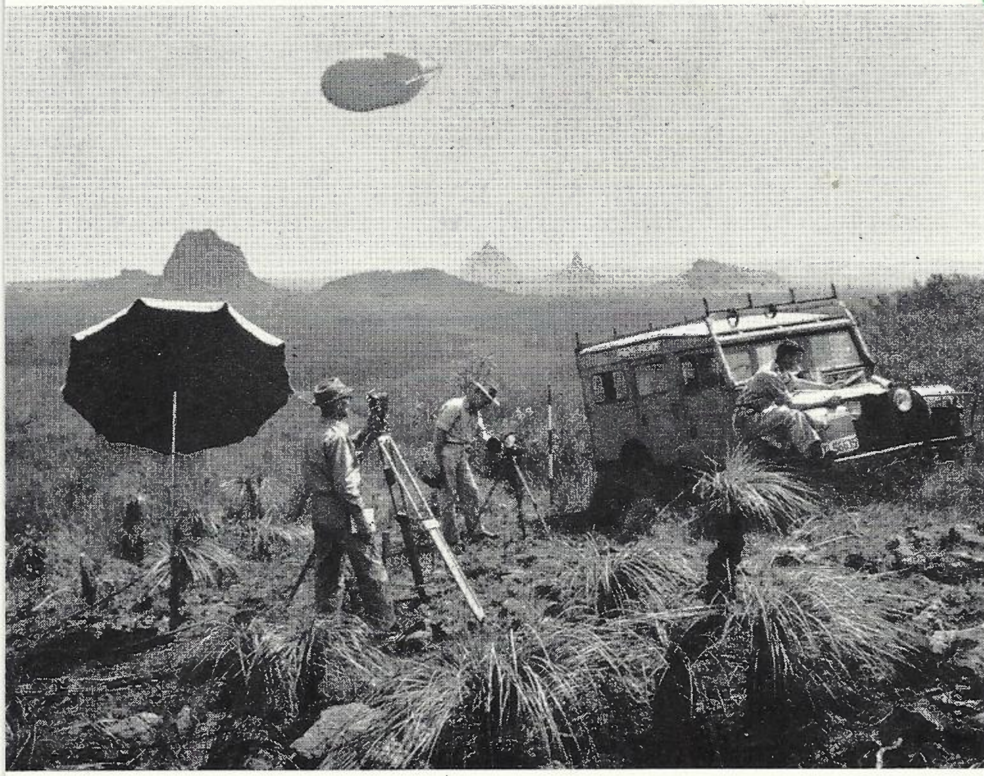

Seacom Route Survey

IN THIS ISSUE

VOL. 15, No. 2 Registered at the General Post Office, Melbourne, for transmission by post as a periodical. JUNE, 1965

WHERE SOUNDS
ARE RARELY HEARD

Water still seeps through limestone caves the world over patiently adding to the already spectacular scene, still ticking the years away largely unheard.

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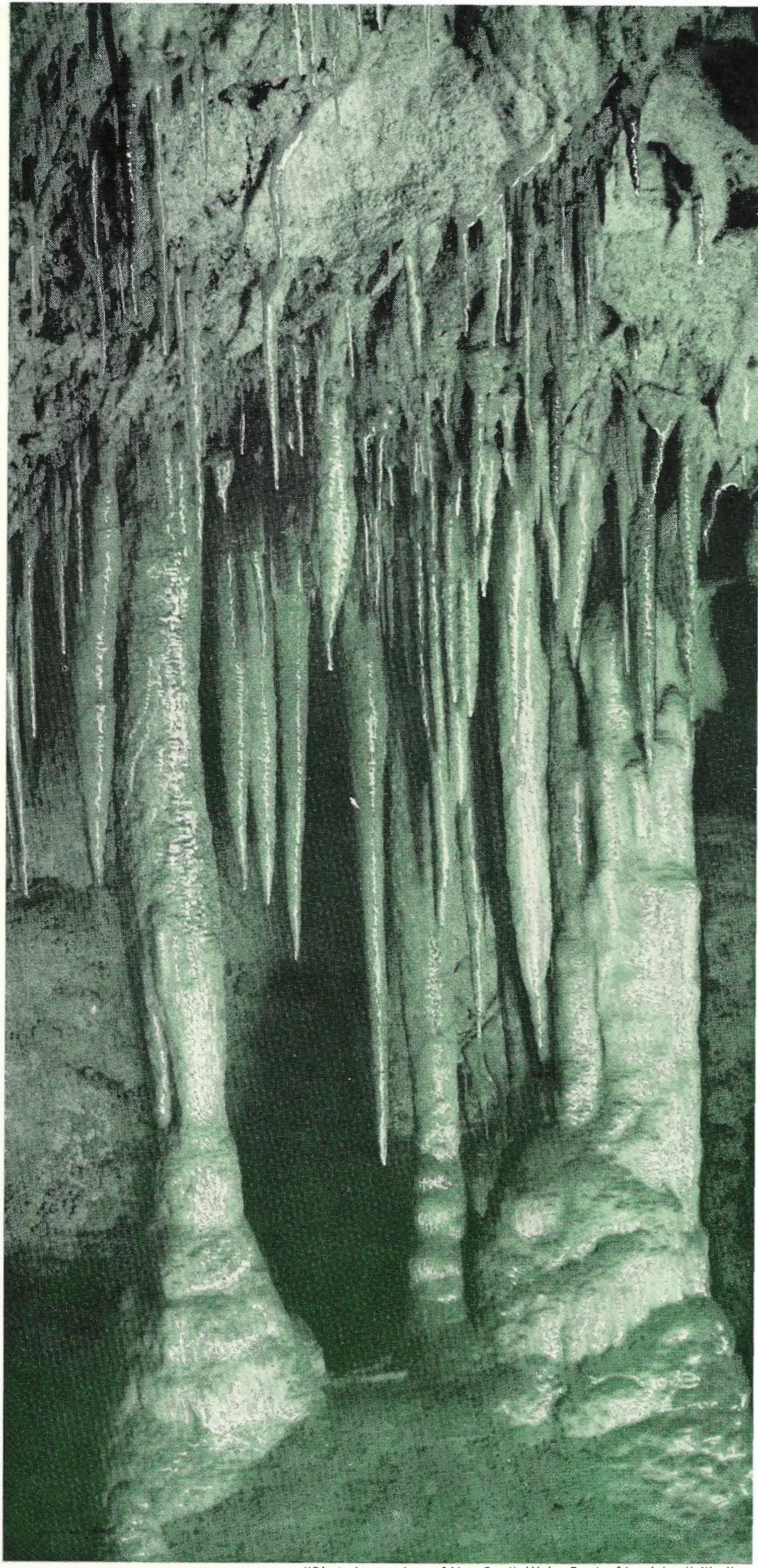

"Photo by courtesy of New South Wales Dept. of tourist activities"

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The

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of Australia

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CONTENTS

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*For addresses see page 159.

SEACOM: TRANSMISSION PERFORMANCE OF BRISBANE-CAIRNS MICROWAVE SYSTEM

*M. STROHFELDT, M.Sc., M.I.R.E.**

INTRODUCTION

A previous paper, by C. J. Griffiths (Ref. 1), outlined the overall planning aspects of the SEACOM submarine cable system which includes the Brisbane-Cairns microwave system as part of the overland radio connection between the Sydney terminal of the COMPAC cable and the southern end of the SEACOM cable at Cairns in Northern Queensland.

This paper discusses transmission aspects of the Brisbane-Cairns microwave system and includes detailed performance estimates for multi-channel telephony and television transmission. The methods used in the calculations are described at some length because of their fundamental importance to radio system planners. Alternative methods are also discussed briefly.

COMPOSITION OF RADIO ROUTE

The field work involved in the selection and survey of the route is described in a companion paper in this issue by V. J. Griffin (Ref. 2). Briefly, the route comprises 30 repeater sections grouped into five main sections according to Post Office traffic distribution requirements. The route configuration and traffic arrangements for telephony are shown in Fig. 1 which includes potential minor system development between intermediate towns. Aerial-support towers and buildings have been designed to accommodate these future minor systems as well as future expansion of the main route beyond the initial provision of one two-way telephony bearer channel and one one-way television bearer (from south to north). Fig. 1 also shows the route configuration for television relays complete with spur paths to the five television transmitters of the National Broadcasting Service along the route. Two of these transmitters (Rockhampton and Townsville) are served by local Australian Broadcasting Commission studios, and the relayed programme is delivered at video frequencies to the town end of the existing 7.5 Gc/s Studios-Transmitter (S-T) link in both instances. Provision will also be made for the insertion of the local programme into the main relay route at these two points to provide an alternative service to transmitters north of the insertion point.

In selecting the route, a number of requirements had to be met. Firstly, it was necessary to establish back-to-back telephony terminals as close as practicable to the trunk exchanges at Maryborough, Rockhampton, Mackay and Townsville, and preferably within approximately a five-mile radius of these exchanges, so as to simplify cable-tail arrangements. The television stations could, with one exception, be served conveniently by spur paths at these same back-to-back terminals; the Cairns terminal site was ultimately so chosen that it will be necessary to serve the proposed Cairns television transmitter station (Mt. Bartle Frere) with a spur at the preceding repeater (Graham Range) rather than at the Cairns terminal.

The second consideration in selecting the route was the desirability of avoiding long repeater hops in the interests of moderate path losses and tolerable fading conditions. These conditions are necessary in view of the stringent SEACOM reliability and noise performance objectives for SEACOM traffic, and path lengths were accordingly restricted to less than 40 miles (with only three exceptions) and every effort was made to avoid apparent ground-reflection and possible ducting situations which could cause abnormal propagation conditions and lead to severe sustained fading and possible system outages.

Lastly, the previous considerations had to be weighed against the economic implications of various alternative route arrangements, having regard to the number of mainline repeaters, the probable need or otherwise for diversity reception to offset bad fading, access road and power supply costs, development potential for minor systems, and maintenance difficulty in bad weather.

PERFORMANCE OBJECTIVES

The C.C.I.R. Recommendation (Ref. 3) for noise performance of actual radio relay circuits specifies three requirements for telephony systems:—

(a) Weighted mean power in any hour.

(b) Weighted one-minute mean power for more than 20% of any month.

(c) Weighted one-minute mean power for 0.1% of any month.

The objective in (a) has been applicable in SEACOM system planning, although (b) is regarded in many countries as the more practical and acceptable design tool. The third objective is even more difficult to measure than the others, and is treated as a planning figure only.

The corresponding Recommendation (Ref. 4) for television performance is specified in terms of peak-to-peak picture signal/r.m.s. noise for 99% of any month, and for more than 20% and 0.1% of any month respectively, after allowing for the difference between circuit distance and the "hypothetical reference circuit" for which the recommendations are applicable.

The Brisbane-Cairns microwave system noise performance objectives for telephony and television are essentially the same as quoted in the relevant C.C.I.R. Recommendations for Los Angeles (1959) and Geneva (1963), except for the SEACOM supergroup in the case of the telephony bearer. The SEACOM objective is 1 pW/km, i.e., the psophometrically weighted mean hourly noise (in any hour) is 1542 picowatts pWo) at a point of zero relative level. Allowing 150 pWo for the multiplexing equipment, the radio system objective becomes 1392 pWo, or the equivalent of 0.9 pWo/km. The corresponding C.C.I.R. objective is 3 pWo/km.

In order to achieve the SEACOM objective in the relevant part of the traffic baseband, it was assumed that it would be necessary to minimise path losses and to adopt conservative radio paths in order to avoid substantial fading noise. In addition, it seemed probable that system loading would have to be restricted to 600 channels or possibly to 300 channels. The planning aim was to provide 600 channels (10 supergroups) on the Brisbane-Maryborough section and 300 channels (5 supergroups) between Maryborough and Cairns, with two supergroups reserved throughout for SEACOM channels. The following discussion covers this arrangement of system loading as well as 600 channels overall.

As stated elsewhere (Ref. 1), the supergroup provision in the baseband is designed to accommodate 80 channels, each 3 kc/s bandwidth, of which not less than half will carry speech circuits and the remainder, 24-channel V.F. telegraph systems. The two supergroups reserved nominally for SEACOM traffic are the third and fourth in the baseband (i.e., 564-804 kc/s and 812-1052 kc/s). The fourth supergroup is allocated tentatively for regular SEACOM traffic, while the third supergroup is for patching purposes and may be used part-time for Post Office traffic on a secondary basis. The performance calculations relate to the 1052 kc/s point in the baseband, which is used as a standard noise-measurement slot.

RADIO SYSTEM PERFORMANCE (TELEPHONY)

The first step is calculation of signal levels on individual paths and the resulting receiver thermal noise levels. The following parameters are used:—

(a) **Path Attenuation** (db relative to isotropic radiators)

$$36.6 + 20 \log d + 20 \log f$$

where d = path length in miles
f = frequency (Mc/s)

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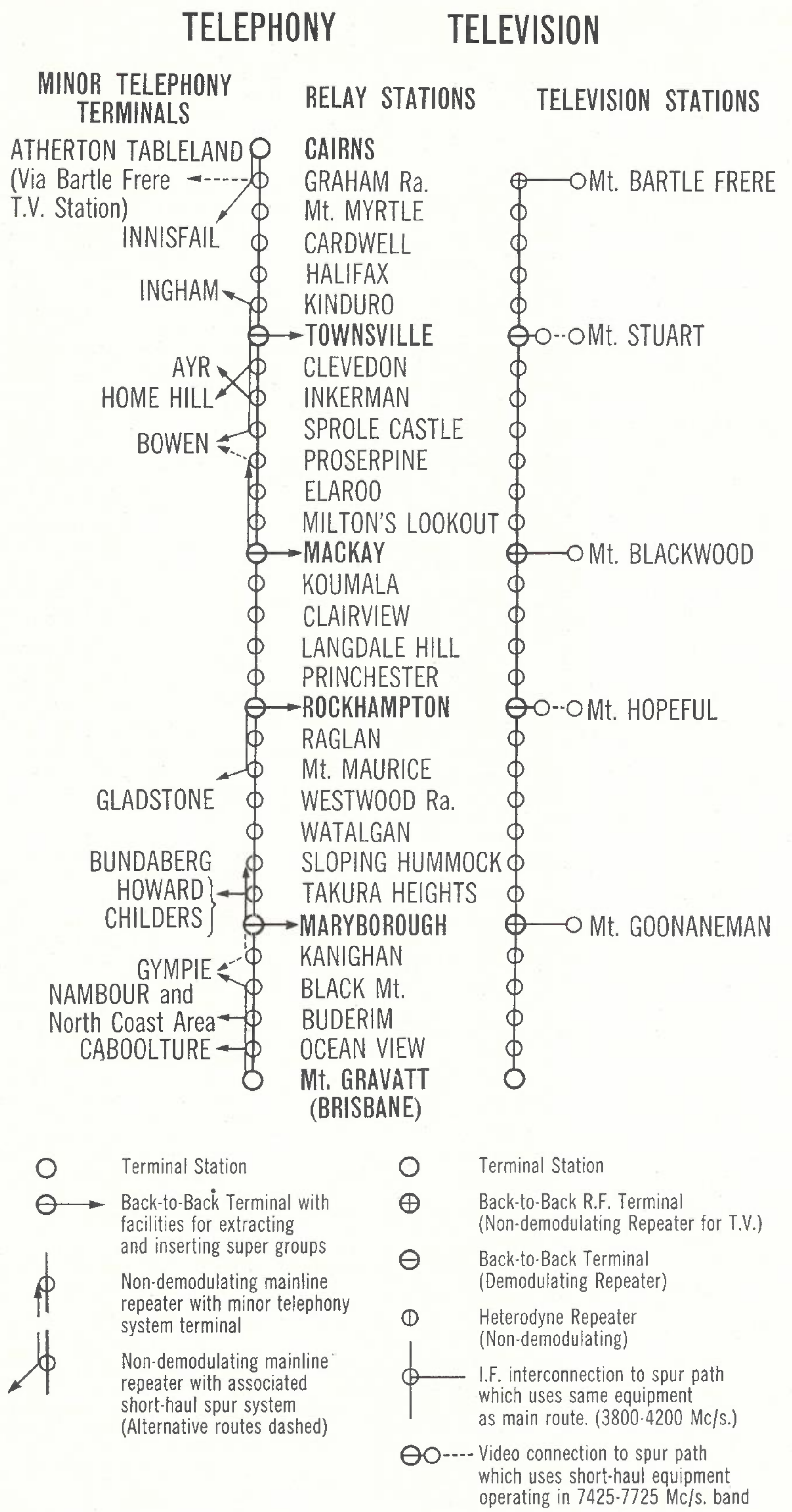


Fig. 1 — Brisbane-Cairns Microwave Route: System Layout for Telephony and Television Relays.

(b) **Transmitter Power.**

Nominally + 7 dbW. (5 watts).

(c) **Antenna Gain** (relative to isotropic radiator).

39 db for the 10 feet diameter parabola used universally on this system.

(d) **Waveguide Loss** (4000 Mc/s)

Circular: 0.5 db/100 ft. Rectangular: 1.8 db/100 ft.

(**Note:** Circular waveguide is used for all vertical runs 75 ft. or longer) Waveguide transition loss: 0.1 db (assumed).

(e) **Fixed Losses** (filters, isolators, cable interconnections).

3 db allowed.

(f) **Receiver Noise Level**

—118 dbW assuming
bandwidth = 25 Mc/s
noise figure = 12 db
(Basic noise = —204 dbW/cycle of bandwidth)

(**Note:** It follows that the signal threshold is —106 dbW approximately, and the receiver "fade margin" is the signal level relative to this threshold).

The speech channel noise level may be derived simply from the following formula:—

Noise level (—dbmOp)
= System Value —overall path loss.

where System Value for this radio system has the following values, which exclude channel weighting as well as pre-emphasis which has been deliberately omitted in the SEACOM system in order to avoid depressing the performance of the middle baseband:

Slot	System Value
1052 kc/s	149.6
1300 kc/s (1)	147.7
2540 kc/s (2)	141.9

(1) Top channel for 300-channel capacity

(2) Top channel for 600-channel capacity

The derivation of these System Values is given in Appendix 1.

Table 1 shows the calculated path losses, non-fading signal levels, and corresponding thermal noise level in the top channel position of the SEACOM supergroup (1052 kc/s) for each path of the Brisbane-Cairns route. It now remains to calculate the mean hourly noise level taking account of signal fading during the hour, and to estimate total noise including contributions originating in terminal equipment and various parts of the radio system.

FADING ALLOWANCES

A rigorous calculation of overall noise performance of a long system

TABLE 1: NON-FADING CONDITIONS

Path	Total Path Loss (db)	Non-Fading R.F. Signal Level (dbW)	Carrier/ Noise (db)	Telephone Channel Noise Level at 1052 kc/s (dbmO)*
Mt Gravatt – Ocean View	67.8	—60.8	57.2	—81.8
Ocean View – Buderim Mt	67.2	—60.2	57.8	—82.4
Buderim Mt – Black Mt	63.5	—56.5	61.5	—86.1
Black Mt – Mt Kanighan	67.8	—60.8	57.2	—81.8
Mt Kanighan – Maryborough	67.3	—60.3	57.7	—82.3
TV Spur: Maryborough – Mt Goonaneman	67.1	—60.1	57.9	—
Maryborough – Takura Heights	62.1	—55.1	62.9	—87.5
Takura Heights – Sloping Hummock	68.2	—61.2	56.8	—81.4
Sloping Hummock – Watalgan	66.8	—59.8	58.2	—82.8
Watalgan – Westwood Range	67.9	—60.9	57.1	—81.7
Westwood Range – Mt Maurice	68.5	—61.5	56.5	—81.1
Mt Maurice – Raglan	66.5	—59.5	58.5	—83.1
Raglan – Rockhampton (**)	67.0	—60.0	58.0	—82.6
Rockhampton – Princhester	69.7	—62.7	55.3	—79.9
Princhester – Langdale Hill	68.4	—61.4	56.6	—81.2
Langdale Hill – Clairview	70.1	—63.1	54.9	—79.5
Clairview – Koumala	68.3	—61.3	56.7	—81.3
Koumala – Mackay	68.2	—61.2	56.8	—81.4
TV Spur: Mackay – Mt Blackwood	60.8	—53.8	64.2	—
Mackay – Milton's Lookout	60.2	—53.2	64.8	—89.4
Milton's Lookout – Elaroo	66.5	—59.5	58.5	—83.1
Elaroo – Proserpine	66.4	—59.4	58.6	—83.2
Proserpine – Sprole Castle	69.4	—62.4	55.6	—80.2
Sprole Castle – Inkerman	69.7	—62.7	55.3	—79.9
Inkerman – Clevedon	68.5	—61.5	56.5	—81.1
Clevedon – Townsville(**)	61.2	—54.2	63.8	—88.4
Townsville – Kinduro	67.2	—60.2	57.8	—82.4
Kinduro – Halifax	66.5	—59.5	58.5	—83.1
Halifax – Cardwell	64.8	—57.8	60.2	—84.8
Cardwell – Mt Myrtle	66.6	—59.6	58.4	—83.0
Mt Myrtle – Graham Range	66.8	—59.8	58.2	—82.8
Graham Range – Cairns	68.0	—61.0	57.0	—81.6
TV Spur: Graham Range – Mt Bartle Frere	58.1	—51.1	66.9	—

* Steady state level (non-fading)

** Television spur uses 7.5 Gc/s short-haul equipment

would involve the statistical signal distribution for individual paths as well as information on fading correlation between paths. In practice, little or none of this information is available, and a simplified "fade allocation" method is proposed in its place.

In this method, the thermal noise contributed by each path is calculated by assessing the mean hourly signal level — which is the non-fading level adjusted by a small margin, depending upon the degree of fading and the presence or absence of diversity improvement. In more general planning, a common overall degradation margin is allowed for all paths on a route according to the number of paths in the route and the assumptions as to the fading configuration. This general method is described further in a later section.

The C.C.I.R. approach (Ref. 5) is based upon a fading situation in which 20% of the hops undergo severe fading in a bad hour, while the remainder have little or no fading. The Rayleigh distribution is assumed to be typical of severe fading over short periods up to a few hours, provided there is no abnormal fading mechanism present (e.g., ground reflections, ducting). Paths in the 80% group may be assumed to be characterised on an average by a log-normal distribution with a small standard deviation (say 3 db).

The mean hourly noise is obtained by integrating these distributions (after inversion to convert from signal to noise), limiting the integrals at a level set by standby bearer switching. The power level diagram in Fig. 2 shows the relativity between levels for the two categories of fading.

If the protection bearer switching level is set for a 25 db signal fade (a typical value), the margins for mean hourly noise, relative to the non-fading level, are therefore 7.1 db for a path undergoing severe fading and 1.6 db for mild fading. The paths most likely to experience severe fading are selected up to a limit of about one-fifth of the number of hops, and the respective margins allocated accordingly. The overall hourly thermal noise due to receivers may then be calculated. For general planning, a later section shows that an overall equivalent margin may be used which is applied to all paths equally.

In the present exercise, additional provision is made for the fact that median signal levels are often depressed, particularly with the onset of severe fading. These depressions are generally thought to be associated with energy diversions on the radio path (a "defocussing" mechanism) and are not amenable to diversity improvement. In this respect, they differ from ground reflection interference which is readily curbed by diversity and is consequently excluded from most performance calculations.

Referring again to Fig. 2, the mean noise level relative to the median is 5.5 db for Rayleigh fading and 1 db

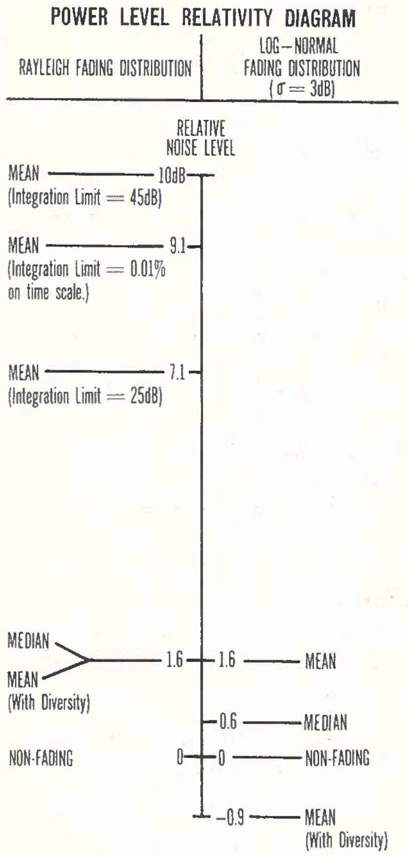


Fig. 2 — Mean Power Levels for Typical Severe and Mild Fading Distributions. (Power Level Relativity Diagram).

for mild fading. Allowing for median depression, the following arbitrary table of allowances has been proposed by Pearson (Ref. 6)* for Rayleigh fading:

Path Length (miles):	29	35	44	58	87
Depression (db):	0.5	2	4	6.5	10

For long paths (longer than 40 miles) with mild fading, the average median loss is about 1 db. It is further assumed arbitrarily that for paths shorter than 30 miles the mean and median levels with mild fading are the same, while for paths in the range 30-40 miles the relative levels are as shown in Fig. 2. The overall fading allocation plan, after allowing for median depression, is shown in Fig. 3.

These allocations are applied to the non-fading noise levels for individual paths of the Brisbane-Cairns route as shown in Table 2, and the overall thermal noise calculated for the SEACOM noise slot (1052 kc/s). The corresponding levels for 1300 kc/s and 2540 kc/s are proportionately higher according to the different system values, and are included in Table 2.

*These figures have since been amended and the revised information is shortly to be published in the Proceedings of the Institution of Electrical Engineers.

TABLE 2: MEAN HOURLY THERMAL NOISE LEVELS

Path		1052 kc/s				1300 kc/s	2540 kc/s
		Non-Fading Level (dbmO)	Fade Allocation (db)	Mean Hourly Noise Level (dbmO)	pWo	pWo	pWo
Mt Gravatt							
		—81.8	1.6	—80.2	9.6		
Ocean View							
		—82.4	1.6	—80.8	8.3		
Buderim Mt							
		—86.1	0.6	—85.5	2.8		
Black Mt							
		—81.8	1.6	—80.2	9.6		
Mt Kanighan							
		—82.3	6.5	—75.8	26.3		
Maryborough					56.6	87.2	332
Maryborough							
		—87.5	0.6	—86.9	2.0		
Takura Heights							
	*	—81.4	—0.9	—82.3	5.9		
Sloping Hummock							
		—82.8	1.6	—81.2	7.6		
Watalgan							
		—81.7	7.2	—74.5	35.5		
Westwood Range							
		—81.1	1.6	—79.5	11.2		
Mt Maurice							
		—83.1	1.6	—81.5	7.1		
Raglan							
	*	—82.6	—0.9	—83.5	4.5		
Rockhampton					73.8	115	436
Rockhampton							
	*	—79.9	—0.5	—80.4	9.1		
Princhester							
		—81.2	1.6	—79.6	11.0		
Langdale Hill							
	*	—79.5	—0.5	—80.0	10.0		
Clairview							
		—81.3	1.6	—79.7	10.7		
Koumala							
		—81.4	7.9	—73.5	44.7		
Mackay					85.5	132	502
Mackay							
		—89.4	0.6	—88.8	1.3		
Milton's Lookout							
		—83.1	1.6	—81.5	7.1		
Elaroo							
		—83.2	5.9	—77.3	18.6		
Proserpine							
	*	—80.2	—0.9	—81.1	7.8		
Sprole Castle							
	*	—79.9	3.9	—76.0	25.1		
Inkerman							
	*	—81.1	—0.9	—82.0	6.3		
Clevedon							
		—88.4	0.6	—87.8	1.7		
Townsville					67.9	107	404
Townsville							
	*	—82.4	—0.9	—83.3	4.7		
Kinduro							
		—83.1	6.2	—76.9	20.4		
Halifax							
		—84.8	0.6	—84.2	3.8		
Cardwell							
	*	—83.0	—0.9	—83.9	4.1		
Mt Myrtle							
		—82.8	7.0	—75.8	26.3		
Graham Range							
	*	—81.6	—0.9	—82.5	5.6		
Cairns					64.9	100	380

* Diversity Path — Rayleigh Allowance Underlined

OTHER NOISE CONTRIBUTIONS (All excluding weighting)

Thermal: Additional thermal noise originates in the modem and R.F. equipment. The proposed allowances are:

Modem: 45 pWo (per modulation section)

R.F.: 2.5 pWo (per hop) in 1052 kc/s slot
5 pWo (per hop) in 1300 kc/s and 2540 kc/s slots.

Intermodulation: This component originates in the modems, in the R.F. equipment through group delay distortion in the amplifiers and in the diversity combiners, from feeders due to reflections, and from the branching filters. The assumed values for these contributions are shown in Table 3.

Interference: This component arises from the imperfect decoupling between aerials and adjoining paths, and makes appropriate allowance for fading (see Appendix III). Another component, grouped here for convenience, arises from the baseband switching for which 3 pWo per modulation section is allowed. A miscellaneous allowance of 2 pWo per hop for the 1052 kc/s and 1300 kc/s slots and 4 pWo per hop for the 2540 kc/s slot is also included.

TOTAL OVERALL NOISE (HOURLY MEAN)

Summing up the various noise contributions discussed above, the results in Table 4 are obtained:

MONTHLY NOISE PERFORMANCE (TELEPHONY)

The two monthly objectives specified by C.C.I.R. refer to the limits for weighted one-minute mean noise power for more than 20% and 0.1% of any month. The first is used in this paper, the relevant standard being the same as for mean hourly noise, viz., 3 pW/km. For the route under study, this amounts to 4626 pW or a level of —53.3 dbmOp. It is noteworthy that the small-percentage objective for the Brisbane-Cairns route is 47,500 pW (or —43.2 dbmOp) for 1542/2500 of 0.1% of the time in a month, i.e., 0.06% approximately, or about 26 minutes in the month.

Time division applies with small time percentages because of the lack of correlation of deep fading on the paths in a long route, and the fact that instantaneous overall high noise levels are consequently attributable to individual paths on a long route. The overall performance for particular high noise levels then becomes a matter of summing the times for equivalent fades on individual paths.

The assumption of non-correlation between deep fades along a long route becomes uncertain when the fade depth considered is not relatively deep (i.e., 30 db or more). In other words, when considering performance of 1% of the time or more, one is dealing with only moderate fading, and there is some finite probability of correlations. However, while the following method of

TABLE 3

	1052 kc/s		1300 kc/s		2540 kc/s
	300 chan.	600 chan.	300 chan.	600 chan.	600 chan.
Modem	13 pWo	35 pWo	13 pWo	35 pWo	44 pWo
Group Delay (per modulation section)	36 pWo	85 pWo	41 pWo	90 pWo	307 pWo
Feeders (per feeder)	4.2 pWo	5.3 pWo	8 pWo	9 pWo	12 pWo
Filters (per hop)	4 pWo	4 pWo	4 pWo	4 pWo	4 pWo
Diversity (per hop)	10 pWo	10 pWo	10 pWo	10 pWo	10 pWo

TABLE 4

1052 kc/s slot (SEACOM)	Loading	pWo	Loading	pWo
Brisbane-Maryborough	600 chan.	340	600 chan.	340
Maryborough-Rockhampton	300 chan.	333	600 chan.	419
Rockhampton-Mackay	300 chan.	290	600 chan.	372
Mackay-Townsville	300 chan.	316	600 chan.	402
Townsville-Cairns	300 chan.	301	600 chan.	386
Total Power		1580		1919
After Weighting		889		1079
Level (dbmOp)		—60.5		—59.7
Corresponding N.P.R. in db		42.0		41.2

Note: SEACOM objective 1392 pWo, **i.e., 58.6 dbmOp** (N.P.R. = 40.1 db)

1300 kc/s slot

	Loading	pWo
Brisbane-Maryborough	600 chan.	424
Maryborough-Rockhampton	300 chan.	449
Rockhampton-Mackay	300 chan.	391
Mackay-Townsville	300 chan.	430
Townsville-Cairns	300 chan.	399
	Total	2093
	After Weighting	1177 pWo
	Level (dbmOp)	—59.3
	N.P.R.	40.8 db

2540 kc/s slot (600 ch. loading)

Brisbane-Maryborough	954
Maryborough-Rockhampton	1150
Rockhampton-Mackay	1100
Mackay-Townsville	1096
Townsville-Cairns	1041
	5341
After weighting	3003 pWo
Level	—55.2 dbmOp
N.P.R.	36.7 db

C.C.I.R Objective 3 pW/km = 4626 pWo — i.e., — 53.3 dbmOp

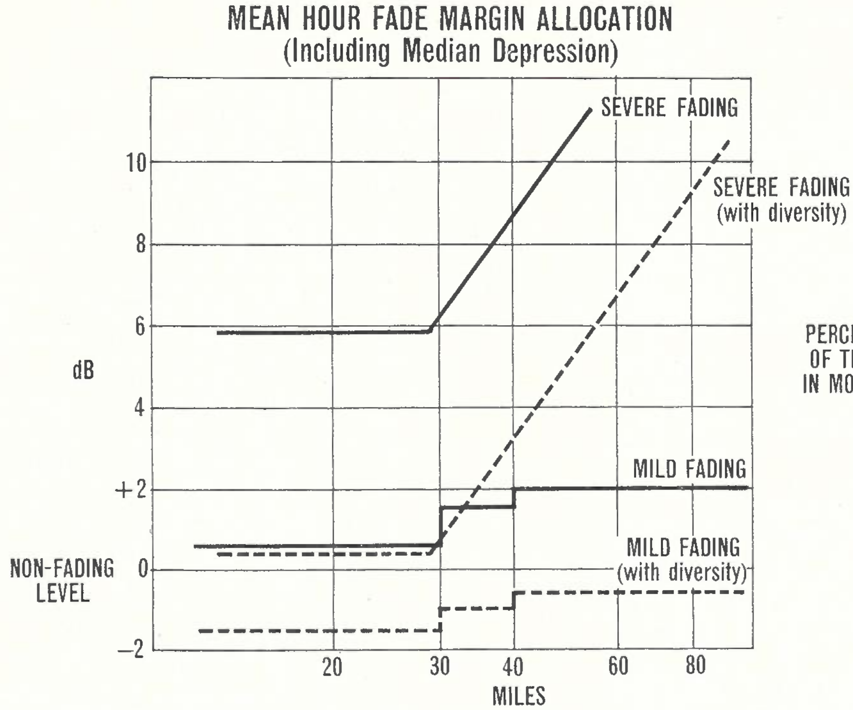


Fig. 3 — Mean Hour Fade Margin Allocation. (Including Median Depression).

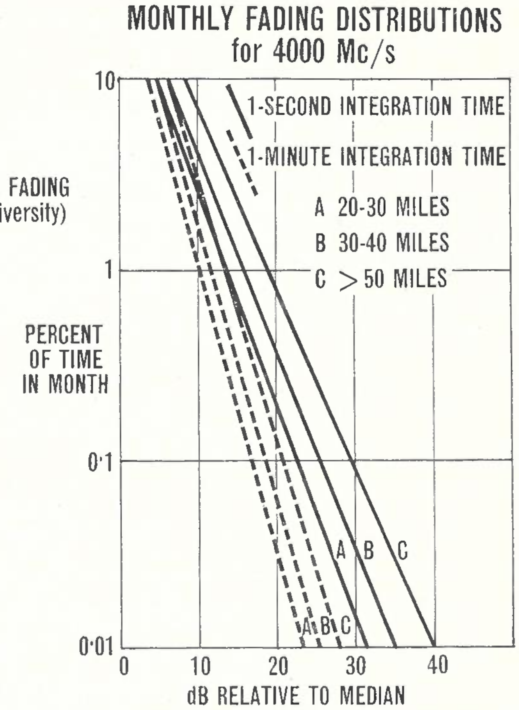


Fig. 4 — Monthly Fading Distributions for 4000 Mc/s.

determining performance ignores this chance, it is expected that the inaccuracy will not be significant, if only because thermal noise is not a predominant part of the overall noise in this context.

Another general qualification on this method of performance calculation is the lack of equivalence between paths in an actual route and the high probability that only a proportion of the paths contribute to deep fading performance. This objection is not particularly valid for the Brisbane-Cairns route, one reason being the equalizing effect of the relatively high density of diversity provision. However, it should be noted that the lack of equivalence tends to make performance estimates based on the equivalence concept conservative, and this is an acceptable fault from a system designer's viewpoint.

The noise performance on a 30-hop route is therefore calculated by adding the noise on one path for 1/30 of 20% of the month (i.e., 0.66%) to the noise produced under non-fading conditions by the remaining 29 paths. The "worst" hop is usually chosen in these calculations as the main contributor, and having regard for the disposition of diversity and the fading prospects of various paths, the Mt. Myrtle-Graham Range path was selected.

A family of monthly fade distributions (as a function of path length) is reproduced in Fig. 4, which is based largely upon analytical results from Bullington and modified to allow for the one-minute integration period (Ref. 6). The equivalent fade for 0.66% of the time is 19 db (for instantaneous fading) and 14 db (with a one-minute time constant). The calculated noise levels are given in Table 5.

TABLE 5: TELEPHONY NOISE PERFORMANCE — 20% OF THE MONTH (1300 kc/s SLOT)

Receiver Thermal Noise	**dbmO**	**pWo**
Faded Path Level	—66.9	204
Non-Fading Levels		
Brisbane-Maryborough	—73.7	42
Maryborough-Rockhampton	—72.2	61
Rockhampton-Mackay	—71.7	68
Mackay-Townsville	—72.1	62
Townsville-Mt Myrtle	—75.3	29
Graham Range-Cairns	—79.7	11
	—63.2	477

Adding other noise contributions, the total noise power at a point of zero relative level is 2030 pW. After weighting, the level becomes —59.4 dbmOp, which means the system has about a 6 db margin over the standard for this particular performance criterion.

The performance over individual modulation sections and for other baseband slots can be calculated similarly.

TELEVISION PERFORMANCE

Assuming the same equipment parameters as for telephony, the ratio of peak-to-peak picture signal to r.m.s. thermal noise after weighting according to the C.C.I.R. characteristic may be derived by adding 29 db to the C/N ratios quoted in Table 2. (The derivation of this conversion factor is given in Appendix II.) Other noise is added from the terminal modem equipment and repeater equipments as follows:—

$$\frac{\text{Peak-to-Peak Picture Signal}}{\text{Weighted* R.M.S. Noise (Terminal)}} = 70 \text{ db}$$

$$\frac{\text{Peak-to-Peak Picture Signal}}{\text{Weighted* R.M.S. Noise (Repeater)}} = 81 \text{ db}$$

*Includes 1.1 db for flat spectrum noise weighting.

On the above basis, the calculated performances for television relays to the respective transmitters along the route are as stated in Table 6. No allowance has been made for the noise contributed by the short-haul 7.5 Gc/s systems at Rockhampton and Townsville, but it should be noted that these are probably not significant since receiver thermal noise will be low for these particular paths and terminal noise will be of the order of —72 db relative to picture signal, which is low compared with the transmission noise on the main route.

The C.C.I.R. objective (Ref. 4) for 80% of the month after an arbitrary adjustment to take care of the difference between the C.C.I.R. hypothetical reference circuit and the actual circuit is given by:—

$$\frac{\text{D.A.P. Picture (db)}}{\text{R.M.S. Noise}} = 56 + 10 \log \frac{3}{\text{No. of sections}} + 10 \log \frac{1550 \times \text{no. of sections}}{3 \times \text{section length}}$$

Table 6 gives the noise performance estimate for transmission only. It covers the various circuits from Brisbane, as well as some intermediate circuits associated with the existing studios at Rockhampton and Townsville. The composition of each circuit can be found by reference to Fig. 1, but the effects of cable tails and their associated terminating equipment, as well as switching centre equipment, would require an additional allowance in calculating overall performance.

These performance estimates refer to noise performance for 80% of the month, it being assumed (in line with C.C.I.R. thinking) that the applicable signal levels are those for non-fading propagation. This assumption is believed to be reasonable for the Brisbane-Cairns route but may not necessarily apply for other routes in Australia.

TABLE 6: TELEVISION BEARER NOISE PERFORMANCE — 80% OF MONTH

Circuit		Distance (Miles)	D.A.P. Picture Signal/ R.M.S. Noise		
			Thermal	Overall	C.C.I.R. Objective
A	Mt Gravatt-Mt Goonaneman	189	79.2	68.0	65.1
B	Mt Gravatt-Rockhampton R/T	367	76.2	66.6	62.3
C	Rockhampton R/T-Mt Blackwood	211	77.9	67.9	64.7
D	Mt Gravatt-Mt Blackwood	578	73.8	64.1	60.3
E	Mt Gravatt-Townsville R/T	772	72.6	63.5	59.1
F	Townsville R/T-Bartle Frere	164	80.4	68.0	65.8
G	Mt Gravatt-Bartle Frere	937	72.0	62.2	58.2

In order to determine the performance for 99% of the month, it is necessary to allow for fading, and the family of monthly distribution curves in Fig. 4 which are based upon short-term fading data with an integration time of the order of one second may be used for this purpose.

TABLE 7: TELEVISION NOISE PERFORMANCE — 99% OF MONTH

Circuit*	Number of Hops	Equivalent Fade db	Faded Path (counting from south end)	D.A.P. Picture Signal/R.M.S. Noise db		
				Thermal	Overall	C.C.I.R. Objective
A	6	23	5th	63.6	62.3	61.1
B	12	26	5th	63.1	61.6	58.3
C	6	23	5th	66.9	64.5	60.7
D	18	28	17th	61.9	60.0	56.3
E	24	29	17th	60.9	59.2	55.1
F	6	23	5th	65.7	63.8	61.8
G	30	30	29th	58.6	57.2	54.2

* Circuit as specified in Table 6.

It should perhaps be noted that the "equivalent fade" method is the same as that postulated for telephony monthly performance, i.e., the total objective time is split on an equal time division basis between the total number of hops in a particular circuit. The total noise is then the sum of that contributed by an assumed faded path for its proportion of the time and that due to non-fading conditions on the remaining paths.

In relation to the "20% of the month" performance objective, there is an admitted inconsistency between the telephony and television approaches. With the former, fading has been taken into account, while with the latter it has not. This situation does not necessarily reflect any significant inaccuracy in the respective estimates, since the overall performances for both telephony and television for 20% of the month appear to be controlled more by equipment noise than that arriving in the receivers. The object in this paper has been to outline the general method of assessment, and the designer will generally have to decide on the relevance of fading to "20% of the month" performance having regard for the balance between receiver thermal noise and other noise contributions. The length of the route and the expected fading conditions will play a major part in reaching this decision.

BASEBAND COMBINING

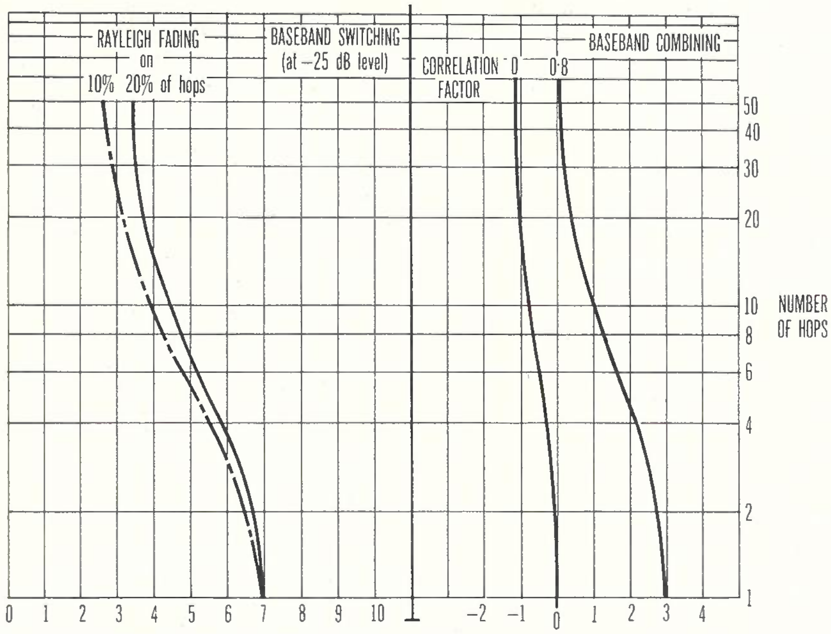
The above description of the method for calculating hourly noise performance for telephony presupposed bearer switching when signals faded 25 db relative to the free-space level. The hourly mean fade under these circumstances is about 7 db, and when applied to a long route of 50 hops, the common equivalent fade on all paths is 3.3 db (assuming 20% of the hops undergo Rayleigh fading).

The Brisbane-Cairns system will, however, be also fitted with baseband combiners at the five demodulation stations in each direction, and an additional improvement in overall noise improvement of about 2 to 2.5 db will be obtained. The combiner provides a form of frequency diversity, although it operates on signals which may have amplitude dissimilarities from causes other than propagation fading.

The improvement in performance resulting from the combiners has not been calculated, since it is not apparently essential in achieving the performance objective. It may, however, be regarded as a valuable margin in respect of maintenance and for reinforcing the SEACOM supergroup performance, which will be desirable when the TASI system is introduced. These matters are outside the scope of this present paper.

In order to prepare an estimate of telephony performance, curves are given in Fig. 5 showing the common equivalent simultaneous fade over a long route of a variable number of hops with and without baseband combining These curves are the type which are useful in general system performance planning. The curves for baseband combining are reproduced from technical data supplied by Standard Telephones and Cables Pty. Ltd., and take account of different

EQUIVALENT HOURLY MEAN FADE AS FUNCTION OF NUMBER OF HOPS



EQUIVALENT SIMULTANEOUS FADE COMMON TO ALL PATHS (in dB)

Fig. 5 — Equivalent Hourly Mean Fade as Function of Number of Hops.

degrees of correlation between the two signals presented to the combiner. These latter curves relate to the ratio-squarer type of combiner.

CONCLUSION

The above estimates have been made on the basis of a tentative method of allowing for fading on microwave paths. The method used is a relatively simple one, when one considers the real complexity of the problem in relation to the statistical combination of different fading distributions for individual paths in a long route. The lack of basic fading information on typical Australian paths is a serious handicap to any rigorous approach to performance calculations, just as it is a problem even in the selection of the paths in the first instance.

The foregoing information refers only to performance aspects. An equally important consideration which will be affected by fading behaviour is system reliability. Experience to date in New South Wales has shown that coastal ducting conditions can cause outages on microwave systems due to a combination of median depressions greater than 20 db with superimposed fast fading to depths below the signal threshold. An extensive programme of signal recordings is planned for the Brisbane-Cairns system in order to check for the presence and extent of "depression" conditions, and it is hoped that the analysis of these recordings will give a much clearer picture of the system performance under fading conditions than is possible at present.

ACKNOWLEDGMENT

The author would like to register his appreciation for all assistance given by engineers, surveyors and lines personnel of the Post Office Engineering Division in Brisbane both in the field and in office studies.

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APPENDIX I

DERIVATION OF SYSTEM VALUE FOR TELEPHONY BEARER

The overall "path loss" is obtained from the following system parameters:—

1. Path attenuation (db relative to isotropic radiators).
2. Transmission line losses.
3. Filter losses (including isolators, transitions with waveguide changes, cable tails, etc.).
4. Aerial gain — total for two ends of path (relative to isotropic radiators).

Let the overall path loss = L db
Transmitter power = +7 dbW
Received signal = 7–L dbW

Receiver Noise Power =
$$-204 + 10 \log B + N \text{ (dbW)}$$

where B = I.F. Bandwidth in c/s

N = Receiver noise figure

(Note: Assumed value is –118 dbW)

Carrier/Noise ratio = 7–L + 118 db

Noise bandwidth reduction in passing from I.F. to speech channel

$$= 10 \log_{10} \frac{25 \times 10^6}{3.1 \times 10^3}$$

$$= 39 \text{ db}$$

F.M. improvement =

$$20 \log_{10} \frac{\text{R.M.S. Deviation per channel}}{\text{Baseband frequency}}$$

$$= 20 \log_{10} \frac{200}{1052}$$

$$= -14.4 \text{ db}$$

Speech Signal/Noise ratio
= 7–L + 118 + 39 – 14.4
= 149.6 – L
∴ System Value = 149.6

The corresponding values for other slots vary in respect only of the F.M. improvement factor. In other systems, there will be an adjustment required for pre-emphasis, which will normally refer to the C.C.I.R. recommended characteristic, and perhaps in I.F. bandwidth, and transmitter power.

APPENDIX II

DERIVATION OF S/N RATIO OF TELEVISION BEARER

Appendix I outlines the method of calculating carrier to noise ratio. The conversion to video signal to noise ratio for a television baseband uses the following equation which includes the F.M. improvement and bandwidth reduction factors:

$$\frac{\text{R.M.S. Video Signal}}{\text{R.M.S. Noise}} = \frac{C}{N} + 20\log\frac{df\sqrt{3}}{fc} + 10\log\frac{B}{2fc}$$

where df = 4 Mc/s nominal deviation at fc (C.C.C.I.R. Rec. 276 refers)
fc = 5 Mc/s (upper limit of baseband)
B = I.F. noise bandwidth

$$= \frac{C}{N} + 6.8 \text{ db}$$

$$\frac{\text{D.A.P. Picture Signal}}{\text{R.M.S. Signal}} = 20\log 2\sqrt{2} \times 0.7$$

$$= 5.9 \text{ db}$$

$$\frac{\text{D.A.P. Picture Signal}}{\text{R.M.S. Noise}} = \frac{C}{N} + 12.7 \text{ db}$$

$$\frac{\text{D.A.P. Picture Signal}}{\text{Weighted R.M.S. Noise}} = \frac{C}{N} + 29 \text{ db}$$

$$\text{From Appendix I, } \frac{C}{N} = 7\text{–L} + 118 \text{ db}$$

$$\frac{\text{D.A.P. Picture Signal}}{\text{Weighted R.M.S. Noise}} = 7\text{–L} + 118 + 29$$

i.e. System Value (Television) = 154

APPENDIX III

INTERFERENCE NOISE IN MICROWAVE SYSTEM DUE TO AERIAL COUPLINGS

Apart from possible terrain echoes and foreground scatterings, the interference at station B will be due to a fixed component N from the preceding path propagating over the same radio path as the wanted signal, and a varible component F from the succeeding path which could have a different strength and fading pattern from that of the wanted signal due to the different transmission paths. See Fig. 6. In both cases, the interfering signal is dependent upon the imperfect front-to-back discrimination of microwave aerials. For the Brisbane-Cairns system, a mean value of front-to-back ratio of 68 db is assumed, in line with the use of shrouded parabolic reflectors. For other systems, the actual figure should be determined from aerial manufacturer's data with particular attention to the dependence upon the included angle between paths.

Referring to a paper by Medhurst (Ref. 7), the distortion/signal ratio in the general case for the 1052 and 1300 kc/s slots is –68 –3, i.e. –71 db, assuming a co-channel frequency situation. The interference takes the form of random noise, and with normal C.C.I.R. loading may be stated as a channel distortion level of –89.5 dbmOp. A similar calculation for 600 channel loading gives a noise contribution of –86.5 dbmOp for the 2540 kc/s slot with a possible increase of 3 db, depending upon the frequency difference between wanted and unwanted carriers.

In order to minimise interference noise, the Brisbane-Cairns system has been given a frequency plan based on 4-frequency repeaters, i.e., transmitter frequencies in one direction are 14.5 Mc/s displaced from those in the other.

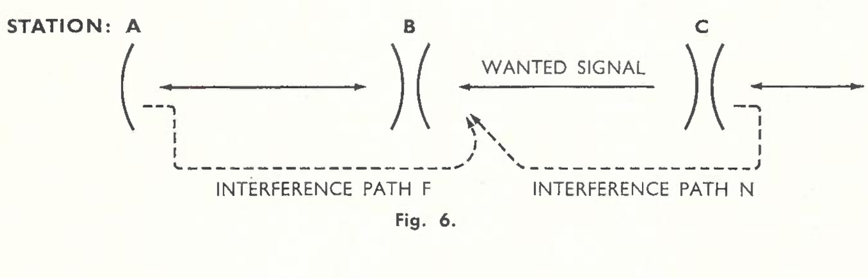

Fig. 6.

TECHNICAL NEWS ITEM

RESONANT REED RELAYS

Over the past few years increasing numbers of reed relays have been used in communications and switching equipment for service in the P.M.G. Compared with the standard 3000 type, the reed relay offers the advantages of:

(i) Increased speed of operation;
(ii) reduced contact wear;
(iii) fewer moving parts and mechanical adjustments;
(iv) compactness and light weight.

A relatively recent addition to the reed family is the "frequency-sensitive" or "resonant" reed relay which is designed to operate at a particular frequency, or number of frequencies, only.

Basically, these relays consist of a vibrating strip of magnetic material fixed at one end and surrounded by a solenoid carrying the operate current. The reed is usually polarized by means of a permanent magnet. The nominal frequency of operation is determined by the mechanical dimensions of the vibrating reed and when a signal of frequency equal to the resonant reed frequency is applied to the coil, the reed vibrates causing intermittent contacts of a contact point provided on the free tip of the vibrating strip and a fixed contact point. The contacts themselves are usually enclosed in a glass tube containing inert gas and the complete unit is housed in a hermetically sealed container.

Available resonant reed relays operate in the audio frequency range from 70 cycles to 1100 cycles and exhibit very high Q factors. Several manufacturers advertise a range of units with resonant frequencies spaced 15 cycles apart. The high frequency selectivity of these devices provides problems when associated with even high quality audio oscillators where very high frequency stability is difficult to obtain. One solution to this problem is provided by the tuning bar generator which uses mechanical techniques for accurate frequency stabilisation. Typical frequency deviation over the ranges —10°C to + 60°C is ± .5 c/s and the duty cycle is typically greater than 2½% when the relay is operated within ± 2% of the nominal frequency.

Multi-resonant devices are available with up to 10 reeds enclosed in a single coil but performance deteriorates as the number of reeds increases and it appears that units with greater than 3 resonances would be unsuitable for application in equipment used by the Postmaster-General's Department.

Typical applications for resonant reed relays include selection of operating conditions of remotely controlled radio transmitting and receiving equipment and signal decoders in electrical communication. It would also appear that these devices can be economically applied to multi-tone signalling systems with which sections of the P.M.G. Research Laboratories are presently concerned.—W.C.

SEACOM: SURVEY AND SELECTION OF BRISBANE - CAIRNS MICROWAVE RADIO ROUTE

*V. J. GRIFFIN, A.M.I.E. Aust., S.M.I.R.E.E. Aust.**

INTRODUCTION

The overall planning aspects of the Sydney-Cairns Section of the SEACOM Submarine Cable System were presented in the February, 1965, issue of this Journal(1). The purpose of this paper is to outline the bases and methods of selection and field measurement of the microwave radio route from Brisbane to Cairns. This route of 1,200 road miles, and 960 miles by radio path, is comparable in length with a route from Sydney to Adelaide via Melbourne.

Because the stringent technical specifications for this radio system placed particular emphasis upon the detailed planning of the route, which is the foundation for reliable performance, the field staff of the Queensland Engineering Division worked in close association with Engineers from the Central Administration, and received considerable guidance in assessing the propagation characteristics of alternative paths.

A companion paper in this issue by M. Strohfeldt(2) will present an analysis of the design and estimated performance of the Brisbane-Cairns Microwave Radio Route.

PRELIMINARY ROUTE STUDY

This was completed within a two months period between October and December, 1961, its purpose being to define a probable radio route and possible alternative sections, and so determine the practicability of establishing a microwave radio system within acceptable economic and technical limits. The study was based primarily upon an examination of the 1 : 63,360 military map series which included height contour information at 50 feet intervals. There were restricted areas in this map series, however, for which such contour information was not available and in these areas it was necessary, therefore, to conduct an aerial survey to quickly and broadly appraise the route possibilities. During the period of preliminary study, a pilot survey team also visited all site areas being considered at that time for the Brisbane to Rockhampton section and gained an appreciation of the detailed field measurments which were about to be undertaken, and the facilities which would be needed to accomplish this work within the tight timetable.

BASES OF ROUTE SELECTION

Field work was commenced in February, 1962, based on an expected landfall for the undersea cable in the vicinity of Cairns.

At about this period, it was quite apparent that a broadband route would be required between Brisbane and Cairns in the near future to cater for increasing interstate traffic and there were many advantages to be gained if Cairns was selected as the cable landfall. In order to assist the Commonwealth Cable Planning Committee in the consideration of a cable landfall near Cairns, the radio route survey was undertaken to an urgent timetable, completion being required within seven months by August, 1962. The work was completed by this date and Cairns was agreed upon for the cable landfall. Although the locations of three of the 30 stations were subsequently reviewed to gain improved all weather access and reduced road costs, it was obvious that the number of paths would remain at 30, and that the variations would not be expected to significantly affect radio path conditions. Close consideration was given to Aerial Profile Recording (A.P.R.) as a possible means of expediting the field work, but this technique was regarded as unsuitable for this particular survey and all measurements were made by physical and optical means.

The main considerations involved in the selection of the route were:—

(i) **Traffic Requirements:** The route was required to provide for "main-line" traffic insertion and extraction at Brisbane, Maryborough, Rockhampton, Mackay, Townsville and Cairns. The selection of repeater stations, however, took into consideration also the possible future need to provide "short haul" radio systems between the above centres and intermediate towns such as Nambour, Gympie, Bundaberg, Gladstone, Proserpine, Bowen, Ayr, Ingham and Innisfail.

(ii) **Path Lengths:** Path lengths of approximately 35 miles represent a reasonable compromise having regard to minimising the number of stations on the one hand, and reducing possible system outages

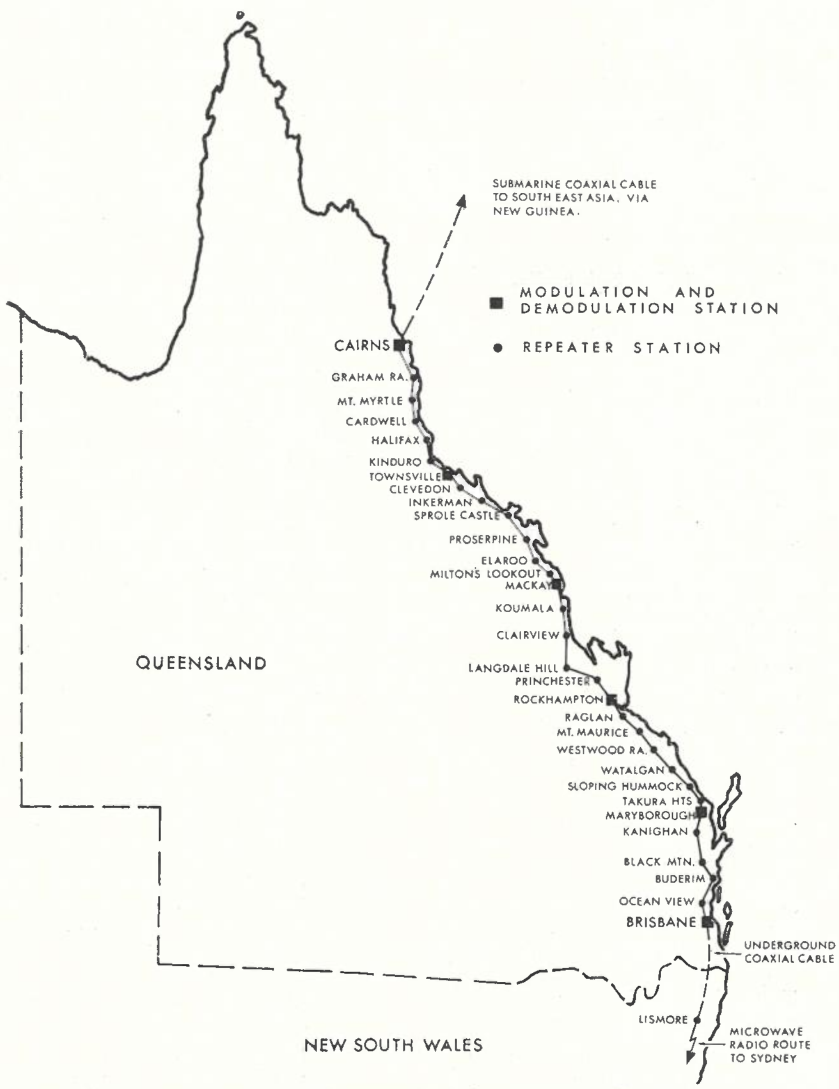

Fig. 1 — Route Plan.

*Mr. Griffin is Engineer Class 3, Radio Section, Queensland. See page 161.

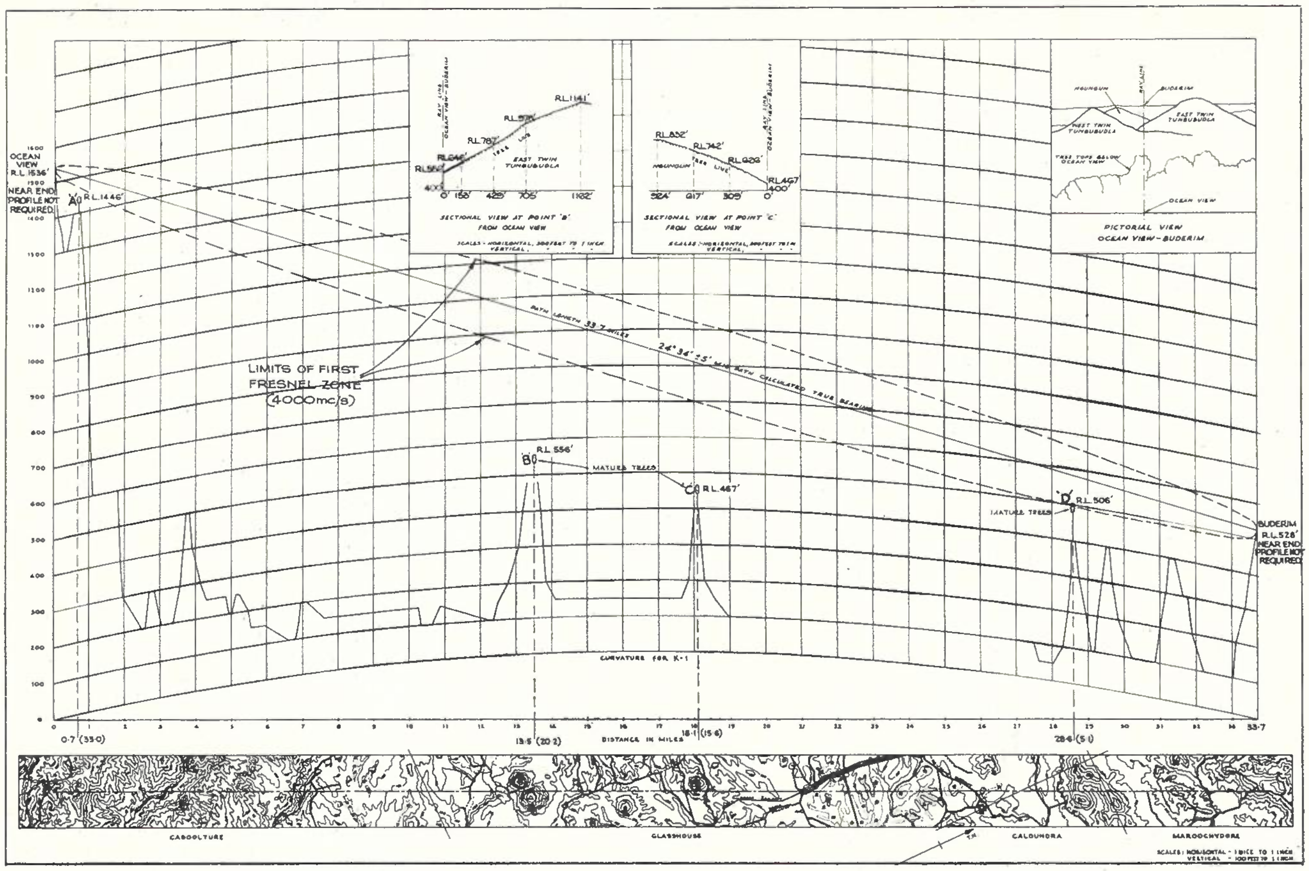

Fig. 2 — Typical Path Profile.

due to severe fading on the other hand, the latter factor increasing at an accelerating rate for paths much in excess of this distance. It is difficult however, to always achieve this optimum because the geographic location of traffic centres largely determines the break-up of the overall route, and in addition, there are generally a number of key sites which cannot be avoided. Of the 30 paths in this 960 mile route, twenty-one are within the range of 30 to 40 miles, six within the range of 13.6 to 28.4 miles and three within the range of 41.7 to 43.4 miles.

(iii) **Site Selection Basis:** A microwave radio relay system requires "line of sight" paths necessitating the use of hilltop or mountain sites at most locations. The selection of suitable sites was based upon:—

(a) Compatibility with the technical performance objectives of the overall system.
(b) Road costs.
(c) Power availability.
(d) Minimum tower heights required to provide adequate clearance over local and intermediate terrain.
(e) Accessibility for maintenance purposes.
(f) Possible limitation of tower height to meet Department of Civil Aviation requirements.
(g) Suitability for building and tower foundations.
(h) Ease of acquisition.

(iv) **Reflection Areas:** Paths which traversed water or flat open country were avoided as far as possible as these generally produce strongly reflected signals which cause interference with the direct signal, producing "fading" of the radio signal and consequent degradation of the signal to noise ratio in the trunk channels. This effect can be reduced by the use of "diversity" operation which is referred to in (vii) below.

(v) **Path Overshoot:** The number of operating frequencies available for use on a route of this type is limited, and a repetition of similar groups is necessary. For example, the radio frequencies employed over a path A-B are a different group from B-C, but often are the same as for C-D. The receiving equipments at B and D are, therefore, tuned to common frequencies and "overshoot" occurs if the signal from A is permitted to reach D. The risk of overshoot interference requires closer investigation when any group of three adjoining radio paths has a configuration such that the line joining A.D. has insufficient angular separation (less than 5 degrees) from the line of shoot from both A to B and C to D, and there is limited natural shielding by the intervening terrain.

Further information on this phenomen is given in Appendix III of Ref. 2.

(vi) **Path Clearance Criteria:** Fig. 2 is a typical path profile showing a direct ray line from ground to ground with the earth curvature drawn for true earth radius ($k = 1$). Although this particular example does not demand high towers at either end of the path to achieve adequate clearance, it indicates the two important factors involved, these being (a) effective earth curvature, and (b) free space clearance.

(a) *Effective Earth Curvature:* Although the surface of the earth is curved, a beam of microwave energy tends to travel in a straight line. However, under average conditions when the atmosphere is in a well mixed state, the beam is subject to refraction due to the almost linear decrease of temperature, pressure and water vapour content with increasing height. This results in a downward bending of the beam, increasing the radio horizon much the same as would result from reducing the curvature of the earth.

This effective reduction in earth curvature, or increase in earth radius, is expressed by the equivalent earth radius factor "k" which is about 1.3 for high radio frequencies in a standard atmosphere. Atmospheric refraction, however, is subject to diurnal and seasonal variations which cause a variation of the "k" factor over wide limits, e.g. from 0.6 to near infinity, although the extent of variation from the standard "k" condition occurs for reducing percentages of the time. When assessing path clearance, it is convenient to assume that the radio beam travels in a straight line and that only the earth curvature (k factor) varies, the clearance varying as "k" increases or decreases. Thus the effective earth curvature causes a reduction in clearance and may be simply calculated.

$$c = \frac{2\ d1\ d2}{3k}$$

where c = curvature in feet
d1 = distance from the point concerned to one end of the path in miles
d2 = distance from the point concerned to the other end of the path in miles
k = equivalent earth radius factor

e.g. curvatures at 5 miles and 16 miles (mid-point) in a 32 mile path are 90 feet and 170 feet respectively for a "k" of 1, and 112 feet and 214 feet respectively for a "k" of 0.8, the latter factor being considered in the calculation of clearance on the Brisbane-Cairns route to ensure propagation reliability under abnormal atmospheric conditions.

(b) *Free Space Clearance:* Propagation between ground based stations does not achieve classical free space conditions due to the presence of the intermediate country. Little ground influence on a radio beam is experienced, however, when the path traverses irregular or broken terrain, provided that the clearance approaches that determined by the first Fresnel Zone. This zone is formed by the boundary of points from which a radio wave could be reflected having a path length equal to ½ wavelength greater than the direct path. (See Fig. 2).

The radius of the zone at a particular point along the path, varies with the frequency of the wave and with the distance from the ends of the path being considered, and may be determined as follows:—

$$F = 2280\sqrt{\frac{d1\ d2}{fD}}$$

when F = first Fresnel Zone radius in feet
D = total path length in miles = d1 + d2
f = Frequency in megacycles/second

Whilst a ½ wavelength at 4,000 mc/s. is approximately 1½ inches only, the radii of first Fresnel Zone at this frequency in a 32 mile path at 1, 5 and 16 miles (mid-point) are 36, 74 and 102 feet respectively. In general, free space conditions apply approximately over a path if the clearance of the radio beam over all points of the intermediate terrain is at least equal to 0.6 of the 1st Fresnel Zone Radius for the particular "k" factor applying at the time. Free space radii in the above example are 22 feet, 44 feet and 61 feet respectively. The clearance criteria for the Brisbane-Cairns route required that the radio wave should have at least a free space clearance (0.6 Fresnel Zone radius) over all points of the path for a "k" factor of 0.8 with a lower clearance limit of 35 feet. If such clearance is not available then it must be gained by high towers, with an upper practical height limit of about 250 feet, and with the consequent considerations of tower costs and attenuation losses in the wave-guide feeder which couples the radio equipment to the aerial system.

If. in a 32 mile path, there is a grazing clearance at mid-point for a "k" of 1, i.e. true earth radius, then the additional clearance required would equal 44 feet (the difference between curvature at "k" of 0.8 and "k" of 1), plus 61 feet for free space clearance, resulting in a tower of 105 feet at each end for supporting the lowest aerials. Additional height may also be required to mount aerials for future development of the route.

(vii) **Diversity Operation:** When a direct and a ground or water reflected wave arrive at the receiving aerial, they will have travelled over different path lengths with a resulting phase difference between the two signals. The variation of the effective earth radius with atmospheric conditions causes the distance travelled by the reflected signal to vary so that the phase difference between the direct and reflected signals changes, and the signal to the receiver is either reinforced or reduced in intensity. This condition is known as "fading", the signal strength varying at a random rate. If the reflected signal is relatively strong then the combined signal can suffer serious cancellation tending towards a null, and to meet these conditions, space diversity reception is employed over the path. Fading can also occur due to signals arriving at the receiving antenna over differing path lengths caused by reflection and/or refraction from irregular atmospheric layers. Fading is usually more severe at night and at early morning when the atmosphere is very still, and is generally less severe during daylight hours when convection air currents help to maintain the atmosphere in a well mixed state preventing the formation of stratified layers having discrete boundaries between different indices of refraction.

In order to ensure a high degree of propagation reliability, space diversity operation is being employed over eleven paths on the

Fig. 3 — Survey Party at Work.

Brisbane-Cairns route, including three which are over-water, requiring the provision of an additional receiving aerial at each end of the path. At each end, both aerials receive the direct and reflected signals, but the aerial spacing is calculated in terms of the site elevations, path length and the relative location of the reflecting surface so that when the signal from one aerial is suffering cancellation the other aerial is receiving a reinforced signal. The signals from both aerials are combined in the appropriate manner in the receiving equipment.

FIELD ORGANISATION AND MEASUREMENTS

Field Organisation

In view of the anticipated expansion of microwave radio networks throughout Australia, an all-States conference of Engineers and Surveyors was arranged by the Central Administration and held in Sydney early in December, 1961, to consider the standardisation of survey practices and plan presentation for microwave path and site selection. The conclusions reached at this conference provided a firm basis for the selection and measurement of the Brisbane-Cairns route.

The field measurements were carried out by two survey teams; each team comprising an Engineer, a Senior Technician, two Survey Officers, two Chainmen and two Linemen. The teams were each equipped with four vehicles, including two of the four wheel drive type, and conventional survey equipment, including two theodolites of one second angle readability. Fig. 3 shows a survey group and some of its equipment. Since ready communication facilities were essential for this class of survey work, where surveyors were required to make critical and co-ordinated measurements when separated by up to 45 miles, each vehicle was equipped with a V.H.F. mobile transceiver. Pack sets operating on the same frequency, were also provided for use when vehicles could not be driven on site, which was often the case. Hand type H.F. transceivers (Handie-Talkies) were used for short distance communication within a general site area, such as the control of tree clearing along a ridge to gain a survey outlook.

The engineers generally worked ahead of their respective measuring teams in conducting an on-the-spot appreciation of all practical paths having regard to the factors mentioned above, and also determined the extent of measurements required to confirm or reject particular site areas. Each particular site was usually interlocked with one or both of the adjacent sites and a variation of one could lead to a variation of a number of sites on either side. It is always possible in this class of survey that what might be developing as a very acceptable section of route could lead to an inescapable site location which is unsatisfactory or unacceptable for propagation reasons or high road costs etc. The lack of map contour information in some restricted sections of the route, together with the relative isolation and limited road conditions in other sections, increased the extent of field appreciation required.

The measurements to be carried out each day very often depended upon the results obtained on the previous day so that daily calculations and an engineering examination of results were essential to confirm or reject the various route possibilities as they developed. Road costs were often the deciding factor in site selection and the Commonwealth Department of Works rendered speedy assistance by furnishing estimates of comparative road costs, based upon examination of aerial photographs or by immediate field investigation.

In Brisbane, two Drafting Officers were engaged in the production of drawings based on the field measurements i.e. Route Plans, Individual Path Profile Plans, "Near End" Path Profiles as required, Individual Site Contour and Site Development Plans.

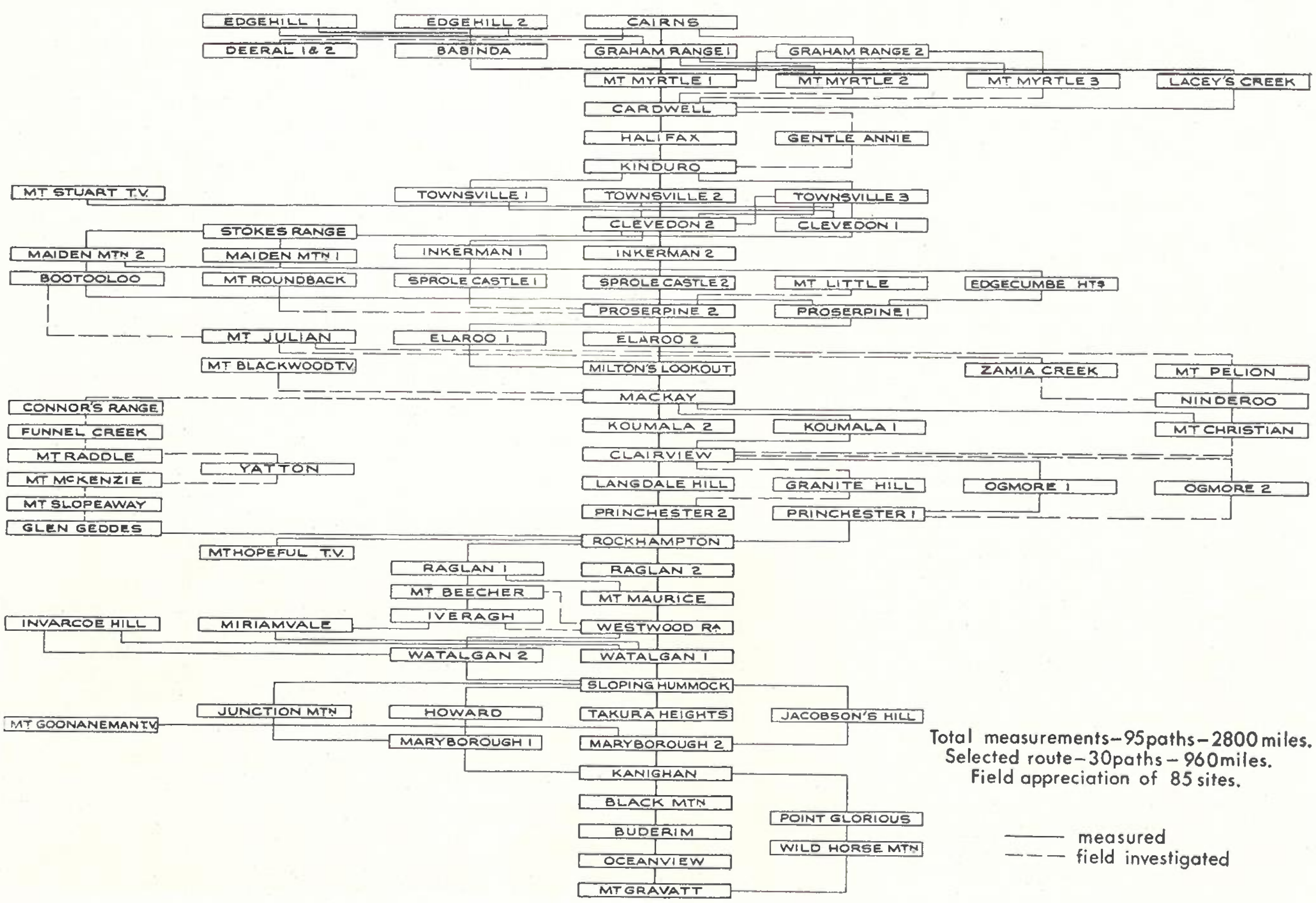

Fig. 4 — Field Appreciation and Measurements Involved in Route Selection.

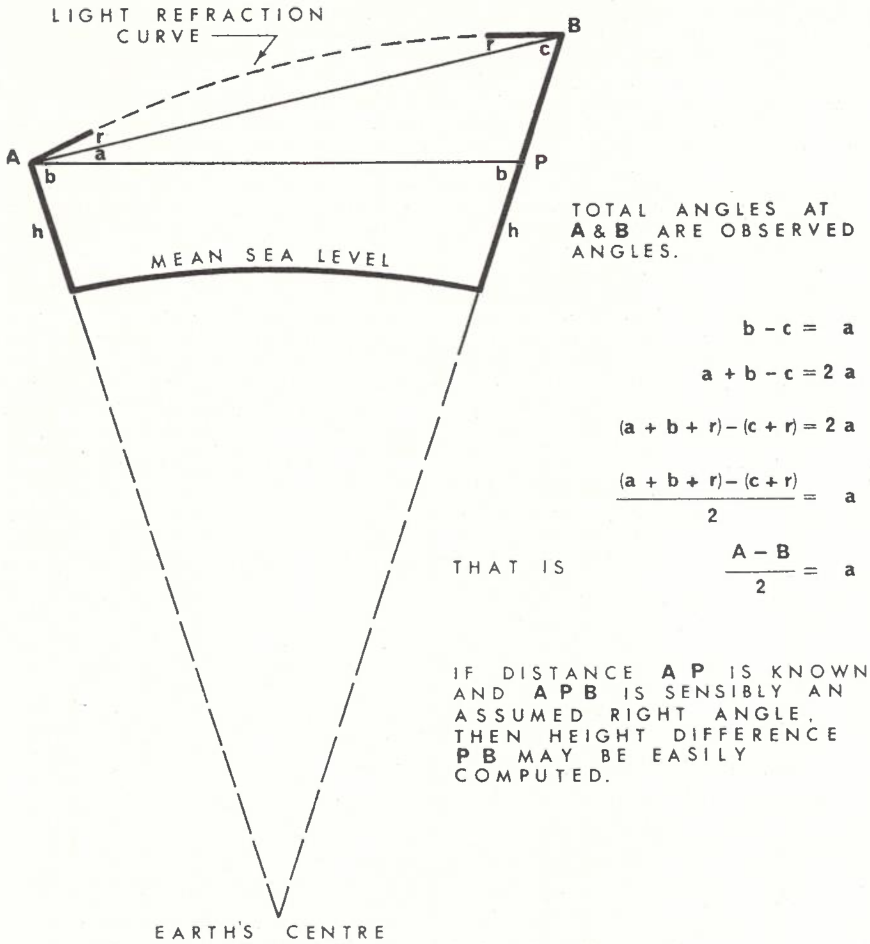

Fig. 5 — Geometry of Reciprocal Levelling.

Field Measurements

Measurements were directed towards assessing the elevation of sites and intermediate terrain to ascertain whether adequate clearance was available or could be achieved with practical tower heights and whether a relatively flat and exposed section of path was a serious reflecting area.

The clearance of a radio path is always critical in one or more of the following conditions:—

(a) Over near-end tree growth, buildings or other structures.

(b) Over one or more dominant high points on the path profile. The high point may be a ridge, in which case its transverse slope, in silhouette, may be important.

(c) Over extensive flat plains on the path profile where, due to earth curvature, a profile segment several miles in length may control path clearance.

(d) Over minor high points which provide a degree of shielding of neighbouring flat areas on the profile, such areas being potential ground or water reflection surfaces. In these cases the locations and levels of the surface and the high point relative to the path ends had to be known accurately.

(e) Topographical or man made features sufficiently close to the radio path to make lateral clearance critical, generally within 200 feet of the path.

The accuracy desired for clearance assessments over critical points was ±5 feet but a greater tolerance was often found more practicable in terms of the field effort involved and when the engineering implications of the poorer accuracy were acceptable. It was necessary, of course, to ensure that all levels on any one path had a common datum.

Measurements of potential ground reflection areas often involved a levelling traverse several miles in length with an accuracy of approximately ±3 feet and an assessment of height and density of any tree cover. Some paths, such as those crossing flooded plains or open stretches of water required only a visual examination to accept them as a definite reflection hazard.

It is interesting to record that of the 30 paths selected for the route from Brisbane to Cairns, there are 14 which do not have ground to ground clearance for true earth radius. This emphasises the fact that the survey was not directed towards a selection of high points which would provide "line of sight" paths over long distances such as 50 miles and above, because, as mentioned earlier, the propagation difficulties increase rapidly for paths in excess of about 35 miles. The survey was directed, therefore, to the selection of paths of reasonable distance which met the path clearance criteria mentioned in (vi) without seeking any unnecessarily high sites which would usually involve a heavy penalty in road construction costs. In fact, it was often advantageous to avoid excessive clearance in order that an intermediate high point could be used to screen an area which would otherwise be a potential ground reflection area.

It will be recognized, however, that considerable and critical field effort was involved when so many of the selected and alternative paths had no line of sight from ground level and the specified clearance in such cases would be dependant upon relatively high towers.

The magnitude of the work involved in the selection and measurement can be gained from an examination of Fig. 4 which shows that 95 paths, totalling 2,800 miles, were measured to determine the final route of 30 paths, which totals 960 miles, even though it was essential that the route should generally follow the main highway or railway from Brisbane to Cairns. In addition there were many other site areas which were investigated in the field but rejected without measurement.

Survey Methods

An extensive and reliable system of survey levels exists in this State, particularly along the populated coastal strip. This system has resulted from close coordination over many years between various Authorities such as the Surveyor-General's Department, Main Roads and Railway Departments and the Commonwealth Departments of the Army and National Development. Direct levelling from this system of bench marks was frequently employed to obtain the elevation of sites or intermediate terrain, each survey team being provided with the automatic type of levelling instruments.

However, the trigonometrical system of levelling was extensively employed particularly in the form which involves simultaneous reciprocal observations between two points, one of which is of known or assumed elevation. The absolute levels of any points in one particular path are not critical but it is important that the relative or differential levels of such points be known to the specified order of accuracy.

Simultaneous reciprocal levelling provides a rapid means of calculating height differential over a distance such as the length of a radio path. This method eliminates earth curvature and minimises the effect of light refraction conditions. The geometry of this method is outlined in Fig. 5. The best results are obtained under the following conditions:—

(a) Path distance up to 35 miles.

(b) Height differential up to 600 feet.

(c) Observations taken between 10.00 a.m. and 3.00 p.m.

(d) Fine weather with similar atmospheric conditions obtaining over the path.

However, measurements can be taken over longer paths, with greater height differential, while still maintaining an accuracy of about ±5 feet.

This method of levelling required a surveyor at the point of known elevation and at the point of unknown elevation, each of whom set up a target such as a 5-inch sun mirror or heliograph, following which each simultaneously recorded the observed angle of elevation or depression of the opposite target. Normally both surveyors were in radio communication and each took a series of up to six readings on each face of the theodolite. The average of the readings on both faces of the instrument then became the individual total angles A and B as indicated in Fig. 5.

There were many occasions when overcast conditions prevented the use of heliographs and it is interesting to note that a 6-inch battery powered type spotlamp, similar to a long-range driving lamp, was employed very successfully under these conditions as the target during daylight hours over distances up to 30 miles.

The tellurometer or electronic type of distance measuring instrument was not used on this survey and distance was normally obtained by means of a "great circle" calculation based upon a knowledge of the latitude and longitude of both points concerned. (The difference between the "great circle" and straight line distance in a 32 mile path is approximately 6 inches). These co-ordinates were obtained by locating each point on a 40 chain/inch parish map by triangulation from known locations, and by then deriving the required co-ordinates from a reference point on this map whose co-ordinates were accurately stated.

Height differences over a short distance or where a lower order of accuracy was acceptable were often established by trigonometrical levelling but in a form which involved an observation only from the point of known elevation to the unknown point. The application of simple trigonometry, including a standard light reflection factor ($k = 1.16$), established the height differential, and in such cases sufficient accuracy of distance was obtained by scaling from a 1 : 63,360 map.

The accuracy of the simultaneous reciprocal form of trigonometrical levelling can be realized from the fact that a level was carried from Brisbane to Maryborough between State bench marks (1st order), over five paths of total distance 155 miles with a resulting known closure error of approximately 3 feet.

The coastal strip of Queensland covers areas of rainfall within the range of 30 to 180 inches/year with tree cover varying from very light to jungle conditions and considerable tree clearing was necessary in the higher rainfall areas to gain survey outlooks. Fig. 6 illustrates types of vegetation encountered along the route.

Two particular areas stand out because of the extent of survey effort involved to gain the optimum solutions viz. the section from Kanighan via Maryborough to Sloping Hummock (three paths), and the section from Clairview via Mackay to Proserpine (five paths).

The area surrounding Maryborough is very flat with medium to dense tree cover and this section of three paths in a total of 30 required approximately 20 per cent. of the total survey effort. A searchlight was used at night to establish a survey line through this flat area and hydrogen filled captive balloons, or "kytoons" (see Fig. 3), were also employed to gain a survey line. The only elevated structure in this area was the Maryborough Water Tower and considerable direct levelling through the scrub on an offset line was necessary. The flat terrain demanded high towers which tended to conflict with the requirements of the Department of Civil Aviation but finally mutually acceptable site areas were selected.

The area to the south and north of Mackay is quite broken and the ultimate solution involved ray lines through narrow folds in the hills to gain practical sites which interlocked and formed the route from Clairview to Proserpine.

ROUTE FEATURES

With the exception of the larger provincial cities such as Maryborough, Rockhampton, Mackay, Townsville and Cairns, the population density of the coastal strip is relatively low and this, together with the nature of the industries such as sugar, beef, dairying and fruit, has not necessitated urban development and consequent road construction to hilltops along the route; consequently the extent of new road construction for the radio route is high. Roads were available to the site areas near the five cities mentioned above but new road construction was required to 20 of the remaining 25 sites, and improvements were necessary at 2 other sites.

A significant feature of the route is the availability of three phase commercial power at every site. This has resulted from successful negotiation between the Commonwealth Department of Works, the State Electricity Commission and the six Regional Electricity Authorities

Fig. 6 — Typical Vegetation along the Route.

concerned. In one remote area, new power line construction was arranged over a distance of 120 miles to supply power to Princhester, Langdale Hill and Clairview repeater stations in the Rockhampton-Mackay section, with capital costs being shared by the Capricornia Regional Electricity Authority and the Commonwealth. The availability of commercial power at all stations will be a distinct advantage in maintaining the radio system and, no doubt, towns such as Marlborough and St. Lawrence and many station properties will benefit also by the power line extensions.

CONCLUSION

A route has been selected for the establishment of the Brisbane-Cairns Microwave Radio System comprising 30 paths in the 960 mile span. In addition to providing for international traffic, this route will cater for the immediate and future trunk and television relay requirements of all provincial cities and major towns along the Queensland coast.

The propagation performance of numerous alternative paths and the maintenance requirements of the associated sites have been closely examined along with economic considerations in selecting the final route which will meet the stringent specifications regarding technical performance and system operation.

The survey was carried out to a tight timetable, necessitating close co-operation between various sections of the Department in the State and Central Administrations, and between this Department and other Authorities, such as the Commonwealth Department of Works and Interior, the State Forestry and Surveyor-General's Departments and property owners along the route.

This has been the first major radio route survey to be carried out in Queensland and undoubtedly all departmental personnel engaged upon this phase of the overall project found it to be a most interesting and satisfying experience.

ACKNOWLEDGMENT

The author wishes to thank his colleagues, and in particular those from the Queensland Drafting Section, for their advice and assistance received during the course of this project.

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TECHNICAL NEWS ITEM

SEMICONDUCTOR INTEGRATED CIRCUITS

Recent advances in semiconductor techniques have led to the availability of multiple devices and integrated circuits in commercial quantities. The multiple device, or integrated circuit module is contained physically in a multi lead metal can similar in appearance to a single transistor.

Multiple devices are usually restricted to active components such as transistors, and a typical unit would comprise a matched pair of transistors for application in a differential amplifier, or a complementary transistor pair for high speed switching or wideband amplifier application. The most important advantage of such an arrangement, apart from the obvious space saving, is the high degree of uniformity of the characteristics of the individual devices and the close tracking of these individual characteristics with varying ambient conditions.

Integrated circuits include both active and passive components, and also the interconnections between them to form a complete circuit module. Typical of the circuit modules already listed in the manufacturers' catalogues and available "off the shelf" are the following examples:

1. Logic Circuits —
   Binary Set reset flip flop
   Half adder
   NOR-NAND logic circuits
   OR AND logic circuits
2. Linear Circuits —
   Audio amplifier, 35 db gain, bandwidth 120 kc/s
   Emitter coupled, 18 db power gain at 200 Mc/s.

These integrated circuits generally fall into one of two different types: viz. hybrid or monolithic.

In the hybrid circuit the individual circuit elements are made separately by semiconductor processes and are then mounted on a ceramic substrate and interconnected by metallized patterns. The individual circuit elements are physically isolated from each other. In the most useful capacitor is the thin passive circuit elements and also the interconnections are fabricated within or on the surface, of a single crystal of semiconductor material, usually silicon.

Resistors used in both hybrid and monolithic construction are typically thin films; in the hybrid type they are obtained by the controlled deposition of nichrome on the substrate but in the monolithic type, the resistance of a layer of silicon is used. Again, for both monolithic and hybrid constructions, the most useful capacitor is the thin film silicon dioxide type. Here, the silicon dioxide forms the dielectric between metallized conductors. The advantages of both monolithic and hybrid type integrated circuits over more conventional arrangements are the great space economy and a very high degree of reliability. The factors governing the choice of hybrid or monolithic construction are as follows.

The hybrid construction has the advantages of lower design and tooling costs and is usually designed using commercial transistor types of known performance. They are also relatively adaptable to design changes and, consequently, are useful for developing prototypes. They are, in fact, often used as the interim design stage for the monolithic types. The monolithic construction has the advantage that transistors may be standard commercial types, or may be custom designed for the particular job. Also, the matching of and the electrical and thermal tracking of a pair of transistors, say, for a differential amplifier are much more precise since such a pair of transistors would be fabricated at the same time and within a few thousandths of an inch of each other in the same crystal of semiconductor.

The monolithic construction is suited to large quantity production: a typical example is a half adder circuit consisting of 16 transistors and resistors. In production 140 of these half adder circuits are fabricated from a single small semiconductor wafer. The monolithic integrated circuit, however, suffers from certain parasitic effects, due mainly to the inherent capacitance between transistor collectors and the common substrate material. These effects may lead to a preference for the hybrid construction for high frequency applications.

The costs of these integrated circuits are, at present, probably higher than for more conventional constructions but the massive development effort being applied to these devices is certain to narrow this gap so that this development is one that will be watched with interest. —E.D.

THE TELLUROMETER

*A. H. FAULKNER, M.A., A.M.I.E.E.**

INTRODUCTION

The Tellurometer is an electronic instrument used in surveying for the precise measurement of line lengths of up to 40 miles with an accuracy of 12 in. or better. Its development a few years ago represented a major breakthrough in the field of surveying, since previously for lines which could not be covered by chaining, the only means of measurement was by theodolite triangulation, using a chained baseline as reference. This system requires the establishment of three stations for each measurement, all intervisible, and imposes severe restrictions on the choice of points to which measurements can be made directly. The Tellurometer, on the other hand enables measurements to be made directly between any two intervisible points.

EMPLOYMENT IN P.M.G.'s DEPARTMENT

A number of Tellurometer equipments have been purchased by the P.M.G.'s Department within the last two years for use in path surveys for projected microwave broad-band bearer systems. These surveys require the precise definition of the ray-line between two adjacent repeaters 30 miles or more apart, and the accurate determination of the levels of potential obstructions in the ray line, relative to that at the repeaters. The Tellurometer provides one parameter for the calculation of these levels, namely distance, the other parameter, angular elevation or depression, being determined by a theodolite having an accuracy of one second of arc. By means of these two instruments, levels can be established to an accuracy of 3 ft. or better. For the purposes of microwave system design, a maximum error of 5 ft. is normally specified.

Another valuable use of the Tellurometer in this application is for the establishment of ray-lines where normal line-of-sight techniques cannot be used because of local obstructions. In such cases, a series of intervisible points is established joining the two ends of the ray-line, but not necessarily on it. Tellurometer and theodolite measurements enable the resulting framework to be precisely calculated. Points on the ray-line can then be located by relating them to this framework.

GENERAL DESCRIPTION

The instrument is enclosed in a weatherproof case $11\frac{1}{2}$ in. by 15 in. by 12 in. in size, and weighs 29 lbs. A back-pack enables it to be carried readily by one man. Instruments purchased by the P.M.G.'s Department have been valve-operated, but a later version is now available using semi-conductors in some sections, thus reducing weight and power consumption. It also provides digital readout of individual measurements, instead of the present cathode-ray-tube presentation.

Fig. 1 shows a side view of the instrument with its aerial mounted in the normal operating position. Fig. 2 shows the method of operation, the instrument in this case being mounted on the roof platform of one of the specially fitted Landrovers used by the Survey Section in Western Australia. Alternatively the aerial can be detached and mounted at the top of the ladder shown in the photograph in the erected position. Connection is then made to the instrument by coaxial cables. This is advantageous when working among trees, which will rapidly attenuate the signal.

GENERAL PRINCIPLES

The Tellurometer is basically a device for enabling an unknown path length to be measured, by expressing it in terms of a number of wavelengths of a master oscillator. This is done by transmitting the oscillation from one end of the path to the other and back again, and comparing the phase of the returning signal with that of the originating oscillator at the moment of return. The oscillator frequency chosen is 10 Mc/s, the free space wavelength at this frequency being approximately 100 ft., so that a phase difference of one complete cycle corresponds to a go-and-return distance of 100 ft., or path length of 50 ft. Since the equipment permits phase change to be measured to one-hundredth of a cycle, or 3.6 degrees, the theoretical accuracy of measurement is one-hundredth of 50 ft., or six inches. By measuring also the number of whole cycles of phase change, distances up to 50,000 ft. or 10 miles approximately can

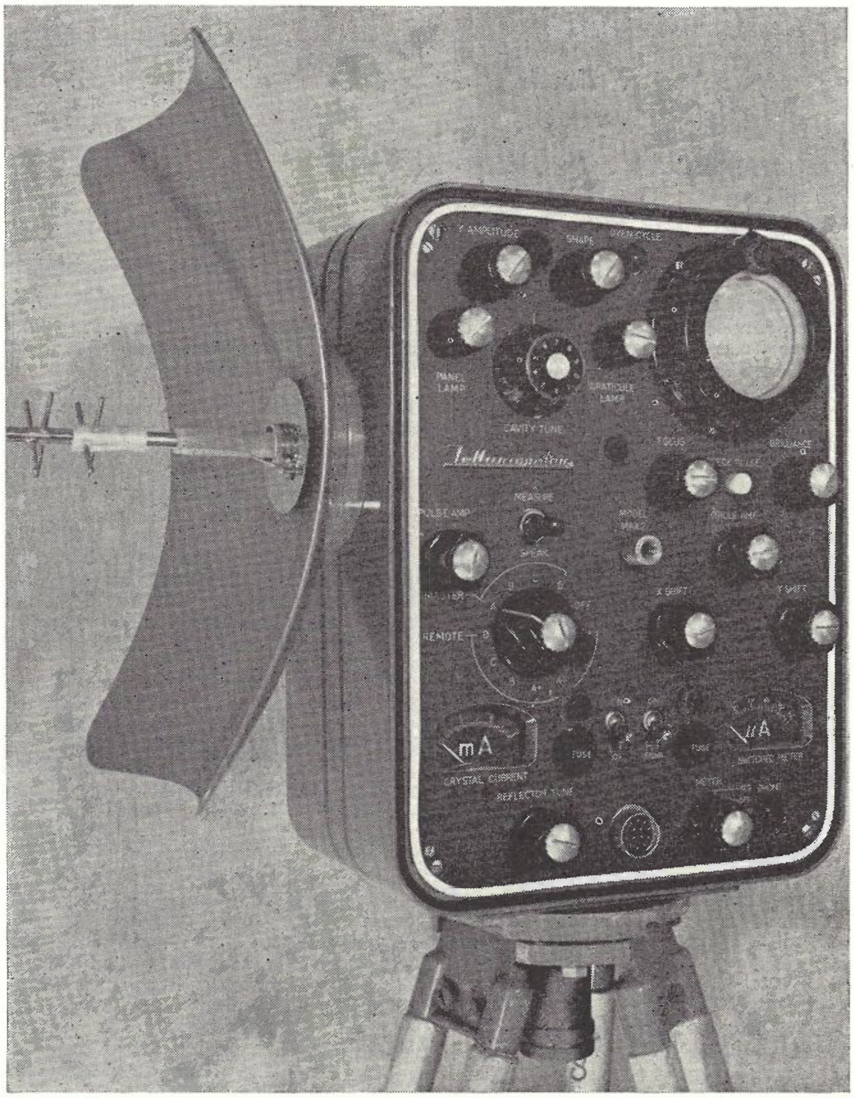


Fig. 1 — The Tellurometer

*Mr. Faulkner is Engineer Class 1, Radio Section, Western Australia. See page 161.

Fig. 2 — The Method of Operation

be measured without ambiguity. For greater distances than this the ambiguity must be resolved by an approximate knowledge of the path length, the limiting distance then being controlled by radio propagation considerations. Normally it is about 40 miles, a line-of-sight path being necessary.

To avoid errors due to variations in propagation, and also for the sake of compactness the 10 Mc/s signal is not transmitted directly, but is frequency modulated onto a 3000 Mc/s carrier.

Two identical instruments are used at the two ends of the distance to be measured, one acting as the master, which makes the measurement, and the other as the "remote" which acts as a repeater. Either of these functions can be selected by switching.

TECHNICAL DESCRIPTION

Master Transmitter

Fig. 3 shows a block schematic of the system. In the master instrument, a low-power reflex klystron oscillator produces an output of about 100 milliwatts at 3000 Mc/s. This is frequency modulated by the application to its reflector electrode of a 10 Mc/s signal produced by a crystal oscillator. This output is radiated by a small paraboloid aerial having a dipole-and-reflector feed.

Remote Receiver-Transmitter

At the remote instrument, the signal is picked up by a similar aerial system and fed to a silicon crystal mixer. Here it is mixed with a local oscillation generated by a corresponding reflex klystron operating at 3033 Mc/s, producing a 33 Mc/s I.F. signal which is fed to an I.F. amplifier. The 3033 Mc/s local oscillator is itself also frequency modulated by a crystal oscillator operating at 10.001 Mc/s. (A 33 Mc/s I.F. is chosen so as to eliminate the third harmonic of 10 Mc/s and the fourth harmonic of 9 Mc/s.) Thus there are present at the mixer input the frequencies shown on the upper line of Fig. 4, these being the incoming 3000 Mc/s signal with its +10 Mc/s and —10 Mc/s sidebands (higher order sidebands are ignored here) together with the 3033 Mc/s local oscillation with its —10.001 Mc/s and +10.001 Mc/s sidebands. These are combined in the mixer, and those products which are accepted by the I.F. amplifier (whose bandwidth is approximately 100 Kc/s) are shown on the lower line of Fig. 2, together with their derivation. These are 32.999 Mc/s, 33 Mc/s, and 33.001 Mc/s.

It will be seen that these frequencies can be interpreted as representing a 33 Mc/s carrier with sidebands at + and — 1 Kc/s — that is a 33 Mc/s signal, amplitude modulated at 1 Kc/s. This signal is fed from the output of the I.F. amplifier to an A.M. detector, giving a 1 Kc/s sine wave which is then shaped into a short pulse of 1 Kc/s repetition rate. This pulse is applied as modulation to the 3033 Mc/s klystron oscillator, in addition to the existing 10.001 Mc/s modulation, and this signal is radiated back to the master receiver.

The one klystron oscillator is made to serve as both transmitter and local oscillator by providing two sets of dipoles in the aerial, at 90 degrees to each other. The klystron output is fed to one set, which thus acts as the transmitting aerial. The received signal from the master transmitter is picked up by the other set, which also obtains a sample of its own klystron output, substantially attenuated by the cross-polarisation. This serves the dual purpose of preventing overload of the silicon crystal mixer, and of avoiding the excessive absorption of transmitter power. Similar cross-polarisation is provided at the master instrument.

Master Receiver

At the master receiver mixer, the incoming signal (3033 Mc/s frequency modulated with 10.001 Mc/s and 1 Kc/s pulse) is mixed with a sample of the master signal (3000 Mc/s frequency modulated with 10 Mc/s). The resultant I.F. output, by the same analysis as before, consists of a 33 Mc/s I.F., amplitude modulated at 1 Kc/s and also frequency modulated by a 1 Kc/s pulse. This signal is applied to both an A.M. detector and an F.M. limiter- discriminator.

The 1 Kc/s sine wave output of the A.M. detector is split into two components with 90 degrees phase difference by a phasing network, and these components are applied to the X and Y plates of a cathode-ray tube to produce a circular trace. The 1 Kc/s pulse output of the F.M. discriminator is applied to the grid of the cathode-ray tube, thus blanking out the trace for the duration of the pulse and producing a small break in the circle.

Measurement of Distance

The measurement of distance is accomplished by instantaneously comparing the phase of the master and remote crystal oscillators. Consider the condition of the remote receiver input when the incoming 10 Mc/s master signal and

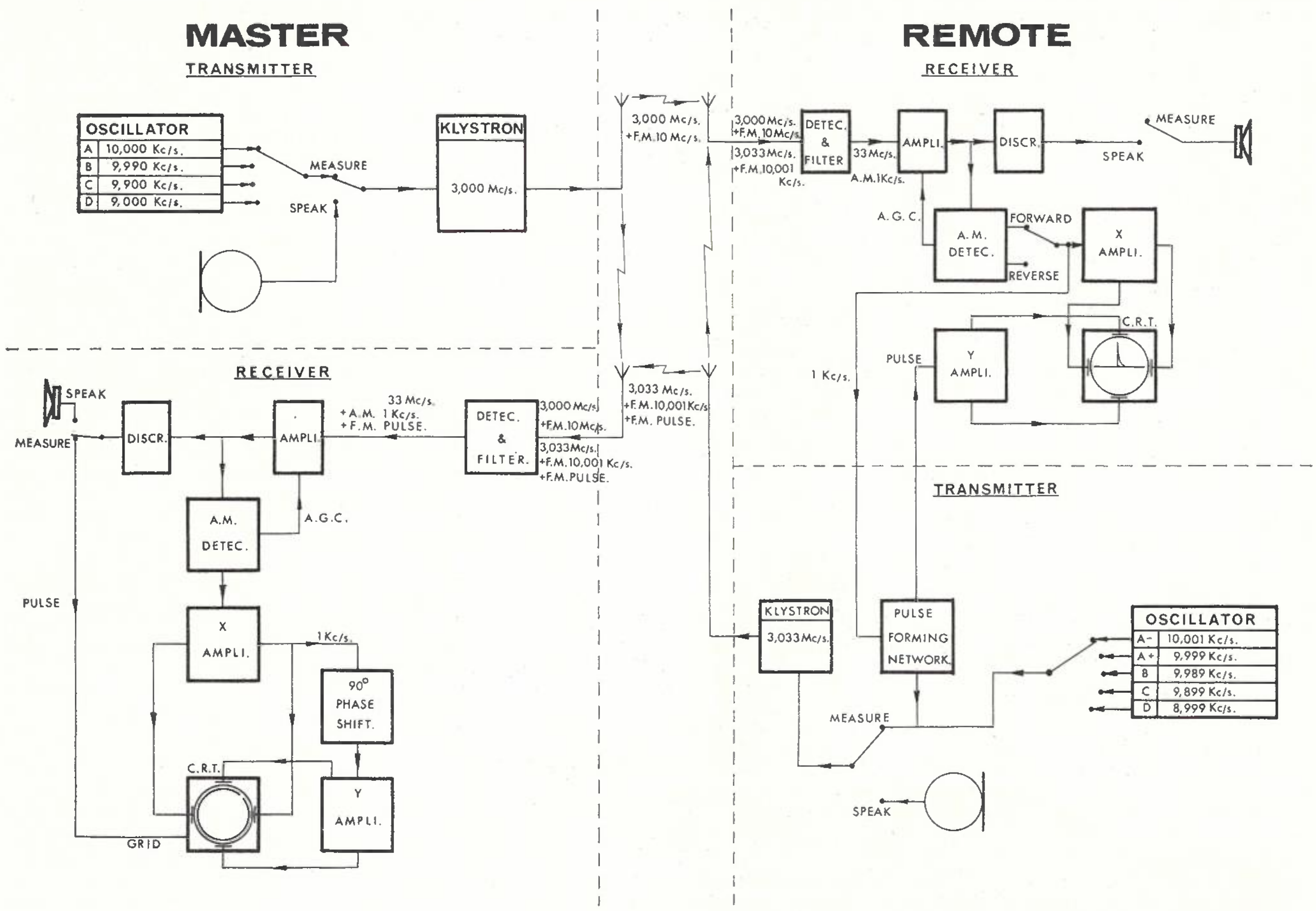


Fig. 3 — Block Schematic

the local 10.001 Mc/s signal are in phase. (This will occur 1000 times each second). Assume that the pulse is produced by this exact phase coincidence and so occurs at this moment.

At this same moment the master oscillator is say x degrees ahead of the remote oscillator, since the incoming signal has taken a time equivalent to this to reach the remote unit. The remote unit oscillator output, together with its marker pulse, are now transmitted back to the master unit. By the time they arrive, the master oscillator will be 2x degrees ahead of the remote oscillator.

Since the pulse represented phase coincidence at the remote unit, there will now be a phase difference of 2x degrees between it and the rotating spot forming the circle, whose position is determined by the phase of the master oscillator. The break generated by the pulse will therefore appear 2x degrees from zero. The position of the break is measured by a circular scale on the CRT having 100 divisions.

If the distance between instruments is changed by 50 ft., this corresponds to one wavelength path change at 10 Mc/s., and consequently the break will move round the circle one complete revolution. Coincidence of zero separation of instruments and zero scale reading is arranged during manufacture, and is not adjustable.

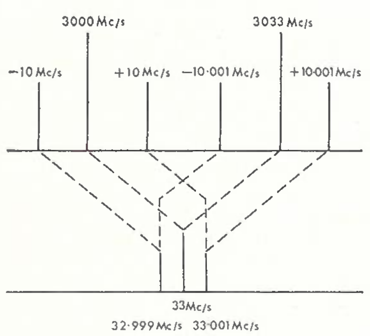


Fig. 4 — Sideband Derivation

Coarse Distance Measurement

Since the indications described above are repetitive every 50 ft., additional facilities are provided to determine the number of whole 50 ft. units represented by the distance to be measured, as follows.

The original pattern, referred to as the A pattern, is produced by a combination of 10 Mc/s and 10.001 Mc/s (A—) or 9.999 Mc/s (A+). (The significance of these alternatives is described later.) Additional crystals are provided to produce combinations of —

Master	Remote	
9.000	8.999 Mc/s	— D pattern
9.900	9.899 Mc/s	— C pattern
9.990	9.989 Mc/s	— B pattern

It will be observed that the master frequencies are 90%, 99% and 99.9% of the A+ frequency, the remote frequencies having a difference of 1 Kc/s from them. The resultant patterns can be considered as a series of cyclometer type dials, as on an electricity supply meter. Normally, in such an arrangement, each successive pattern or dial pointer, rotates at 1/10 the rate of the one preceding it. Here, however, it is the difference in rate between each successive pattern and the A pattern which decreases by successive factors of 10. Thus —

$$A - D = 10 - 9 = 1$$
$$A - C = 10 - 9.9 = 0.1$$
$$A - B = 10 - 9.99 = 0.01.$$

Hence it is necessary to subtract each reading from that of the A pattern to obtain the actual indication, as shown in Fig. 5. This technique is used to avoid the necessity for crystals down to 10 Kc/s in frequency which would be called

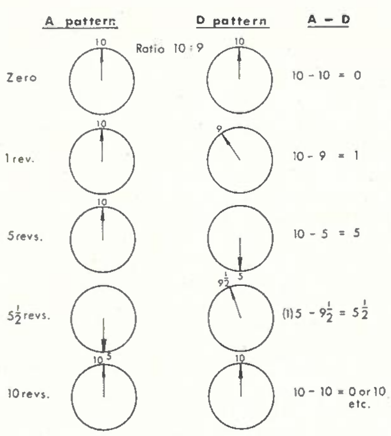


Fig. 5 — Coarse Pattern Readings

for in a direct-reading system. For the D pattern one rotation represents 500 ft. (half wavelength at 10 — 9 = 1 Mc/s); for the C pattern 5000 ft. (10 — 9.9 = 0.1 Mc/s); and for the B pattern 50,000 ft. (10 — 9.99 = 0.01 Mc/s).

Instrument and Propagation Corrections

"A+/A—": A switch is provided on the instrument labelled "A+/A—". This substitutes a 10.001 Mc/s crystal for the 9.999 Mc/s when taking the A reading, and thus reverses the direction of rotation of the pattern. Averaging the A+ and A— readings eliminates zero error of the instrument.

"Reverse Reading": Another switch, labelled "Reverse Reading", shifts the pattern by 180 degrees by switching to a reverse-polarity A.M. detector. This corrects for scale displacement error.

Errors due to Reflections: In order to avoid errors caused by reflections in the radio path, which would cause a phase shift of the received signal, a number of A pattern readings are taken at slightly different klystron frequencies. A mechanical tuning control on the klystron is provided for this. Since the number of wavelengths of path-length difference between direct and reflected path depends on frequency, a sufficient frequency shift is employed to change this difference by a wavelength. A complete cycle of additive and subtractive error is then covered and the error can be averaged out. Where multiple reflection occurs, the pattern is more complex, and complete correction may not be possible. Such paths are avoided where practicable.

Atmospheric Corrections: Changes in atmospheric pressure, humidity and temperature will alter the velocity of propagation and corrections are applied to allow for this. Barometric and wet-and-dry bulb readings are taken by both stations at the time of making the measurements.

Talk Circuit

To provide communication between the two operators, a switch is provided which converts the instruments to conventional F.M. transmitter/receivers. Press-to-talk operation is employed, and lightweight headsets are provided for the operators.

OPERATING PROCEDURE

A typical set of readings taken in the field is shown in Fig. 6. These readings are taken and recorded by the "Master" station, which controls the operation by means of the Talk Circuit. The A, B, C and D pattern readings are taken first, the remote station operator shifting his pattern selector switch as required by the Master station. These results are shown under the heading "Coarse Readings".

The master klystron frequency is then shifted in successive steps, the remote klystron being retuned each time and the A pattern reading taken. These are then arranged as shown in the table headed "Fine Readings". The resultant value is then substituted for the original A reading in the coarse figure to give the accurate value of transit time in millimicroseconds. This is then converted to distance using a figure for velocity of propagation corrected for atmospheric conditions according to the "Met Readings" values.

CONCLUSION

The Tellurometer represents a remarkable achievement in producing a distance-measuring instrument of such a high degree of accuracy in such a small space, particularly since conventional tubes and components are used. Although somewhat complex in its theory of operation, the circuit complexity is less than that of a domestic television set, and its operation can readily be carried out by non-technical staff.

TYPICAL EXAMPLE

TELLUROMETER FIELD SHEET

MASTER STATION: KINGS BTY. PEG INST. No. MA2 OPERATOR R.G. STEWART.

REMOTE STATION: KLIPFONTEIN INST. No. RA2 OPERATOR R COULTER

DATE 5-3-59 CONDITIONS BLUSTERY-DRY-WIND APPROX.

TIME 16·30-17·05 30 KNOTS ACROSS LINE.

NOTE. Add 100 as A-reading is in effect A+ reading taken anti-clockwise

COARSE READINGS

	Initial				Final			
	A+74·5	A+74·5	A+74·5	A+74·5	A+76·5	A+76·5	A+76·5	A+76·5
	B 63·5	C 44·5	D 66·0	A− 22·5	B 65	C 45	D 67	A− 22
Diff.	11	30	085	152÷2 76	11·5	31·5	09·5	154·5÷2 77·25

APPROX. DISTANCE 11 COARSE FIGURE = 113077·25 mμ secs

MET. READINGS

	Dry Bulb F.	Wet Bulb °F.	Dep. °F.	Dew Point °F.	Vap. Press. Ins.	Baro. Rdg. Ins.	Corr. Baro. Ins.	Baro. Ser. No.
MASTER INITIAL	62	58	4	55	·432	28·68	28·68	Master
FINAL	62	57	5	54	·417	28·66	28·66	
REMOTE INITIAL	72	62	10	56	·448	29·96	29·96	Remote
FINAL	70	62	8	57	·465	29·96	29·96	
SUM	266				1·762		117·26	
MEAN	66·5				4405		29·315	

FINE READINGS

	A+	A−	Diff.	A+R	A−R	Diff.	Mean Diff.	Fine Reading
1	74·5	22·5	52	26·5	75·5	51	151·5 / 2	75·75
2	76	23	53	26·5	75·5	51	152 / 2	76
3	76	23	53	26·5	75	51·5	152·25 / 2	76·125
4	76	23	53	27	75	52	152·5 / 2	76·25
5	76·5	23	53·5	27·5	74	53·5	153·5 / 2	76·75
6	76	23·5	52·5	27	76	51	151·75 / 2	75·875
7	76	22·5	53·5	27	75	52	152·75 / 2	76·375
8	76	23	53	27	75·5	51·5	152·25 / 2	76·125
9	76·5	23	53·5	27·5	74·5	53	153·25 / 2	76·625
10	76·5	22	54·5	26	74·5	51·5	153 / 2	76·5
11	21	76	55	27·5	74	53·5	154·25 / 2	77·125
12	76	21·5	55·5	27·5	75	52·5	153·75 / 2	76·875

AVC		BOTTOM	MIDDLE	TOP
	MASTER	43	43	44
	REMOTE	43	43	44

Fine readings total 916·375
mean 76·365

Fig. 6 — Typical Set of Readings

AUTOMATISATION OF THE AUSTRALIAN TELEX NETWORK — PART 1

*R. K. McKINNON, B.E., D.P.A.**

A feature of telegraph traffic since World War II has been the shift from public telegraph networks operated by P.T.T. administrations such as the Australian Post Office to telegraph services in which the administration simply provides the necessary facilities which subscribers themselves operate. Subscribers with a closely defined sphere of interest and a heavy volume of traffic have in general chosen customer engineered private wire leased services, and these were quickly developed during and after the war. An obvious need developed for a general switching network which would cater for subscribers with more widely dispersed communication requirements, would cater economically for relatively light traffic loadings compared with leased private wire service, would permit efficient international connection and would allow easy transfer of traffic to and from the extensive Australian public telegraph network. As a result teleprinter exchange service was introduced in 1954 (1) as a manual network and has shown phenomenal rates of growth in subscribers and in traffic. Even when the manual network was established it was recognised that if customer demands met predictions the service would have to be converted to automatic operation, and long term planning for eventual automatic operation started at that time. An important consideration in planning eventual automatic operation was the choice of the subscribers terminal machine (2) as in the 1950's new designs were becoming available from a number of United States and European sources, and in contrast to telephone switched service about 2/3rds of the capital investment per line connected is associated with the subscribers terminal equipment. The machines then in service, Teletype Corporation Model 15 and Creed Model 7, although modified in minor ways over the years were basically of the 1920's design era and lacked many of the circuit features and subscriber facilities required in a modern telex service. Other important decisions to make were the type of switching mechanism to use in an automatic exchange system, and the main features of the telex transmission path. One important component in telegraph signalling paths is the polarised telegraph relay and the type chosen is described in an article by K. V. Sharp on p. 116 of this *Journal*.(3) It was also important to decide upon the main features of telex operation as seen by the subscriber, these features in turn being inter-dependent with economical terminal unit and exchange equipment design. These and other features of the automatic telex system currently being installed are discussed in this article.

HISTORICAL BACKGROUND OF TELEX SERVICES

Historically, subscriber operated teleprinter switching systems awaited the development of a relatively simple teleprinter, suitable for use in widely dispersed subscribers offices. The start-stop principle was used in the 1920's in the United States and Europe to develop such teleprinters which resembled an office typewriter in operation and required a minimum of auxiliary equipment.

The first large telegraph switching network using these newly developed start-stop page printers was established by the Bell system in the United States in about 1930. This network used d.c. subscriber loops and V.F.T. trunk connections and was designated the T.W.X. System. The system was manual in operation and had grown to 60,000 subscribers by 1962, when the network was converted to automatic operation through partial integration with the telephone switching system, using tone signalling subscriber terminals (4). In Europe the firm of Siemens and Halske developed an experimental fully automatic switching network connecting various branches of the firm in 1930, and following trials by the German P.T.T., telex was established in 1935 as a public service. In 1934 the C.C.I.T.T. Convention in Prague had this new telegraph system demonstrated to it and passed its first resolutions on international co-operation in the telex field. Experience gained in Germany with the system which opened in 1935 and was designated T.W.35 resulted in an improved version known as T.W.39 going into service in 1939. T.W.39 equipment is still in service in Germany, and in many other countries including Canada and the United States (Western Union Telex System) where networks have been provided relatively recently. Telex development particularly in Germany pre-war was very rapid and since re-establishment of the network in Germany following the end of the war the German network has expanded to more than 50,000 subscribers (5).

After the 1939/45 war the Netherlands administration developed common control switching techniques with the teleprinter key-board used for selection and using printing service codes for call supervision whereas previous designs such as T.W.39 were dial selection systems, using step by step switching principles, conventional 10 impulse per second dials for selection purposes, and terminal unit supervisory indicators under line circuit current control. The Netherlands system permitted faster signalling from the subscriber and simplified the design and maintenance commitment of terminal equipment (6). Telex systems since then have taken elements from each type and there are common control systems operating with dial selection without printing service code call supervision and step by step systems such as that of the B.P.O. (7), with printing service code supervision.

In 1948 the C.C.I.T.T. adopted a set of standards for international telex services and these standards have been progressively extended with successive C.C.I.T.T. meetings. The main features of these recommendations were:—

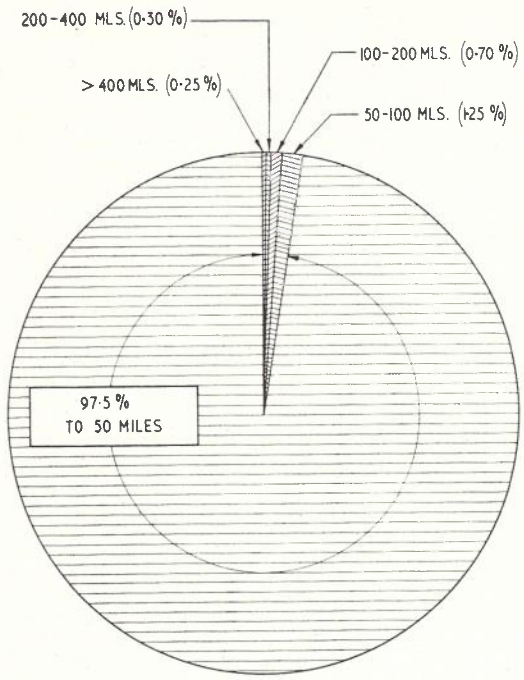
(a) Standardization of the speed of transmission at 50 bauds.
(b) Standardization of teleprinter keyboard arrangements such that these must be in accordance with international alphabet No. 2.
(c) Standardization of two alternative signalling methods designated as Type A and Type B. (Since then a third type, Type C has been added).
(d) That alternative methods of selection should be permitted, namely, dial pulse or teleprinter code.
(e) That the principle of unattended reception with automatic answer-back verification should be adopted.
(f) Standardization on the important principle that for international circuits, the out-going country should conform with the signalling of the in-coming country.

International traffic has become a very important feature of telex service. The first intercontinental telex service was established in 1952 between the United States and several European countries, and since that time has spread to most parts of the world. The type of channel most commonly used for intercontinental circuits in the early years was the radio telegraph circuit protected by Van Duuren automatic error correction and detection equipment operating in the well known synchronous 7 unit code 3 stop polarity 4 start polarity principle and these are still in widespread use (8). In recent years with the establishment of submarine telephone cables, there has been a trend toward conventional V.F.T. channels and the availability of such channels has permitted fully automatic operation on these intercontinental circuits. However, in the interests of economy there has been a move to introduce time division multiplex systems on these V.F.T. channels, this leading to some problems in switching on a fully automatic basis because synchronous time division systems were not easily compatible with the C.C.I.T.T. recommendations for trunk signalling then current as these were based upon pulse signals of time duration inconsistent with those involved in teleprinter signalling. The British Post Office in order to overcome this difficulty and yet retain the advantage of synchronous multiplex operation over such highly expensive circuits developed a new method of trunk signalling which has become known as Type C signalling and has received the approval of C.C.I.T.T. (9).

CHARACTERISTICS OF AUSTRALIAN TELEX TRAFFIC

Telex is a service used primarily by industrial and commercial organizations and therefore will inevitably have a smaller penetration than the telephone service. Development studies show that

*Mr. McKinnon is Engineer Class 4, Telegraphs, Headquarters. See Vol. 14, No. 2, Page 169.



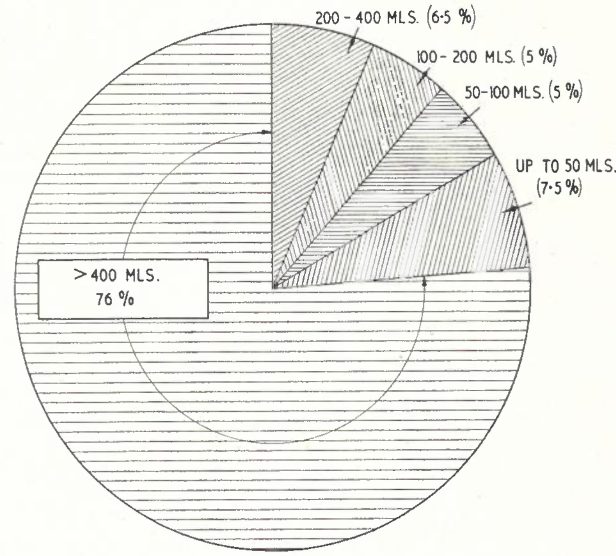


Fig. 1 — Traffic Distribution by Distance.

it is most probable there will be about 5,000 subscribers in the whole of Australia by 1970, increasing to about 11,000 by 1980. Compared with the telephone service where the community of interests centres primarily in the local service areas, telex calls are predominantly made over long distances. Factors which tend to make this so are the relatively high cost of the telex terminal equipment per line previously mentioned, and the lower cost of telegraph channels for trunk calls. A marked difference between telephone and telex traffic distribution by distance is illustrated in Fig. 1.

The second feature of telex traffic is the heavier loading per subscriber line than in telephony. Following studies made on the manual system, the automatic telex network was based on an average subscriber loading in the busy hour of 0.15E per subscriber. This compares with a typical loading per telephone subscriber in a metropolitan exchange area of 0.08E per subscriber line.

Subscriber traffic in the present manual system, may be divided into 3 main groups namely, local, trunk and printergram traffic. Table 1 below shows these 3 categories of call and their development over the period from 30/6/60 to 30/6/64 and demonstrates that the important traffic loads are in the trunk and printergram field.

It will be noted that these figures show that trunk traffic on a per subscriber basis, is continuing to rise steadily. International traffic is another class of traffic in which there is a striking difference between telex and telephone networks. Fig. 2 shows the development in number of international calls and the number of paid minutes of international call time per subscriber in recent years in the Australian system. This figure demonstrates the importance of international operation in the telex network.

Call holding times for the present Australian manual system on effective trunk calls average 4.5 minutes. This figure is much higher than in European automatic telex systems and is thought to be due mainly to manual operation where delays in setting up calls tend to cause subscribers to batch their traffic. In computing equipment quantities for the automatic telex system it has been assumed that call holding times will decrease and a call holding of effective trunk calls of 2.1 minutes has been used. European systems show that there is a high percentage of ineffective calls in telex operations because of the world wide feature of high loading on individual telex subscriber lines and for this reason a heavy allowance has been made for ineffective calls in computed equipment quantities which are dependent upon the number of calls. This factor coupled with the much lower call holding times on printergram traffic has led to an overall average for all classes of traffic, effective and ineffective, of 70 seconds, this figure being in line with statistics made available by European telex administrations. A factor which may cause Australian call holding times to differ from the European pattern is the high percentage of subscriber lines

TABLE 1: TRAFFIC DEVELOPMENT BY TYPE OF CALL

Year	No. of Calls		
	Local	Trunk	Printergram
1957-58	6,794	150,496	644,253
1958-59	5,960	228,561	704,347
1959-60	11,324	344,330	832,334
1960-61	23,984	488,349	939,012
1961-62	36,210	696,482	1,095,643
1962-63	68,769	931,783	1,276,224
1963-64	101,315	1,311,023	1,417,473

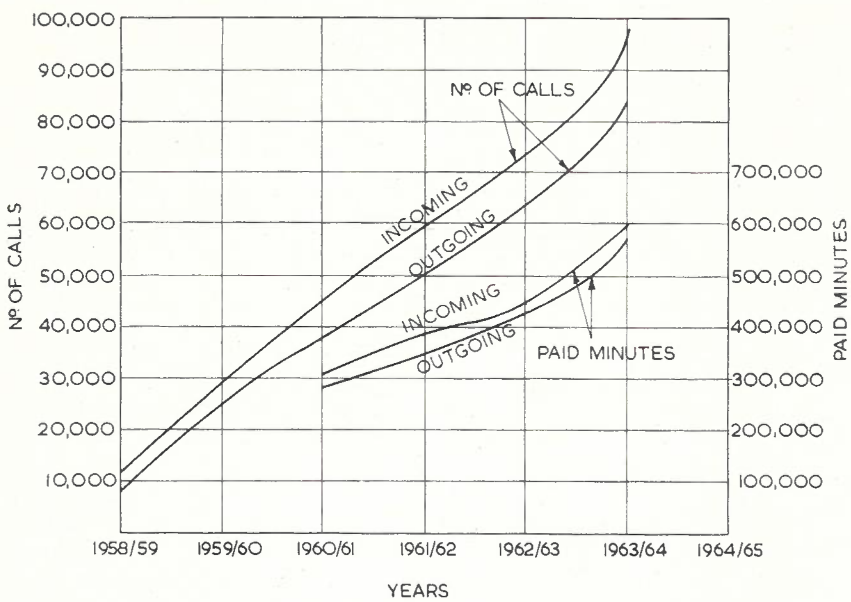


Fig. 2 — International Telex Traffic — Australia.

in Australia equipped with local tape preparation and tape transmission facilities. More than 50% of Australian subscribers are so equipped whereas European figures lie generally between 10% and 20%. It is of course intended to review the call holding time estimates referred to above following the cut-over of the automatic system and the actual measurement of traffic.

GENERAL FEATURES OF THE AUTOMATIC SYSTEM

Type of Switching System

The system chosen for Australia is the L.M. Ericsson ARB10 system, which consists basically of trunk exchanges of the ARM 20 or ARM 50 type with appropriate telegraph type repeaters and registers working in conjunction with specially developed telegraph exchange subscriber stages coded ARB111, which are roughly equivalent to the ARK system well known in the telephone service. Fig. 3 shows the general network being provided. Only 6 transit exchanges are provided. ARB exchanges being dependent upon a single transit exchange.

ARB exchanges have a maximum size of 400 lines, the smallest ARB block being an exchange of 20 line capacity. Typical exchange installations such as that at Sydney consist of an ARM transit exchange of 600 lines to which are connected three 400 line dependent ARB exchanges on the same exchange floor together with an 80 line ARB exchange remotely located at Newcastle and with the capability of connecting many other dependent exchanges at various provincial centres as well as provide additional 400 line blocks in Sydney itself. Key board selection from the subscribers terminal machines is used rather than dial selection as in the German T.W.39 system mainly because of the cheaper subscriber terminal unit and advantages in speed of signalling. Printing service code supervision is used with the following codes:—

OCC Subscriber engaged
DER Out of order
ABS Subscriber absent or office closed
NA Connection not admitted
NC No circuits. (All trunks busy).
NP Not a working line
MOM Wait

It was possible using keyboard selection with printed service code supervision, to design simple subscribers terminal units suitable both for manual operation and for automatic operation without conversion at cut over. Since early 1960 all telex subscribers have been equipped with the Siemens and Halske Model 100 page printer using terminal units of this type, and thus no special attention is required at the subscriber terminal at cut-over to automatic operation.

Type of Signalling System

Before discussing the basic trunk signalling chosen it is worth noting the terminology used in describing a telegraph signalling system. An important point is that in a telegraph system there is a limitation in that only two steady state conditions are available. These in C.C.I.T.T. terminology are referred to as "stop" polarity and "start" polarity corresponding respectively to "mark" and "space" in this country. C.C.I.T.T. has separately identified a number of signalling functions for use on international telex trunks and these are directly applicable to a national signalling system. These are summarized below in Table 2.

TABLE 2: DEFINITION OF MAIN SIGNALLING FUNCTIONS

Signal or function	Definition
Free line	The condition of the circuit when not seized but available for traffic
Calling Signal	The signal transmitted over the forward signalling path to indicate seizure for a call
Call Confirmation Signal	The signal transmitted over the backward signalling path following the initiation of a call, to prove the continuity of the line and the response of the distant terminal equipment.
Proceed-to-select signal	The signal returned over the backward signalling path after the call confirmation signal, to indicate that the selection information may be transmitted.
Selection signals	The signals (e.g. 5 unit start stop International Alphabet No. 2 code combinations) transmitted over the forward signalling path to indicate the number required.
Call connected signal	The signal returned over the backward signalling path to indicate that the call has been extended to a called subscriber. In the case of fully automatic switching between subscribers, this signal will start the equipment for determining the charge for the call.
Idle circuit condition	The condition of a circuit when a connection is established but signals are not being transmitted.
Clearing signal	The signal used to initiate the release of the connection. Clearing can be by either party and is followed by reversion to the free line condition.
Service signals	If a "busy", "out of order", "office closed", or "number unobtainable" (i.e. not connected, service ceased or barred access) condition is encountered in the distant network, this shall be indicated by the return of a signal to the calling end.

The type of signalling chosen for the Australian automatic system is the C.C.I.T.T. type "B" system. In this system the free line condition is start polarity in both directions, and the calling signal is characterised by changing this condition to stop polarity on the forward path. This call is answered on the backward path by the distant repeater returning the call confirmation signal, a 25 millisecond pulse of stop polarity. When a device at the distant exchange is connected and ready to receive signals a second 25 millisecond pulse, the proceed to select function, is reverted on the backward path. Selection signals, consisting in the Australian case of the 5 unit start-stop International Alphabet No. 2 code combinations for digits preceded by the receiving device opening code combination, "Figures shift", are then sent forward. The call connected condition is characterised by changeover of the backward path to the steady state stop polarity condition and telegraph signalling may then take place over the complete circuit. Clearing is by changeover to steady state start polarity on either path, clear confirmation being returned as steady state start polarity on the other path. These conditions are shown in Fig. 4 below. In part 2 of this article the complete signalling system will be discussed and this figure illustrates only the main principles of the trunk signalling method employed.

Numbering and Charging

The group charging plans for telephone purposes used in Australia (10) are based on the community of interest characteristics and because of the preponderance of calls made over the distance of less than 100 miles, fairly accurate assessments of the distance involved by these calls is required. The "Zone" charging basis assists in ensuring that this is achieved. In Australia, as elsewhere to date, telex is predominantly a long-distance service and provided that traffic in the over 400 miles category is appropriately charged, variations of the other charges and combinations of mileage categories would make little difference to the total revenue received. It was therefore decided that the number of rates to be applied and the number of charging areas should be kept to an absolute minimum. In view of this a five digit closed numbering plan has been

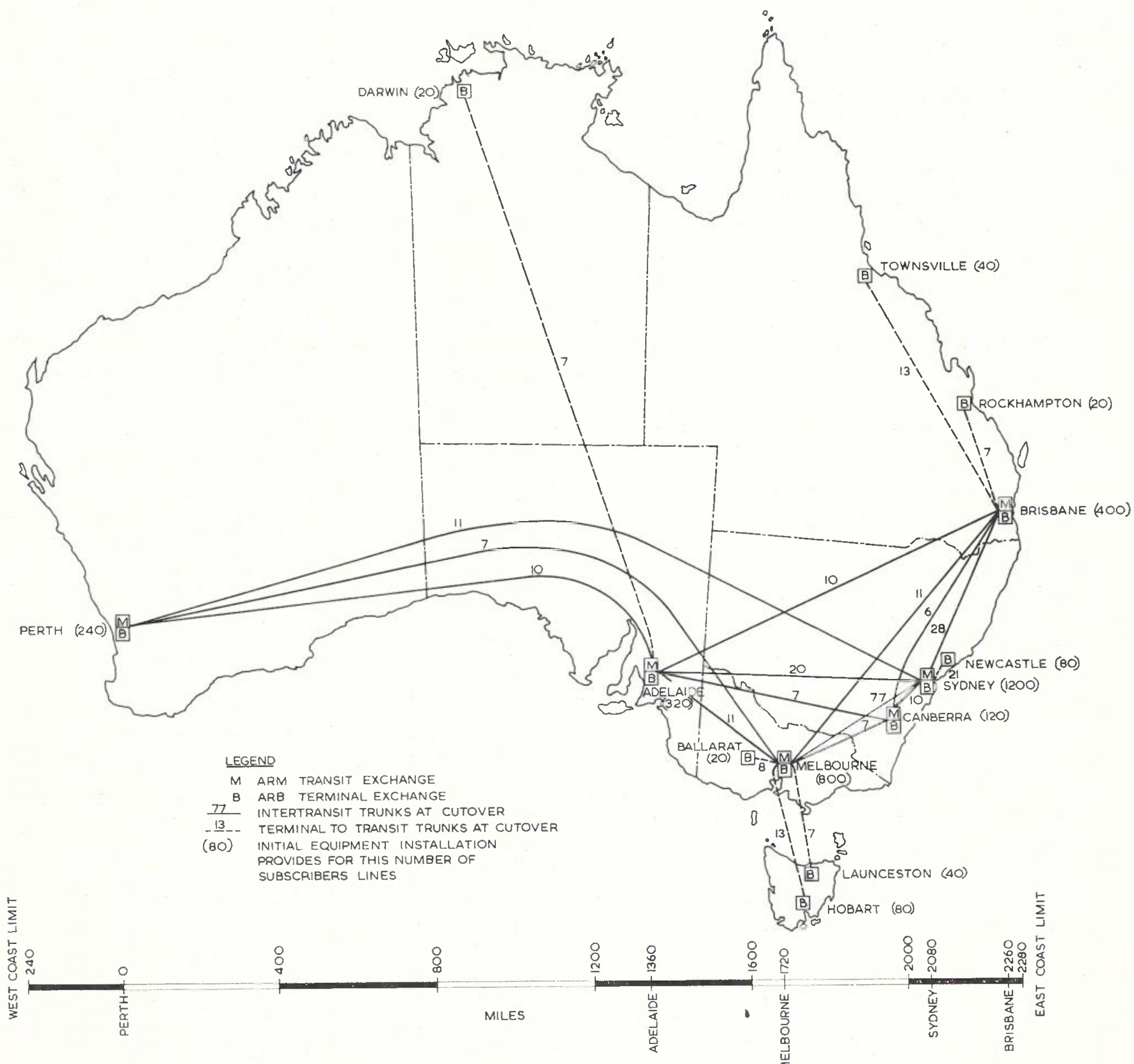


Fig. 3 — Australian Automatic Telex Network.

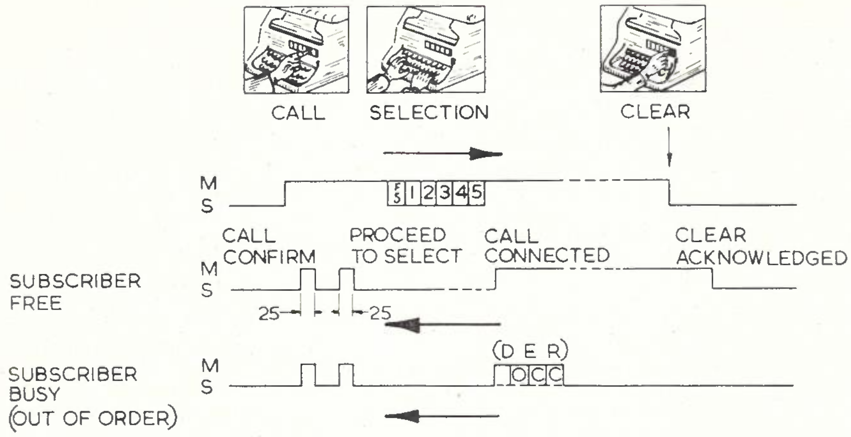


Fig. 4 — Standard Trunk Signalling Method.

devised which will equitably cater for the needs of the telex subscribers in all States for a great many years. It provides for the division of Australia into 44 charging areas with charging discrimination obtained on examination of a maximum of two digits. These charging areas and the A, B, digits allotted to them are shown in Fig. 5 which also shows the charging centre for each charging area.

The principle of charging is that the charge should be based upon the distance between charging centres of the tariff zone in which the calling subscriber and the called subscriber is situated. Fig. 6 shows this principle. All calls are multi-metered including calls within the same charging area, these calls being multi-metered at the base rate. Night rates are provided for calls made between 6 p.m. and 9 a.m. except in the case of calls not exceeding 100 miles between charging centres.

The equipment provides a maximum of 7 rates of which it is intended to use four for meter pulsing and one as a "no charge" rate. Some categories of call such as calls to the printergram service (which permits transfer between the telex network and the public telegram network and therefore is of advantage to the Administration), calls to service positions such as manual assistance, complaints, directory enquiries, are of course not charged and the equipment is arranged to take account of this requirement. The proposed table of pulse periods for the various rates is shown in Table 3 below.

One feature of the Australian charging method is that pure random Karlsson multi-metering is used but in order to allow a calling subscriber to check an answer back to the called subscriber machine, the commencement of metering

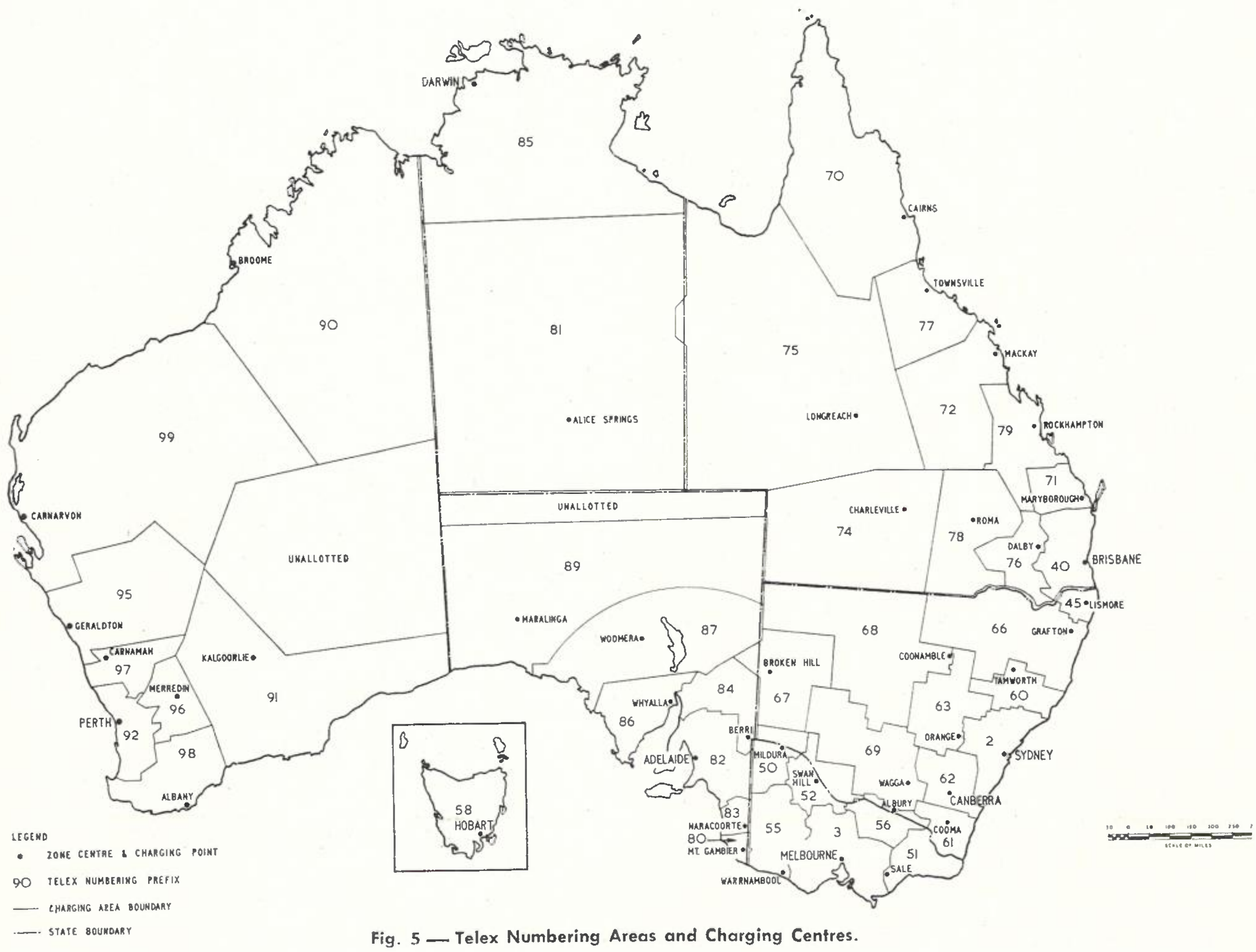


Fig. 5 — Telex Numbering Areas and Charging Centres.

TABLE 3: METER PULSING RATES

Number of seconds between pulses	Distance between Zone charging centres.	
	Day	Night
⟨ 100 miles	90	90
⟩ 100 ⟨ 200 miles	45	60
⟩ 200 ⟨ 400 miles	20	30
⟩ 400 miles	12	15

is inhibited for a period which is adjustable by the Administration between 5 and 12 seconds. Since the automatic telex system itself calls for answer back, a subscriber has the opportunity in this period to observe an incoming answer back and immediately clear, if he has not obtained the correct connection, thus avoiding charge.

Trunking Pattern

The basic trunking arrangements employed in the ARB stages are shown in Fig. 7. The maximum size ARB exchange consists of 400 ARB lines and the group arrangements allow for a maximum of 100 trunks, or 200 trunks depending upon which of the two alternative grouping arrangements is chosen. The smaller grouping arrangement was chosen for the Australian exchanges, this catering adequately for the traffic offered. Fig. 7 also shows the main elements of common equipment provided per 400 line subscriber terminal exchange, the legend giving the purpose of each of these, Fig. 8 shows how ARM transit stages are employed in telex switching. As shown in the figure, ARB terminal exchanges may be either directly associated with a transit exchange or may be "remote" exchanges trunked off a transit exchange some distance away. In the Australian network as shown in Fig. 3, Hobart and Launceston will each trunk off Melbourne transit exchange, Darwin off Adelaide, Newcastle off Sydney, Rockhampton off Brisbane. Provision is made for trunking an ARB exchange

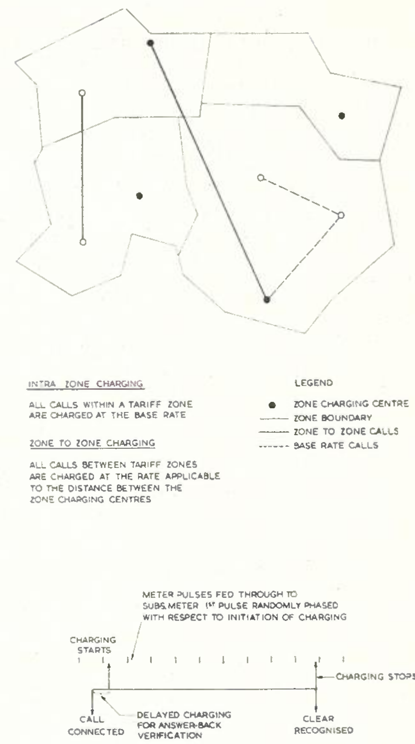


Fig. 6 — Principle of Telex Charging.

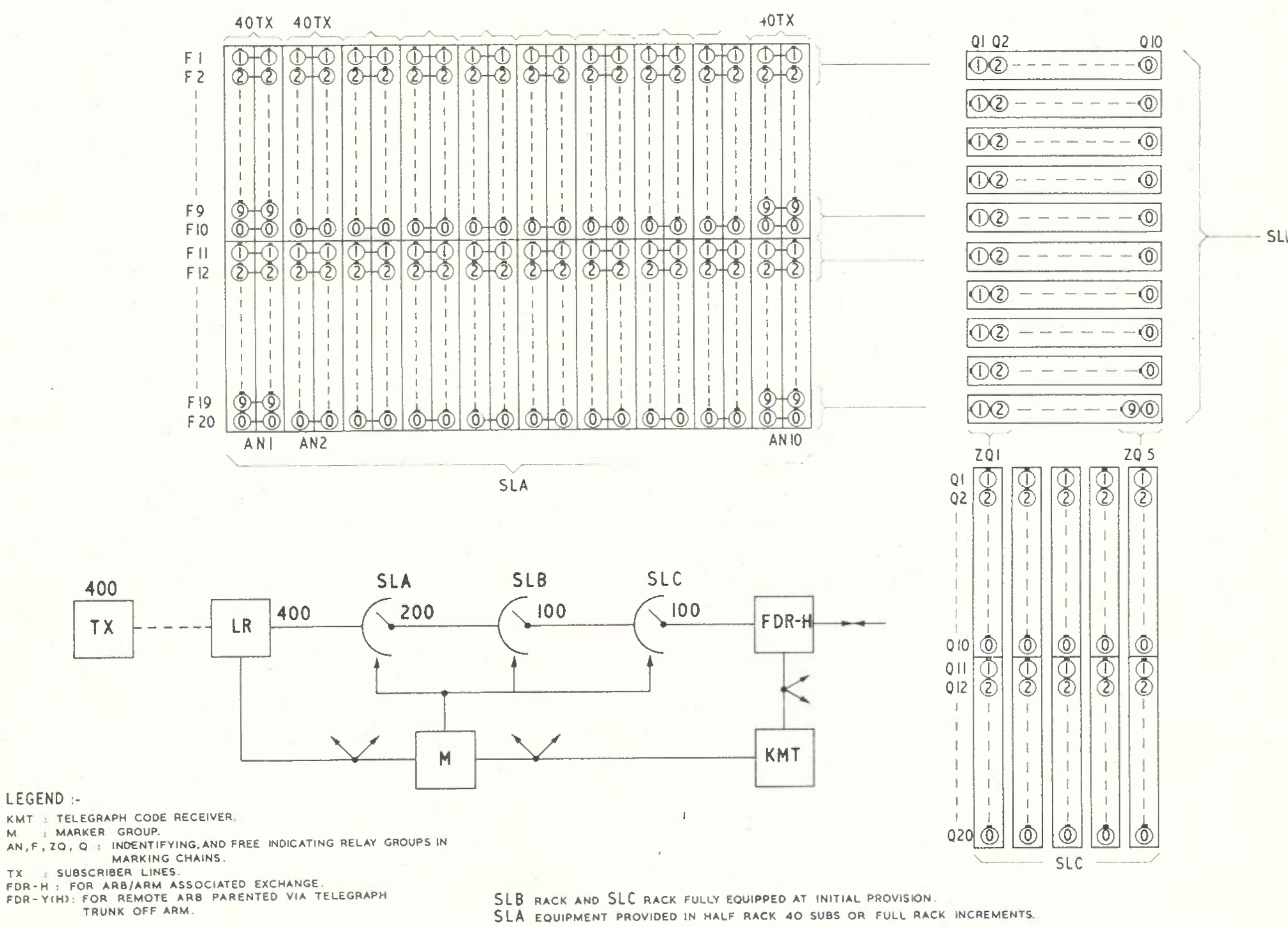


Fig. 7 — Basic Trunking Arrangement ARB Stage.

off more than one ARM transit exchange although this facility is not used in the initial trunking of the Australian network. In future years it may be desirable, for example, to trunk Darwin terminal exchange off both Adelaide and Brisbane transit exchanges.

Special Features

A comparison of Figs. 3 and 5 shows that although there are 44 tariff zones in the Australian automatic telex system there are exchanges in only 10 of these, although there are some 200 subscribers spread throughout the remaining tariff zones these subscribers are generally too widely dispersed to be economically grouped together in an exchange in their own tariff zone, and the telegraph channel network still predominantly governed by private wire and public traffic requirements often does not provide a convenient common grouping point within the tariff zone. The telegraph channel network rather tends to form a simple star pattern in each State based upon the capital city as the centre of the star network. For transmission reasons discussed later it is preferable to maintain this simple star pattern. These subscribers constitute a problem in automatic handling with the charging scheme referred to earlier. L. M. Ericsson offered an ingenious solution enabling these subscribers to be connected to city ARM exchange but automatically metered according to their remote tariff zone origin. The signalling system transmits a 5 unit start-stop tariff zone code identifying the tariff zone of the calling subscriber which is used in the rate setting equipment with the A, B digits of the called subscribers number to set up the appropriate metering rate. This type of subscriber has become known as the "out of tariff zone" subscriber and the automatically transmitted tariff zone code as the "T" code. The theoretical number of tariff zones which could operate from one rate setting centre (the ARM equipment controls the rate setting function) is 31 excluding the all blank code combination.

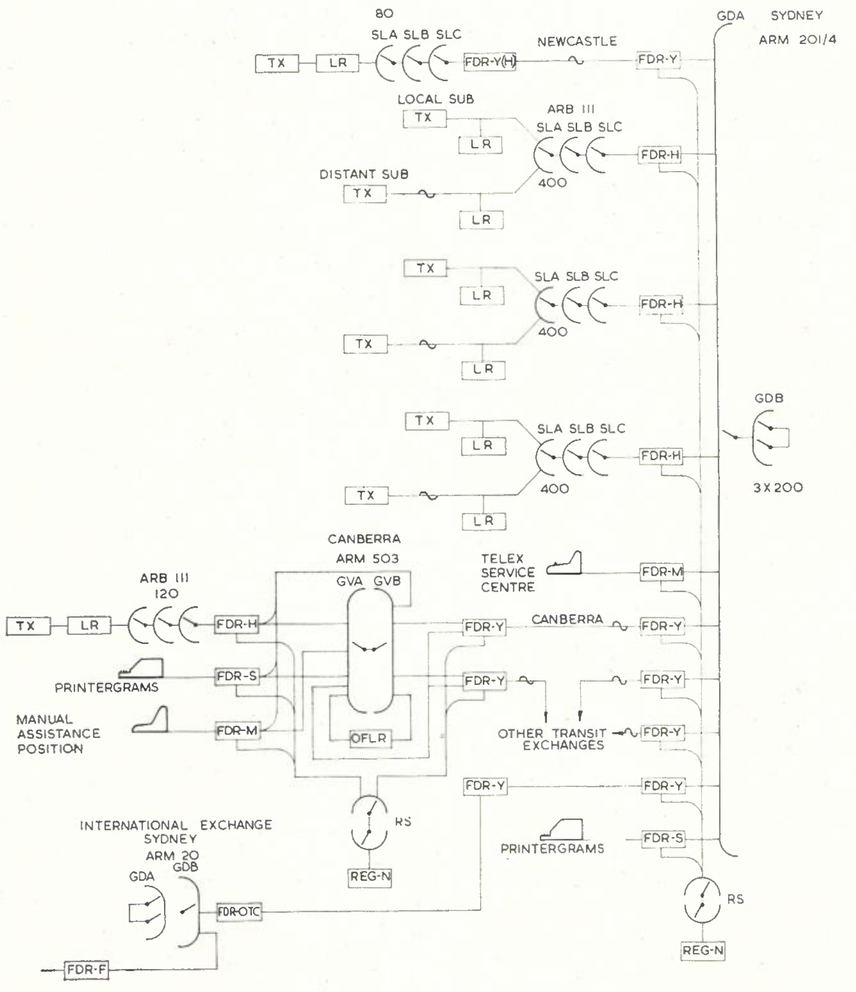
A second feature of the Australian automatic system is a very flexible classification facility, enabling calls to be examined at the point of entry to the transit network thus enabling certain classes of call to be barred from the general trunk network, or from particular trunk routes as well as permitting calls to be examined at the terminating exchange for compatibility with the called subscriber's class. In addition, the calling subscriber's class may be used to modify rate setting enabling special rates for particular classes of customer. As for the tariff zone mark the class mark is carried through the signalling system as a 5 unit start-stop code and has become known as the "K" code. It will be observed that the total information needed for rate setting purposes is then the T code, the K code and the A, B digits of the called subscribers number.

PBX facilities are provided at every terminal exchange, the only limitation on number allocation being that each number must of course be in the same 400 line block as these in effect form unit terminal exchanges. A 400 line terminal exchange may be equipped with relay sets enabling up to 180 lines to be PBX connected in up to 30 separate groups.

A variety of special markings may be made on subscribers lines so that calls to these numbers receive special printing codes. A subscriber may not wish to receive traffic for an extended period as for example over the Christmas holiday period and his line may be strapped to return the characters ABS followed by clearing signal. Similarly a line which is not connected returns the C.C.I.T.T. standard code NP indicating "not a working line".

Semi-automatic positions are being provided at each transit centre to cater for a further range of special requirements or to handle service difficulties, the combined facilities in one location being referred to as a Telex Service Centre. These semi-automatic positions provide for

(a) Calls to be handled through an operator for toll-ticketing reasons. Examples of this class of call are conference broadcast calls in which one subscriber may make a simultaneous call to a number of other subscribers with full communication between all parties (conference) or with the originator only able to



LEGEND

∿	VOICE FREQUENCY TELEGRAPH CHANNEL
LR	SUBSCRIBERS EXCHANGE LINE EQUIPMENT
TX	SUBSCRIBERS TERMINAL
FDR-H	ARB TO ARM REPEATER ASSOCIATED EXCHANGE
FDR-Y	TRUNK REPEATER
FDR-Y(H)	ARB TO ARM REPEATER REMOTE WITH TRUNK SIGNALLING
FDR-M	TELEX SERVICE CENTRE REPEATER
FDR-S	PRINTERGRAM REPEATERS
FDR-OTC	INTERNATIONAL EXCHANGE TO NATIONAL NETWORK REPEATER
FDR-F	INTERNATIONAL TRUNK REPEATER
RS	REGISTER FINDER
REG-N	TELEGRAPH REGISTER

Fig. 8 — Typical ARM Transit Exchange Connections in Telex.

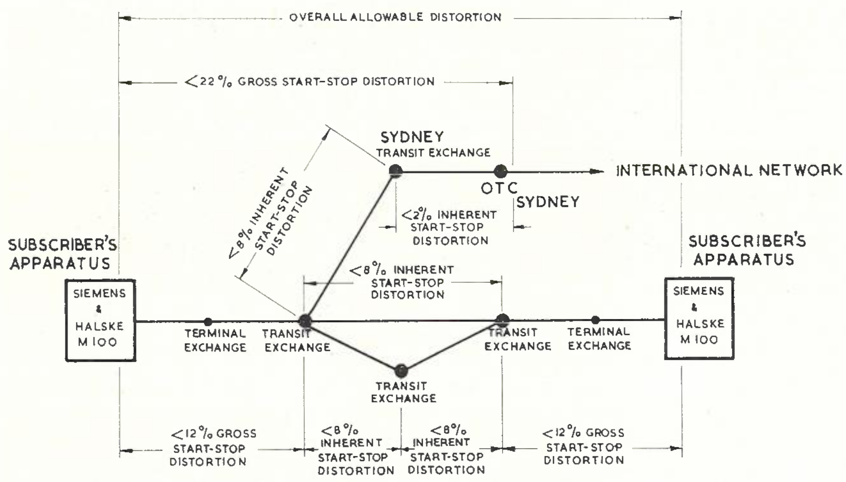


Fig. 9 — Overall Distortion Reference System. (Representing a connection which is just satisfactory.)

send (broadcast). The system of charging for these calls does not lend itself to fully automatic operation and for this reason semi-automatic facilities have been provided. Other calls in this category are press calls which are charged at a special concessional rate but which may be made from subscriber lines handling full rate traffic on an automatic basis at other times. Prior to the introduction of telex service in 1954 part-time private wire point to point service had been provided for many subscribers on a lease rate applying to the particular customers hours of service and the route involved. Many of these services had a number of short session periods in each week and extension of session times were made available at scheduled additional lease rates. These services were a problem to handle. Following the introduction of telex many of these have now been connected to the telex network for switching load reasons but are still charged at lease rates for fixed session times and ticketed for additional session times. These services will now be handled through the semi-automatic positions.

(b) Assistance to subscribers who experience difficulties in setting up a call in the normal automatic way, or who experience difficulties during the progress of an already set up call. Operators where possible will connect the call for the subscriber, or suitably advise the customer about the service difficulty if this is not possible. Genuine fault conditions will thus be filtered from service difficulties due to subscriber maloperation or to congestion on particular routes and faults transferred to the appropriate engineering maintenance group. Subscribers with an unduly high occurrence of service difficulties can be put on line observation through these positions, and a continuous printer record kept of their traffic in order to analyse the type of difficulty experienced.

(c) Enquiry traffic which may concern national directory or national rate information. All international enquiry traffic is directed to the international telex exchange at Paddington, Sydney.

Although semi-automatic positions are provided for these main traffic loads all subscribers are to be connected as automatic exchange lines, no facilities being provided for terminating manual subscriber lines on these positions since the exchange system as a whole has been based upon a transmission plan which permits fully automatic connection between any two subscribers. Regenerative repeaters can however be switched in, on semi-automatic position connecting circuits, in handling assistance traffic which may arise because of temporary transmission deterioration on a particular route.

The Telex Transmission Plan

The objective of the telex network is to provide economic low-error-rate message or data communication, with full interconnection possibilities between all subscribers and to the international network. The main problems in achieving this objective in a telex system are the effects of cumulative distortion on built up connections and the effect of circuit aberrations such as intermittent failures to start or stop polarity of a section or sections of the overall circuit. In practice the first mentioned problem means that the number of telex trunks which may be connected in tandem has to be limited and the network structure arranged to conform with this limitation. Restrictions must be placed on alternate routing since this would increase the number of tandem connected trunks. The Australian telegraph channelling network has been built up over many years and the quality of performance of equipment on different routes is not identical. Allowance has been made for this and the possible introduction of lower distortion voice frequency telegraph systems in future years, by constructing the transmission plan in terms of distortion limits per link, and this is shown in Fig. 9. Important features are that the subscriber path to its transit exchange (which may be through a "remote" terminal exchange) shall not produce more than 12% of gross start-stop distortion at the output of the terminating relay set of the transit exchange and in the reverse direction shall have a margin to gross start-stop distortion of 30%. Connections between transit exchanges shall not exceed 13% gross start-stop distortion and shall not traverse more than one other transit exchange. In order to maintain this rule alternate routing may take place only at the originating transit exchange. Alternate routing is prevented on international calls to ensure that gross start-stop distortion at the point of exit from the Australian national system, the international exchange at Sydney does not exceed 22%. Incoming international traffic will be regenerated by the Australian international operating authority, the Overseas Telecommunications Commission (Australia) so that the input from international trunks at the Sydney transit exchange should be not more than 5%.

Editorial Note: Part II of this article will deal with Subscribers terminal equipment, Exchange equipment, National signalling and inter-operation with the International exchange, test and control equipment.

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MERCURY - WETTED CONTACT TELEGRAPH RELAYS

*K. V. SHARP, A.R.M.I.T.**

INTRODUCTION

Telegraph relays are required to conform to high standards of reliability and operating speed over long periods of time. When compared with the average control relay, telegraph relays are required to be more sensitive, and they must repeat impulses more accurately with minimum time delay. At the standard telegraph signalling speed of 50 bauds on continuous signals, in one second a telegraph relay would operate 5 times as often as a dial impulse repeating relay in a bimotional selector. Transit time of the changeover contact set must be low. The contacts should have reasonable power handling capacity; immunity from the effects of external fields is essential.

Mechanically, telegraph relays should have a robust contact assembly with high contact pressure, absence of contact bounce at varying drive conditions and ease of adjustment. The relay should have as few moving parts as possible and should not be susceptible to faulty operation due to vibration or movement.

Over the years a variety of polarized telegraph relays have been used, (See Fig. 1), culminating in the development of small efficient relays possessing in varying degrees the desirable properties listed. Each of these relays has, however, used an "open" type of contact assembly with mechanical contact adjustment.

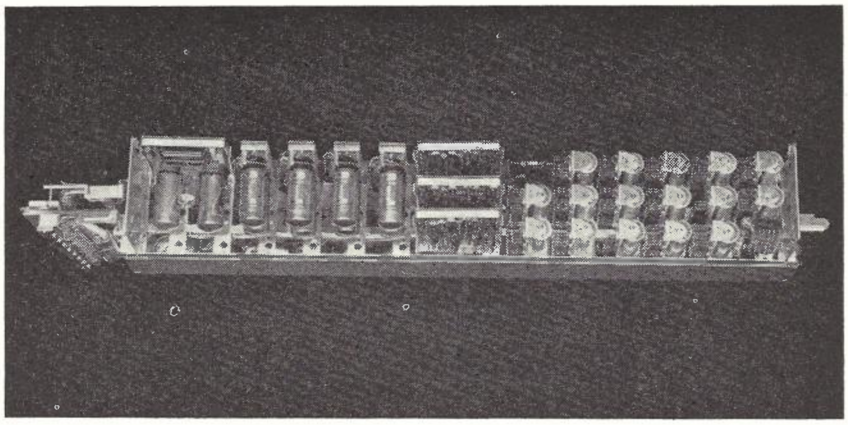

Fig. 2 — Relay Set TSG for Use in Automatic Telex

The development of the reed relay and later the mercury-wetted contact assembly, provided the opportunity for a new approach to polarized telegraph relays and relays of the new polarized mercury-wetted contact type were offered to the Postmaster-General's Department in Australia as part of the Automatic Telex equipment. After exhaustive tests the relays were accepted and have become the standard telegraph relay to be used in the Automatic Telex equipment to be supplied and installed by L. M. Ericsson Pty. Ltd.

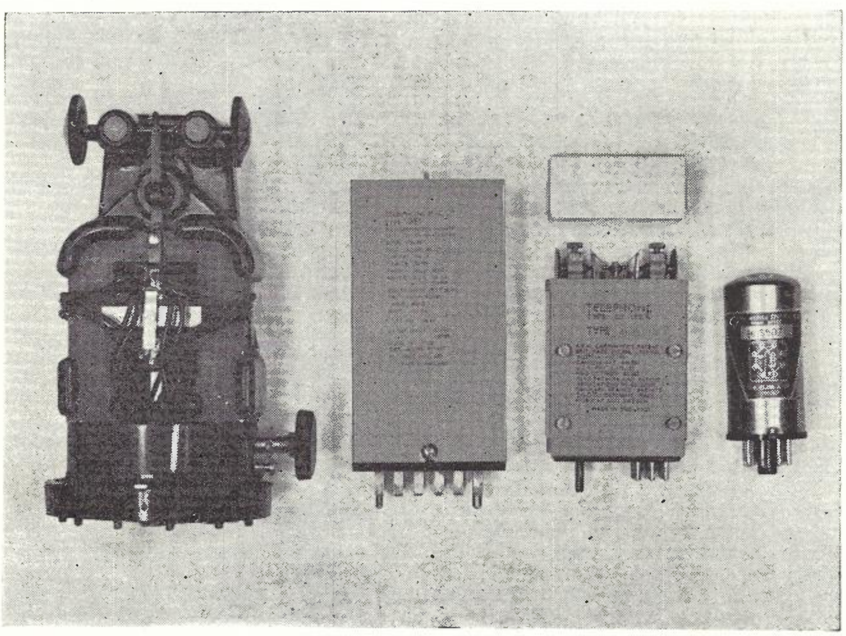

Fig. 1 — Telegraph Relays Past and Present. Left to Right: Creed, Carpenter 3E1, Carpenter 4H39, Clare.

TYPES OF RELAY

The relay originally offered to the Australian Post Office was the Clare Type HGS5002 manufactured by C. P. Clare and Company of the United States of America. Subsequent tests of this relay type proved that the degree of inherent distortion at the output of the relay was higher than desired. Electrical compensation of relays was found to be possible employing external circuit components and signal distortion could be completely eliminated in this way. However it was considered that, since the relays could be easily interchanged, electrical compensation was likely to cause maintenance difficulties, and as well, initial lining up procedures for new exchange equipment and subscribers lines would be made more complicated. Negotiations with manufacturers ensued to arrange for closer control of relay bias during manufacture to comply with requirements. It was felt that for the small amount of extra cost involved, a more accurately adjusted relay would be more suitable. At the same time a minor modification was introduced in that non-magnetic sideplates were incorporated into the relays. This modification was found necessary because of the difficulty encountered in maintaining the side plates in a magnetically "soft" condition — a requirement if magnetic biassing of the relays was not to occur. This more stringently adjusted and modified relay was coded HGS.5066. However, it was found that the stricter distortion limits required by the Post Office, combined with the test and adjustment technique being used by the Company, brought about a slowing down in production and an increase in costs.

The adjustment procedure being used involved driving the relay with a sharp

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fronted, short duration pulse and accurately measuring operate and release times. At the same time the bias adjustment was being carried out to provide relays with non-biassed output. Required bias conditions were obtained by saturating the biassing magnets and then demagnetizing until the correct condition was reached.

Subsequently the Post Office agreed to testing of the relays using a sinusoidal drive current, the method of testing telegraph relays used by the Post Office for many years and originally suggested to the Company by the Post Office. This alteration of technique produced the desired result and relays of the required characteristics were produced under the coded type HGS 5071. The only difference between these relays and the HGS 5066 is that the testing procedure has been altered.

The three relay types mentioned here are only part of a large range of relays available in the HGS 5000 series; many different specifications can be accommodated in this and other series in the manufacturers range. The relays type HGS 5082 seen in Fig. 2 are an example of a special relay for a specific application. They feature different windings from the type HGS 5071 — resistance and turns values have been altered, but mechanically the relay remains the same.

RELAY DESCRIPTION

The particular Clare mercury-wetted contact relay in which we are interested for telegraph signalling uses a Form C type of mercury capsule, providing a break-before-make (changeover) action; no bridging of the contacts occurs. Previously mercury-wetted contact relays employed a make-before-break action and these are still available, but are not suitable for telegraph signal repetition. The mercury wetting of the contacts eliminates to a large extent the requirement of high contact pressures and since the contact surfaces themselves are well separated before the mercury globule ultimately breaks, a very fast contact breaking action is achieved. Similarly full contact is made as soon as the mercury surfaces touch together, because of the cohesive and flow properties of the minute mercury pods carried on the contacting surfaces. The action of the mercury-wetted contact is illustrated in Fig. 3B.

The construction of the relay is illustrated in Figs. 3 and 3A. The glass capsule J closes the mercury pool C, the contact assembly B and the reed type armature K which is looped into and soldered to the connection and fill tube, M, extending through the bottom of the capsule. The armature is connected to a pin in the octal socket F with a short connection wire G soldered to the tube M. The armature reed which has a number of small vertical grooves on its surfaces is positioned in the narrow gap between the two fixed contacts with its lower end immersed in the mercury pool. A film of mercury is carried up the reed to the contact area to form the armature contacting surface, no contacts being attached to the armature itself. The armature reed is made of magnetic material.

The fixed contact assemblies, B, consist of the contact mounting pieces (pole pieces) which extend outside the capsule, and the contacts themselves which are mounted horizontally across the pole pieces. Three contacts are used on each pole piece. Contacts are platinum 0.012 in. diameter, spherical shape, slightly flattened and welded to the pole pieces.

The capsule J has the required amount of mercury inserted and is filled with hydrogen at a pressure of approximately 150 pounds/sq. in., via the tube M which is then crimped and sealed with solder. The hydrogen gas filling provides

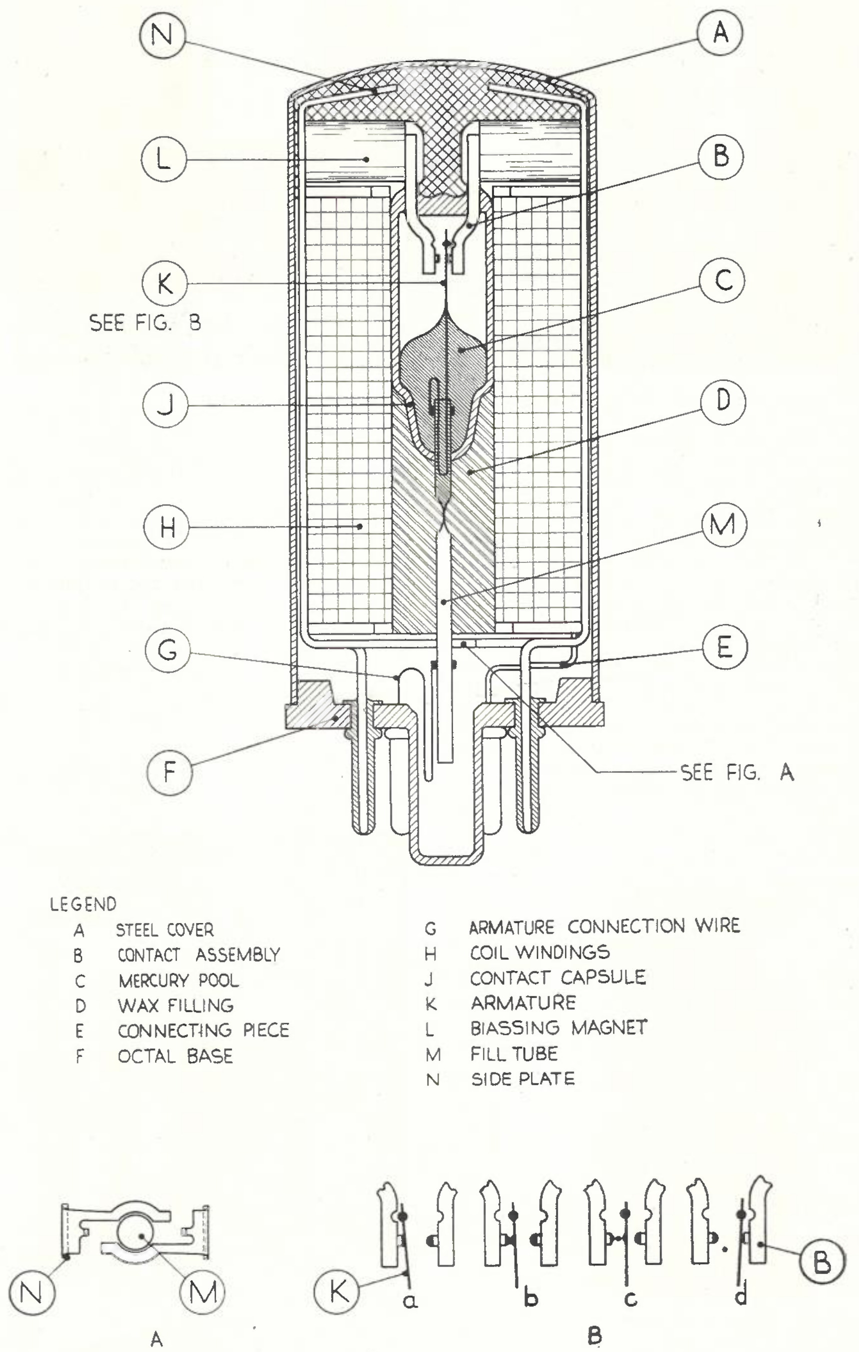

Fig. 3 — Clare Mercury-Wetted Contact Polarized Telegraph Relay—Sectional Representation.

A. Side plate bottom view, showing placement of plate around the fill tube M.
B. Mercury-wetted contact action.

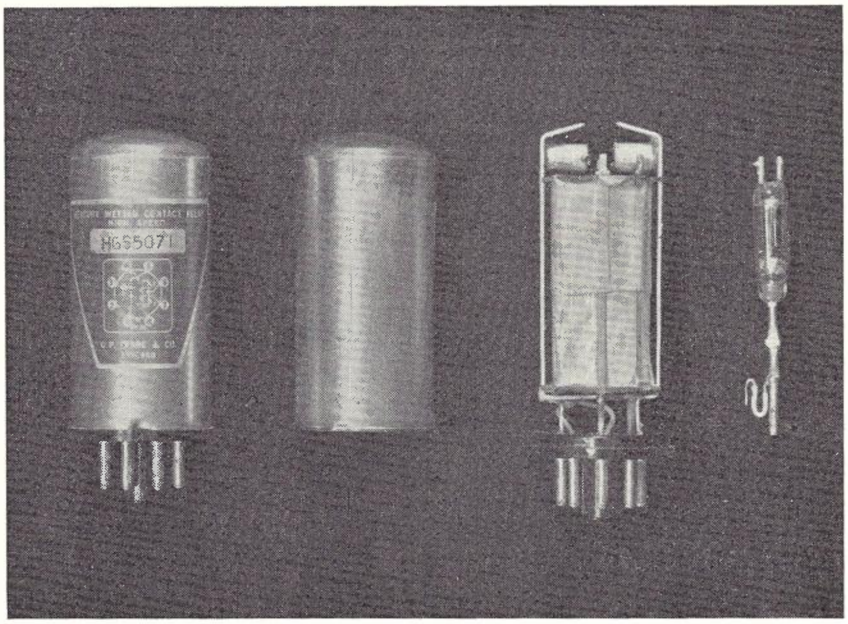

Fig. 4 — Mercury-Wetted Contact Relay Dismantled

a protection against oxidation of the contact surfaces so that they readily wet with mercury, as well as increasing the voltage breakdown characteristics of the small contact gap.

Biassing magnets L are soldered to the pole piece extensions outside the capsule to provide polarization and connection is made to the pins of the octal socket by means of the side plates N which also form part of the relay magnetic circuit.

Mounted between the capsule and the side plates are the operating coils H, bifilar wound on an acetate former. Each coil layer is insulated with cellulose acetate film. When winding is complete the coil is coalesced by heat and pressure fusing the cellulose acetate into a solid mass. Coil connections are made to the octal base with solid connecting pieces E (one only shown) which also form the supports for the insulating discs placed on top of and below the coils.

The whole of the relay assembly is enclosed in a pressed steel cover A, the inside is potted with wax and the cover is crimped to the base. The whole assembly is shown in Fig. 4.

No contact adjustment is possible with a relay of this design and consequently reliability of the relay becomes a major factor. Correction of circuit failure due to a faulty relay can be made only by replacement of the relay.

Reliability tests on a number of relays have been carried out over long periods of time with load conditions representing actual circuit conditions likely to be encountered in field use. Drive was provided from a 50 c/s A.C. source and total relay operations in excess of 3,000 million were performed. Relays were continuously monitored for output distortion and no increase in distortion was detected over the period of the tests. Several relays incorporated into a telegraph relay set being used on a heavily loaded circuit, where earlier types of telegraph relay had required maintenance attention at monthly intervals, have operated for a period of two years without fault or attention of any kind.

Sensitivity of the relays tested was found to be consistently in the range 20-24 ampere turns which is a decided decrease in sensitivity compared with telegraph relays previously used, which had sensitivities of approximately 5 ampere-turns.

Contact bounce was found to be non-existent, because of the mercury-wetted contact action, even though relays were tested with large drive currents, far in excess of those expected to be met in actual operating conditions. Output of the relays was found to be virtually distortion free up to 400 c.p.s. but instability and bias became evident when the speed of drive was increased much beyond this point.

Because of the metal cover, effective shielding of the relays is possible to prevent air radiation and magnetic coupling between relays.

Maximum ratings for contacts are specified as 2 Amperes maximum current, 500 Volts maximum voltage, the product of current and voltage not to exceed 100 voltamps. Contact suppression design information is supplied with the relays and must be fitted as indicated. Contact resistance is in the range 25-50 milliohms and figures are available for relay inter-electrode capacitance values. Because these capacitance values vary with the type of relay, only typical values are given here:—

	Micro-microfarads
Open contact to armature	3.5—8.5
Open contact to coil	4.5—10.0

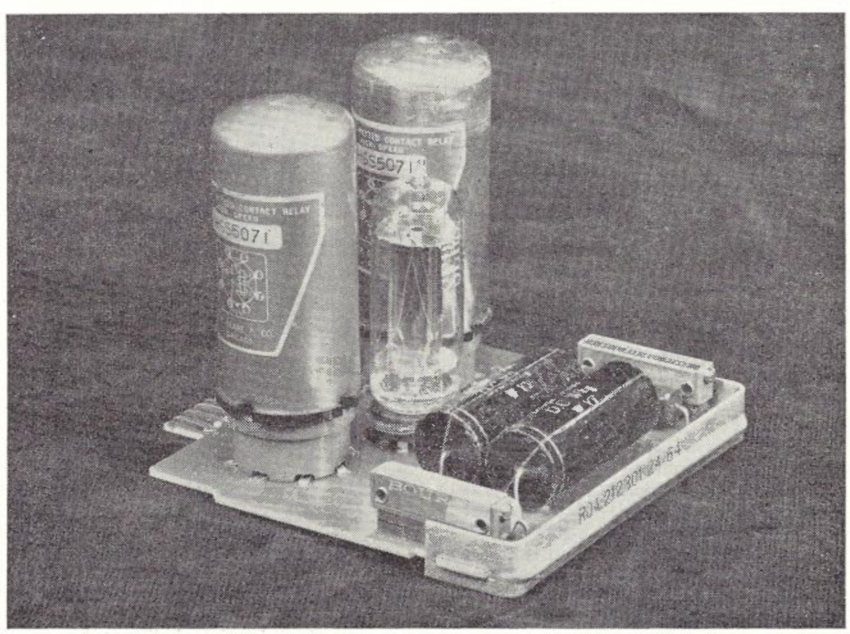

Fig. 5 — Clare Relays Mounted on ROA Board for Automatic Telex

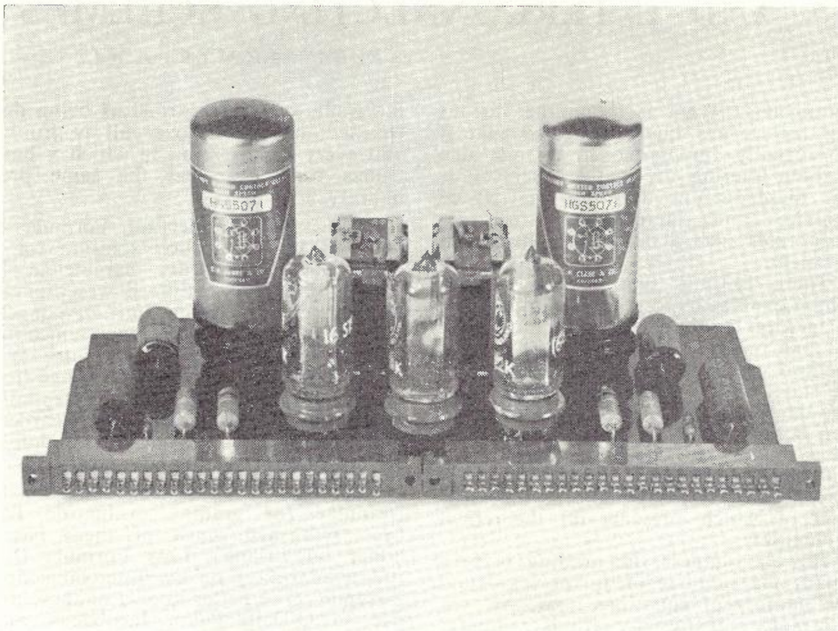

Fig. 6 — Prototype Telegraph Universal Repeater Using Clare Relays and Printed Circuit.

Armature to coil	7.0—20.0
Open contact to cover	9.5—21.0
Armature to cover	7.5—19.0

Coil resistance of types HGS 5002, HGS 5066 and HGS 5071 is 135 ohms, 3,400 turns of wire being used on each coil (two coils).

Coil inductance of the above types was measured at 0.15 Henry, with theoretical approximate inductance calculated for series HGS 5000 relays from

$$L = K N^2$$

where $K = 1.0 \times 10^{-8}$
N = number of turns.

Calculated value 0.116 Henry.

MECHANICAL FEATURES

Each relay weighs approximately 5 ounces, is rugged, easily transported and is not subject to normal mechanical shock, although severe shock can cause a tendency to instability and bias. Relays which have been dropped should be suspect and should not be used.

Operating temperature limits are from 225°F ambient to —37.8°F this lower temperature being the freezing point of mercury. These temperatures are those specified by the manufacturer and no attempt has been made to verify them by laboratory testing.

Physical dimensions of the relay are as follows:—

Diameter 1.2 inches.
Height (overall) 3.3 inches.
Height (above socket) 2.64 inches.

MISCELLANEOUS ASPECTS

Materials

Contact material as mentioned previously is platinum which although expensive is protected against wear and erosion by the mercury film. In addition platinum is readily wetted with mercury because of its low oxidation rate.

The metal parts which pass through the lead glass of the capsule are made of a nickel-iron alloy with approximately the same co-efficient of expansion as the glass over the normal operating temperature range. This ensures that a good seal is maintained between the surfaces.

The armature itself is also made of a nickel-iron alloy which besides being magnetic is a good conductor and wets readily with mercury.

Effects on Maintenance Procedure

Because of the fully enclosed make-up of the relay and the absence of adjustment facilities, a faulty relay must be discarded and replaced. This is a radical departure from normal practice and would at first sight appear to be a costly procedure. However the proven reliability of the relays both in laboratory tests and in field experimental use appears to cancel any disadvantage in this regard.

Since the possibility exists of an intermittently faulty relay being tested and found to be in apparent good working order and re-inserted into a circuit only to cause further maintenance requirements, all relays found faulty should be rendered obviously unworkable by crushing or a similar process.

Design Considerations

Because of the mercury pool in the contact capsule, mercury-wetted contact relays must be mounted in a vertical position ± 30 degrees. This presents obvious problems in mounting the relays, particularly if mounting in 2,000 type bases is desired. The height of the relays, plus the necessity for allowing space for insertion and withdrawal, limits the number of relays which can be fitted into standard mounting bases, and forces the designer to use more and/or larger bases. The equipment for Automatic Telex allows for mounting the mercury-wetted relays on printed circuit card fittings (ROA boards) which can be inserted and withdrawn horizontally in the exchange panel equipment. (Fig. 5).

The use of mercury-wetted contact relays would seem to presage a redesign of telegraph switching and control circuit mountings. (Fig. 6). Research, however, is continuing on the development of position — independent mercury contact relays and the present design disadvantage may eventually be successfully overcome.(1).

It is interesting to note that some circuitry has already been designed in which the relay components (coil, capsule etc.) have been directly mounted on printed circuit boards without potting of the components. No plug and socket connections were used and the components were hard wired. This technique raises its own problems of ensuring rigidity of component mounting and bias elimination and so far the Australian Post Office has not entered this field. It is however an indication of the present trend in the use of polarized relays.

CONCLUSION

Investigations are under way at present in the Australian Post Office and other administrations on the development of solid state switches to replace electro-mechanical relays. This effort is being concentrated particularly on output relay replacement for voice frequency telegraph carrier systems.

The design of a static device which meets all the properties of an electro-mechanical relay and yet overcomes its own inherent limitations regarding excess currents and voltages likely to be encountered under fault conditions is not simple nor cheap. The relay, particularly the mercury-wetted contact relay is cheap by comparison and its reliability and ruggedness would seem to indicate its continued general use for some time to come.

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SURVEY OF GRADINGS AND INTERCONNECTING SCHEMES

*J. RUBAS, A.R.M.T.C., A.M.I.E. Aust.**

INTRODUCTION

In the widest sense an interconnecting scheme is any connecting array, whereby a group of trunks comprising a particular route is connected to the outlets of a switching stage. Usually this implies schemes where the selector availability is less than the number of trunks in the route. In a more restricted sense the term is sometimes applied to homogeneous connecting patterns, which employ only one, or at most two, kinds of interconnections (e.g. only pairs and threes).

Grading is one form of interconnecting, designed particularly for sequential hunting from a fixed (home) position. In a grading the interconnection number (i.e. the number of outlets connected to the same trunk) increases as we proceed in the direction of hunting from first to last choice.

Economic and purely engineering considerations in the design of switching equipment place an upper limit on the total number of outlets provided per switch and also the number that can be allotted to a particular route. Therefore, in most switching systems some method of interconnecting the outlets is necessary to accommodate the trunks of larger routes. In our local networks interconnected routes comprise the great majority of all routes, hence the traffic carrying capacity of such routes is of considerable economic importance.

This article will survey the results of more recent research on gradings and interconnecting schemes and will attempt to isolate the most important factors affecting the performance of such schemes. The main points will be illustrated by the results of simulation studies carried out by the author.

METHODS OF INVESTIGATION

To simplify the discussion we will first define a few symbols, which will designate the main variables.

A — Total traffic offered to the grading or interconnecting scheme;
B — Average congestion probability (grade of service);
N — Total number of trunks in the grading;
K — Availability;
G — Number of grading groups or splits;
h — GK/N — Average interconnection number, i.e. the average number of outlets connected to one trunk; sometimes also referred to as the **mixing ratio** of the grading;
h_1, h_2, h_n — Specific interconnection numbers used in a grading or interconnecting scheme.

Unlike the full availability group, the performance of an interconnecting scheme depends on a large number of parameters. What is more, the various parameters are interlocking, so that it is virtually impossible to change one without altering any of the others. It is for these reasons that the analysis of gradings and interconnecting schemes constitutes such a difficult mathematical problem.

There is only one general method which enables us to compute exactly the congestion probability of an arbitrary grading or interconnecting scheme. This method employs the so-called equations of state, which define the probabilities for the various states of occupancy that can occur when the grading is subjected to a traffic load. Under assumption of statistical equilibrium, we end up with a system of linear equations, the solution of which presents no theoretical difficulties.

However, unless the grading is very small, the number of unknowns — and the number of equations necessary — is enormous and presents serious computation problems. In a full availability group of N trunks we need to distinguish only N+1 different occupancy states, as we are not interested in the precise distribution of busy trunks within the group. In a grading, however, we must cover all possible ways in which 0, 1, 2, ... N trunks can be occupied. The number of unknowns, thus, depends not only on the number of trunks, but also on the number of grading groups and the number and scope of the interconnections employed. The number of equations required to solve even a small grading for, say, 15 trunks may exceed 3,000. In gradings of practical size the number of unknowns runs into millions. Hence, even when a large and fast electronic computer is available, grading performance evaluation by the equations of state method is practicable only for very small gradings. It is, however, very useful as a starting point for approximate methods and as a check on their accuracy.

Another approach is to analyse special types of grading, constructed in such a way that for a given number of calls in progress all combinations of busy trunks are equally probable. The number of different probability states is thus reduced to N+1, making the solution relatively easy.

The classical example of this approach was given by A. K. Erlang in deriving his well known Interconnection Formula. The assumptions under which this formula was derived, however, are very restrictive and can hardly be met in a practical interconnecting scheme. Erlang postulated that a scheme with N trunks and availability K must be divided into $\binom{N}{K}$ groups, each group being hunted in all possible (i.e. K!) sequences. The offered traffic is pure chance and equally divided among grading groups. Under these conditions the traffic can be regarded as being distributed at random over all N trunks, and every combination in which x busy trunks can occur has the same probability.

Erlang's Interconnection Formula is the best known explicit solution for a grading with arbitrary parameters N and K. For a long time it was thought to represent the lower limit of congestion for any grading or interconnecting scheme. The more recent work has shown, however, that lower congestion can be obtained with small sequentially hunted gradings. It may be regarded, therefore, as the limit only for randomly hunted interconnecting schemes.

A large number of approximate formulae for grading evaluation has been published, most of them based either on Erlang's Loss Formula (for full availability) or his Interconnection Formula. The better known of these are due to O'Dell, Palm, Jacobaeus, and Lotze. The A.P.O. traffic capacity tables for step-by-step gradings are based on these formulae.

Very useful estimates of the mean and variance of traffic overflowing an average grading can be obtained by approximating it with a geometric group model (Ref. 1). Mean and variance of the overflow traffic can be read off from an appropriate geometric group graph. The controlling geometric parameter "p" is computed from two grading parameters only — the total number of trunks and the availability. At poor grades of service ($B > 0.05$) "p" can be estimated from the following simple formula:—

$$p = \frac{N-K}{N} \qquad (1)$$

As the grade of service improves, equation (1) returns a value of "p" which is too high. This in turn leads to overestimates in the parameters of overflow traffic. The error is not serious, however, and acts as a safety factor to cover less efficiently designed interconnecting schemes.

Yet another approach is to reduce a grading to an equivalent full availability group of trunks, which will overflow traffic with approximately the same characteristics as the grading under investigation. Of the two best known equivalence methods one is due to Berkeley, the other to Wilkinson. Berkeley considered only the mean value of the traffic, which was assumed to be equally distributed among the grading groups. Wilkinson's method employs both mean and variance and is, therefore, more accurate than Berkeley's. Besides providing another parameter of the overflow traffic, Wilkinson's method is more flexible and can handle asymmetric gradings and non random offered traffic loads. Both methods are, however restricted to sequentially hunted

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gradings with interconnection span increasing in the direction of hunting.

The remaining — and currently the most popular — method available to investigate grading performance is simulation. This can be carried out manually (e.g. using dice or a roulette wheel to generate call arrivals and releases), by a specially built electro-mechanical or electronic traffic machine (analogue simulations), or by an electronic digital computer, using a suitable program. Simulation on a digital computer is the most convenient — and the most versatile — of the three simulation techniques listed above and has received wide application in recent years. Provided that a computer with a large high speed store is used, any grading or interconnecting scheme, hunted in any desired fashion, can be simulated without much difficulty.

PARAMETERS AFFECTING PERFORMANCE

As stated before, the number of trunks fully defines a full availability group. To define a grading or an interconnecting scheme several parameters are required. The two most important ones are the total number of trunks and the availability. Next in importance is the number of grading groups or splits. But even having fixed these three parameters there is still a variety of ways in which the outlets of the various groups can be interconnected to give access to the specified number of trunks.

The effect of N and K on the interconnecting scheme capacity is well known — the increase in either or both will raise the traffic capacity. However, the effect of G is not as well known. If we increase G (while keeping N and K constant), we must also increase h and change the structure of the interconnection pattern. Generally, increase in the number of splits tends to raise the traffic carrying capacity. This increase, however, follows the law of diminishing returns. Eventually a point is reached, when further increases in G have no further effect on the traffic capacity of the scheme. In certain B.P.O.-type straight gradings the efficiency even starts going down when the optimum mixing ratio is exceeded (Ref. 2).

Having fixed N, K, and G, the pattern can still be varied by the choice of interconnection numbers to be used and the actual position of the various interconnections. The effect of the actual configuration on the traffic capacity is by no means negligible (as we shall see later) and has received considerable attention from traffic engineers. No single clear-cut parameter can be found, however, to define the pattern. We can only speak of the general methods employed to construct the pattern and the interconnection numbers used. Thus, for example, we have the familiar B.P.O.-type gradings, with progressive commoning and straight interconnections between contacts of adjacent groups. We can provide a variant of the above by still using straight ties (i.e. joining contacts of the same choice), but skipping over adjacent groups and interconnecting non-adjacent groups as well. Or we can use diagonal interconnections, joining contacts which belong to different choices. Simultaneously with the above mentioned changes we can vary the interconnections numbers associated with each choice (or hunting step). If the mixing ratio is an integer, we may decide to use only one interconnection number, h, and construct a homogeneous scheme.

A characteristic, which is sometimes used in comparing similar interconnecting schemes, is the so-called distribution of busies. This is usually shown in the form of a symmetrical matrix, the elements of which indicate the number of times that the outlets of one group are interconnceted with those of every other group. The main diagonal, which represents interconnections within the same group, has no meaning and is left blank. The busy matrix for the interconnection scheme of Fig. 1 is given below.

Group	1	2	3	4
1	–	6	6	6
2	6	–	6	6
3	6	6	–	6
4	6	6	6	–

The matrix of busies indicates the degree of mixing and symmetry existing in the pattern. Thus, it also indicates how well load surges in any one particular group are shared by the rest of the interconnecting scheme. It is to be exance will be obtained from those interconnecting schemes, which have all elements in their busies matrix the same (as happens to be the case in the above matrix). That is, each group is interconnected with every group the same number of times. On the other hand, the matrix of busies gives no indication of the variety, position and sequence of the interconnections used, all of which have an effect on the traffic capacity of an interconnection scheme. Hence it is of rather limited use without additional information to supplement it.

At this stage it is necessary to mention the influence of the hunting method on the interconnection scheme design. With random (or random start sequential) hunting the traffic carried by a trunk is proportional to the number of outlets connected to it and does not depend on the position a trunk occupies in the scheme. Since with this form of hunting the maximum efficiency is obtained when all trunks carry equal amounts of traffic, the ideal is to use only one interconnection number and have a homogeneous scheme with a perfectly uniform matrix of busies. This ideal can be achieved only for a few combinations of the number of trunks, groups, and the availability, so that in most cases it is necessary to use two interconnection numbers, which are adjacent and lie immediately above and below h (i.e. h_n and h_{n+1}).

With sequential hunting from a fixed position the general design philosophy has always been to start with low commoning numbers at the early choices and progressively increase them going towards the late choices of the hunting sequence. The last choice is normally made a full common. This type of design, which is commonly known as grading aims to equalise the traffic loads carried by trunks occupying different positions in the hunting sequence. More recent research has shown that the degree of desirable concentration in commoning towards the late choices is broadly proportional to the offered traffic load. It was also found that even homogeneous schemes, designed for random hunting, performed quite well under sequential hunting — better, in fact, than with random hunting. These findings reverse the older belief about the relative efficiencies of the two methods of hunting.

INVESTIGATION OF SOME PARTICULAR CASES

In the absence of well-defined parameters, it is difficult to discuss interconnection pattern configurations without concrete examples. We shall, therefore, consider in this section a few typical schemes, which were investigated by the author using a computer simulation program (Refs. 3, 4). In the cases where sequential hunting was employed it was always from left to right in the patterns shown. The schemes shown in Figs. 1 to 5 all have an availability of 10 and provide 22 trunks. The last two figures (6 and 7) show 10-trunk schemes for an availability of 5.

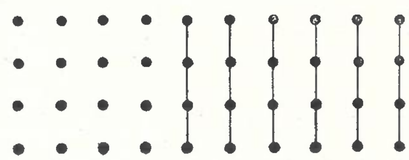

Fig. 1 — Simple 4-Group Grading with Individuals and Full Commons Only.

A very simple 4-group, 22-trunk grading is shown in Fig. 1. It has only individuals and full commons, hence it lacks the gradual progression of commoning desirable in a sequentially hunted grading. It also has a very low mixing ratio of only 1.8. We expect it to perform poorly, which it does, as will be seen from Table 1. Yet the matrix of busies for this grading has all elements equal, since every group is interconnected with every other group exactly 6 times. This clearly illustrates that the busies matrix alone is quite inadequate as an indicator of grading quality.

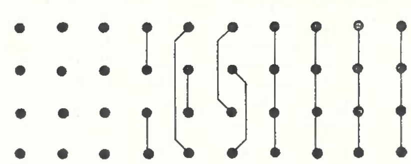

Fig. 2 — 4-Group Grading with Individuals, Pairs, and Full Commons.

The grouping shown in Fig. 2 is a distinct improvement on the one discussed previously. It contains all interconnection numbers possible in a 4-group grading, namely individuals, pairs, and fours. It conforms to the B.P.O. grading formation schedule for K = 10, G = 4, N = 22 and minimises the sum of differences between choices allocated to different interconnection numbers: (3 - 3) + (4 - 3) = 1. What is more, some skipping is introduced among the pairs for better distribution of load variations in individual groups. (Incidentally, skipping ensures that the matrix of busies again has all elements alike — every group is interconnected with every other group 5 times). On the other hand, the mixing ratio remains the same as for the previous grading, i.e. 1.8. Nevertheless, Table 1 shows that the second grading gives about 7% lower congestion at 18 erl. offered load than the first. Other tests suggest that the difference in performance is considerably greater at lower offered loads.

The obvious next step in improving the design of our K = 10, N = 22 grading is to increase the number of grading groups and thus raise the mixing ratio. If we go to 6 groups we might finish up with something like the grading shown in Fig. 3. This move has, naturally, required a redistribution of the interconnection numbers and we now have individuals, pairs, threes, and sixes. The number of full commons was kept the same, as in the previously discussed grading, but the front end of the new scheme bears no relationship to the previous one. Skipping is liberally employed among pairs and threes to even up the matrix of busies, which now looks as follows —

Group	1	2	3	4	5	6
1	–	5	6	6	5	6
2	5	–	5	6	7	5
3	6	5	–	5	6	6
4	6	6	5	–	5	5
5	5	7	6	5	–	5
6	6	5	6	5	5	–

This matrix is by no means perfect and could have been improved by rearranging a few interconnections. Nevertheless, the performance of Fig. 3 grading is significantly better than that of the previously discussed gradings, both under light and heavy loads (see Table 1). It appears that the increase of the mixing ratio from 1.8 to 2.7 is mainly responsible for the improvement.

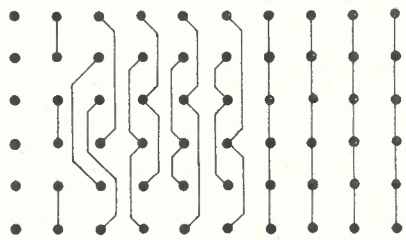

Fig. 3 — 6-Group Grading with Individuals, Pairs, Threes, and Full Commons.

The pattern shown in Fig. 4 has the same main parameters at that shown in Fig. 3, but was designed for random hunting. It is a pseudo-homogeneous interconnecting scheme, only two interconnection numbers (2 and 3) being employed. In the strict sense it is no longer a grading, as it lacks the full commons. It is, therefore, interesting to compare its performance under sequential hunting with that of the previously discussed gradings. Evidently, as Table 1 shows, the scheme shown in Fig. 4 gives lower congestion than any of the

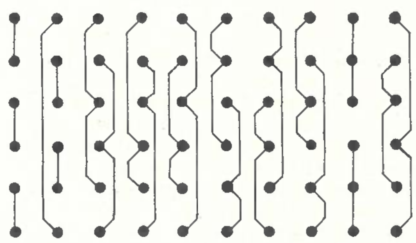

Fig. 4 — 6-Group Pseudo-Homogeneous Scheme with Interconnection Numbers 2 and 3.

gradings discussed before. This result will surprise many traffic engineers brought up in the old tradition. It certainly makes obsolete the conventional ideas about sequential grading design.

The last scheme investigated in the K = 10, N = 22 series is shown in Fig. 5. This scheme is similar to the one shown in Fig. 4, but uses diagonal (instead of straight) interconnections. It is a standard cyclic interconnecting scheme. Table 1 shows that it gives higher congestion than the scheme shown in Fig. 4 at both levels of traffic load. Numerous other tests (not reported here in detail — see Ref. 4) on straight and diagonal interconnections have shown that there is very little difference in efficiency between the two methods.

Other aspects usually swamp any effect that diagonal interconnections may produce. In our case the difference in performance is almost certainly due to a poorer distribution of interconnections between the groups which exists in the last scheme. A comparison of the busies matrices clearly shows this:—

Group	1	2	3	4	5	6
1	–	4	4	4	3	3
2	4	–	4	3	4	3
3	4	4	–	3	3	4
4	4	3	3	–	4	4
5	3	4	3	4	–	4
6	3	3	4	4	4	–

Group	1	2	3	4	5	6
1	–	5	4	3	2	4
2	5	–	5	2	3	3
3	4	5	–	5	2	2
4	3	2	5	–	5	3
5	2	3	2	5	–	6
6	4	3	2	3	6	–

The matrix shown first is for the scheme of Fig. 4, while the second

TABLE 1: COMPARISON OF K = 10, N = 22. GRADINGS HUNTED SEQUENTIALLY FROM A HOME POSITION

Grading of Fig. No.	Number of Groups	Traffic Offered in Erl.	Measured Congestion and 95% Confidence Limits	Congestion given by Erl.* Int. Formula	Number of calls processed in test
1	4	18	0.1182 ± 0.0028	0.0980	60,000
2	4	18	0.1100 ± 0.0026	0.0980	60,000
3	6	18	0.1055 ± 0.0025	0.0980	60,000
4	6	18	0.0962 ± 0.0025	0.0980	60,000
5	6	18	0.1003 ± 0.0020	0.0980	100,000
2	4	11.7	0.0094 ± 0.0006	0.0089	100,000
3	6	11.7	0.0085 ± 0.0006	0.0089	100,000
4	6	11.7	0.0083 ± 0.0006	0.0089	100,000
5	6	11.7	0.0093 ± 0.0006	0.0089	100,000

* Erlang's Interconnection Formula

one corresponds to Fig. 5. In the first matrix no two elements differ by more than one, which is as good as can be achieved with the scheme of this type. In the second case the difference between the biggest and smallest element is 4; some groups are interconnected only twice, while others share the same trunks up to 6 times.

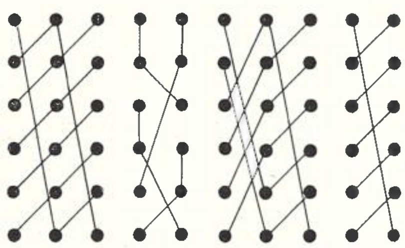

Fig. 5 — 6-Group Pseudo-Homogeneous Scheme with Diagonal Interconnections.

At this stage it is instructive to make the following observations. First, with 18 erl. offered the scheme of Fig. 4 and with 11.7 erl. offered the schemes 3 and 4 showed lower congestion than predicted by Erlang's Interconnection Formula. If the load is reduced further, the improvement over the Interconnection Formula becomes more marked. Second, the relative efficiencies of certain interconnection schemes change when the traffic load is varied. This can be clearly observed if we compare gradings of Figs. 2 and 3 with the schemes of Figs. 4 and 5. At 18 erl. schemes of Figs. 4 and 5 are more efficient than those of Figs. 2 and 3, while at 11.7 erl. the difference is wiped out or even reversed. The reason for this variation is the degree of trunk concentration in the early choices, which is considerably higher in the gradings of Figs. 2 and 3. Hence, for maximum efficiency sequentially hunted gradings should be designed with reference to the traffic load they are expected to handle.

The next thing we want to investigate is the effect of the hunting method on the efficiency of various interconnection arrangements. Only two methods of outlet hunting were investigated — sequential from a fixed (home) position and sequential from a random starting position — as these are the most commonly used methods in commercially produced switching equipment. (From the traffic carrying capacity point of view purely random and random start sequential hunting are equivalent.)

The results of simulation tests are summarised in Table 2. Note, that Figs. 1, 2 and 3) are quite unsuitable for random hunting and behave as if they were hunted sequentially in the opposite direction to that for which they only homogeneous and pseudo-homogeneous interconnecting schemes were investigated for the effects of hunting. Conventional gradings (such as given in were designed.

The above given test results leave little doubt that sequential hunting from a fixed position is superior under normally encountered traffic loads. The above results also show that this superiority diminishes as the traffic load increases. Overseas investigations indicate (Ref. 5) that under very heavy loads random hunting becomes more efficient. Such heavy loadings, however, can be encountered only on first choice routes in alternate routing systems, and then only rarely.

Finally, we will examine the effect of input traffic unbalances between the grading groups. This is of considerable interest to all telephone equipment engineers, as in practice it is virtually impossible to achieve perfect traffic balance at all times. It has been long observed that low availability gradings and interconnecting schemes are more susceptible to input traffic unbalances than those of relatively high availability. Simulation tests have confirmed this belief. Therefore, the examples given here are confined to schemes of lowest availability in common use.

To illustrate the effect of traffic unbalances on the traffic carrying capacity, test results on two small interconnecting schemes of availability 5 are given in Table 3. Both schemes have the same number of trunks (N = 10) and the same number of grading groups (G = 4). The first, shown in Fig. 6, is a randomly hunted homogeneous interconnecting scheme, while the second is a straight grading with skipping and is hunted sequentially. The unbalance ratio given is the ratio of traffics offered to the first and second halves of the scheme (e.g. 1 : 3 indicates that the lower two groups are offered three times as much traffic as the upper two groups). The overall offered traffic was 4.75 erl in every case.

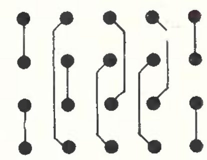

Fig. 6 — Homogeneous 4-Group Interconnecting Scheme.

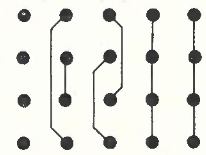

Fig. 7 — 4-Group Grading with Pairs and Fours.

It is interesting to note that both schemes are affected by unbalances to about the same degree, although the grading of Fig. 7 appears to behave a little better. This contradicts the popular belief that randomly hunted interconnecting schemes are less sensitive to traffic unbalances than sequentially hunted gradings. From this and other tests it appears that the method of hunting is less important than the structure of the pattern. The more and better distributed the interconnections are, the less the performance will be affected by traffic unbalances. The matrix of busies is a useful indicator in this regard. If busies matrix for Fig. 6 is compared with that for Fig. 7 (both given below), it is evident that the latter scheme provides more interconnections between groups than the former, and hence distributes the load better over the trunks.

Group	1	2	3	4
1	–	2	2	1
2	2	–	1	2
3	2	1	–	2
4	1	2	2	–

Group	1	2	3	4
1	–	2	3	3
2	2	–	3	3
3	3	3	–	2
4	3	3	2	–

TABLE 3: EFFECTS OF TRAFFIC UNBALANCE

K = 5, N = 10, G = 4, A = 4.75 erl.

Unbalance Ratio	Average Congestion for Scheme of		
	Figure 6	Figure 7	Erl. Int. Formula
1 : 1	0.0464 ± 0.0020	0.0382 ± 0.0018	0.0397
1 : 2	0.0495 ± 0.0020	0.0427 ± 0.0018	
1 : 3	0.0594 ± 0.0022	0.0465 ± 0.0020	

TABLE 2: COMPARISON OF HUNTING METHODS

Grading of Fig. No.	Availability	Number of Trunks	Number of Groups	Traffic offered in erl.	Congestion when hunting is	
					Sequential from fixed position	Random start sequential
4	10	22	6	11.7	0.0083 ± 0.0006	0.0128 ± 0.0007
5	10	22	6	11.7	0.00925 ± 0.00062	0.0130 ± 0.0007
5	10	22	6	18.0	0.1003 ± 0.0020	0.1085 ± 0.0026
5	10	22	6	25.0	0.2585 ± 0.0042	0.2600 ± 0.0042
6	5	10	4	4.75	0.0396 ± 0.0020	0.0464 ± 0.0022

Another observation worth mentioning is the effect of input traffic unbalances on the character of the overflow traffic. It was observed that the variance to mean ratio of the overflow traffic increases with the degree of input traffic unbalance. The precise functional relationship, however, is not simple.

CONCLUSIONS

The results of current research into the capacity of gradings and interconnecting schemes can be expressed in a few practical rules.

For best results the interconnection scheme must be designed for a particular mode of hunting and for a given traffic load. While a grading and a homogeneous, or pseudo-homogeneous scheme are both efficient with home start sequential hunting, grading is quite unsuitable for random hunting.

At the most commonly used traffic loadings home start sequential hunting is superior to random (or random start sequential) hunting.

With home start sequential hunting the degree of trunk concentration in the early choices should be inversely proportional to the design traffic load.

Higher mixing ratio generally results in higher efficiency. It should never be less than 2.

For best results one should endeavour to interconnect as many different combinations of groups as possible. This is particularly important, if traffic unbalances are expected. The matrix of busies is a useful tool under these circumstances for checking the symmetry of the interconnection pattern.

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TECHNICAL NEWS ITEM

BROADBAND COMMUNICATIONS SYSTEM FOR TELEVISION AND TELEPHONY — EAST-WEST ROUTE

The Posmaster-General's Department has called world-wide tenders, closing in January, 1966, for the supply and installation of a broadband communications system linking the broadband networks in Eastern and Western Australia. The system will terminate at Port Pirie or Port Augusta in the east and Merredin or Northam in the west.

The system will ultimately provide at least 600 trunk telephone channels and two television relay channels in both directions. A proportion of the trunk channels will be made available to important towns along the route (e.g. Kalgoorlie, Norseman, Ceduna), and the present and future need for telephone facilities at intermediate points is recognised.

The tender Schedule specifies, in detail, the requirements for a microwave radio system and also sets out the main requirements for a coaxial cable system as an alternative to the radio system. Furthermore, tenders are invited for any other alternative solution which the tenderer may consider to be suitable.

A microwave system, if adopted, would follow the Eyre Highway and require repeater stations at 25-30 mile intervals over the route distance of approximately 1,400 miles. For such a system to be economically provided and operated, high equipment reliability and low power consumption are essential as the majority of stations would be unattended and require on-site generation of power. Power for the equipment would probably be obtained through a large capacity battery using a diesel engine, wind charger or thermo electric source. It is anticipated that the repeater buildings could be of thin-walled, dust sealed, metal construction, shaded from the sun, so that heat from the station load could be dissipated by heat exchange through the walls and roof. The selection and survey of the route between Norseman and Ceduna would also be carried out by contract to complement similar work being carried out by the Department on the two end sections.

If a coaxial cable system were used, it is anticipated that buildings would be required at intervals of 70 to 80 miles and that intermediate repeaters would be buried integrally with the cable. All equipment would be transistorised and have low-power consumption. It might be practicable to supply power to distribution points along the route for distances of the order of 300 miles by means of a special high voltage transmission line built into the cable. Power would be supplied to the individual repeaters over the coaxial cable conductors. Consideration would be given to laying the coaxial cable along the route of the Transcontinental Railway in preference to the Eyre Highway.

AUSTRALIAN PENTACONTA CROSSBAR P. A. B. X.

*A. O'ROURKE, A.R.M.I.T. Grad. I. E.Aust.**

INTRODUCTION

The Australian Pentaconta Crossbar P.A.B.X. has been developed in Australia by Standard Telephone and Cables (S.T.C.) as a replacement for the well-known uniselector and line finder types. Already more than fifteen of these units have been installed in the Melbourne metropolitan area, and the purpose of this article is to present an outline of the trunking, facilities and operation of the equipment. The particular P.A.B.X. discussed below is situated at Walton's Department Store in Melbourne; it caters for 290 extensions, 45 incoming exchange lines and 30 direct outgoing exchange lines.

The basic unit in the Pentaconta system is the crossbar switch which provides 52 outlets for any one inlet; a detailed description of this switch has been published in the October, 1961 issue of this *Journal* in an article referring to the French C.G.C.T. Pentaconta P.A.B.X. at the Myer Chadstone Centre(1). This switch contains 13 horizontal bars called selecting bars and a 14th doubling bar. Each selecting bar in conjunction with a vertical operating bar controlled by a vertical magnet can operate either of two spring-sets, an upper or a lower. The doubling bar is used to further divide the thirteen upper and thirteen lower spring sets into two series, giving a total of 13 X 2 X 2 = 52 outlets (Fig. 1).

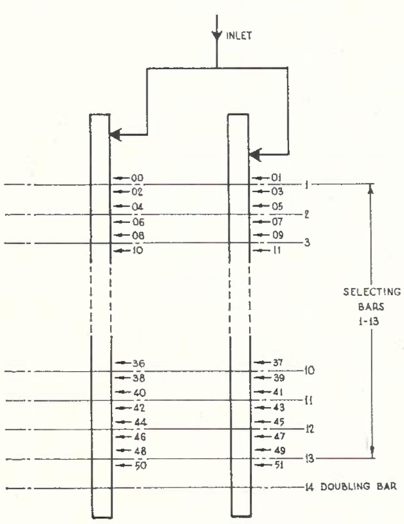

Fig. 1 — Basic Crossbar Switch

Nineteen of these individual crossbar switches are mounted side by side in a frame to form the multi-selector, shown in Fig. 2.

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EQUIPMENT ARRANGEMENT

General

The switching equipment is mounted in completely enclosed cabinets which afford adequate protection against the entry of dust. Front and rear doors give access to the equipment. Terminal strips are mounted in a separate compartment at the top, so that installation may be carried out with the cabinet doors closed. The space between the two rows of terminal strips is used as the cable runway and joins with troughing for cabling between rows of cabinets and MDF, TCF, etc. Multi-selectors are mounted on the front side of the cabinets together with shelves for jack-in relay sets (Fig. 3.) The relays generally are of the 3000 type, but magnetic counting relays and thermal delay relays are also used. Access to the rear of the above items is given by opening gates which carry further relay set shelves (Fig. 4). The cabinets are 3 ft. 4 in. wide, 1 ft. 8 in. deep and 7 ft. 9 in. high with 6 in. extra for the terminal strip compartments and cable troughing.

The Line Unit

The line unit, illustrated in Fig. 3 (labelled 200-299), and Figs. 4, 5 and 6, carries the equipment for 100 (actually 104) extension line circuits plus 25 exchange line circuits. On the front side are the two line multi-selectors and the exchange multi-selector, which is only required for systems over 200 lines. On the shelves below the multi-selectors are mounted the extension line circuits, 13 per base, requiring eight bases, and the following relay sets:
- Call Back Finder and Miscellaneous Circuits.
- Two 50 Group Markers for the two line multi-selectors.
- 1000 Group Marker (not required in systems less than 200 line).
- Exchange Marker Connecting Circuit (not required in systems less than 200 line).
- Revertive Exchange Line Circuit 4.

On the rear gates are mounted (see rack in centre of Fig. 4, and Fig. 6):
- Direct Local Links 1-6.
- Direct Outgoing Exchange Circuits 1-6.
- Incoming Exchange Line Circuits 1-12.
- Revertive Exchange Line Circuits 1-3.

In addition, three positions are available for use as Incoming Exchange Line Circuits 13-15 or Indirect Outgoing Exchange Line Circuits 1-3, as required.

The Group Unit

The Group Unit is illustrated in Figs. 7, 8 and 9 and is associated with two line units to form a complete 200 line group. On the front side are the three intermediate multi-selectors and the local multi-selector (for systems over 200 lines) associated with the 19 local links of the 200 group. On the shelves below are mounted the following relay sets:
- Number Transfer Circuit.
- 200 Marker Connecting Circuit (for systems of more than 200 lines).
- 200 Group Marker.
- Conference Circuit.
- Executive Lines Circuit.
- Local Marker Connecting Circuit (for each frame of Two Hundred selectors).

or 200 Marker Connecting Circuit (for connecting the local link to the 50 group marker).
- 1000 Group Marker.

On the rear gates are mounted (see right-hand rack of Fig. 4, and Fig. 9):
- Indirect Local Links 1-7.
- Tie Line Circuits 1-9.
- Operators Pulsing Keysender Circuits.
- Operators Marking Keysender Circuits.
- Operators Circuits.

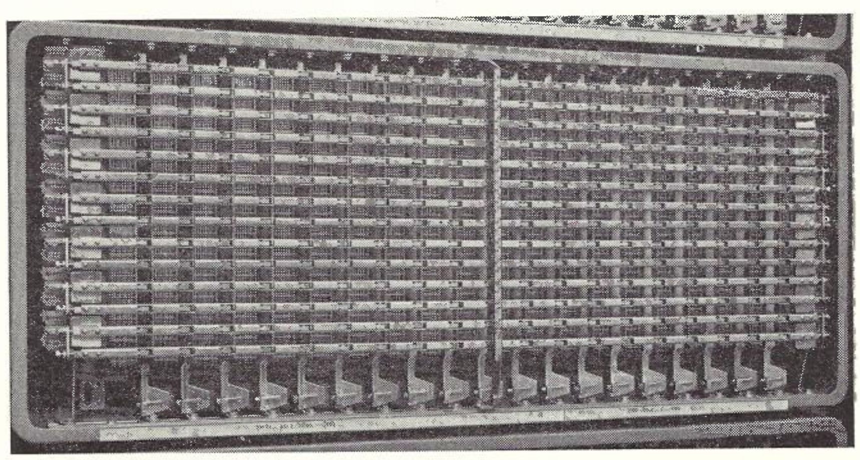


Fig. 2 — Multi-selector Showing Fourteen Horizontal Selecting Bars, the Lowest Being the Doubling Bar, and Nineteen Verticals.

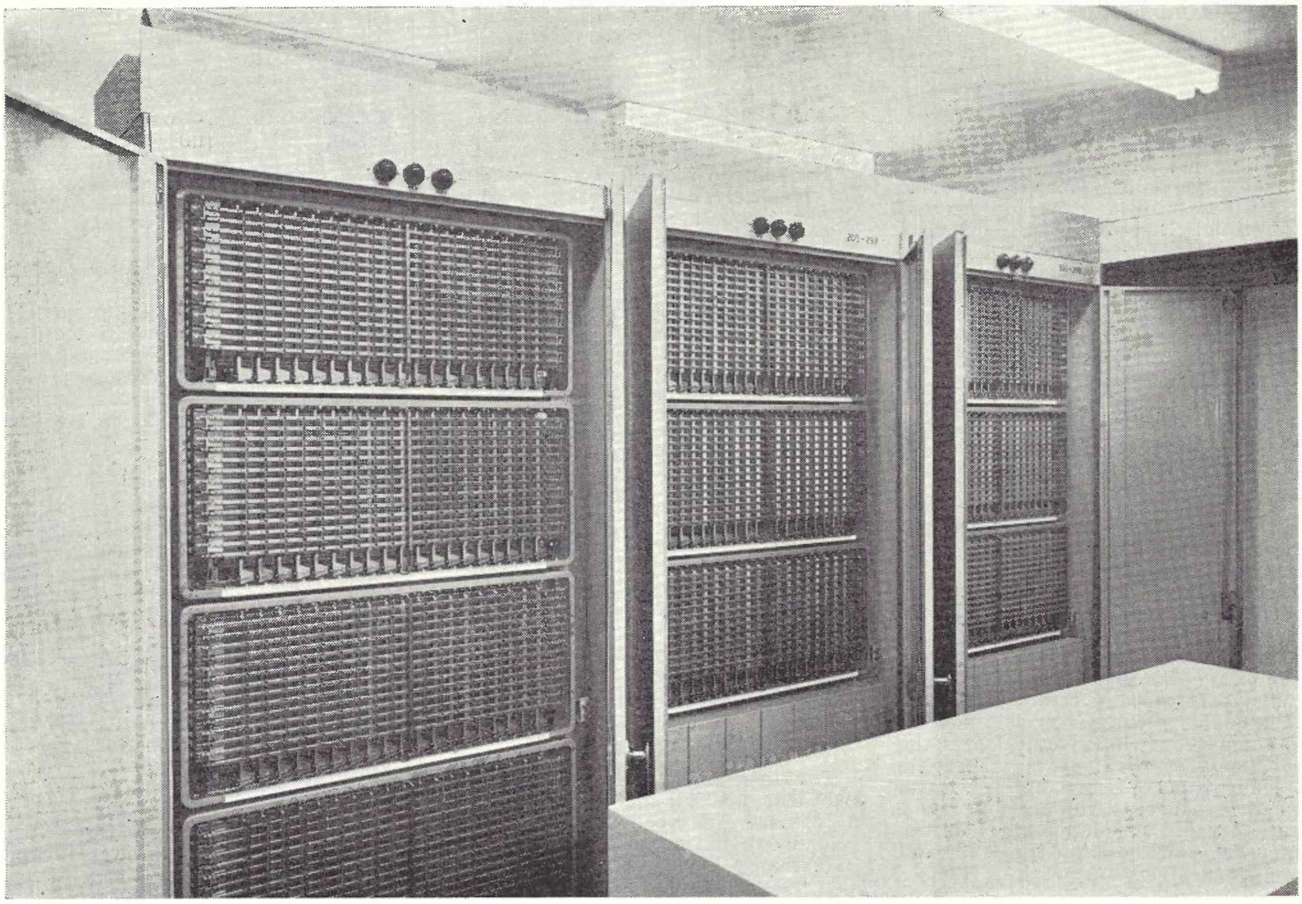


Fig. 3 — Suite Containing a Group Unit and Two Line Units.

Operators Rapid Call Circuit.
Service Line Circuits.
Test Potential Allotter Circuit, which provides for the cyclic testing of incoming and revertive exchange line circuits that may be parked on busy extensions.

A typical equipment layout for 400 lines is shown in Fig. 10.

FACILITIES

There are two types of facilities, Basic, which are provided in all cases, and Optional, which may be added as required.

Basic Facilities

Classes of Service: By simple wiring alterations, it is possible to arrange for any extension to be given any one of the following classes of service —

(a) Unrestricted, having direct access to the public exchange for originated calls;
(b) Semi-restricted, having access to the public exchange for originated calls via the P.A.B.X. operator.
(c) In S.T.D. areas (Subscriber Trunk Dialling), unrestricted access for local calls, but via the P.A.B.X. operator for trunk calls;
(d) In S.T.D. areas, unrestricted access for both local and trunk calls.

In addition access may be restricted, if required, on certain tie line routes.

Temporarily Restricted Extensions: In addition to the classes of service referred to above, it is possible to arrange for a further group of extensions to be temporarily restricted from direct access to outgoing exchange lines during busy periods. An extension in this group, attempting to call, receives busy tone and may be granted a call at the discretion of he operator.

Keysender Operation on Exchange Line Calls: Calls on incoming or revertive exchange line circuits are switched to the required extension by keysender operation. The ten digit keys and the keysender relay set do not generate impulses, but mark the desired extension by contact combinations and forward this information directly to the marker. The connection is set up immediately the last key is released.

Automatic Operator Recall: If an incoming exchange call which has been switched to an extension is not answered within 45 seconds, it is automatically brought to the operator's attention by the steady glow of the CALL lamp of that circuit.

Call Back: At any time during an incoming exchange call, the call back facility may be used by operation of the call back button on the extension telephone. Depressing the button will automatically hold the exchange call, and return local dial tone to the extension, who may then (a) return the call to the operator by simply hanging up, (b) transfer the call to another extension by dialling that extension's number and waiting for him to take the call, (c) dial the exchange access digit (usually 0) and make a call through the public exchange network. In the case (c), transfer of the incoming exchange call to the outgoing exchange call is prohibited, and should the extension attempt the transfer by replacing the handset instead of depressing the call back button, the incoming exchange call will be held and the operator recalled.

Through Clearing: At the conclusion of an exchange call, the connection is automatically cleared when the extension handset is replaced.

Chain or Automatic Sequence Calls: In the event of an incoming exchange line caller informing the operator of the desire to speak to more than one extension number in succession, the operator, in order to prevent automatic through clearing, operates the Hold Key associated with the exchange line. This automatically returns the exchange caller to the same operator when the called extension replaces the handset, so that the call may then be directed to the next extension in sequence. The Hold Key may also be used to hold an incoming exchange call prior to keying of the extension number.

Parking: Operators may extend calls to busy extensions to await attention. At the end of a call in progress, the previously busy extension is automatically called and on answering, is connected with the new caller. There is no limit to the number of calls that may be parked on a busy extension and calls are answered in random sequence. At the end of 45 seconds, any call that has not been answered is brought to the attention of the operator, who may answer the call again and either (a) repark the call, (b) connect the caller to another extension, or (c) release the call.

Trunk Offering: The operator can cut in on busy extensions and offer an urgent call, the operator's intrusion being signalled by a warning tone.

Group Hunting (P.B.X. Rotary Group): Two or more extensions may be grouped under one common call number enabling an incoming call to be directed to the first free line in the group. The normal operation of extensions in the group is not affected and calls to numbers other than the first line of the group test only that line. Groups are restricted to numbers within a particular 50 group and must be either all even numbers or all odd numbers.

Service Lines (Information): These lines are provided for the use of extensions requiring operator assistance and for enquiries. A single digit code, usually 9, is generally used. These lines may also be used for operators' calls to extensions by operating a service line key and dialling the extension number, or keying the number on the keysender if a pulsing keysender is fitted.

Revertive Calls: The operator can call a public exchange number by dial or pulsing keysender if fitted, and revert the call to an extension by keying the extension number.

Monitoring of Calls: Operators can monitor calls which have been established; a warning tone indicates the intrusion.

Tie Lines: These are used for connecting to another P.A.B.X. (or P.M.B.X.) thus giving direct communication between all extensions. Tie lines are generally called by means of a single-digit code, followed by the number of the required extension at the remote P.A.B.X. Tie line circuits may also be used for certain special facilities such as Credit Authorization, Central Dictation, etc.

Night Switching: At night or any other time when the operator is not in attendance, the Night Service Key is operated and all incoming exchange line calls will be switched through directly to one or several pre-determined extensions. By using the automatic transfer facility (push button) calls may be answered by the night service extension and then transferred to any extension as required. If the night service extension is busy, a tone is injected on to the line to indicate a waiting incoming call.

Automatic Night Switching: If the operators positions are left unattended, an incoming exchange line call unanswered within a period of approximately sixty seconds will cause Auto-

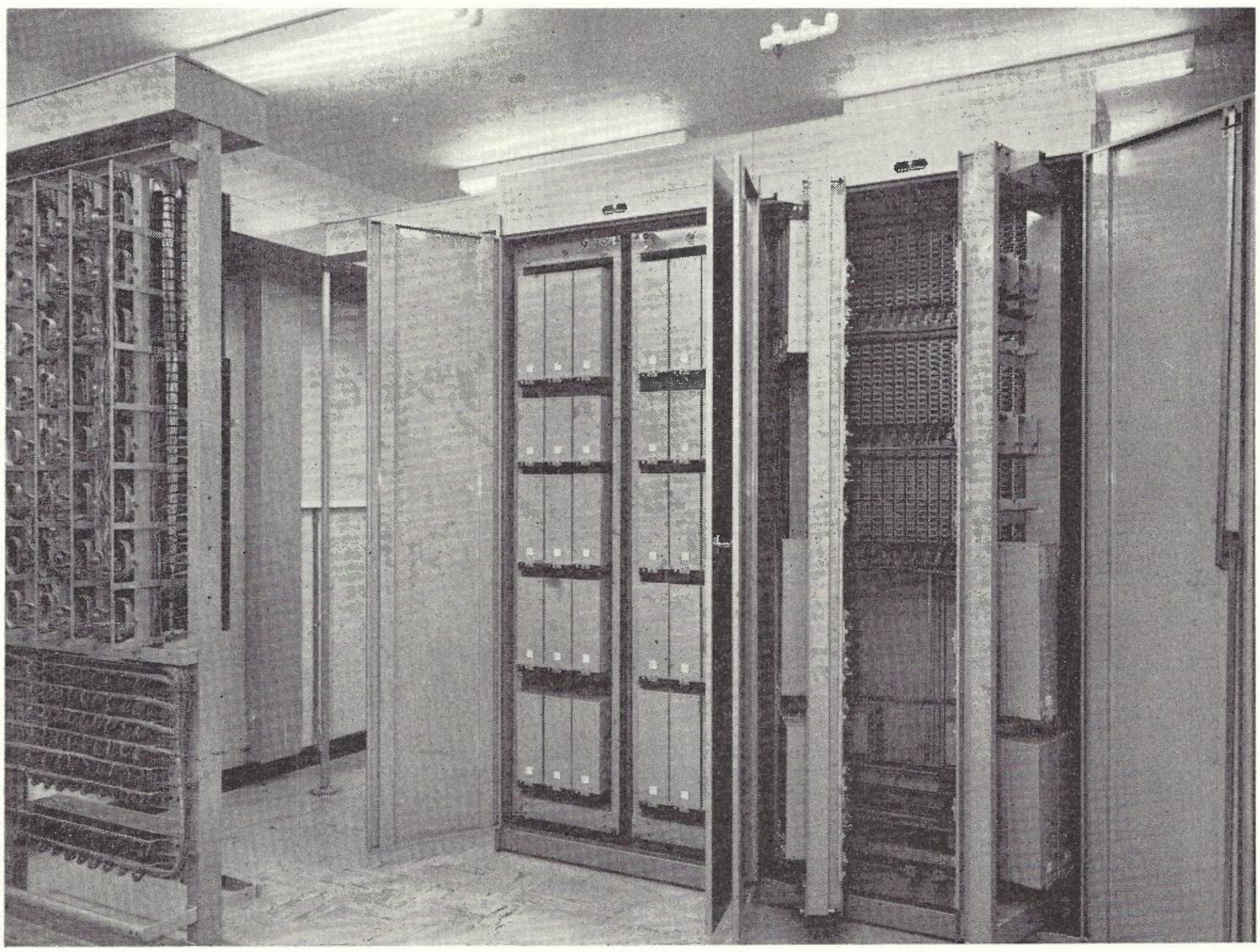


Fig. 4 — L to R Shows TCF, Rear View of Line Unit and Opened Rear Gates of Group Unit.

matic Night Switching to take place. An audible signal is given after approximately 30 seconds and if the call remains unanswered after a further 30 seconds, the call is automatically directed to the night service extension. Further calls are night switched immediately.

Optional Facilities

Operators Pulsing Keysender: This allows the operator to use the keysender on outgoing exchange line calls and service line calls, as well as for internal calls. The dial is retained for standby use.

Rapid Call Keys: Enable operators to call frequently wanted pre-determined public exchange numbers by operating a single key.

Call Back and Transfer on Outgoing Calls: Operation is similar to the basic call back facilities (a) and (b), but applies to outgoing exchange calls as well as incoming calls.

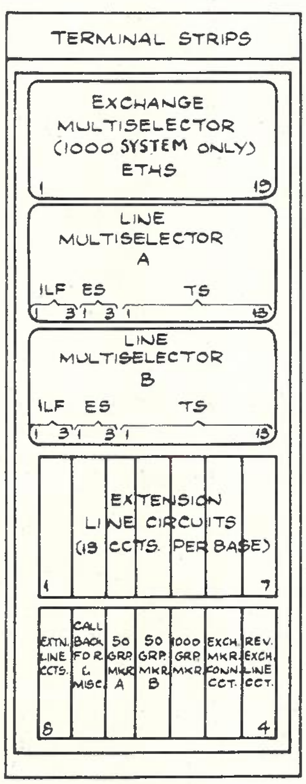
Executive Lines: Extensions connected as such may signal the operator by simply pressing the call back button on the telephone.

Conference Facility: This allows a number of extensions to be connected together in a conference.

Paging Service (Code Calling): This allows a number of persons to be located from any extension by coded lamp signals or other means. The person called can answer from any telephone by dialling a special code.

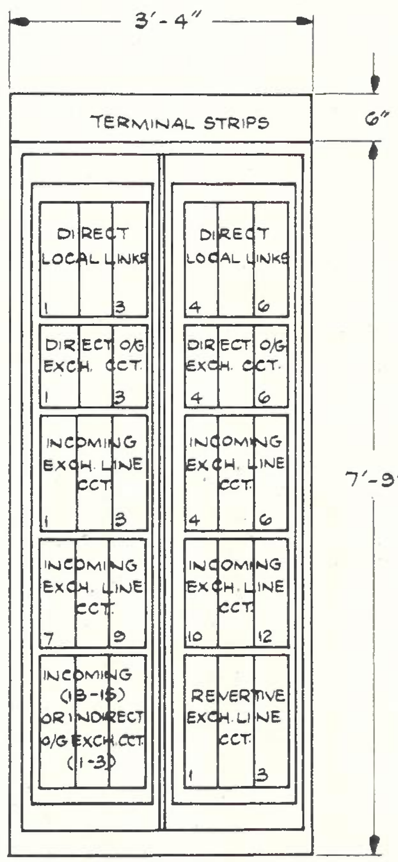
Centralised Dictation Recording: With this facility, any extension has access to a centralised recording machine by dialling a particular code and then proceeding to dictate. The recorded dictation may be played back for checking.

Credit Authorization: By means of a stamping unit associated with extension telephones, a perforated authorization may be stamped on sales dockets from a central credit bureau. It is possible to provide authorization over tie lines from a central bureau that may serve several branch stores.



FRONT

Fig 5 — Equipment Layout on Front of Line Unit Rack



REAR

Fig. 6 — Equipment Layout on Rear of Line Unit Rack

In Dialling: Outside callers may dial directly to P.A.B.X. extensions with this facility; calls to busy extensions or those not answered within a certain time are directed to the operator.

Message Accounting: On the introduction of S.T.D., facilities will be available for recording trunk line call charges and their allocation to particular extensions.

Satellite Operation: In this arrangement, all incoming exchange line calls for a group of co-operating P.A.B.X.'s are received at a central operator's position (or positions) and directed as required over tie lines to satellite P.A.B.X.'s.

Blind Operators Facilities: Operators' positions can be specially adapted for use by blind operators.

OPERATION OF 200 LINE SYSTEM

General

The basic 200 line group is shown in Fig. 11. One nineteen vertical multi-selector is provided for each group of 50 extensions — the extra 2 outlets in the 52 outlet multi-selector are used for call back lines. The 19 verticals are divided as follows:

(a) three 1st line finders (1LF) each connected to a local link and carrying the basic internal traffic originated within the 50 group;

(b) thirteen terminal selectors (TS) which carry all terminating traffic for the 50 group as well as the overflow component of originated traffic;

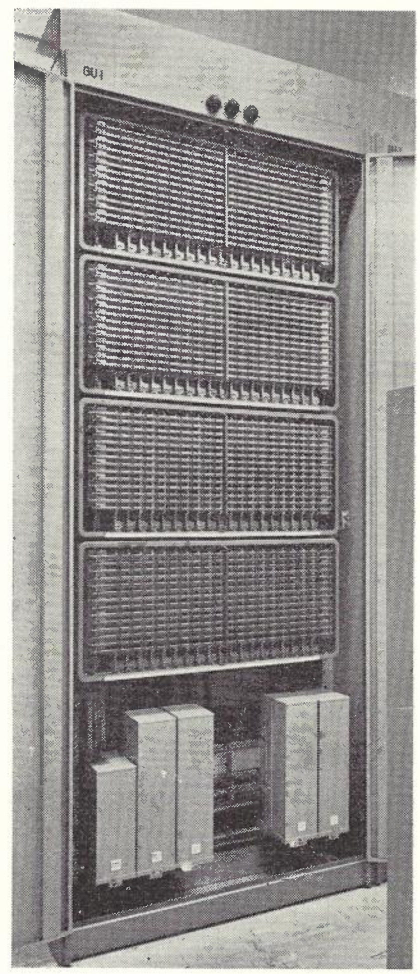


Fig. 7 — Front of Group Unit with Doors Open

(c) three exchange selectors (ES) carrying the basic load of originating traffic and connecting directly to outgoing exchange line circuits (O/G).

The second switching stage comprises three "intermediate multi-selectors", equalling 57 verticals, divided as follows:

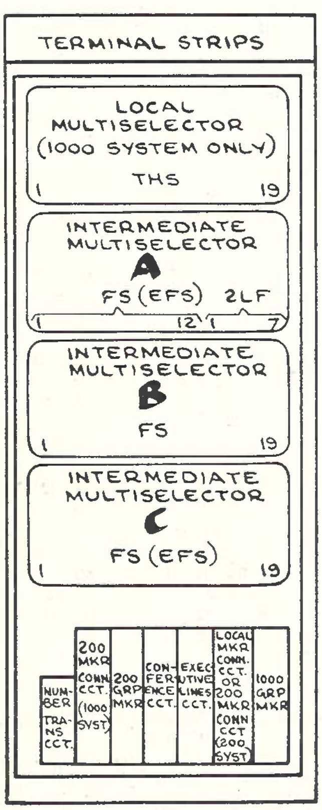
(a) seven 2nd line finders (2LF) each connected to an indirect local link. These with the three local links for each 50 group make a total of 19 links for the 200 group;

(b) nineteen fifty selectors (FS) connected to the nineteen local links for completion of internal calls;

(c) thirty-one exchange fifty selectors (EFS) available for association with incoming (I/C) and revertive (REV) exchange line circuits.

Local Call

When an extension originates a call, the line is connected to a free local link over 1LF if a direct circuit is available; otherwise an indirect local link is seized and the associated 2LF selects a free TS in the required 50 group, which in turn selects the calling extension line. This is a typical line finder process. Dial tone is now returned to the caller for the local link, the caller dials the three digits of the required extension and the three trains of impulses are stored on magnetic counting relays in the local link. After receipt of the last digit, the stored information is sent forward to the markers which set the associated FS and a free TS, thereby completing the connection to the called extension. Ringing current, ring tone and subsequently battery feed are supplied from the local link.

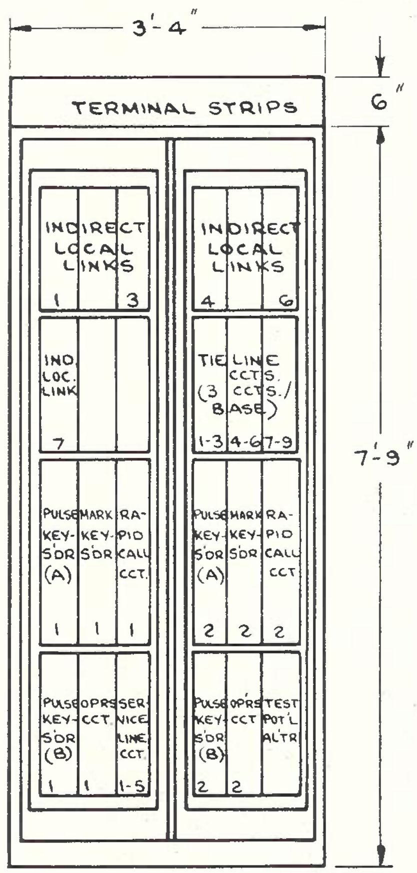


FRONT

Fig. 8 — Equipment Layout on Front of Group Unit Rack

Outgoing Exchange Call

If the first digit dialled corresponds to that for an exchange call (usually "O"), the local link is released and the extension line is reselected by an ES if a free direct outgoing exchange line circuit is available. Otherwise a free revertive circuit is seized and the connection made via the associated EFS and a free TS. On receiving public exchange dial tone the caller may proceed. Should no free outgoing line be available (or no free TS) busy tone is returned to the caller. Busy tone is also given to the caller if no local link is available but in this event, it is possible to gain access to an exchange line (if a free circuit is available) by operation of the call back button on the telephone.



REAR

Fig. 9 — Equipment Layout on Rear of Group Unit Rack

Incoming Exchange Call

An incoming exchange call is signalled on the operator's position, and extended

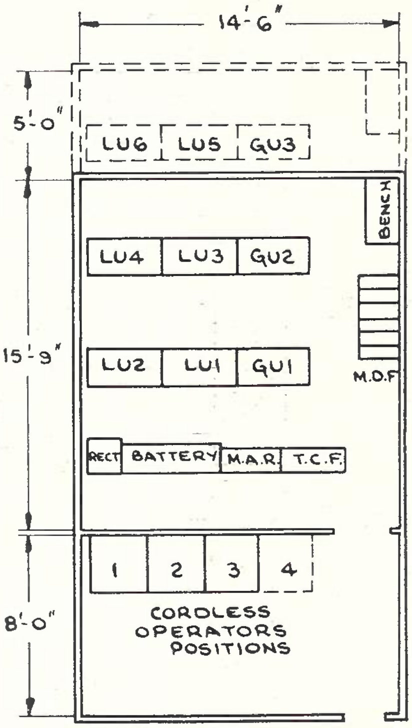


Fig. 10 — Typical Equipment Layout for 400-600 Line P.A.B.X.

to the required extension by means of a marking keysender which, after the last digit is keyed, forwards its information to the markers. This causes immediate setting of the associated EFS and a free TS and the called extension is rung from the exchange line circuit (I/C).

Flexibility of Selectors

From the foregoing, it will be seen that the 13 terminal selectors in each 50 group carry the terminating local traffic and incoming exchange traffic as well as the overflow components of originated local and exchange traffic, thus assuring particularly good utilization as well as a high degree of flexibility. As the four groups of 13 terminal selectors in a 200 group are fully available from the 52 outlets of the intermediate multi-selectors, the need for grading or interconnecting between these stages is avoided.

Operation of Marker in 200 Line System

The function of the marker is to evaluate the call information received, set up all the horizontal bars of the required multi-selectors, select, and in some cases operate, free selectors, for both originating and terminating calls. It also ensures by the operation of a mutual exclusion chain circuit, that only one call may be set up in any 200 line group at a time and that simultaneous requests for connection are handled in consecutive order.

Fig. 12 shows the switching arrangements of a 200 line system with the

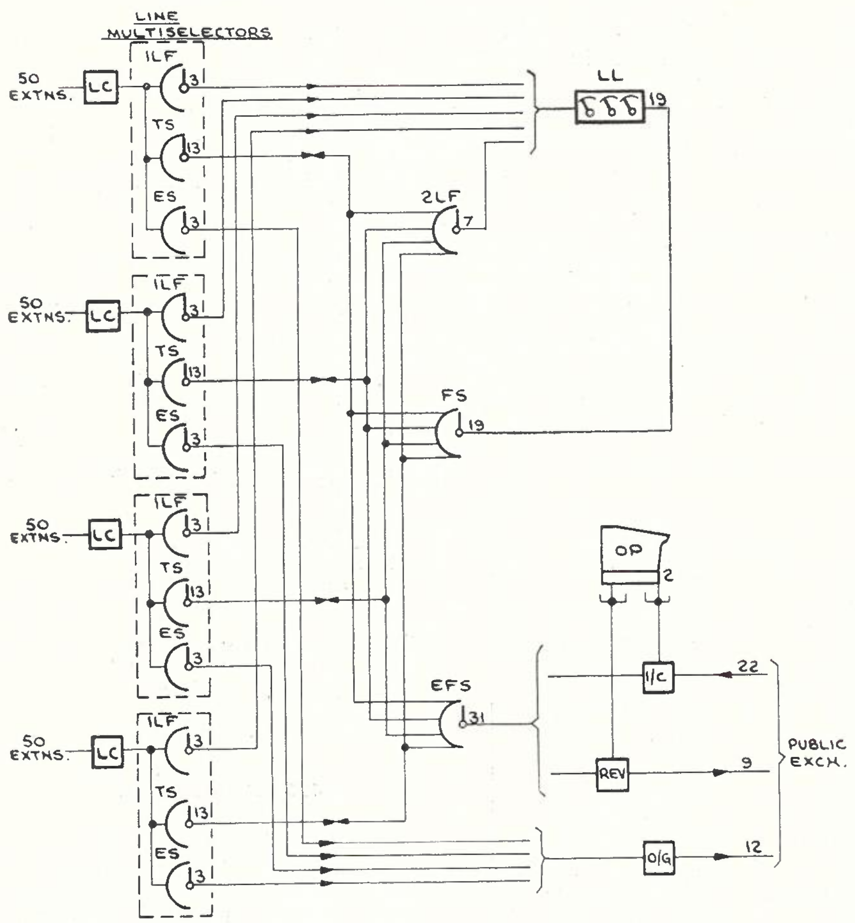


Fig. 11 — Block Diagram of Basic 200 Line Circuit

operating paths of the marker. The marker is divided into several parts, each of which comprise a jack-in relay set:

(a) 50 group marker associated with each 50 group and directly controlling the line multi-selector (1st switching stage);

(b) 200 group marker controlling the setting of the intermediate multi-selectors (2nd switching stage);

(c) Marker connecting circuit which is seized by either the local link or marking keysender to set up a terminating call. As well as busying the marker against originated calls, it examines the first digit of the called number;

(d) Number transfer circuit which receives the tens and units information on terminating calls and passes this on to the particular 50 group in a suitable form.

On a call originated by an extension, the extension line circuit, in conjunction with the particular 50 group marker, causes the setting of the line multi-selector and seizure of a free local link (if one is available). In the 200 group marker, the main marker chain circuit is opened to busy the circuit to terminating calls while the originated call is set up. Originated exchange calls are handled in a similar manner, except that a direct outgoing exchange line circuit is seized instead of a local link. Distributor circuits ensure that local links and outgoing exchange lines are seized in cyclic order, thus minimizing the effects of a faulty circuit.

If all direct circuits are busy, the 200 group marker sets the horizontal bars in the particular intermediate multi-selector (for 2LF or EFS respectively — depending on whether it is a local call or exchange call) to select a free TS in the calling 50 group and an indirect circuit is seized.

When the local link has received the three digits of the called extension's number, the marker connecting circuit is seized as soon as the marker is free. The number transfer circuit receives the tens and units information and causes the particular 50 group marker to set the bars on the line multi-selector. The 200 group marker sets the bars on the intermediate multi-selector and the TS and FS selector magnets are operated to complete the connection. Approximately 100 milliseconds is required to complete the two stage marking action.

In a similar manner, the marking keysender seizes the marker as soon as the keying operation is completed on either an incoming or a revertive exchange line call under the control of the operator. In the case of a revertive call, the pulsing keysender, if fitted, may first be used to set up the number of the outside party, then the internal extension number is keyed and the marking action may be completed while the outside pulsing is still proceeding.

OPERATION OF 1000 LINE SYSTEM

General

When the number of extensions exceeds 200, the 1000 system is used as shown in Fig. 13. This comprises a number of 200 groups (up to five) as required, and an additional selector stage, the "Two Hundred Selector" (THS) is added. A THS is associated with each local link and selects a free FS (Fifty Selector) in the required 200 group. Similarly, an Exchange Two Hundred Selector (ETHS) is associated with each exchange line circuit other than the direct outgoing circuits available to the Exchange Selectors (ES). Both the THS and ETHS provide access to as many as five 200 groups, the outlets being "graded" on the Trunk Connecting Frame (TCF) to the groups of FS. The local links in this case may be considered as final selectors with access to 1000 lines as well as performing the functions of 1st group selectors.

Exchange line calls are handled in a similar manner to the 200 system. Outgoing calls are routed via direct circuits when these are available. Revertive circuits are available primarily for the use of operators to revert calls to extensions (in the case of restricted access, etc.); a small number of these circuits may be reserved exclusively for operators' use and are not accessible to calling extensions. If the total number of circuits required for the overflow traffic from the direct lines exceeds the required number of revertive circuits, a number of indirect outgoing circuits may be provided and taken into use first. Only when these, too, are all in use is a revertive circuit selected by a calling extension. As in the 200 system, incoming calls are extended over ETHS, FS and TS to extension by marking keysender operation, and as no impulsing is involved, the connection is set up almost immediately. Fig. 14 shows the trunking diagram for the 300 line P.A.B.X. at Waltons.

Operation of Marker in 1000 Line System

In systems over 200 lines, a TCF is introduced for grading the outlets of Two Hundred Selectors to the various 200 groups. Each THS frame is controlled by a 1000 group marker and an associated local marker connecting circuit. The ETHS has a similar 1000

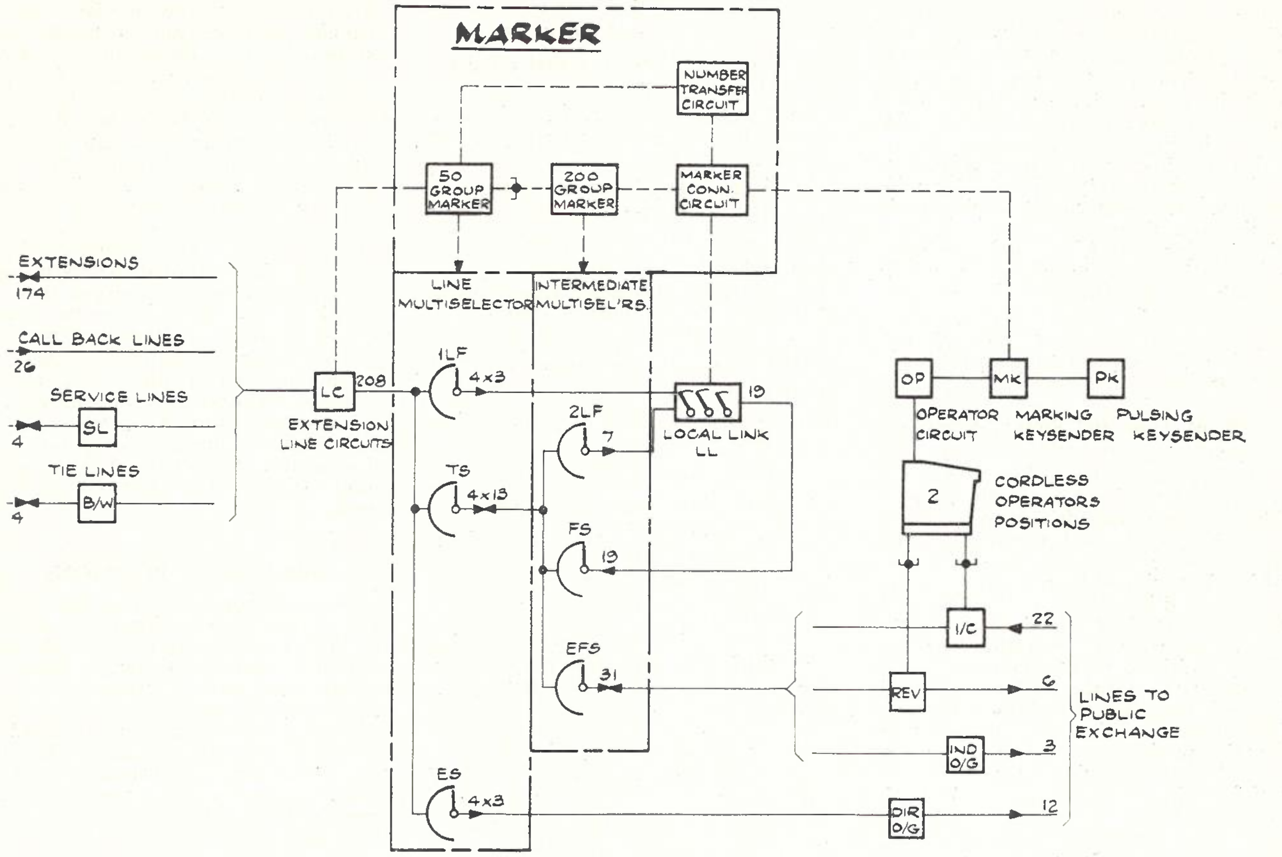


Fig. 12 — 200 Line System Marker Arrangements

group marker and exchange marker connecting circuit. In the case of an 800 line system, i.e. 4 groups of 200 lines, there would be a possible 4 local 1000 group markers and 8 exchange 1000 group markers, dependent on the provision of 2 line units and one group unit per 200 extension line group. Associated with each 1000 group marker is a set of coupling relays for temporarily coupling this marker to the required 200 group marker (See Fig. 15).

Internal Call

The seizure of a local link over 1LF (or TS and 2LF) is effected in the same manner as for a 200 system. After receipt of the dialled digits the local link seizes the local 1000 group marker associated with its THS frame. This seizes the required 200 group marker, and the local marker connecting circuit causes the operation of the particular coupling relays. Once these have operated, the way is clear for the hundreds, tens and units information to be passed from the local link into the number transfer circuit, where they are used for setting the FS and TS selectors. At the same time, the 1000 group marker controls the setting of the THS bars to complete the connection.

Exchange Call

On incoming and reverted exchange line calls the operator calls the three digits of the required extension on her keysender. Operation of the answer key on the operator's position causes the keysender coupling relays to connect the marking keysender to the exchange marker associated with the exchange line circuit. The call is set up in a similar manner to a local call by the 1000 group marker of the ETHS, and after operation of the marker coupling relays, connected through to the required 200 group.

On outgoing calls, the direct circuits are first taken into use in the same way as in the 200 system. When these are all busy a revertive circuit (or indirect outgoing circuit) is seized and the connection established over ETHS, FS and TS to the calling extension. Although any particular exchange line circuit has access via its ETHS to a limited number (usually 13) of Fifty Selectors in each 200 line group, in this case the selection of an exchange circuit is conditional upon a free circuit being available.

THE 2000 LINE SYSTEM

The 1000 system may be extended to 4-digit operation by adding another magnetic counting relay (thousands) to each local link (and tie line links, if provided). If more than five directions (five 200 groups) are required from the THS's, an additional selector is associated with each THS, giving a total availability of 104 outlets, which may be divided into as many as 2000 extensions. In all other respects the operation of the 2000 line system is similar to that of the 1000 line system.

MISCELLANEOUS FEATURES

Tie Lines

In a 200 line system, first digits not otherwise required may be used as single-digit codes for special services such as tie lines, special groups of exchange lines, etc. In such cases the local links initiate the switching action immediately the first digit is received. The tie lines, etc. are connected to spare extension line circuits arranged in hunting groups as required, so that the call is switched to the first free line in the group (P.B.X. groups). In a 1000 line system, the number of extensions is usually limited to 700 as certain digits such as 9 and 0 are used for calls to operators or exchange calls respectively, and digit 1 is not usually used. Accordingly the 52 outlets of the THS (two hundred selectors) are normally divided into four directions (for the groups 200-300, 400-500, 600-700, 800) each having thirteen outlets. The fourth direction can be split, if required, into two directions of seven and six outlets respectively. As shown in Fig. 13, large groups of outgoing tie lines are connected via the TCF to these THS outlets. Incoming tie lines are connected to link circuits equipped with magnetic counters; these circuits function in a similar manner to local links, and are associated with a Tie Line Two Hundred Selector (TTHS).

As in the 200 system, small groups of both-way tie lines (or service lines, etc.) are connected as a hunting group (PBX) to normal extension line circuits.

Ring, Tone and Power Supply

These items follow conventional A.P.O. practice for large P.A.B.X.'s. Ringing current and tones are supplied from a dynamotor driven from the 50 volt DC supply and mounted on the Miscellaneous Apparatus Rack (M.A.R.) which is equipped with monitoring and alarm facilities. A second machine is fitted as standard practice with automatic changeover operation in the event of failure of one machine.

Main power supply is from a 24 cell lead-acid enclosed type battery mounted in a wooden cabinet, and floated from a mains rectifier at a normal voltage of 52 volts. The equipment will operate satisfactorily over a range of 44 to 56 volts.

Alarms

The equipment provides alarm indications of the following conditions:

(i) Extension line short-circuited, earthed or hand-set off (P.G.).

(ii) Extension does not dial all digits of called number.

(iii) Extension does not hang up when called number is busy or does not answer.

(iv) Either extension fails to hang up at end of conversation.

(v) Call back button pressed.

The above alarms (Supervisory) are subject to approximately 9 seconds delay and may be disconnected by operation of a key on the M.A.R.

(vi) Marker held for excessive period.

(vii) Marker chain faulty.

(viii) Faulty operation of fifty selectors (FS).

(ix) Fuse alarm.

(x) Ring fail (auto. changeover to spare machine).

(xi) Total ring fail.

(xii) Charge fail.

(xiii) Circuit breaker operation (on M.A.R.).

Provision is made for extension of alarm indications to the public exchange.

Testing Equipment

In a switching system with marker operation, it is difficult, if not impossible, to trace the operations of the various markers because of the quickly changing marker relations and the very short times of occupation. Such systems, therefore, require the provision of an adequate and convenient method of testing the correct operation of crossbar switches and markers, and for this purpose a special test set has been developed. It may be connected to any local link by means of a test plug and cord and to a test extension number on the P.A.B.X., usually 299. The local link may be tested under long or short line conditions, and testing to a free or busy extension. All functions of the local link may be tested in this manner under conditions more severe than in normal service. To examine the operation of crossbar switches and markers involved in the connection, the operation may be repeated as often as desired by means of the Reset key on the test set, or a remote control Reset switch. It is quite simple to check the operation over all available circuits by busying each circuit (FS or TS) after it has been tested.

OPERATORS' POSITIONS

Operators' positions are in the form of a floor type console, illustrated in Fig. 16. All exposed surfaces are faced with a plastic laminate material which is extremely resistant to wear. Access to all equipment and terminals is obtained by raising the hinged key panel, which is shown in detail in Fig. 17. The design is such that key operations are kept to a minimum; at the same time the operator retains full control over connections.

A call is answered by pressing the Answer Key associated with the Call Lamp and is extended by operating in

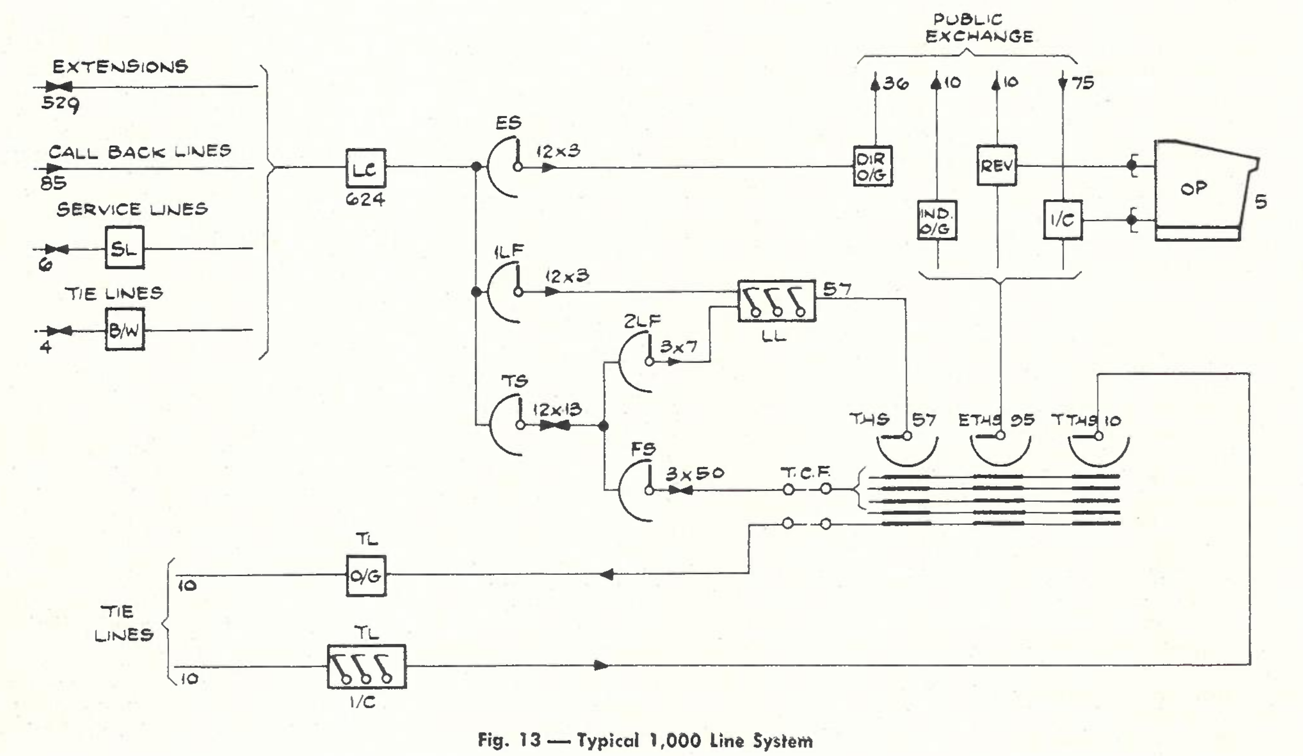


Fig. 13 — Typical 1,000 Line System

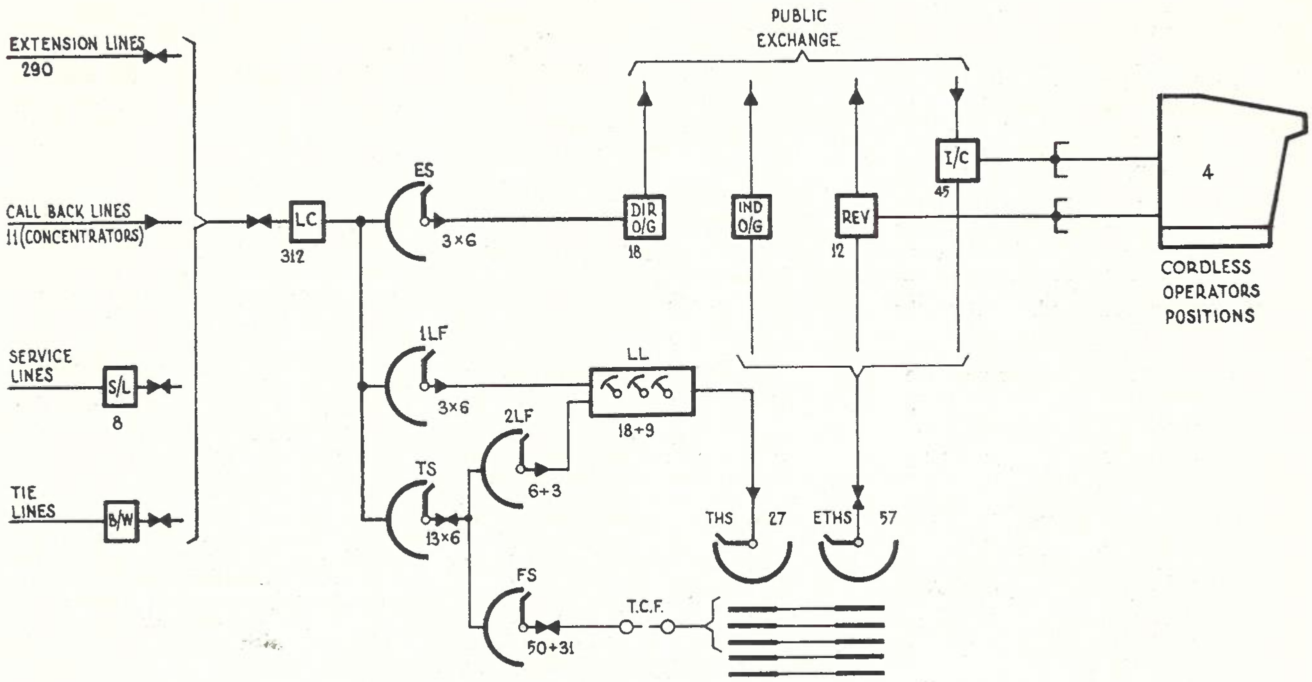


Fig. 14 — Trunking Diagram of Waltons 300 Line P.A.B.X.

sequence the three (or four) digits of the required extension number. No other operations are required. The progress of each call is indicated by a Supervisory Lamp, and the Operator may monitor calls in progress.

The key panel associated with each operator's position is divided into three sections; details of a typical position are as follows (Ref. Fig. 17):

I. Left hand section, commencing at the top of the panel:

(a) Revertive Lines Nos. 1-10.
- Ten pull-type, locking, Hold Keys.
- Ten busy lamp indicators (red)
- Ten supervisory lamp indicators (green)
- Ten call lamp indicators (white)
- Ten magnetic locking, push-type, Answer Keys

(b) Spare panel for ten incoming lines.

(c) Incoming Lines Nos. 21-30.
- Ten pull-type, locking, Hold Keys
- Ten supervisory lamp indicators (green)
- Ten call lamp indicators (white)
- Ten magnetic locking, push-type, Answer Keys

(d) Ten incoming lines Nos. 1-10 identical to (c).

II. Centre section, commencing at the top of the panel:

(a) Ten service lines Nos. 1-10, with key and lamp facilities identical to the revertive lines of I (a).

(b) Two spare panels for 20 incoming lines.

(c) Ten incoming lines, Nos. 11-20, identical to I (c).

III. Right-hand section, commencing at the top of the panel (See left-hand operator's position Fig. 16):

(a) Four pull-type, locking keys, fitted to the first operator's position only. They are, from left to right, Night Service Key, Buzzer Key, Extension Bell Key (for connecting an external bell in conjunction with the switchboard buzzer) and Restrict Access Key, (for temporarily restricting outgoing exchange access to pre-wired groups of extensions).

(b) Three spare panels, for optional facilities i.e., Rapid Call Keys, Executive Lines, etc.

(c) Ten indicator lamps directly associated with functions of the equipment or with the row of keys below them. Lamps one to five, and eight and nine, are used generally and are labelled as follows, in order from left to right.

(i) Wrong Connection — indicates incorrect operation of the keysender, or congestion of a switching stage.

(ii) Auto Transfer — indicates that Automatic Night Switching has taken place, or will take place within 30 secs.

(iii) Error — indicates a discrepancy in the operation of the pulsing keysender (if fitted).

(iv) Call Pilot — indicates a call condition awaiting the operator's attention.

(v) Button Pilot — indicates an operated magnetic locking key.

(vi), (vii), lamps are not used.

(viii) Call waiting — should the operator book a revertive trunk call for any extension, this lamp indicates that the line to the trunk exchange is parked on the operator's special extension.

(ix) Exchange Call — indicates that a temporarily restricted extension is attempting to gain access to an outgoing exchange line.

(d) Six push-button, non-locking keys, respectively,

(i) Cancel Internal — for re-directing a call or cancelling an incorrectly keyed extension whilst holding an exchange line.

(ii) Cancel External — for opening the exchange line to release a wrongly dialled or incompleted connection whilst the internal connection is held.

(iii) Button Release — for releasing any magnetically held key.

(iv) Trunk Offer — to allow the operator to intrude into a busy connection and offer an important call.

(v) Wait — For a revertive trunk call, the operator can key a special extension number and park the trunk operator thereon. This enables further calls to be answered. When the trunk operator is ready with the required call, she speaks to the switchboard operator who then presses the wait button, releasing the trunk operator from the special extension and placing her back on the original revertive circuit.

(vi) Exchange Access — when momentarily operated, will cancel the restriction imposed by the Restrict Access Key.

(e) The lower panel in this section contains the dial, the keys 1-0 of the digit keysender a non-locking pushbutton labelled Release, which releases both the keyed extension and exchange line connections (including the Answer Key) whilst the call is still under the control of the operator, and facilities for using a pulsing keysender. These are,

(i) an Internal lamp to indicate completion of keying of the extensions number,

(ii) a Transfer key and lamp to indicate that the digit keys have been connected to the pulsing keysender equipment,

(iii) an External lamp to indicate when all outgoing pulses have been sent.

SERVICE RESULTS

As is the case with all new installations, whether step by step or crossbar, some initial "teething troubles" occurred whilst the equipment settled in. However, once the operators and maintenance technicians became familiar with the facilities and operation of the P.A.B.X., it was apparent that this type of P.A.B.X. had certain advantages over step by step equipment.

An investigation of results to date has shown firstly, that the push-button consoles, compared with an equivalent cord board, are more compact and require less effort on the part of the operators, even though the facilities offered are considerably greater. As explained earlier, the operator uses only a few buttons to completely control any call. There are no jack fields or cords to wear out, consequently less of the operator's (and subscriber's) time is taken up by maintenance technicians doing essential repairs.

Secondly, the crossbar mechanisms have eliminated the maintenance needed on wipers, cords, banks and the mechanical adjustments required by uniselectors and bi-motional switches.

The high degree of flexibility inherent in the design of the trunking of the multiselectors ensures that a good grade of service is provided. Distributor circuits in the markers arrange for local links and outgoing exchange lines to be seized in cyclic order, thus minimizing the effects of a faulty circuit.

A special test set is provided with which all available circuits can be checked rigorously by busying out each circuit after it has been tested. With this method of testing, all connecting cross points in a call through the P.A.B.X. may be checked; any piece of equipment which may be faulty can thus be readily located. The points mentioned above may be summarized briefly as a higher grade of service to the subscriber with an all-round decrease in fault conditions and maintenance requirements.

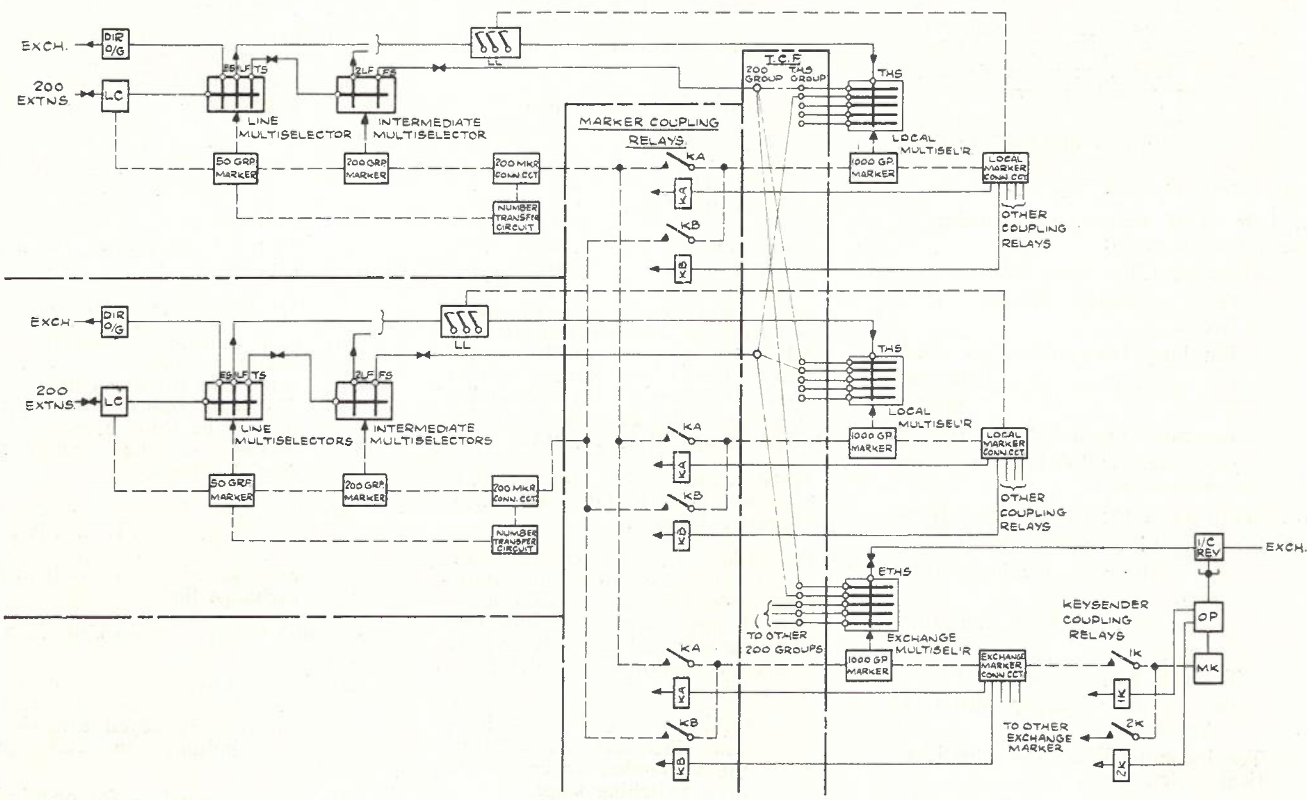


Fig. 15 — 1,000 Line System Marker Arrangements

Fig. 16 — Operators' Consoles and Public Address System Microphones

CONCLUSION

Waltons is a large department store of four floors using a total of 290 P.A.B.X. extensions. The store was opened to the public within a month of cutover of the P.A.B.X., which has given a satisfactory grade of service with extremely low fault incidence considering the heavy traffic carried. The ease and speed with which the operators handle incoming calls to extensions are a considerable improvement over other types of systems owing to the push-button control and the automatic release feature on completion of the call, i.e., through clearing with replacement of the extension's handset.

The Australian Pentaconta P.A.B.X. system was the first crossbar type P.A.B.X. to be developed in Australia to meet Australian requirements and further facilities are continually being added which will ensure that it will maintain its position amongst the leaders in the P.A.B.X. field.

ACKNOWLEDGMENT

The author wishes to thank S.T.C. Pty. Ltd. for permission to use extracts and drawings from their publications.

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1. K. V. Sharp, "A Pentaconta Crossbar P.A.B.X."; Telecommunications Journal of Aust. Vol. 13 No. 2, page 124.

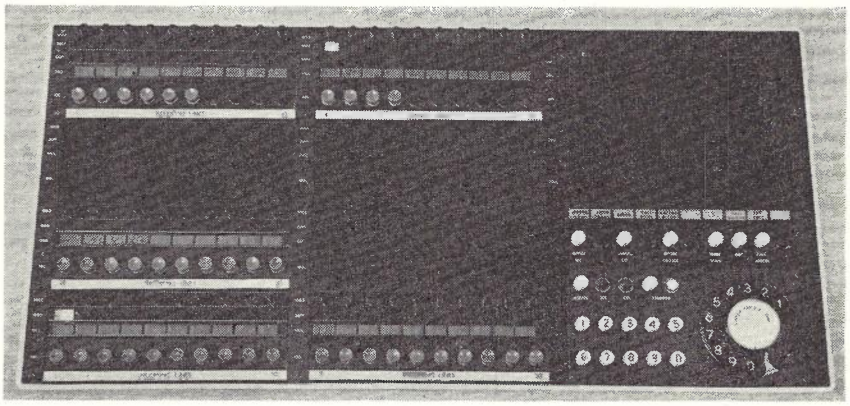


Fig. 17 — Layout of Operator's Key Panel

NO PROGRESS CALL DETECTOR — N.P.C.D.

*L. J. BLOXOM**

INTRODUCTION

The first ARF 102 Crossbar Telephone Exchange in N.S.W. was cutover at Petersham in May, 1963, followed 3 months later by a contractor installed exchange at Haymarket. One of the problems which arose at Petersham, and which remains not entirely satisfactorily resolved, is the matter of providing observation facilities. Normally for this purpose, L.M.E. provide a Reg. K, which is a Reg. L working with an RKR relay base attachment, which performs meter or registration wire checking, failure of revertive signal, and in some circuits insulation test of the "a" and "b" legs of the calling subscriber's line. Additionally the RKR in conjunction with a KOB relay set provides facilities for observations of traffic handled by the register.

A tangible difference in the results of observations made through the RKR and the results of traffic route testing was apparent at Haymarket and at other exchanges. The TRT runs were made on an "observe service" basis in 800 call blocks to 16 exchanges including local, based on traffic dispersion figures and programmed by the Sydney Service Co-ordination Centre. Six months after cutover 0.2% lost calls were detected on local exchange calls and an average of 2% on the 800 call block to other exchanges. (Only 10% of all originating traffic is local). However, the service sampling observations were consistently showing an average of 3 to 4% of observed traffic resulting in "no progress" calls. At this time there were some 80 routes to other exchanges, Petersham being the only route using multi-frequency code (MFC) signalling. As very few defective calls were observed on this route and in the local exchange, it appeared that investigation of the "step-by-step" route component of the traffic would probably reveal the cause of the call failures.

In these circumstances, the matter was discussed by the Service Staff and the following action decided upon. A No Progress Call Detection Device would be built (which has subsequently been named, No Progress Call Detector (N.P.C.D.)), for attachment to a Reg. L in similar manner to an RKR. Its functions are:—

1. To hold the register at the switching stage for further investigation of the result of the switched call.
2. To insert a V.F. Detector across the outgoing signalling leads for a period of approximately 6 seconds prior to switching the S.R. relay set to listen for ring tone, busy tone, voice announcement, and N.U. tone.
3. If tone detected, the register to complete its switching function and release.
4. If tone absent, that is, a no progress call condition:
   - (i) hold the R.S.L. and S.R. connection,
   - (ii) hold the forward connection and additionally place a loop across the forward signalling leads,
   - (iii) hold the digits of the called number in the crossbar storage switch of the register,
   - (iv) open circuit the calling subscribers "C" wire to place him on line lockout,
   - (v) open circuit his "a" and "b" wires so no interference occurs to his follow on call if made,
   - (vi) disconnect the time throwout feature of the register.

A team of three comprising a senior technician and two technicians were assigned at Haymarket Exchange to design build and to commission the device. The circuit of the N.P.C.D. is the result of this groups work. Some small but valuable additional circuitry features, evolved in the process proved of considerable benefit elsewhere in Crossbar Service. The physical unit is shown in Fig. 1 and the circuit in Fig. 2. The unit is wired on a KSR base then plugged into the base of a register rack in similar manner to the RKR and wired to one register on the rack. Two designs have been produced to accommodate either Ericsson type relays or alternatively 3000 type relays.

CIRCUITRY

When the last digit is sent from the register, or when T.D.1 releases in the case of a number length unknown call, T.K.1 operates and connects the tone detector across the outgoing "f and g" signalling leads of the Reg. L., at the same time opening the circuit of the timing relay T.K.2, which has a release time of 6 seconds. During this period, the detector is waiting for tone to be returned from the distant final selector or call terminating device. On reception of tone, T.K.3 operates in the detector circuit, and T.K.3A is operated as a slave after a delay of approximately 300 milli-seconds. (This delay is to ensure that noise is not detected as tone). When T.K.3A operates, positive is connected to R.5 in Reg. L part 1 which operates and switches the call. When the register releases T.K.1 releases and N.P.C.D. is restored to normal.

On a no progress call, after T.K.1

*Mr. Bloxom is Senior Technical Officer, Metropolitan Equipment Service, N.S.W. See page 160.

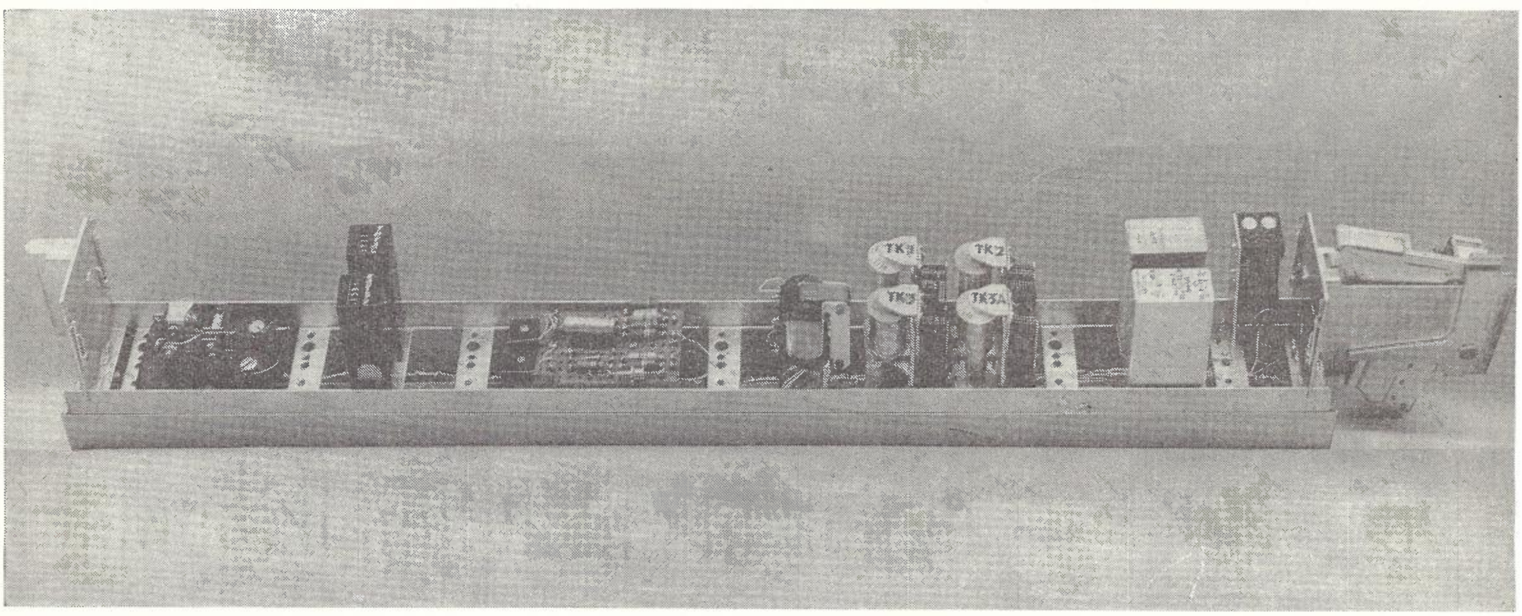


Fig. 1 — The No Progress Call Detector

operates, T.K.2 releases after its time delay and opens the calling subscriber's "C" wire and replaces the 600 ohm. LR/BR coil, with a 600 ohm. resistance connected to negative potential to hold R.1 in the Reg. L at the same time opening the "a" and "b" wires into the register. The subscriber is placed on line lockout, and on restoring the handset to the switch-hook and lifting off again, is free to originate a further call or calls. T.K.2 in releasing opens the circuits of K.1, K.3, and K.4 relays in part 1, to prevent the register timing out. T.K.2 contacts operate the alarm.

One of the keys normally mounted on the KSR base designated AK in the circuit is operated and continuous ring

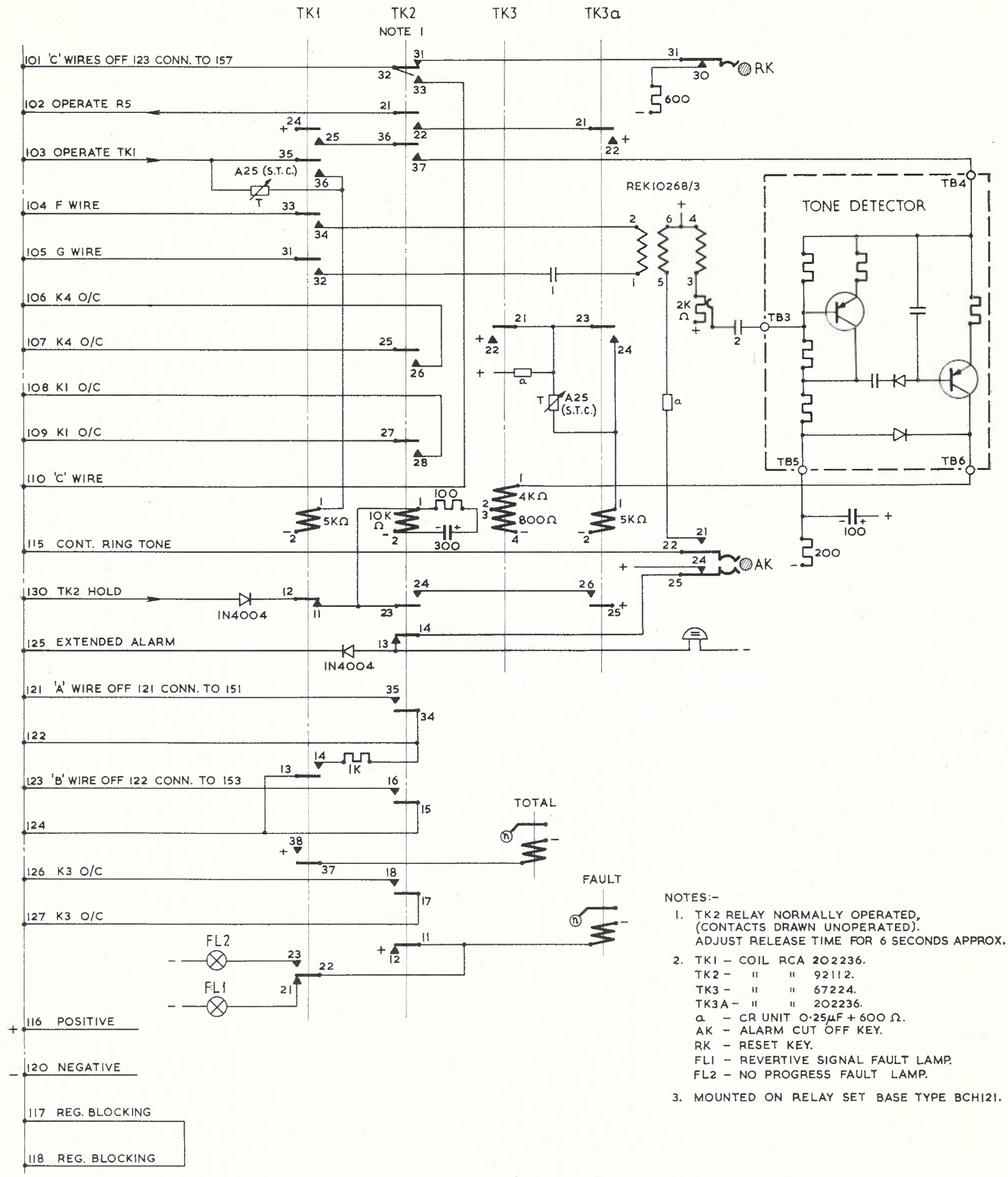


Fig. 2 — The N.P.C.D. Circuit

tone is applied across the forward signalling leads for trace purposes by a coil R.E.K. 10268/3. Another contact of the same key extinguishes the alarm. To trace the call, the called number is obtained from the digit store of the register and the indicated FUR group or groups checked for a circuit with continuous ring tone. On locating, the FUR is held and the register reset by operating key RK and restoring AK to release the register for further traffic. The distant exchange is called in, and the suspect switching failure investigated by trace.

The N.P.C.D. performs an additional function which is supervising revertive signals whilst the register is controlling M.F.C. call routing. During this part of the call, T.K.2 relay is held operated to a positive return from K.S.2 normal in part 2 of the register. K.S.2 is interworking with K.S.6, the P chain, and control relays setting up the call. Should K.S.2 remain operated under a fault condition where the revertive signal is not received, that is K.S.2 is held operated by the K.S.R., T.K.2 will release after 6 seconds and function as described previously. The failed call is again investigated by trace. This circuitry will detect for example failure of a number length signal or failure of any other revertive signal. Two meters mounted on the base provide a continuous record of faulty and total calls switched.

PRACTICAL RESULTS FROM N.P.C.D.

The use of the N.P.C.D. has confirmed the 3 to 4% average no progress calls observed by Plant Performance. Investigation of these calls by trace has resulted in location of faulty switching equipment in approximately 70% of traced calls, an extremely small percentage of these faults being in crossbar equipment. Probably follow up of the results of distant exchange investigation of the 30% balance would have indicated a greater fault detection figure. For example, on a trace call to a distant 6 figure "step by step" exchange, the incoming third selector on the direct route may be found to be switched to a level corresponding to the fifth digit, and the fourth selector switched to a level corresponding to the sixth. The fourth selector dropped out on switching due to a fault in its own circuitry, or that of the selected trunk ahead or terminating relay and switch. In these circumstances, further investigation would be left to the distant exchange where perhaps a 136 outlet test might be performed on the level appropriate to the digits dialled on the third selector and similarly on the 20 possible fourth selectors. Further, the failure may have occurred due to the final selector "A" relay adjustment not operating over the ohmic resistance of the junction loop plus the D.R. coil of the register. However, referring to the 70% detected faults these have been found to be due to every day switching failures which occur in step by step exchanges. For example, no vertical, no cutin, open circuit wiper cords etc.

Where immediate attention has been available for the N.P.C.D., up to 18 failures a day have been recorded, with a resultant 13 faults being detected on investigation. Additionally, number length signal failures in 1GVM's have been found particularly following restrapping of number length analyser blocks for network number length changes. The rapid extension of the Haymarket installation with additional equipment including S.T.D. facilities has resulted in the N.P.C.D. being used only when staff is available. When no staff is available, the R.K. key is operated permanently and the register functions on a "grade of service" basis.

It is considered that the discrepancy between observation and TRT results at Haymarket is due to the TRT giving an erroneous picture of the network because calls are made on

1. a percentage only of all routes and
2. these TRT called numbers are possibly the best tested equipment routes in the network.

Recently the N.P.C.D. was installed as a fault finding expedient in a newly cutover hybrid crossbar extension in a suburban exchange, experiencing an unusually high failure rate on originating traffic and without a TRT or service control rack equipment. In a period of 24 hours it had detected 5 1GV marker faults, 3 of which were number length failures and 2 of which were caused by crossed marker number length signals. In addition, defective network switching equipment, and minor link failures in the crossbar extension were detected.

CONCLUSION

The development of the N.P.C.D. has provided crossbar maintenance personnel with an additional extremely useful and productive fault detection aid, and currently, work is in hand to provide a unit for each crossbar exchange in the Sydney Metropolitan area. A further innovation will be the fitting of perspex fronted panels on the three parts of the Reg. L. A further development of the circuit, would be the detection and holding of stop on busy network troubles. These are found now by investigation of blocked junctions on FUR's during traffic.

ACKNOWLEDGMENTS

The author wishes to acknowledge the assistance provided by Senior Technician K. McNamara, Technicians P. Andrew and L. Gibbons of Haymarket Exchange Maintenance Staff who designed the circuits.

TECHNICAL NEWS ITEM

MULTI-FREQUENCY DIALLING

Applications of M.F. dialling arise due to the present trend away from Strowger and towards register-common control telephone systems. Tones can be transmitted by means of a keystrip fitted to a telephone in place of the dial and it is anticipated that the resulting saving in register-holding-time will enable a reduction to be made in the number of registers provided in an exchange. M.F. dialling may also find application in telephone instruments connected to long part-privately erected party lines which can be of low insulation and unsuitable for the transmission of loop-disconnect impulses. The P.M.G. Research Laboratories are investigating the latter application.

The frequency of signalling is necessarily in the speech range (say, 700-1700 c/s) to suit the transmission characteristics of telephone lines and, in order to minimise the probability of mis-operation due to ill-timed speech, each digit is represented by two frequencies. Each of these two frequencies can be drawn from two mutually exclusive groups of four, and guarding circuitry at the receiving end can detect the absence of one frequency or the presence of a third and either ignore the signal or register a fault.

Several methods of generating tone in the telephone instrument have been suggested. One such method uses tuned magnetic reeds which are plucked whenever a key is depressed (or released) and allowed to vibrate at the natural frequency in a magnetic field. A surrounding coil transmits the electric frequencies to line. All the energy produced is derived from manual operation of a key and any attempt to extract power results in damping of the signal. Tuned reeds, therefore, are suitable only for short lines of high insulation resistance. If amplification is provided at the telephone it is but a short step further to generate tone by means of a transistor oscillator. A scheme has been suggested[1] using, in the telephone, only one transistor which is capable of maintaining oscillation simultaneously at two frequencies. The two frequencies are selected and initiated by the operation of an appropriate key which selects the required tappings on the oscillator coils. Some kind of mechanical locking is desirable to prevent more than one key from being depressed at the same time.

Extensive field trials are needed to determine the maximum saving in calling time that can be achieved by tone calling and although such schemes are certain to suffer from many teething troubles, one feels the expense will ultimately be justified.—R.E.

1. Bell System Technical Journal, Jan. 1960.

TRANSISTORISED REPEATER DESIGN FOR LONG HAUL SYSTEMS

*K. BARTHEL**

INTRODUCTION

This paper describes some of the changes which have to be made in the design of broadband line transmission equipment when valves are replaced by transistors. It is shown that the use of transistors gives freedom in several aspects where restrictions were previously placed on the designer. Some results on field trial systems adopting the design criteria outline, are given.

SECTION 1 — DESIGN PHILOSOPHY**

General

During the last few years, advances in transistor design have resulted in the production of transistors which are at least on a par with special quality vacuum tubes with respect to power rating and bandwidth. The special quality tubes which were used in line with repeaters for long haul communication systems on coaxial cables can now be replaced by transistors with many advantages.

Because the cathode material of a vacuum tube is gradually consumed, the maximum useful life obtainable is about 10,000 to 30,000 hours, and figures of 10^{-5} to 10^{-6} per hour are quoted for failure rate due to accidental failures. Because of this relatively high failure rate, tubes are sometimes operated in parallel in broadband line equipment, or standby lines are provided.

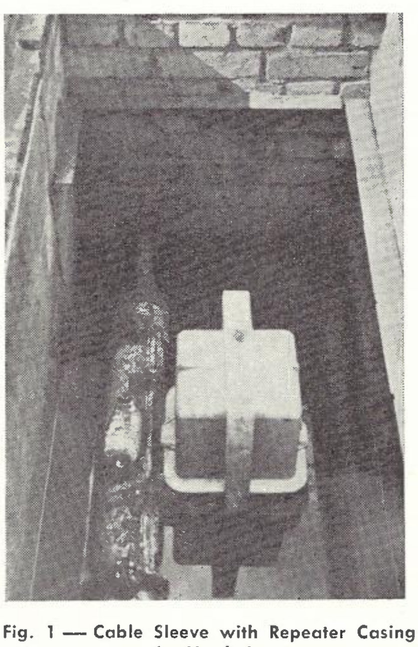


Fig. 1 — Cable Sleeve with Repeater Casing in Manhole

**Section 1 was presented at the 1964 International Symposium on Global Communications.

*Mr. Barthel is with the Central Laboratories, Siemens Halske A. G. Munich. See page 160.

With transistors, however, there is no reason for "death from old age", since the transistor does not suffer from the erosion of active material. With perfect manufacturing techniques, its useful life would be unlimited. Practically, failure rates in the order of 10^{-8} per hour can be obtained. This means that the critical supervision required with vacuum tubes can be considerably relaxed when transistors are used, since the failure rate is not dissimilar from passive components such as resistors and capacitors.

The repeaters using transistors therefore need no longer be readily accessible, but can be accommodated in sealed containers in manholes or buried directly in the ground. Various casings, with capacity up to 12 repeaters can be provided. Fig. 1 shows such an enclosure for a single repeater. The cable sleeve is attached directly to the repeater casing. This underground installation technique makes it simple to provide uniform repeater sections at the exact design spacing, so that no line building-out networks are required in the buried repeaters. Building-out networks are only required in main offices above ground level. It can be appreciated that this simple accommodation of repeaters gives a number of advantages both economical and technical.

Temperature Control

The temperature of buried repeaters, or repeaters laid in insulated cable pits changes at the same rate as the temperature of the cable laid at the same depth. Fig. 2 shows an insulated repeater cable pit, and the Styropor thermal insulation on which the repeater stands. The assumption that the underground temperatures will be uniform throughout a large area is confirmed by measured results taken by the Meteorological Service. These measurements show very good agreement between underground temperatures taken at the same time and depth.

The temperature versus time response of the underground repeaters and the cables agree very closely, as can be seen from Fig. 3. Because of this agreement, changes in gain and attenuation slope of the cable may be changed by simple automatic adjustment related to the ambient temperature of the repeater. Previously, this compensation was provided by line pilots and the elimination of these provides considerable economy. Furthermore, unlike pilot regulation which represents a closed control loop, this temperature adjustment is a compensation effect and does not involve critical loop controls. An adjustment of this kind allows only the compensation of one predetermined disturbing characteristic, in this case the temperature. It can be realised that due to small residual temperature differences, the gain adjustment achieved in this way will not be perfect. The residual errors of the individual repeaters may be cumulative, so that after each 10 to 12 temperature adjusted repeaters, pilot control repeaters must be provided.

This gain adjustment as a function of temperature, is produced bv a thermistor in the feedback equaliser of the line repeater. By adding two or three resistors to the thermistor circuit, the control characteristic can be adapted very closely to the temperature-caused attenuation changes of the preceding repeater section. Since there are now only about 10 pilot controlled repeaters per hundred repeaters, very long regulating sections of 500 to 1,000 km may have only 10 cascaded regulators. For such a limited number of regulators, the critical

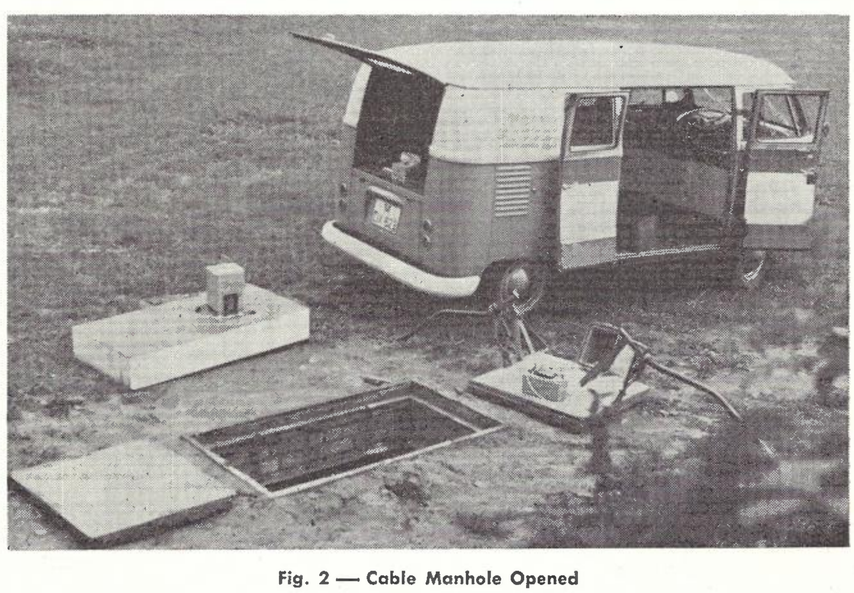


Fig. 2 — Cable Manhole Opened

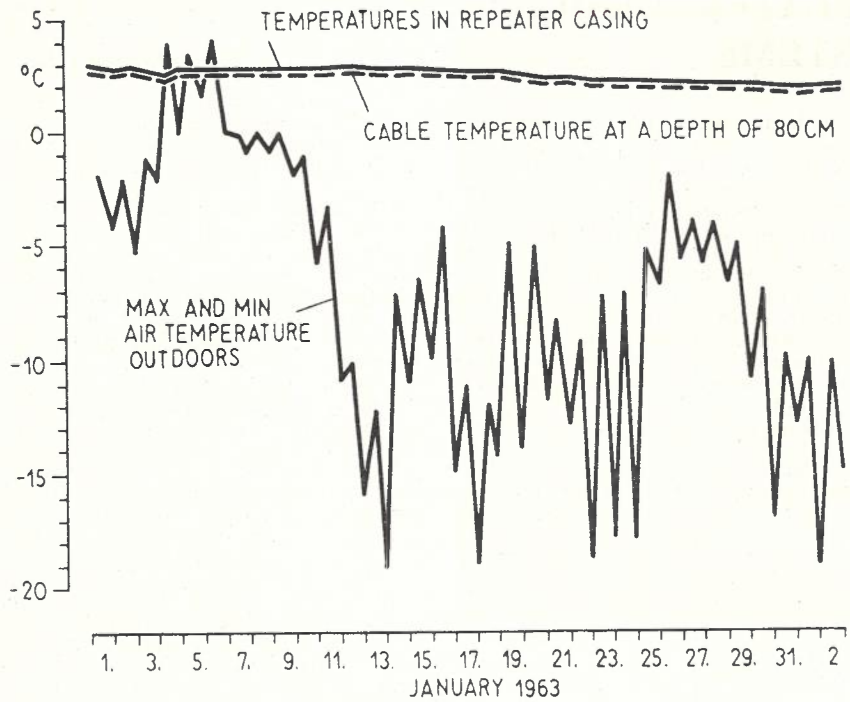


Fig. 3 — Underground Repeater Point Temperatures

requirements placed on the dynamic behaviour of regulators in existing line equipment can be greatly simplified.

Power Feeding

The line repeaters of existing long haul communication systems receive their power supply via the same coaxial line which transmits the communication signals. Since the power requirements for transistor amplifiers are much simpler and only a single voltage is required, it is possible to use series fed D.C. power. Power feeding over the cable is carried out over the inner conductors of the two coaxial tubes. A given main office may feed power in both directions for about one half of the repeaters in that section. Between the repeaters at the ends of the power feeding sections, the coaxial line is D.C. isolated by transformers, and is free of any power feeding current.

Fig. 4 shows that the cost of the supply for the dependent repeaters is very moderate. Apart from the power separation filters, all that is required is a Zener diode to cater for over-voltage limiting and a capacitor across the amplifier power terminals for filtering purposes.

Supervision

Series feeding also presents one important difficulty. Any interruption of the power feeding loop will cause all the associated repeaters to be disabled, and the fault cannot be located by way of the repeaters. It is possible by means of relays to re-energise all repeaters up to the point of interruption, but such relays have disadvantages. Firstly, they consume power and secondly, the difficulty in securing positive contact closure after many years of idleness is very great. No satisfactory relay has been found, so another solution was tried to find the point of interruption in the power feeding loop. Fig. 4 also shows the simplified power feeding circuit with the components providing the fault location under the alternative scheme. At each underground repeater, a suitable resistor is connected between the inner conductors of the coaxial tubes. By a resistance measurement in the main office, the number of such parallel resistors still effectively connected can be determined, and the location of the break in the power feed loop can be determined accordingly. In order to avoid undesired losses of feeding current through these resistors during normal operation, a diode is connected in series with each resistor with such polarity that it offers a very high resistance to the normal power feeding voltage. Under fault conditions, the normal power feed voltage is removed from the line, and a test voltage of opposite polarity is then applied so that the diodes conduct and the transverse resistances are measured.

Apart from power feed supervision, it is necessary that the performance of the buried repeaters should be monitored in such a manner that will not only indicate actual failure of the repeater, but will also reveal that the performance of a given repeater is deteriorating. If this can be achieved, measures can be taken in advance to replace a repeater showing deterioration. This is most desirable because buried repeaters are not easily accessible. Ideally, the supervision methods should be useable to track down any erratic contacts which may appear in the line equipment by measurements from the main office in addition to those characteristics previously mentioned.

It is possible to meet these requirements by pulse supervision techniques. The top part of Fig. 5 shows one method of applying pulse supervision to a line system. Band pass filters are connected between the outputs of the line repeaters in one direction and the inputs of those in the other direction. The pass band of these filters is above the useful line frequency band, and the pulse bandwidth is governed by the repeater section length. When a supervisory pulse is

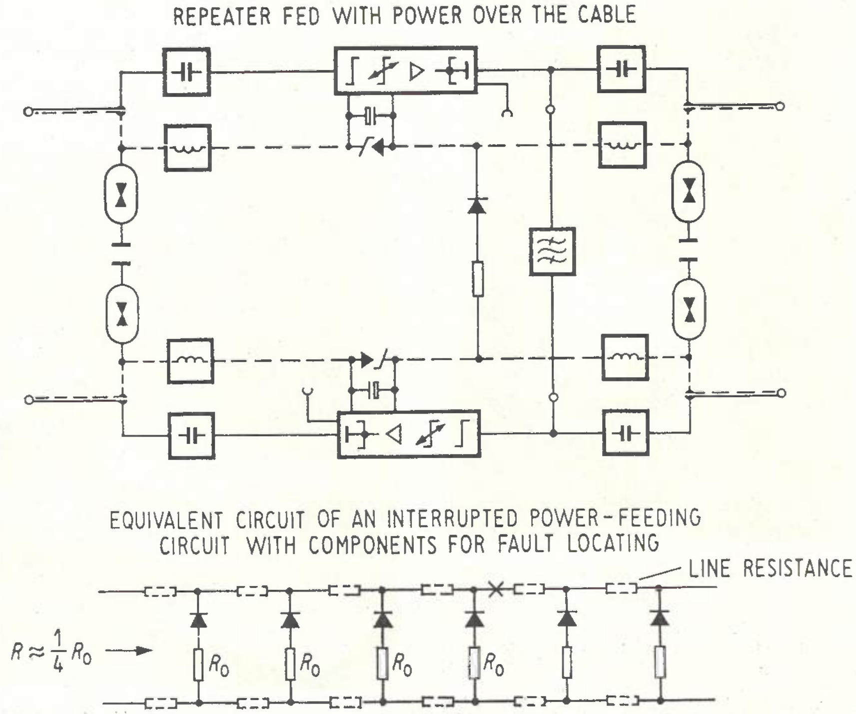


Fig. 4 — DC Series Feed

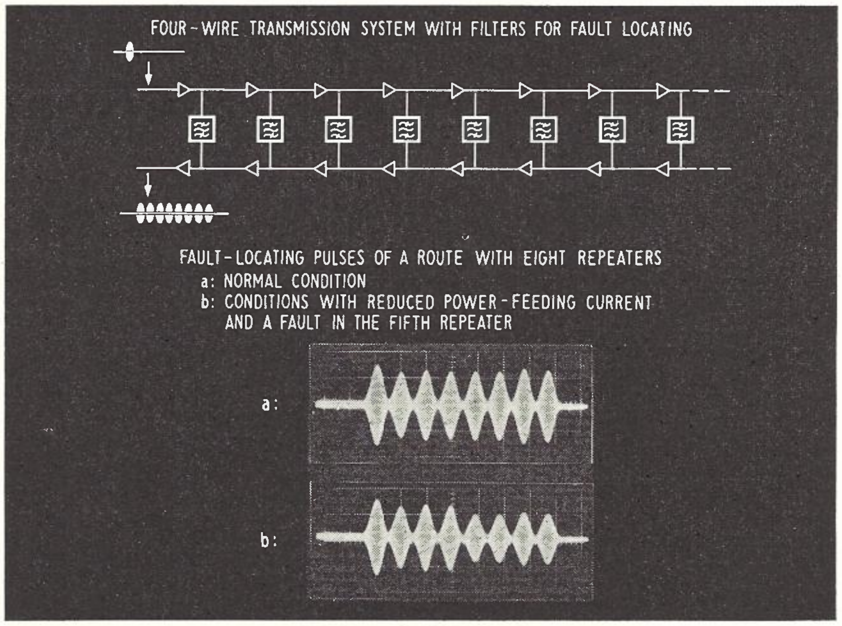


Fig. 5 — RF Fault Locating

sent from the testing office, having a carrier frequency equal to the mid-band frequency of the filters, it will be returned to the testing office via the filters of the repeaters in the opposite transmission direction. Due to the finite propagation times, one test pulse returns a series of pulses, one from each operating repeater. All of the returned pulses should be of equal amplitude if the line equipment is functioning correctly. For convenience, the fault locating section and the power feeding section are made identical.

To detect repeaters with reduced performance the following technique is adopted. In such a repeater, for example with reduced current gain due to a transistor ageing, the feedback and stability are reduced. They are more susceptible therefore to changes in gain due to power supply changes. If the power feeding current in the route is reduced, the performance of such a repeater will be more adversely affected than a good repeater. Consequently the returned supervisory pulse from this repeater and all successive repeaters will be of smaller amplitude as illustrated in the second section of Fig. 5. Positive warning of this deterioration, and location of the "Sick" repeater are thus provided.

It is possible to record the amplitudes of the returned pulses over a period of time, and therefore occasional fluctuations in the gain of a repeater due to a dry joint can be detected; in the case of severe trouble of this type, fluctuation of pulse amplitude can be readily seen by inspection.

Electrical Protection

Closely linked with the problems of power feeding are the problems of interference from extraneous fields such as those created by short circuits in power mains or lightning discharges. The interference produced by such occurrences can be avoided if:

(i) the length over which interference occurs is made short,
(ii) the outer conductors of the coaxial tubes are not grounded, and
(iii) repeaters are fitted with over-voltage protection.

With D.C. series feeding, a continuous D.C. path must be provided for all the power fed repeaters in the section, i.e. the D.C. path is half the distance between two main offices. In Europe this length is 50 km.

Fig. 6 shows the measured results obtained during a short circuit test over a line section of this length, with the outer conductors either earthed or isolated. The short circuit current was 1600 amps of 16-2/3 c/s in a line running parallel to a cable containing small diameter coaxial pairs. The induced current was measured about half-way along the route and the induced voltage was measured at the ends, to determine maximum values. The cable sheath carried 35amps. Where the outer conductor of the small diameter was not earthed, it carried 70 mA and the inner conductor, 3.7 mA. The voltage between the cable sheath and the outer conductor was 180 Volts and between the outer conductor and the inner conductor the voltage was 3.5 Volts. Under the same conditions, the induced voltage was 300 Volts between the cable sheath and a balanced pair with metallic continuity grounded at one end. These values are shown in line 2 of the diagram. Line 3 of the diagram shows the induced currents and voltages when the outer conductor of the small diameter coaxial tube was grounded at one end, and line 4 shows the measured results when both ends of the outer conductor were grounded. A comparison of the values of line 4 and line 2 shows that both the induced current and voltage are smaller by a factor of 30 when the outer conductor is not grounded. It should be remembered that the D.C. power feeding voltage is added to the interfering voltage between the inner and outer conductors of the coaxial tube.

In this particular case, with the outer conductor ungrounded, no additional measures such as over-voltage protection would be required in the line repeaters. However, it is not possible to guarantee that the isolation of the outer conductors of the coaxial tube will be maintained. Breakdown or leakage to earth

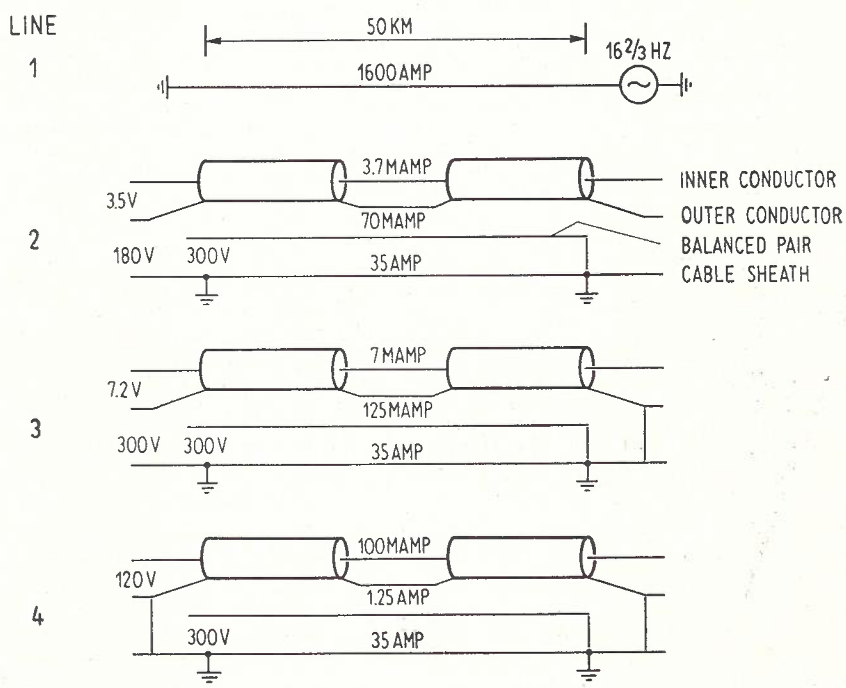


Fig. 6 — Influence of Short Circuits on a Cable

could appear resulting in effective grounding of the route at both ends. Should this occur, interference due to a short circuit of this type would endanger the repeater.

Apart from power surge interference, lightning discharges can give rise to voltages in the coaxial line with peaks of several thousand volts. Part of the frequency spectrum of these surges will fall into the transmission range, and consequently reaches the repeaters via the high pass sections of the power feed filters, and could thus destroy the transistors. To prevent this, over-voltage protectors can be connected at the line end of the power filters, but the firing voltage must be so high that they are not affected by the normal power feeding voltage. When these protectors fire, pulses are created containing energy which can still endanger the transistors.

Fig. 7 shows this coarse protection followed by a second stage protection barrier. In this case, over-voltage protectors with low firing voltages are connected in the high pass filter sections of the power filters and semi-conductor diodes. Similar protective measures are provided at both the input and output repeaters. Repeaters equipped with this two-stage protection were subjected to several thousand impulses generated by capacitor discharge, and having up to 100 kv peak voltage, a rise time shorter than 1 μs, and durations up to 0.5 ms between the half amplitude points. The effectiveness of the protective system was shown by the fact that no repeaters were damaged during these tests.

Cable Protection

It was previously pointed out that because of the reliability of the repeaters, it is possible to lay the cable route cross-country using directly buried repeaters on the cheapest or shortest route. Since access to the underground repeaters is rarely needed, poor route conditions and other difficulties can be tolerated in the same way as those associated with the submerged repeaters on submarine cables. Unfortunately, this is not possible if the cables are to be supervised and protected by gas pressure. Gas cylinders, which need frequent replacement, have to be connected every 10 to 20 km depending on the cable make-up. To permit the full use of the potential advantages of transistorised line repeaters, a cable having very high longitudinal permeability is necessary. If such a cable were available, gas pressure installations would only be needed at the main offices, but unfortunately these cables are not yet available.

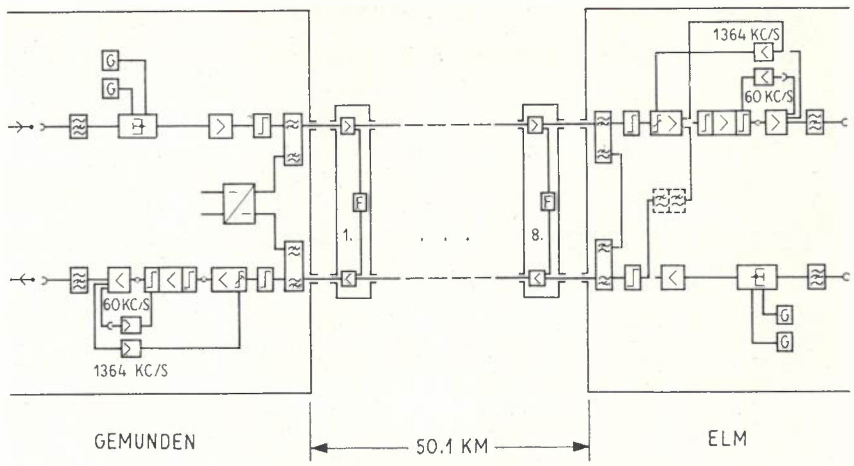


Fig. 8 — V 300 Trial

SECTION II — OPERATIONAL PERFORMANCE

Field Trial System — V300

The above discussion dealt generally with problems encountered in transistorised line repeaters. In order to show results of one application of this philosophy, a field trial route equipped with a V300 system using two small diameter coaxial tubes over a working length of 50 km was arranged in a long distance cable paralleling a railroad with electrical traction. This aluminium-sheathed cable also contains 48 balanced wire V.F. pairs. Fig. 1 has illustrated the connection of this cable to the repeater casing.

Fig. 8 shows the layout of the route with 8 underground repeaters and two terminals. The terminal at Elm can be used as a transmitting and receiving station, or when looped with correct levels, it can also operate as a main repeater station. Under this condition, the mop-up equalisers, pilot regulating system and field amplifiers are omitted. When used as a repeater, the overall route becomes 100 km with 16 underground repeaters and two main repeaters.

The values shown in Fig. 9 have been measured for the attenuation/frequency curve of 100 km loop. Curve 1 shows the line response attained by the equalising line repeaters alone, without additional equalisation at the receiving station. Curve 2 shows the frequency response, as above, but with additional equalisation at Gemunden. A response flat to within ± 0.2 db has been obtained. To give an idea of the route stability, Curve 3 shows the same response taken about one year later, and without changing equaliser settings. It can be seen that there are only very minor changes.

Noise Considerations: An important parameter of any transmission system is noise power. Corresponding to a C.C.I. recommendation, it should not exceed 3 pW/km for route equipment. Fig. 10 shows the effective noise as a function of the relative transmitting level on line. Specific noise power is the sum of the basic noise and the intermodulation noise, and the measuring channels are at 70 Kc/s, 534 Kc/s and 1248 Kc/s. The curves reveal that the relative transmitting level may vary by at least ± 7 db before the 3 pW/km is exceeded. With normal equalisation within the limits of about ± 2 db, the noise power has less than 1 pW/km. This value of 1 pW/km is used as a basis in planning and engineering because even if the initial line-up is not carried out very critically and also after a long operating period, the route will still comply with the C.C.I. recommendations. In measuring the curves of Fig. 10, the system was loaded with white noise at a level corresponding to peak traffic conditions.

Temperature Control: Fig. 11 shows the effect of temperature control with the V300 system. Curve 1 simultaneously shows the temperature variation and the attenuation variation of the 100 km small diameter coaxial tubes at 1364 Kc/s. It can be seen that the temperature variation in the test line varied about 9°C over a 6-month period in a cable buried at approximately 80 cm, while the line attenuation varied by about ± 10 db. The temperature controlling equipment of the repeaters re-

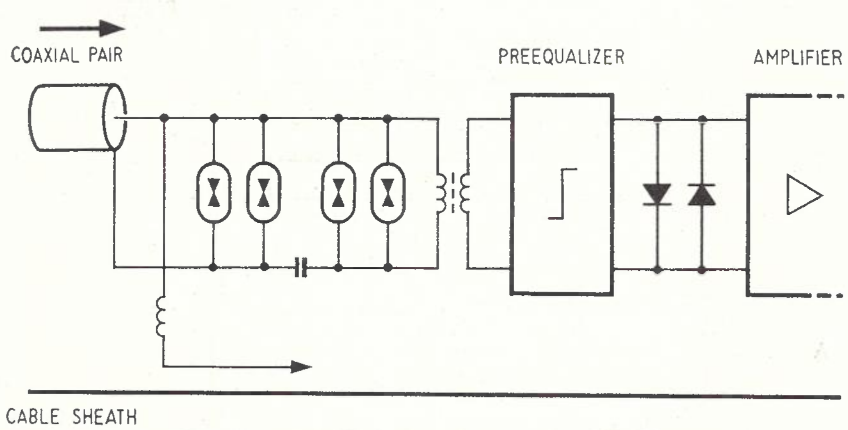


Fig. 7 — Overvoltage Protection at the Input of a Line Repeater

duced this attenuation variation to about ± 2 db as shown in Curve 2. This measurement was made by measuring the level variations of the 1364 Kc/s pilot with the pilot regulation disconnected. This result reveals that the temperature control is not yet optimally dimensioned. We expect a further reduction of the attenuation variation of between 5:1 to 10:1.

Field Trial 4 and 12 Mc/s Systems

To evaluate the performance of transsistorised 4 and 12 Mc/s repeaters, the route shown in Fig. 12 was set up using four 2.6/9.5 mm coaxial tubes of an available 8-tube cable. The transmitting and receiving terminals are co-sited so that only one station need be manned and by a minimum of staff. With the arrangement shown, a route length of 117 km results with 12 underground repeaters for one transmission direction i.e. 13 repeater sections. This length includes the equivalent length of the two line building-out networks of 4.4 km each, as shown in the figure. The cable sections between repeaters were made accessible at midpoint, so that the 12 Mc/s system could be evaluated on the same cable route. This is achieved by replacing the V960 repeaters with V2700 repeaters and installing V2700 repeaters in the midpoint cable boxes. This results in a V2700 route which has 12 repeater sections and is about 55 km long when the route is arranged omitting the two lower lines of repeaters shown in the figure. The V960 route was operated for test purposes from June to October, 1964 and the V2700 route after October, 1964.

The results obtained from these tests equipped with V960 repeaters are shown in Fig. 13 Curve 1. This curve was taken without mop-up equaliser. It can be seen from the deviations for the 14 repeater sections, that a repeater offsets the attenuation of a cable section to within ±0.1 db.

Curve 2, taken with mop-up equaliser shows the improvement in the overall frequency characteristic, which is within the limits of ±0.2 db for the 117 km route. The mop-up equalisers used with the V300 system consist of four resonant type equaliser sections, which can be changed for attenuation, width and centre frequency over wide limits. With

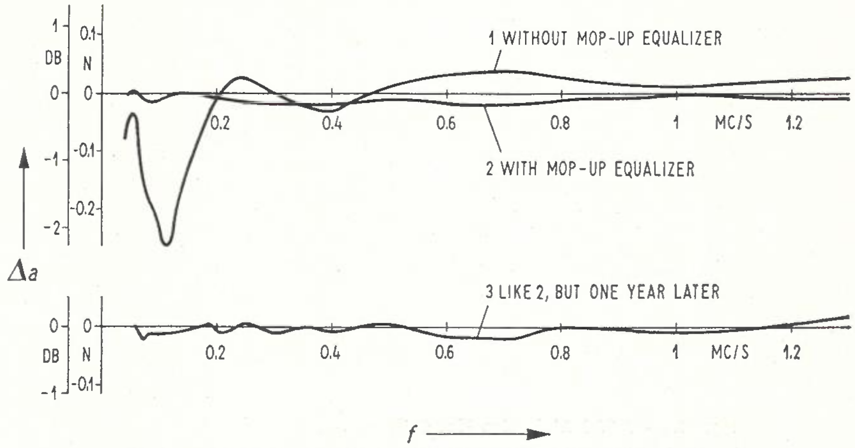


Fig. 9 — V 300 Trial, Line Response (100 KM, 18 Repeater Sections)

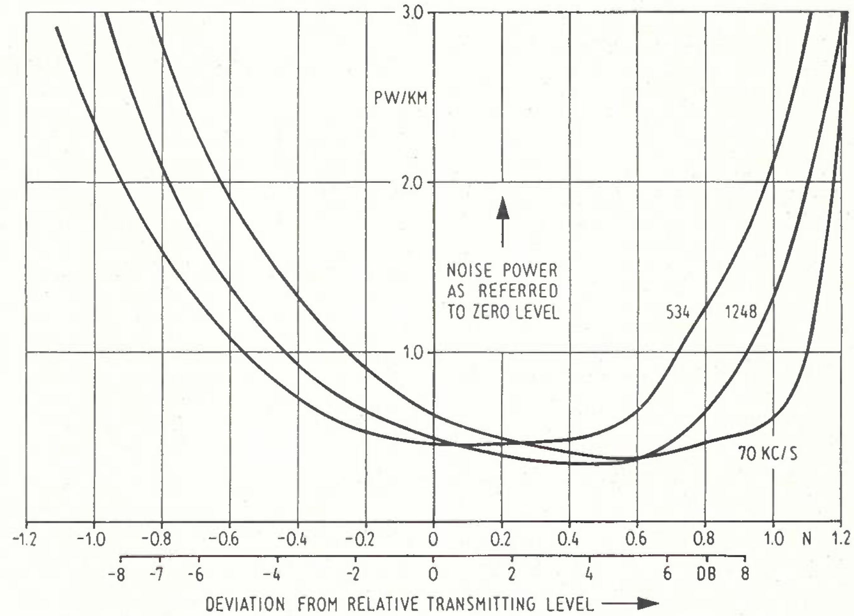


Fig. 10 — V 300 Trial Plus Intermodulation Noise

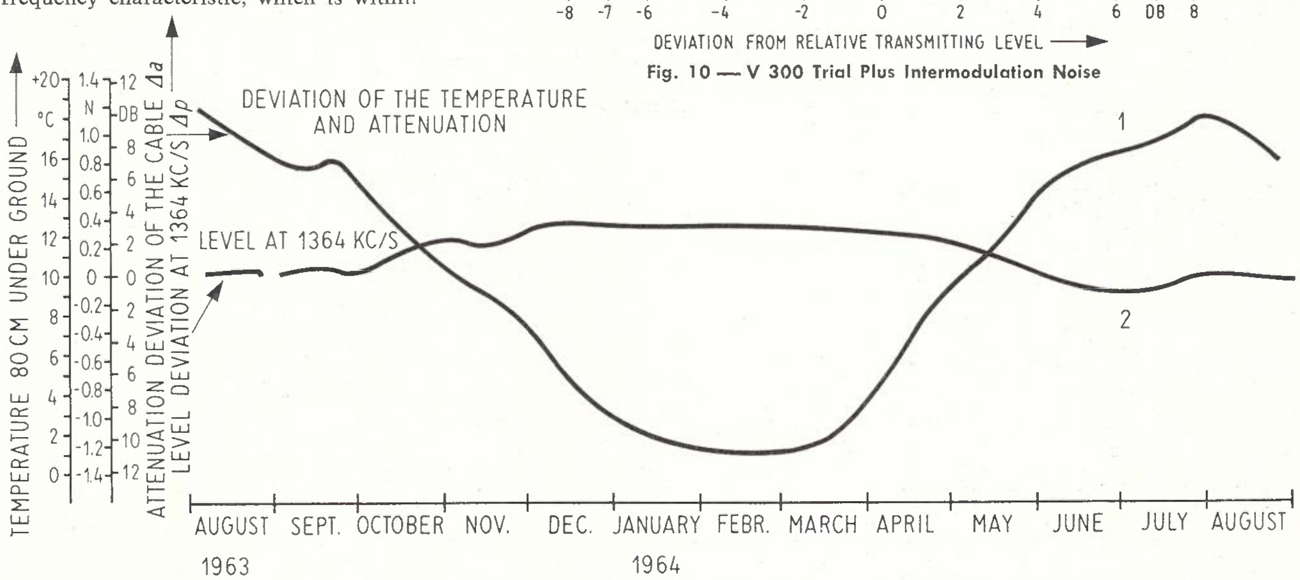


Fig. 11 — V 300 Trial Without Pilot Regulation

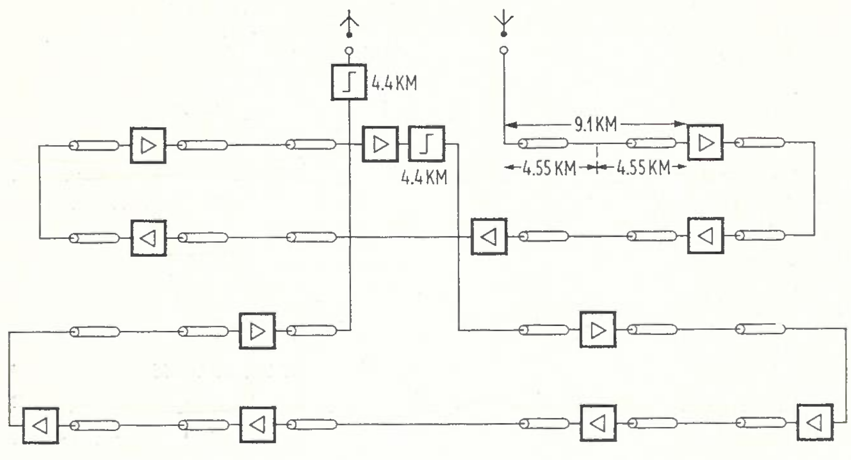


Fig. 12 — V 960 Trial. Line Plus Building Out Networks 117,4 KM

systems having a line frequency greater than 4 Mc/s, echo equalisers are used.

Fig. 14 shows the kilometric noise power of the V960 trial route as a function of the transmitting level. When the line level is too low, the basic noise increases and reaches the 3 pW limit when the level is 8 db below normal. With an excess level, the composite noise first drops to a minimum of about 0.5 pW and then increases as the distortion products increase rapidly so that the 3 pW limit is reached about 8 db above reference level. The rise is very steep at the high end because the overload limit of the amplifiers is being approached. The values shown in the figure apply for the 2.6/9.5 mm coaxial tube. When the V960 system is used on the small diameter tube, the attenuation increases by a factor of approximately 2.3, and thus the noise and distortion increase in the same ratio. This increases the value for the noise power at the nominal level to about 1 pW/km in the case of V960 systems with small diameter coaxial tubes. This value, and a permissible excess level of 6 db, have been used as a basis in the early planning of this system.

FLEXIBILITY OF THE SYSTEM PHILOSOPHY

As stated earlier, now that transistors are available, which are on a par with special valves in long line communication systems where power is concerned, it would be uneconomical to use shorter repeater section lengths in transistor systems than in the corresponding valve systems. The longer the repeater section length, the fewer the repeaters and consequently fewer components are required. This means that systems with greater repeater section lengths should be more reliable in operation, for the simple reason that non-existent components cannot fail. Carrying out this philosophy, the V960 systems was planned for 9.3 km repeater spacing, and the V2700 system for 4.65 km, when using the 2.6/9.5 mm coaxial tube. The length of 9.3 km in this coaxial tube corresponds to a repeater section length of about 4 km for a small diameter coaxial cable. The V960 repeater has been designed so that it can be used both on the centre tube and the small diameter tube by simply replacing the equaliser. The interesting question which now arises is why the V300 repeater is not able to cover twice the repeater section length, i.e. 8 km, but only 6 km corresponding to the C.C.I.T.T. recommendations.

To appreciate the reason for this, the history of the development of the small diameter tube and the V300 system must be taken into account, together with the fact that at the beginning of the development, the transistors available were not as suitable as those now manufactured. To take advantage of the improved transistors now available, we have begun the development of a V300 repeater for a section length of 8 km on the small diameter tubes. This development has the special approval of the German PTT and will be included in future C.C.I.T.T. recommendations. Thus the following repeater section lengths result for the transistorised line repeaters:—

	Small-diameter Coaxial Tube 1.2/4.4 mm	Coaxial Tube 2.6/9.5 mm
V300	8 km	(18.6) km (Not proposed)
V960	4 km	9.3 km
V2700	(2) km	4.65 km

The underground accommodation for the repeaters is designed so that all three systems can be mutually exchanged by simply changing repeaters and equalisers, a system which offers remarkable operational and economic advantages.

If for instance, a connection for 960 voice channels is planned on a coaxial pair 2.6/9.5 mm and it can be assumed that even more channels will be needed within a few years, the repeater casings will, of course, be set up every 4.65 km; but a V960 repeater will be inserted only in every other casing, and the coaxial tubes directly interconnected in the remaining repeater casings. Should the 960 voice circuits no longer suffice, Type V2700 repeaters will then be inserted in all casings and the V960 repeaters used on another route.

Eventually even the 2700 voice channels will no longer suffice and systems with even wider bands will be developed. The coaxial tube offers no limitations; it is up to repeater engineering alone to determine what the successor system will look like. According to the scheme used hitherto, it would have to provide three times as many voice channels as the V2700 system with half the repeater section length, hence a V8100 system with a repeater section length of 2.3 km. Such a transmission system should be realizable in the near future and would well fit into an existing network.

SPECIAL SYSTEM REQUIREMENTS

Other aspects might lead to a different solution. The Swedish PTT for instance, has suggested that we develop a V10800 system with repeaters spaced 1.6 km. The Swedish long-distance cable contains, apart from the coaxial tubes, loaded balanced lines with loading coils spaced at intervals of 1.6 km. When the cable was laid, care was taken in Sweden, with its great number of rivers, creeks and small lakes, that the loading coil sleeves lie in dry ground, and not in water. To avoid all potential trouble with regard to the accommodation of the underground repeaters, the repeater casings will be inserted next to the loading coil sleeves. Thus a repeater spacing of 1.6 km is obtained, where a larger number of voice channels can be provided, namely 10,800, than with a repeater section length of 2.3 km.

We consider this case as an exception

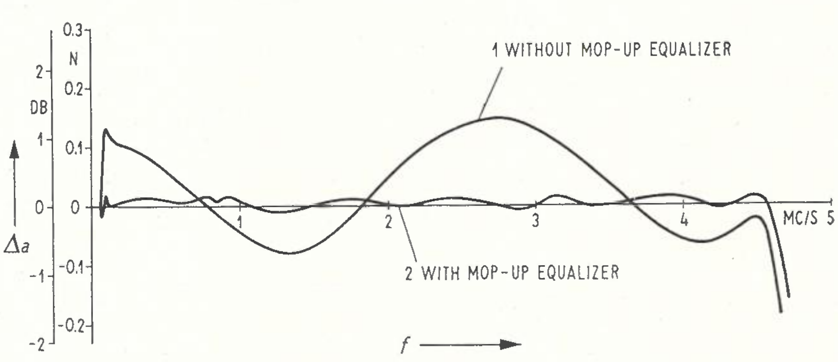


Fig. 13 — V 960 Trial, Line Response (117 KM, 13 Repeater Sections)

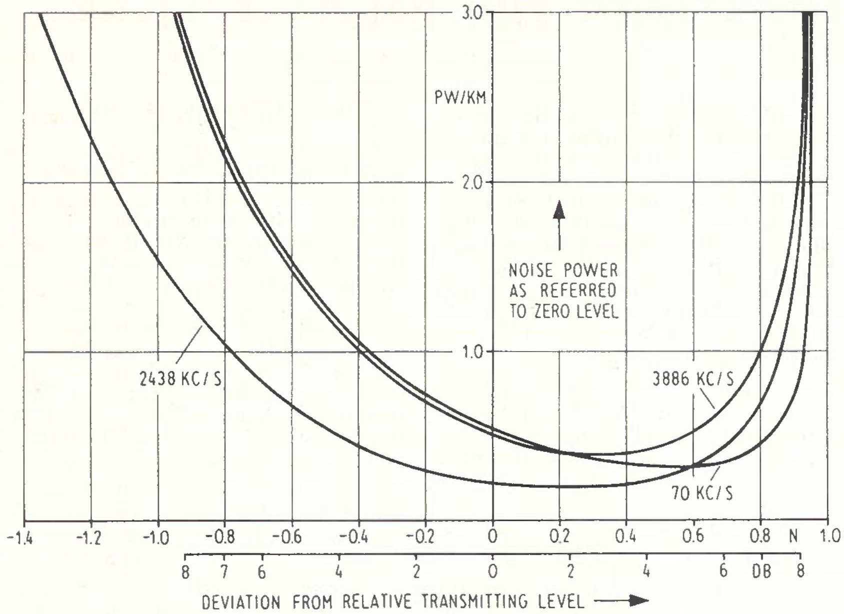


Fig. 14 — V 960 Trial. Basic Plus Intermodulation Noise

and feel the most economical and technically soundest solution would be to triple the number of voice circuits, while halving the repeater section length. This scheme presupposes a certain amount of optimism with respect to technical progress, because the transistors for the subsequent systems of higher bandwidth must in each case, apart from the higher limit frequency also provide a somewhat higher power.

If, as in the case of systems with coaxial tubes, the increasing voice circuit requirements on the same lines can be satisfied only by replacing the equipment, the step from one system to the next should be neither too small, nor too large. Not too small, to avoid frequent changes, not too large, since this is uneconomical and the system will become obsolete before being fully utilized. A time interval of 10 to 15 years seems reasonable. During this period the voice circuit requirements will have increased by a factor of 3, if the yearly growth rate is 6% to 10%. According to statistical data these values are attained in many countries.

CONCLUSION

This paper has examined some of the many aspects which must be assesssed in producing a design for a fully integrated range of broadband line equipment. It has been shown that by this process, greater flexibility in planning of route capacities can be provided, together with very important long term economies. The discussion has been limited to coaxial cable bearers, because it is felt that the channel capacity available will grow sufficiently with improving techniques in the future to provide very large traffic capacity.

TECHNICAL NEWS ITEM

NASCOM VOICE/DATA CIRCUITS IN AUSTRALIA

The United States National Aeronautics and Space Administration (N.A.S.A.) has a number of tracking stations at various locations on the Australian mainland. The N.A.S.A. communication system (NASCOM) comprises a network of voice/data circuits and a network of telegraph circuits linking these stations, via a switching centre in Adelaide and the O.T.C. overseas terminal at Paddington, with the U.S.A. In August, this year, a new switching centre is scheduled to go into operation in Canberra, all circuits being routed via this centre, with Adelaide becoming a minor switching centre for all circuits west and north of it. The tracking stations are located at Brown Range near Carnarvon, W.A., Red Lake and Island Lagoon near Woomera, S.A., Tidbinbilla and Orroral Valley near Canberra, A.C.T., and Darwin, N.T. In addition, tracking facilities on a ship located in the Indian Ocean during missions connect, via radio to O.T.C. Perth, with the mainland network.

The Postmaster-General's Department leases telegraph and voice circuits to the Department of Supply which acts as agent for N.A.S.A. Until the present, data transmission over the network has been by telegraph circuits at low speed; however, N.A.S.A. now require to transmit 2,400 baud data between each of the tracking stations and their communication headquarters at Goddard near Washington, U.S.A. This necessitates the upgrading of the standard voice channels in terms of both attenuation and group delay distortion. The N.A.S.A. requirement is that the voice/data circuits between their extremities i.e. between any tracking station and Goddard, shall meet the stringent amplitude and delay distortion requirements specified in Bell System schedule 4B. Tentatively, the sections provided by the Department (tracking stations to O.T.C. Sydney) are permitted to utilise half of the 4B tolerances. This means for example, that the attenuation distortion in the frequency range 500-2800 c/s referred to 1000 c/s must be in the range —0.5 to + 1.5 db, and the group delay distortion in the range 1000-2600 c/s must not exceed 0.25 mS. As the Departmental section comprises up to four links in tandem under normal conditions, and up to five links under patch conditions, the allowable tolerances must be shared by the links and each link must be given individual treatment to prevent undue accumulation of errors. The design of the necessary equalisation system has been undertaken by the P.M.G. Research Laboratories.

All circuits between tracking stations and the U.S.A. make use of the Canberra-Sydney link. The tracking stations to the north and west of Adelaide make use of the Adelaide-Canberra link also. The Brown Range to Adelaide link is divided at Perth into two links; the Island Lagoon-Red Lake to Adelaide link is divided at Woomera. Separately adjusted equalisers will be necessary for each normal link and for each patch; consequently, it is necessary that patching be effected at the terminal points only of each link, and only to the nominated patch. Patching within an equalised link cannot be done without jeopardising overall equalisation.

A Research Laboratories team visited Adelaide recently, and conducted measurements of group delay and attenuation distortion of the links involved to the north and west of Adelaide. The links to the east of Adelaide have not yet been finalized. The detailed equaliser designs of the measured circuits have been carried out, and equalisers are being manufactured under contract.

It is intended that the equalisers for both directions of transmission for all links terminating in Canberra will be installed in Canberra. Equalisers for all other links terminating in Adelaide will be installed in Adelaide. Equalisers for the outer links will be installed at the intermediate patching stations. The only exception to the above is that attenuation equalisers will generally be associated directly with the portion of the circuit which contributes most to the attenuation distortion. On delivery of the equalisers to the Research Laboratories by the manufacturer, the equalisers will be finally adjusted to meet the required specification and then forwarded to State Administrations for installation. The complete network will then be remeasured as a final check. The whole equalisation project is scheduled for completion by August, 1965.

CABLES AND CONDUITS ACROSS THE BRISBANE RIVER

*J. L. HOARE, B.E.**

INTRODUCTION

In common with other growing cities, telephone development in the City of Brisbane (population 660,000) is substantial and the demand for additional trunk, junction and subscribers' lines is continuous. The area of the city is divided by the Brisbane River which winds its way through the centre of the city and the 400 yard wide river presents some problems to the telecommunication engineer. The river is tidal with flows up to four knots while during times of heavy rains, it carries substantial runoff. In addition, dredging may be required at any time to maintain shipping channels although recent port development has been concentrated in the lower reaches of the river clear of the city proper. The river is spanned by four bridges within the city and, although use has been made of these bridges to carry some cables, they are not satisfactorily located to serve all routes while cable maintenance cost can be high on bridges subject to vibration. Accordingly, it has been necessary to provide groups of submarine cables at locations across the river and, where this has been done in recent years, the cables have been laid in a 10 feet deep trench dredged across the river.

GENERAL

The need recently arose to provide additional cables across the river and it was decided to lay the following cables:

(a) Two 8-tube coaxial cables to carry circuits to Mt. Gravatt, the site of the radio terminal.

(b) Eleven 400 pair and two 200 pair cables for junction purposes.

Of the junction cables, 2,600 pairs were required for immediate use while the remaining pairs were to meet future demands. At the location selected for this crossing, the river is 350 yards wide, needing 430 yards of cable between shore manholes which, because of terrain considerations, etc., could not be located at the river edge. A sectional view of the river is shown at Fig. 1.

The cost of providing construction of this type is high. The need to provide wire armouring substantially increases the size and weight of the cables. Problems of manufacture, transport and handling have, to date, restricted wire armoured cables to 400 pairs — a cable of small capacity by modern standards. In addition, costs of dredging are high, while locations for suitable access to the river banks are becoming hard to find. This means that in these circumstances it is prudent to provide cables additional to those required for immediate use.

During recent years, developments in cable hauling techniques have meant that in straight conduit runs, the lengths of cables that can be hauled are limited at present by the capacity to handle and transport drums of cable. On this basis, it was considered that no problem would be presented in hauling unarmoured cables between shore manholes if satisfactory conduits could be provided. The question to be answered then was whether a suitable conduit was available. Such a conduit should meet the following requirements:

(i) It should be flexible enough to allow it to follow a gradual but definite contour on the bed of the trench and at the shore ends (one bank was 20 feet above low water level).

(ii) It should be strong enough to resist deformation when covered by eight to 10 feet of mud. In considering this point, it was intended the conduits should remain full of water at all times.

(iii) Joints in the conduits should be secure enough to ensure mud or silt would not enter.

(iv) The pipes should be light to handle but heavy enough to lie on the trench bottom when filled with water.

(v) They should be of smooth and uniform internal diameter.

(vi) They should not be affected by salt water.

Bearing these points in mind, it was decided that a four inch diameter rigid P.V.C. conduit of 0.25 inch thickness should prove to be satisfactory and a limited quantity of this pipe was obtained for experimental purposes. Trials with this pipe showed that it could be laid satisfactorily while information available indicated a pipe with wall thickness of 0.25 inches would eliminate the chances of deformation under the expected load.

Although the armoured cables to be laid were designed to meet anticipated requirements for some years, it was considered desirable to provide conduits for future use and, accordingly, an order was placed for 3,300 yards of pipe to provide seven conduits across the river.

INSTALLATION OF CABLE

Preliminary sampling of the river bed showed the bottom of the trench would consist of sand and gravel over most of its length and mud nearer the shore. Previous experience had shown that, in these conditions, cables could be hauled on the trench bed with tensions equivalent to a co-efficient of friction of approximately 0.3. As the cables to be drawn varied in weight from 25 lbs per yard to 32 lbs. per yard, and as equipment was readily available to handle working loads up to 10,000 lbs. it was decided to haul the cables in groups of two, except for the coaxial cables which were to be hauled separately.

The following preparatory work was necessary on the cable drums:—

(i) The cable drum cheeks were reinforced by a welded spider attached to the bolts supporting the drum barrel to ensure the drums did not collapse during laying.

(ii) "D" brackets were arranged in a circular pattern around the drum cheek through which the inside end of the cable protruded, to enable any creep on this end to be restrained against the drum cheek.

(iii) Wire rope slings were attached to the wire armouring on the leading end and the joints encapsulated in epoxy resin. This meant that the hauling force was applied to the armouring of the cables only.

(iv) Each drum was clearly marked for identification purposes.

(v) Brakes were prepared for fitting to the drums to control any tendency to over-run during hauling.

It was decided to set the cable drums up on cable jinkers for hauling and standard jinkers were modified to accommodate the oversized drums. As State Traffic Regulations did not permit the movement of cable drums of the weight of the drums to be laid by jinkers, the drums were moved to the site by transporter, loading and unloading being done by a mobile crane. The modified cable jinkers were located and anchored in position and drums located in a definite pattern to allow the quick-

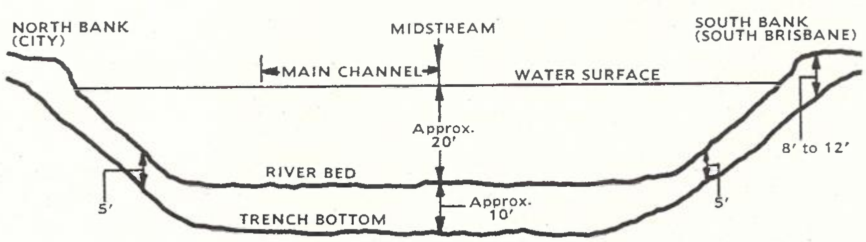


Fig. 1 — Plan of Work.

*Mr. Hoare is Engineer Class 3, Primary Works, Brisbane. See page 160.

est possible loading of them onto and from the appropriate cable jinker as required.

Hauling power was provided by a HD.16 tractor hauling directly on its own winch. The rope used was a high tensile ⅝ in. steel rope. A 10,000 lb. dynamometer mounted on a ¾ ton concrete block provided a means of measuring the hauling tension. Attachment of the hauling rope to the leading end of the cable was made by a 10,000 lb. swivel and hammerlock links. A 12 gallon drum filled with foam polyurethene was attached by a four feet rope to the leading end of the cable to maintain this end above the bottom of the trench. In addition, an empty four gallon drum attached to the leading end by a 40 feet rope served as a marker while the cable was being hauled.

Conditions were suitable for cable hauling from 1½ hours before slack water to 1½ hours after slack water. Outside these times, the tidal run was judged sufficient to sweep the hauling rope from the line of the trench, eventually causing the leading end of the hauled cable to leave the trench. On the other hand, the effect of the tidal flow on the hauling rope during the hours selected for work allowed the cables to be distributed over the width of the trench. Accordingly, the coaxial cables were drawn two feet apart on successive slack tides in the centre section of the trench and other cables, laid in pairs, were hauled when the tide was beginning to either flood or ebb, so they were distributed either upstream or downstream from the coaxial cables. To ensure the cables were drawn into the position required, it was essential that the hauling wire should be completely within the trench and close to the centre before hauling commenced. After each haul, the rope was returned across the river by launch and then tensioned before being lowered into the trench. Tensions required to haul the cables conformed closely to those anticipated. (Table 1).

TABLE 1: TENSIONS DEVELOPED DURING CABLE HAULING

Cable	Weight per Yard	Length Hauled	Tension
8 tube coaxial	32 lbs.	400 yards	3,800 lbs.
2-400 pair cables	56 lbs.	400 yards	6,200 lbs.

INSTALLATION OF CONDUITS

Space available on the river banks limited the length of conduits that could be prejointed on land to 180 feet lengths. This meant the conduits either had to be jointed elsewhere and floated into position or lengths of 180 feet had to be jointed together as the conduits were drawn across the river. Experiments previously carried out had shown conduits led into shallow water with the leading end open, settled satisfactorily on the bottom, but a more positive method of filling the conduits would be necessary if the conduits were floated into position 20 to 30 feet above the trench bottom. In addition, the effects of tidal flow and surface winds would certainly present some problems to floating and holding in position the length of conduits involved. As, in addition to these disadvantages, the floating of the pipes would have caused interference to river traffic, it was decided that the pipes would have to be drawn across the river, jointing being done as and when necessary.

Rigid P.V.C. conduits are suitably jointed by a socket and spigot joint using a chemical solvent welding process. Although the ideal joint requires that the solvent should be applied to a dry pipe and kept free of water for 24 hours, tests carried out showed a joint allowed to set for 15 minutes and then, immersed in water, would withstand a tensile load of approximately 6,000 lbs. This load was applied from ½ hour to 24 hours after the initial immersion took place. However, as more expert investigations have established the damaging effects of water on newly jointed pipes, it was decided to provide mechanical reinforcing for those joints required to be immersed soon after formation. On this basis, it was reasoned the joints would be strong enough to allow the installation of the pipes and this was sufficient as the pipes would eventually be covered by eight feet of mud and sand. It was also necessary to be certain the pipe joints would not allow any appreciable penetration of mud and silt over the years. Here again, inspection of joints made and immersed in water soon after jointing indicated this possibility was slight as, in addition to the adhesion of the solvent weld, socket and spigots were a firm fit. The stability of the joints would also be assisted by the uniformity of temperature below the river bed.

Pipes making up each 180 ft. length were supplied in 36 feet lengths and jointed on land by solvent jointing days before they entered the water. While laid out, they were protected from direct sunlight by hessian covering. Provision had to be made in the leading pipes to allow the free entry of water, but at the same time to reduce to a minimum entry of mud, sand and river gravel. The open ends of the pipes were sealed by wood plugs. Transverse pins holding these plugs in position provided a convenient point to which the hauling rope was attached. Longitudinal slots were then cut along the leading pipes and covered with a fine screen mesh. It was decided to lay the seven conduits in one group with one central pipe surrounded by six. This group was held in this configuration by metal bands placed at 18 feet intervals. (Fig. 2).

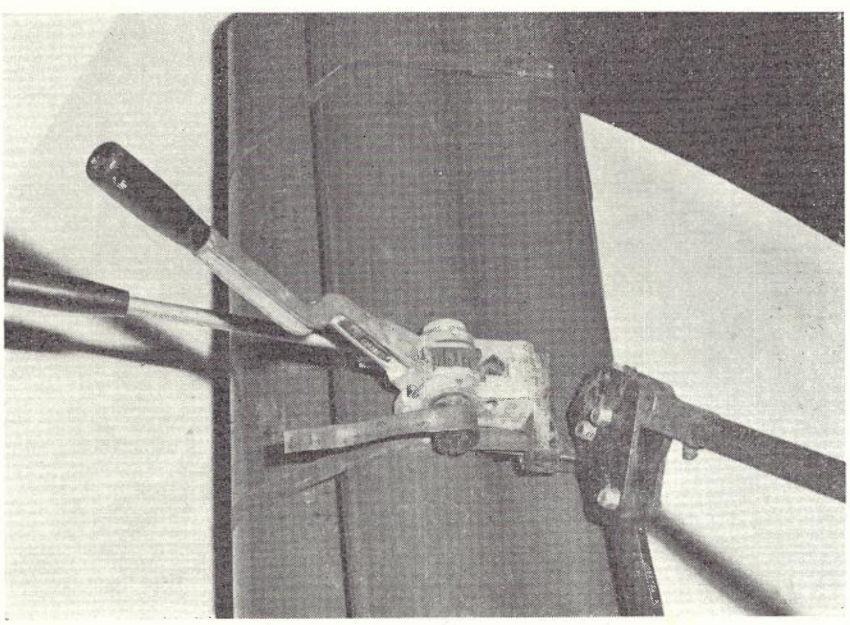


Fig. 2 — Banding of Conduits.

Although duct rodding machines available permit one to rod empty ducts over lengths of 500 yards, the need to leave the P.V.C. conduits full of water meant a machine of this nature would not be satisfactory. It was, therefore, decided to pre-wire each 180 feet length of the conduits with 200 lb. G.I. wire and, when the installation was complete, to

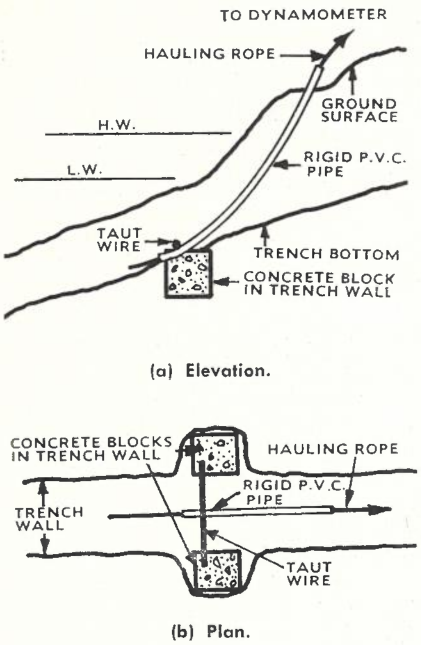


Fig. 3 — Hauling Line Guide.

replace this wire with an insulated stranded copper wire. G.I. wire was selected as the initial wire because it can be easily and quickly jointed with press type sleeves and speed was essential in this operation. The use of stranded insulated copper wire as the ultimate draw wire was made on the basis of the ability of copper to resist corrosion. The insulation of this wire will be kept under supervision with the ultimate idea that, should the insulation resistance fall to zero, consideration will be given to replacing the draw wire. Whether this will be done will depend on when it is proposed to install a cable in the pipe.

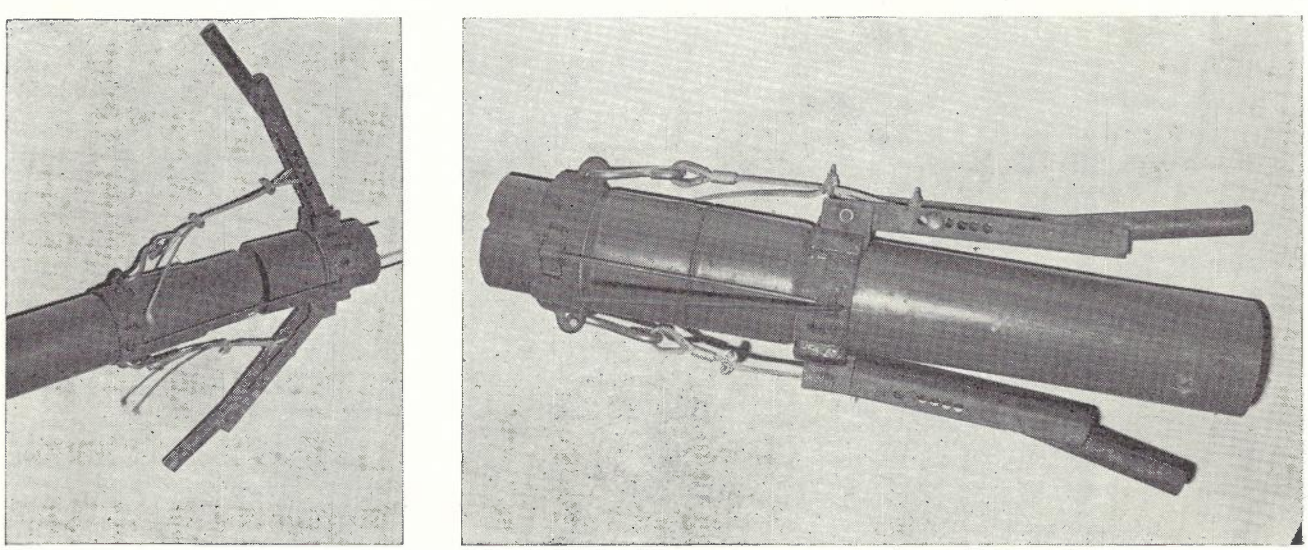
Investigations by a diver indicated that tidal flow did not cause any appreciable water turbulence at the bottom of the trench. However, as it was anticipated the drawing of the conduits would take approximately four hours, it was essential the pipes and hauling wire must at all times be kept at the bottom of the trench to avoid the effects of tidal flow above the trench. This was arranged by having the hauling line pass under a guide at the bottom of the trench at the shore from which hauling took place. This guide, in the nature of a length of 4 in. P.V.C. pipe was held in position by a wire rope stretched tightly across the bottom of the trench between two concrete blocks positioned on the wings of the trench at trench bottom level. (Fig. 3).

The first section of 180 feet of conduits were led to the water's edge and connected to the hauling wire lying in the centre of the trench. As in the case of the cables, a flotation drum to keep the end of the pipes just off the bottom of the trench and marker drums was attached. As hauling commenced, a diver confirmed that the pipes entering the water filled, causing the conduits to lie on the bed of the trench. Hauling ceased temporarily when the trailing end of the first section neared the water and jointing of the next section of pipes commenced. The sections were joined by an eight inch length of P.V.C. pipe used as a coupling between spigots on the end of each section, the pipes being pulled into position by a "Highfield" lever operating on metal collars behind the spigot. (Fig. 4). These collars were then joined by rods to form the mechanical joint reinforcing the solvent weld. To enable the pipes to be jointed, it was necessary to defer banding of each 180 feet length until jointing to the previous section was complete. The operation of completing each seven pipe joints and banding the pipes in the section jointed took approximately half an hour and the whole pipe laying operation three and one half hours. The hauling tension did not rise above 2,000 lbs. On completion of the pipe laying, the 200 lb. G.I. draw wire in each pipe was used to pull a flexible brush ahead of the stranded copper wires through the conduits to clean out any mud or silt which may have entered. It was found actually that little mud had entered the conduits and what had, was confined to the leading end of the first pipe, apparently entering as the pipes left the river at the end of the haul. The slotted leading ends were then cut away and the pipes extended to the shore manhole.

An inspection of the conduits by a diver showed the conduits lying on the trench bottom were not affected by tidal flow of the water above the trench. However, as a precaution to ensure the pipes did not move pending the natural refilling of the trench, the conduits were tied to the armoured cables lying in the trench. In addition, 200 tons of mud were dropped into the trench at the main channel. It is proposed that, in the future, plastic jacketed cables will be drawn in these conduits.

CONCLUSION

If, as anticipated, experience confirms that conduits of this type are suitable for river and creek crossings, the need for H.W.A. cables for locations of this nature will cease to exist. This would mean that disadvantages of high cost and low pair capacity of H.W.A. cables are eliminated, as relatively cheap plastic jacketed cables of any size can be provided. In addition, cables will need to be provided only as and when required. The size of any cable that can be installed over any length would be restricted only by the capacity to handle large drums of cable on the land.



(a) (b)

Fig. 4 — Mechanical Joint in Conduit and "Highfield" Lever. (a) Before Operation of Lever. (b) Completed Joint.

DESIGN OF THE TELEPHONE EFFICIENCY TESTER TYPE R 3

R. W. KETT, A.M.I.R.E.E. (Aus

INTRODUCTION

In order to maintain standards of telephone communication, it is necessary that all telephone instruments and components should be capable of meeting certain specified standards of performance. Some tests (e.g. the frequency response of a telephone) can only conveniently be made under laboratory conditions. Other tests (e.g. the resistance of a transmitter to vibration) are destructive. Tests of this nature are therefore made only on small samples drawn from new deliveries, or when changes in design or materials are involved.

A need exists however for a rapid means of testing comparatively large samples of 100 or more components in a non-destructive manner when deliveries are being made. In 1939 an instrument known as the R1A Telephone Efficiency Tester (T.E.T.) was designed by the Postmaster-General's Department for the purpose of measuring the transmitting and receiving "efficiency" of C.B. and L.B. telephone instruments. With modifications (Type R1B) this instrument has remained in use until the present time. These instruments were installed in the Postal Workshops throughout the Commonwealth and in two of the Department's Materials Testing Laboratories.

Standardization of the instruments was obtained by the use of travelling "Working Standard Handsets" which were recalibrated by the P.M.G. Research Laboratories at regular intervals. Their calibration was obtained by comparison with similar standard handsets calibrated by the B.P.O. Inspection Branch, who derived their standards from the B.P.O. Research Laboratories. As a result the standards used in the field were at least third generation or possibly worse and were subject to long term drifts of an uncertain nature.

The R1 T.E.T. tested telephones of all types in a circuit having a 22 V repeating coil type exchange circuit and a 300 ohm non-reactive local line. This cirswept 7 times per second from 300 to 2900 c/s. A more stable and more easily reproduced tone source was therefore desirable.

With these factors in mind the R3 T.E.T. was designed.

cuit, a part of the old "Standard of Local Line Transmission", is no longer used as the basis for planning and is obsolete in the field.

The need for more accurate specification of the T.E.T. had become apparent during the last 20 years, in particular of the frequency response of the artificial voice and artificial ear used for testing transmitters and receivers respectively and the spectrum of the testing tone. In addition, it is desirable that the testing circuits should not be rendered obsolete whenever an improved telephone is introduced into the network.

Lack of correspondence between different instruments had been traced to large variations of the spectrum of the testing tone, which was a saw-tooth wave

DESIGN OBJECTIVES

The design objectives may be briefly summarised as follows:

(i) The equipment should be capable of testing all current Auto., C.B. and L.B. telephones, Operator's sets, Buttinskis and Deaf-aid telephones.

(ii) The tests should include both electrical and electro-acoustic transmitting and receiving efficiency, sidetone and the performance of a line regulator if fitted.

(iii) Facilities should be provided for testing the performance of dials, generators and bells and also insulation resistance.

(iv) The equipment should be capable of testing any type of instrument under its own limiting line conditions, giving a meter indication

*Mr. Kett is Engineer Class 3, Telephonometry, Research Laboratories. See page 160.

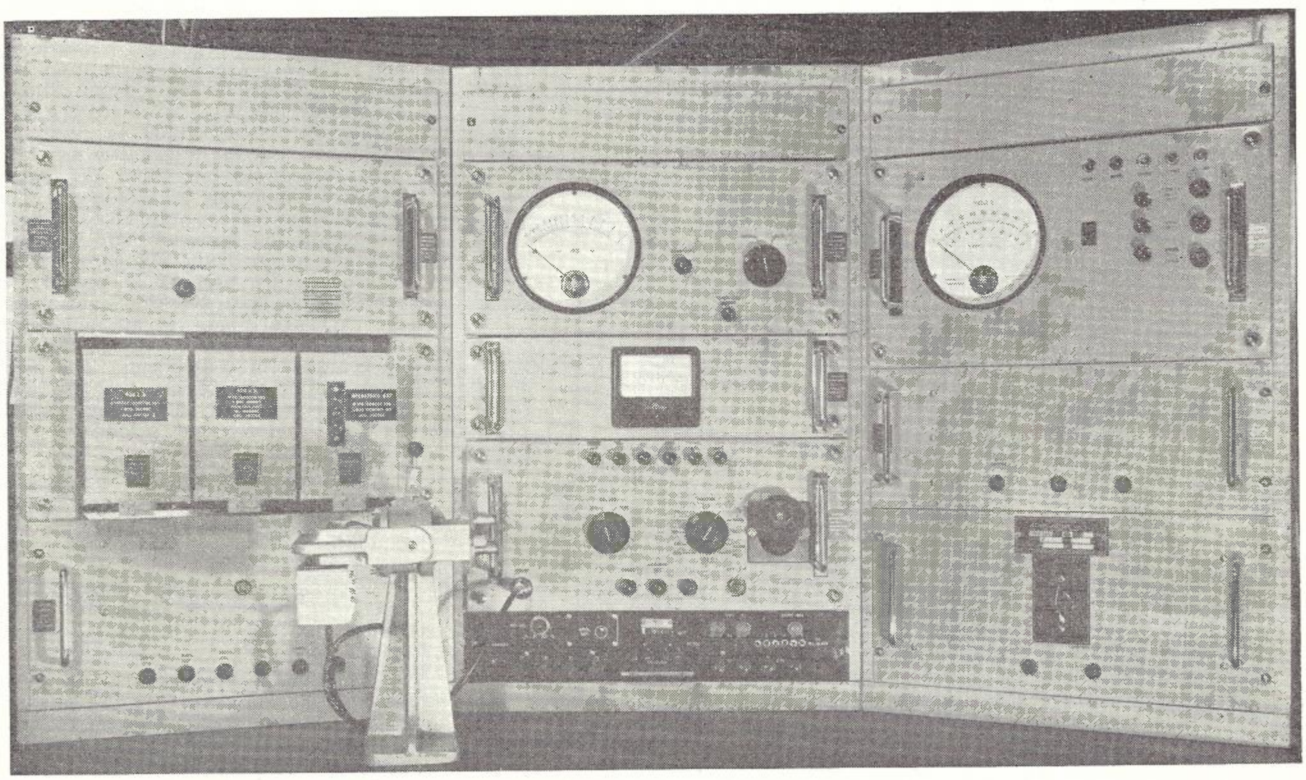


Fig. 1

of zero db if its performance is equal to the appropriate Australian Post Office standard.

(v) It should be possible to test new types of telephones introduced in the future without recourse to "figures of merit" and under their own limiting local line conditions. Also, as far as can be envisaged, the equipment should be capable of testing new types of calling device when these become available.

(vi) The calibration should be readily checked by the operator and the calibrating procedure should involve the whole of the transmission circuit. If possible, it would be desirable to dispense with the necessity for a daily line-up using a group of calibrated Working Standard Handsets.

(vii) The calibration should hold to at least ± 0.1 db for short-term drifts of power line voltage of the order of 10%. Also, the calibration should not drift more than say 0.2 to 0.3 db for a 30°C temperature change. At the same time, the calibrating procedure should be capable of detecting and being compensated for any such drift.

(viii) Good agreement should be maintained between T.E.T's situated in the different States, the various units which comprise the T.E.T.'s being interchangeable and readily disconnected for maintenance and calibration.

(ix) Finally, the T.E.T. must be truly representative of current A.P.O. Specifications and Planning Standards and built from components readily obtainable in Australia.

DESIGN

To provide the required versatility in the R3 T.E.T. with respect to the transmission testing circuit it was decided to provide these circuits as plug-in units. The standard A.P.O. relay base has been used for ths purpose.

The circuit of a typical C.B. Standard Circuit Unit is shown in Fig. 2.

It contains a 50 V exchange circuit, a simplified limiting local line and a calibrated induction coil and its associated components. The symmetrical design of the local line resistance permits the use of a simple three element network which as well as giving a good approximation to the insertion loss of an actual cable (within ± 0.5 db from 200 to 3000 c/s) also reflects the correct impedance to the telephone for sidetone measurements. Its total d.c. resistance was taken as a fixed design parameter in order that feeding-current conditions should be correct. A calibrated induction coil is included for two reasons. First to provide an accurate circuit for the measurement of transmitters and receivers, and second to provide a standard against which similar induction coils may be judged. The circuit is so arranged that complete telephones or components of the same type may be tested by substitution in this circuit.

It will be seen therefore that any of the parameters from transmitter to junction impedance may be altered at will to cater for new telephone designs by designing a suitable plug-in Standard Circuit Unit. It would even be possible to provide for 4-wire equipment if necessary.

Local Battery Standard Circuit Units are similar in principle, except that it is considered adequate to test the telephone straight into a 600 ohm non-reactive load as being representative of a long open-wire line or carrier termination.

A unit has also been provided for the testing of lightweight operators' sets in their own working circuit.

In the transmitter frying test, the local line is short-circuited in the case of C.B. Units and the L.B. voltage raised from 2.7 to 4.5 V in the case of L.B. Units. To test a regulated telephone, the local line is removed completely from the circuit after reading transmitting or receiving efficiency or sidetone and the reading repeated. Provided the reading does not increase more than a specified amount, the regulator is performing its function. The Standard Circuits for regulated telephones are also fitted with a Battery Cut-off Key to check regulator insertion loss.

It has been found that very wide variations may exist in the impedance of receivers, particularly the type 4T. This impedance also shifts if the receiver is subjected to transient switching voltages. Therefore, in order to provide a stable impedance at the receiver terminals of each standard circuit, the circuit is terminated by a resistor equivalent to the magnitude of an average receiver's impedance, acoustically terminated at 1000 c/s.

For certain measurements, e.g. calibration and sidetone, it is necessary to inject the testing tone into the transmitter terminals of the telephone network. If a balanced circuit is used there is a danger of spurious voltages appearing at the junction through stray capacities, particularly between the primary and secondary windings of the oscillator transformer and the capacity to earth of the wiring (see Fig. 3). Since the telephone instrument circuit is itself not balanced about the transmitter terminals with respect to the line, the whole standard circuit has been re-arranged so that between the a.c. voltmeter earth and one transmitter terminal there will be a zero impedance path (Fig. 2). This has been done by using a T network to represent the local line and re-arranging the exchange circuit in an unbalanced form. An incidental advantage has been an economy in components. The oscillator output transformer has also been provided with an electrostatic screen between primary and secondary. (Fig. 4.)

The source impedance of the artificial transmitter is 70 ohms. This corresponds to the actual value under limiting line conditions of a 65 ohm transmitter (measured at 50 mA) in a 400 C.B. or 801 telephone. 65 ohms is set as the maximum permissible value for transmitters for use in either C.B. or L.B. telephones.

The 50 V positive terminal is earthed only at the Standard Circuit Units and the V.T.V.M. and circuit earths are carefully arranged within the switching panel to avoid any possibility of cross-talk due to shared wiring resistance in any two circuits.

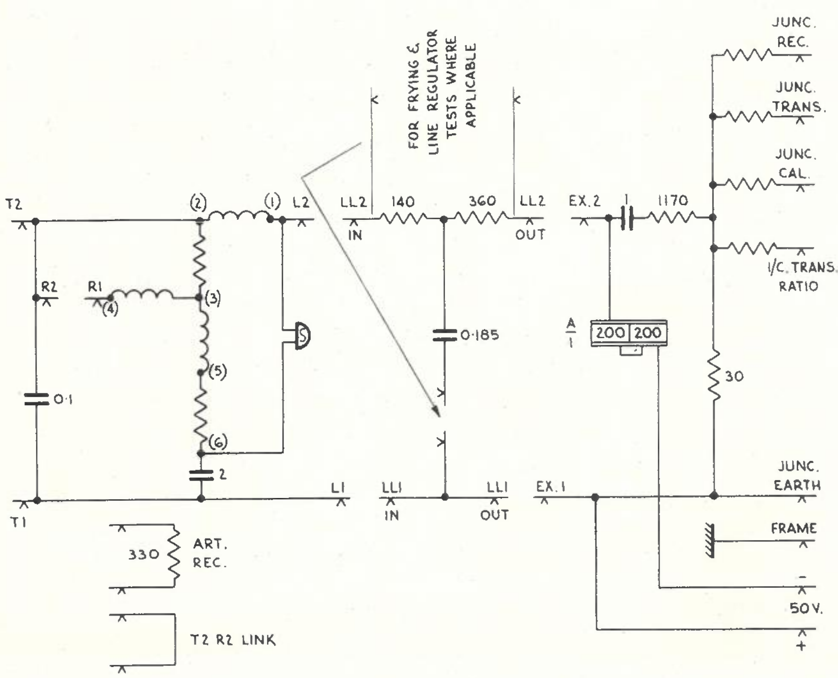


Fig. 2 — 300 C.B. Standard Circuit Unit

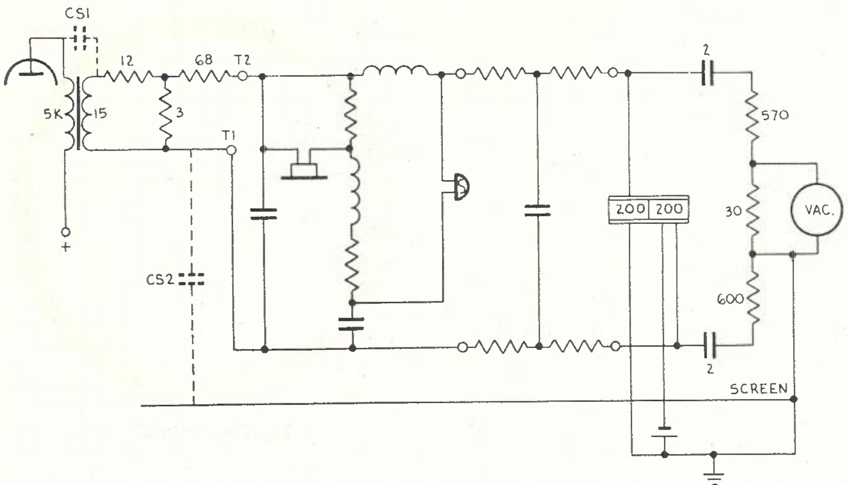


Fig. 3 — Stray Capacities Using Balanced Circuit

The previous T.E.T. type R1A was designed as a permanently wired rack. This entailed taking the entire equipment out of service if a fault developed. When modifications were required, these were made by the local staff and frequently, instruments have been found on inspection to be inaccurate through being in non-standard condition. It was decided therefore to retain the advantages of rack-type mounting, but to provide for plugged connections to all panels, so that a faulty panel could be quickly removed and replaced by a new panel. The type of connector used is available in a variety of pin configurations and advantage has been taken of this to make it impossible to cause damage by misconnection of the connecting cables. The R3 T.E.T. has been designed so that several possible physical layouts may be used and each installation may be mounted to suit local conditions.

Types of T.E.T. Available

A comprehensive tester which performs all of the required tests has been designed and designated the type R3A.

In certain situations, for example, factory production lines, the testing may be limited to say transmitter insets only. In such a case a tester may be assembled from the required basic panels, but having a simpler switching panel. Designs exist for the following testers:—

(i) Type R3B — Transmitter Inset Tester
(ii) Type R3C — Receiver Inset Tester
(iii) Type R3D — Induction Coil and Printed Circuit Board Tester.

Also available as separate units are:

(iv) The Dial Tester
(v) A Bell Tester
(vi) A Generator Tester

The R3B, C and D testers are appropriate for use where sampling procedures are in force and will enable the necessary specification tests to be performed.

STANDARDISATION

Previously, the T.E.T.'s have been standardised daily by means of Working Standard Handsets. A statistical comparison of the accuracy obtained by this method and that obtainable by calibrating the instrument initially in the laboratory and maintaining its calibration by simple electrical and acoustical checks, showed that there was nothing to be gained by retaining Working Standard Handsets with their inherent tendency to drift out of calibration.

Samples of Standard Circuit Units, heated from 20° to 50°C, showed no measurable change in transmission under "CALIBRATE" conditions. Small changes in feeding current will however occur as the resistance of the 200 + 200 ohm feeding relay rises with temperature; this should be equivalent to 0.013 db/°C for a 300B Standard Circuit and 0.007 db/°C for those using 920 ohm local lines.

Annually the Standard Circuits Units and other components requiring standardisation will be exchanged with the Research Laboratories and their calibration checked.

As new telephones are introduced in the future, Standard Circuit Units will be developed. First an accurate assessment of the permissible local line limits will have to be made by the Immediate Appreciation or some similar technique after standard electrical performance of the transmitter, receiver and induction coil have been established. From this data, a prototype Standard Circuit Unit will be constructed and its junction tappings adjusted so that standard transmitters and receivers of the appropriate type will give zero readings on the V.T.V.M.

It should be realised that this process in ensuring direct reading of the T.E.T. without the complication of figures of merit, obscures the differences between different types of telephone. It is presumed that these differences have been accurately accounted for in determining the Local Line Limits.

Daily Calibration Check

A quick check of the stability of the instrument and of the condition of the switches has been provided (Fig. 4).

The oscillator output is first adjusted to 5 V, read as zero db on the V.T.V.M. Then oscillator voltage is fed to the transmitter terminals of the Standard Circuit in use and the gain of the V.T.V.M. adjusted to give a zero db reading also.

It will be noticed that the same meter, multiplier and rectifier is used for each reading; drift of the rectifier is therefore

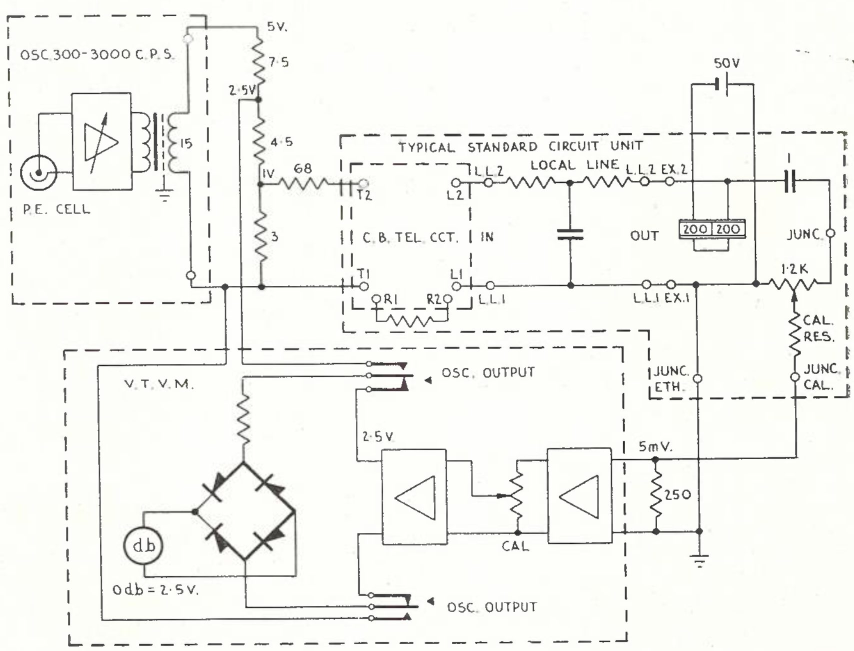


Fig. 4 — Transmission Circuit — Calibration

compensated for in the most important region of the meter's scale. The calibration is not dependent upon the meter sensitivity or amplifier gain but only upon the insertion loss of passive elements in the Standard Circuit.

Once calibrated the T.E.T. may be checked by the insertion of any other Standard Circuit Unit available. A reading within ± 0.2 db should be obtained.

GENERATION OF THE TESTING TONE

Various possible types of testing tone may be considered for obtaining a single lumped value of "efficiency". Single frequencies are unsuitable because of the irregular frequency response of telephone components and some type of noise having a bandwidth of 300 to 3000 c/s to approximately correspond with the bandwidth of A.P.O. trunk line channels is required.

Some administrations use a band of noise filtered from a white noise source or a mixture of several inharmonically related tones. From the point of view of reproducibility and short-term stability, the generation of a sine wave rhythmically swept over the voice-frequency band at a linear rate in time appeared the most promising.

Thought was given to shaping the oscillator spectrum to represent the energy content of human speech. However, modern telephones are not dependent on volume efficiency alone for their performance and any form of weighting of the upper frequencies could disguise discrepancies in manufacture.

The R3 Rhythmic Oscillator is illustrated in Fig. 5. It consists of a photo-electrically scanned disc driven by a synchronous motor and produces a sine wave swept 312.5 — 3000 — 312.5 c/s 25 times per second.

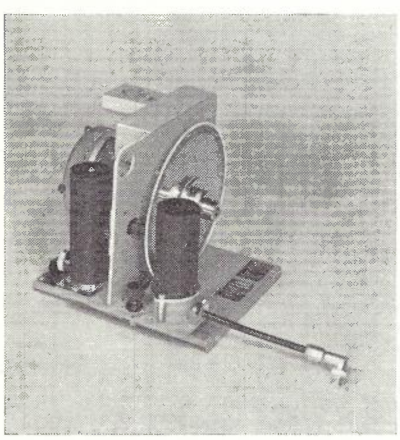


Fig. 5 — R3 Rhythmic Oscillator

Wavelengths were calculated to the nearest 0.05° and an accumulated error of 0.05° was found. This was distributed among the five lowest frequencies, the lower cut off frequency thus becoming 312.5 c/s which is an acceptable error.

This data was used by a draftsman to draw the tone disc about four times full size, drawing each wave sinusoidally. Cumulative errors in setting out the starting points of each wave were avoided by supplying the draftsman with the true starting point for each wave and its wavelength. A reduction negative was made to the precise size required, from which prints are made on cut film.

The degree of success may be judged from Fig. 6 — which shows an analysis of the oscillator output by means of a set of one-third octave filters. Readings were taken to the nearest 0.5 db. A slope of 3 db per octave is equivalent to equal energy per cycle. That is to say the original design requirement of a constant amplitude signal varying at a linear rate in time has been achieved to about ± 1 db. A reproduction of the tone disc appears in Fig. 7.

Reproduction

The tone is reproduced by means of a standard 16 mm Sound optic, a 10 V 7.5 A S.C.C. exciter lamp (a readily obtainable type in Australia) and a vacuum photo-cell. The resolution of the optical system is inherently much higher than required, so that comparatively large drifts in alignment would be needed to cause measurable deterioration of the high frequency response in service. The exciter lamp which is nor-

Fig. 7 — Tone Disc

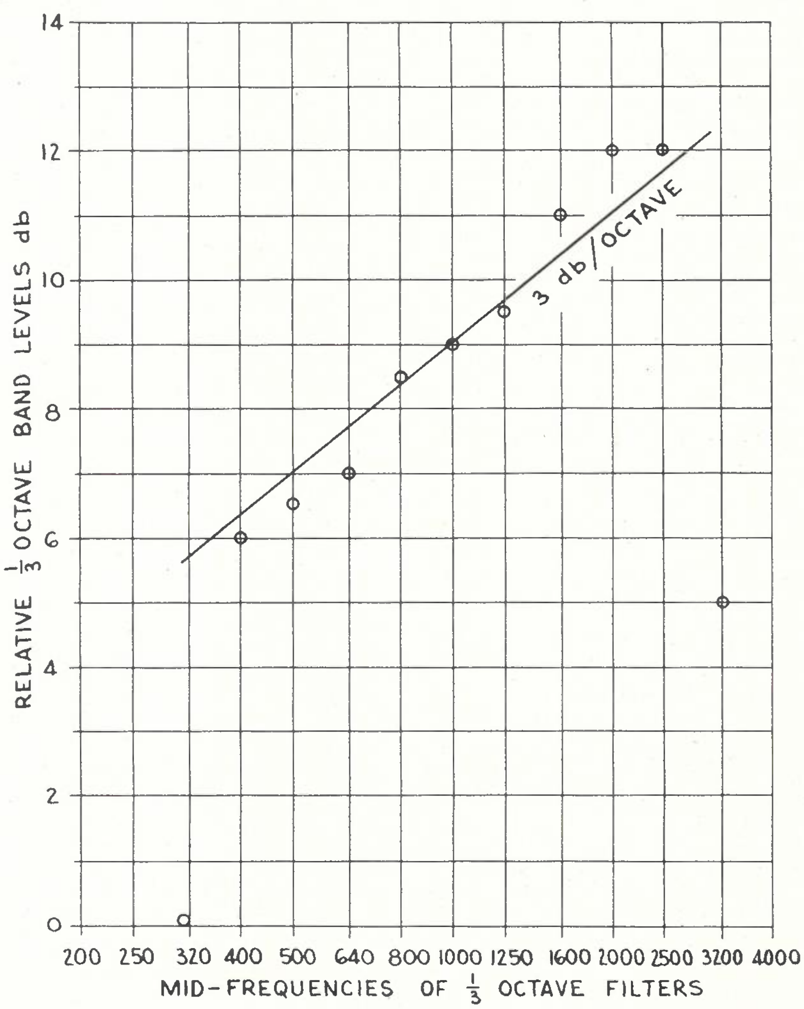


Fig. 6 — 1/3 Octave Analysis of Output of Oscillator

mally rated to have a 100 hour life has been under-run about 5% which approximately triples its life. The very high value of current taken through the centre contact of this lamp results in a small amount of oxidation of the centre solder tip and causes a slight variation of the light output. The effect on the reproduced signal is too small to be noticed in motion picture reproduction, but under the more critical conditions of the oscillator it appears as intermittent drifts of 0.1 to 0.3 db. This difficulty has been overcome by connecting a short flexible tail to the centre contact of the lamp and terminating it under a substantial terminal.

The design was initially made with a gas type photo-cell but it was found that these cells are very unstable even if their exciting voltage is carefully controlled. Large drifts in output occur with time and temperature. The first few minutes of operation in particular were found to be quite unpredictable. Two identical cells were tried and whereas one dropped approximately 2 db in 80 seconds, the other rose by about the same amount. A vacuum type photo-cell was substituted and was found to be stable and practically independent of voltage and temperature changes. The oscillator plus its associated amplifier were placed in an oven and heated from 20°C to 50°C. A steady drop in output reaching 0.4 db at 50°C was experienced and the oscillator returned to its original output on cooling. This is equivalent to 0.013 db per °C. Provision has been made for adjusting the oscillator gain to compensate for such long-term variations.

During the course of the design it was found that the wave train of the oscillator when displayed on a cathode-ray oscilloscope showed irregular variations in output at various parts of the frequency band. This effect was eventually traced to electrostatic charges on parts of the rotating perspex discs, between which the sound track is supported, causing low frequency modulation of the photo-cell. This effect has been effectively eliminated by reducing the aperture of the photo-cell cover to a minimum and extending it with a short tube reaching almost to the face of the perspex. This tube as well as providing additional electrostatic screening for the photo-cell also discharges the rotating plate.

It was discovered that the rather high inertia of the rotating disc had a tendency to prevent the motor from reaching synchronism. A simple slipping clutch device was incorporated to enable the motor to work into a resistive rather than a flywheel load during starting and synchronism can now be obtained without difficulty.

The exciter lamp output varies with voltage to produce a variation of about 0.15 db per volt of a.c. line variation at 230 V. To stabilise the exciter voltage and also the other potentials in the T.E.T., the entire equipment is run from a 230 V, 300 V. A. stabiliser.

The amplifier delivers 5 V r.m.s. into a 15 ohm load. A specially designed output transformer has been used in which the secondary winding lies between two halves of the primary but separated from it by electrostatic screens.

In some localities more than two T.E.T.'s may be operating under the one roof. In these circumstances it may be more economical to generate the oscillator tone at one point and reticulate it via 600 ohm lines to the various test positions. Two oscillators are used with a changeover and distribution panel to ensure continuity of supply. At each T.E.T. a local power amplifier is used to restore the level to 5 V into 15 ohms.

ARTIFICIAL VOICE

An artificial voice for the measurement of transmitting efficiency was required, capable of delivering a sound pressure of 95 db re $0.0002/\mu$ bar at approximately 1 in. distance from its orifice over the range 300-3000 c/s. Its frequency response should be reasonably uniform over this range and the variation between the frequency response of various samples as small as possible. Various types of commercial public-address type horn-driver units were examined and one having a simple response to equalise in the required range was selected. The general shape and size of these units enable an artificial voice approximating to a human head to be constructed.

The equalisation was partly obtained by the insertion of acoustic resistance in the form of a stack of fine wire mesh in the orifice, and also by means of a simple electrical equaliser. At the same time, the wire mesh provided effective dust-proofing of the voice-coil assembly. A response within ± 2.5 db over the range 500 to 3200 c/s was found to be obtainable by these means. The Artificial Voice units have been selected to have similar equalised response curves. It has been calculated that the difference between these Artificial Voices and a theoretical artificial voice having an ideal response would give an error of not greater than 0.6 db when used to measure a No. 13 transmitter. The errors between individual Artificial Voices have been found to be much less than this. The low frequency response is difficult to obtain without the risk of overload. Considering that the response of transmitters is usually low between 300 and 500 c/s and that a linear frequency/time sweep is being used, this loss will have a negligible effect in comparing the volume efficiency of transmitters. Fig. 8 has been drawn therefore with a linear frequency scale to show a typical frequency response.

The Artificial Voice is provided with three rubber stops set at 120° spacing which align the mouthpiece of the handset under test in a fixed position with respect to the orifice of the artificial Voice. A large number of handsets and operator's sets of different origin were measured and the mean value and range computed. By using ½ inch diameter flat rubber stops on a pitch circle diameter of 1.65 inches, any of these mouthpieces can be supported.

In these Laboratories it is usual to locate a handset in the B.P.O. modal position by reference to the earcap centre line and the effective source point of the artificial voice. A compromise has been made however for the

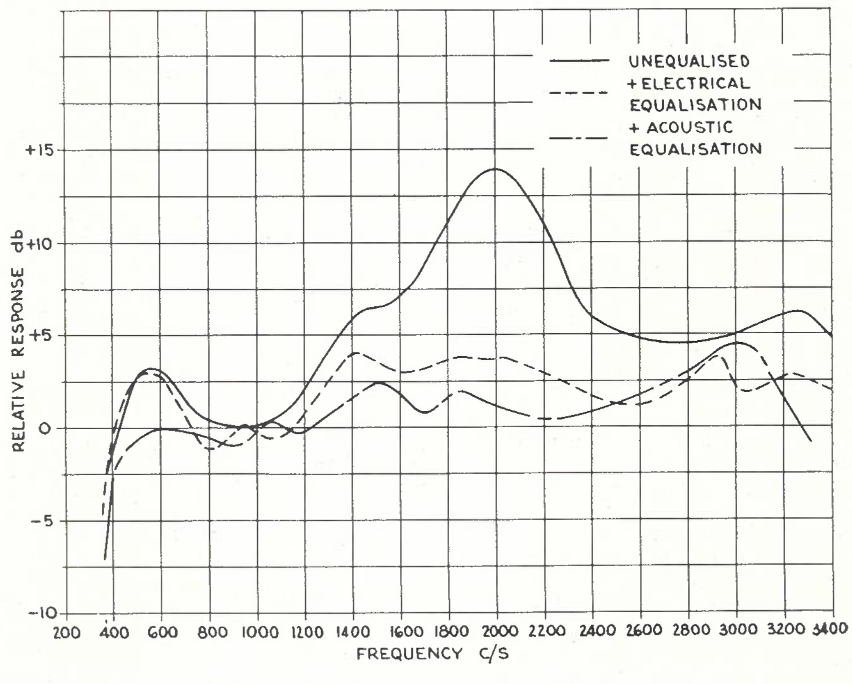


Fig. 8 — Frequency Response of Artificial Voice

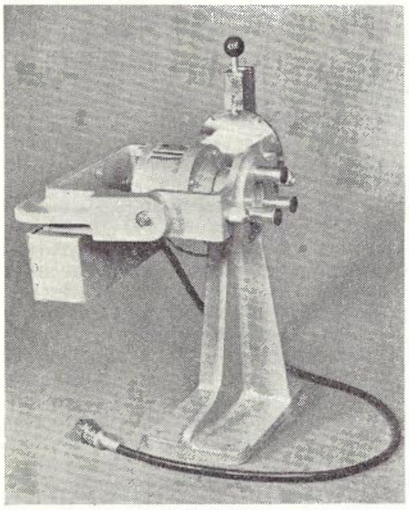


Fig. 9 — Artificial Voice

T.E.T. Artificial Voice, and the mouthpiece is set in a plane parallel to the orifice. This has been done, as it is difficult to quickly and accurately set the earcap position by hand when testing on the T.E.T. Further, a change in handset involves a change to a different Standard Circuit Unit, which in turn has been calibrated using a similar handset. The spacing of the stops from the orifice approximates to the B.P.O. modal position for typical handsets.

It is necessary that telephone transmitters should not exceed certain limiting values of dynamic resistance when turned face up or face down. To enable these tests to be performed, the Artificial Voice may be indexed to the required angle. The artificial voice is shown in Fig. 9.

To calibrate the Artificial Voice, it is fed with Rhythmic Oscillator tone and the level measured with a calibrated microphone. Each Artificial Voice carried its own equaliser and calibrating pad, and the latter is adjusted to give a free field pressure of 95 db re $0.0002/\mu$ bar at the plane of the rubber stops. To compensate for the loss of output as the voice coil resistance rises with temperature, the series resistor of the calibrating pad is shunted with a thermistor. This gives a temperature coefficient of ± 0.01 db/°C or better compared with —0.08 db°C without compensation.

To avoid possible damage or alteration of the sensitivity through changes in atmospheric pressure when being transported by air, the diaphragms of the driver units have been perforated with a hole of approximately 20 mils diameter.

ARTIFICIAL EAR

The Artificial Ear was required to have a performance of similar standard to the Artificial Voice. A large number of moving coil microphones and commercial telephone receivers were used in experimental models, but it was found that unless an expensive unit was used it would be difficult to obtain a satisfactory frequency response. Experiments were then made using a 4T receiver. It was found that much better results could be obtained, particularly if the 4T receiver was operated into a resistive load of the order of 3 to 5 ohms.

Although the frequency response obtained was satisfactory, it was discovered that 4T receivers are subject to unpredictable changes in sensitivity. This was known to be partially due to friction at the pivots causing the armature to return to a different quiescent position after an impulse and also, since they are hermetically sealed, after a thermal or barometric change. These effects were only slightly reduced in special samples manufactured with reduced magnetic strength, molybdenum sulphide lubricated pivots and diaphragms with pinholes. Further investigation of these same samples revealed that they were subject to peculiar thermal drifts, not always returning precisely to their initial sensitivity. Starting at 20°C, their usual behaviour was to decrease to —0.6 db at 24°C followed by an increase to +0.5 db at 30°C and a drop to —0.2 to —0.6 db at 40°C, returning to approximately their initial sensitivity on cooling to 20°C. One sample was found which dropped more than 6 db between 30 and 40°C but returned to its initial sensitivity at 20°C. This performance was found to be repeatable.

Recently, an inexpensive miniature moving coil microphone has become available giving a frequency response in the Artificial Ear equal to the 4T receiver. It has been tested up to 50°C and has always returned to its initial sensitivity on cooling.

In order to adjust the sensitivity of the Artificial Ear during calibration, resistance may be added in series or in shunt with the microphone's voice-call. Series control gives a better temperature coefficient since the d.c. resistance of the voice-coil then becomes about one third of the total d.c. resistance in circuit for a suitable sensitivity, but has the disadvantage of giving a poorer frequency response. It also allows variations in input impedance between different V.T.V.Ms. and thermal variation of their input resistors to affect the overall calibration. A satisfactory solution was found in using a non-inductive shunt resistor of fine copper wire which effectively compensates the circuit. An overall temperature coefficient for a typical Artificial Ear is —0.01 db/°C. To indicate the type of response which can be obtained, Fig. 10 shows the response of a typical R3 Ear having a 3 c.c. acoustic coupler similar to the British Standard Ear (2) and a Ballantine Artificial Ear. The construction of these microphone capsules

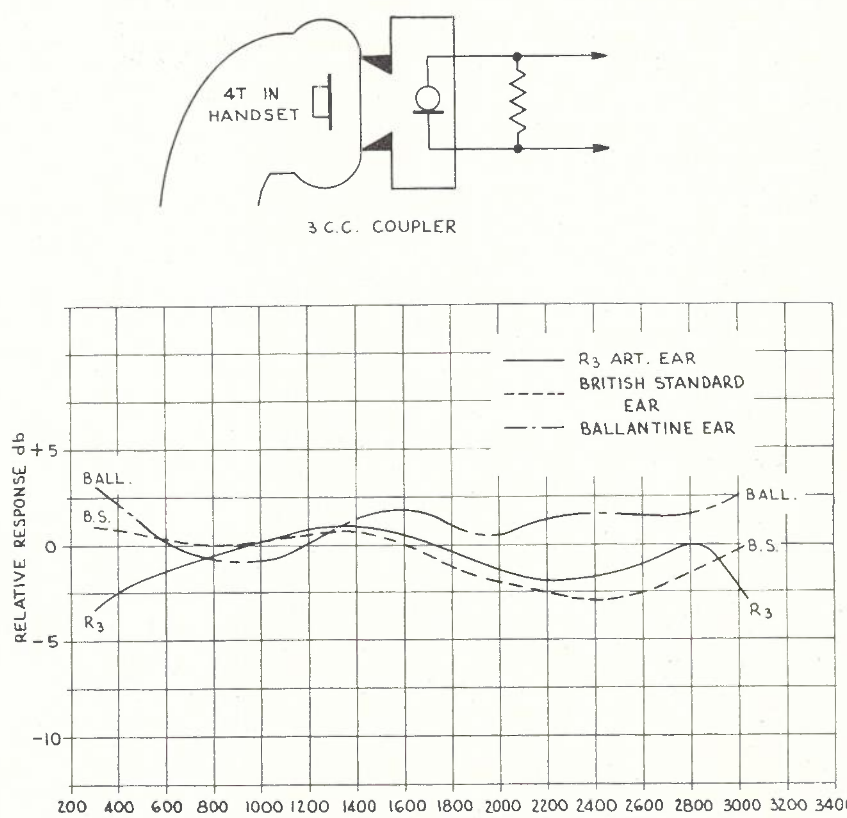


Fig 10 — Frequency Response of 4T Receiver on Three Types of Artificial Ear

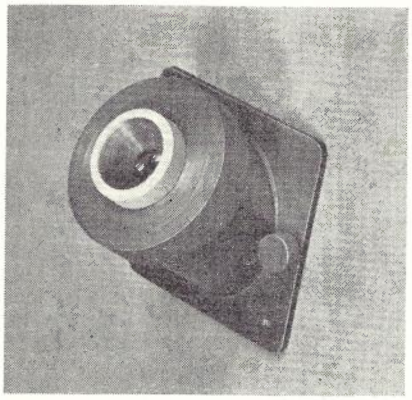


Fig. 11 — Artificial Ear

is such that their response at 3Kc/s can be readily adjusted and advantage is taken of this during calibration. To smooth the response and also provide mechanical protection for the microphone diaphragm, a sintered copper filter is placed between it and the 3 c.c. coupler. The Ear has been made demountable for calibration (see Fig. 11).

In order to test unmounted receiver insets type 3T or 4T, a jig has been designed which allows both the 50 c/s test for loose components and an efficiency test to be made.

In order that Artificial Ears should be interchangeable, it is necessary that the input transformers which are mounted on the switching panels should all have identical turns ratios. A special code number has been allotted by the manufacturer to guarantee that all such transformers will have a winding accurcy ± 1% of the nominal value.

METERING CIRCUITS

To avoid confusion of scales, efficiency is displayed on a 6 in. round switchboard type meter calibrated in decibels, and the remaining tests, transmitter and insulation resistance, generator output and C.B. and L.B. supply voltages, are shown on a 4 in. square meter. Special attention has been paid to designing scales which can be read easily. It has been observed that scales calibrated above and below a centre zero are particularly prone to cause error (3). For example —3.8 may be read as —4.2. The staircase scale has been designed to improve accuracy in this respect. The scale is illustrated in Fig. 12. The style of lettering has also been adapted from those shown in Ref. 3 to give good readability.

INDUCTION COILS AND PRINTED CIRCUIT BOARDS

Induction coils are tested by making a comparison of their transmitting, receiving and sidetone ratios with a similar calibrated coil contained in the appropriate Standard Circuit Unit. The coil to be tested is placed in a jig and associated with a bell, resistors and condensers of specified accuracy, thus becoming electrically equivalent to a complete telephone without its handset.

The 800 series telephone circuit being designed as a printed circuit unit is therefore already in a condition suitable for test. In practice, the tolerances of the resistors and condensers on the board give a spread of readings larger than would occur with the induction coils alone. As the printed circuit level circuits.
board is, however, a complete entity in itself, this is accepted as part of the normal production spread, and acceptance limits are set accordingly.

The 801 telephone has varistor regulation of its transmitting and receiving performance and also of its sidetone. The regulation may readily be tested on the T.E.T. R3A by observing the increase of reading of the Transmitting, Receiving and Sidetone ratios when the Zero Line key is operated, excessively increased readings indicating that the regulation is insufficient. The 801 Standard Circuit Unit is unregulated, this being the basis for specification. Under long line conditions it is desirable that the insertion loss of the varistors in the circuit should be negligible. To measure their insertion loss precisely it would be necessary to remove them from the circuit. With printed circuit construction this is inconvenient, but sufficiently accurate results may be obtained by disconnecting the 50 V battery supply, and short-circuiting the exchange battery terminals. Under receiving conditions the a.c. potentials across the varistors are much smaller than the d.c. potentials and the varistors exhibit sufficiently high impedance to be regarded as open-circuit.

The accuracy of testing of the regulation exhibited by varistors is highly dependent upon the d.c. potentials in the testing circuit and the insertion loss of the local line. The required accuracy of the components in the 801 Standard Circuit have been determined on the basis of an equivalent error in reading of not greater than ± 0.02 db in any of the three ratio readings, regulated or unregulated. This ensures that the reproducibility of tests between Standard Circuit Units of this type will be within the required 0.1 db.

Particular attention is required in setting the 50 V d.c. potential, and fine and coarse taps are provided for this purpose on the rear of the power supply. Heating of the 50 V transformer causes a slight drift after switching on of the order of —0.1 V in the first 20 minutes and a further —0.1 V after 1½ hours. Adjustment after 1 hour gives satisfactory overall results.

To avoid possible errors due to multiple earthing, the 50 V d.c. supply is connected to the test circuit earth only at the exchange terminals in the Standard Circuit Unit and the Switching Panel wiring is carefully arranged to avoid common paths in high and low

It has been found that the resistance of the external leads connecting the printed circuit board to the terminals of the T.E.T. is critical. A 3 ohm resistance in the transmitter leads gives a 0.2 db error in the Zero-line Receiving reading and only 1 ohm resistance gives a similar error in sidetone readings. It is quite possible to achieve these resistances with modern tinsel cords, which on this account must never be used for tests of this nature.

Other possible sources of error in measuring printed circuit units have been investigated. The effect of oscillator voltage errors up to ± 2 db is negligible and provided the oscillator is correctly adjusted will not occur. Variation of the mains frequency can cause shifting of the oscillator spectrum. Since the frequency responses of the 801 telephone induction coil ratios are steeply sloped, some error might be expected. For a shift of mains frequency from 49 to 51 c/s, the worst errors are in the sidetone readings but do not exceed 0.2 db.

A problem for which a satisfactory solution has still to be found is the effect of heating of the Exchange feeding relay. A typical 400 ohm copper winding may change as much as 4.5 ohms after carrying 30 mA for 20 minutes or 7.5 ohms after 100 mA (Zero line) for a 5 second test applied once in every two minutes. This variation is only significant in the measurement of regulation under zero line conditions when the relay resistance becomes a controlling factor.

As a test of cross talk in the T.E.T. circuits, reversals of the transmitter and receiver connections to a printed circuit board are theoretically permissible. All switching panels are tested in this way and provided the change in reading does not exceed 0.05 db, the wiring of the panel is considered to be satisfactory. This test is quite powerful and led to the detection of certain faults in the layout of the wiring to the switches which occurred during manufacure. It has been found desirable to screen all the wiring in the switching panels and

Fig. 12 — V.T.V.M. Scale

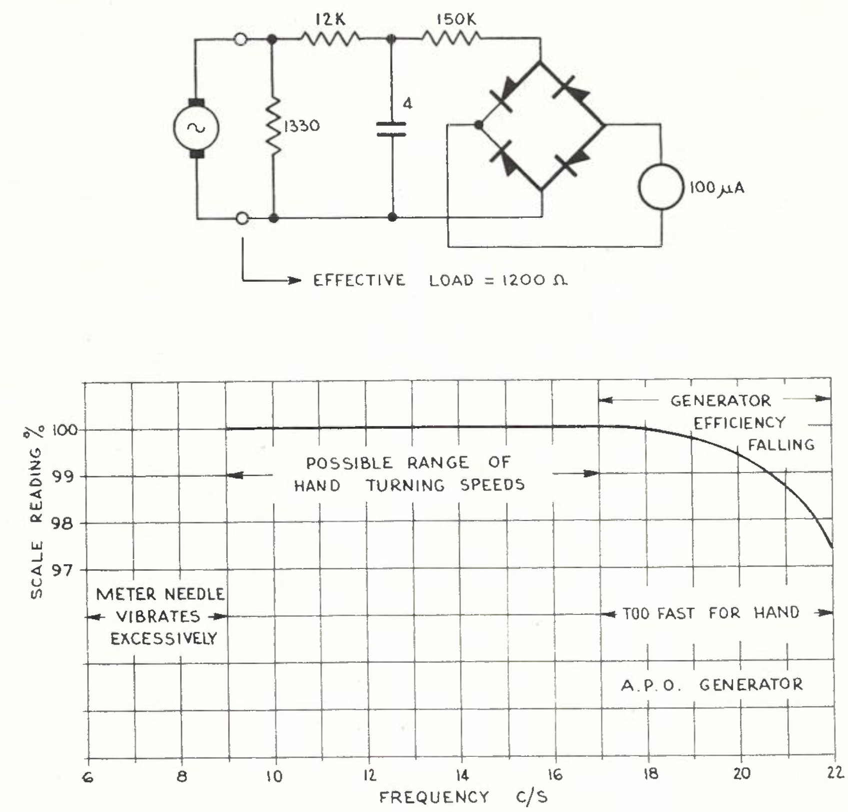


Fig. 13 — Magneto Generator Testing Circuit

it is particularly important that pairs of leads carrying heavy oscillator currents should not be split.

NON-TRANSMISSION COMPONENTS

Up till now it has not been possible to test the output of magneto generators except by means of a laboraory test bench. A means has therefore been devised for measuring the generator output irrespective of the speed of turning Fig. 13 shows the circuit used. Its operation is based on the fact that a magneto generator is an alternator and that over the range of possible hand-turning speeds its voltage output and frequency are theoretically directly proportional to speed. It will be seen that the generator is loaded by 1200 ohms and that the effect of speed variation is removed by means of an integrating circuit. The instrument is calibrated in watts by using a source of known voltage at 16-2/3 c/s. The circuit has been tested by driving an A.P.O. generator from a variable speed source (Fig. 13). Operating it by hand at a frequency of about 9 to 10 c/s the reading becomes steady enough to be meaningful. 17 to 18 c/s was found to be the highest frequency which could be obtained by most people with an A.P.O. generator.

The generator testing circuit has also been built as a separate unit with an insulation test provided.

A simple test panel from which a 59 U type bell is energised under the limiting condition of A.P.O. Specification No. 815, Clause 10.7, or PBA-1 type bell under its appropriate conditions at 16-2/3 c/s or 50 c/s has been provided. Should it become necessary in the future to test other types of calling device, a simple rewiring of the switching panel will enable a microphone to be connected and the acoustic output measured. The Artificial Ear could be adapted to perform this function.

The bell testing circuit has also been built as a separate unit with an insulation test provided.

POWER SUPPLIES

The T.E.T. requires for its accurate calibration that the 50V and 2.7 V d.c. supplies be maintained at the correct voltage and that the exciter lamp supply for the oscillator should also be constant irrespective of the variations of mains voltage. It was therefore considered economical to regulate the 230 V supply to the tester with a 300 VA mains regulating unit of the passive type. All types of R3 T.E.T. may be powered by the one basic unit fed from the mains regulator. As far as possible, silicon diode rectifiers have been used, and this has assisted materially in keeping down the size of the power units. The T.E.T. is substantially independent of mains variations from 190 to 260 V.

It is not convenient to operate a number of T.E.Ts. from a centralised power supply. Interaction between T.E.Ts., particularly since the 2.7 V and 50 V loads are continually being switched, creates serious regulating problems. The wiring resistance must also be carefully controlled. It is considered more satisfactory to supply each T.E.T. from its own power supply. The disadvantage of disabling all the T.E.Ts. if a breakdown occurs in the power supply is also avoided.

Reticulation of a 230 V regulated supply is permissible, only if due allowance is made for the impairment of regulation by the wiring resistance and the possibility of variability of the loading at points in the 230 V system. Oversize conductors will generally be required to preserve good regulation.

MAINTENANCE

Maintenance of the T.E.Ts. by local staff has not always been convenient, especially when detailed knowledge or special equipment is required. There is also the pressure to get the equipment working again as quickly as possible. Local staff should therefore confine their maintenance to replacement of exciter lamps, contact cleaning and repair of cords. In the event of a fault arising which cannot be quickly cleared in this manner, the Research Laboratories will immediately despatch a replacement unit by air and the faulty unit will be repaired and if necessary its calibration re-adjusted. Special travelling cases have been provided for the various items of the T.E.T.

Modifications should not be made to the units locally. Not only is there the danger of non-standard conditions interfering with the accuracy of the T.E.T., but also it is desirable that improvements of real value should be incorporated in all T.E.Ts.

Operating instructions (4) have been arranged so that those who already have some knowledge of the more general tests will readily find the additional information required when confronted with a new type of test. Photographs and schematic circuits have been used generously in order that the operator should have a clear understanding of the nature of the test he is performing and the circuit conditions.

CONCLUSION

The R3 T.E.T. is a completely new design of tester incorporating features aimed at improving its accuracy, and at the same time providing for easier maintenance and calibration. A feature of the design is the ease with which it may be modified to keep abreast of changes in the design of telephone instruments.

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TECHNICAL NEWS ITEM

THE RESEARCH LABORATORIES' COMPUTER USAGE

About two years ago a small digital computer, type 160A of Control Data Corporation, was installed in the P.M.G. Research Laboratories in Melbourne. It appeared at the time that there was already being performed in the Laboratories such an amount of numerical work as would justify the cost of a computer to save the time of professional staff by whom the work was being performed. It was felt that in many cases either the thoroughness of analysis suffered through the pressure of time and the sheer toil involved, or numerical work was altogether bypassed. The provision of a computer in the Laboratories was therefore expected not only to save time, but to lead to an improvement in the standard of work done on projects calling for extensive numerical computation. Also foreseen was the use of the computer as a medium of simulation or automatic control in experimental assemblies.

Work done with the computer in the period since its installation has fulfilled the expectations which led to its acquisition. Its application, primarily on a feasibility study basis, in the CARGO project has already been described in this *Journal* (1). It has made possible the automatic analysis of plant observations whose results are recorded automatically on punched tape. One project of this class was an analysis of the time intervals characterising the dialling of telephone calls, with particular reference to the possible use of fast (20 i.p.s.) dials in connection with crossbar equipment. Observations for this project were made at Toowoomba with a recording unit constructed in the Research Laboratories; the punched tape records were returned to the Laboratories for analysis. This project is not yet completed, but it can be said that the dial speed has not a very important effect on the total time of establishing a call-a time which is significant where common control equipment is used.

A somewhat similarly organised project relates to the incidence of errors in telegraph channels. This work is still in progress.

A project for the use of the computer to simulate a switching area is still in course of development.

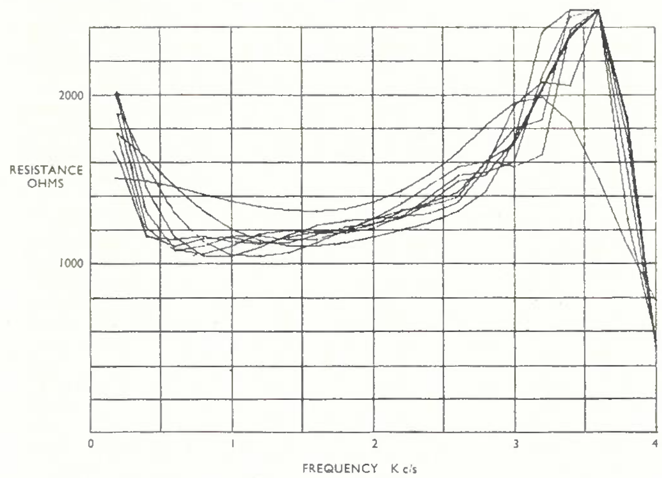

Fig. 1 — Input Resistance, 1-8 Sections 6½ lb. Cable, Loaded 88 mH at 6,000 feet, Terminated in 1200 ohms Resistance.

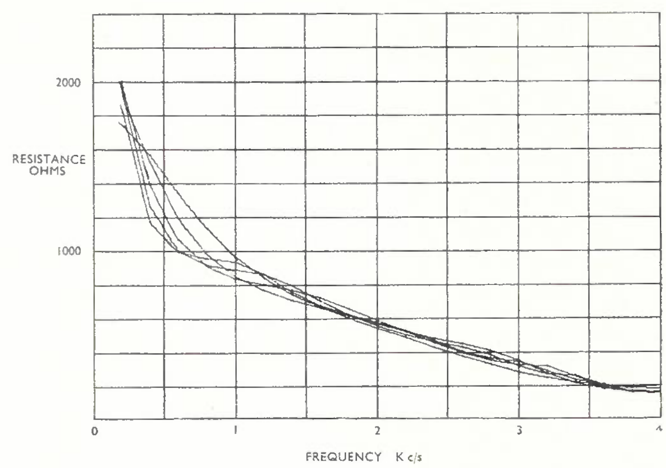

Fig. 2 — Input Resistance, 1-8 Sections Cable as in Fig. 1 With Windings of the First Loading Coil Reversed.

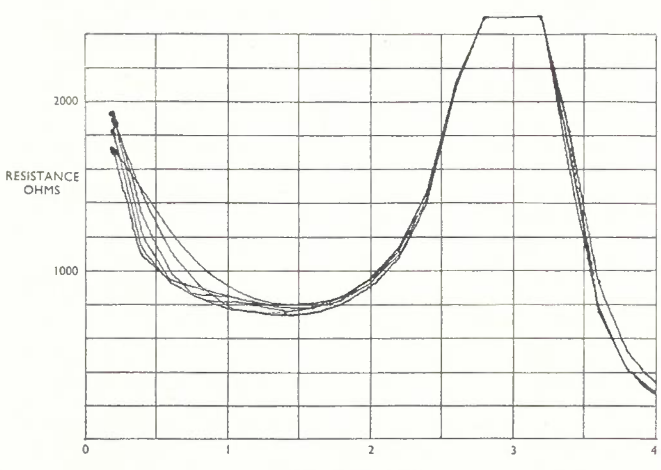

Fig. 3 — Input Resistance, 2-8 Sections Cable as in Fig. 1 With Windings of the Second Loading Coil Reversed.

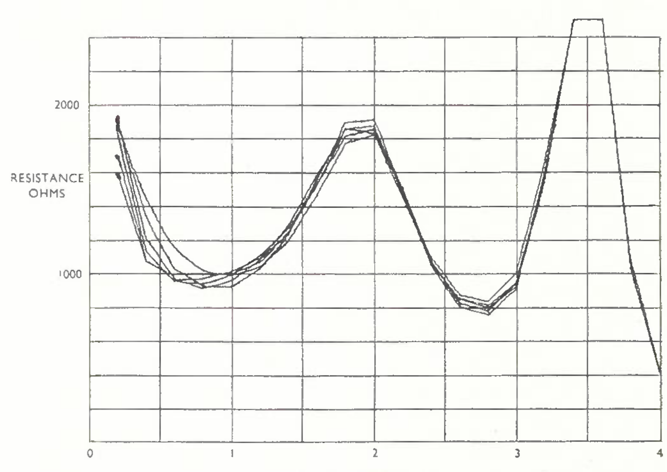

Fig. 4 — Input Resistance, 3-8 Sections Cable as in Fig. 1 With Windings of the Third Loading Coil Reversed.

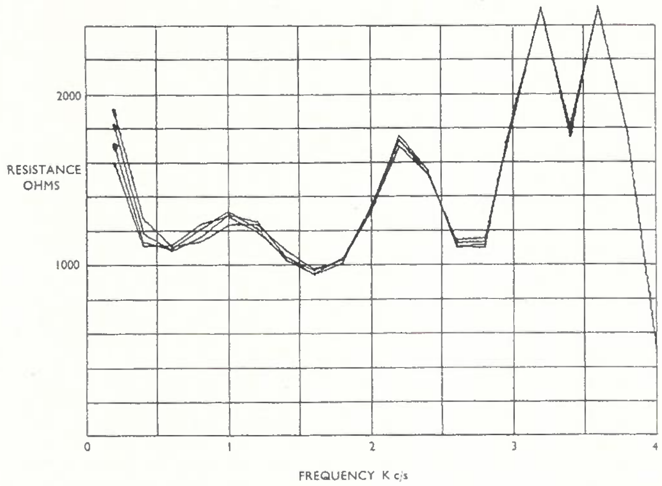

Fig. 5 — Input Resistance, 4-8 Sections Cable as in Fig. 1 With Windings of the Fourth Loading Coil Reversed.

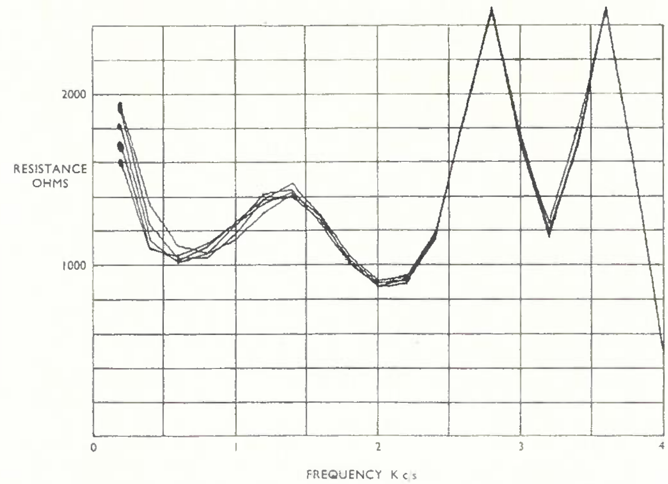

Fig. 6 — Input Resistance, 5-8 Sections Cable as in Fig. 1 With Windings of the Fifth Loading Coil Reversed.

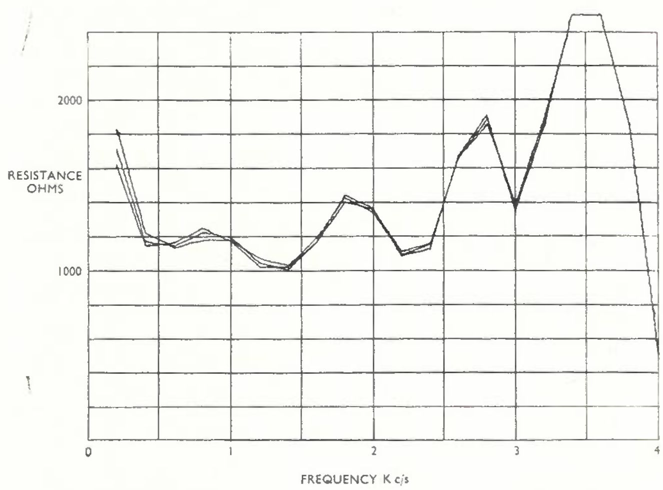

Fig. 7 — Input Resistance, 6-8 Sections Cable as in Fig. 1 With Windings of the Sixth Loading Coil Reversed.

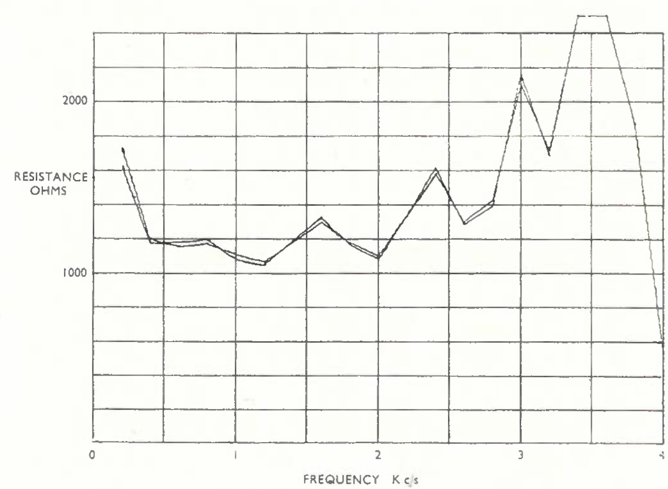

Fig. 8 — Input Resistance, 7-8 Sections Cable as in Fig. 1 With Windings of the Seventh Loading Coil Reversed.

The Laboratories group working in the field of pulse and television techniques has made extensive use of the computer. One phase of this work has been the development of television system testing methods based on waveform response as distinct from the well-known methods used in the conventional line systems of the Department and based on specification of steady-state amplitude and phase as functions of frequency. Waveform methods are more directly related to the characteristics of the television signal, but lead to greater difficulty in the prediction of cascaded responses. The theory of time series methods has been known for some years; their application, however, had been regarded as difficult and laborious until the advent of the computer, and this is now one field in which the computer is extensively and regularly used.

Line transmission calculations in the more conventional field have also been made the subject of extensive computer use. It has proved practicable not only to perform the conventional calculations of transmission characteristics of regular line systems, but also to analyse the behaviour of composite line assemblies of irregular nature such as appear in the operation of a metropolitan telephone network, where loaded cable and non-loaded cable are combined to form a circuit terminated in telephone instruments whose impedances are again very different from the characteristic impedances of the cables. One task of this nature, which also brought into play a more recent addition to the equipment of the computer in the form of a digital plotter controlled directly by the computer, was the plotting of the input impedance of various lengths of loaded junction cable having a loading coil reversed or omitted at various points in the length. The results are reproduced herewith, both as illustration of the work of the computer and for reference by those to whom they may be of use. The first figure shows, superimposed, the resistive component of the input impedance of from one to eight sections of 6½ lb. cable with the normal 88 mH loading at 6,000 foot intervals; the following figures show the corresponding component of the same range of lengths with a reversed loading coil, in the first position from the end observed in Fig. 2, and in succeeding positions in the succeeding figures. The cable is terminated in 1200 ohms resistance.—R.B.

(1) I. T. Hawryszkiewycz, "Computer Compilation of Summaries of Technical Assistance Reports", Telecommunications Journal of Aust. Vol. 15, No. 1, Page 27.

TECHNICAL NEWS ITEM

INTRODUCTION OF LOADED CABLE FOR SUBSCRIBERS' TELEPHONE LINES

Inductive loading of underground cable pairs for telephone communication to reduce transmission loss has been standard practice on inter-exchange circuits for many years. Now the Australian Post Office is extending the principle of loading to the local line between the subscriber's telephone and his exchange, particularly in rural areas. The current high cost of copper has increased the scope for economic application of loading in the subscriber network.

Loading reduces the transmission loss of a circuit and enables the use of lighter gauge conductors. However, apart from the transmission loss at voice frequencies, the resistance of the circuit must also be considered, as direct current signalling is used on local subscribers' lines. The recently introduced crossbar exchange equipment permits substantially increased resistance on the subscriber's line and greater advantages of loading can now be achieved. The loading system used is 88 millihenry coils at 6,000 ft. spacing. The maximum transmission distances for loaded local lines compared with those for unloaded cable are as shown.

Conductor weight	4 lb./mile	6½ lb./mile	10 lb./mile	20 lb./mile
Loaded cable	3.3 miles	4.7 miles	6.5 miles	12.7 miles
Unloaded cable	2.62 ,,	3.41 ,,	4.37 ,,	7.0 ,,

The main problem in the introduction of loaded subscribers' cable was the need to match the telephone impedance to that of the loaded line to preserve satisfactory sidetone performance. In the absence of such matching, the speaking subscriber would hear his own voice in the telephone receiver at a disturbingly loud volume. The A.P.O. standard telephones are designed for use on unloaded cable and any modification of the telephone for use on loaded cable was undesirable. Studies, using computer techniques, tested an extensive range of possible network combinations against data from trial loaded cable installations to determine the most suitable network for matching. It was established that simple shunt impedance would afford a suitable compromise for any combination of telephone and cable length likely to be found in practice.

Loading of subscribers' lines has been introduced mainly on economic grounds, but it can also have the effect of bringing about a general reduction of loss in rural networks. Loading is one of several means of providing better and cheaper subscribers' service — particularly in rural areas where subscribers' lines can now be cabled over greater distances. Other methods, for example, include rural carrier systems, line concentrations, various types of radio services, etc. all of which are being used by the A.P.O. today for an improved rural telephone service.

Contributions, Letters to the Editors, and Subscription Orders

may be addressed to:

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★

R. W. KETT, author of the article, "Design of the Telephone Efficiency Tester Type R3", was educated at Caulfield Grammar School and obtained the Diploma of Communication Engineering from the Royal Melbourne Technical College in 1945 at which time he joined the P.M.G. Research Laboratories as Engineer Grade 1. He has been chiefly concerned with telephone instrument measurement techniques and research into carbon microphone performance. His present position is that of Divisional Engineer of the Telephonometry Division of the Research Laboratories. He is an Associate Member of the I.R.E.E. (Aust.).

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★

J. L. HOARE, author of the article "Cables and Conduits Across the Brisbane River", joined the Postmaster-General's Department, Queensland, in 1948. Prior to joining the Department, he was employed as an apprentice and then Engineer with the City Electric Light Company in Brisbane. His technical training was received at the Brisbane Central Technical College and the University of Queensland. He graduated as a Bachelor of Mechanical and Electrical Engineering with first class honours in 1944. All his service with the Postmaster-General's Department has been spent in the external plant field. In 1955, he was appointed Divisional Engineer, Metropolitan District Works, and is now attached to the Primary Works (Conduits and Cables) Division.

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★

L. J. BLOXOM, author of the article, "No Progress Call Detector—N.P.C.D." joined the Postmaster-General's Department in 1941 as a Telegraph Messenger and qualified as Technician-in-Training in 1943 and Senior Technician Telephone Equipment in 1948. Until 1962 he was employed on maintenance of 2000 and pre 2000 type automatic telephone exchanges and attained the position of Supervising Technician Grade 3. With the advent of crossbar equipment Mr. Bloxom participated in the installation and test out of the Petersham crossbar extension and subsequently took over the maintenance of Haymarket crossbar exchange as Supervising Technician Grade 4 from the date of cutover in August 1963. In October 1964 Mr. Bloxom was seconded to a position of Acting Senior Technical Officer Grade 2 assisting the Supervising Engineer Metropolitan Equipment Service Sydney in all aspects of service pertaining to ARF102 crossbar equipment, particularly with regard to service control equipment, technical investigations and improvements and service standards.

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A. H. FAULKNER

A. H. FAULKNER, author of the article "The Tellurometer" is an Engineer with Radio No. 2 Division, Perth. He graduated in Engineering at Cambridge University, England, in 1941, and in 1945 was granted a Master of Arts Degree. He saw five years sea service with the R.N.V.R. as Escort Group Radar Officer, after which he joined the British Post Office Research Station, Dollis Hill, as Engineer, and was engaged in the design and construction of microwave television relay systems. Mr. Faulkner was the Post Office representative on the Radio Components Standardisation Sub-Committee on Waveguides, and the Radio Components Research and Development Sub-Committee on microwave test equipment. In 1952 he came to Australia and joined the P.M.G.'s Department, Radio Section, Central Office, leaving in 1955 for private employment. In 1961 he re-joined the department, and has been responsible for the design of micro-wave broad-band bearer systems in Western Australia. Mr. Faulkner is an Associate Member of the Institution of Electrical Engineers.

★

V. J. GRIFFIN

V. J. GRIFFIN, author of the article, "SEACOM: Survey and Selection of Brisbane-Cairns Microwave Radio Route", joined the Department in Brisbane as a Junior Mechanic-in-Training in 1942 and qualified for appointment as Engineer in 1949. During the following six years he was engaged on duties concerned with the operation and maintenance of National Broadcasting Stations and Studios and Radio Telephone Equipment. In 1955 he was promoted as Divisional Engineer, Radio Telephone Division, and in October, 1961, he was appointed as Project Engineer for the establishment of the Brisbane-Cairns Microwave Radio Route. Mr. Griffin is an Associate Member of the Institution of Engineers, Australia, and a Senior Member of the Institution of Radio and Electronic Engineers, Australia.

★

A. H. O'ROURKE

A. H. O'ROURKE, author of the article "Australian Pentaconta Crossbar P.A.B.X.", is at present Class 2 Engineer, with Metropolitan Service Section, Melbourne. He served with the R.A.A.F. as a Radar Mechanic between 1942 and 1946 and joined the Postmaster-General's Department in 1949 as an Adult Technician-in-Training, subsequently qualifying as a Senior Technician. Before completing a Diploma course in Radio Engineering in 1958, he spent a number of years on technical work with different Commonwealth Departments. These positions included the production of geiger counters and associated equipment used in the search for uranium at the Bureau of Mineral Resources, and the maintenance and construction of electronic instruments necessary for nuclear research at the laboratories of the Australian Atomic Energy Commission. Mr. O'Rourke spent a further period at the Chemical Physics laboratories of C.S.I.R.O. before rejoining the Postmaster-General's Department in 1960 as a Grade 1 Engineer. He is a Graduate Member of the Institution of Engineers, Australia.

★

M. STROHFELDT, author of the article "Transmission Performance of Brisbane-Cairns Microwave System" received the degrees of Bachelor of Science (First Class Honours in Physics) and Master of Science from the University of Queensland in 1951. After occupying radio research positions in the Radiophysics Laboratory (C.S.I.R.O.) and Department of Supply engaged mainly with radio propagation projects he joined the Postmaster-General's Department in 1954 in the Research Section (Propagation Division). In 1958, he became Acting Divisional Engineer (Planning and Standards) in the Headquarters Radio Section gaining the appointment in 1960. In this capacity he has been closely involved with microwave route selection, path surveys, system designs and frequency planning for all Departmental radio-telephone development in recent years, particularly for television relay expansion during Phases 3 and 4, and for broadband telephony systems.

M. STROHFELDT

ANSWERS TO EXAMINATION QUESTIONS

Examination No. 5149 — 6th July, 1963, and subsequent dates. To gain part of the qualifications for promotion or transfer as Senior Technician (Telecommunications), Radio, Postmaster-General's Department.

QUESTION 1

(a) *Define or briefly explain the separation of thermionic valve amplifiers into the following classifications:—*

(i) *Class A*

(ii) *Class B*

(iii) *Class C*

(b) *List the important characteristics of each class, and give two examples of the application in each class.*

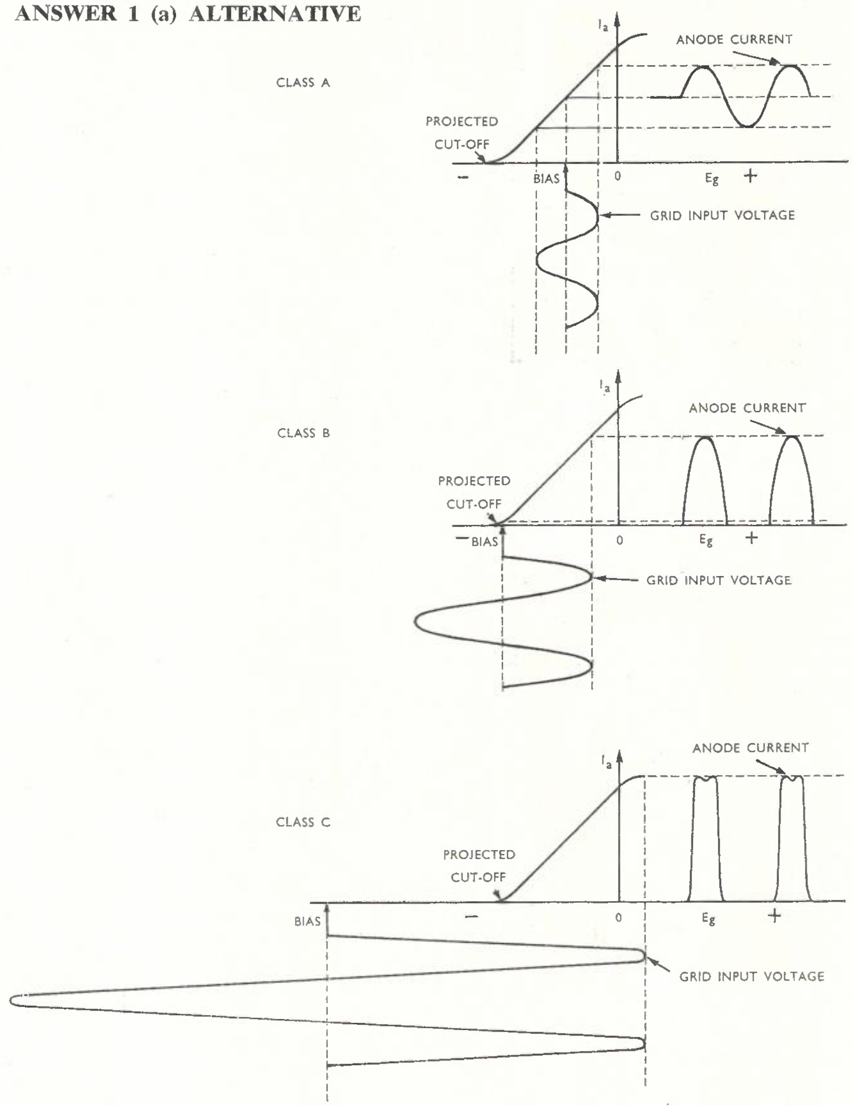
ANSWER 1 (a)

Class A. In a Class A Amplifier, the grid is biased to the centre point of the linear section of the valve's characteristic Eg/Ia curve, thus providing an anode current which varies linearly with the grid input voltage over the complete input cycle of 360 electrical degrees.

Class B. In a Class B Amplifier, the grid bias is approximately equal to the cut-off value, so that anode current flows only during the positive half cycle (approximately 180 electrical degrees) of the grid input voltage.

Class C. In a Class C Amplifier, the grid is biased appreciably beyond the anode current cut-off value, so that anode current flows for less than 180 electrical degrees during the positive half cycle of the grid input voltage.

ANSWER 1 (a) ALTERNATIVE



ANSWER 1 (b)

Class A.

Characteristics: Low power output; Low anode power efficiency (20 to 50%); Constant input anode power; High voltage amplification; Low distortion; Normally no driving power as no grid current is drawn.

Applications: Voltage amplifiers at radio, intermediate and audio frequencies; Low power audio output stages; Low distortion oscillators.

Class B.

Characteristics: Moderate power output; Moderate anode power efficiency (40 to 50%); Input anode power low at zero signal, and varies directly with signal level. Distortion is high when used single ended, but relatively low in push-pull. Requires some driving power if fully driven, as some grid current flows.

Applications: Push-pull high power audio output stages for modulator or public address. Radio frequency power amplifiers for modulated carrier (single-ended if used with anode resonant circuit). Transmitter buffer amplifiers.

Class C.

Characteristics: High power output; High anode power efficiency (up to 70%) ; Input anode power is drawn for considerably less than half the input cycle. Very high distortion (requires anode resonant circuit to restore input in wave form). Provided the grid swing reaches saturation, anode current is directly proportional to anode voltage. Requires substantial driving power if grid swing reaches saturation.

Applications: Radio frequency power oscillators; R.F. power amplifiers (unmodulated); Plate-modulated R.F. power amplifiers.

QUESTION 5

Describe the functions and properties of radio frequency transmission lines under the following headings:—

(i) *Types and their usage.*

(ii) *Characteristic impedance.*

(iii) *VSWR.*

(iv) *Lumped circuit equivalents.*

(v) *Filters and stubs.*

(vi) *Phasing sections.*

ANSWER 5

Types and their Usage: There are two basic types of transmission lines, the open wire line and the coaxial line. The open wire line has the advantage of having an air dielectric which because of its low losses, enables efficient and economical transmission of radio frequency energy over long distances. These lines are frequently used at H.F. stations.

The coaxial line however, generally has a plastic dielectric which results in higher losses, but because of its shielded construction it has the advantage that it can be placed in proximity to buildings or equipment without increasing its losses.

Characteristic Impedance: When a radio frequency voltage is applied to the input of a transmission line, the input impedance of the line is determined by its distributed constants R, L, G and C, and by the amplitude and phase of the wave reflected from the far terminal.

When the line is extremely long and the effect of the reflected wave becomes negligible because of attenuation, the input impedance depends only on the distributed constants. In this case, providing the resistance and conductance per unit length are very much smaller than the inductance and capacitance per unit length respectively, the input impedance is called the characteristic impedance, which is almost purely resistive and has a value $Z = \sqrt{L/C}$.

The input impedance of any line whether short or long also equals the line's characteristic impedance whenever it is correctly matched, because under these conditions, no reflection occurs.

V.S.W.R.: When a transmission line which is not terminated in its characteristic impedance is excited by a radio frequency voltage, a stationary voltage pattern exists along the line which varies from a maximum to minimum value in a cyclic fashion. The ratio of two adjacent maximum and minimum voltage values is called V.S.W.R. This value can be determined using either a reflectometer or a slotted line. The V.S.W.R. indicates whether or not the line is matched, having a value of 1 for correct matching.

Lumped Circuit Equivalents: Since the impedance of an unmatched line varies in magnitude and phase along its length, sections of a line can be used as the equivalent of lumped circuit components. The relationship between the component type and the length of the line is shown in the diagram below, where the size of the component is drawn in proportion to its resistance or reactance.

Filters and Stubs: Because transmission lines can be designed to have low resistive and dielectric losses, their resonant properties can be used to provide high Q filters such as the coaxial filters which are used with VHF systems. Sometimes $\lambda/4$ sections of line are placed across a load to filter out 2nd harmonic currents which operate because of their high impedance at the fundamental and their low impedance at the harmonic.

Stubs are merely short sections of a line which operate as a lumped circuit component. They are often used to tune the input impedance of aerials.

Phasing Sections: Phasing sections are often used to enable separate loads to be excited with different phases e.g. two sections of an aerial array. In order to achieve the desired phase relationship, a length of transmission line is inserted in series with the feed to one of the loads, so as to delay the excitation of the load by an amount equal to the electrical length of the line.

QUESTION 7

(a) What is the approximate range in decibels of the sound output of a full symphony orchestra?

(b) Obviously it is necessary for the first amplifier following the microphone, which amplifies the sound from such an orchestra to handle this range faithfully without introducing distortion. If the average output of the microphone is, say —65 dbm what maximum level must the amplifier handle?

(c) If the microphone amplifier signal/noise ratio is to be of the order of 60 db, what is the maximum level of noise which can be allowed in the input of the amplifier.

(d) What would you say was the minimum gain in db's necessary between the microphone output and the microphone channel fader in a modern broadcasting chain? Explain why this gain is necessary.

ANSWER 7

(a) The range is approximately 70 db.

(b) As the average output of the microphone is —65 dbm, the range of the output from it will be —65 dbm ± ½ (70 db) i.e. —30 dbm to —100 dbm therefore the microphone amplifier must handle a maximum input level of —30 dbm.

(c) The maximum level of noise in the amplifier would be —65 dbm —60 db i.e. —125 dbm to ensure a signal noise ratio of 60 db.

(d) In a high level mixing system as employed in modern broadcasting studios the microphone channel fader follows a low noise pre-amplifier, and is followed by further audio amplification. Assuming the fader to be well designed, its inherent noise can be ignored when used in a position of high audio level. The most likely source of noise to affect the low noise input amplifier will be the amplifier stage following the fader and it is therefore necessary that this noise shall be low compared to the noise level at the output of the fader, say at least 10 db lower. As in actual operation 15 db or so attenuation is held on the fader for operational reasons the minimum gain necessary between the microphone output and the channel fader would be 25 db. Modern low noise pre-amplifiers usually have gains of 30-40 db.

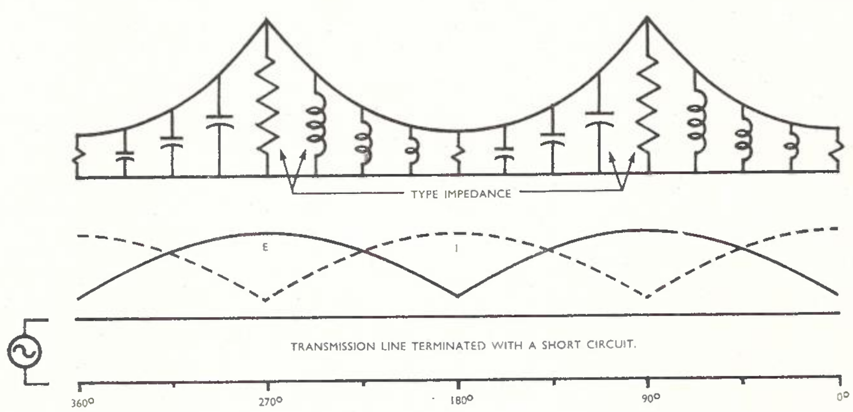
QUESTION 10

10 (a) Draw and label all the features of the modulation wave-form of a television transmitter, over three line intervals. Mark the levels corresponding to "black" and "white" picture as a percentage of the peak synchronizing pulse.
10 (b) What is the average power output of a 10 kW. television transmitter when operating at —

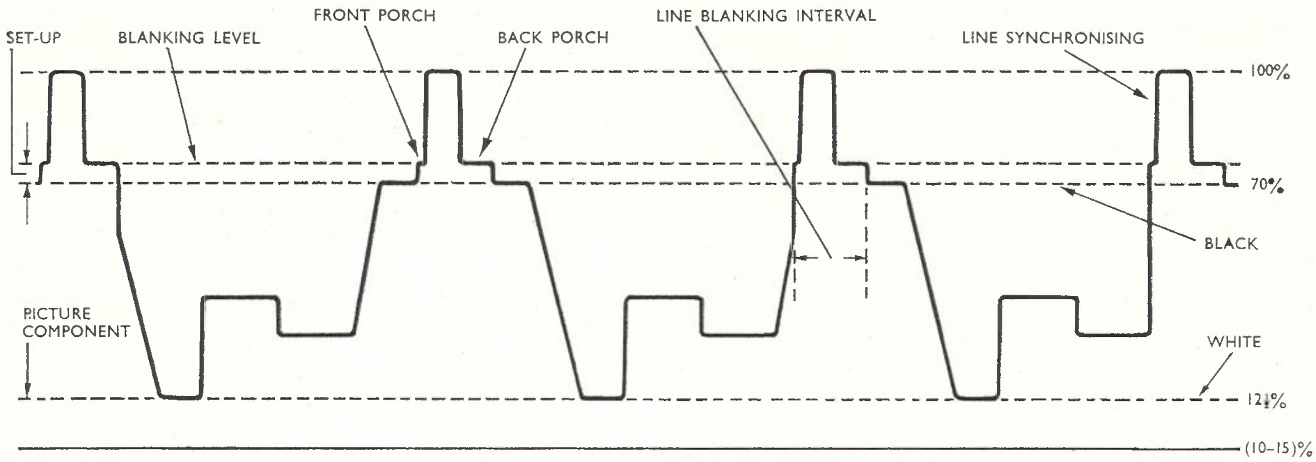
(i) "blanking level",

(ii) at 25 per cent, of peak carrier level (i.e., near white level)?

N.B. — The power contributed by the line and field synchronizing pulses may be neglected and the blanking interval may be taken as one-fifth of the line interval.



ANSWER 10 (a)



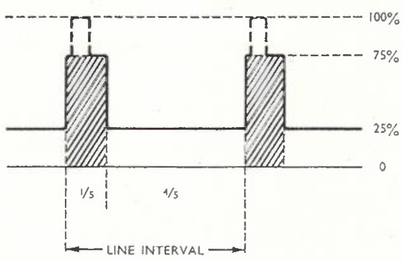
TELEVISION TRANSMITTER MODULATION WAVEFORM.

ANSWER 10 (b)

(i) The rated power of a television transmitter is the power level during the synchronising pulses. The "blanking level" is 75% of the amplitude of the synchronising pulses and therefore the average power output of a '10KW' TV transmitter when operating at "blanking level" is:

$$P_{OB} = 10 \times \frac{(75)^2}{(100)} = 5.625 \text{ KW}$$

(ii) The modulation waveform for this part of the question is shown below.



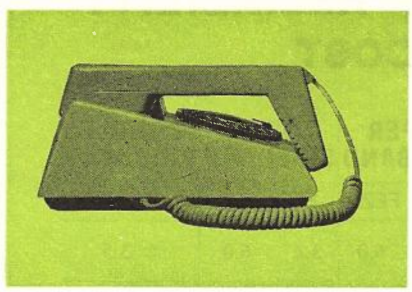
Power contributed by the shaded area averaged over a line interval

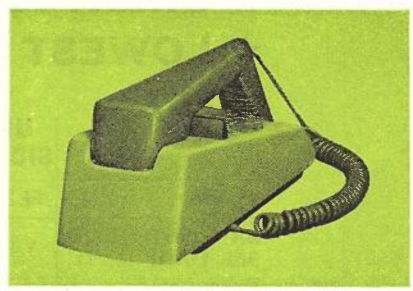
$$= 10 \times \frac{(75)^2}{(100)} \times \frac{1}{5} \text{ KW} = \mathbf{1.125\ KW}$$

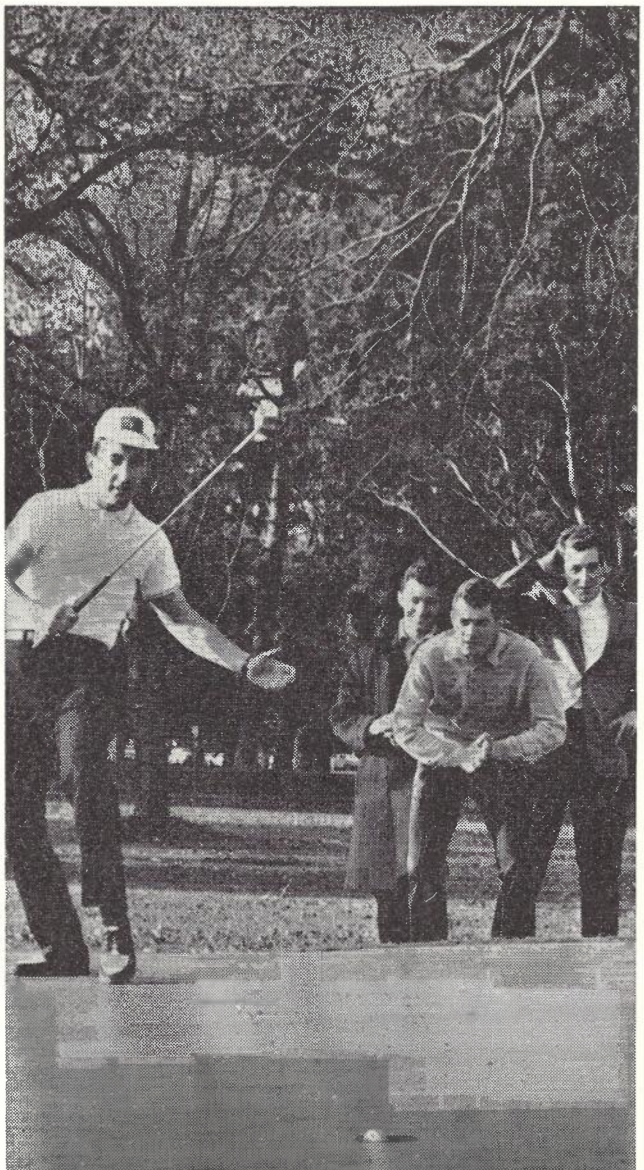
Power contributed between the shaded areas averaged over a line interval

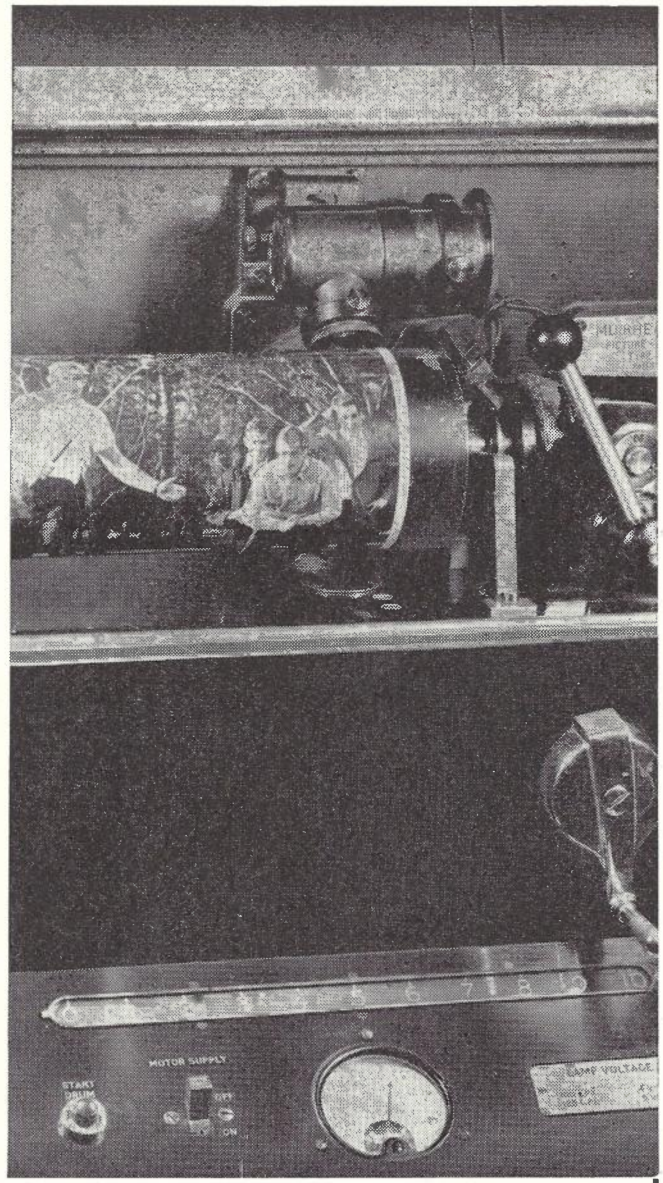
$$= 10 \times \frac{(25)^2}{(100)} \times \frac{4}{5} \text{ KW} = \mathbf{0.5\ KW}$$

Average power output of a 10 KW TV transmitter with the modulation shown above = 1.125 + 0.5 = **1.625 KW**









From putting green to picturegram ASC cables are the important link

In rolls a putt worth £5,000 to the new champion. Click! Press photographers have captured this exciting moment on film.

But that's only the beginning of the story. Soon afterwards, golf fans thousands of miles from the putting green will open their newspapers and see this picture.

The Postmaster-General Picturegram section flashes pictorial news to all capital cities. Picturegrams are transmitted over interstate trunk lines and city cable networks.

Austral Standard Cables have supplied more than 5 million miles of telephone cables to the P.M.G. These cables range in size from 1 pair to 3,000 pair plastic or paper-insulated cables — including Type 375 multi-tube coaxial cable capable of transmitting thousands of telephone conversations.

AUSTRAL STANDARD CABLES for safe, sure communication. MAKERS OF AUSTRALIA'S TELEPHONE CABLES.

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AS 29

THE **Mullard**
PREFERRED RANGE OF SILICON ZENER DIODES

When approaching the maximum limiting values, either electrically or thermally, the comprehensive data and curves, as contained in Volume 4 of the Mullard Technical Handbook, should be consulted.

	± 5%						± 10%		± 15%			
Nominal Zener Voltage (V)	230mW	260mW	400mW	1.5W	7W	75W	230mW	25W	230mW	260mW	7W	Nominal Zener Voltage (V)
4·3			BZY88C4V3						OAZ268	OAZ208		4·3
4·7	OAZ240	OAZ200	BZY88C4V7									4·7
5·1	OAZ241	OAZ201	BZY88C5V1						OAZ269	OAZ209		5·1
5·6	OAZ242	OAZ202	BZY88C5V6	SZ56A	OAZ222							5·6
6·0			BZY88C6				BZZ10					6·0
6·2	OAZ243	OAZ203	BZY88C6V2	SZ62A	OAZ223				OAZ270	OAZ210	OAZ290	6·2
6·5			BZY88C6V5				BZZ11					6·5
6·8	OAZ244	OAZ204	BZY88C6V8	SZ68A	OAZ224							6·8
7·2			BZY88C7V2				BZZ12					7·2
7·5	OAZ245	OAZ205	BZY88C7V5	SZ75A	OAZ225				OAZ271	OAZ211	OAZ291	7·5
8·0			BZY88C8				BZZ13					8·0
8·2	OAZ246	OAZ206	BZY88C8V2	SZ82A	OAZ226							8·2
9·1	OAZ247	OAZ207	BZY88C9V1	SZ91A	OAZ227				OAZ272	OAZ212	OAZ292	9·1
10				SZ10C	OAZ228	BZY91C10						10
11				SZ11C	OAZ229	BZY91C11						11
12				SZ12C	OAZ230	BZY91C12			OAZ273	OAZ213		12
13				SZ13C	OAZ231	BZY91C13						13
15				SZ15C	OAZ232	BZY91C15		SZ15B				15
16				SZ16C	OAZ233	BZY91C16						16
18				SZ18C	OAZ234	BZY91C18		SZ18B				18
20				SZ20C	OAZ235	BZY91C20						20
22				SZ22C		BZY91C22		SZ22B				22
24				SZ24C		BZY91C24						24
27				SZ27C		BZY91C27		SZ27B				27
30				SZ30C		BZY91C30						30
33				SZ33C		BZY91C33		SZ33B				33
36						BZY91C36						36
39						BZY91C39		SZ39B				39
43						BZY91C43						43
47						BZY91C47		SZ47B				47
51						BZY91C51						51
56						BZY91C56		SZ56B				56
62						BZY91C62						62
68						BZY91C68		SZ68B				68
75						BZY91C75						75

Most of the stud mounted zener diodes are available with reversed polarity. For further information please contact the Mullard Technical Service Departments.

Mullard now have available from local production heatsink extrusions for use with power zener diodes. Forward a stamped, self-addressed envelope, endorsed "Heatsink" and receive a leaflet detailing mechanical dimensions and thermal characteristics.

Mullard

Mullard-Australia Pty. Ltd.

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Permits reverse power **surges 50 times greater** than conventional silicon rectifiers

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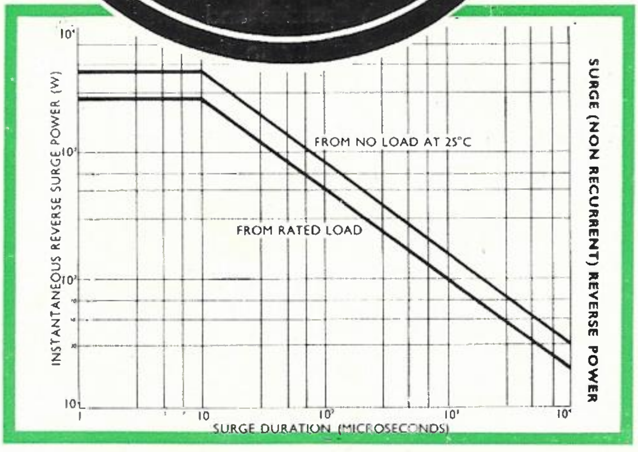
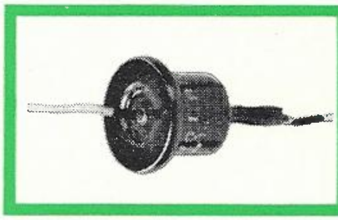
Can be **series connected** without voltage equalising resistors and, in many applications, without equalizing capacitors

SILICON AVALANCHE RECTIFIERS



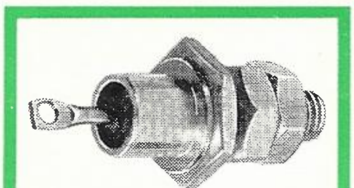
Typical example of avalanche characteristics
Surge (non recurrent) reverse power



TYPE RAS 310 AF

Rated Forward Current (At 25°C)	1.25 A
Rated Crest Working Reverse Voltage	1000V
Minimum Reverse Avalanche Voltage	1250V
Rated Maximum Reverse Surge Power	4kW
Rated Maximum Temperature	140°C

Standard Outline VASCA SO-16, JEDEC DO1, IEC 1-101



TYPE RAS 508 AF 800V. 1000 A.V.V. 5A

(Illustrations twice actual size. Data sheets for each type available.)

FOR FURTHER INFORMATION CONTACT:

Standard Telephones and Cables Pty. Limited

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