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COMPUTERS AND COMMUNICATIONS — THE PRESENT AND THE FUTURE

P. S. BETHELL, B.Sc., Dip. P.A., M.I.E. Aust.*

Editorial Note: This paper was presented at Brisbane in June, 1970, at a Data Transmission Conference organised by the Electrical and Electronics Board of the Institution of Engineers, Australia. It is reprinted by the kind permission of the Institution. Some other papers presented at the Conference will be published in subsequent issues.

THE COMMUNICATIONS EXPLOSION.

It is worth reflecting that our most common medium for telecommunications — the telephone — has been in existence for somewhat less than 100 years. In fact, even 50 years ago the telephone was still something of a novelty with less than 200,000 telephone lines in service and the telephone density about four to each hundred of population. The number of telephone services is now (June, 1970) approximately $2\frac{3}{4}$ million and the telephone density has risen to more than thirty per hundred of population.

As yet there appears to be no tendency for the rate of growth in telephony to diminish; on the contrary, the rate of growth for several decades has been of the order of 5 to 6 per cent., but in the last year this had increased to 6.4 per cent., and in the current year it seems likely to exceed 7 per cent. If we look at the long distance network we find that only a few years ago the typical rate of growth was of the order of 6 to 8 per cent. per annum, but in the past three years this has increased into the range of 12 to 15 per cent. In the international sphere the growth is even more marked; international calls from Australia currently growing at 25 per cent. each year.

Assuming the current rates of growth in telephony were to continue until the year 2000 A.D. we would have:

- 160 telephones per hundred of population;
- a trunk network 40 times the size of that now existing;
- an increase from 200 to 1100 in the number of calls per year per head of population;
- 30 per cent. of the calls long distance;
- 40 times as many international calls per head being made each year.

It is clear that in terms of voice communications, this rate of growth cannot continue indefinitely, but will begin to diminish in the future. Already in countries like Sweden and the United States, where telephone development is appreciably higher than in Australia, the rates of growth are lower.

IMPACT OF DATA TRANSMISSION.

The arguments in the preceding section suggest that there will be a reduced rate of growth of voice communications, but this does not mean that the growth of telecommunications in general will diminish. In fact it appears likely that any slackening in the demand for voice services will be more than offset by the demand for other forms of communication, particularly data transmission. Some of this growth will be taken by the ordinary public telephone network, some will be on private lines and some on new, special purpose, switched networks.

At the end of 1969 there were about 400 data terminals in Australia connected to Post Office lines and it is estimated that these will increase by at least a factor of ten by 1974. There are indications from other parts of the world that this type of growth will continue much later than 1974. In the United Kingdom, where there were 4000 data terminals in 1969 — more than twice the density of Australia — it is estimated that the number will grow to 40,000 by 1974. In the U.S.A. the present density is much higher again, but it is still expected to grow by a factor of ten within five years.

A factor which should offer a guide to the growth of data transmission is the number of computers in operation. In Australia the number of computers in service has increased by a factor of about three in the past five years and indications are that this rate of growth will continue. However, the average computing power of these machines is steadily increasing, and, taking into account new modes of use, the extent of data transmission use would be increasing at an appreciably higher rate.

In terms of the total information being handled by the communications networks it has been estimated that, in the United States, the data traffic will be occupying as much communications capacity as all of the traffic between people by 1975. If this estimate is correct, we might expect that a similar situation could be reached in Australia by 1980.

THE MARRIAGE BETWEEN COMPUTERS AND COMMUNICATIONS.

The last decade has seen dynamic change both in computer technology and in the range of computer applications. Ten years ago computers were being used on a reasonable scale in two main areas. They were used as a tool by scientists, engineers and mathematicians for the solution of problems which, by their magnitude or complexity, could be handled better by computer than by manual methods. They were also used in the field of business to replace some of the repetitive clerical functions in areas such as accounting, payroll preparation and stock control. In both cases information for processing was prepared on punch cards or paper tape and taken physically to the computer bureau. The computer operated in a batch mode and dealt with only one user and generally one type of process at any one time.

While computers were being used in this mode, there was little requirement for data transmission, as no dynamic interaction occurred between the computer and its environment (e.g., inquiry and response). In a few cases, the time factor dictated that media should be transferred to or from the computer by line transmission as an alternative to physical transportation, but in most cases the economics were against it.

The space age brought with it a need for instant response, higher speeds and large storage capacity. Whilst improvements in technology were able to meet these requirements, the resultant higher costs for the larger computers dictated that in many cases they could only be used economically with more than one simultaneous user. Since the average cost of computing power tended to decrease with larger machines, conditions favoured the concept of shared use through remote access facilities. The ability to undertake more complex computations, and the massive storage and retrieval facilities on the larger machines extended the computers' range of application to embrace a wider spectrum of users. At the same time, sufficient real time capacity was available to carry out line terminating functions essential for remote access.

Thus, the mating of communications with computers is leading to much larger and more complex computer systems. At the same time, there have been parallel developments of more sophisticated and varied peri-

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pheral equipment for remote terminations. It has become practicable for large organisations, whose operations are widely spread geographically, to make use of centralised computers covering many types of application. Smaller organisations are able to share common computers so that, with access to communications lines and only relatively inexpensive terminal apparatus in their own premises, they have the same facilities as if owning a large scale computer.

DEVELOPMENTS IN TIME-SHARING AND ON-LINE OPERATION.

With widespread use of data terminals in user locations, generally each terminal is used only intermittently. Under these conditions it is uneconomic to provide a direct line from each terminal to the computer owing not usually to line costs (at least in local networks), but to the relatively high cost of line-terminating computer hardware and a wasteful use of computing time. The now well-established time-shared services have overcome this problem by use of the switched telephone network. Customers with data terminals use their telephone to gain access to the computer via the public network and then switch over to data operation. The lines from the computer into the switched network need only be provided on the basis of the number of simultaneous calls which are to be handled.

Existing time-sharing systems of this form use, as data terminal devices, teleprinters (or their equivalent), operating at line speeds of less than 200 b.p.s. (The normal arrangement is a keyboard with page printing and an option of tape perforating.) These terminals are designed to operate in conversational mode and are suitable for a wide range of problem-solving applications. There is no doubt that there will be continued growth in demand for this facility.

Time-sharing as just described is not suitable, nor is it the most economic means, of carrying out large-scale processing of the type now frequently undertaken in an off-line mode at a computer bureau. The sheer volume of input and output data for large-scale applications demands higher speeds (600/1200 b.p.s. or 2400 b.p.s.) and larger storage and computing capacities than would normally be available on a time-shared service.

A remote processing terminal may require a number of data machines possibly of more than one type to be connected to the data line, e.g., card-readers, punches, tape-readers or printers. Generally the only satisfactory means of utilising the full line capacity is to use at the terminal a device which incorporates some storage which can communicate with the computer at the full speed capability of the line. With such arrangements one has, in essence, a distributed computer system; main processing is undertaken centrally, but limited functions are performed by control devices in the various remote locations.

Control devices used in remote locations take various forms depending on the requirements and on the particular type of operation being performed. Here are some examples:

Groups of cathode ray displays are normally connected to a 'controller.' This is usually a relatively uncomplicated device providing the basic storage for the screens, polling of the various terminals to enable them to send to line in sequence, and selection of the particular terminal which is addressed by messages from the line.

A remote line printer requires a terminal device to enable characters which are received sequentially from the transmission line to be assembled into printing lines. This operation also involves exchange of some control signals with the computer.

When various forms of data device are required at a single terminal the controller must perform the appropriate control functions for each type of device, e.g., card-readers, tape-readers, keyboard entry stations, etc., as well as providing the appropriate interface to the transmission line.

The form of the 'black box' for use in the remote premises may vary widely. In the simplest case it is merely a special purpose controller and in the more complex cases it is, in itself, a small computer. One form of general purpose device which is now coming fairly generally into use is one which employs magnetic tape as the storage medium. On the one hand it is capable of sending and receiving data on the transmission line and on the other hand exchanging data with different forms of terminal device in an off-line mode.

FUTURE TRENDS.

If we look into the future we will find that patterns of computer usage and technological change will be inevitably interlocked. Considering first the usage patterns, it is clear that there will be much wider use being made of computers as computing power becomes cheaper and facilities for shared use of computers are developed. Changes are likely to be characterised by:

(a) In business more extensive computer use within the types of functions now being undertaken, but also a steady increase in the types of functions, particularly in the management area.

(b) Many future computer systems will be characterised by the existence of very large data files. These may be set up purely for information retrieval purposes, but in many cases they will be readily available for other processing functions. The file data would otherwise have to be inserted each time the processing run is undertaken. These large data files will characterise large in-house computer systems, but in many cases they will be set up to satisfy the requirements of particular groups within the community, such as lawyers, doctors, hospitals, librarians, etc.

(c) There will be a much more widespread use of computers in education. In the first place there will, of course, be a need to teach computer science much more widely. Also computer-aided instruction will become much more general and computers will become a generally available tool for students for their problem solving. It will be impossible for every school and teaching institution to have its own computer; so these developments must lead to large-scale use of data transmission facilities.

(d) There will be a progressive integration of various computer systems into one large system. For example, integration in the banking area could reduce physical transfers of documents and money—possibly a chequeless society. In this society when a customer makes a purchase from a firm all he will need to do is to produce his identification card, which can then be used not only to check his credit rating, but also to initiate transfer of the appropriate amounts from his account to that of the firm. With such integrated systems one can envisage in the future the possibility of the decentralised office in which individual workers may remain in their own homes and carry out their work by means of a data terminal. The computer is also likely to be accessible from the home for the housewife herself who will use the data terminal to order from the supermarket from a catalogue.

Technological changes, apart from those within the computers themselves, are likely to take place in two areas—in speeds of transmission and in type and variety of terminal devices.

Considering first transmission speeds, it is now practicable and common for data transmission to take place at 2400 bits over voice channels. Within the next year or so in Australia, we will also be using transmission at 4800 bits and it is generally accepted that by the end of the 1970's 9600 b.p.s. on voice channels will be common. Although prices of modems increase steeply with their speed, there is a tendency for these prices to fall with time. In this country, with its long distances and consequent relatively high line costs, customers will tend to cope with steadily increasing data transmission business by using modems of higher speed. However, there will continue to be a steady demand for modems operating at 200 b.p.s. for time-shared applications in which advantage cannot be taken of higher transmission speeds.

Speeds higher than 10 K.b.p.s. will require wideband circuits which are already available in Australia on many routes. The C.C.I.T.T. has already standardised on modems to operate at 48 K.b.p.s. on wideband analogue circuits of 48 Khz (equivalent to 12 telephone circuits). Transmission at these speeds will generally be required only for computer-to-computer operation.

Another development which could affect data transmission techniques will be the progressively more widespread use of pulse code modulated (PCM) systems. These systems operate on the principle of encoding speech for transmission in digital form. This is the reverse of the process now employed for data transmission, where digital data is converted to analogue form for transmission on a telephone line. Since with PCM on present techniques one speech channel consists of a data stream of approximately 56 K.b.p s., PCM systems provide potentially large numbers of high speed data channels. Early use of PCM will be in the local junction network over relatively short distances, but it is forecast that ultimately PCM systems will supersede the present analogue frequency division type systems.

As regards terminal equipment, there is no doubt that these will continue to proliferate as they have done in the past. At this stage, however, there are certain probable developments which are worth some comment.

One of the major changes in the telephone which is likely to occur on a wide scale during the 1970's is the introduction of push-button selection to replace the traditional rotary dial. The version of the push-button telephone most likely to gain general acceptance is one which sends the digital selection data by means of multi-frequency tone signals. Clearly the tone signalling arrangements in the telephone are really a built-in modem which would enable the selection buttons to be used after the setting-up of the call for data sending. Although the push-buttons would normally represent only numerical characters, two additional buttons can be provided to send a further two code combination which may represent special functions or be used to modify the meaning of the numerical buttons.

Computers can be programmed to respond to such devices by means of selections of pre-recorded words, thus eliminating the need for any special data reception attachment. The widespread use of push button telephones clearly will open the way for the use of data transmission techniques from almost anywhere. Thus it will put the small retailer, the housewife, the travelling salesman and the public in general within reach of computers.

A telephone attachment which would enhance the utility of the push-button phone as a data sending device is the automatic dialler. One version uses small punched cards to automatically dial commonly used numbers. Such cards could also be used as data sources and would be particularly useful in providing, for example, customer identification sequence or special message formats required by a computer.

Another development in the telecommunications area which may have far-reaching consequences in the data transmission business is the T.V. telephone. Whilst this will be designed primarily for transmitting pictures from person to person, the possibility obviously exists for using the same screen for displaying digital data from a computer.

In the area of printing two possibilities are worth mentioning. At present there are cheap forms of data sending, but printing tends to be relatively expensive. There is therefore scope for development of a very cheap printing device which may be used in association with a low cost sender such as the push-button telephone. There is also a need for development of a medium speed printer at reasonable cost. At present there is a gap in the range between character printers, operating at speeds generally less than a thousand characters per minute and line printers which operate at upwards of 36,000 characters (300 lines) per minute. There is also a substantial gap in the cost of these two families of devices.

THE NEED FOR NEW DATA SWITCHING NETWORKS.

It is now generally recognised by telecommunications administrations that whereas the existing telephone and telex networks, backed up by private leased lines, can meet the data transmission requirements of a large number of users, there will be many whose needs can be better met by special data transmission networks tailored to meet their particular requirements. Later papers in the conference will describe the first step now being taken by the Australian Post Office to meet some of these special needs—the provision of a Common User Data Network. By using store-and-forward techniques, this network will be able to cater for varying speeds and will provide facilities such as concentration, temporary storage and assembly of messages, error control, priorities and speed and format conversion. Many of these facilities would otherwise have to be provided by the user's private network.

For wideband transmission, which is likely to be required particularly for communications between computers, there are likely to be few individual users who will require full-time wideband channels. Use of these facilities is likely to be characterised by short periods of rapid interchange, which implies a requirement for switching facilities to enable the circuits to be paid for on the basis of usage. Whilst it will be possible to develop C.U.D.N. facilities to carry wideband messages, it is likely to be more economical to deal with this traffic on a line-switched basis so that there will be direct connection between the terminals. A small trial switching system of this type is therefore being developed. A system of this type would, of course, be suitable for switching high speed data in non-digital forms such as, for example, facsimile transmissions.

With the introduction of C.U.D.N. there will be three separate networks within Australia carrying non-voice traffic—telex, tress (for public telegrams) as well as C.U.D.N. The need for interfacing each of these networks and of providing enhanced facilities in each, leads to the conclusion that there is a requirement for a new data network capable of embracing all of these requirements plus all of the newly emerging requirements of the computer industry. Such a network would provide for switching of lines of various speeds, providing line switching as well as store-and-forward switching and for digital and analogue forms. The Post Office is therefore already seriously considering the facilities required in such a network which it believes will be needed in the second half of the 1970's.

It should be mentioned that the need for special data networks has been recognised internationally and the C.C.I.T.T. (the international body charged with technical development of international communications) has been studying the question for two or three years and is continuing to pursue this study actively. There is no reason why C.U.D.N. should not be connected via international links to overseas terminals or to compatible networks in other countries if such demands should arise. However, the more comprehensive network which is planned for the future will probably be designed to meet the standards recommended for the international data network and will thus form part of a worldwide special network for data transmission of all forms.

SUMMARY.

The 1970's will be a period in which data transmission will grow rapidly as a result of more extensive use of on line computer facilities. These developments will bring computer facilities to a wider spectrum of users and to many new areas of application. Some of the social changes which will be brought about by remotely accessed computers before the end of this century will have commenced before the end of the 1970's.

MISS. A. WRIGHT, I.S.M.

The retirement of Miss A. Wright from the Department brought an opportunity for the Telecommunications Society of Australia to express appreciation for service which began in 1950 and in fact is still continuing. Miss Wright has served the Society in a clerical-administrative role both in the distribution of the Journal for the Council of Control and as Assistant Secretary to the Victorian Division. She has seen the Society grow from the Postal Electrical Society of Victoria to the present multi-Division structure. Her association with this Journal has spanned a time when she was responsible for all Australian and overseas subscribers (up to 1958), to a time when she was responsible for all Victorian subscribers, and on behalf of Council of Control, dealt with all overseas subscribers as well as the paper work associated with the printing and publication of each issue.

The Society honoured Miss Wright at a presentation function on June 25, 1970, in Melbourne. The Board of Editors takes this opportunity to record its sincere appreciation for loyal service maintained with unflagging enthusiasm and thoroughness over such a significant part of the total history of the Journal.

Miss Ann Wright speaks with Mr. R. Kitchenn, General Secretary (Left) and Mr. A. Morton, Secretary Victorian Division, at her farewell function in Melbourne on 25 June, 1970.

THE DEVELOPMENT OF DATA TRANSMISSION SERVICES IN AUSTRALIA

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

GENERAL BACKGROUND.

Data transmission is an expression which includes what has been known traditionally as telegraphy. The traditional forms of telegraphy were mainly concerned with the transmission of messages between people, more usually in plain language, and tended to operate over transmission paths and with switching plant particularly designed for telegraph purposes. Telegraphy continues to advance on a broad field, particularly in the development of the worldwide direct switching telex network, but also in the development of extensive public and private telegraph systems working in the message switching (or 'store and forward') mode. In recent years there has been widespread development of telegraph techniques to transmit 'messages' between machines, in languages adapted to machine input and output.

The rapid increase in the application of computers in a great many areas of business, government and industry has been the most obvious impetus to the development of these techniques (Ref. 1), but more generally it is the process of automation which has demanded these techniques. Perhaps the most common requirement is in the automation of clerical processes. Here a frequent requirement is the collection of unprocessed data from many points to a central point for processing. Examples are the automation and centralisation of ledger records in the banking industry and data collection from many terminals for totalisator purposes. Data dissemination from a central computer to a number of peripheral terminal devices is another requirement frequently encountered. Often these two requirements are combined, with data entry to a central computer from a number of terminals over telecommunications networks and data dissemination from the same central point to a number of terminals, as for example in the meteorological data collection and distribution system. A further situation which is frequently encountered is that in which there is an interaction between a terminal and a central computer, i.e., the terminal sends data to the computer, which responds with data directed to the same terminal. Examples are airline reservation systems in which the availability of a seat on a particular flight can be ascertained from airline sales offices by interrogating the computer which sends back an answer usually appearing in the form of a cathode ray tube visual display. Time sharing computer services also use this interactive mode. Some of the more frequently encountered data system configurations are shown in Fig. 1.

It is the particular purpose of this article to place the introduction of datel services and the equipment provision made for these services in the general context of telecommunication development. In doing so there are many subjects which can only be lightly touched upon, and some sub-

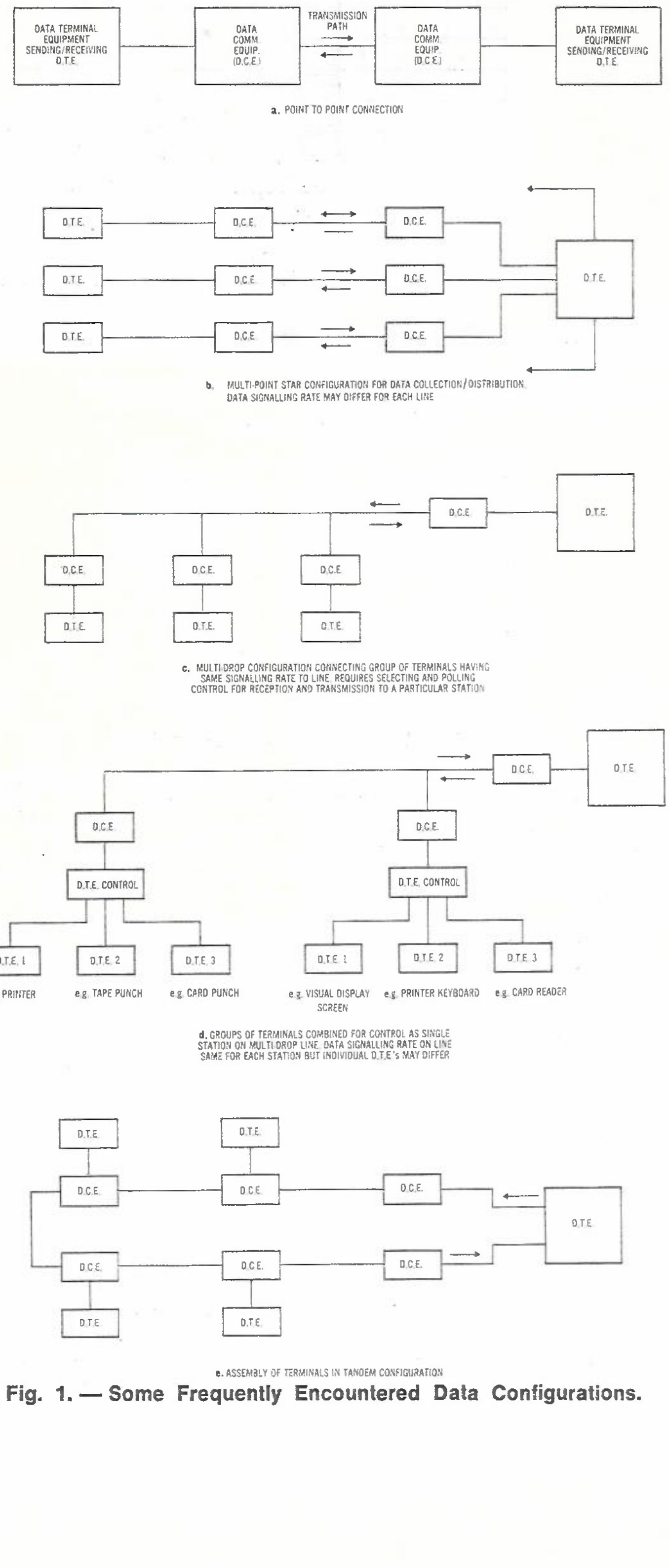


Fig. 1. — Some Frequently Encountered Data Configurations.

*Mr. McKinnon is Engineer Class 4, Subs. Equipment and Telegraphs, H.Q. (See Vol. 14, No. 2, P. 169).

Bits b7 →					0	0	0	0	1	1	1	1
b6 →					0	0	1	1	0	0	1	1
b5 →					0	1	0	1	0	1	0	1
b4	b3	b2	b1	Row \ Col	0	1	2	3	4	5	6	7
0	0	0	0	0	NUL	DLE	SP	0	(@)	P	`	p
0	0	0	1	1	SOH	DC1	!	1	A	Q	a	q
0	0	1	0	2	STX	DC2	"	2	B	R	b	r
0	0	1	1	3	ETX	DC3	£	3	C	S	c	s
0	1	0	0	4	EOT	DC4	$	4	D	T	d	t
0	1	0	1	5	ENQ	NAK	%	5	E	U	e	u
0	1	1	0	6	ACK	SYN	&	6	F	V	f	v
0	1	1	1	7	BEL	ETB	'	7	G	W	g	w
1	0	0	0	8	BS	CAN	(	8	H	X	h	x
1	0	0	1	9	HT	EM	)	9	I	Y	i	y
1	0	1	0	10	LF	SUB	*	:	J	Z	j	z
1	0	1	1	11	VT	ESC	+	;	K	([)	k	
1	1	0	0	12	FF	FS	,	<	L		l	
1	1	0	1	13	CR	GS	—	=	M	(])	m	
1	1	1	0	14	SO	RS	.	>	N	^	n	—
1	1	1	1	15	SI	US	/	?	O	—	o	DEL

TRANSMISSION CONTROLS — FORMAT EFFECTOR — INFORMATION SEPARATORS — DEVICE CONTROLS

NOTES TO THE CODE TABLE QUALIFYING THE SIGNIFICANCE OF THE CHARACTER SHOWN, RESERVING FOR NATIONAL USE OR ALLOWING OPTIONS TO APPLY

TABLE OF CONTROL CHARACTERS

NUL	Null	DLE	Data Link Escape
SOH	Start of Heading	DC1	Device Control 1
STX	Start of Text	DC2	Device Control 2
ETX	End of Text	DC3	Device Control 3
EOT	End of Transmission	DC4	Device Control 4 (Stop)
ENQ	Enquiry	NAK	Negative Acknowledge
ACK	Acknowledge	SYN	Synchronous Idle
BEL	Bell	ETB	End of Transmission Block
BS	Backspace	CAN	Cancel
HT	Horizontal Tabulation	EM	End of Medium
LF	Line Feed	SUB	Substitute
VT	Vertical Tabulation	ESC	Escape
FF	Form Feed	FS	File Separator
CR	Carriage Return	GS	Group Separator
SO	Shift Out	RS	Record Separator
SI	Shift In	US	Unit Separator

Fig. 2. — 7 Bit Coded Character Set.

jects of importance which are entirely omitted. It is to be hoped that other authors will fill out the data transmission picture with more detailed treatment of these subjects in this very important field.

CODES FOR DATA INTERCHANGE.

One of the many problems which hampered the early development of data transmission was the variety of codes available from machine suppliers. These had developed over the years within the data processing industry without particular reference to their suitability for transmission over telecommunications networks, or their compatibility one with the other. This is a problem of standards and the main responsibility for data standards is shared by two international authorities, the International Consultative Committee for Telegraphy and Telephony (C.C.I.T.T.) and the International Standards Organisation (I.S.O.). These two bodies eventually undertook the development of a standard alphabet and code for data interchange. Their work was based on the development of a standard by the United States national standards body. The alphabet and code standardised is covered by C.C.I.T.T. Recommendations V3 and V4 and corresponding I.S.O. Recommendations.

These international recommendations have been issued by most national standard bodies as national standards. As an indication of the wholehearted commitment to these standards, in some countries it is interesting to note that the world's biggest customers for data processing equipment, the U.S. Government, passed a law requiring that all data tele-processing equipment which it buys or leases after July, 1969, should use this standard code and character set. Australian Standard XI-1969 (Ref. 2) entitled '7 bit Coded Character Set for Information Processing Interchange' contains the material of C.C.I.T.T. Recommendation V3 (Ref. 3). Later standards to be issued will cover its character structure for start-stop and synchronous transmission and its implementation in various forms of information interchange media. The 7-bit (code element) coded character set is shown in Fig. 2.

Standard Alphabet and Principles of I.S.O./C.C.I.T.T. Code for Information Interchange.

The I.S.O./C.C.I.T.T. Standard is a 7-bit code giving 128 code combinations arranged in Fig. 2 in 8 vertical columns and 16 horizontal rows. Important points to notice from a data transmission point of view are:

(a) There are two kinds of character — control and graphic.

(b) Ten of the 32 control characters are allotted as communication controls.

(c) Although a 7 intelligence bit code, an eighth parity bit is added in location b8 and is therefore transmitted after the 7 significant bits of the character, and may be used for error detection purposes.

(d) For asynchronous systems, the parity bit is chosen in such a way that the number of 'one' bits is even, in synchronous systems such that the number of one bits is odd.

(e) One of the transmission control characters, DLE (Data Link Escape), may be used to change the meaning of a limited number of contiguously following characters. It is used exclusively to provide supplementary data transmission control functions.

Although there are many other codes in use, there is widespread acceptance of this code, or subsets of it, in the development of new data terminal equipment or of data systems. The acceptance of this standard has greatly stimulated the growth of data transmission services.

TRANSMISSION OF DATA.

The introduction and expansion of data transmission facilities have naturally been based upon the exploitation of the existing transmission grid provided basically for telephone transmission. More recently the somewhat different requirements of data transmission have been injected into the specification of new transmission plant. Digital data communication is efficiently coded compared with voice communication of language. All languages are highly redundant and follow structural rules. These two factors limit the loss of information which

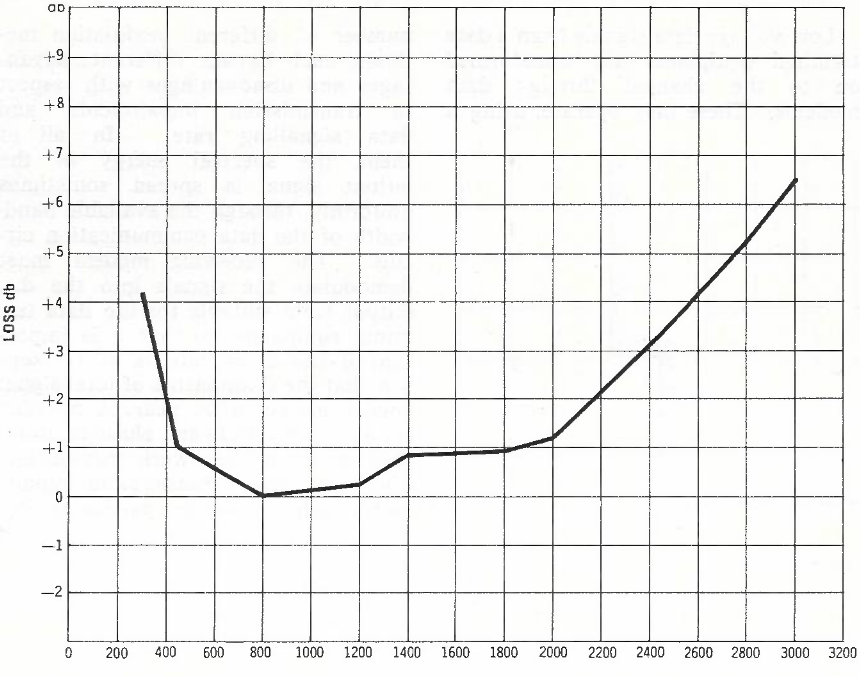


Fig 3. — Typical Measured Attenuation/Frequency Curve of Single Carrier Channel Between Melbourne and Sydney.

occurs in voice communication when bursts of noise occur, or when there is momentary loss of transmision. Disturbances in random data transmission cause output errors which cannot be so simply eliminated. Error protection systems have been designed which add a designed redundancy and structure (format) to data transmission. At the receiving end, error detection and correction is then possible. The raw error rate, that is the error rate in data transmission over a channel without the application of an error protection system, is of primary importance.

Channel Capacity and Errors (Refs. 4 and 5).

According to information theory, the capacity or rate of passing information of a communication channel is proportional to frequency bandwith and signal power and inversely proportional to noise power. The relation connecting these quantities considering an idealised channel limited in bandwidth and disturbed by random noise is:

$C = W \log_2 (1 + S/N)$ bits/second

where C is the channel capacity in bits/second, W is the channel bandwidth in Hz and S/N is the signal to random noise power ratio.

If noise increases for the same signal power (i.e., S/N is reduced), channel capacity decreases, provided the bandwidth remains constant. Within a communication system there are two basic types of noise, idle or random noise and intermodulation noise. Intermodulation noise is the result of non-linearities in the equipment through which the signal must pass. Within design limits these non-linearities are small, but upon increasing signal power beyond the design limits non-linearities become important. Thus signal power and noise in practical communication systems are not independent variables when signal power rises to the point where non-linearities causing intermodulation occur.

Many parts of the total communications network are affected by data loading. In what might be called the 'hard-wired 'portion of data path which is the path between the data modem and the long distance carrier channel modem the data signal is at voice frequency. Here the path is through open wire or underground cable pairs, exchange mainframes and in the case of operation over the switched network, through electro-mechanical switches. In this portion of the total path the effect of impulse noise is particularly important and is, in practice, the most serious form of disturbances to data.

Transmission Impairments.

For a channel of given bandwidth two departures from the idealised channel, which was the basis of original theoretical studies are of particular importance. These are attenuation distortion and envelope delay distortion. (As previously mentioned, noise also enters into the information transfer equation in a fundamental way.) Attenuation distortion is the unequal attenuation of different frequences transmitted over a channel; envelope delay distortion is the unequal time delay of the information (envelope) carried in the different frequencies. Figs. 3 and 4 give typical curves

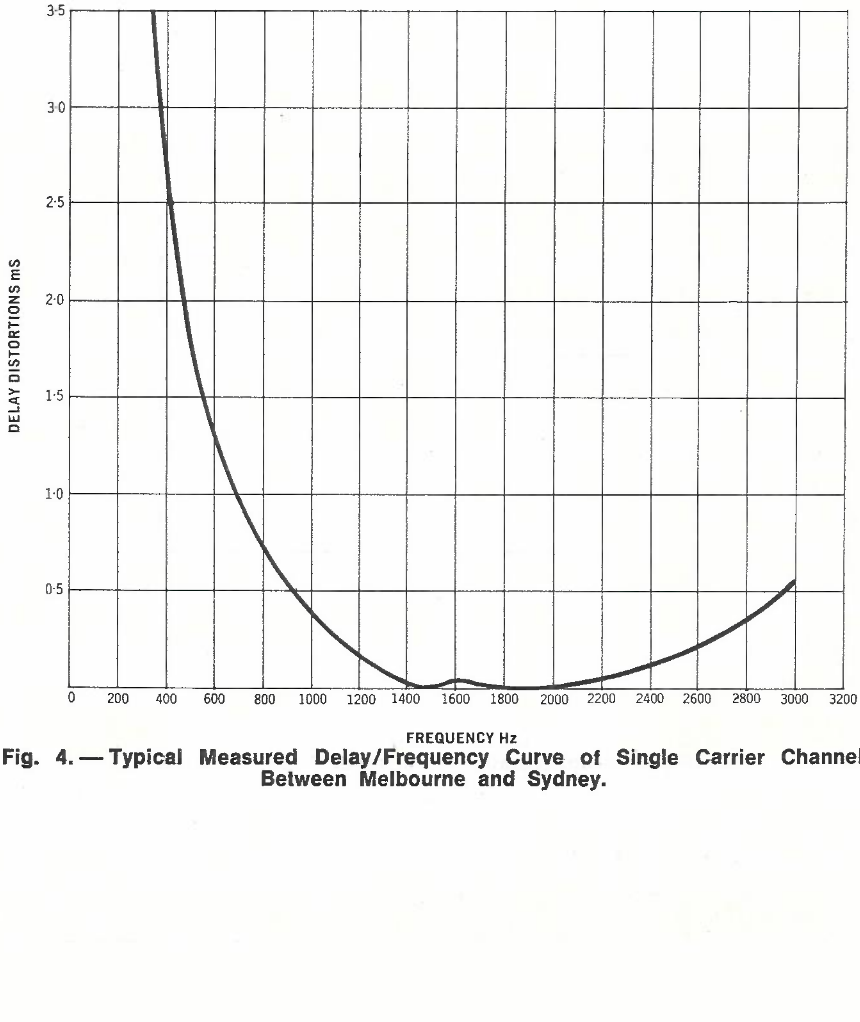
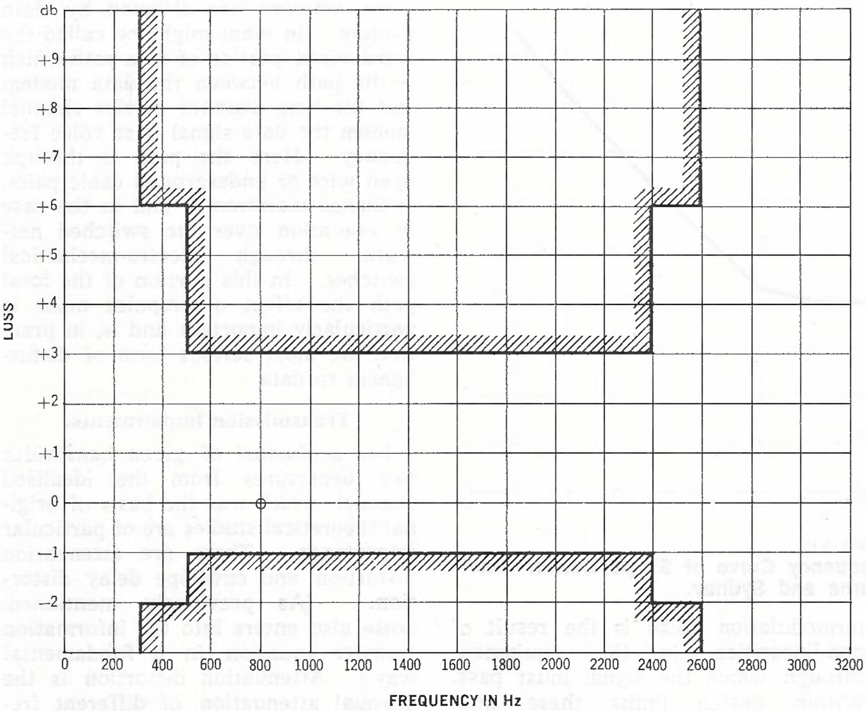


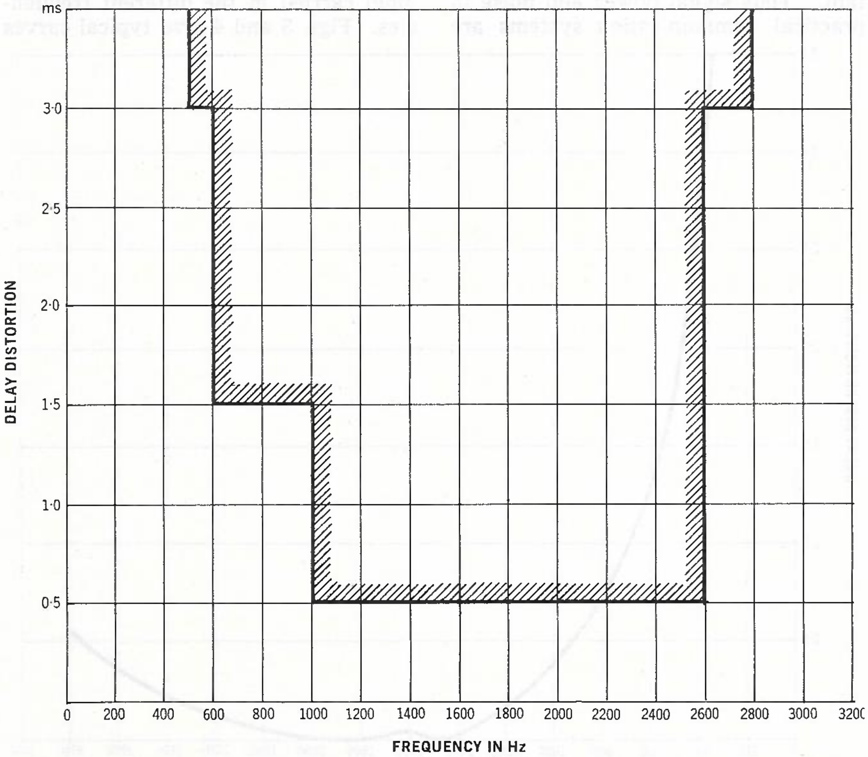
Fig. 4. — Typical Measured Delay/Frequency Curve of Single Carrier Channel Between Melbourne and Sydney.

for a standard carrier voice channel with a nominal pass band of approximately 3 kHz, using standard 4 kHz channel spacing.

Low voltage data signals from a data terminal equipment are transformed on to the channel through data modems. These may operate, using a number of different modulation methods, each having different advantages and disadvantages with respect to transmission impairments and data signalling rate. In all of them, the spectral energy of the output signal is spread, sometimes uniformly, through the available bandwidth of the data communication circuit. The receiving modem must demodulate the signals into the d.c. output form suitable for the data terminal equipment so that it is important if the error rate is to be kept low that the components of total signal energy arrive in as near as possible the same amplitude and phase relationship as when they were transmitted. There are other transmission impairments which assume particular importance for certain forms of modulation, e.g., phase jitter with respect to multi-phase modulation, channel asynchronism for frequency shift operation using small frequency deviation.



PERMISSIBLE VARIATION OF OVERALL LOSS WITH FREQUENCY FOR THE VOICE-FREQUENCY CHANNEL



PERMISSIBLE VARIATION OF OVERALL DELAY DISTORTION WITH FREQUENCY FOR THE VOICE-FREQUENCY CHANNEL

Fig. 5. — Specification of Channel Characteristics.

Conditioning of Channels.

Attenuation distortion and envelope delay distortion can be brought within specified limits by additional compensating equipment added to the channel. Channels may also be selected for low noise. These measures are frequently taken to ensure satisfactory error rate performance for data signalling at a given rate and with a given form of modulation, e.g., for 2400 bit/second data transmission using 4 phase differential modulation. The attenuation distortion and delay distortion characteristics shown in Fig. 5, which is taken from C.C.I.T.T. Recommendation M102, are, for example, specified in this case, together with other important parameters.

Switched Telephone Network as Transmission Medium.

Specification of the desired transmission characteristics is possible within limits on leased circuits, but when the switched telephone network is used the spread of characteristics encountered in that network must in general be accepted. Attenuation distortion may be quite severe for extreme switching path conditions, and envelope delay distortion variable depending on the routing of the particular call. Most countries have made a series of tests of the performance of the switched network with respect to data transmission and Fig. 6 is typical of the results achieved in one large network.

The addition of a data transmission load to the network may, by its different nature, affect the network both for speech and for data and specifi-

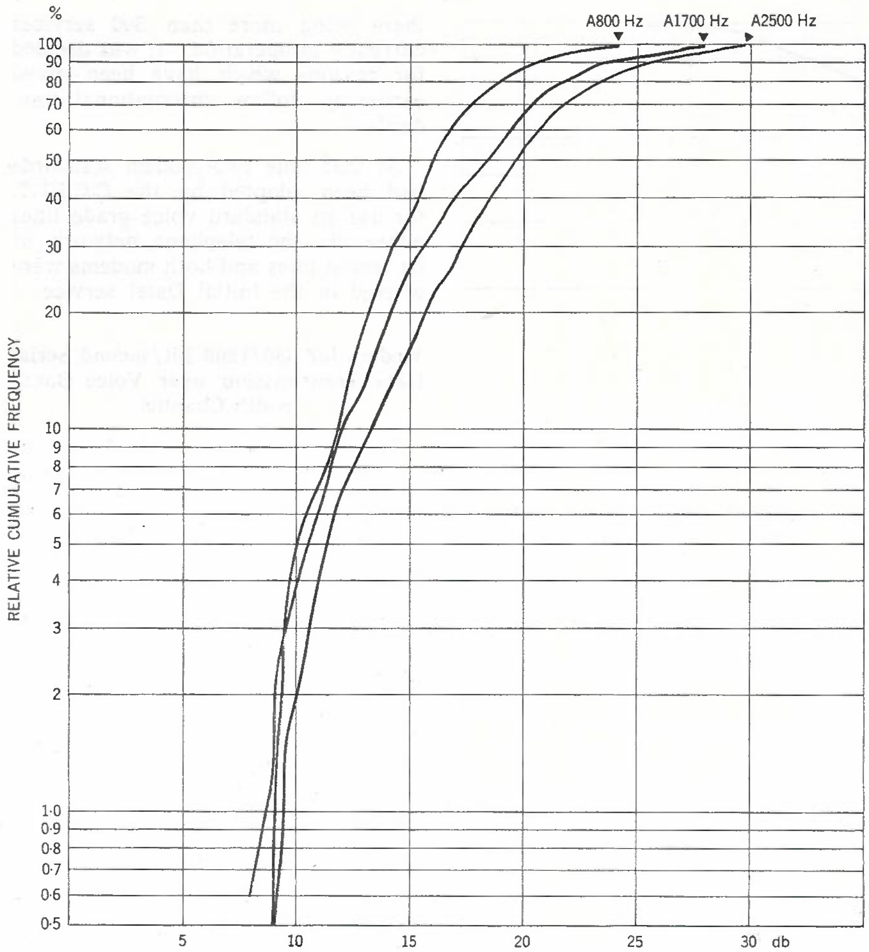


Fig. 6a. — Relative Cumulative Frequency Distribution of Overall Loss at 800 Hz, 1700 Hz and 2500 Hz in Subscriber to Subscriber Test Connections.

cation of transmission conditions must for those reasons be conservative. Circuits in switched telephone networks are generally equipped with some form of in-band signalling system which must not be falsely operated by data tones. Power loadings of individual voice circuits when combined for group amplification are based upon statistical distribution of instantaneous power loads, in groups of speech circuits, a distribution which is distorted if voice circuits used for constant load data transmission are a significant percentage of the total number of circuits in use. Consequently the design for modems for use on the switched telephone network and transmission plan conditions applied to them are restrictive, to avoid interference with signalling systems and to avoid potential amplifier overloading problems.

In some long distance telephone connections within Australia and on international calls, echo suppressors are used to attenuate echoes. Inserted at four-wire points, echo suppressors operate by increasing the loss in the transmission path that is opposite in direction to the one being used. It is a frequent data transmission requirement to have both directions of transmission open, with frequency separation from the modems at the two-wire tails. In this case it has been possible to use a modem generated control signal which is internationally standardised to disable echo suppressors, perhaps the only case at the present time in which the data equipment can automatically control the telephone network path to a particular data need.

As telephone networks are modernised the opportunity exists for specialised treatment of data, for example by class marking data calls. This would permit control of routing in such a way as to offer more favourable path conditions. Discrimination for data is already employed in Australia, under manual control for international data switching. Most intercontinental channels from Australia have a spacing of 3 kHz and are equipped for TASI (Ref. 6) operation which would be ineffective on channels carrying continuous signal data. Manual control permits connection of data to full bandwidth channels selected for low noise and excluded from TASI operation. Recognition of data calls throughout a network under automatic control is of course very much more complex and the large capital investment in existing long-life switching plant which is not suited to adaption for this purpose limits the special treatment which could be given to data calls.

Data transmission over the present switched telephone network has the many disadvantages mentioned, viz., the wide spread of transmission characteristics leading to design restrictions on data modems, the effects of impulsive noise which is more severe than is the case in leased channels leading to higher error rates. Connection over the switched network has, however, one very important advantage in the almost universal availability of the service and in its lower cost for light duty applications than the comparable leased circuit or network. Consequently the switched telephone network has been used extensively for light duty data transmission purposes in which its switching or concentrating capability is of particular benefit. The Australian General Electric and I.B.M. time-sharing computer services are particular examples of applications in this country.

DATA MODEMS.

In Australia data service commenced with customer provided data modulators/demodulators (modems) in the latter half of the 1960's. The Post Office examined modems submitted for 'permit to connect' against standards specified in its Handbook 'Telecommunications Facilities for Data Transmission' (Ref. 7). Broadly, the conditions specified guarded Post Office plant against interference and safeguarded Post Office staff against potentially dangerous circuit conditions. 'Permit to connect' gave no guarantee of effective operation on a data channel, or of compatibility with other modems. Development of services was slow. The Post Office itself decided to provide modems at rental in 1967, and the service was introduced as the Post Office Datel service in late 1968. The word 'datel' is derived from two words; data and telecommunications, and signifies transmission of data over the telecommunication circuits. Since introduction of the Datel Service, development has been rapid,

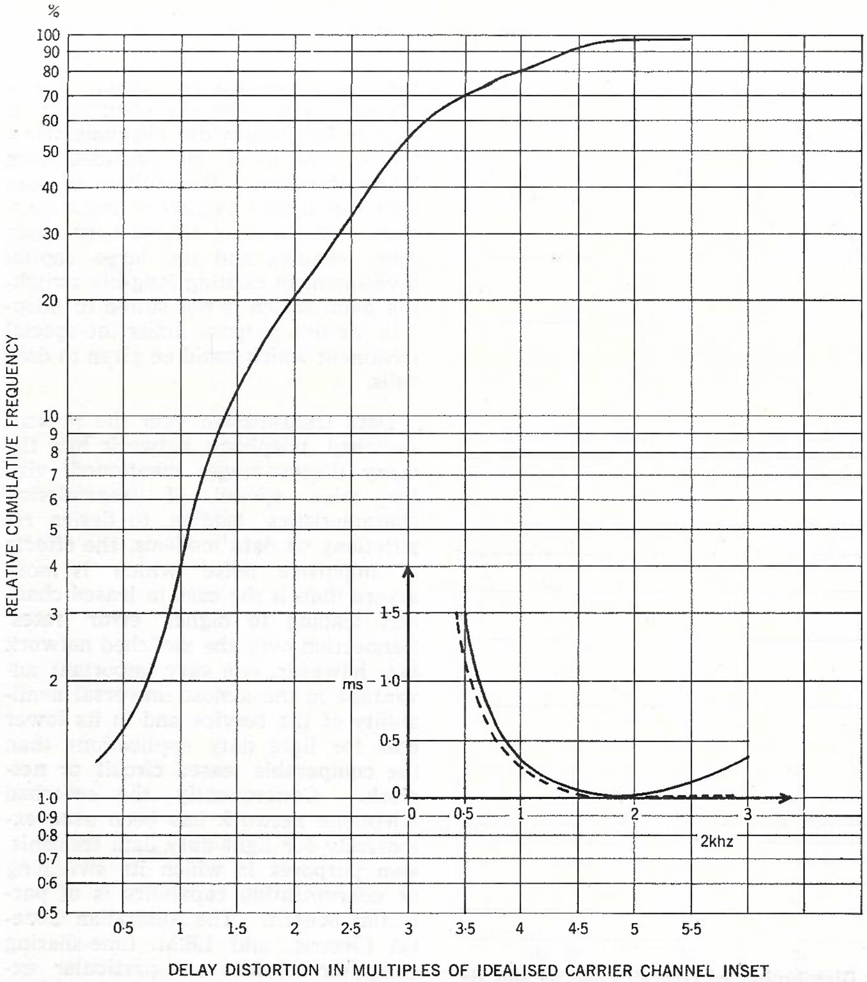


Fig. 6b. — Relative Cumulative Frequency Distribution of Delay Distortion in Multiples of Idealised Carrier Channel in Subscriber to Subscriber Test Connections.

there being more than 600 services currently in operation. It was decided for reasons which have been given earlier to follow international standards.

At that time two modem standards had been adopted by the C.C.I.T.T. for use on standard voice grade lines either via the telephone network or on leased lines and both modems were offered in the initial Datel service.

Modem for 600/1200 Bit/second Serial Data Transmission over Voice Bandwidth Channel.

The first of these, to C.C.I.T.T. Recommendation V23, is for the transmission of data at data signalling rates of 600 or of 1200 bits per second in one direction, with transmission in the reverse direction at 75 bits/seconds as an option. On four wire leased circuits these modems may be used for duplex data transmission at 600 or 1200 bits/second with the low speed backward (or supervisory) channels also available. The modem employs binary frequency shift modulation for both data and backward channels. For the forward or data channel different centre frequencies and deviations are used according to the data signalling rate, which since the modulation is binary is also the modulation rate in bauds. Mode 1 provides optimum transmission performance for this type of modulation for a data signalling rate of 600 bits/second. Mode 2 is used

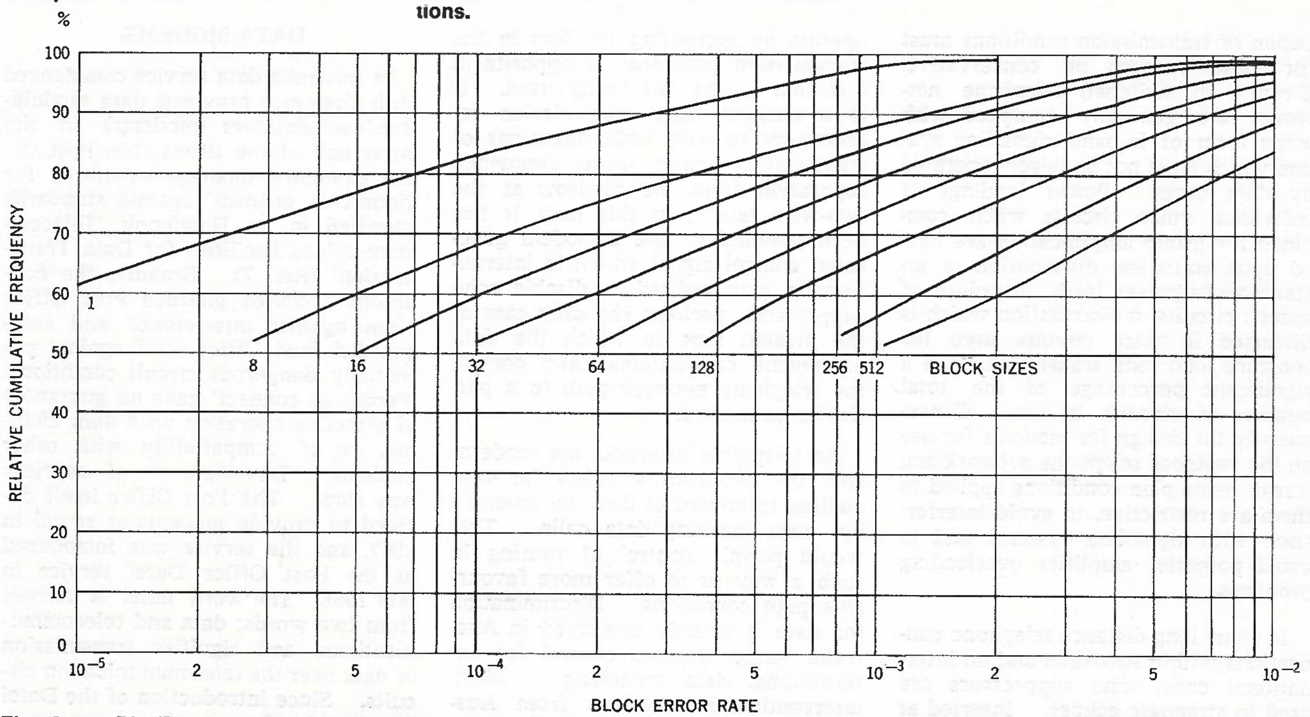


Fig. 6c. — Bit (Block Size = 1) and Block Error Rates for Data Transmission over Test Connections Through Switched Network at 1200 B.p.s. Using C.C.I.T.T. Recommendation V23 Modem.

TABLE 1.—CHARACTERISTIC FREQUENCIES OF 600/1200 BIT/SECOND MODEM

Mode	Description	Fo	Fz	Fa
			(Symbol 1, mark)	(Symbol O, space)
Mode 1	Up to 600 bauds	1500 Hz	1300 Hz	1700 Hz
Mode 2	Up to 1200 bauds	1700 Hz	1300 Hz	2100 Hz
Backward Channel	Up to 75 bauds	420 Hz	390 Hz	450 Hz

for 1200 bits/second. Table 1 lists the characteristic frequencies used in 600/1200 bit/second modems.

The Post Office after evaluating tenders from manufacturers throughout the world selected equipment from Standard Radio and Telefon AB of Sweden. Fig. 7 is a block schematic of one of the 9 options available, in what has been called Plan 32 service. The option shown in Fig. 7 is suitable for use on the switched telephone network providing what it known as 'half-duplex' operation over a two wire connection. Transmission and reception of data is possible in both directions alternately.

The modem uses six interchange circuits with the data processing terminal equipment as is shown in the figure. At each end the data modem is connected to line by means of a signal at the interchange circuit 'Connect Data Set to Line' (20) and as a result a signal is returned via the interchange circuit 'Data Set Ready' (6) to indicate that the connection has been made. After this, a blocking circuit in the modulator through which the data signals are passed to the filter is disabled by a signal at the interchange circuit 'Request to Send' (4). This signal also causes the Ready for Sending Unit to reverse the polarity of the interchange circuit 'Ready for Sending' (5), which indicates to the data processing terminal equipment that the modem is ready for sending. An inbuilt delay circuit in the Ready for Sending unit delays the polarity reversal for about 20-50 mS or 400-1000 mS, depending upon strapping, allowing for transmission of echo suppressor disabling tone where the modem is so equipped, and permitting the switched path transients to die away.

The remaining interchange circuit 'Data Signalling Rate Selector' (23) carries out the function of selecting the appropriate channel mid-frequencies for either the 600 to 1200 baud data transmission. The polar data signals are fed to the modulator, where they are transformed to higher carrier frequency signals. These carrier signals are then translated to a lower frequency by a band translator in order to bring them within the frequency band required for transmission over telephone circuits.

In reception the received carrier frequency signals are fed via the separation filter to the demodulator, where they are translated to a higher frequency band by a band translator and then demodulated and converted to the digital form. After pulse shaping the signals are fed out of the modem via the interchange circuit Received Data (3). The functions of the interchange circuits involved in the connection of the data set to line are the same as previously mentioned.

In this half-duplex system a portion of the signal energy sent out from the data channel modulator to line is fed back to the data channel demodulator via the line transformer. This signal energy would be demodulated in the normal way, converted to its original binary form and fed out via the interchange circuit Received Data (3) to its own data-processing terminal equipment. To prevent this undesirable effect from taking place, a facility is provided which inhibits the data channel demodulator while data is being sent. On Fig. 7 this facility is shown as a lead between the Request to Send control and the data channel demodulator.

Some data terminal equipments expect the modem to clock the data out of the data source. At the receiving end the clocked modem, which is synchronised with the sending end, regenerates the incoming signals so that undistorted signals can be fed on to the receiving terminal equipment. There is also a traffic advantage in that only intelligence bits are sent, whereas in asynchronous operation start and stop elements must be sent. A clocked option is available on the modem described for synchronous modem operation.

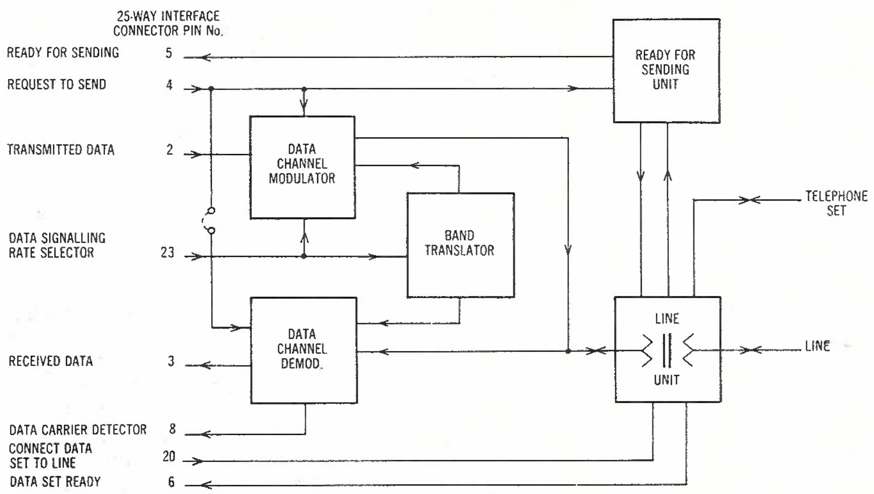


Fig. 7. — Block Cchematic Diagram of 600/1200 Baud Modem Type E.

Modem for 200 Bit/Second Serial Data Transmission over Voice Bandwidth Channel.

The second modem offered at the commencement of datel service was the 200 bit/second modem to C.C.I.T.T. Recommendation V21. These were purchased from the same company in the same frame and using the same power unit as for the 600/1200 bit/second modem. This feature of the design allowed a high degree of flexibility in the use of equipment in a market which did not at that time have a clear pattern of demand. Fig. 8 shows this modem with covers removed. The modem offers a data transmission facility (known as Plan 31 service) suitable for subscribers using simple data processing terminal equipment operating at low speed, e.g., a low speed data teleprinter, and provides for duplex asynchronous operation so that data may be sent simultaneously in both directions or in either direction at will. Frequency shift modulation is em-

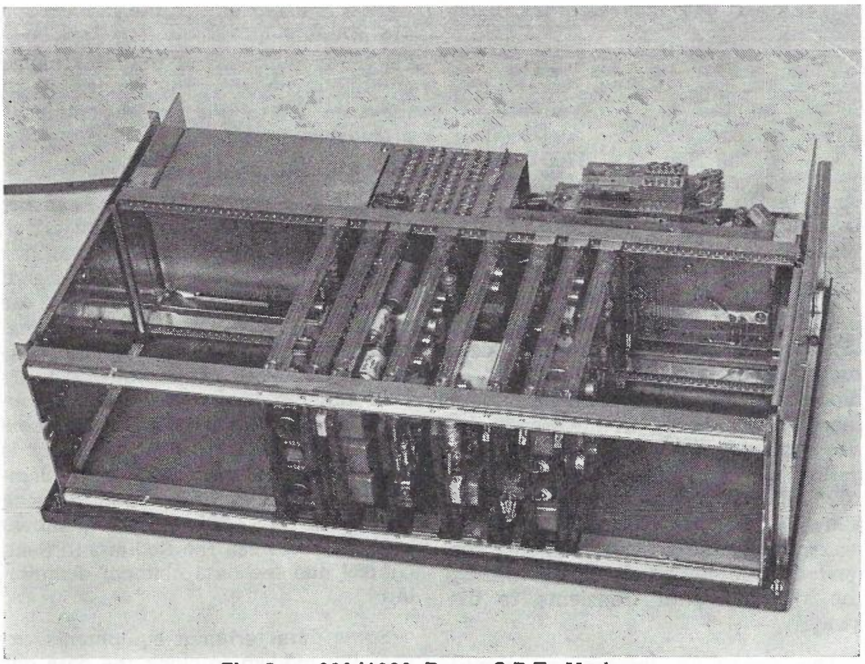


Fig 8. — 600/1200 B.p.s. S.R.T. Modem.

TABLE 2.—CHARACTERISTIC FREQUENCIES USED IN 200 BIT/SECOND MODEM.

Channel No.	Nominal Mean Frequency (Fo, Hz)	Binary Symbol 1 (Fz, Hz)	Binary Symbol 0 (Fa, Hz)
1	1080	980	1180
2	1750	1650	1850

ployed using the frequencies listed in Table 2.

The facility is so arranged that upon a telephone connection being set up between stations equipped with these modems the calling party transmits on the lower frequency channel (channel 1) while the called station transmits on the higher frequency channel (channel 2).

Fig. 9 is a block schematic of the 200 baud modem. When the switched telephone network is used a connection is set up between two subscribers in the usual way. The functions of the standardised C.C.I.T.T. Recommendation V24 interface are as described for the 600/1200 b/s modem. After the connection sequence (called the 'hand-shaking' sequence in the United States), polar data signals are fed to the modulator via the interchange circuit Transmitted Data (2) and the channel mid-frequency is selected by means of a signal at this interchange circuit Select Transmit Frequency (11). The latter signal also connects the carrier frequency signals to the correct side of the separation filter. The received carrier frequency signals are fed via the separation filter to a demodulator in which they are brought to a higher frequency band by a translation modulator. This frequency depends upon the frequency of the translation oscillator and is controlled by a signal at the interchange circuit Select Transmit Frequency (11). The signals are then fed through an amplifier limiter to the discriminator, where they are changed back to digital form. After pulse shaping, the signals are fed out of the equipment via the interchange circuit Received Data (3). The demodulator is equipped with an amplitude detector which supervises the amplitude of the carrier frequency signals. The output from this detector is connected to the interchange circuit Data Carrier Detector (8) and to the data signal output switch. When the input level falls below the predetermined minimum operating level, the polarity on the interchange circuit (pin 8) is reversed and the data signal output is blocked.

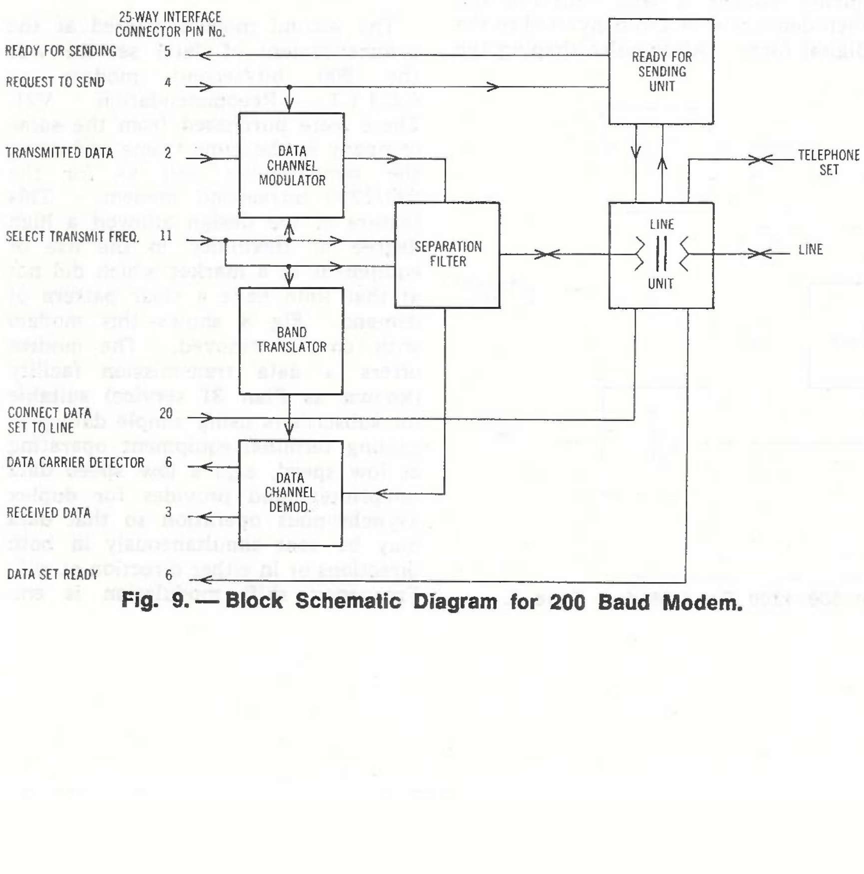


Fig. 9. — Block Schematic Diagram for 200 Baud Modem.

Modem for 2400 Bit/Second Serial Data Transmission over Voice Bandwidth Channel.

At the fourth Plenary Assembly of the C.C.I.T.T. in 1968 at Mar del Plata, in the Republic of Argentine, a modem for transmission of 2400 bits/second serial binary data over a voice bandwidth channel was recommended. The principal characteristics of the modem specified in this Recommendation (V26) are:

(a) That it is designed for 2400 bits/second operation over four wire leased voice channels having specified characteristics of particular importance with respect to group delay. These characteristics are specified in Recommendation M102, two of the leading characteristics being shown in Fig. 5.

(b) That it uses four phase differential modulation with a modulation rate of 1200 bauds, using a carrier frequency of 1800 Hz for 2400 bits/second synchronous mode transmission.
(c) That the data input is divided into pairs of consecutive bits (dibits). Each dibit is encoded as a phase change relative to the phase of the immediately preceding line signal.
(d) It is capable of operating as a full duplex transmission facility.
(e) An optional backward (supervisory) channel with a line signalling rate of 75 bauds having the same characteristics as the backward channel in the 600/1200 bit/second (Rec. V23) modem may be provided.

There is an apparent advantage in four phase (quaternary) modulation as compared with binary since for the same modulation rate the data signalling rate may be doubled. Transmission theory shows that this is not done without disadvantages in other directions such as in margin to noise. (Refs. 4 and 5.) Greater pains are therefore taken to achieve channel performance closer to the ideal than, for example, with channels for the 600/1200 bit-second Recommendation V23 modem.

It was unfortunate that C.C.I.T.T. was unable to agree upon a single coding table, the Recommendation allowing two alternative arrangements as given in Table 3 below. Alternative A is in general use in Europe, alternative B in the United States.

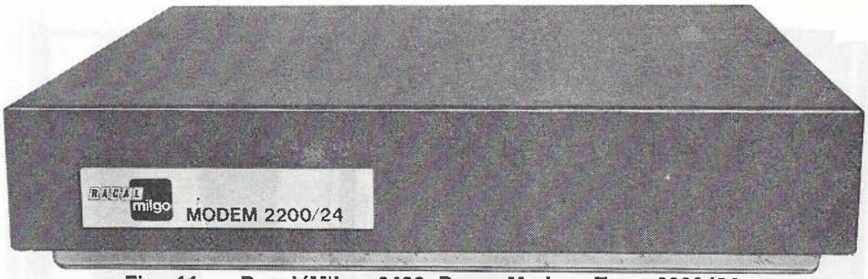


Fig. 11. — Racal/Milgo 2400 B.p.s. Modem Type 2200/24.

The phase change is the actual on line phase change in the transition region from the end of one signalling element to the beginning of the following signalling element.

Fig. 10 shows the phase change relationship which occurs. Alternatives A and B are of course incompatible with each other, which does lead to administrative complication in the provision of international data circuits at this speed. The main difference between the two alternatives is in respect of ability to maintain synchronism. Alternative A loses synchronism if a long string of binary 0's is transmitted, because the absence of phase changes at the receiving end does not permit the recovery of timing information for automatic adjustment of the receiving clock. In alternative B there is always a discrete phase change for successive dibit pairs no matter what the dibit pair happens to be.

TABLE 3.—ALTERNATIVE CODING PATTERNS C.C.I.T.T. RECOMMENDATION V26.

Dibit	Phase Change.	
	Alternative A.	Alternative B.
00	0°	+45°
01	+90°	+135°
11	+180°	+225°
10	+270°	+315°

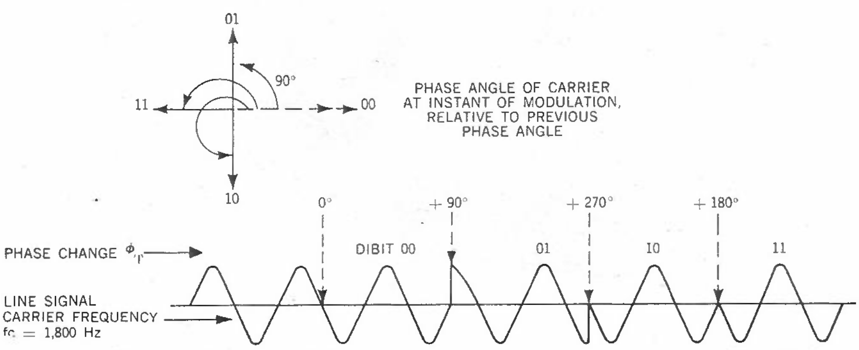


Fig. 10. — Phase Change Relationships C.C.I.T.T. Recommendation V26 Modem, Alternative A.

It is worth noting that the probability of error in the detection process depends in some degree on the specific assignment of binary code pairs to the various phase shifts. The most probable error is that of interpreting a particular phase change as one of the immediately adjacent possible phase changes. Consequently the Recommendation assigns binary pairs having a minimum of difference to adjacent phase change conditions.

The Australian Post Office has purchased two modem models from different manufacturers for 2400 bit/second datel service over leased voice bandwidth channel. One of these modems is the Racal/Milgo 2200 (Fig. 11). The second modem is the S.T.C. GH 2024 modem (see Fig. 12). The main difference between the two modems from an operational point of view is the Racal/Milgo 2200 has either coding alternative available, as a strapping option, whereas the S.T.C. GH 2024 (Ref. 2) provides only the 'European pattern,' alternative A. It is convenient to have a modem offering either coding alternative as some of the circuits on which service will be provided will terminate in the United States, or in areas under U.S. influence and will have to 'talk' to modems in those countries using alternative B coding table.

In case of degraded performance of the voice link required for operation of these modems it may not be possible to operate at 2400 bits/second. Both types of modem offer reduced speed operation, e.g., the Racal/Milgo 2200 will also operate at 1200 bits/second with 2 phase modulation and the S.T.C. modem at 1200 or 600 bits/second with frequency shift modulation to C C.I.T.T. Recommendation V23 standards. The S.T.C. GH 2024 has an option (not yet available in Australia) allowing convenient transfer to operation over the switched telephone network at the reduced speeds quoted, in the event of failure of the leased circuit This 'fall-back' possibility is the reason for the change in modulation method at reduced speed to standards agreed internationally as suitable for switched network operation.

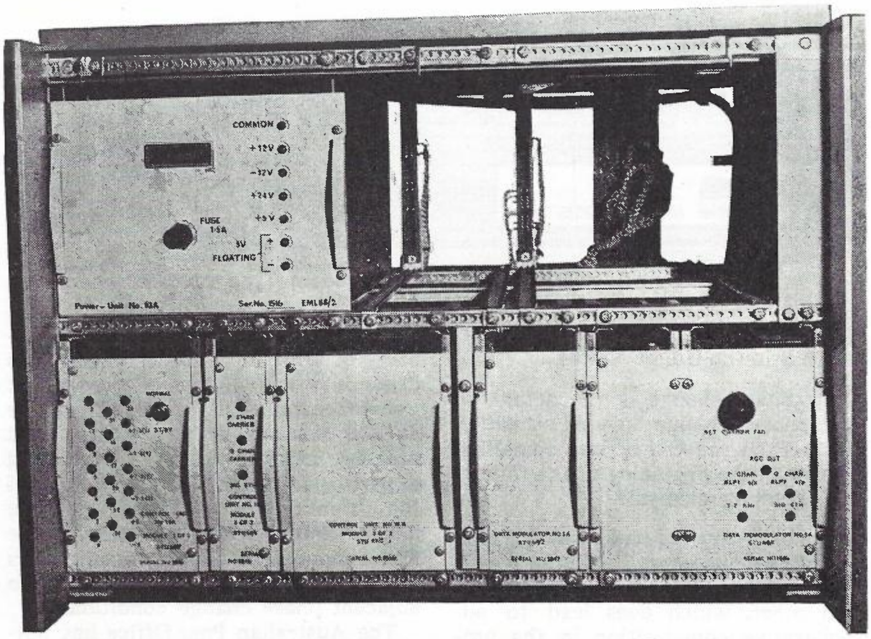


Fig. 12. — S.T.C. 2400 B.p.s. Modem Type GH 2024.

Modems for High-speed Serial Data Transmission.

There are of course other basic subdivision of transmission systems than the 4 kHz separation voice circuit. Moving up the bandwidth scale the group bandwidth of 48 kHz is being exploited for data transmission purposes in a number of countries, notably in the United States. The data signalling rate in early modems designed to exploit this bandwidth was 40.8 kilobits/second, but later development has shown that 48 kilobits/second is readily achievable. At the 1968 Plenary Assembly a C.C.I.T.T. Recommendation for 48 kilobits/second operation over a group bandwidth channel of specified characteristics was accepted. An interesting feature of the Recommendation is that it represents a departure from earlier high speed modems which were based upon multiphase modulation methods. Recommendation (V35) specifies a vestigial side band amplitude modulated suppressed carrier system, which transmits a pilot carrier for timing recovery purposes, held closely in synchronism with the data signalling input clock. The Australian Post Office does not yet provide modems for this data signalling rate, but experimental work is proceeding upon transmission and modem problems which are encountered in the provision of such service.

Modems for Parallel Data Transmission

There is frequently a requirement for data collection from a number of points, although the volume of data from each point is small. The requirement here is for a cheap outstation modem and limitations in data signalling rate may be subordinate to the requirement for a simple, cheap outstation terminal.

Since the volume of traffic is low it is also desirable to use the switched telephone network as a means of concentration to central modem equipment. Parallel transmission methods with signalling characteristics suitable for operation over the switched telephone network are ideal for such a requirement.

C.C.I.T.T. Recommendation V30 has standardised such a system for operation over the switched telephone network The basic system consists of two groups of four frequencies, one frequency from each group being transmitted simultaneously (two times one out of four), giving a maximum of 16 character combinations, with a modulation rate of up to 40 bauds. It is worth noting that the system lends itself to simple error protection as both frequencies must be present for a character to be validly recognised. In practice, in a single system using an intercharacter rest condition a character signalling rate of approximately 20 characters/second is possible. The basic system includes provision for expansion up to 64 character combinations by the addition of a third four-frequency group (three times one out of four). Table 4 below gives the frequency allocations.

The modem for outstation use may be designed to be powered from the exchange loop current of the telephone network and does not have to be connected to commercial power supply. Fig. 13 is an illustration of an outsta-

TABLE 4. — ALLOCATION OF FREQUENCIES IN C.C.I.T.T. RECOMMENDATION V30 PARALLEL MODEM.

Group	Channel No.			
	1	2	3	4
A	920	1000	1080	1160
B	1320	1400	1480	1560
C	1720	1800	1880	1960

NOTE. — For the basic 16 character system, only groups A and C are used.

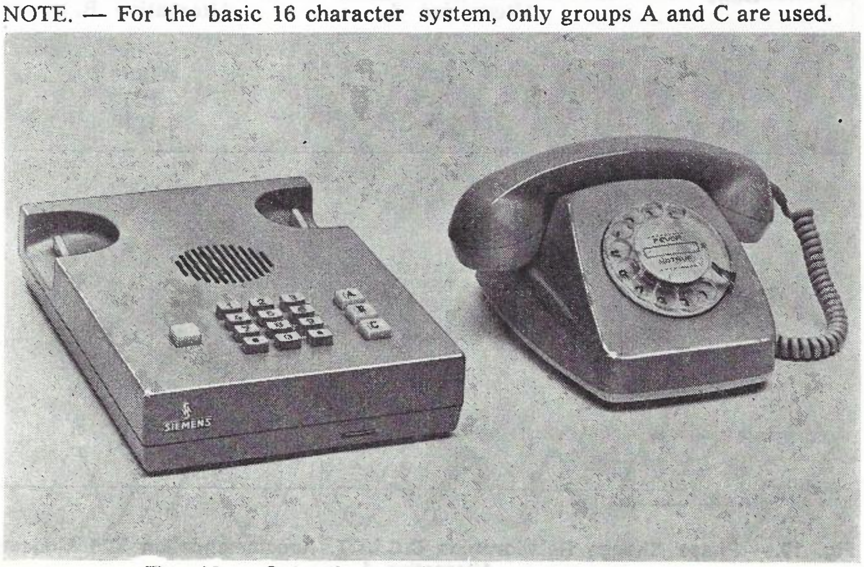


Fig. 13. — Outstation Modem for Parallel Operation.

tion modem of this class. After establishing the telephone connection, the handset is placed in the shaped handset rest in the body of the modem case. This action operates 'switchhook' contacts, which connect the telephone line in a 'no-break' fashion to the modem. Modems of this type are not leased by the Australian Post Office, but may be provided by communication firms on a 'permit to connect' basis.

The transmission from the instation to the outstations is limited either to simple acknowledgment over a low speed backward channel or to analogue signals non-simultaneous with forward data (voice answering system).

The pushbutton telephone set can of course be used as an out-station parallel data modem for data signalling over an established circuit path. It is unfortunate that the two by one out of four frequency system used (vide C.C.I.T.T. Recommendation Q23) does not coincide in frequencies with that of Recommendation V30. If pushbutton signalling is introduced in the near future in Australia these sets may also provide convenient, cheap data entry for low speed light duty applications.

DATA SWITCHING.

In general there are three methods of interconnecting data terminals for the transmission of digital data. These are illustrated in Fig. 14. The first of these is the direct connection over a leased circuit of the terminals and this method is widely used by heavy duty customers, at speeds ranging from low speed telegraph type operation at 50 bits/second to 2400 bits/second operation over specially conditioned voice circuits. There are in addition two forms of switching available for the interconnection of data terminals.

The first of these is the well-known circuit switching method as used, for example, in the telephone network. With data terminals linked to exchange lines via data modems and with appropriate line controls to switch the modems into the circuit path after call establishment the telephone network provides good service over a wide area for light duty applications. In some countries there are as well specialised direct switching systems specially designed to handle data at a range of data signalling rates including rates well above those which can be achieved on voice band channels.

The second switching method is that of message switching, sometimes known as 'store and forward' switching. The essential feature of this type of system is the storage of data in switching centres before delivery. The destination of the message is not known by the switching centre until at least part of the message containing the 'address' is received. The method has many advantages for heavy duty users with operator loading, concentration, error control, speed and code transformation requirements and other special facility features. The method has been widely used by single user organisations in this country for systems for airline and meteorological purposes. The Australian Post Office Tress system is a very large public telegraph network operating on this basis and internationally Australia's cable traffic is switched using this method.

The Post Office has recently placed contracts with Univac (Australia) for a large network of the message switching type to handle data transmission for a number of Government and private organisations on a general service basis. The system is known as the Common User Data Network (CUDN) and is engineered to provide convenient transfer of traffic to and from other forms of data connection such as telex and datel services as well as fulfil its primary role. This system is typical of new networks, being established in a number of countries for versatile data switching, and will no doubt be the subject of future articles in the Journal.

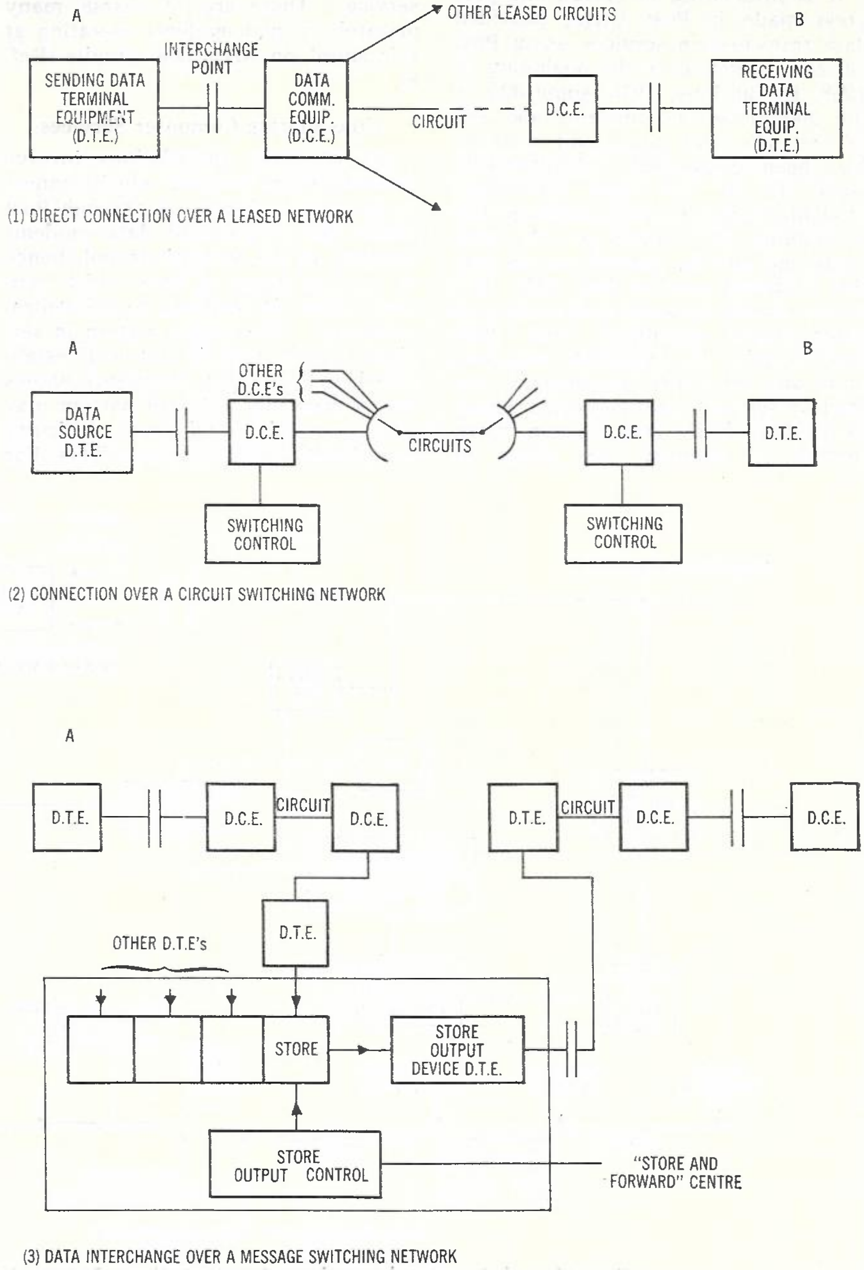


Fig. 14 — Methods of Interconnecting Data Terminals.

The terminal links to CUDN centres are in general, private lines operating as low speed telegraph circuits, or are datel circuits. The links between CUDN centres operate as datel links and will initially use 2400 bits/second transmission, using modems of the types shown in Figs. 11 and 12. The Post Office is currently exploring the market for 4800 bits/second operation over specially conditioned point to point voice channels and it is possible that CUDN centres will be linked with circuits operating at this bit rate, when suitable modems become available.

Growth in Services.

It is interesting to review the progress made in Post Office provided data transmission services using Post Office modems since the beginning of 1968. By 30 June, 1970, some 325 of the 200 bit/second modems and 285 of the 600/1200 bit/second modems had been connected. Additionally, some 12 of the 2400 bit/second modems were in service, although full availability of modems at this data signalling rate for general service was not proposed until 1 Jan. 1971. Privately owned modems in the following approximate quantities, 100 (200 bits/second), 15 (600/1200 bits/second) and 40 (2400 bits/second), remain in service from the period before Post Office datel service began, when 'permit to connect' was given to privately owned modems which had passed Post Office tests.

Approximately 88 per cent of the 200 bits/second modems are connected to the switched telephone network, mainly for time-sharing computer services run by Australian General Electric and I.B.M. The remaining 12 per cent. are used in leased service banking applications in metropolitan areas and in time-sharing computer applications using the Honeywell service. Some 20 per cent. of the 600/1200 bit/second modems are used on switched network applications, the remaining 80 per cent. upon leased line service. All of the 2400 bits/second modems are used in leased line service. There are, of course, many privately owned modems operating at this speed on NASCOM circuits (Ref. 9).

Time-Sharing Computer Services.

All of these installations involve teleprinter-line terminal which connect to the switched network through Post Office 200 bits/second data modems installed at the outstations and thence to a p.b.x. group of lines which connect, again via modems, to the central computer. The traffic pattern in services of this type is not well established and overseas experience shows that a markedly different pattern may develop. This could cause difficulty to ordinary telephone subscribers. For this reason the Post Office applies conditions of service which control this and other matters in the interests of all telephone subscribers. Automatic answering may be provided, with recorded voice announcement from the computer centre prior to completion of the path into the computer. Fig. 15 shows the arrangement used by Australian General Electric. The user's programmes are mostly for calculations of the engineering and scientific types. The comparatively simple type of terminal used precludes transmission of large volumes of information, and the computer companies' tariff scales do not encourage the transmission and holding of large amounts of information on file, so that these systems are not generally economical for A.D.P. type applications. The Australian General Electric and I.B.M. services use the switched telephone network with the great majority of calls in the local network, although there are a few terminals in provincial centres using S.T.D. access. At the time of writing A.G.E. has computer centres established in both Sydney and Melbourne, and I.B.M. in Sydney. One service, that of Honeywell, uses leased line connection which can be quite competitive with switched network operation since most traffic is local, and line costs for local lines are low. Substantial equipment simplification when compared with systems using

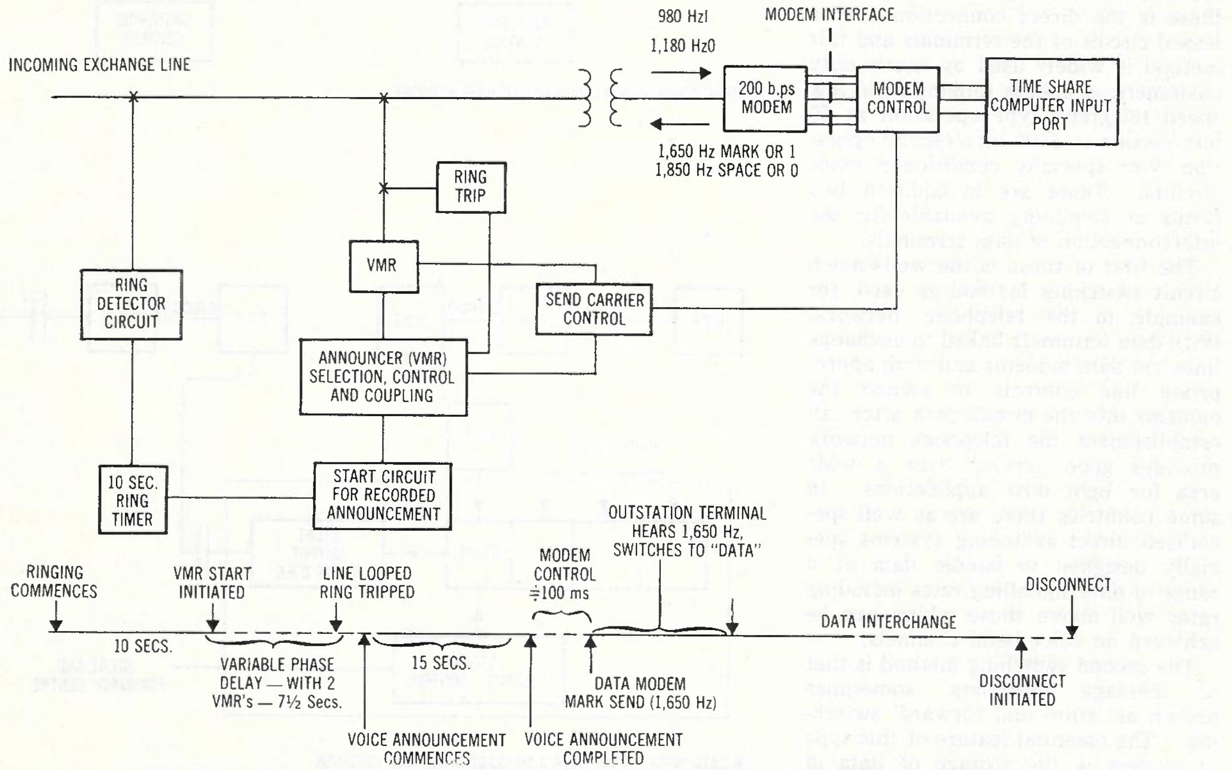


Fig. 15. — Automatic Answering of Data Call on Switched Telephone Network.

the switched network follows since the need for call connection and voice answering disappears.

Line Connection of Remote Terminals of Batch-processing Computers.

Utility organisations offering publically available service have been established in Europe and the United States for data-processing on this basis. In Australia, Control Data of Australia Ltd. and Compunet Pty. Ltd. are already established while other leading computer firms are in the planning stage. Adelaide University has also commenced operation on this basis. Connections over channels of remote terminals for these utilities form one of the main markets for the 2400 bits/second modem.

Tape to Tape Terminals.

Medium speed (600 and 1200 b/s) tape transmission and reception is a frequently encountered service requirement, both over leased lines and through the switched network. Usually the terminals include error detection and correction equipment (Ref. 10). The Defence services A.D.P. network, with terminals of the type mentioned in every State connect through the switched telephone network to a limited number of similar terminals at the Defence A.D.P. centre at Canberra.

Banking and Totalisator Systems.

Banking systems are under development or are currently being installed involving the three modem types referred to above, as well as d.c. telegraph techniques. These systems use a variety of terminals of the accounting machine type and permit a bank-teller to up-date a local record, e.g., a savings bank passbook, and at the same time up-date a central ledger record kept at the central computer. The networks are of the private line type and have, in some instances, involved the introduction of polling-type operation. In this case a plurality of branches is connected to an omnibus (multi-station) line, and as each terminal machine has an entry set up on its keyboard, it waits until the central processor interrogates (polls) it and records the entry in the central file before clearing the terminal. Totalisator systems have similar requirements, although d.c. telegraph techniques and the telex network have been exploited to a much greater extent.

Stock Exchange Systems.

There are two competitive systems, one installed and the other in process of installation, each providing the facility whereby the simple coded message of interrogation to a central processor may result in an answering message giving the latest buying, selling or other price information for a particular stock. One is operated by the Melbourne Stock Exchange using a simple keyboard and tape-printing terminal unit working with 50-baud d.c. telegraph transmission over dedicated private lines, the terminals being known by the name Quotron, manufactured by the Scantlin Electronics Incorporated, U.S.A. This installation will also provide a Telex interrogation capability so that remote brokers, who do not wish to pay for permanently connected lines, may use teleprinters installed in their offices to connect through the Telex system to the Melbourne Stock Exchange computer. The other system is known by the name Stockmaster, is also of U.S. origin, and was installed by Reuters Economic Services in association with the Sydney Stock Exchange. This system involves 1200-baud transmission through modems connected to private telephone lines using the polling mode and omnibus working. Many terminals are in operation in Sydney, and the system extended over long-distance data channel to Queensland, Victoria and New South Wales.

International Data Services.

There are a number of leased international data services in operation, mainly for NASCOM (Ref. 9). During 1969, after extensive testing conducted by the Post Office and the Overseas Telecommunications Commission in collaboration with overseas communication authorities, international service over the switched telephone network commenced. Because of the previously mentioned technical limitations in international switched network operation, calls are switched through a special O.T.C. operating position at Paddington, N.S.W., where an international channel suitable for data transmission may be selected for the international connection. These calls first pass through a Post Office operator (selected by code 016) for call accounting purposes. Initial services have been of the medium speed tape to tape type using error detection and correction (Ref. 10). One of the factors which has to be borne in mind in systems using the automatic repetition process for connection is the long round trip delay on circuits having satellite sections. The outgoing store at the data transmitting terminal in systems using continuous block transmission must have sufficient capacity to ensure that the blocks to be repeated are still available.

CONCLUSIONS.

The telecommunication system, which was developed over many years basically for voice communication, is now in the process of adapting to the rapidly growing data transmission load. Most of the principles involved have been known and used for many years, but their impact has been especially in telegraph systems, which operate at relatively low speeds. In adapting the transmission grid to the transmission of data at higher speeds, boundary conditions are encountered which must be observed for low error-rate data transmission. There is some flexibility within these boundaries to emphasise a particular characteristic sought, such as a high data signalling rate by use of a complex modulation method, but this can only be done with an eye to the disadvantage which might follow in respect of other characteristics. Future development of transmission systems might eventually follow lines which lend themselves to somewhat simpler exploitation for data transmission than do present frequency division multiplexing systems, but this may be many years off.

Switching of data over the switched network for light duty applications is quite suitable for many applications, particularly those in which the wide availability of the telephone network is of importance, and its concentration ability exploited. Heavy duty users are successfully using extensive leased network, and, in addition, a special message switching network is being implemented for customers having large volumes of data generated from a number of sources. This network also integrates with the low speed public telegram (Tress) and telex networks. The characteristics of the switching systems mentioned have had an influence upon the modems connecting to the transmission paths established for these networks.

Development of data transmission services in Australia since the commencement of datel service has been rapid and the introduction of higher speed modems and of new switching systems will further stimulate this growth.

ACKNOWLEDGMENTS.

The introduction of datel service has involved a great many people from a number of areas within the Post Office and from the telecommunications industry, and much of the material in this article has been drawn from sources which represent the collective work of these groups. Particular thanks are expressed to S.T.&C. Pty. Ltd. (Australia) Racal (Australia) Pty. Ltd., and Siemens (Australia) Pty. Ltd. for material drawn from their publications and permission to publish photograph of plant and their manufacture.

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TECHNICAL NEWS ITEM

COMPUTERISED CABLE TESTING.

A computerised telephone cable testing system, the first of its kind in Australia, has been installed by Conqueror Cables Pty. Ltd., the cable and wire division of IRH Industries Limited,

Known as the Sievematic, the system has been developed by a member of the L.M. Ericsson group, with which Conqueror Cables has some association, and replaces laborious manual testing procedures. Conqueror has contracts to supply substantial quantities of telephone cable to the Australian Post Office and the Sievematic system was specially designed to meet the requirements of A.P.O. cable specifications.

With the advent of Subscriber Trunk Dialling, and with other sophisticated systems under development, the A.P.O. requires more stringent quality control, involving increased testing and statistical test results taken over a large number of lengths of cable. The Sievematic system combines programming equipment, logic circuitry, automatic measuring equipment, a digital computer and facilities for the automatic print-out of test results.

Each item of test equipment has its own inbuilt checking circuits and is mounted on trolleys. Being highly mobile, each Sievematic unit is taken to the heavy drums of cable, rather than the reverse, as was the case with the previous testing method.

With the Sievematic system, before testing commences, a programme is prepared on a punched tape to suit the particular cable under test and on this tape is superimposed the format for the final read-out of the test results.

This information is then fed into a tape reader, which 'instructs' one of the items of test equipment to test the cable for capacitance and unbalance, mutual capacitance, conductor resistance and conductor resistance unbalance. Results of these tests are recorded on a punched tape, which is fed into the print-out equipment, giving a complete graphical record. In the case of insulation resistance testing, results are displayed by an ink recorder, and, after analysis, are stated on the test certificate.

The digital computer calculates mean and maximum values as required and prints out the calculated results on the bottom of the certificate. If required, the tape on which the results are recorded may be fed into a larger computer programmed to analyse results over a period of time so as to keep a constant check on trend and quality.

The time needed to train personnel handling the Sievematic equipment is substantially less than that required for manual testing operations.

Chief features claimed for the Sievematic System are:—

Virtual elimination of human error.

The equipment's high mobility dispenses with the need for permanently fixed testing bays.

Production bottlenecks are eliminated.

Reduced training time for test personnel.

High measurement accuracy.

Automatic calculation of test results.

PROGRAMME CONTROL OF THE IST PROJECT

F. J. W. SYMONS, B.E., D.I.C. and M. K. WARD, B.E., M.Eng.Sc.***

INTRODUCTION.

The Research Laboratories of the Australian Post Office (A.P.O.) are conducting a practical feasibility study of the telephone network of the future, under the name of the IST (Integrated Switching and Transmission) project. In this project four telephone exchanges, both crossbar and step by step, in the Melbourne metropolitan network, will be connected by PCM (pulse code modulation) transmission to a digital switching stage. The digital switch will be controlled by the programme stored in the memories of two exchange control processors.

The IST project incorporates almost all the general foreseeable trends in telecommunications networks, and these are listed below: —

(a) stored programme control;
(b) digital transmission in the form of PCM;
(c) digital switching.
(d) advanced semiconductor technology;
(e) remote control of subscribers' switching stages;
(f) common channel signalling between processor controlled exchanges.

The initial stage of the project will include the first four trends, and the last two will be included as the project advances. Common channel signalling is the major study of an associated project currently being carried out by the Research Laboratories. (See Ref. 1.)

The objectives of the project are to study the techniques involved in the trends outlined above, to obtain field experience in the operation of new systems, and to identify and solve the various interworking problems encountered when placing new principles, systems and technologies in the existing network. It is of great benefit for an administration to acquire this kind of knowledge and experience well in advance of the widespread introduction of new techniques so that the widespread introduction can be carried out efficiently and economically.

This paper deals only with the control aspects of the project and it describes the first complete programme control system for a telephone exchange which has been designed in the A.P.O. Other papers will be published by other authors describing the hardware, signalling and network aspects. Background information can be found in three papers by H. S. Wragge (Refs. 2, 3 and 4). A description of part of the hardware is given in the paper by A. Domjan (Ref. 5), and a description of the signalling scheme used over the PCM systems is given by G. L. Crew (Ref. 6).

SYSTEM DESIGN OF THE IST EXCHANGE.

Although the equipment and programmes being produced for the IST project will be used to provide the exchange facilities required at a particular location in the Melbourne telephone network, the objective has also been to design and produce a modern switching system which is capable of meeting a wide range of requirements throughout the Australian telecommunications network. The overall objective can be summarised as being to design a system which is capable of providing flexible fully-automatic unattended exchanges suitable for a wide range of purposes and which can maintain service in spite of hardware and software faults.

Programme Control.

In the IST project exchange, all the control functions are exercised by the programmes stored in the memory of the processors. No call handling decisions of any significance are taken by hardware. Hardware devices are used for some routine detection and timing functions, such as the detection and generation of dial pulses. The hardware also filters out any short term changes of state so that only valid changes of state should be detected by the programmes. In this way the load capacity of the control processors is increased without any reduction in their decision making role. As the exchange is completely under the control of the programmes, it is their operation which determines the way in which the exchange operates, the facilities it provides and the extent to which the exchange meets all the requirements demanded of it. The programme control system is one of the most important aspects of the whole exchange. The design of the programme control system has been undertaken very carefully in order to ensure that it is capable of providing the performance and facilities required. Electronic stored programme control using modern high-speed processors has three main features to offer, flexibility and versatility in the provision and changing of exchange facilities, the economical control of large exchanges, and the possibility of co-ordinated control of the whole network. A description of the programme control system designed by the authors and the way in which the programmes operate is given in later sections, after a brief description of some of the main characteristics of the exchange.

Function of the IST Exchange in the APO Network.

The IST exchange will switch traffic between the Gardenvale (terminal crossbar), Clayton (terminal crossbar), South Oakleigh (terminal hybrid crossbar and step-by-step) and Windsor (local tandem crossbar) exchanges, as shown in Fig. 1. As far as the rest of the network is concerned the IST exchange will essentially be in parallel with the Windsor crossbar exchange.

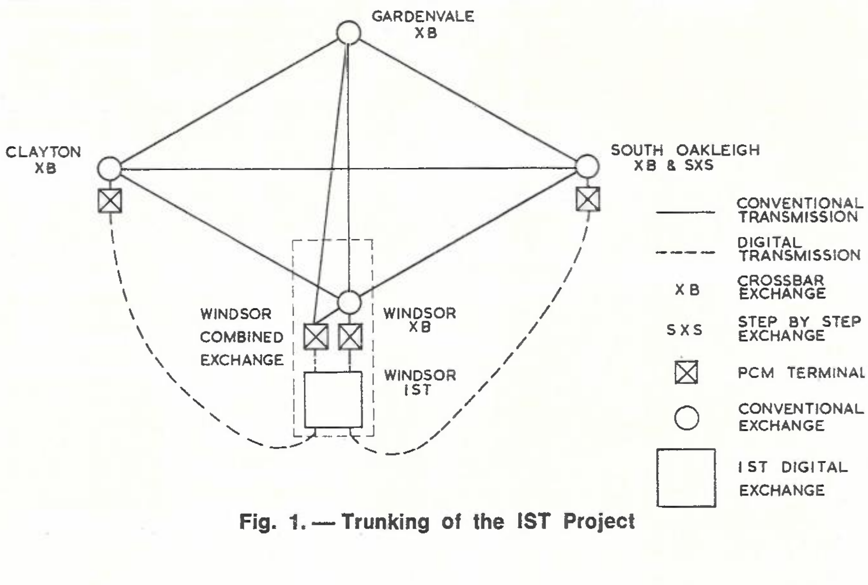

Fig. 1. — Trunking of the IST Project

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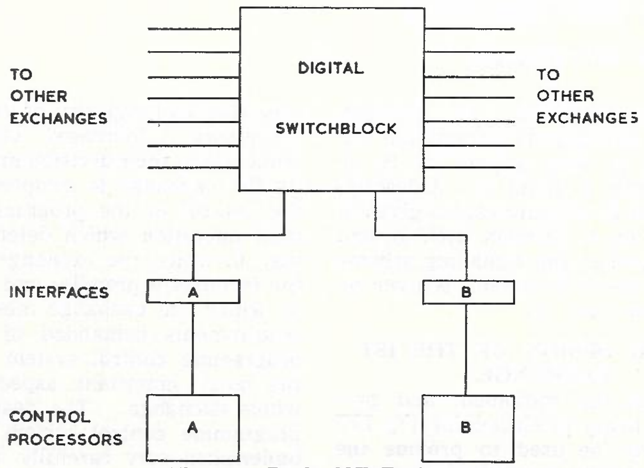

Fig. 2 — Basic IST Exchange

The Basic IST Exchange.

The IST exchange consists of three main parts, as shown in Fig. 2. These are the digital switch block (or speech matrix), the interfaces, and the control processors. With the highly centralised control situation of processor control, it is necessary to have two processors to obtain the high degree of reliability required by a telephone exchange. There are many possible ways of interworking the two processors. The method chosen to obtain the best security of control function is that of sharing the load between the two processors which are both actively handling traffic as long as they remain healthy. The two processors each have independent access to the switch block through their own interface equipment. The reliability aspects will be described in detail in a later section.

IST Exchange Topology.

As shown in Fig. 3, one full availability switch block is used in the IST exchange for all purposes, including lines to other exchanges, signalling senders and receivers, and service facilities such as recorded announcements and automatic testers. Lines to other exchanges are connected to Traffic Groups, and all other connections are made to Service Groups. The signalling senders and receivers are used for sending and receiving signalling tones and decadic pulse trains to and from other exchanges. Any incoming line can be connected to any signalling receiver, and any signalling sender can be connected to any outgoing line. The use of one full availability switchblock also enables any signalling sender (or sending test unit) to be connected across the switchblock to any signalling receiver (or receiving test unit). This feature enables a wide range of exchange system performance and monitoring tests to be carried out automatically under programme control.

OPERATIONAL SOFTWARE SYSTEM.

In the IST exchange all control is exercised by the programmes contained in the computer-like switching processor. Those programmes which occupy the processor memory, either continuously or as required, when the exchange is in service are called operational programmes. All other programmes used in the development or testing stages are called support programmes. The support programmes will be described in a later section.

The manner in which the operational programmes combine together, or interwork, in order to provide the facilities required by the exchange is determined by the operational software system, or basic programme framework. This programme framework must have certain characteristics if it is to be suitable for telephony. The basic characteristics are described below.

Task Multiplexing: The processor is required to control the setting up, supervision and clearing down of many

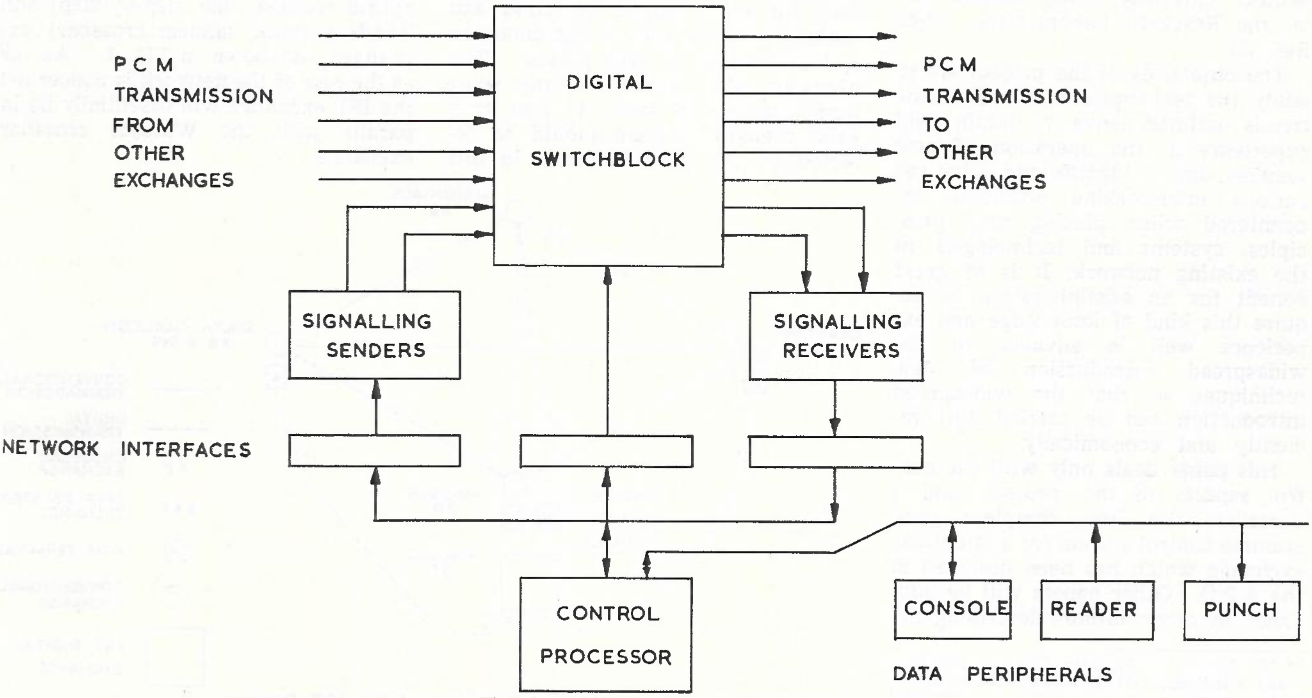

Fig. 3. — IST Exchange Topology

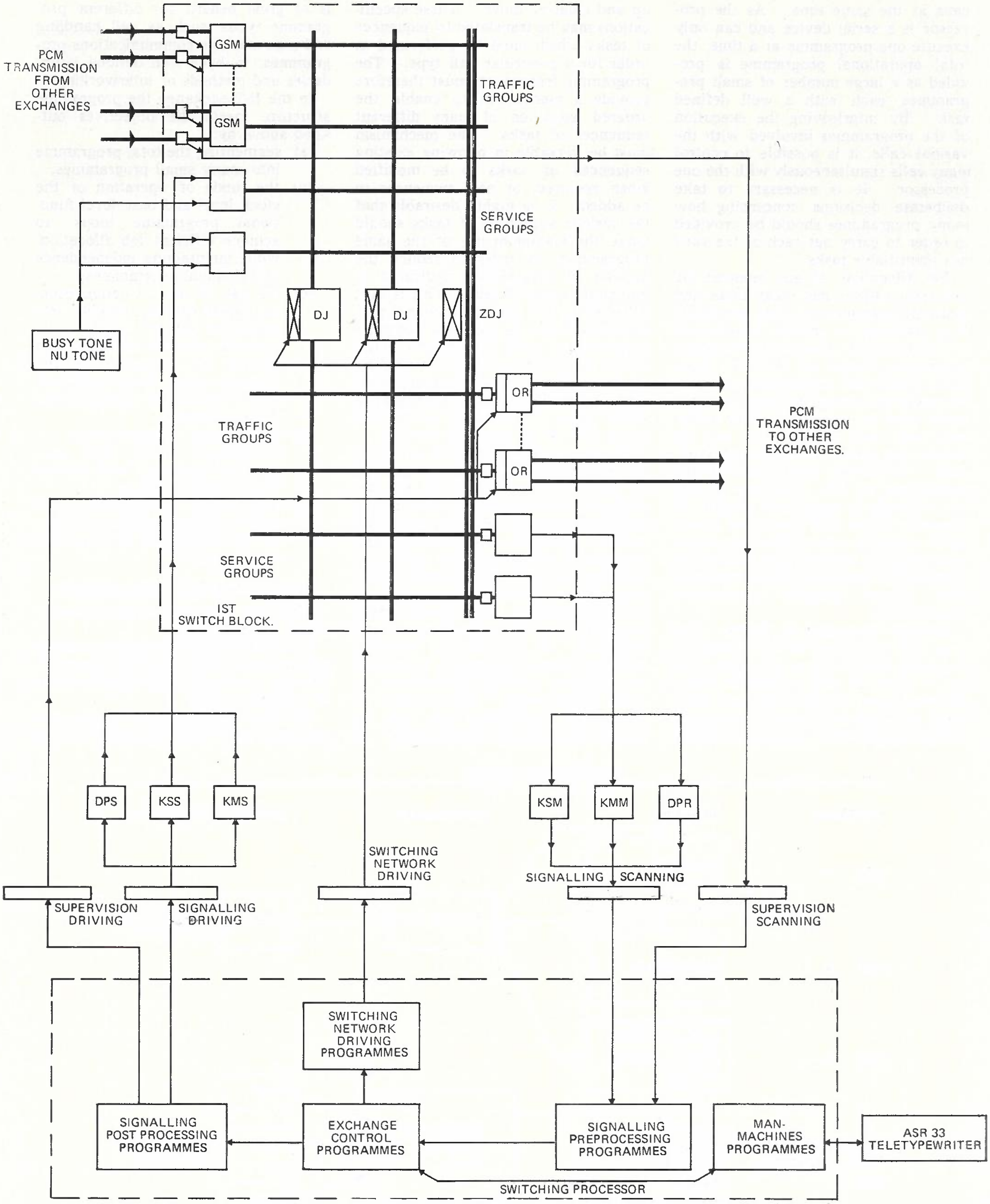

Fig. 4. — Control of the I.S.T. Exchange. (See Appendix 1 for Glossary of Abbreviations.)

calls at the same time. As the processor is a serial device and can only execute one programme at a time, the total operational programme is provided as a large number of small programmes, each with a well defined task. By interleaving the execution of the programmes involved with the various calls, it is possible to control many calls simultaneously with the one processor. It is necessary to take deliberate decisions concerning how many programmes should be provided in order to carry out each of the various identifiable tasks.

Job Allocation: At any moment the processor usually has many tasks and hence programmes awaiting execution. It is necessary to provide a method of job allocation in order to decide which programme should be executed next. Some tasks and programmes have to be executed at regular intervals; some tasks must be executed within a certain time, and some tasks can be carried out when time becomes available. It is very desirable that the mechanism of job allocation should not consume a significant amount of processor time, and should be essentially a simple one, while at the same time being a flexible one, and being suitable for incorporation in any possible future dynamic programme organisation.

Ordered Execution of Tasks: Not only is it necessary for the processor to handle many calls at the same time, but it must be able to handle many different types of call at the same time. Each call type will have its own particular specification regarding setting up and clearing down. These specifications may be translated to sequences of tasks which must be performed in order for a particular call type. The programme framework must therefore provide a mechanism to enable the ordered execution of many different sequences of tasks. The mechanism must be versatile in allowing existing sequences of tasks to be modified when required, or new sequences to be added. It is highly desirable that the various sequences of tasks should make the maximum use of the same programmes, in order to reduce the number of programmes dedicated to individual types of calls. This is best achieved by the use of functional programmes, such as network scanning programmes, path search and route search programmes, which are used by all calls of all types, combined with sets of decision making programmes which have a knowledge of the call types, and of the state of the call.

Programme Modularity: In order for the programme structure to provide all the necessary operational and developmental requirements, the various individual programmes must have well defined functions, boundaries, and methods of communicating and interworking with other programmes. This gives the individual programmes internal independence and allows great flexibility in design, modification and operation. It also enables selective optimisation and changes to be carried out without causing interactions to other programmes. The concept of programme modularity can also be applied to groups of programmes. It is of great benefit for different programme types, such as call handling and man machine communications programmes, to have well defined boundaries and methods of interworking.

In the IST exchange the programme structure meets the objectives outlined above by:

(a) segmenting the total programme into many small programmes;
(b) the mode of operation of the clock level and base level functional programme loops to achieve efficient job allocation, while maintaining independence of individual programmes;
(c) the use of sets of action code, call phase decision making programmes which control the ordered execution of tasks, and initiate the execution of the various clock level and base level functional programmes when required;
(d) maintaining independence of programme units and programme types by a well defined way of interworking;
(e) maintaining independence of functional programmes and data by the formation of exchange data tables.

Types of Operational Programmes.

There are four main types of operational programmes:

(i) **Call Handling Programmes:** These programmes handle the detection, setting up, supervision, and clearing down of telephone calls.

(ii) **Test Programmes:** These programmes test the operation of the

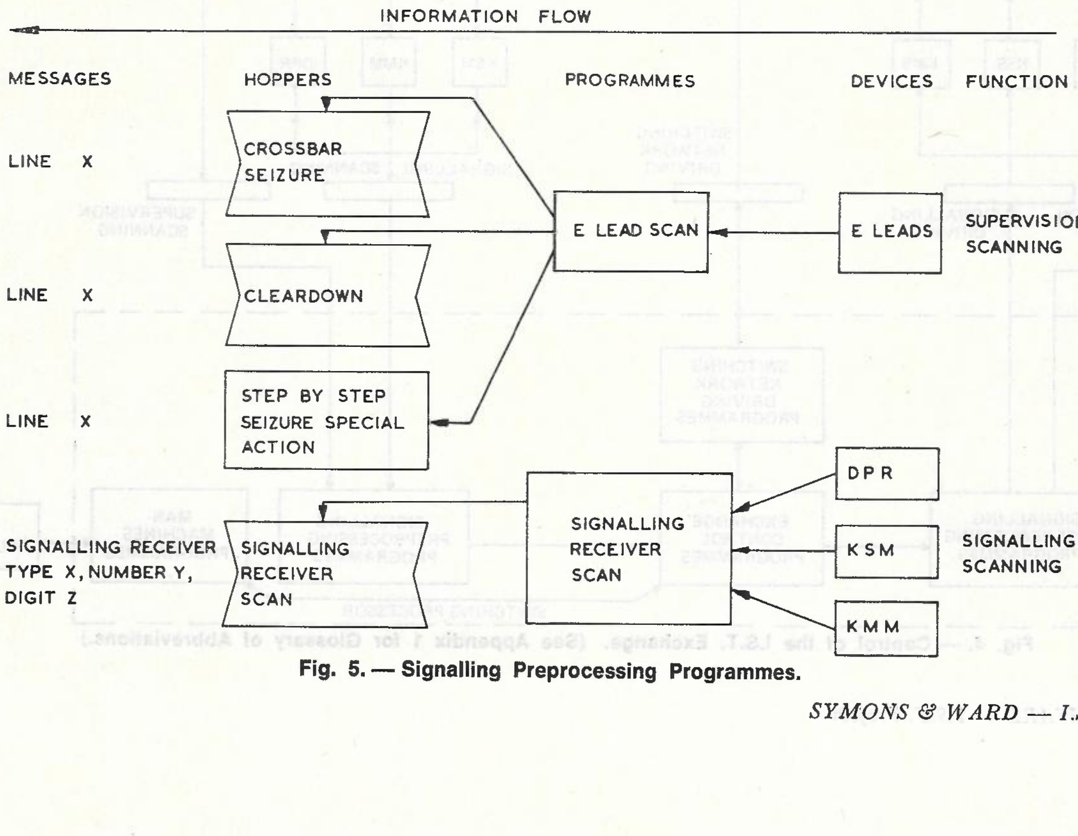

Fig. 5. — Signalling Preprocessing Programmes.

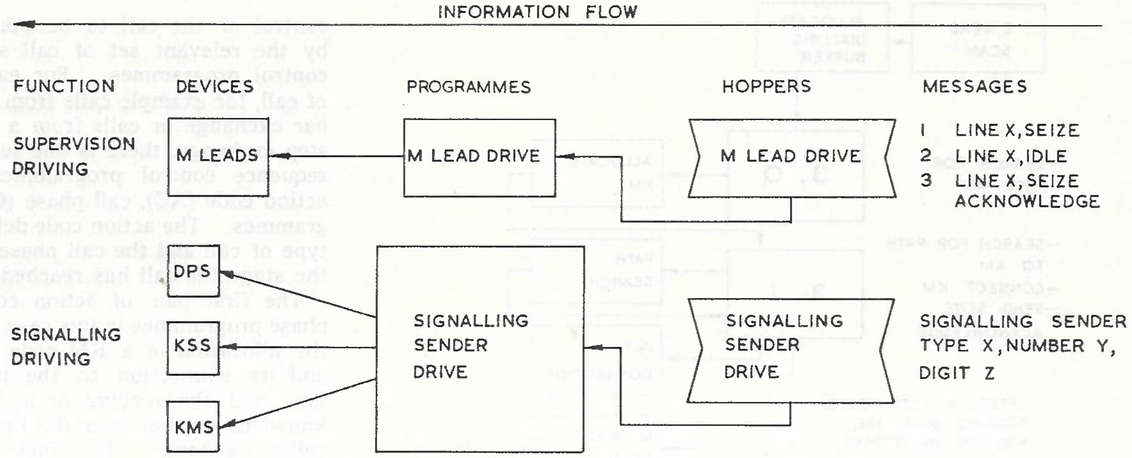

Fig. 6. — Signalling Postprocessing Programmes

whole system, both hardware and software.

(iii) **Security Programmes:** These programmes enable the exchange to operate as a fully automatic unattended exchange, maintaining service in spite of the occurrence of hardware and software faults.

(iv) **Man-machine Communications Programmes:** These programmes enable communications to and from the processor by means of the console teletypewriter. Man-machine programmes enable the processor to issue system performance reports and to accept operator commands for the modification of parameters, etc.

CALL HANDLING PROGRAMMES.

As shown in Fig. 4, there are four main types of call handling programmes (see Appendix I for a glossary of abbreviations).

Signalling Preprocessing Programmes (SPRP): These programmes scan the signalling receivers and the lines from other exchanges, and detect all the messages sent to the IST exchange from the other exchanges. These messages are of two basic types, supervision messages such as the seizure of a particular line, and signalling messages such as the identity of a digit which has been received. The signalling preprocessing programmes detect all these messages and pass them on to the exchange control programmes by placing the relevant data in the appropriate programme hopper. The hoppers provide a mechanism of storing messages in an ordered queue of first-in, first-out. At the appropriate time the exchange control programmes take the messages one at a time from the hoppers, a process called unloading the hopper, and arrange the necessary action to be carried out. Typical messages sent by the SPRP are 'line x' to the 'Crossbar Seizure Hopper,' and 'Signalling Receiver type x, number y, digit z' to the 'Signalling Receiver Scan Hopper,' as shown in Fig. 5. The SPRP are arranged so that they report each event detected only once to the exchange control programmes. It is only by means of the SPRP that messages from other exchanges are received.

Signalling Postprocessing Programmes (SPSP): These programmes perform a function complementary to that of the SPRP. They drive the signalling senders and the lines to other exchanges so that signalling and supervision signals can be sent from the IST exchange to other exchanges. The supervision signals may be forward signals on the go path of an outgoing junction or backward signals on the return path of an incoming junction. The SPSP are informed of the messages which are required to be sent by the exchange control programmes. This is achieved by the exchange control programmes loading hoppers which are unloaded by the appropriate signalling postprocessing programme at some later time. Typical messages are 'line x - seize' and 'signalling sender type x, number y, digit z' as shown in Fig. 6.

Switching Network Driving Programmes (SNDP): Only one programme falls into this category and it is called

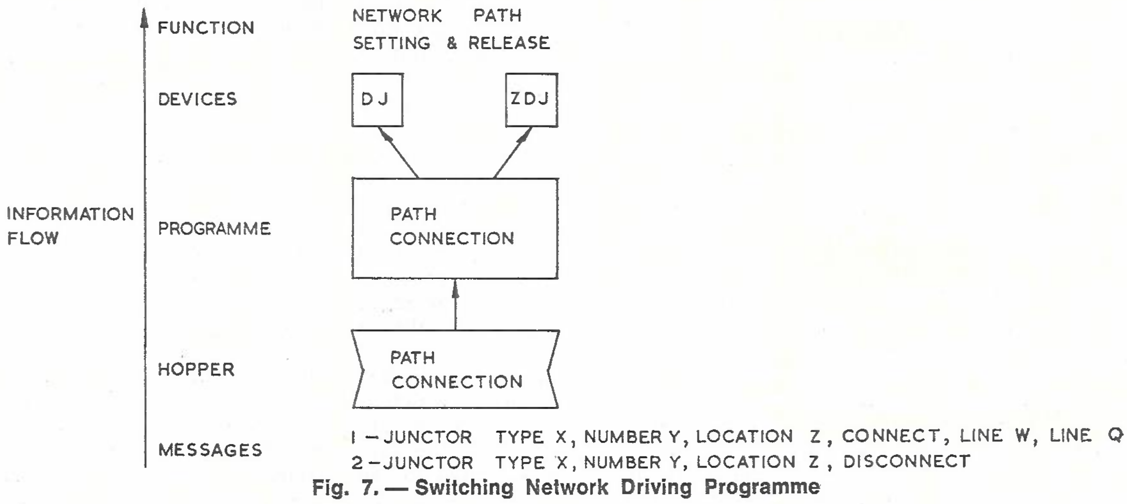

Fig. 7. — Switching Network Driving Programme

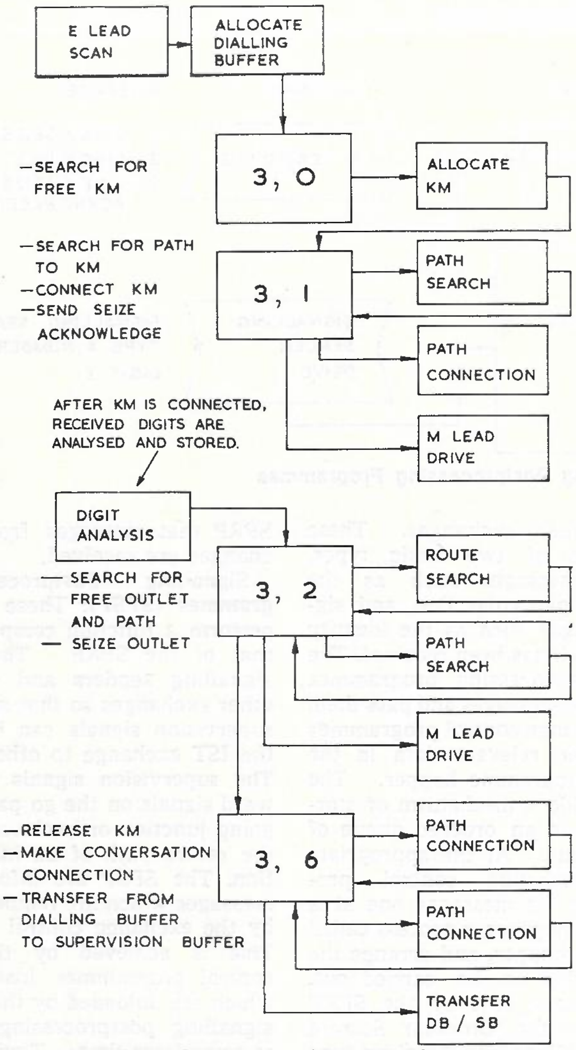

Fig. 8. — Simplified Programme Sequence for a Crossbar Call

the Path Connection Programme. This programme, when required to do so by the exchange control programmes, passes setting up and clearing down orders to the junctors of the switching network. Examples of actual messages sent to the path connection programme are shown in Fig. 7.

Exchange Control Programmes (ECP): These programmes determine the way in which the IST exchange operates. They analyse the information received from the SPRP, take decisions based on all information available and arrange appropriate action by sending messages to the SPSP and the SNDP.

Control of Crossbar Calls.

A simplified version of the programmes involved in the setting up of a call which originates on a line from a crossbar (XB) exchange is shown in Fig. 8.

The occurrence of a new call is detected by the E Lead Scan programme, which is one of the SPRP. This programme regularly scans the conditions of all lines connected to the exchange. By comparing the signalling conditions of a line with those detected in the previous scan, the E Lead Scan programme recognises any change which has occurred. If a change from the idle signalling condition to the seized signalling condition occurs on an incoming line which is connected to a crossbar exchange, the E Lead Scan programme loads an entry into the Crossbar Seizure Hopper, giving the identity of the line which requires service. This hopper is unloaded a short time later by an exchange control programme called the Allocate Dialling Buffer programme. This programme arranges for a special area of memory called a dialling buffer to be allocated to the new call. The dialling buffer is used to store all the information which is relevant to this particular call during its setting up phase. After the dialling buffer has been allocated to the call, the programme arranges for the control of the call to be taken over by the relevant set of call sequence control programmes. For each type of call, for example calls from a crossbar exchange or calls from a step-by-step exchange, there is one set of call sequence control programmes called action code (AC), call phase (CP) programmes. The action code defines the type of call and the call phase defines the stage the call has reached.

The first pair of action code, call phase programmes in this case, arrange the allocation of a KM code receiver and its connection to the incoming line, and the sending of a seize acknowledge signal over the line to the calling exchange. To achieve this the action code, call phase programmes arrange the execution in turn of the Allocate KM programme, the Path Search programme, the Path Connection programme and the M Lead Drive programme.

Once the signalling receiver has been connected, the digits transmitted from the calling exchange in MFC (Multi frequency code) can be received. Each digit is recognised by a SPRP called the Signalling Receiver Scan programme, which loads a hopper with the KM identity and the received digit This hopper is unloaded by an ECP called the Digit Analysis programme, which arranges for the received digits to be stored in the dialling buffer dedicated to this call and also for the analysis of the digits to determine what action is now required. The analysis of digits is achieved by the use of translation tables, which indicate whether the currently received digit in conjunction with those already received is sufficient to specify the route required by this call. Compelled sequence MFC signals required by the calling exchange are originated by the Digit Analysis programme. It informs the appropriate SPSP of the signal to be sent by loading information into the Signalling Sender Drive Hopper.

As soon as sufficient digits have been received to determine the required route, the Digit Analysis programme transfers control of this call to the appropriate set of decision making Action Code, Call Phase programmes. The first of these programmes (3, 2) arranges the seizing of a free channel on the desired route by causing to be executed, in sequence, the Route Search programme, which finds a free channel, the Path Search programme, which finds a path across the IST switchblock between the incoming channel and the outgoing channel, and the M Lead Drive programme, which puts a seizure on the outgoing channel. Control is then passed to the next Action Code, Call Phase programme (3, 6), which releases the KM signalling receiver and establishes the conversation connection by loading two hopper messages for the Path Connection programme. In the 3, 2 programme, the Route Search and Path Search programmes may be executed several times until an outgoing channel is found which is both free and has a path across the IST switchblock. If there is no free channel on the chosen route, control is transferred to another Action Code, Call Phase programme, which arranges for a second choice route to be used.

Once the conversation connection has been established it is no longer neessary for the processor to retain in its memory much of the information which was used during the setting up of the call. Action Code, Call Phase programme 3, 6 therefore initiates the execution of the Transfer DB/SB programme. This programme releases the sixteen word dialling buffer (DB) after it has transferred all necessary information about the call to a supervision buffer (SB) of four words. The supervision buffer is retained by the call for the whole of the conversation and contains the following information:

a) incoming line identity;
(b) outgoing line identity;
(c) details of the path used across the exchange for the connection.

No more action is carried out by the programmes until the conversation ends. At the end of the conversation the incoming line sends a clear forward signal which is detected by the E lead scan programme. This programme places an entry in the Cleardown Hopper giving the identity of the line which has just cleared forward. This hopper is unloaded a short time later by the Cleardown programme. This programme arranges the disconnection of the path across the exchange, and the releasing of the outgoing channel and then initiates the execution of the Release Supervision Buffer programme which clears the supervision buffer for use by another call. Once all this action has been completed all traces of that call have disappeared from the processor.

Control of Step-by-Step Calls.

The handling of calls from step-by-step (SXS) exchanges, or any other type of call, is the same in principle as that described for crossbar calls. For SXS calls some special action is required as soon as a seizure is detected. Otherwise, misinterpretation of signalling information may occur. Instead of loading a SXS seizure hopper indicating the particular action which has to be carried out as soon as time becomes available, several programmes are executed immediately in a particular sequence in order to arrange the selection and connection of a dial pulse receiver (DPR) and the sending of a seize aknowledge over the line to the calling exchange. These programmes are, in order, Allocate Dialling Buffer, Allocate DPR, Path Search, Path Connection and M Lead Drive.

Once these programmes have been executed, control of the establishment of the call is exercised in a similar way to an XB call by a set of action code, call phase programmes.

ORGANISATION OF OPERATIONAL PROGRAMMES IN LEVELS.

Since the processor is a serial device, it can perform only one task at a time. The processor therefore has to share its time over the large number of tasks which must be performed in any given period of time. This is achieved by dividing the total operational programme into a large number of small programmes, each with a well defined task. At any time the decision as to which programme should next be executed depends on which tasks are required to be carried out and on the relative priorities of these tasks. The processor has a series of eight priority interrupt lines which assist in the allocation of priorities to programmes. Associated with each interrupt line is a programme level and each operational programme is allocated to a particular programme level, depending on its function and relative priority. If a signal is applied to an interrupt line while a programme in a lower level is being executed, the processor stops executing that programme and starts to execute the first programme in the level corresponding to the interrupt line. Only when the programmes in the interrupt level have been completed does the processor return to continue the execution of the programme which was interrupted.

There are two programme levels in addition to the interrupt levels, namely, base level and demand level. Programmes in base level are executed when no interrupts are recognised by the processor. The demand level programmes are those which are only executed when requested by another programme. They are all independent of each other and are not linked in any way. The demand level programmes consist of two basic types, sub-routines and the action code, call phase programmes for call sequence control. The operational programmes most directly involved in call handling are in clock level, base level and demand level.

Clock Level Programmes.

Every 20 ms the processor is interrupted by a signal from the interrupt clock. This causes the processor to jump immediately to the first of the clock level programmes. The clock level programmes are normally all executed in a fixed sequence every time the clock interrupts. After the clock level programmes have all been executed, the processor returns to complete the execution of the programme, normally in base level, which it was executing when the clock interrupted. Execution of the base level programmes continues until the next clock interrupt occurs. This situation is shown in Fig. 9, which also shows how the clock interrupts to the two processors are interweaved so that the two processors are never both executing clock level programmes at the same time. This feature enables considerable simplification of the way in which the two processors co-operate in order to provide continuous service should either fail.

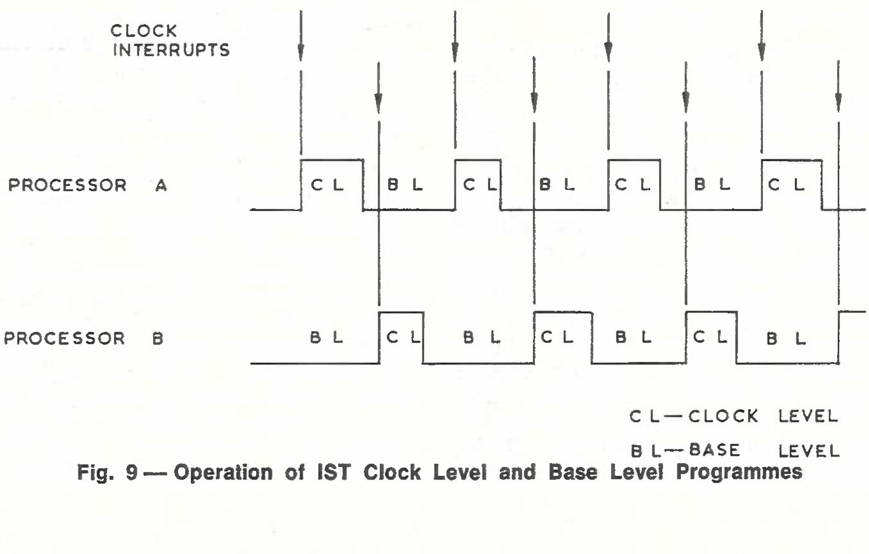

Fig. 9 — Operation of IST Clock Level and Base Level Programmes

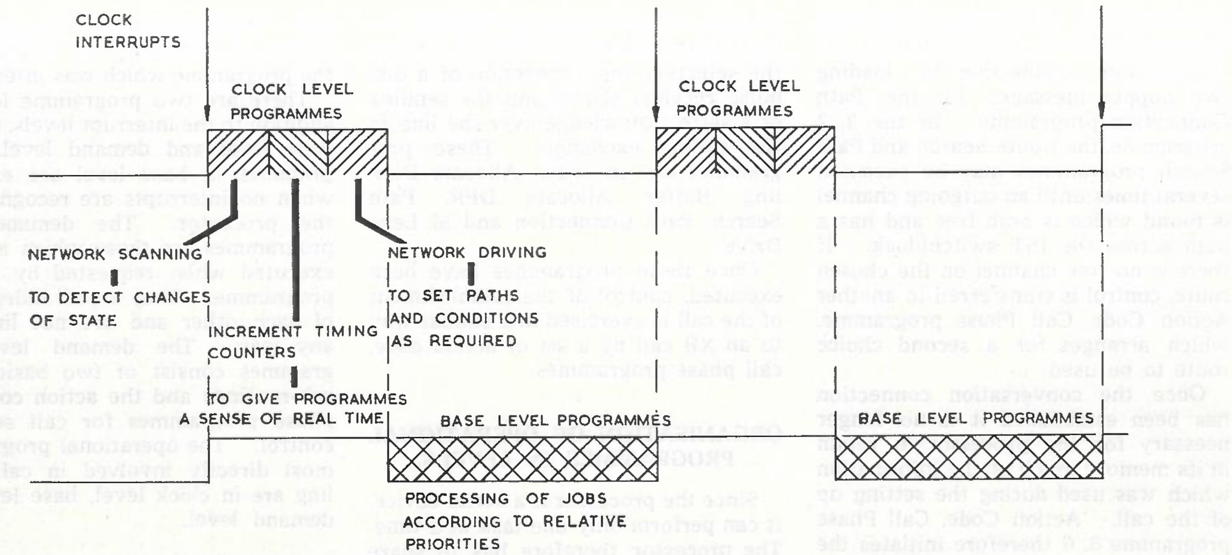

Fig. 10. — Basic Functions of the IST Clock Level and Base Level Programmes

The clock level programmes have three basic functions to fulfil, as shown in Fig. 10.

Network Scanning: The network scanning programmes consist mostly of all the signalling preprocessing programmes described in an earlier section. The conditions of all the E leads in the exchange are scanned every clock interrupt period to detect new calls and to collect other supervision information. The various signalling receivers do not all have to be scanned each clock period. Each receiver type is scanned in groups one after another, with one group being scanned each clock interrupt period. The size of the group for each receiver type depends on the total number of units and the rate at which the units are required to be scanned. The group sizes can be changed simply as the exchange grows. This method allows scanning at submultiple rates of the basic clock period, whilst preserving an even distribution of work over all clock periods.

Incrementing Timing Counters: The clock interrupt every 20 ms provides the processor with a sense of real time. This sense of real time must be made available to programmes in all levels and this is achieved by the use of timing counters. For example, when a base level programme has initiated the sending of an MFC signal to another exchange ,a response should be obtained from that exchange within a certain time. The base level programme therefore activates a timing counter, i.e., starts a timeout, by placing in the counter a negative number equal to the number of 20 ms periods in the time to be measured. During every clock period all active timing counters are incremented by one. If the counter reaches a value of zero, then the specified waiting time has expired, i.e., timeout has occurred and appropriate action may be taken by initiating the execution of the relevant programme. If the event being timed occurs before the timeout expires, the timing counter is rendered inactive.

Network Driving: The network driving programmes consist mainly of all the signalling postprocessing programmes and the switching network driving programmes described earlier. The network driving programmes are performed in clock level mainly to simplify the interworking of the two processors. The fact that the two processors are never in clock level together provides a simple mechanism for ensuring that the two processors are not delivering instructions to the network at the same time. All the network driving programmes are hopper fed with messages from the exchange control programmes. If there are jobs awaiting action in the hoppers then the programmes are executed until the hoppers are empty. As soon as a particular hopper is empty the next programme is executed.

When the clock level programmes have been executed, the processor returns to complete the programme which was being executed when the clock interrupt occurred. In order that the interrupted programme should not be aware of the break in its execution, it is necessary for the processor on entering clock level to store any information such as register values, which might be destroyed by the clock level programmes. Immediately before leaving clock level this information is restored so that processing of the base level programme continues as if the interrupt had not occurred.

Base Level Programmes.

Programmes in base level are only executed when no interrupt has been recognised to force the processor into a particular interrupt level. The base level programmes therefore are those which do not have to be executed periodically or immediately following an external event. Also, the base level programmes are all hopper fed functional programmes, so that each programme is only executed when its particular function is requested. The functions performed by base level programmes fall into several categories such as general exchange control (Route Search, Digit Analysis, Clear-down), switch control (Path Search), hardware device control (Allocate KS, KM and DPS, and Signalling Unit Clear-down), software device control (Allocate DB, Transfer DB/SB, and Release SB), and timing control (Timeout and Cleardown Timeout).

The action of the base level programmes can be described by taking the Path Search programme as an example. There are four basic connections required for handling calls in the IST exchange:

(a) incoming line to signalling receiver;
(b) signalling sender to outgoing line;
(c) incoming line to outgoing line;
(d) busy tone or number unobtainable tone to incoming line.

Whenever any one of these connections across the exchange is required, an entry is placed in the hopper of the Path Search programme giving details

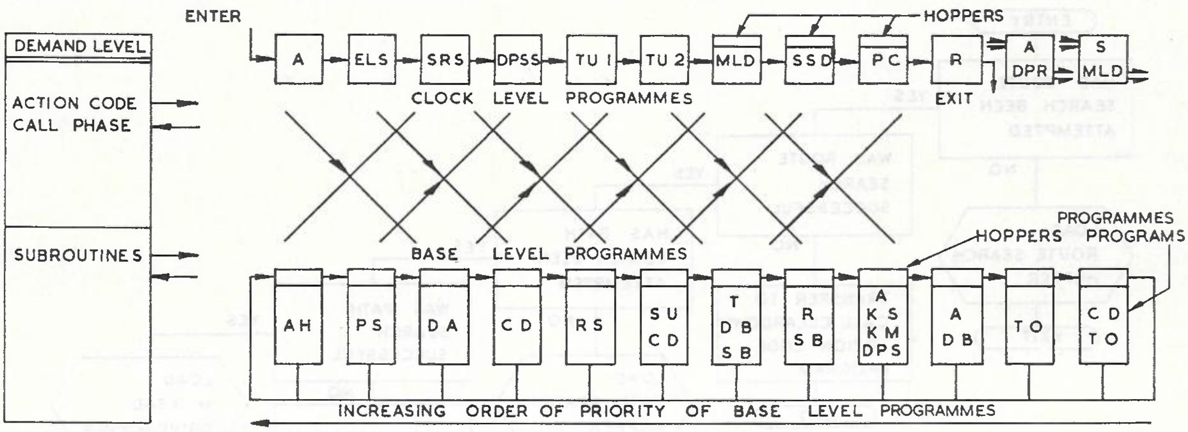

Fig. 11. — IST Programme Structure

of the lines between which a connection is required and of the dialling buffer which is holding information pertinent to that call. The Path Search programme maintains two tables called the timeslot occupancy map and the location occupancy map. These tables contain a complete description of the free or busy state of all possible connections across the exchange. By consulting these tables the Path Search programme is able to select and allocate a suitable path across the exchange. The Path Search programme makes no reference to the actual network when allocating a path, but relies completely on the record kept in the tables. As these tables are the only record kept of the state of the network, it is necessary for them to be completely reliable in their accuracy. The Path Search programme stores in the dialling buffer the results of its calculations (e.g., path identity) so that other programmes may use this information.

When the execution of a base level programme has been completed, processing continues in base level until an interrupt occurs. The matter of deciding which programme to execute next is the important task of job allocation. In the executing of the IST programmes job allocation is not performed by a particular supervisory programme, but is an operation implicit in the whole structure of the framework into which all the programmes fit. The base level programmes are arranged in a multiple loop, as shown in Fig. 11. The programmes are arranged in a loop in rank order of priority. At the completion of any programme a check is always made, starting with the highest priority programme, to see if any higher order programme requires execution. Only if no entry exists in the hopper of a programme of higher priority is any programme executed. This arrangement avoids the use of a complicated job scheduling routine and provides a simple but versatile means of job allocation which absorbs the minimum amount of processor time and memory. The operation of call handling programmes using this method of job allocation does not depend on any knowledge of the functions of the programmes awaiting execution. All that it is necessary to know is the rank order of priority of the base level programmes. If at any time a new base level programme is required, it can be added very simply to the most appropriate place in the loop, depending on its relative priority, affecting only the exit information in a special table of the programme immediately ahead of it in priority. A similar arrangement of base level programmes has been described by Treves (Ref. 7).

Demand Level Programmes.

Demand level programmes do not lie in any interrupt level or in base level and are not hopper fed. They are therefore not executed regularly but must be requested by some other programme. There are two classes of demand level programmes:

Subroutines: There are many relatively small programming tasks which have to be carried out by a number of programmes at various times. Most of these are provided as subroutines which are used, as required, by any programme. A typical example of a subroutine is the Find First One subroutine, which is used by many programmes when searching for the identity of the bits in a word which indicate that a change of state has occurred. Subroutines are executed immediately they are called by a programme and upon completion, the execution of the calling programme is continued.

Action Code, Call Phase Programmes: The AC, CP programmes are responsible for the controlling of the ordered sequence of tasks required to handle each call correctly. These programmes do not perform any functional tasks themselves, but initiate the execution of functional operational programmes. They make decisions concerning which programme should next be initiated for a particular call by interrogating the dialling buffer which contains information pertinent to that call.

There is a group of AC, CP programmes for controlling each different sequence of tasks required by the exchange. The action code value defines the group and the call phase value defines an individual programme within the group. In the IST exchange, one group controls the setting up of calls originating from step-by-step exchanges (AC 1), another controls the setting up of calls originating from crossbar exchanges (AC 3), while a third controls the premature cleardown of calls (AC 2). Further groups are used for arranging maintenance and diagnostic tests on the exchange.

The way in which an AC, CP programme works is illustrated by taking as an example the action code, call phase programme 3,2 which was shown in Fig. 8. A simplified flow chart of programme 3,2 is shown in Fig. 12.

When an AC, CP programme is entered it has as data the identity of the dialling buffer holding information about the call on which a decision is to be made. On initial entry the programme 3,2 interrogates a bit in the dialling buffer and so decides that a route search has not yet been attempted for this call. It therefore initiates the search for a free outgoing channel on the required route by placing an entry in the hopper of the Route Search programme. Processing then continues at the highest priority programme in base level. After the Route Search programme has allocated an outgoing channel, programme 3,2 is

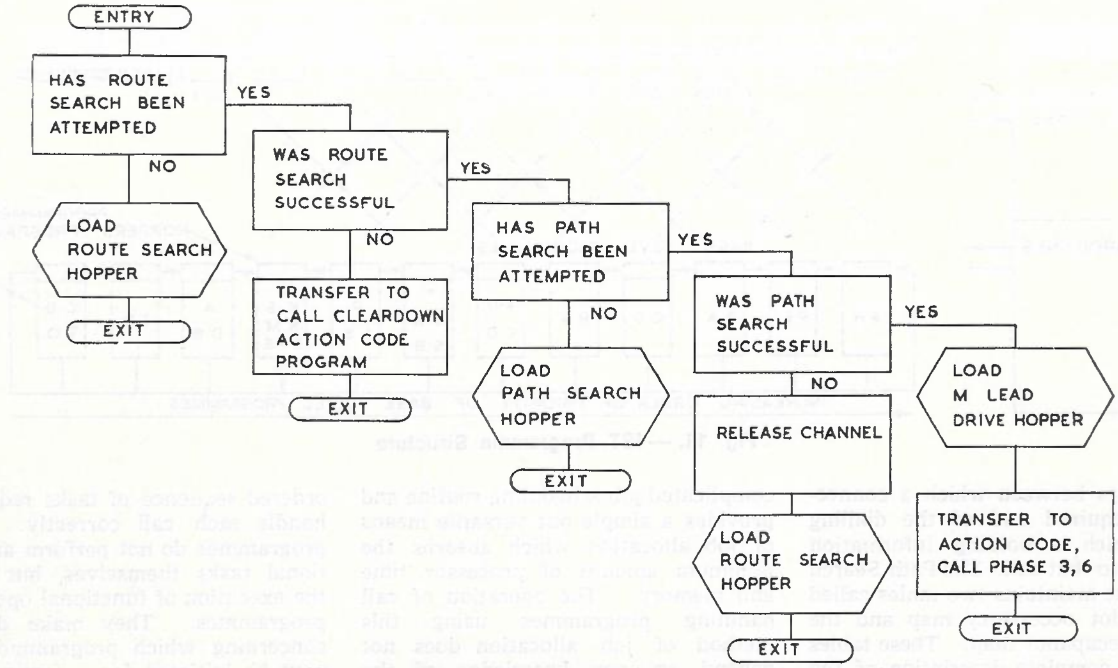

Fig. 12. — Simplified Action Code, Call Phase Diagram 3,2.

entered again and after checking that a successful route search has been performed, it initiates a search for a path from the incoming channel to the selected outgoing channel by placing an entry in the Path Search hopper. When the Path Search programme has allocated a path across the exchange, programme 3,2 initiates the sending of a seizure signal on the outgoing channel by placing an entry in the hopper of the M Lead Drive programme. It then transfers control of this call over to programme 3,6, which organises the progress of the next stage of the call.

Programme 3,2 also is responsible for initiating the correct action should all channels on the required route be busy or should there be no free paths to the selected outgoing channel, and for all other possible situations which could occur. If, for example, there is no free path to the outgoing channel selected, programme 3,2 organises the selection of another outgoing channel and the search for a path to that channel. Programme 3,2 also controls the maximum number of attempts allowed to be made to find a suitable path to the exchange. This number is currently set at 3, but is a parameter which can be changed quite simply if necessary.

STATE INFORMATION.

From the description given above it can be seen that every programme has its own particular function to perform. Any one programme always carries out the same function; for example, path search, for all calls which are handled by the exchange. There is no association of particular programmes with particular calls., However. information individually identifying the status of all calls, switches, lines and devices must be available as data for the programmes. This state information is kept in reserved memory spaces called buffers and tables. The most important of these are:

Dialling Buffers: From the moment a new call is detected until it reaches the conversation stage, it is allocated an area of memory of sixteen words called a dialling buffer. In this dialling buffer is stored all information relevant to that call necessary to ensure that the call can be set up or broken down as required. Examples of this information are:

(a) incoming line identity;
(b) outgoing line identity;
(c) signalling sender and receiver identities;
(d) details of paths used between lines and senders and receivers;
(e) digits received from incoming line;
(f) current action code, call phase;
(g) whether route search has been initiated and successful.
(h) whether path search has been iniated and successful.
(i) various other call control information.

Supervision Buffers: As soon as a call reaches the conversation phase it is possible to conserve memory space. The dialling buffer is released and the call is allocated a supervision buffer of four words. The information contained in the supervision buffer consists of incoming and outgoing channel identities, the details of the path connecting them, and a few control bits.

Line Tables: Each line connected to the exchange is allocated two words of memory (32 bits), called the class of line word and the line condition word. These words contain information describing the type of line and its current usage.

As mentioned above, the dialling buffers and supervision buffers always contain the identity of the lines involved. In addition the identity of the dialling or supervision buffer allocated to a line is stored in the line condition word. This means that it is always possible to find out all the information relating to a call, starting from either of the lines connected, or from the dialling buffer or supervision buffer. This feature is especially valuable in enabling the healthy processor to take over calls set up by a processor which has failed.

Line Last Look Tables: These tables contain the last condition of the E leads as obtained by the scanning programmes. All changes of state in these signalling leads are detected by comparing their present state with that stored in the line last look tables. Two bits per line are required, with eight lines sharing a word, making a total of three words per 24 channel PCM system.

Device Status Buffers: Every device such as a signalling sender or receiver which is connected to the exchange is allocated one word of memory called the device status buffer. In this word is stored information on the current state of the device, e.g., free or busy, healthy or faulty, and some last look information. As with line tables, cross referencing is possible between a device status buffer and the dialling buffer for a call which is using the device.

Route Tables: Selection of an outgoing channel on the required route is achieved by searching over the route tables. The Route Search programme and route tables have been designed to allow a random distribution over the exchange of bothway, incoming and outgoing junctions.

Junctor Maps: All connections across the exchange are made with reference to the timeslot occupancy map and the location occupancy map as described earlier. These tables contain a complete description of all possible connections across the exchange by detailing the status of all junctors. The timeslot occupancy map requires one word per highway timeslot and will be provided in full in the initial field trial so that no restriction is placed on the use of highway timeslots. The location occupancy map requires a maximum of 96 words, but in the initial field trial it need be only as long as the number of locations contained in the junctor which is equipped to the greatest extent.

Device Location Tables: The service groups have been organised to allow any signalling sender or receiver, tone generator, recorded announcement, test device or similar unit to be connected to any inlet or outlet on the service groups. For each type of device connected to the service groups, a location table is provided which lists against the number of the unit the identities of the group and the highway timeslot to which the unit is currently connected. It is possible to rearrange the distribution of devices connected to the service groups to meet varying traffic and other requirements as the exchange grows, without changes to the programmes. It is necessary to change only the information stored in the relevant location tables. This can be done by means of the man-machine communications programme.

MAN-MACHINE COMMUNICATIONS PROGRAMMES.

Although the IST exchange is designed to operate in an unattended automatic mode, it is necessary for information to be passed between the processor and operating personnel. Output messages, originated by the processor, provide information on system performance, detected fault conditions, traffic statistics, etcetera. Input messages, originated by the operator, allow:

(i) new exchange data to be presented to the processors;
(ii) the operator to request particular information from the processors;
(iii) the operator to initiate the reading in and execution of programmes which are kept off-line on paper tape. These programmes are normally detailed test programmes, which are only required to be executed when a particular fault condition has been detected.

In the IST project the device used for man-machine communication is an ASR 33 teletypewriter. The ASR-33 has a standard keyboard, and a ten character per second reader and punch. Messages are transferred to and from the processor and the ASR-33 in ASCII code over a normal telegraph line so that the ASR-33 may be located at any distance from the processor. In an operational exchange, two ASR-33 units would normally be connected in parallel to the control processors. One unit would be located adjacent to the processors, while the other would be located in a regional maintenance centre.

To allow efficient transfer of messages, the ASR-33 is operated in interrupt mode. When the unit is in its input state, an interrupt will be generated whenever a character is sent from the keyboard or from the reader. When the unit is in its output state, an interrupt will be generated whenever a character sent from the processor has been printed and if required, punched on to paper tape. The interrupt line used by the ASR-33 is lower in priority than that used for clock interrupt.

Several operational programmes are required for handling ASR-33 messages. When an interrupt is received, programmes in the ASR-33 interrupt level arrange the sending or reception of the next character. Base level programmes are involved in the generation or interpretation of messages. One clock level programme is also involved. Since both processors use the same teletypewriter it is necessary to ensure that each processor can seize the unit for its exclusive use in outputting a message. This can most conveniently be achieved if each processor attempts to seize the ASR-33 only when it is in clock level since the two processors are never in clock level at the same time. The possibility of dual seizure is therefore eliminated.

RELIABILITY.

Telephone exchanges are required to provide continuous reliable service over a large number of years. In the highly centralised control situation of a processor controlled exchange, fault tolerance is not an inherent or natural characteristic, and it is possible for a relatively minor failure to cause the complete breakdown of the exchange. A second processor is utilised to provide the necessary level of reliability and dependability.

Faults can come from a number of causes, such as permanent hardware failures, transient hardware failures, electrical disturbances and software errors. It is necessary to provide a control system which can continue to provide service, even if degraded, in spite of the occurrence of any of these types of failures, and which can also recover to full control capacity from the effects of any of these failures. An attempt has been made to build in reliability at all levels of the IST system design, both in the hardware and in the software.

In the IST exchange, security of the control capability is obtained by the duplication of processors and of most of the interface equipment. The processors are both fully active when healthy and share the load of the exchange between them. Both processors continuously scan the whole network and take note of all changes of state. Each processor accepts only half of the work of the exchange, as the programmes are arranged so that the processor which first detects a new call, handles that call for its whole duration. This arrangement is greatly simplified by the fact that the two processors scan the network alternately during different time intervals. Each processor must be able to carry the full rated load of the exchange. The second processor provides security and an increased overload capacity, rather than an increase in the rated load capacity.

In the event of the failure of one processor, all calls in the process of being set up by that processor will be broken down by the processor remaining on-line. All relevant lines, paths, signalling senders and receivers, and dialling buffers will be released by the healthy processor. The supervision of calls already established by the processor which fails, will be taken over by the processor remaining on-line. In order to enable the load sharing and take over procedures to be performed effectively, the two processors interchange certain information at appropriate times. This information is that required:

(a) to allow the two processors to share the load evenly and to avoid competing and interfering with each other;
(b) to allow the healthy processor to break down cleanly any calls being set up by the other processor at the time of the failure;
(c) to enable the healthy processor to allow all existing calls to remain undisturbed by the failure of one processor.

The interprocessor messages sent for a simple successful call from Clayton to South Oakleigh are listed in Appendix 2.

The processor remaining on-line attempts to return the failed processor to service by reloading the programme into its memory, and putting the processor through various tests of its memory, control unit and arithmetic unit. If the failed processor passes all these tests, it is given a completely updated picture of the state of the network, devices, lines and calls, and is then put back into service. If the cause of the breakdown had been software or an electrical disturbance or a transient hardware fault, the processor will continue to carry traffic until a similar fault is encountered again. If the failure had been a permanent hardware one in the processor, the processor will fail to pass the tests, and the location in the programme where the failure was detected will assist in determining the nature of the fault.

In the event of the failure of both processors, a small hardware device tries alternately to put one or other of the processors back into service. As soon as either of the processors is on-line it takes control and tries to put the other processor into service. When all the various automatic devices are unable to handle the situation, recourse must be made to manual methods of initiating recovery.

MAINTENANCE AND OPERATION.

The exchange control system has been designed to allow unattended automatic operation to be the normal mode of operation. Whenever a fault is encountered a message is printed on the console teletypewriter. Various traffic statistics and other information can also be printed as required. When the exchange is unattended there would normally be two teletypewriters working in parallel, one at the exchange and one at the regional control or service centre. According to the nature of the fault the staff at the regional centre would know whether it was necessary or not to travel to the IST exchange to affect repairs.

The basic maintenance and operational tool is the processor and the various test, man-machine and security programmes. The programmes are continuously conducting tests on the processor, the interface equipment, the switchblock, the signalling senders and receivers and on each other. Only when both processors have failed should it be necessary to resort to essentially manual methods of fault finding. Enough maintenance and diagnostic programmes are included in the memory to provide the basic maintenance and diagnostic functions. After the general location, extent and type of fault has been established by these programmes, special programmes relevant to the particular fault are loaded into an area of memory reserved for this purpose. These on-demand programmes are used to examine the conditions in detail and to printout information which will inform the mantenance technician which circuit card or sets of cards to replace.

Examples of Test Programmes.

The types of test programmes used are illustrated by the following examples:—

Signalling Scanning: Every 20 ms all signalling leads of the exchange are scanned by the processor. Before scanning the signalling leads, test commands are sent to the interface equipment involved, and scanning only continues if the correct responses are received. If the correct responses are not received a diagnostic programme is executed.

The signalling leads of the PCM systems are scanned in groups, with three 16 bit words per system. After testing the interface the four system alarms of each PCM system are scanned and checked for valid operation before the signalling information is collected. For example, if a particular system is indicated as being out of synchronisation its signalling leads will contain invalid information, and their scanning is inhibited until the system regains synchronisation.

Path Setting: All paths across the exchange are made by means of the delay and zero delay junctors. All junctors have a number of locations, each of which is used to maintain one connection, or conversation. The contents of the locations are not normally scanned for the purpose of path searching and selection, this function being performed entirely in the memory maps of the junctor timeslot and junctor location occupancy. Once a path has been selected, the appropriate order is passed to the particular junctor. If a programme error has occurred this could result in either a connection being broken down unintentionally, or else an unwanted double connection could be made. A simple test takes advantage of the fact that in normal operation each location receives alternate commands of connect and disconnect. If a particular junctor location receives two successive commands to connect, the operation is inhibited by the junctor hardware and a fault bit is set. After sending out each path connection instruction the processor checks the condition of the fault bit. If it has been set a test programme is entered. Normally this programme will repeat the instruction in case an intermittent fault has occurred, but if the fault persists further analysis will be performed.

Maintenance Programmes.

The two examples given above concerning signalling scanning and path setting illustrate the type of test programmes which are used during normal call handling to check that the system is performing as required, and the type of test programmes which are responsible for initiating the corrective action if faults occur. There is another family of test programmes which are separate from the normal call handling programmes. These are the maintenance programmes which are used to carry out a series of tests on the functioning of all parts of the exchange, both hardware and software. The tests are performed in a cyclic manner and use whatever spare processing capacity of the processor remains from the call handling tasks. Examples of these programmes are given below.

Serial Testing of Exchange Equipment: Each incoming PCM serial pulse train contains the speech information of 24 junction circuits. Before each pulse train leaves the exchange on its outgoing line it passes through a large number of digital switches in the form of semiconductor gates, all of which are time-shared with many other circuits. Failure of any of these gates would cause results like an error in the outgoing pulse train, probably degrading the intelligibility of the speech, or incorrect switching across the exchange. In the normal setting up of a call no check is made of either the quality of the transmission across the exchange or of the correctness of the path actually established. These checks are left to a low priority maintenance programme which checks the transmission from all inlets to all outlets in a cyclic manner by means of a serial test unit, one of which is associated with each PCM system or system speech memory. Under programme control, the serial test unit can be used to place either of two complementary patterns on the speech bits of any incoming channel in the exchange. The maintenance programme sets up a path across the exchange to the outlet of the particular outgoing channel and scans a simple detection circuit to see whether the pattern transmitted has been received. The pattern is then inverted and the detection circuit scanned again. If both patterns are transmitted correctly across the exchange then all equipment involved (and associated software) must be working correctly. If either of the tests fail, then a path is set through another junctor or to another outlet and the test is repeated. By testing all the inlets, paths and outlets it is possible to deduce what type of fault has occurred and what item of equipment is involved. If a particular junctor has failed, for example, then it is marked permanently busy in the memory records consulted by the call handling programmes, so that it will not be allocated to future calls, and a fault report is made on the teletypewriter. After the fault has been cleared the maintenance staff, by means of a message punched on the teletypewriter, can arrange for the junctor to be placed back in service.

Testing of Signalling Senders and Receivers: In addition to the connections used when handling calls, it is possible to connect any signalling sender to any signalling receiver by means of the normal switchblock. This facility is used by maintenance programmes which check the functioning of the various signalling senders and receivers and their interface equipment. In a typical test a dial pulse sender (DPS) is connected to a dial pulse receiver (DPR). The programme instructs the DPS to send a particular digit and then checks to see if the DPR has reported the detection of the same digit. The programme continues by commanding the DPS to send all ten possible digits, and then continues by checking another pair of senders and receivers. If the correct digit is not received at any time, the programme tries another path through the exchange, or another DPS or another DPR and builds up a pattern of failures. Examination of the pattern of failures will determine what type of fault has occurred. If it is a DPS, for example, it will be marked permanently faulty in the memory, and a fault report will be printed out. After the fault has been cleared the maintenance man can type in a message to restore the DPS to service.

Deductive Maintenance.

In the four examples given above of test programmes and maintenance programmes, it can be seen that the fundamental approach to testing and maintenance has been to use the powerful deduction facility provided by the processor. The IST system has been designed to take maximum advantage of this facility, which enables many powerful checks to be made in both direct and indirect manner with a corresponding reduction in exchange hardware size and complexity. By the provision of programmes independently situated in memory and independently executed, the system can, in effect, get outside itself and view its own performance from afar. This provides a facility for valid self-monitoring.

The approach of deductive analysis is also applied to checking the programmes. One example of the type of approach being followed concerns the overall timeout placed on the use of the dialling buffer. There are a large number of specific timeouts provided in the programmes. Many of these apply to specific events, such as the reception of a backward MFC signal on a particular channel. In addition to these specific timeouts, there is an overall timeout on the use of the dialling buffer during the setting up of a call. Any one of a large number of situations, some outside the IST exchange and some inside the IST exchange, can cause the incomplete setting up of a call. When this overall dialling buffer timeout expires, the call is broken down and congestion tone is returned to the subscriber. It is not possible, at the moment that the timeout expires, to work out the cause of the trouble, as it could even be a very slow dialling subscriber, with all hardware and software operating correctly, without a fault anywhere. Whenever an overall dialling buffer timeout expires, or clear forward is received before the dialling buffer has been released, the contents of that dialling buffer are dumped either in memory or on tape. The dialling buffer contains the identity of all the lines, signalling senders and receivers, and other units involved, and all other information concerning the state of the call. After a few timeouts have occurred, all this information can be examined, either automatically or manually, and a search made for common information. If there is one DPR, for example, involved in most of the timeouts, then it is highly likely that the DPR or its associated interface is faulty, and it can be taken out of service for repair. If many of these timeouts occurred with different DPRs but after only two digits had been received, then it is most likely that there is a software fault, and its likely area can be deduced.

PHASES OF THE IST PROJECT.

The shortage of resources has determined to a large extent the way in which the various phases of the IST project will be carried out. On initial cutover (Phase 1) the IST exchange will include all basic call handling programmes with only a small number of test, security and man-machine communications programmes. This phase is called the essential simplex (one processor) phase. With this approach it should be possible for the cutover date and the gaining of experience in handling live traffic to occur at the earliest possible date with the limited resources available. Phase 2 of the project will be the addition of a second processor and its interface for the purpose of providing the required level of reliability and dependability. This phase is called the essential duplex (two processor) phase. Phase 3 of the project will involve the extension of the operational test programmes to provide a range of maintenance and diagnostic programmes. Phase 4 of the project will involve the remote control of subscribers' switching stages, or concentrators. The basic design of the programme control system has been carried out in such a way that it caters for all the project phases mentioned above. It allows the facilities of the exchange to be increased steadily from the bare minimum to whatever is ultimately required by the addition of suitable programmes as they become available.

Topics for Later Study.

Several aspects of the control facility have been set aside for more detailed study at a later date when more resources become available. Some of these topics will be mentioned briefly. No provision has been made for any special reaction to be made to traffic overload conditions. For the initial stages of the field trial, only two step-by-step seizures will be accepted by each processor in any one clock interval of 20 ms. Additional step-by-step seizures will be given busy tone. Only two crossbar seizures will be serviced by each processor in any one clock interval. Additional crossbar seizures will be ignored until the next clock interval. This approach seems a reasonable one for the initial project stages, especially when it is realised that one seizure every clock period of 20 ms represents 6000 erlangs of traffic given a mean call holding time of 120 seconds. As the traffic builds up to an overload position the general effect on the operation of the exchange will be an increase in the delay involved in handling calls. It is considered that detailed study of better ways to react to overload conditions should be left until later stages of the project.

For similar reasons no attempt has been made to incorporate into the programme structure any type of dynamic control. It is believed that the existing structure could easily be included in any useful dynamic system. No network management functions have been included, as it is considered that it is better to wait until the facilities of this nature which are really required for the APO network become more clearly defined. Detailed work on the automatic detection, localisation and repair of faults will be carried out at later stages when more resources become available.

The Extent of the Initial Field Trial Installation.

In the initial field trial installation a total of 96 (incoming plus outgoing) PCM circuits will be connected to the IST exchange. A few of these circuits will be allocated to MFC receivers and special test lines, so that a total of about 88 (incoming plus outgoing) circuits will be available for traffic purposes. The expected traffic loading of the exchange from the 38 incoming circuits is 30 erlangs. Two traffic group speech memories (GSM) and two traffic output registers (OR) will be provided, each being 25 per cent. equipped. Two partially equipped delay junctors (DJ) and one partially equipped zero delay junctor (ZDJ) will be provided. The hardware will be able to be extended by the addition of suitable plug-in units.

Scope of the Initial Programmes.

The initial programmes and data formats have been designed to allow the exchange to grow to 12 times its initial cutover size without changes being required to either the programmes or the data formats. The only changes required are essentially those of changing the parameters which describe the extent to which the exchange has been equipped. Up to six traffic groups each fully equipped for eight PCM systems (a total of 1152 incoming and outgoing junctions), and two fully-equipped service groups can be used, together with up to eight delay junctors each with up to 96 locations, and up to four zero delay junctors each with up to 192 locations. The junctors can be dimensioned to cater for any traffic patterns and loading, up to a total traffic of more than 600 erlangs.

DEVELOPMENT ASPECTS.

As the IST project includes the first complete programme control system for a telephone exchange which has been designed in the APO, and as the design was being carried out in a developing situation, the approach adopted to the design has deliberately been a systematic and cautious one. A great deal of attention has been paid to ensuring that the design was based on both the overall facility requirements of the exchange and on the use of suitable efficient programming techniques. The different programme types, such as call handling and man-machine communications programmes have been given well defined boundaries and ways of interworking. The individual programmes have been given well defined functions, boundaries and methods of communicating and interworking with each other, resulting in a well defined modular structure. In this way the programmes have considerable independence of each other wth great flexibility in internal design, modification and operation. Individual programmes can be changed or optimised without causing interaction to other programmes. Considerable use has been made of parameters to control the behaviour of the programmes and of the exchange. The ability to record, as required, the occurrence of a large number of events has also been included. Aspects like modularisation and the use of parameters have deliberately been taken further than absolutely necessary so that maximum control can be maintained over the operation of individual programmes and so that considerable detail of the performance of the programmes can be obtained when checking the behaviour of the exchange under different conditions.

Testing of Programmes.

From the outset the importance of developing at an early stage suitable methods of testing the programmes has been recognised. An attempt has been made to provide systematic, automatic and comprehensive methods of testing the programmes and the programme control system. Effort has been concentrated on the design of a test package to enable the functional testing under completely controlled conditions of the individual, or unit programmes, and on the design of a simulation testing system to test the operation and performance of the total programme control system. (Programmes of this type which are used to assist in the development of the operational programmes are called Support Programmes). The simulation testing system involves the use of another processor which simulates the action of the IST exchange interface and network hardware, and the action of the exchanges to which the IST exchange is connected. The two processors containing the operational programmes are connected to the third processor by means of special interface equipment similar to the normal interface equipment, as shown in Fig. 13. As far as the operational programmes are concerned there is no difference between the situation when controlling

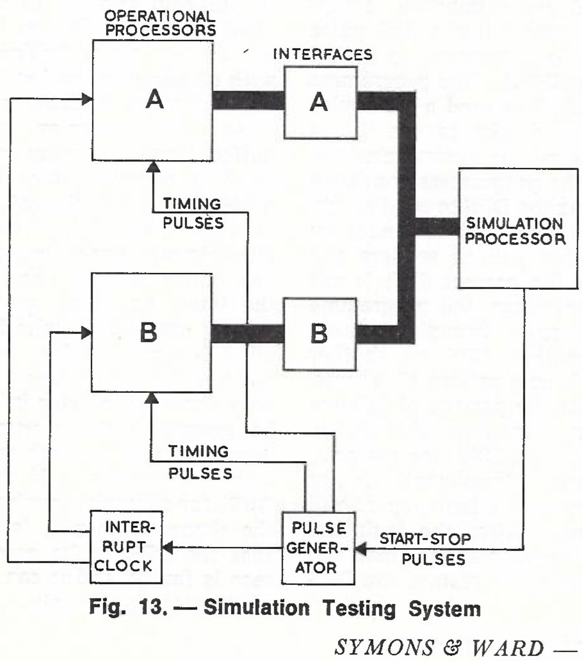

Fig. 13. — Simulation Testing System

live traffic and the situation when connected to the simulation processor. Hardware and software facilities are included in the system to enable a wide range of tests to be carried out under controlled and reproducible conditions while preserving completely the real time situation of the operational programmes. Both normal and fault conditions can be simulated. A separate paper will be published describing in detail this simulation testing system.

Another set of the support programmes are the programmes written to test the operation of various parts of the hardware. These range from programmes to test units which will actually be connected to the processor in the exchange, to programmes for the testing of the operation of individual printed circuit cards to be used in the exchange hardware.

Progress Achieved.

The progress achieved at the time of publication in the design, development, production and testing of the programmes is summarised below. The design of the operational software system. or programme structure, described in this paper was completed by the authors by April, 1969. The functions of almost all the individual call handling programmes, and the detailed specifications of about 70 per cent. of the call handling programmes, had been completed by August, 1969. Since that time the rate of progress in the design has been decreased by pressure of other work. By the time of publication all the call handling programmes should be specified, and most of the test, security and man-machine communications should be specified. More than half of the 100-120 units programmes necessary for phase 1 of the project will have been written and tested.

CONCLUSION.

Although the digital switch in the IST project will not be handling live telephone traffic until 1971, the experience gained during the development of the IST programme control system has already proved extremely valuable. It has helped considerably to increase the knowledge and appreciation within the APO of the various advantages and disadvantages of stored programme controlled exchanges. The A.P.O. is on the threshold of the widespread application of programme controlled exchanges and there is a continuing need for basic studies of this type to highlight desirable trends and techniques in order that the APO may take full advantage of the developing technology.

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APPENDIX 1.

GLOSSARY OF ABBREVIATIONS USED IN THE FIGURES

A—Acceptance programme for clock level.
A/D—Analogue to digital converter.
ADB—Allocate dialling buffer programme.
ADPR—Allocate dial pulse receiver programme.
AH—Action handling programme.
AKSKMDPS—Allocate KS, KM or DPS programme.
BT—Busy tone.
CD—Cleardown programme.
CDTO—Cleardown timeout programme
DA—Digit analysis programme.
D/A—Digital to analogue converter.
DB—Dialling buffer.
DJ—Delay junctor.
DPR—Dial pulse receiver.
DPS—Dial pulse sender.
DPSS—Dial pulse sender scan programme.
ELS—E lead scan programme.
GSM—Group speech memory.
KM—MFC receiver.
KMM—receiving part of KM.
KMS—sending part of KM.
KS—MFC sender.
KSM—receiving part of KS.
KSS—sending part of KS.
MFC—Multi-frequency code.
MLD—M lead drive programme.
NU—Not available tone.
OR—Output register.
PC—Path connection programme.
PS—Path search programme.
R—Release programme for clock level.
RS—Route search programme.
RSB—Release supervision buffer programme.
SB—Supervision buffer.
SMLD—Special M lead drive programme.
SRS—Signalling receiver scan programme.
SSD—Signalling sender drive programme.
SUCD—Signalling unit cleardown programme.
TDBSB—Transfer from dialling buffer to supervision buffer programme.
TO—Timeout programme.
TU1—Timeout update programme.
TU2—Timeout update programme.
ZDJ—Zero delay junctor.

APPENDIX 2.

INTERPROCESSOR CHANNEL MESSAGES.

The interprocessor channel messages sent for the setting up of a simple successful call from Clayton to the crossbar part of South Oakleigh are listed below:—

1. Seizure on (incoming) line x accepted.
2. Dialling buffer x (DBx) seized for the call on line x.
3. Code receiver KMx seized for DBx.
4. Map seized.
5. Highway timeslot x (HTSx) and HTSy and location w of junctor z seized for path from line x to KMx.
6. Map released.
7. (Outgoing) line y seized.
8. Map seized.
9. HTSp and HTSq and location s of junctor r seized for path from line x to line y.
10. Map released.
11. HTSx and HTSy and location w of junctor z released.
12. KMx released.
13. Supervision buffer y seized for connection between line x and line y using HTSp and HTSq and location s of junctor r.
14. DBx released.

THE FEASIBILITY OF DOMESTIC SATELLITE COMMUNICATIONS FOR AUSTRALIA

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INTRODUCTION.

The principal characteristic of the population distribution over the Australian continental area of nearly three million square miles is the heavy concentration in the south-east corner. Over 60 per cent. of the population resides south-east of a line from the immediate north of Sydney to the immediate west of Adelaide. The distribution is reflected in the shape of the national telecommunications network, and an impression of this is conveyed by Fig. 1, which shows the main broadband trunk network only.

In the north of the continent particularly, adjacent homesteads may be separated by distances exceeding 50 miles and the costs of connecting them to the network by existing methods are in many cases prohibitive.

The ribbon-type development of the network also presents major problems in securing reliability of long-distance trunk systems by route diversity. It can be seen from Fig. 1 that apart from the meshed network developing in the south-east corner, the early prospects for terrestrial route diversity for much of the network are remote in view of the costs.

Nevertheless, significant economic developments are occurring in the north and west, particularly in major mineral ventures. This increases the demand for circuit capacity and reliability on the existing trunk network to more remote centres. In addition, the frequent emergence of new mines far from the reaches of the network, accompanied by short lead-time notification of telephony requirements, gives rise to difficulty in providing telephone service. Provision of T.V. relay facilities is often impracticable.

In this environment the study of a satellite system for domestic communications invites attention, not only as a competitor with terrestrial systems in the provision of conventional facilities over long distances, but also the provision of services which could not otherwise be effected.

EXISTING DOMESTIC SATELLITE COMMUNICATIONS.

Even prior to the establishment of a national satellite system, the possibility exists of operating domestic trunk circuits over a satellite by

* Mr. Kellock is Engineer Class 4, Planning Branch, Headquarters. See Vol. 18, No. 3 p. 286.

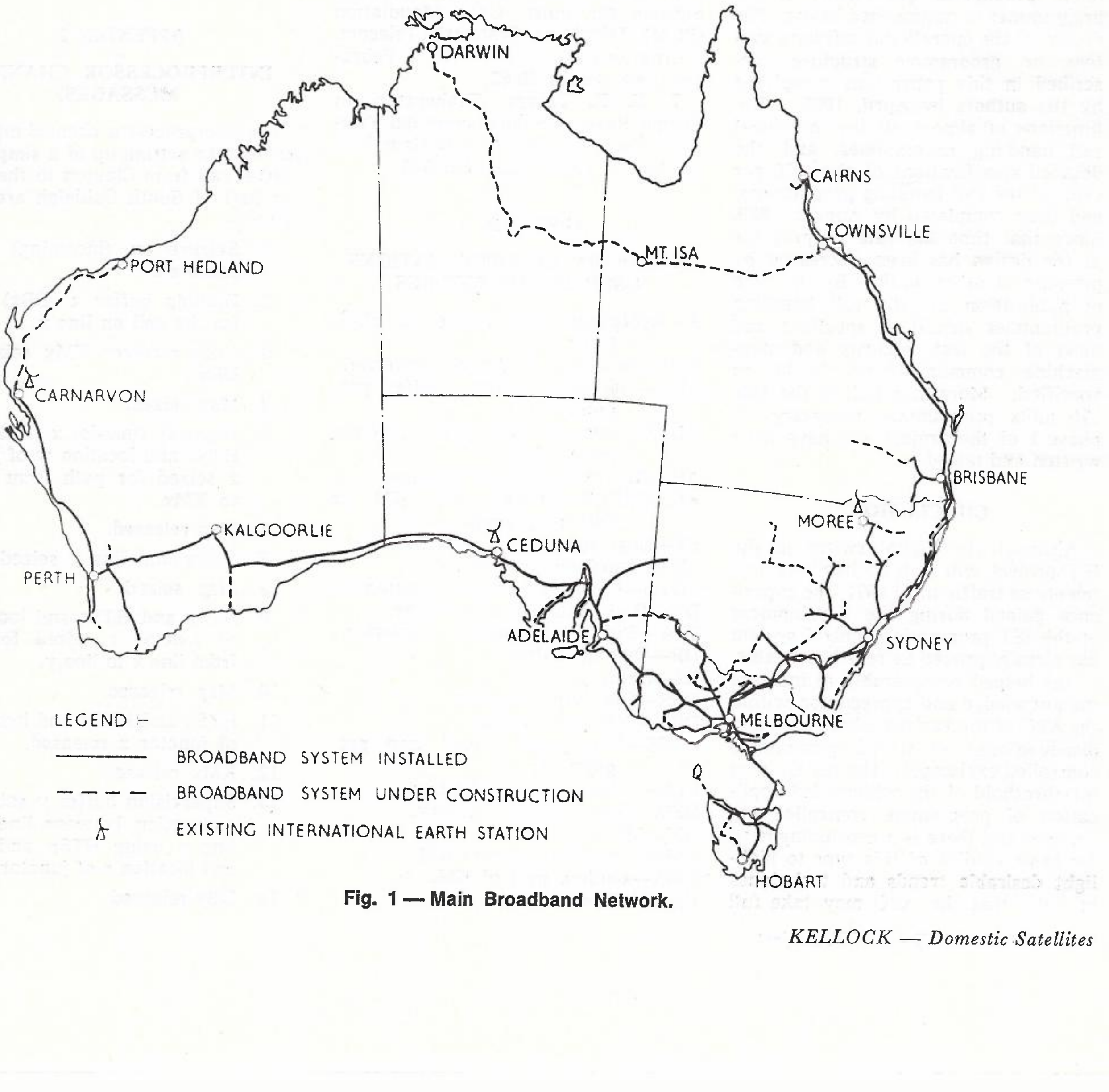

Fig. 1 — Main Broadband Network.

using facilities furnished for the international service.

Since November, 1969, 24 circuits have been operating between Perth and Sydney by the Intelsat III F-4 satellite over the Pacific Ocean. These have been set up through existing earth stations at Moree, near the east coast, and Carnarvon, near the west coast, which were established for the international service (Ref. 1).

Detailed performance assessments have been carried out by both observations and customer surveys, using an interview format of the same type as that used by A.T. & T. and European Administrations on international calls in order to facilitate comparisons. Correlation will be made between observations and survey results to test the validity of the survey technique.

The circuits are controlled on a one-way basis by manual operators at the outgoing end using decadic pulse signalling. The service had to be opened with 6A switching-type echo suppressors temporarily, and, although observations indicated that traffic was passing satisfactorily, customer surveys indicated a level of difficulty encountered which was above normal. Many of the difficulties described, however, were consistent with the effects of switching-type echo-suppressors. Early in 1970 these echo-suppressors were replaced by suppressors designed for satellite operation. At the time of writing, preliminary observations indicate that the transmission quality had significantly improved, but survey results are not yet available.

FEASIBILITY STUDIES.

A feasibility study carried out in 1966 was directed at the possibility of establishing a system for domestic communications, using a dedicated satellite. This indicated that the total annual charges of a satellite system would substantially exceed those for providing the same facilities by conventional terrestrial systems.

A further study has been carried out recently in the light of developments in costs and technology. The study included consideration of provision of facilities for the following services: point-to-point trunk telephony (South-east - Perth-Darwin); multiple access trunk telephony; T.V. relay; T.V. distribution for retransmission; and a telephone subscriber's service.

A model has been developed for the purpose of the study which basically assumes the use of current or imminent technology in order to consider a relatively pessimistic facilities/cost ratio. This has been developed around a satellite of payload which could be encompassed by a Thor Delta launch vehicle. Eight satellite channels of 40MHz bandwidth, receiving at 6GHz, transmitting at 4GHz, and developing a total output power of 36 watts,

Fig. 2 — Initial Earth Stations Assumed in Model for Trunk Telephony.

have been postulated. This could provide facilities for up to 3600 circuits of point-to-point telephony, one TV relay (East to West), two TV distribution programmes, multiple access trunk circuits using PCM/FM and a telephone subscriber's service.

Potential earth station locations for trunk telephony purposes are indicated in Fig. 2. Further stations for TV reception may be justified in other locations, depending on the extent to which the TV distribution facility is required. Antennas at the major earth stations at Perth and Darwin and the Eastern States would be 60 ft. diameter and at earth stations for multiple access telephony and reception of TV distribution would be 30 ft.

Satellite, launching and earth station costs used in system assessments have been based on estimates of costs which can be projected with reasonable confidence over the next 3-5 years. The profitability assessments have been checked for sensitivity to launching failures and a range of R. and D. costs.

Preliminary assessment indicates that such a system would be profitable, although it may be marginally uneconomic in its early years as compared with equivalent terrestrial facilities. This position would probably exist no matter when a satellite system is introduced, since major requirements which could form the basis of such a system will arise successively. As these requirements normally cannot be postponed for any length of time they will tend to be provided individually by terrestrial systems if a satellite system is deferred. For example, since the 1966 study, the Adelaide-Perth, Perth-Port Hedland and Townsville-Darwin links have been committed to terrestrial broadband systems.

Once established, however, a satellite system will improve in profitability over the years as compared with individual terrestrial systems. It also provides the potentiality for facilities which would not otherwise be possible, in particular the telephone subscriber's service. A significant benefit which is not directly quantifiable is the improvement in reliability achievable on the long distance trunk network exemplified by satellite links available between the South-east, Perth, Port Hedland, Wyndham and Darwin earth stations. Additional reliability could be achieved by further earth stations, for instance near Hobart, but at additional cost which could not immediately be justified by capacity needs alone.

There appear to be advantages in the establishment of a domestic satellite system and the planning and feasibility studies which have been undertaken will be continued.

Discussions are also in progress on the desirability of including facilities for other national agencies such as an air/sea navigation system and meteorological facilities. The additions would either improve economic viability of the system or yield enhanced potentialities for national operations.

THE SUBSCRIBER'S SERVICE.

A major problem of the Australian Post Office derives from the number of very remote homesteads for which it is not practicable to provide connection to the network by terrestrial means. Some dimension is provided by the 3560 outstations to the Royal Flying Doctor Service. This service operates on common-use high-frequency channels and outstations are not given voice connection to the telephone network. In addition, more than 36,000 remote subscribers are connected to exchanges by means of part-privately erected lines which in many cases operate as a party line service. Nine hundred of these lines are over 30 miles long and may extend to up to 300 miles. The majority of these telephone services are not technically suitable for connection into an automatic network. A subscriber's service by satellite could serve mobiles and mineral prospectors in addition to homesteads.

In order to examine the possibilities of providing this service:

(a) network problems are being explored by studying possible arrangements for system operation and network integration, and
(b) an experimental programme limited to the satellite link has been undertaken using ATS-1 facilities made available by the National Aeronautics and Space Administration.

To assist in the study of network problems and to guide the experimental programme, one possible system arrangement has been examined in some detail. Although other arrangements are possible, the feasibility of a subscriber's service is indicated by the concept studied. The system is intended to be expandable and the concept has been developed around a transponder capacity for 125 speech circuits accessible by 1000 outstations. Multiple access would be provided by

Fig. 3 — Outstation Antenna for Subscriber's Equipment Experiment.

the use of digitally-modulated single-channel carriers, the individual carriers being multiplexed by frequency division. For signalling and network control reasons the out-station subscribers could be grouped into blocks of about 100 and each block could have access to about 12 circuits. A further band would enable satellite subscribers to obtain direct inter-connection. Access to the telephone network could be given through several main earth stations (designated as ports) to minimise the length of the terrestrial network which must be traversed. Four-wire circuits to the telephone at the out-station end would avoid the need for an echo-suppressor at that end.

Signalling from the subscribers would be in-channel, both in-band and out-of-band. A 2 out of 12 multi-frequency code would be used in-band for information signalling, and subscribers' identification. The out-of-band signal is primarily for supervisory purposes. From the ports, low data rate (120 to 600 bits/sec) common-channel signalling is to be used.

The experimental programme is concluding in mid-1970, working through ATS-1 in the 4 and 6GHz bands available. NASA's Cooby Creek (Queensland, Australia) earth station has been operating in a multi-channel mode (using delta digital modulation) to simulate a network port operating with a multi-station network. A cheap outstation with a 12 ft. antenna and uncooled parametric amplifier has been developed (Fig. 3). The experimental programme was designed to indicate (a) the overall RF signal to noise ratio required for satisfactory performance; (b) the minimum channel spacing required to avoid excessive adjacent channel interference; and (c) tolerances allowable for differing RF signal power levels at the satellite receiver input to accommodate variations in signals from different outstations in the system.

The delta modulation codecs which are proposed for a practical system, and which have been used in the experiments, operate at 40 kilobits/sec. rate. The main part of the experiment effort is however concentrated on the assessment of channel error rates under a variety of conditions representative of multi-channel operation. The principal experiment uses three carriers modulated with uncorrelated pseudo-random sequences which are transmitted from Cooby Creek through the satellite to the small earth station. The earth station receiver selects one of these channels as a measurement channel. Error rates in the link are measured as the channel separation, clock rates and relative carrier levels of the three channels are varied.

The results of all the experiments being done under this programme are still being assessed, so no definite conclusions can yet be given. However, the 40 kilobits/sec. phase-shift keyed delta-modulated channels appear to require a spacing of about 50kHz. The error rate rises sharply for lesser values of separation. In addition to these quantitative measurements, subjective tests and demonstrations of speech transmission through the satellite were carried out. The speech quality was commented on favourably by over 100 participants, including several international transmission experts who were delegates at a recent C.C.I.T.T. meeting in Melbourne.

In studying the economics of a subscriber's service by satellite, it is assumed that the costs of the space sector are justified by other facilities which the system provides. Attention is then concentrated on the development of a sufficiently cheap outstation. Both a fully automatic dialling service and a system employing manual operators are under consideration, with outstation cost a major factor in selection. The service may evolve from a simple system with one port and manual operators to one with several ports and automatic dialling.

At the conclusion of the current installation programme for TV transmitters only some 3 per cent. of the Australian population will not be wtihin the primary service area of a transmitter. Most of the residual population however cannot be served practically by terrestrial transmitters. Although not included in the system model at this stage, direct TV transmission to domestic receivers in remote areas is a sufficiently significant requirement for parallel studies to have commenced on this aspect.

NETWORK PROBLEMS.

A number of problems arise in integrating a domestic satellite system into the national telephone network. Most of these derive from the time delay inherent in transmission through the geostationary satellite.

Multiple satellite hops must be avoided and this involves information transfers in the signalling system to preclude connection of two satellite links in a tandem connection. Signals must be originated at the switching centre adjacent to the satellite circuit selected and transmitted to succeeding trunk switching centres, indicating that a satellite link has been included in the connection. The succeeding switching centres where there is a satellite/terrestrial circuit choice must be programmed to select terrestrial circuits, on receipt of the satellite selection information. The logic also dictates that, in any event, at switching centres where there is a choice, terrestrial circuits should be selected as a first alternative except on terminal links or links beyond which there is no possibility of satellite tandem connection, assuming that no signal of satellite circuit connection earlier in the chain is received.

These rules call for the maintenance of a reasonable balance of terrestrial circuits between switching centres which are also linked by satellite. The balance may not be easy to maintain in a network like Australia's, where the reason for employing satellites for trunk circuits is to link centres so remote that terrestrial connection is expensive or difficult.

The problem could be intensified by the inclusion of a subscriber's service in the satellite, as many such subscribers may wish to make trunk calls to centres solely or substantially served by satellite trunks. The situation may arise where the tandem connection of two satellite circuits cannot be avoided. This possibility gives added incentive to the Post Office Research Laboratories' current development of an echo canceller in order to minimise difficulties arising from echo-suppressors on links with long transmission delays. The echo canceller, which is also being developed in several other countries, is based on the concept of generating a signal of the same wave form as the reflected signal at a four-wire/two-wire connection point, but of opposite polarity so that when added they mutually cancel. Even with the inclusion of such a device, the problems arising from 'pure' delay would remain.

The 'two-hop' constraint also implies that domestic satellite systems will increase the pressures on international operators to maintain a balance between terrestrial and satellite circuits.

A technique for minimising round-trip transmission times proposed in several countries, including U.S.A., involves splitting the directions of transmission in each circuit so that one direction is by satellite and the other by terrestrial means. This is not, however, a practicable solution in cases where the link is provided solely or substantially by satellite.

Transmission delay will also inhibit the use of the multi-frequency telephone signalling system, employed in the Australian national network, using compelled sequences in which forward signals continue until acknowledged by backward signals. The round-trip transmission time via the satellite link which must be added for each such acknowledgment would result in unacceptable post-dialling delays and lengthy engagement of signalling registers during call set-up. Interfaces are being designed for signalling conversion from compelled sequence to pulse operation, and reverse, at network entry points adjacent to the earth stations.

It is generally desirable to minimise excessive length in the terrestrial circuits to be connected in tandem with a satellite circuit in order to reduce cost, noise, transmission delay and to improve reliability. Multiple access operation by the smaller earth stations provided for trunk telephony will assist in achieving these improvements by entering the terrestrial networks as close as practicable to the terminal exchange. This will also minimise the treatment needed to avoid the double satellite hop. The special needs for traffic on the satellite subscriber's system to connect to the network close to the terrestrial terminal point has been mentioned in connection with the number of ports. The ports would in general comprise earth stations established to provide multiple access trunk service, but the total number would depend on the relative economics of increasing the number of ports. Inherent in the concept however are certain numbering, routing and charging problems which must be worked through.

Demand assignment of some form is of course essential for service to subscribers who inherently have low calling rates. Initially at least it may, for economic reasons, take a manual form. An automatic form of demand assignment, of which INTELSAT'S SPADE system is an example, is seen as necessary for the multiple access trunk stations and for overflow from heavy traffic links on a point-to-point basis, to achieve economies in circuit requirements. In a national system, however, circuit assignment could be carried out from a central control station. In the initial stages of the system, when the full capacity is not taken up, demand assignment may not need to be comprehensively applied.

The present restriction of commercial communication satellites to 4GHz and 6GHz bands results in co-ordination problems with the existing long-distance trunk network. The standard broadband microwave systems employ these bands, and it is necessary to apply co-ordination criteria wherever an earth station is proposed near existing or planned microwave routes in these bands. Despite the present relatively uncongested nature of the Australian network, the pattern familiar to other administrations emerges—most switching centres to which it is proposed to connect satellite circuits are, or are planned to be, approached by microwave systems. As a result the earth stations must normally be located at least one microwave hop from the destination of their services. The required terrestrial tail adds markedly to the cost of the satellite system, particularly if widespread use is to be made of the TV distribution facility in developed areas. A move to unshared bands for satellite communications should materially aid economic viability of a satellite system and the outcome of the World Administrative Radio Conference on Space Telecommunication in 1971 will have an important bearing on this.

CONCLUSION.

There appear to be advantages to be gained by adopting a satellite system for Australian domestic communications at an appropriate time in the future. The system should be designed in the light of further developments in technique, in available spacecraft E.I.R.P., and in space frequency allocations. A national satellite system would afford potential for telecommunication services to remote areas of the continent and be an important aid to national development.

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TECHNICAL NEWS ITEM

INTERNATIONAL ELECTROTECHNICAL VOCABULARY.

The Standards Association of Australia announces the endorsement of the International Electrotechnical Vocabulary, published by the International Electrotechnical Commission, as Australian Standard C50. It will form a basic standard in a new series to be published in the field of electronics and telecommunications.

Currently it contains 22 volumes applying to the following specific areas:—Fundamental definitions, electronics, electro-acoustics, machines and transformers, static converters; transductors, switchboards and apparatus for connection and regulation, protective relays, scientific and industrial measuring instruments, generation, transmission and distribution of electrical energy, nuclear power plants for electric energy generation, electric traction, signalling and security apparatus for railways, electromechanical applications, automatic controlling and regulating systems, electro-heating applications, electrochemistry and electrometallurgy, radiocommunications, waveguides, radiology and radiological physics, detection and measurement of ionising radiation by electric means, and electrobiology.

It standardises terminology and definitions in both English and French. Besides this, it lists the terms in six other languages—German, Dutch, Swedish, Italian, Spanish and Polish. A separate index is given for each language.

The various standards being produced for telecommunications and electronics will refer to this vocabulary for all technical terminology, so that Australian standards in these fields will be fully compatible with those produced by overseas countries subscribing to the work of the IEC.

Information concerning Australian Standard C50 may be obtained from the various offices of the Standards Association in all capital cities and Newcastle.

THE WORK OF THE TELEPHONE TRANSMISSION STUDY GROUPS XII AND XVI OF THE C.C.I.T:T:

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INTRODUCTION.

Study Groups XII (Telephone Transmission Quality and Local Networks) and Study Group XVI (Telephone Circuits) of the International Consultative Committee on Telegraphy and Telephony (C.C.I.T.T.) have similar interests in formulating recommendations on transmission matters connected with international communications and because the same delegates frequently attend both Study Groups their meetings are usually arranged to follow consecutively at the one location. This was the case when the two Study Groups met in Melbourne under the chairmanship of Professor F. Kroutl, of Czechoslovakia (Study Group XII) and Mr. J. Billen, of the U.K. Post Office (Study Group XVI) between 16 February and 13 March, 1970, at the invitation of the Australian Post Office (A.P.O.). On this occasion the A.P.O. organised a seminar (under the auspices of the International Telecommunications Union) on National Telephone Transmission Planning, which was held during a period of two days between the meetings of the two Study Groups; a number of delegates to the C.C.I.T.T. meetings presented papers on the planning procedures used by their national administrations.

The Melbourne meetings of Study Groups XII and XVI, the first to be held in the 1968/1972 period following the Plenary Assembly at Mar Del Plata in 1968, formulated preliminary replies to many of the questions entrusted to them, on the basis of contributions received from the participating administrations since 1968, and discussions between the experts present at the meetings. Further meetings will be held in the European autumn of 1971, in which the Study Groups will probably be able to formulate final replies, at least to a number of questions, for submission to the next Plenary Assembly in 1972.

A general review of the work of all C.C.I.T.T. Study Groups was published by S. Dossing (Ref. 1) following the 1968 Plenary Assembly. It is the object of this paper to describe in more detail the recent work of Study Groups XII and XVI on some questions of major importance, paying particular attention to the matters discussed during the 1970 Melbourne meetings. Exact details of all the questions under study cannot be given here because of space limitations, but the reader may obtain full information from Refs. 2 and 3.

LOUDNESS RATINGS..

It will be appreciated that in the planning of telephone networks the loudness of the perceived acoustic signal presented to the receiving subscriber's ear is of considerable importance. The C.C.I.T.T. specifies

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Fig. 1. — The opening of the Melbourne meeting of Study Group XII (From L. to R.: Mr. J. Rouviere, Director of the C.C.I.T.T.; Mr. J. L. Knott, Director-General, Australian Post Office, and Professor F. Kroutl, Chairman of Study Group XII.)

the loudness performance of telephone connections in terms of a 'volume reference equivalent' which is defined as the received volume inferiority of the connection relative to that of a specified reference circuit when the same talker and speech material is used at the sending ends. The reference circuit specified by the C.C.I.T.T. is a uni-directional connection model known by the acronym N.O.S.F.E.R., maintained in the C.C.I.T.T. Headquarters, Geneva, which uses stable and precisely defined electroacoustic transducers. Both Study Groups are concerned with the specification of values of reference equivalents for various purposes, but Study Group XII is charged with the recommendation of the limits for national telephone systems forming part of international connections. In particular, telephone Administrations have been asked to study the percentage of international calls which are made with reference equivalents less than 20.8 dB for sending, and 12.2 dB for receiving. These reference equivalents apply for the whole of the national connection from the subscriber's telephone to the virtual switching points (points of defined relative level) of the international exchange. Studies are also under way to determine what lower limits of reference equivalents should be recommended to ensure that overloading of transmission systems does not occur, what optimum values should apply to ensure maximum subscriber satisfaction, and what allowances should be made for the ageing of telephone microphones and receivers. The Australian Administration has already made a statistical study of the reference equivalents of the Australian portion of international calls, applying a technique not used hitherto, and this technique has now been applied in the United Kingdom network, and the results of the latter measurements were presented in a recent Study Group document. Whereas in Australia the statistical study indicates that a substantial percentage of international calls lie below the upper limits of sending and receiving reference equivalents, in the United Kingdom at the present time only 38% of connections would have sending reference equivalents less than 20.8 dB and 89% of receiving reference equivalents would be less than 12.2 dB. The United Kingdom Administration expects that by 1975 both send ing and receiving reference equivalents will be less than the C.C.I.T.T. limit for all international calls. The mean figures presented for the United Kingdom and Australian networks were put together during discussion at the Melbourne meeting and the overall reference equivalents for United Kingdom to Australia calls were calculated. At the present time, the mean overall reference equivalents for calls from United Kingdom to Australia was found to be 24 dB, and for the opposite direction 23.5 dB, in both cases with standard deviations of about 5 dB. Study Group XII expects to receive further information from participating administrations which will permit it to tabulate the distributions of sending and receiving reference equivalents for a number of national telephone systems. As a result of this it will be possible to produce a table of sending and reference equivalents for international calls between a number of different countries.

The study of how to allow for variations with time of the loss of national circuits and of microphones and receivers has been proceeding for some years with little progress so far. The preliminary reply of Study Group XII notes that as far as circuit variations with time are concerned, with modern equipment these are negligibly small; the principal source of variations is the dispersion of losses over different circuits arising from matters such as manufacturing tolerances, minimum adjustment steps in attenuators, commissioning and maintenance procedures, measuring set errors, and within-office cabling losses.

It has been observed from national studies that telephone receivers do not deteriorate appreciably with time and that there is no need in network planning to take account of this source of variation. Telephone microphones show greater variations, but it may be possible to allow for this by providing a fixed margin. Information supplied by the Australian Post Office based on its survey of subscribers' services in 1965 (Ref. 4) suggests that a suitable allowance would be 2dB. Further information is still being sought.

ASSESSMENT OF TRANSMISSION QUALITY.

The loudness of received signals is an important part of service transmission quality, and what has been said above refers to studies of planning objectives to ensure that at least connections capable of transmitting signals of adequate loudness are provided. There is also a need for techniques giving a realistic assessment of overall transmission quality of existing telephone circuits, taking into account not only loudness but factors such as noise, distortion and sidetone—for example, the study of circuits in service or circuits set up for experiments in a laboratory. Accordingly this question is being studied under two headings: (a) The assessment of transmission quality in service , by any means: and (b) the assessment of transmission quality by objective methods (Questions 2 and 7 of Study Group XII). The American Telephone and Telegraph Company has already reported to the C.C.I.T.T. on a method of service assessment of transmission quality used by that Company. This involves a technique known as call-related customer interviews which take place after the completion of a telephone call. (It may also be used in laboratory investigations.) In the interview the participants are asked:

(a) Whether they had any difficulty in talking or hearing on the connection.
(b) Specific questions about the type of difficulty experienced, for example, low volume, hum, crosstalk, echo, etc.
(c) To classify the quality of the call into four categories; excellent, good, fair or poor, with a fifth category added where serious degradation is experienced.

In some countries it is possible to evaluate the performance of a telephone call by service observation during the course of the call by monitoring the connection; for example, Czechoslovakia has described the use of repetition rate observations for the study of certain types of circuit performance. In other countries legislation does not permit service observations. However, Study Group XII favours the use of call-related interviews for studies of service transmission quality. It is apparent that such studies would be expensive, and that when subscriber dialling becomes commonplace in trunk networks, it will be only possible to use them in special investigations. It would of course be desirable to have an objective measurement technique for evaluating transmission quality so that, for example, the evaluation of working circuits could be carried out automatically. The study of the determination of transmission quality by objective measurements is being studied under Question 7 of Study Group XII. This is, however, a long-standing and seemingly intractable question with no answer yet in sight. Study Group XII has declared that two areas of interest would be distinguished in future studies:

(a) The feasibility of devising instrumentation capable of carrying out the general assessments such as those resulting from the call-related interview, and
(b) The instrumentation and supporting theory related to assessments of specific criteria, such as articulation or conversational opinion tests, etc.

LABORATORY MEASUREMENT TECHNIQUES.

The Measurement of Loudness Ratings.

It has been mentioned previously that loudness is perhaps the most important quality of a telephone call from the point of view of meeting customer needs. Loudness is not a simple function of acoustic power. A simple but commonly used technique for objective measurement of approximate loudness involves sub-division of the signal into frequency bands, weighting these bands according to their contribution to the loudness, and summing the weighted components on a 'squared mean root' basis rather than the 'root mean square' basis used to obtain the total speech power.

Under its Question 15/XII Study Group XII is studying the C.C.I.T.T. volume reference equivalent method of loudness rating—which involves the subjective comparisons of loudness—and comparing it with the following techniques:—

(a) The objective reference equivalent measuring equipment (O.B.D.M.) used by the German Federal Republic and certain other Administrations which is essentially an objective loudness measurement associated with a circuit model based on the C.C.I.T.T. reference circuit;

(b) The electroacoustic rating system (E.A.R.S.) used by the A.T. & T. Company—which uses a very similar loudness measuring technique to that of the O.D.B.M.—but measures performance relative to a zero length acoustic airpath, ;

(c) The one-metre airpath method used by the United Kingdom. This requires subjective loudness balancing relative to a high quality electroacoustic equipment having the form of a telephone circuit model but designed to simulate an acoustic airpath of one metre length.

Comparisons between these three different rating systems are being made in 'round robin' tests involving a number of laboratories using telephone sets with stable electroacoustic transducers. The object of the study is to determine the relationships which apply between the various methods and select a system which combines the best elements of all—hopefully it will be an objective measuring technique.

The requirements of a satisfactory method of measuring loudness ratings of a telephone suitable for replacement of the C.C.I.T.T. method have been stated to be:

(a) The criterion of loudness of received speech with fixed talking distance and speaking volume used in the C.C.I.T.T. method could be retained but should not be interpreted excessively strictly;

(b) In view of the large body of information now in use which has been assembled on the basis of reference equivalents, it is important that the numerical values associated with the equivalent losses of existing items should not be unduly changed;

(c) So far as is possible—and this is difficult to achieve—the equivalent loss of any complete speech path must be equal to the sum of the values of equivalent loss allocated to each separate component part;

(d) The methods used for assessing equivalent losses should be as realistic as possible so that real and genuine improvements in performances are properly reflected in the results of the assessment;

(e) The methods chosen ought to be based on simple fundamental principles and be capable of being employed in any reasonably well-equipped telephometric laboratory without serious disagreements in test results; in practice this implies use of an instrumental method based on acceptable theoretical foundations.

The measurements which have been reported so far have shown that improvements are necessary in the design of artificial mouths and ears which have been in use, and that there seems to be advantages in using an intermediate telephone system in the comparison between the reference system and the instruments under study. This is referred to as an intermediate reference system (I.R.S.). In addition it has been observed that the variability of the C.C.I.T.T. reference equivalent method can be improved by a change of technique. At present the level of loudness at which the comparison is made with the reference system depends upon the reference equivalent of the circuit under test, and reduced variability would follow from making all subjective assessments at the same loudness level.

Study Group XII has made detailed proposals for further tests to be made in C.C.I.T.T. laboratories, using the various reference systems and stable telephone sets. Although it had been hoped that at the Melbourne meetings it would be possible to formulate proposals for the definition of a provisional objective method for the determination of loudness ratings, this was not achieved. Further studies will have to be made in national laboratories and in the C.C.I.T.T. laboratory in Geneva.

Measurement of the Efficiency of Microphones.

Although telephones with microphone amplifiers and new microphones to replace the carbon microphone are now in sight, telephone administrations expect to be faced with the need to make sensitivity and frequency response measurements on carbon microphones for some years to come.

At the Melbourne meetings a working party of microphone experts under the chairmanship of R. Archbold (United Kingdom) considered the various techniques available for conditioning carbon microphones prior to measurement with the object of choosing a method which results in the carbon granules being in a state which produces repeatable measurements and which is representative of real working conditions. The working party examined the specifications for ten different conditioning methods and formulated a draft recommendation for a preferred method, which is based on a technique being considered for a standard to be issued by the Institution of Electrical and Electronic Engineers (I.E.E.E.). Nevertheless there are reasons to believe that one standard conditioning technique may not be applicable to all designs of carbon microphones and the matter will remain under study whilst further experience is gained.

Artificial Voices, Mouths and Ears.

Objective measurements on telephone instruments require the use of electroacoustic transducers, which simulate the average acoustical and dimensional characteristics of human voices and ears. The matter is primarily the concern of Study Group XII, which is concerned with applying the results of modern technology to produce more accurate and reliable simulations. For artificial ears a new design recommended by the International Electro-technical Commission (I.E.C.) has been adopted by the C.C.I.T.T. However, this design simulates conditions in which the telephone receiver is tightly held against the ear—as in audiometric hearing-threshold determinations—whereas many telephone users hold the receiver more loosely, with consequent changes in sensitivity and overall frequency response. The studies will be continued on the modifications to the I.E.C. artificial ear which may be necessary to adapt it for telephone use.

Standardisation of an acceptable artificial voice is less advanced and it has been decided to gain experience with a particular sound source before deciding on an international recommendation for an artificial mouth. This sound source — the Bruel and Kjaer Type 4216 — will be studied in the C.C.I.T.T. Laboratory, whose measurement programme is controlled by Study Group XII. Although similar to the artificial mouths in use by some Administrations, the term 'sound source' is being used to describe it because of the limitations it possesses in relation to an acceptable artificial mouth.

SPEECH POWER VERSUS REFERENCE EQUIVALENT.

The efficient utilisation of transmission systems and the achievement of noise objectives for long connections requires that the statistics of the signal loading be known. The components of the multichannel signal on such systems include the powers contributed by:

(a) Speech signals,
(b) Telegraph and data signals,
(c) Pilot tones and carrier leaks.

Both Study Groups are interested in the collection of up-to-date statistics of all these signals. Data on the electrical power of speech signals are also needed for the design of voice-operated devices such as compandors and echo suppressors. In the case of speech signals the signal power is influenced by a number of factors such as the send reference equivalent of the local end (which includes a component due to the send efficiency of the telephone) and factors which determine the vocal level generated by talkers, such as the degree of sidetone suppression, room noise levels and the overall reference equivalent of the connection. In multichannel signal calculations knowledge of talker activity (i.e., the fraction of conversation time during which speech signals are actually being generated) is of as much importance as a knowledge of speech power, whilst the talker is active.

Study Group XII has under active consideration at present a study of the effect of the introduction of more efficient telephones upon the powers of speech signals, whilst Study Group XVI is concerned with the effect of possible increases in power at low reference equivalent on transmission system loading. Up-to-date data on speech signal statistics are also necessary to the work of C.C.I.R./C.C.I.T.T Joint Study Group Special C, which is concerned with the noise performance of transmission systems.

In the past, data on speech powers on telephone circuits have been obtained by operators observing the readings of volume meters. Collecting such data is a tedious task and because speech signals fluctuate considerably, subjective factors in the reading of volume meters lead to some uncertainties of results which might be circumvented by a purely objective method. Some Administrations, including the Australian Post Office, have designed equipment which involves the determination of the probability distribution of the instantaneous values of samples of the speech signal, and to evaluate the relationships between such new techniques and the older methods, a tape recording of a simulated telephone conversation was made by the C.C.I.T.T. and distributed to Administrations in 1969 for comparative speech power and activity factor measurement. The results of these comparisons were discussed during the Melbourne meetings; they showed quite good agreement between speech powers averaged over the conversation, but the agreement between measurements of activity factor were less satisfactory. (The difficulty in measuring activity factor lies in the need to distinguish between—on the one hand — very short pauses within a 'talk spurt' which are dependent upon the speaker and the language used and on the other hand the longer pauses which occur between the 'talk spurts.' It is desirable also to have rules to distinguish between speech signals and circuit noise.)

As a number of Administrations will use computers to analyse the results from sampled data speech power meters, it was agreed that programmes might be written to make the necessary distinctions which are necessary to ensure improved accuracy in talker activity measurement.

Laboratory measurements by Administrations are proposed to determine the relationships, if any, between speech power and the reference equivalent between the talker's telephone and the point of speech power measurement.

ECHO AND PROPAGATION TIME.

Echoes in telephone connections are produced at points of impedance discontinuity in the two-wire parts of the connection (where bi-lateral transmission is used). They are perceptible, as with acoustic echoes, only when the round trip propagation time is long, say more than 25 ms and their disturbing effects are at their worst when the round trip propagation time is about 200 ms. In telephone practice echo is controlled at present by impedance balancing at 2/4 wire hybrid junctions and by the use of echo suppressors working on the voice-operated switch principle. A new technique for echo control which is now being developed involves cancellation of the returning echo by the injection of a modified version of the forward-going signal.

Even when echoes are completely suppressed, the propagation delays such as those experienced in communication via artificial satellites are sufficiently long to cause serious interference with the pattern of conversational interchange which has been developed by the human race during thousands of years of evolution. The C.C.I.T.T. has declared that mean one way propagation times exceeding 400 ms (800 ms round trip) are not satisfactory in long distance telephone circuits and that propagation times up to these figures will be satisfactory only if efficient echo suppressors are used. (These figures permit the use of not more than one synchronous satellite in both go and return channels of a connection.)

New designs of echo suppressors of the voice-operated switch variety have been developed in recent years for use on circuits including communication satellites, but agreement has yet to be reached in the C.C.I.T.T. as to the final details of their characteristics. However, a full specification is expected to be agreed upon by the end of 1970, and Study Group XVI is concerning itself with formulating rules for the use of such echo suppressors in international circuits and also with the rules which may be necessary to control their use in conjunction with old designs of echo suppressors which are permanently connected in many of the older long distance circuits in the northern hemisphere.

Study Group XII is studying the conditions (if any) under which satisfactory telephone conversations would be possible in connections having one-way propagation times greater thas 400 ms and this question is of considerable interest because it may indicate the possibility of using more than one synchronous satellite in a connection. It is certain that extremely efficient echo suppressors would be necessary and for that reason much interest is being shown in the echo canceller development. (Discussions at the Melbourne meetings were helped by demonstrations of an experimental echo canceller, described in Ref. 5, in the A.P.O. Research Laboratories nearby.) Echo cancellers are effectively equivalent to a self-balancing hybrid transformer and are therefore not subject to the impairments inevitably associated with the voice operated switch type of suppressor. However, their design requires a knowledge not only of two-wire line impedances, but also of their phase angles, and both of them must be known over the voice frequency band. It would be more convenient still to have the time response of the two-wire line to a known signal such as an impulse. Study Group XVI has asked administrations to collect the relevant data determined by either method.

CIRCUIT NOISE.

Study Group XII is collecting data on the quantitative value of the impairment produced by circuit noise on telephone circuits. Such data have been determined for example, by the United Kingdom Administration for gaussian noise and telephones of the type used in that country (Ref. 6). However, the techniques for transforming such information into a form which could be applied to any type of telephone have yet to be worked out. (The requirements of data transmission in respect to impulse type noise are more stringent than those of telephone transmission, so that the telephone transmission Study Groups are no longer considering this type of noise.)

A topic of particular interest at present is the improvement of existing recommendations for noise limits in short-distance analogue carrier systems forming part of an international connection. In the 1964/68 Plenary Period, Study Group XVI had proposed a noise limit of 500 pW psophometric measured at a point of zero relative level, but a relaxation to 1000 pW was proposed by Study Group XV (Transmission Systems) on economic grounds. Consequently the present text of the relevant Recommendation (G 125) provides that the future objective for all of the channels in a system shall be 500 pW (mean during any hour) averaged over all channels, but that for existing systems the all-channel average may be 1000 pW.

Nevertheless, further evidence from administrations with opposing points of view are still being presented and a document presented by the Swiss Administration to Study Group XII proposed a relaxation of the Recommendation to permit higher noise powers. However, several administrations will be making important contributions to this subject during 1970/71 and the proposal to revise the Recommendation on noise limits for short distance carrier systems will be reviewed at the next meeting of Study Group XII in 1971.

Guidance as to the form in which the results of further investigations should be presented was given by Study Group XII. This should be in accordance with the conclusions of that Study Group about the preferred forms of transmission quality assessment. The further studies will make use of a set of hypothetical reference connections (recommended by Study Group XVI) which represent models of common types of connections used in the international service.

INTELLIGIBLE CROSSTALK.

Study Group XII has been charged with the task of establishing a threshold value for intelligible crosstalk on telephone circuits taking into account variables such as:

(a) Room noise at the subscriber-set location;
(b) The sending, receiving and side-tone characteristics of the telephone sets;
(c) The statistical distributions of speech signal levels observed in practice;
(d) Circuit noise levels.

At the Melbourne meeting the United Kingdom Administration presented data which the Study Group converted into a chart in which the crosstalk reference equivalent thresholds for intelligibility and audibility could be read off for a range of receiving reference equivalents and circuit noises. However, it was decided to call for results from other administrations before making a formal recommendation and the factors which ought to be considered in further studies were set out.

A further part of the question asks Study Group XII whether crosstalk ratios of 53 dB in the presence of a noise level of —63 dBmOp and 62 dB in the presence of a noise level of —67 dBmOp might be acceptable for international circuits pending a complete answer to the first part of the question. At the Melbourne meeting Study Group XII decided that these figures for crosstalk reference equivalent (attenuation) were probably too low. However, it rests with individual administrations to make decisions as to what percentage of subscriber dissatisfaction is permissible. It was noted that the highest standard of freedom from intelligible crosstalk are required for subscribers' cables and local networks, since the identity of the interfering signal may be known or identified as a particular local source. The social implications are evident. In an international circuit, on the other hand, the identity of an interfering talker is likely to be unknown—and he may be speaking in a foreign language—and the particular combination of subscribers and plant resulting in crosstalk in a particular case would have a very low probability of recurring. Thus it could be that while the probability of intelligible crosstalk of one in one hundred calls might be acceptable for international calls, a much lower probability for local calls would be adopted —say one call in one thousand.

Pulse Code Modulation.

The characteristics of pulse code modulation (P.C.M)systems have been under study for at least 20 years, but international agreement on the standardisation of basic parameters such as the number of quantising levels, the sampling frequency and compandor characteristics is now essential as a result of the rapid increase in the application of P.C.M. to commercial transmission systems and the imminence of digital switching telephone exchanges.

Since the IVth Plenary Assembly of the C.C.I.T.T. (Mar Del Plata, 1968) set up Special Study Group D to study digital transmission and switching, all questions relating to P.C.M. have been assigned to that Study Group for the time being, except for a question on measurement of transmission performance, which remains with Study Group XII. In addition to this work by Study Group XII, Study Group XVI has been recently asked to propose models representative of the several evolutionary stages in the development of the world network during which it is confidently expected that there will be a mixture of analogue and P.C.M. digital transmission systems. Study Group XVI has also examined the possibility of a reduction in circuit losses consequent upon the introduction of P.C.M., thus offsetting the transmission impairments due to the quantising noise inherent in all digital transmission systems.

Study Group XII is concerned with methods of evaluating impairments due to P.C.M. and the progress of this study is relevant to the choice of a companding law for terminal equipment —a choice which is to be made by Special Study Group D. (Agreement has already been reached, in the latter Study Group, on an 8 kHz sampling rate, and 8 bits per sample, i.e., 256-level quantising for international circuits.)

Instantaneous companding as used in P.C.M. transmission systems has the effect of reducing the magnitude of the quantising level steps for low signal amplitudes and increasing them for high level signals; consequently the signal to quantising noise ratio is approximately constant over a range of amplitudes of about 30 decibels. Without companding, low-level speech signals would sound rather granular.

At present there are differences in opinion between the relative advantages of adopting 'μ-law' or 'A law', and in the segmentation characteristic for P.C.M. compandors. The subdivision of the characteristics into a number of linear segments facilitates the realisation of these devices by digital circuit techniques.

For high level signals within the dynamic range the compressor output with a 'μ law response is proportional to log $(1 + \mu x)$, where x is the input signal, and with an 'A-law' response the output is $(1 + \log Ax)$. (Both A and μ are constants.) At low signal levels the compressor output is directly proportional to the signal input, in both cases. The expandor has a complementary characteristic.

The differences in perforformance of the two laws are small for practicable values of the constants A and μ, but discussion continues around the significances of these differences and the relative ease of commercial implementation. The existence of established commercial designs in various parts of the world makes it difficult to reach a universally acceptable standard.

Study Group XII has already tentatively decided on some of the techniques to be used in P.C.M. transmission assessments; for example, P.C.M. links will be compared with analogue systems into which random noise has been added at a level proportional to the instantaneous amplitude of the speech signal, and the telephone connection models (reference connections) to be used in the studies have been agreed upon. In the past Administrations have used various techniques to make subjective comparisons, such as articulation tests and listening comparison tests, but it is agreed that any such technique which might be adopted in the interests of a rapid accumulation of data must be validated by 2-way conversation tests which approximate as closely as possible to actual working conditions.

Study Group XVI, looking at the place of P.C.M. in the international telephone network at the Melbourne meeting, saw future developments taking place in two phases. In the first phase, P.C.M. systems would be increasingly employed to provide junctions between local exchanges and primary centres (minor centres in the current Australian terminology) together with relatively short circuits between primary and secondary centres, with conventional switching equipment. During this period satellite systems with demand-assigned circuits will be brought into service with digital modulation (probably P.C.M.) for telephone channels.

In the second phase, which might begin about 1975, P.C.M. systems will be used over greater distances and new digital switching systems working on the time division principle will start to appear. For a time the new switching systems will have to interwork with analogue transmission systems and for a period of at least ten years there will be a complex mixture of analogue and digital switching systems expected to exist in both national and international networks.

After examining the possibility of reducing the loss of 4-wire international circuits provided by P.C.M. equipment, Study Group XII decided that a reduction from 0.5 dB per link (at present recommended for analogue systems) to 0 dB might be possible provided certain assumptions were valid. The validity of these assumptions will be checked by other Study Groups.

CONCLUSION.

The Melbourne meeting of Study Groups XII and XVI gave the opportunity for telephone engineers of the Australian Post Office, the Overseas Telecommunications Commission and Australian manufacturing companies to participate in the work of these international transmission groups. It was apparent that the Australian organisations are able to make significant contributions to international studies of telephone transmission questions and this was recognised by the meetings through the nomination of an Australian chairman (Mr. S. Dossing) to the Working Party on subscribers' tolerance to echo and propagation time, the nomination of an Australian (Mr. D. A. Gray) as special rapporteur for the revision of rules for the application of echo suppression and Mr. R. G. Kitchenn as the Australian correspondent in the work of preparing new transmission chapters for the Manual on Automatic Networks and the Handbook on Local Networks.

ACKNOWLEDGMENT.

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TECHNICAL NEWS ITEM

MINIATURE LASER HAS COMMUNICATIONS FUTURE.

Scientists at the Bell Telephone Laboratories have developed what they expect will be a low-cost, pocket-size, reliable and versatile infrared laser — the first such device that may be practical for use in communications systems.

The new laser is a semi-conductor device that operates continuously at room temperature and can be powered by torch batteries.

Bell claims a single high-frequency light beam produced by the laser could inexpensively carry hundreds of thousands of telephone calls, television signals or other communication messages.

Although such message-carrying capacity was not needed at the moment, a spokesman said, lasers might play a major role in future communications when picture phones become common, when high-speed computer conversations were more widespread, and when communications needs in general expanded beyond current carrying capacities.

When all the kinks are ironed out the new laser should be the size of a pen light or cigarette lighter, should cost a few dollars at most, and should be capable of giving a lifetime of service.

Lasers currently in use tend to be bulky, fragile and shortlived, and cost hundreds or thousands of dollars.

Gas lasers, for example, are large and delicate and costly. Solid state lasers, such as ruby lasers, require large power sources and present tremendous cooling problems, making continuous operation impractical.

—Lea Fitzgerald in New York.

THE PERTH TO PORT HEDLAND CHANNEL DOUBLING SYSTEM

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INTRODUCTION.

A channel doubling system provides 24 narrow band 300-2200 Hz telephone channels in the standard 12-channel 60-108 kHz group bandwidth by means of the application of conventional frequency division multiplexing techniques. Such carrier telephone sytems are occasionally used by telephone administrations as a temporary expedient to meet urgent needs for circuit relief on a fully loaded route pending the installation of standard equipment for long term needs. The original channel doubling (or band economy) system was developed for use on the first transatlantic cable in 1957, when the demand for channels far exceeded the design capacity of the original installation (see Ref. 1). Later the Australian Post Office (A.P.O.) faced a similar situation on the Adelaide to Perth (East-West) open wire route. Four channel doubling systems recovered from the transatlantic route were obtained from the British Post Office and installed on the East-West route. These gave interim relief and were in use on this route until the opening of the East-West microwave link in July, 1970.

In 1968 the A.P.O. faced the same situation on the 1100 mile open wire route between Perth and Port Hedland in Western Australia. It had been intended to use some of the channel doubling system recovered from the East-West route for the Perth-Port Hedland route, but these systems would not have been available in time. Because channel doubling systems were no longer in production and there was a world-wide shortage of such equipment, the situation was met by the decision to manufacture a channel doubling system in Australia. The manufacture was a joint project of the A.P.O. and Hawker de Havilland (Australia) Pty. Ltd. Manufacture of the system commenced in October, 1968, and it was placed into service in June, 1969.

The original design of the channel doubling system was prepared by the British Post Office Research Station, Dollis Hill, England, and the Telephone Manufacturing Company (T.M.C.) built the equipment from this design. Fortunately the A.P.O. was able to purchase this design and manufacturing information, and agreement was obtained for Hawker de Havilland to use it in this project.

THE PERTH-PORT HEDLAND SITUATION.

Port Hedland, on the northern coast of Western Australia, has become a very important port and processing centre for the crushing and loading of iron ore. The iron ore is sent by rail from the newly developed iron ore mines in the Hamersley Ranges and adjoining areas. As a consequence of the rapid development of Port Hedland, the trunk telephone traffic to Perth, the principal city of Western Australia, rapidly exceeded the capacity of the available facilities. The existing trunk facilities between Perth and Port Hedland are provided by two open-wire bearers on an 1100-mile route (see Fig. 1). Each bearer was loaded to capacity with a conventional three and twelve channel open wire carrier system.

Plans were well in hand to provide a broadband coaxial cable system from Carnarvon to Port Hedland to link up with the Perth-Carnarvon coaxial cable system installed in 1968. However, some means of providing trunk relief had to be found to meet the very urgent need for more channels to Perth. It was considered that in this case the best solution to the problem was to use a channel doubling system in conjunction with one of the existing 12 channel open wire systems.

At that time those manufacturers who were experienced in making carrier telephone equipment were completely committed with existing contracts and were unable to accept the manufacture of this system as a 'one off' project, and it became necessary to find a company with experience in

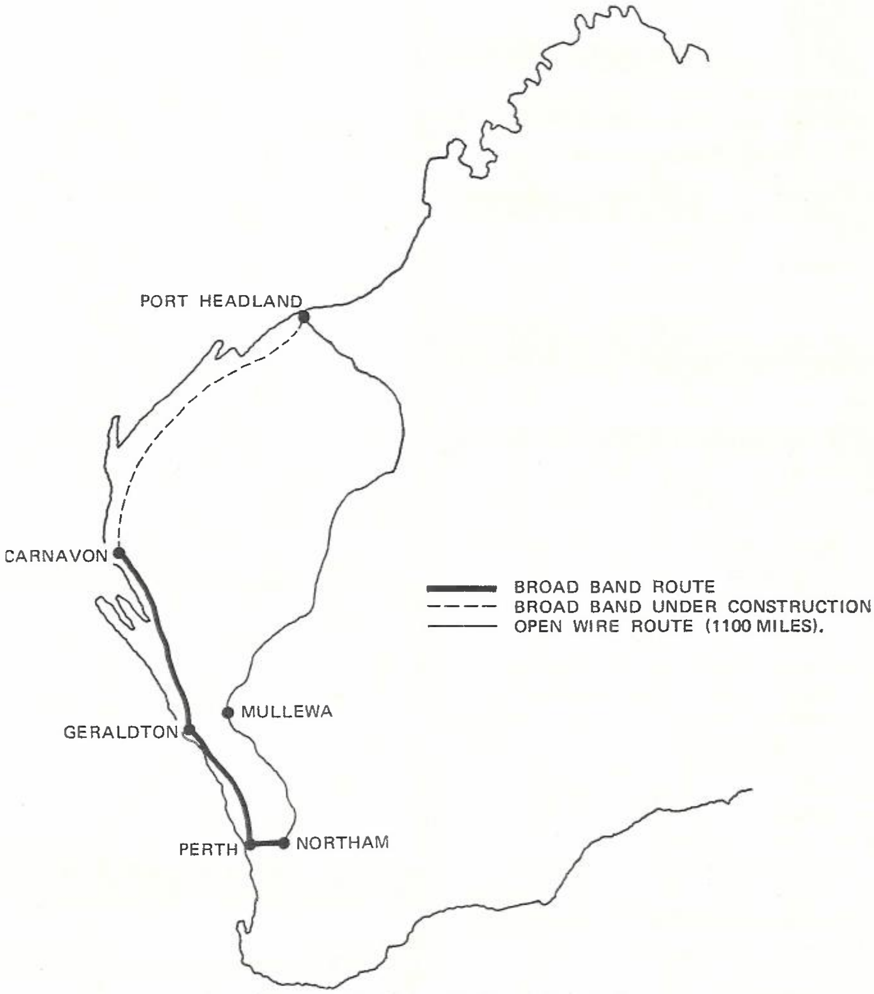

Fig. 1. — Perth to Pt. Hedland Trunk Route

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the electronic industry and with a production capacity to handle this particular project. After inquiry it was found that Hawker de Havilland was in a position to be able to manufacture the system. This company had had extensive experience in aircraft electronics and defence work and had a proven manufacturing capacity. Thus, a 'cost plus' contract was let to Hawker de Havilland to manufacture this system on the understanding that they would be given considerable assistance by the A.P.O. The manufacturer was given all the design information, the loan of specialised test instruments and considerable professional engineering assistance. It is emphasised that this joint co-operation was seen as the only way of achieving the aim of having the system made in time to ensure that a useful and profitable period of service could be achieved.

The A.P.O.'s part in the manufacture of the system was given to the A.P.O. Research Laboratories as a special project. Their tasks were:

- (i) Preparation of new designs for equipment items previously realised using vacuum tube techniques.
- (ii) The preparation of the test specifications.
- (iii) The co-ordination of the testing.
- (iv) The overall supervision of the project.

During the latter stages of the project, A.P.O. Research engineers were 'in residence' at the Hawker de Havilland works to assist with final testing of the system.

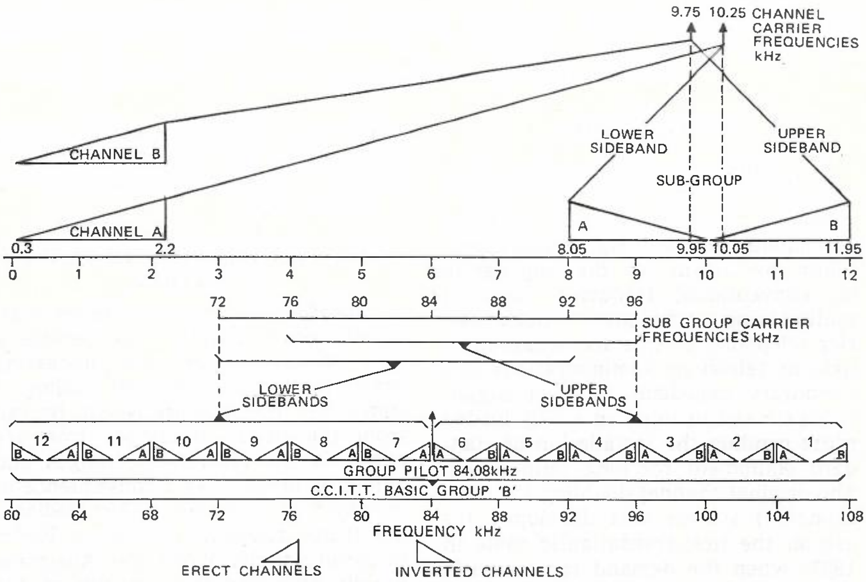


Fig. 2. — System Frequency Allocation

METHOD OF OPERATION OF A CHANNEL DOUBLING SYSTEM

The system uses a two-stage modulation process to transfer each voice band channel into its appropriate slot in the 60-108 kHz group band. This is a similar technique to that which is used in modern 12-channel modem equipment and the modulating frequencies are chosen so that there is the least possible trouble due to unwanted products of modulation and demodulation. The first major operation on the voice frequency signals applied to a channel in the transmit direction is their restriction to a narrow band of 300 to 2200 Hz. This is made by using a pair of very sharp cut-off high-pass and low-pass filters. Thus the pass band of each channel is just less than 2 kHz wide (see Fig. 2).

Every channel is designated as a A type or B type. In an A type channel the narrow band voice signal modulates a 10.25 kHz carrier in a conventional balanced modulator, after which the 8.05 to 9.95 kHz lower side band is selected by a sharp cut-off band-pass filter. Similarly in a B type channel the upper side band 10.05 to 11.95 kHz of a 9.75 kHz carrier is selected for transmission. From Fig. 2 it will be seen that the outputs of an A and a B channel together occupy a band of from approximately 8 to 12 kHz. Thus two nominal 2 kHz channels are put into one 'conventional' 4 kHz bandwidth channel. The outputs of the A and B channels are combined in the sub-group panels (see Fig. 3). A band-stop filter is placed in the output of each A and B channel. The purpose of these filters is to suppress the carrier leak from the channel modulators. From Fig. 2 it will be seen that carrier leak from an A channel (10.25 kHz) could produce a very annoying 500 Hz equivalent tone in the 10.05 - 11.95 kHz band of channel B. These sharply tuned filters had an insertion loss of at least 50 dB at their centre frequency.

Each 4 kHz wide A and B combination in sub-group 1-6 modulates one of the sub-group carriers of 76, 80, 84 88, 92 or 96 kHz, the upper sideband being selected. Sub-groups 7-12 modulate sub-group carriers of 72, 76, 80, 84, 88 and 92 kHz, the lower sidebands being selected. The combined sub-groups form 24 channels in the frequency range 60 to 108 kHz (C.C.I.T.T. Basic Group 'B').

SYSTEMS FACILITIES AND THEIR APPLICATION.

The Perth-Port Hedland channel doubling system differs from the original channel doubling systems in that it provides more flexibility at its 60-108 kHz group connection interface. The 24 narrow band channels consist of two groups of 12 channels, each rackside of equipment providing 12 narrow channels. Rackside No. 1 houses channels 1A to 6B, which lie in the frequency range 84 to 108 kHz, and rackside No. 2 houses channels 7A to 12B, which lie in the frequency range 60-84 kHz. Each rackside has a group combining panel, which provides for the following combinations of channels:

- (i) 24 narrow band channels to occupy the full 60-108 kHz group band, or
- (ii) 12 narrow band channels and six normal (300-3,400 Hz) band channels to occupy the 60-108 kHz group band.

After amplification the channel doubling signals are combined in a combining hybrid with those from the other channel doubling rackside or six channels of a conventional bandwidth system. These latter signals pass through a 3.5 dB gain group combining amplifier which compensates for the insertion loss of the combining hybrid.

At Port Hedland the second of the above combinations was used to derive 24 narrow band channels and 12 normal band channels from the two 60-108 kHz group bearers of the two open wire systems. It was necessary to retain the 12 normal band channels for use with the voice frequency telegraph systems and for the trunk circuits that would be transit switched at Perth to other centres in Australia.

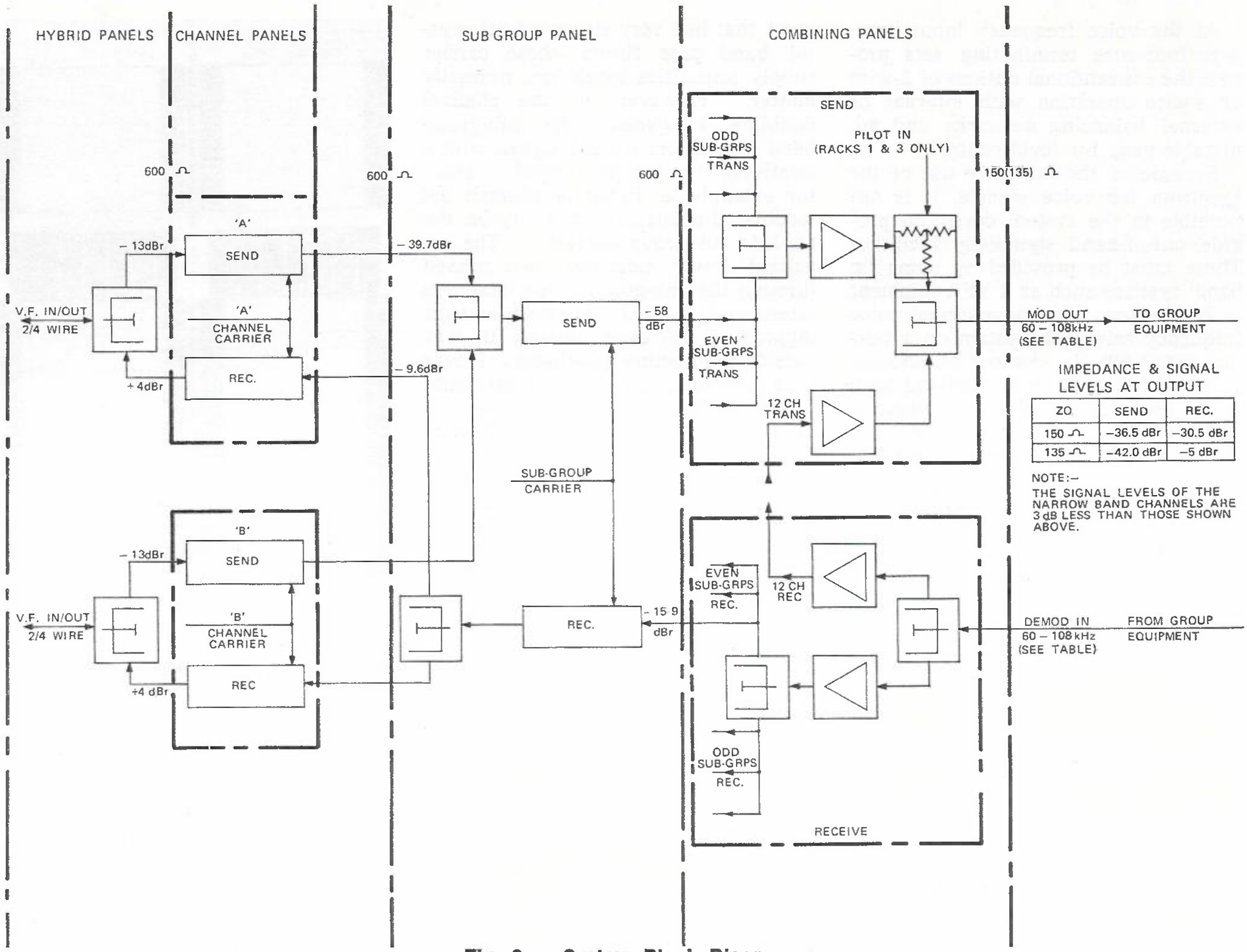


Fig. 3. — System Block Diagram

Fig. 4 shows the equipment arrangement at Port Hedland.

The 60-108 kHz group interface is designed to provide for connection to either of two types of group terminals. These are:

(i) the 135 ohm, —42 dBr send, —5 dBr receive, or

(ii) the 150 ohm, —36.5 dBr send, —30.5 dBr receive.

The Port Hedland terminals used the 135 ohm interface conditions, whilst the Perth terminals used the 150 ohm conditions. The flexibility of the group frequency interface with respect to signal levels and impedances was obtained by using strappable pads and impedance changing straps in the group combining amplifier.

At the 60-108 kHz group connection point the line-up level of a narrow channel was made to be 3dB lower than that of a normal channel. This was to compensate for additional loading of broadband group equipment by 24 instead of the usual 12 channels in the 60-108 kHz band. Provision was made for the injection of an 84.08 kHz group pilot from an external source, into the 84-108 kHz band of rackside No. 1.

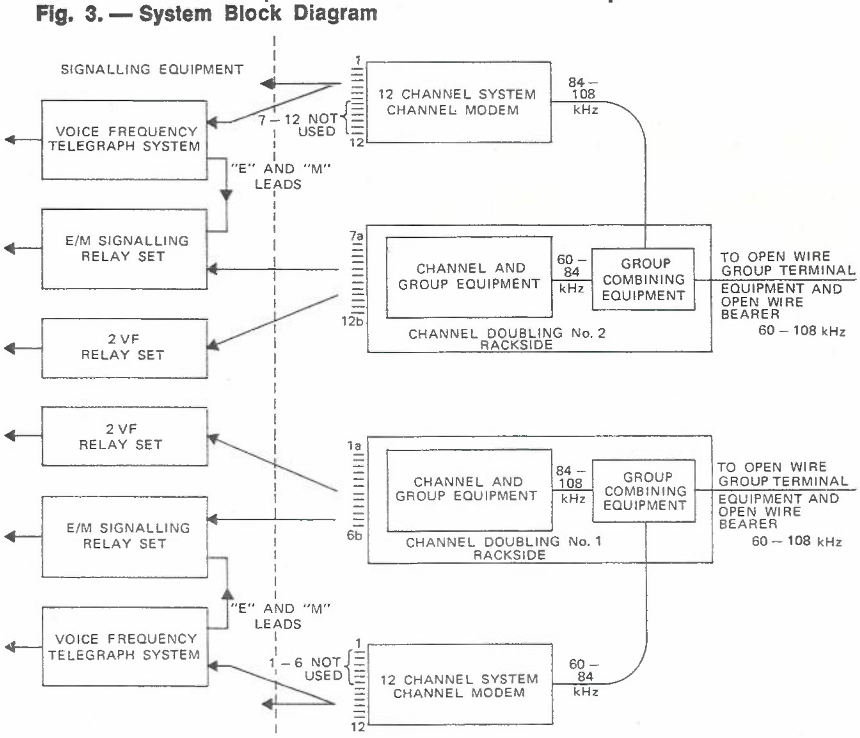


Fig. 4. — Equipment Arrangement at Port Hedland to provide 12 Normal and 24 Narrow Band Channels

At the voice frequency input, two-wire/four-wire terminating sets provide the conventional options of 2-wire or 4 wire operation with internal or external balancing networks and adjustable pads for level control.

Because of the intensive use of the spectrum for voice signals, it is not possible in the system design to provide out-of-band signalling facilities. These must be provided by using 'in band' systems such as 2 VF equipment or by the use of a conventional voice frequency telegraph system on a normal 300-3,400 Hz channel of another voice circuit. At Port Hedland both 2 VF and voice frequency telegraph systems were used to provide the signalling for the trunk circuits (see Fig. 4.).

The system is operated from a direct current, negative 24-volt power supply and requires sub-group carrier signals (72, 76 . . . . . 96 kHz) and the group pilot signal of 84.08 kHz to be supplied from external equipment. The channel carrier supplies of 9.75 and 10.25 kHz are generated within each rackside.

THE NEED FOR NEW AMPLIFIER DESIGNS.

The original system had used valve type amplifiers that required the old-style —24 and +130 volt supplies. To eliminate the use of obsolete components which are no longer available and to expedite manufacture, it was decided to design new amplifiers and channel carrier supply oscillators using transistors. Thus it was possible to operate the entire system from a —24 volt supply.

SUBGROUP CARRIER SUPPLY PROBLEMS.

It was decided to use a type of group carrier supply equipment that was fairly common and readily available in A.P.O. carrier terminals. This type of carrier supply was intended to work with 'single modulation' channel modems, but it provided all the sub-group carrier frequencies required in the channel doubling system.

During the final factory tests on the channel doubling system it was found that there was about 45 to 50 dB of intelligible crosstalk between some pairs of channels. After many hours of investigation the trouble was found to be due to the fact that each carrier supply signal contained most of the other carrier supply frequencies at a level of about —40 dB relative to the required carrier frequency. As this carrier supply equipment was designed to work with channel modem equipment that had very sharp cut-off crystal band pass filters, these carrier supply impurities would not normally matter. However, in the channel doubling equipment the sub-group band pass filters were designed with a relatively 'broad' pass band. Thus, for example, a signal in channel 3A modulated a 104 kHz impurity on the 88 kHz sub group carrier. The resultant lower sideband then passed through the sub-group filters and was attenuated by only a small amount (approx. 5 dB) even though it was outside the nominal passband. It was then demodulated by the 84 kHz sub-group carrier appearing as a —45 dB intelligible crosstalk signal in channel 4B.

The conclusion from this situation was that a channel doubling system needed a group carrier frequency supply which has at least a 60 dB rejection of all other frequencies. The solution to this problem was to provide a tuned amplifier for each of the sub-group carrier supplies to give a 20 dB rejection of unwanted frequencies. Such amplifiers were designed and built and subsequently installed as a field modification. However, on the initial installation tests of the system, this inter-channel crosstalk was not noticed because it was masked by the noise from the 1100-mile open wire bearer.

MANUFACTURE OF THE SYSTEM.

Mechanical.

The original channel doubling system used type 56 Unit Construction Practice (U.C.P.) techniques and consequently all the original manufacturing drawings the A.P.O. purchased from T.M.C. were based on this construction. By good fortune the A.P.O. had four surplus 12-channel modem racksides in Tasmania that had been made by T.M.C. (Aust.) Pty. Ltd., using type 56 U.C.P. construction. Therefore, the opportunity was taken to use the racks, panels, jacks, etc., from these surplus recovered 12-channel modems for the channel doubling system. Also these recovered channel modems provided voice frequency terminating sets, channel modulators, channel amplifiers, group demodulators, and group combining hybrids which were incorporated into the new system without any change.

In type 56 construction the rack is made of a pressed metal framework with sockets down each side for plug in panels which can be plugged in and out of the rack as required. Each panel consists of a number of units mounted side by side across its width (Figs. 5 and 6).

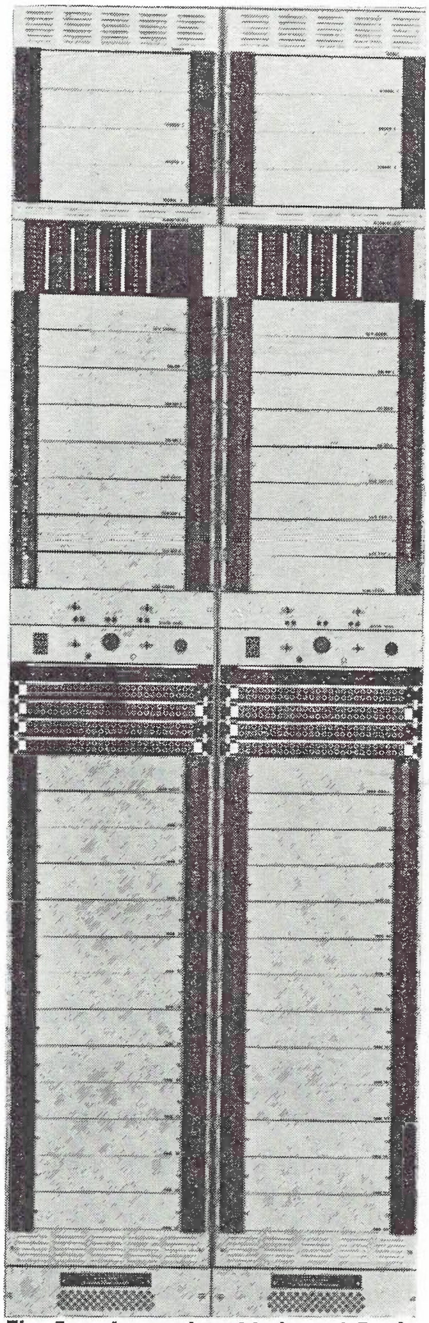


Fig. 5. — A complete 24-channel Doubling Terminal on U.C.P. Racks

The acceptance of the existing U.C.P. racks, panels and units as a construction standard saved a considerable amount of time in the manufacture of the system because there was no need for the development of new mechanical construction.

As the new system used semi-conductor devices in place of the valves used in the original design we were able to use modern materials and printed circuit card techniques to maximum advantage. This assembly technique was used for all filters, pads, amplifiers and transformer units.

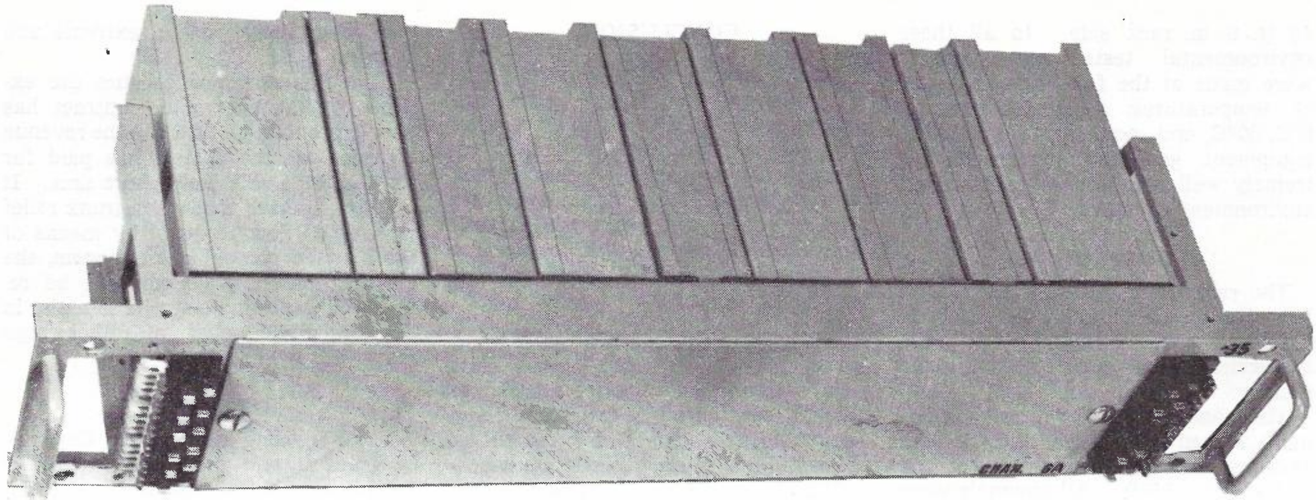


Fig. 6. — A Channel Panel Assembly

Filters.

As the system used 408 filters, special attention was given to the development of techniques for their speedy manufacture. There were four stages of testing in the manufacture of filters:

(a) Checking individual inductors for inductance value and loss.
(b) Resonating inductor and capacitor pairs at their prescribed resonant frequency before assembly in filters.
(c) Setting the frequency of the attenuation peaks of the filter characteristics by fine adjustment of the inductance of the relevant resonant circuits.
(d) The use of swept-frequency techniques to check the performance of each filter in its pass and stop bands. Also this technique was used to measure the system channel frequency responses during final tests (see Fig. 7).

Generally it was quite practical to obtain the high performance required of the filters by paying strict attention to the original 10-year-old B.P.O. specifications for the inductance and capacitance value. It was not necessary at any stage to alter the component values to obtain satisfactory results.

Test Specifications

It is considered that one of the major factors contributing to the successful completion of the project in the brief time available was the preparation of an extremely detailed test specification. This gave details of the tests required for:

(a) Individual units, e.g., amplifiers, hybrid, filters, etc.
(b) Assembled panels.
(c) Individual rack sides.
(d) Complementary pairs of rack sides.

These test specifications were prepared by the A.P.O. Research Laboratories and incorporated the original B.P.O. and T.M.C. test specifications and the specifications of units designed by the A.P.O. Research Laboratories.

Environmental Testing.

The equipment was designed to operate under subtropical climatic conditions in buildings without air-conditioning. Consequently it was important to check the equipment performance, before delivery, under the environmental conditions expected.

By virtue of their experience with defence electronic projects, Hawker de Havilland had extensive facilities for conducting environmental tests on the electronic apparatus. Environmental tests were made on samples of one of each type of amplifier and carrier supply oscillator. Also a special large insulated box was constructed to enable an environmental test to be made on a fully equipped

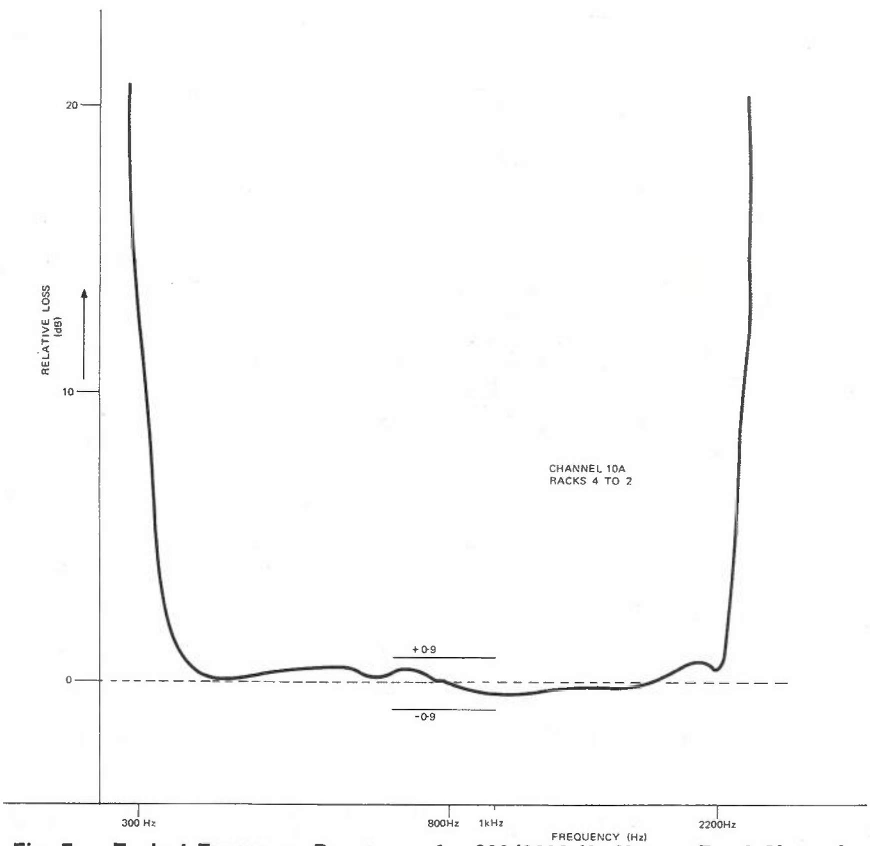


Fig. 7. — Typical Frequency Response of a 300/2200 Hz Narrow Band Channel

10 ft. 6 in. rack side. In all these environmental tests, measurements were made at the following sequence of temperatures; room temperature, 0°C, 50°C, and room temperature. The equipment generally performed extremely well under these extremes of environment conditions.

INSTALLATION.

The racks were sent by air freight from Hawker de Havilland in Adelaide via Perth to Port Hedland and were in service ten days after leaving the factory.

The manufacturing contract was formally signed in October, 1968, and the systems were carrying traffic at the end of May, 1969. All channels were fully in service by June, 1969.

CONCLUSION.

The successful outcome of this project demonstrated that a team consisting of the A.P.O. and an Australian manufacturer with their pooled resources of knowledge, specialist test instrumentation and manufacturing ability, was able to produce a particular piece of transmission equipment in a short space of time to meet a particular demand.

Whilst it was appreciated that a voice band of 300 to 2,200 Hz results in a transmission impairment relative to the accepted voice frequency band of 300 to 3,400 Hz of about 4 dB, it was a matter of sheer economic necessity and service to the subscribers to provide them with some form of service when there was an extreme and pressing need.

Time has now proven that the expense of the cost plus contract has been more than justified by the revenue returned, as the system has paid for itself after a relatively short time. It is fully expected that when trunk relief is given to Port Hedland by means of the planned coaxial cable system, the channel doubling system will be re-used elsewhere in Australia to assist in the immediate relief of other high trunk traffic situations.

REFERENCE.

1. 'Increasing the Traffic Capacity of Transatlantic and other Submarine Telephone Cables,' P.O.E.E.J., Vol. 52, p. 140, July, 1959.

TECHNICAL NEWS ITEM

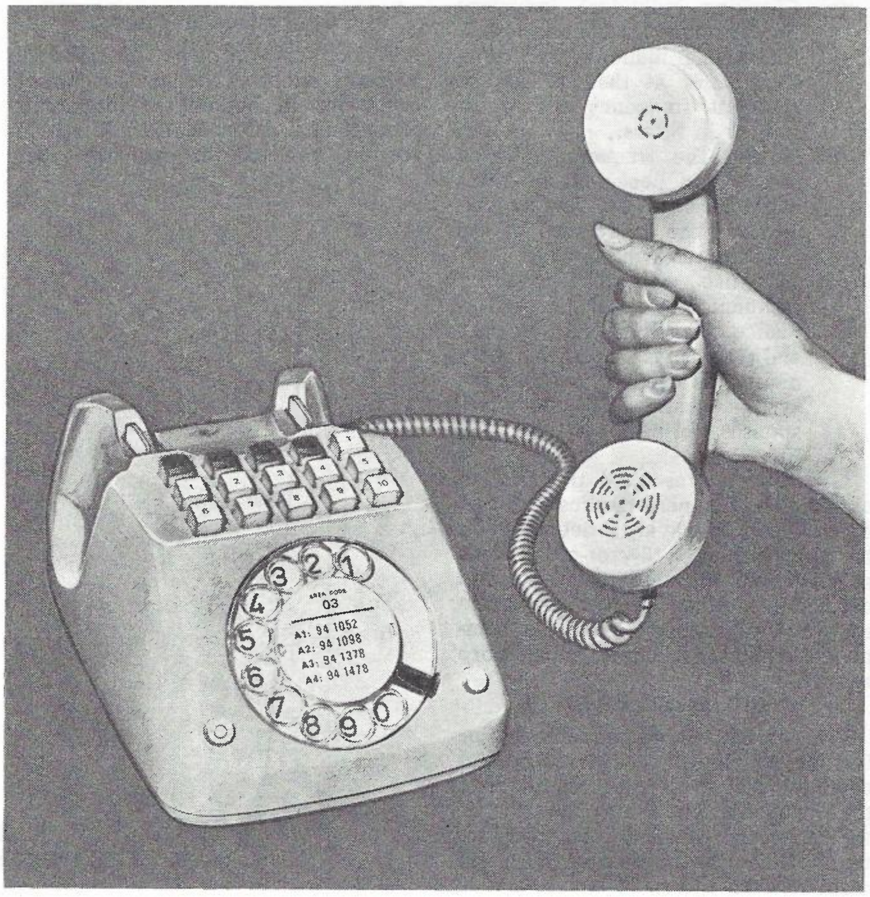
NEW INTERCOM PHONES

Intercommunication telephone facilities in Australia have for many years been provided using the well known A5 and A10 telephones. (See December 1957 issue of this Journal).

New lamp signalling intercommunication equipment (See Figure) developed by the West German firm, Telefonbau und Normalzeit, will supersede the A5 and A10 for future installations. Initial supplies will be imported under an order placed with Amalgamated Wireless (Australasia), Ltd., but the new equipment will be eventually manufactured in Australia.

Two systems, with capacities of two exchange lines and six extensions (2/6) and four exchange lines and eleven extensions (4/11), will be available. The facilities are comprehensive and the telephones are housed in attractive pastel green ABS mouldings.

A number of interesting features have been incorporated in the design. Cable terminations are made on insulation crushing terminals, the relays are sealed reed types including multiple-reed units. To extend lamp life, the filaments are heated by a small current applied continuously while they are idle.



Extensive use is made of semiconductors and printed circuit boards are used to facilitate modular construction and facilitate maintenance. The power supply module and exchange line control circuits are housed in a central unit. A Terminating and Connecting Unit (T.C.U.) associated with each telephone, houses the exchange access relays and local transmission bridge. Multiple cable and instrument cord terminations are also effected in the T.C.U.'s.

A detailed article will be devoted to this interesting new equipment in an early issue of the Journal.

RELIABILITY TESTING OF COMPONENTS

*G. FLATAU, F.R.M.I.T.**

INTRODUCTION.

Reliability is defined as the probability that an item will perform its required function under stated conditions for a stated time. Any quantative reliability estimate must be related to the environment in which the item will be used and the duration of such an exposure. The numerical answers thus derived represent only a probability , subject to statistical laws. Whilst there is a close relationship between quality control and reliability testing, only the latter provides a numerical answer to the question of how long quality can be expected to be maintained during service.

Reliability is designed into a part or equipment by the proper choice of materials, constructional methods, production controls and a knowledge on the designer's part of the environmental stresses to be expected in operation. An inherently unreliable item may never be proved as such unless the test methods and statistical analysis of results are properly chosen, although the unwary may be temporarily deceived by results from low stress tests on limited numbers and of short duration.

Quantitative values of component reliability requirements vary enormously, as they are influenced by the type of end use and what the user is prepared to pay for increased life expectancy. The highest reliability is required in important unattended and inaccessible equipment (such as underwater repeaters, communication satellites), in devices whose failure would involve great expense or loss of military security (manned space flight, ballistic missiles, etc.), or where failure endangers human lives (aircraft guidance, train supervisory equipment, ship radar). Sometimes one needs high reliability for a short mission after extensive storage time, such as in military equipment, whilst on the other hand a submarine repeater is expected to operate continuously for a period up to 20 years without a fault. Somewhat lower in the reliability hierarchy are those equipments and devices whose failure involves loss of revenue or inconvenience, but which being accessible may be repaired, or duplicated in the more important cases, such as telecommunication equipment, computers and similar systems often classed as 'professional' grade of equipment.

* Mr. Flatau is Principal Officer, Physics and Polymer, P.M.G. Research Laboratories, Melbourne (see Vol. 17, No. 3, Page 256).

In this area the concept of maintainability, i.e., the ease of repair, servicing or replacement of parts, becomes particularly important and may be traded off against reliability (by cost effectiveness studies, the cost of labour often being the dominant factor). Hence accessibility of parts within an apparatus, as well as proper documentation so that repair can proceed quickly, is of great importance, a fact which has not yet been realised by some manufacturers.

FUNDAMENTALS OF RELIABILITY THEORY.

Reliability theory (Ref. 1) is concerned with the formulation of a mathematical framework for predicting the life expectancy of a part, and makes use of the laws of statistical probability as applied to random events, i.e., the occurrence of failures. The first essential must be a definition of what constitutes a failure in a particular piece of equipment or part. This is relatively simple in the case of a catastrophic failure, but a degradation failure (parameter drift outside set limits) is determined by where and how the device is to be or was, used and how tolerant associated equipment would be to performance changes of the item under test. (Furthermore, the true cause of failure must be determined from the physical, chemical or mechanical changes which have occurred, as there may be more than one failure mechanism and it is important to know which was the dominant cause.)

If one accepts that failures will occur randomly in time and this, as will be shown later, is not necessarily true in all cases, one would expect a constant average failure rate and thus the probability (R) of an item operating for t hours may be given by:

$$R = \exp(-\lambda t)$$

where λ is the average proportional failure rate per hour. (In practice failure rates, especially for components, are often expressed in per cent per thousand hours or failures per item per million hours.)

The inverse of the failure rate is the mean time between failures (MTBF) or mean time to failure (MTTF) of an item.

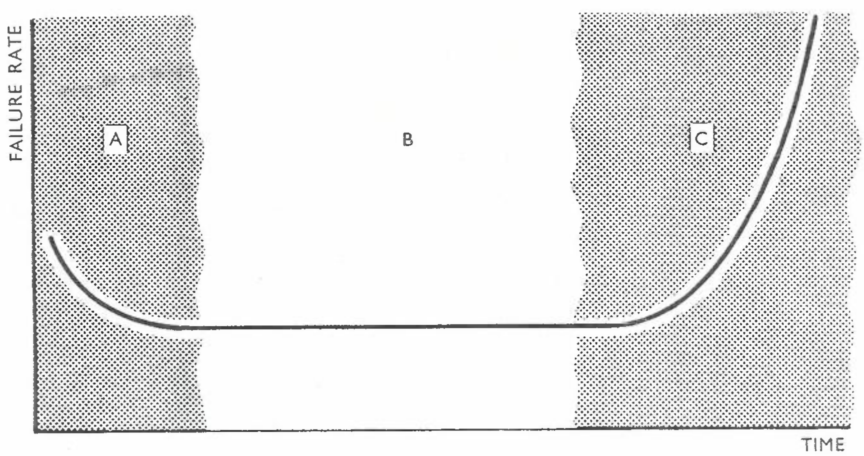
The variation of failure rate with time is often represented by the 'bath tub' curve, which consists of three distinct parts (Fig. 1):

A. A region of rapidly decreasing failure rate, sometimes referred to as the 'infant mortality' or 'burn-in' period.

B. A region where the curve runs parallel to the time axis, which is the constant failure rate region where failures (usually catastrophic in nature) occur randomly.

C. A region of rapidly increasing failure rate, the 'wear out' period, where degradation failures due to age become predominant.

There is reason to believe that the constant failure region is essentially



A = EARLY FAILURE PERIOD

B = "CONSTANT" FAILURE RATE PERIOD

C = WEAR-OUT FAILURE PERIOD

Fig. 1. — Example of Failure Rate/Time Pattern

formed by the tails of the early and wear-out regions, which implies two separate failure mechanisms and time dependent ageing. The realisation of these factors has led to the development of mathematical theories which attempt to describe the time dependence of failure rates in terms of physical degradation phenomena. Experience has shown that the early failure region can be attributed to deficiencies in raw material control and production processes and that tightened inspection coupled with debugging and burning-in of parts prior to delivery can eliminate most of these early failures (rogues). This does not mean, however, that even with 100 per cent. inspection and tightest production controls, all rogues are likely to be eliminated, as many incipient early failures would not be detectable by any means short of dissecting, and hence destroying, the item under test. If one can eliminate infant mortality the failure rate should be purely a function of the ageing mechanism and the distribution in time of wear-out, which enables the calculation of the expected failure rate at any time provided that the probability distribution of the wear-out times is known. To get such information one needs, however, to have a statistically sufficient number of failures, and such numbers can only be obtained in the increasing failure rate region, which under most circumstances is far along the time axis. As answers are required at the design stage and not when the design is obsolete, recourse is frequently taken to accelerated or high-stress testing.

HIGH STRESS TESTING.

There is a physical, not a statistical, reason for every failure and hence it should be possible to speed up the ageing process by a suitable increase of those factors causing degradation and failure until lifetimes have been compressed to durations acceptable in laboratory testing. This assumes that the physico-chemical processes which cause degradation are known and that acceleration in their rate of application will not change their effect or introduce additional phenomena. The study of Physics of Failure is an important part of reliability testing and is covered in a later section. An important factor to be considered in high stress testing is whether it is permissible to extrapolate results obtained under high stress conditions to the more moderate stress conditions pertaining in actual service.

The requirement is thus for a mathematical model capable of describing the interrelation of stress severity and lifetime, and which can provide a theoretical basis for the interpretation of the physical processes which cause ageing. One model which has been used extensively is the Arrhenius reaction rate equation, which is empirical in nature and was originally postulated for physicochemical processes in homogeneous gases and solids. One form of the equation is:

$$R(T) = \exp(A - B/T)$$

where $R(T)$ = Time rate of degradation
T = Temperature in degrees Kelvin
A, B = Constants which must be obtained experimentally.

A and B can be derived from a plot between $\ln R(T)$ and $1/T$. If this plot is linear and test times are chosen to produce equivalent degradation at two stress levels,

$$t_1 \, . \exp(A - B/T_1) = t_0 \, . \exp(A - B/T_0)$$

where t_0 is the time to produce failure at temperature T_0, and t_1 is the time to produce similar failure at temperature T_1. It follows that:

$$t_0/t_1 = \exp . (-B(1/T_1 - 1/T_0))$$

Hence t_0/t_1 is the acceleration factor obtained from the Arrhenius model, and the constant B defines the slope of the linear plot between $\ln(t_0/t_1)$ and the reciprocal of absolute temperature. If one accepts the Arrhenius model, and despite it being empirical it does seem to fit many circumstances, two or three tests at elevated temperatures T_x, T_y, T_z, will yield life times t_x, t_y, t_z, which enables us to construct the necessary plot and by extrapolation find the expected life time t at ambient temperature T. However, such extrapolation has little validity unless it is certain that only one failure mechanism is involved over the whole temperature range, that 'rogue' failures have been excluded, and that statistical confidence limits are clearly stated.

One of the difficulties with the above model is that it is essentially based on the application of thermal stresses, yet degradation and failure can be due to other stresses, such as voltage, mechanical wear and vibration. Whilst linear relations can be obtained in many cases by substitution of a non-thermal parameter (i.e. voltage) for T in the above equation, a multi-stress model due to Eyring, based on quantum-theoretical consideration is finding increasing favour. The basic equation is:

$$R(T, S) = (AT \exp(-B/KT)) \exp((C + D/KT)S)$$

where A, B, C, D are constants, T the thermal stress, S a non-thermal stress and K is Boltzman's constant. The Arrhenius equation is a special case, applicable over a limited temperature range, of the above relationship.

The above discussion has been confined to constant stress testing, where each life test has been at a constant stress level and a new sample used for every different accelerated stress level. One of the drawbacks in such a method is that testing times tend to become excessive at the lower stress levels if statistically significant failure numbers are to be achieved. For this reason step-stress testing is often adopted. In step stressing the samples are tested for fixed time intervals at successively higher stress levels until an adequate number of failures has been achieved. The tests are replicated for a number of different fixed time intervals and a family of curves relating stress and time is derived which permits life predictions for any value of stress to be made. It is clear that the roles of stress and time are interchanged in these two methods. In constant stress testing, the aim is to predict the time to failure at a fixed stress, whereas in step-stress testing the magnitude of stress degradation to cause failure in a fixed time interval is obtained. Nevertheless step-stress results can also be analysed in terms of the Arrhenius or Eyring model, with the proviso that the failure mechanism must be applicable over the whole stress range of interest and that no extraneous failure modes are introduced at the higher stress levels. In a well designed step-stress experiment the stress parameters, the size and number of the stress steps and of the time increments must be carefully chosen and are usually based on exploratory tests, unless information on the stress-time relationship of the device under test is already well documented.

Step stress testing makes the assumption that the probability of failure is independent of the particular combination of stress and time used to produce degradation and/or failure. It is not at all certain that such an assumption is valid for all types of components (and hence equipments), but step-stress testing is widely used, particularly in the semi-conductor field.

PHYSICS OF FAILURE.

In order to design tests which truly evaluate component reliability, it is necessary to have a knowledge of the relevant physico-chemical processes which produce failures in actual service, and possibly, although this is often unachievable, at least a general understanding of how the interaction of multiple environmental and operational factors will influence a failure mechanism. By the same token, a failed item from test or service represents purely statistical information until a diagnosis of the failure cause has been made, which can then be fed back to the designer or manufacturer to be considered in future product improvement.

Physics of failure analysis is concerned with the diagnostics of failure mechanism and for its execution relies on specialist skills such as metallurgy, solid state physics, analytical chemistry etc.

Some of the more common failure mechanisms in components and assemblies are listed below:

Corrosion;

Oxidation;

Diffusion, Migration;

Pyrolysis;

Contamination;

Crystal lattice defects;

Surface film formation;

Stress relaxation;

Fracture and fatigue;

Moisture permeation or adsorption

These failure phenomena can be due to a variety of constructional, production or operational causes such as:

Dissimilar metal contact;

Shock and vibration;

Thermal overloads;

Radiation (ultraviolet, nuclear, solar, etc).

Insufficient protection from the environment;

Differential coefficient of expansion of bonded materials;

Vapours released by materials of construction;

Lack of manufacturing control regarding cleanliness, dimensional tolerances, material quality, etc.

Misuse (human or in design), etc.

The existence of a time dependent ageing mechanism preceding 'wear-out' has been mentioned before, and this concept has gained preference over the concept of a sudden 'catastrophic' failure. However, in actual fact many of the failure mechanisms listed above cannot be detected prior to failure, as there is no visual, electrical or mechanical indication that a catastrophic failure may be imminent. In other cases such as with corrosion, diffusion, moisture permeation, etc., incipient failure is often foreshadowed by measurable degradation of parameters.

In general, failure diagnosis implies destructive testing, as enclosures have to be opened, encapsulants removed or parts dissected. Operations of this nature obviously require skill and specialised equipment, and by and large cannot be attempted in the field, but require a laboratory equipped to perform microscopy, spectography, X-ray diffraction, micro chemical analysis, etc., as well as orthodox electrical and mechanical measurements. It is impossible to give a comprehensive list of the variety of failure mechanisms which may be encountered, but the following lists a few typical examples:

(a) The formation at high temperatures of Gold-Aluminium-Silicon intermetallic compounds at the point of contact between the gold wire lead and the aluminium metallisation on the silicon substrate of semiconductors. The intermetallic compound, often referred to as 'Purple Plague,' is brittle, mechanically weak, and causes high resistance or open circuit contact between lead and device. An interlayer of molybdenum between gold and aluminium will prevent the formation of undesirable intermetallic compounds.

(b) Corrosion in capacitors at the point where the foil is bonded to external tags, resulting in open circuits. This is due to either inadequate sealing and/or insulation, or dielectric materials containing impurities capable of forming an aggressive electrolyte when dissolved in moisture.

(c) Surface films on sliding contacts made from palladium or platinum. The film, often called 'brown powder,' is formed by the frictional effects of the sliding action of the contact acting on chemisorbed organic vapours on the metal surface, resulting in polymerisation. To avoid such high resistance contacts, polymer materials in close proximity need to be chosen with care or a change in the contact material of at least one contact member must be made.

(d) Tracking and eventual breakdown of insulation between silver electrodes. The cause is silver migration under the influence of a voltage gradient, and in the presence of high humidity. This is known to occur with phenolic insulants but not with P.V.C., nylon and most other thermo-plastics.

(e) 'Poisoning' of selenium rectifiers as evidenced by lack of reverse resistance. This is due to contamination by minute amounts of mercury vapour, from fungicidal varnishes or metal brighteners.

(f) Corrosion of fine copper wire in coils potted in epoxy resin. Most likely this is due to the presence of unreacted amine in the encapsulant.

PRACTICAL ASPECTS OF RELIABILITY TESTING

To establish the reliability of an item in terms of failure rate or MTBF, two basic decisions have to be made initially; what is the number to be tested, and what are to be the test conditions?

The number of samples to be tested will depend on the degree of statistical confidence expected of the final result, the minimum number of failures which are required to occur before the test is terminated, and the maximum length of time available to complete the tests. In addition such factors as the cost of each item (which will usually be of no further use after the test), the complexity of test equipment and the available labour supply to perform measurement, must be considered. It is usually inexpedient to set the test duration for a time longer than one year, and in fact often only a few weeks are available. Ideally one would like to test until 100 per cent. of the sample had failed, or at least 50 per cent., but with high reliability components and limited test time this is impracticable and hence one is forced to compromise and aim for a smaller number of failures, such as 10,5 or even 1. The degree of statistical confidence with which the failure rate is to be expressed is again a matter of compromise, 90 per cent. or perhaps 60 per cent. being desirable but not always possible of achievement. Table 1 shows some typical figures and demonstrates the type of trade-off which can be made between the various parameters.

TABLE 1.

Confidence Level. %	Minimum Number of Failures Required at Confidence Level.	Failure Rate in % / 1000 Hours	Test Items Required to Complete Test in One Year.
60	0	1	12
	1	1	25
	1	0.001	25760
	5	1	78
	5	0.1	774
	5	0.001	77280
	10	1	129
90	1	1	52
	1	0.1	516
	1	0.001	51520
	5	1	129
	5	0.001	128800
	10	1	3864
40	0	0.001	6250
	1	1	17
	5	1	65

It is obvious that the number of components required at the low failure rates is so large that one will probably have to be satisfied with single failures and a low confidence level. Statistical prediction can of course be on the basis of zero failures, although such a result is intuitively unsatisfying.

The test conditions must be chosen so as to impose stresses on the items under test which correspond in some known ratio to the conditions prevailing in service. A degree of acceleration is usually necessary, in order to produce some failures in the available time span, but the degree of acceleration should be limited to a range where the stress acceleration factor has been determined. If the acceleration factor is not known or if it is desired to test under a combination of stresses (i.e., temperature, humidity plus rated voltage), the test conditions should be such as not to exceed the manufacturer's ratings. Where there is an interest in a number of stress variables, a factorial experiment may be possible to determine the interaction of the various factors.

In view of the large numbers which may have to be tested, often requiring measurement of several parameters at frequent intervals, reliability testing should be highly automated and interfaced with data logging equipment for real time, or subsequent, computer data storage and analysis. Samples must be selected by means of recognised sampling procedures and should be checked on receipt for compliance with specified performance parameters, irrespective of whether or not all these parameters are to be monitored during the reliability test sequence.

Failure criteria are set in terms of permissible parameter drift, which obviously includes catastrophic failures, but it is sometimes desirable to continue tests past the point where the specified limits have been exceeded, in order to get a clearer idea of the drift rate and the true wear out point.

At the completion of testing, an examination of both failed and surviving samples can reveal significant factors regarding the existing failure mechanisms and may provide explanations for early or unusual failures.

THE INTERPRETATION OF TEST RESULTS.

Test results are in the first instance commonly assembled in tabular form and list for each particular test condition the life achieved either to failure or to the termination of testing for each individual item. If the total lifetimes for all specimens is summed and divided by the total number of failures the answer is the MTBF, and the reciprocal of the MTBF gives the average failure rate. These results must be qualified by a statement of the associated confidence level. Note that the calculation described assumes that failures are exponentially distributed, i.e., one presupposes to be in the constant failure rate part of the 'bath-tub' curve.

Now in practice this assumption is often found to be invalid for a number of reasons. Firstly, as has been mentioned before, the failure rate versus time curve is likely to have only two components, a lengthy decreasing failure rate period followed by a gradually rising failure rate as wear out commences. Secondly, component parameters are not always distributed around a mean value because manufacturing controls in selecting parts within tolerance may produce a truncated distribution, or selection, to allow for lifetime parameter drift, may produce a skewed distribution. In such cases some samples have a greater probability of exceeding the failure limits at an early time and a period of constant failure rate may not occur. Thirdly, components which degrade due to a wear phenomena (abrasion, corrosion, erosion) will generally require a certain time or number of operations before first failure, and prior to this no random failures are to be expected. In such cases, relay contact failure being one example, there is no constant failure region and instead a Poisson distribution of failures exists, the critical parameter being the time to first failure. It should be noted that subsequent to the first failure, there may be (i.e., for a relay contact) a further extensive period where performance is satisfactory, except for occasional (random) faults of short duration, until at a still larger number of operations the fault becomes permanent. The particular application will determine if one or more transitory failures can be tolerated or whether first failure is the only parameter of interest.

In practice, one is thus obliged to fit a distribution to the experimentally obtained values without any preconceived ideas. Obviously graphical representation is most meaningful under the circumstances and therefore cumulative failure rate or percentage of survivors versus time is plotted on linear, log-linear or probability graph paper to see if the available data will produce a smooth curve or better still a straight line.

Over recent years the Weibull distribution has become widely used. This distribution is capable of describing individually all three failure regions of the classical 'bath tub' curve. The cumulative distribution function for a population is given by:

$$F(t) = 1 - \exp[-(t - \gamma)^{\beta}/\alpha], \quad \text{for } t \geqslant \gamma$$

where $F(t)$ = cumulative proportion of failures up to time t
α = scale parameter
β = shape parameter
γ = location parameter

The failure rate will be decreasing, constant or increasing, depending on β being less, equal or greater than 1. If one can assume that an item is subject to failure from the instant it is put into use, $\gamma = 0$.

If further $\beta = 1$, the Weibull reliability function becomes: $R(t) = \exp(-t/\alpha)$ where $R(t)$ is the probability that no item will fail before time t; this is the basic exponential function with α equivalent to mean sample life or MTBF.

The calculation of the constants α, β and γ from experimentally obtained data is fairly involved, but several types of Weibull graph papers have been designed which enable these determinations to be made graphically. The use of one such type of Weibull probability paper, due to Kao (Ref. 2), is demonstrated in Fig. 2. This paper is constructed on the basis of taking the natural logarithm of the Weibull cumulative failure equation twice and using a different scale parameter η, so that:

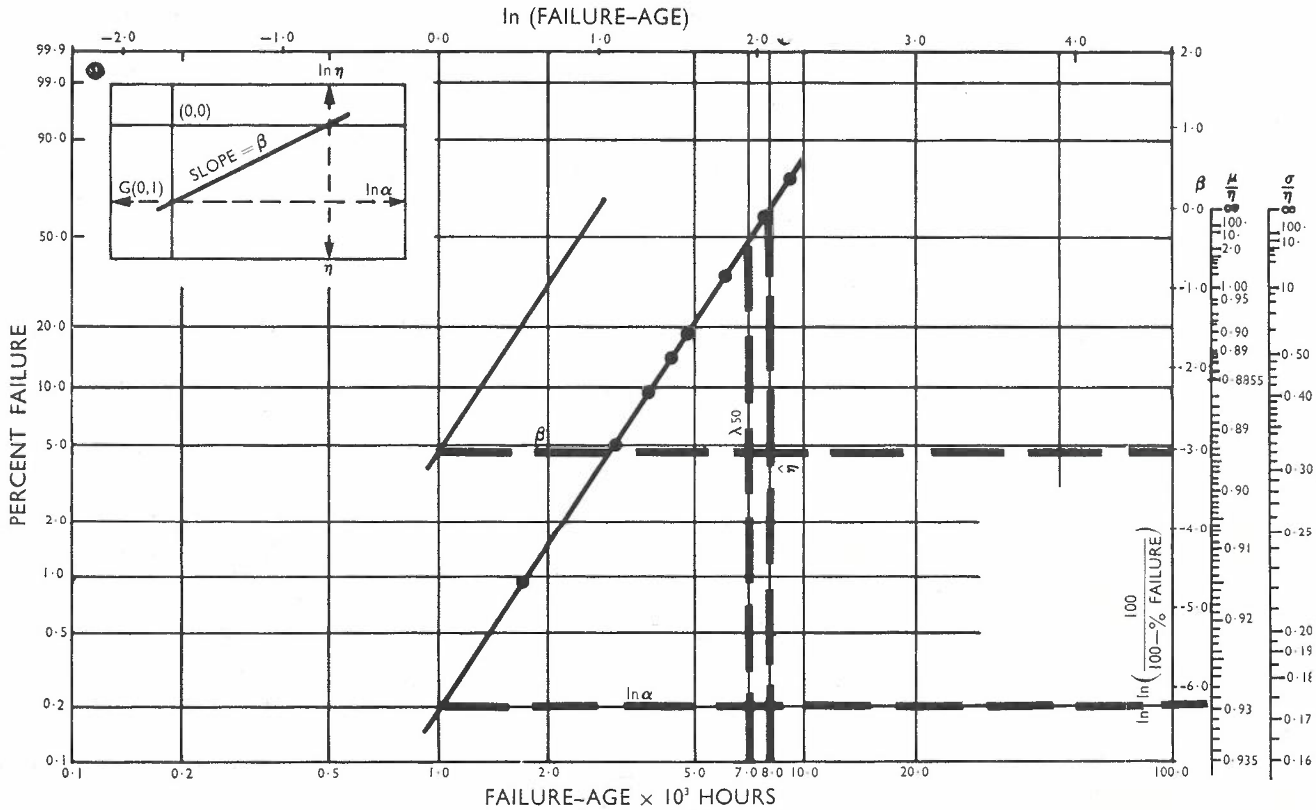
$$\alpha = \eta^{\beta}$$

When plotted on ln versus ln natural log paper the Weibull distribution function will appear as a straight line.

It must be stressed that large scale extrapolation of the Weibull distribution, as may be necessary with very long-lived items, can lead to false conclusions and should be avoided. This is because the Weibull parameters are not necessarily invariant over the whole time span of interest.

In searching for a failure rate-time relationship there is a misconception that a straight line relationship must be shown even if it involves extensive manipulation of scaling factors. In fact artificially introduced constants and/or function operators can often mask important changes in behaviour caused by the appearance of a new or additional failure mode, and thus give a completely wrong impression of the lifetime behaviour of the component or system.

It must never be forgotten that the failure rate derived from a series of tests really applies only to the production batch from which the test sample was drawn, and that repetitive testing of batch samples will be necessary to



Assumed failure free period γ=500 hours
From graph:
$\beta = 3\cdot0$
$\ln\alpha = 6\cdot2$
$\alpha = 1\cdot808$
$\hat{\eta}$=8000 hours
$\frac{\mu}{\eta} = \cdot893$
$\frac{\sigma}{\eta} = \cdot322$
Initial failure rate=0·2%/1000 hours

Results
Characteristic life (63·2 percentile) = 8000 hours
Mean life, μ = 7644 hours
Standard dev., σ = 2571 hours
Median life = 7500 hours
90% probability of survival = 4300 hours
99% probability of survival = 2200 hours

Fig. 2. — Weibull Plot and Interpretation of Data

establish sufficient confidence in the reliability result. It is quite likely that the numerical results of failure rate or MTBF will then vary due to small changes in manufacturing processes or operator skills, changes which are often unknown to production management. For this reason periodical reliability demonstration tests are usually called for with high reliability equipment, particularly in military and space technology. A well-known application of this technique is the American AGREE testing procedure (Ref. 3), which is designed to ensure that the purchaser's risk of accepting an equipment with an MTBF below that specified or rejecting one with MTBF greater than the specified requirement is in both cases less than 10 per cent. The test plan, a truncated sequential test, is chosen so as to obtain results in a reasonable time without too great a risk to purchaser or producer, and thus compares observed reliability with a predetermined standard agreed to by both purchaser and manufacturer, i.e., AGREE testing is not primarily concerned with absolute results. Similar methods can be used for components, when AGREE testing is not applicable, by comparison testing of various manufacturers' products where absolute values of failure rate are only of secondary importance, and ranking is needed to optimise cost-performance decisions.

The major objective must be to present the data in a format which will give the user a maximum of information. The results may be in the form of absolute values, comparative figures or assurances that specified limits have been met. In every case the test methods, stresses, numbers tested, etc., as well as the statistical uncertainties in the data must be clearly stated. Failure rate calculations and demonstrations are after all not just an exercise in statistics, but are needed for life expectancy prediction, design improvement or maintenance planning by engineers who require hard facts in order to make these decisions.

COMPONENT RELIABILITY DATA.

Tabulations of component failure rates can be found in numerous books and articles, but many of these have little significance because the conditions of test or usage are not stated. In fact some such tabulations attempt to combine failure data from all sorts of different applications into a "generic" reliability figure for the particular component (i.e., metal-oxide resistors), without concern for environmental and electrical load conditions.

However, some excellent reliability data are being published by various laboratories specially set up to collect and assess the relevant information, such as the RADC Reliability Centre (U.S.A.), CNET Reliability Centre (France) and the Royal Radar Establishment (U.K.) to name just a few. Many component manufacturers also are now able to provide well documented reliability assessments of their product. For a comprehensive listing of attainable failure rates of components under various load and usage conditions, reference should be made to the U.S. MIL Handbook 217A (Ref. 4).

In table 2 the achievable failure rates for a number of common components (compiled from a number of sources) have been listed. The range quoted covers at the low end high grade professional components under optimum stress conditions, and at the high end is representative of the same type of component under the most severe conditions likely to be encountered in service by Telecommunication and similar equipment.

To appreciate these figures they must be related to the number of similar components likely to be found in an equipment or assembly. For instance the failure rate of blowers is high, but as there is likely to be only one per equipment rack, a 2%/1000 hour failure rate results in a probability of failure once every six years. On the other hand a relatively small electronic assembly can contain 10,000 soldered joints, which, with a failure rate of 0.01%/1000 hours, results in one failure on an average every 40 days. Electronic systems can contain 1 million components and connections and even if a 0.001%/1000 hour failure rate for each item were achieved the system MTBF would be of the order of 100 hours only. This could be unacceptable in many situations, and redundancy concepts would need to be introduced into the design to increase the MTBF.

A perusal of the available data suggests that most types of components can now be manufactured to a very high reliability standard, and even some types such as electrolytic aluminium foil capacitors which were once regarded as unreliable are now being produced to meet very demanding situations. By and large, joints and connections now limit the attainable reliability of assemblies, and this is not surprising when one considers the numbers involved, and especially in the case of joints, that these items are often subject to operator variability. Hence the emphasis in the connection field has been switched to crimping or solderless wraps where the human element is largely removed and, provided the jointing machine is periodically checked, much better reliability can be achieved. Integrated circuits owe their extremely high reliability to the fact that not only are they produced with completely automated equipment, but also because the interconnection between 'components' is made on the semi-conductor chip as part of the production process. This advantage becomes even more pro-

TABLE 2.

Component.		Failure Rate %/1000 Hours.
Transistor	silicon planar, low power	0.00002 - 0.04
Diodes	silicon, low power	0.00003 - 0.1
,,	zener	0.0003 - 0.25
Integrated circuits		0.000001 - 0.003
Resistor, H.S.	carbon	0.0005 - 0.2
,,	metal oxide	0.00003 - 0.05
,,	wire wound	0.00001 - 0.75
Capacitor	paper	0.00005 - 0.1
,,	plastic film	0.0005 - 0.05
,,	ceramic	0.00003 - 0.05
,,	electrolytic, aluminium	0.001 - 0.4
,,	,, tantalum	0.005 - 0.1
Relays	3000 type	0.005 - 0.5
,,	sealed, reed	0.00001 - 0.04
Lamps	neon	0.001 - 0.5
Connectors	multipin	0.003 - 0.2
,,	edge	0.0001 - 0.05
Joints	soldered	0.00002 - 0.01
,,	wrapped	0.00001 - 0.02
,,	crimped	0.001 - 0.01
Transformer	power	0.005 - 0.2
Motors, Blowers		0.01 - 2.0

nounced with large-scale integration, providing the connections to the peripherals can be made equally reliable.

For the system planner or operator the equipment mean time between failure is the critical parameter, and minimum values are beginning to be called for in contracts issued by authorities other than the military. It has been suggested that in order to achieve satisfactory system life, component failure rates should be kept below 0.005%/1000 hours for telecommunication equipment (such as electronic exchanges), 0.00005%/1000 hours for underwater repeaters and 0.02%/1000 hours for computers.

RELIABILITY STANDARDS.

Because guaranteed reliability in space and defence programmes is considered essential, coupled with the fact that production quantities for most contractors in these fields are so huge as to make reliability assurance economically feasible, U.S. MIL standards are well established and have found acceptance in many countries other than the U.S.A. Some of the more widely used standards are:

- MIL 721—Definition of effectiveness terms for reliability, maintainability, etc.
- MIL 781—Reliability test, exponential distribution.
- MIL 756—Reliability prediction.
- MIL 785—Requirements for reliability programme (for systems and equipments).
- MIL 790—Reliability assurance programme for electronic parts specifications.

The latter document is used in conjunction with 'established reliability' specifications for components, to obtain qualification approval and requires the parts manufacturer to document his processes and controls, and to provide facilities for failure analysis and corrective procedures. MIL Handbook 217A is used for reliability predictions and for the comparison of such predictions with results tendered by contractors, and lists failure rates for most MIL specification components under the various conditions of usage and electrical loading.

In the United Kingdom a system of common standards for electronic parts of assessed quality has been introduced as a consequence of the Burghard Committee report (Ref. 5). Under this system, administered by the British Standards Institution, component specifications covering inspection and sampling, testing and requirements are being evolved. For a manufacturer to retain type approval for a particular component he must provide the test data over each six months' period, for all components produced to a detailed specification irrespective of their destination. Hence the results are representative of a much larger population (possibly his total production), and consequently failure rate calculations, in terms of specified tests such as endurance, long term damp, heat, etc., can be made by any user. As this information must be published every six months, it permits users the opportunity to check on long-term production drifts in parameter spread. The British Common Standard System is perhaps not as demanding as the MIL system, but at the same time is probably much more practical for non-military use and should be of immense value in the rationalisation of component types used throughout industry and Government in the U.K. A fundamental difference between the MIL and BS system is that in the former the sample size to be tested depends on the magnitude of the failure rate to be proven, whereas in the British System the sample size depends only on the production batch size.

The European countries, whilst aiming for the standardisation and reliability assurance of components on a national scale, have also been firm supporters of the International Electrotechnical Commission (I.E.C.). Reliability is being studied by Technical Committee 56 of the I.E.C., and a number of recommendations have already been published by this body. It is very likely that the major Western European countries will soon come to an agreement of Common Standards based on the work of the I.E.C. and probably incorporating many features of the British system, such as manufacturer approval, qualification requirements and certified test records.

In Australia MIL or DEF standards have up till now been used for all Defence equipment, with a mixture of B.S.I., I.E.C. and A.S.A. specifications used by other users. The policy of the Standards Association of Australia is to adhere to I.E.C. recommendations wherever possible, a view shared by many large private and Government organisations. S.A.A. Committee TE 21—Reliability of Electronic Components—is responsible for the preparation of suitable specifications and will soon issue some I.E.C. documents, with amendments, as Australian Standards.

Many other bodies such as I.S.O., C.C.I.T.T. and C.C.I.R. are also engaged in the preparation of specifications or recommendations regarding reliability.

CONCLUSION.

A paper of this nature can only briefly touch on the many facets of reliability theory and application, and in fact no mention has been made of such important aspects as redundancy, maintainability, or system reliability prediction based on parts reliability information. For those interested in or concerned with these subjects, an extensive literature is available, ranging from the simple 'how or why' approach to abstruse mathematical expositions.

As has been indicated, there is extensive knowledge on how to test, how to interpret results and how to diagnose causes of failure, and standards and specifications are being developed on both the national and international level. We have, therefore, a situation where reliability testing and predictions can be made available by most manufacturers, used by designers and specified by consumers. However, the application of reliability concepts in purchasing clauses will increase costs, as no manufacturer will assume the commercial risk of providing parts with guaranteed reliability without considerable additional and long-term testing, nor would the user be satisfied unless this had been done. Reliability testing is costly and, except for large production quantities, is much more expensive than conventional quality assurance testing. However, the cost and complexity of most modern systems are such as to demand and justify valid life expectancy assurances for planning purposes. In a country such as Australia, it is at present not possible to institute reliability programmes on the scale applied in the U.S.A. to such projects as Minuteman or Apollo, but there must surely be scope for more modest efforts perhaps along the lines of the British System of Common Standards, resulting in certified test records. The economic benefits of assured reliability in reduced downtime, labour cost savings and reduced spare parts inventory must be clearly demonstrated to management, so that the extra funds to cover the increase in price may be made available. Just as quality control had to be 'sold' in the past two decades so it will be necessary to demonstrate the value of reliability assurance in the years to come. There is, however, one vital difference. Quality control demonstrates that a part or equipment leaves the factory in a condition which meets the user's specification, whereas reliability demonstrations in the laboratory are based on assumptions, not always valid, that the service environment and the service life have been reproduced in an accelerated form. It thus becomes crucial to know what actually does happen in the field, to record and tabulate failures and wherever possible to arrange for failure analysis and to use this data to find correlation factors with laboratory results, which can then be used in future testing. To make a reliability programme successful it is essential to establish close communication between operations, design and manufacturing so that relevant information is available for use in all these areas. The provision for this feed-back and feed-forward should be the initial step by any consumer or manufacturer planning to establish reliability objectives for manufactured products.

The day is near when we will not be able to afford to just think, hope or believe that our equipments or systems will perform up to expectations, but when we will have to give guarantees regarding the probability of a failure free period for these items so that planning for maintenance, system redundancy, fund provision for replacements, etc., can proceed with an assurance many times greater than is possible today.

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TECHNICAL NEWS ITEM

COMMUNICATIONS VITAL TO ELECTRICITY SUPPLY.

The Electricity Commission of New South Wales, whose transmission lines reach to all corners of the State, also has a large communications network.

Though it makes extensive use of Post Office services, there are compelling reasons for having its own communications facilities.

Instantly available communications, remote control and telemetering are essential in operating and maintaining the transmission network which delivers power to the county councils which retail electricity throughout the State.

To ensure continuity of supply these facilities must give immediate contact between generating plants and control centres, especially when abnormal conditions, such as storms, might interrupt the power system.

The importance of reliability is so high that most of the Commission's communications channels are duplicated, to guard against interruptions of any kind.

Because the demand for electric power doubles itself in New South Wales approximately every eight years, the Commission constantly has to expand generating capacity, and this in turn necessitates enlarging its communications facilities.

To provide for larger needs when the Liddell power station comes into operation early next year, a new high-capacity microwave system will be built.

It will have a capacity of 600 channels, as against the present 20 channels.

A member-company of the Australian Telecommunications Development Association has designed and is building the microwave bearer equipment—a project valued at about $500,000.

The solid-state 2000 MHz system will link all the coalfields power stations in the Newcastle and Hunter Valley region with the northern area control centre at Waratah, and with Sydney's three metropolitan control centres and the interconnected State system control centre at Carlingford.

Australian manufacturers are providing much of the equipment required to provide the various services which will operate over the microwave system.

These include a private automatic telephone network; and telemetering, signalling, automatic interrogation and remote switching.

Because of the many patrols and maintenance crews engaged along the transmission lines, the Commission makes great use of VHF radio and mobile transceivers.

These are organised into seven regional networks and they are being added to by about four new repeater stations a year as the needed coverage grows.

The equipment for fixed repeaters, two-way sets in vehicles and radio links between repeaters have been made in Australia by ATDA members.

Recently a local manufacturer supplied a selective calling system which enables mobile operators to call and be called by dialling instead of by voice.

This will enlarge the effective VHF coverage by enabling staff to be contacted when working nearby, but not close enough to hear a voice call.

THE AUSTRALIAN POST OFFICE ROLE IN NASCOM — PART 2 OPERATIONAL ASPECTS

*J. LIIV, M.I.E. Aust.**

INTRODUCTION.

Descriptions and details of the development of the U.S. National Aeronautics and Space Administration Worldwide Communications Network (NASCOM) are included in an article by K. A. McKenzie (Ref. 1) and this paper describes the Network from the operations viewpoint. The Australian Sector of the NASCOM Network forms part of this worldwide network and provides communications facilities leased from the P.M.G.'s Department for the transmission of NASA Mission-related information necessary for the support and conduct of the NASA space programmes and projects. Initially, conventional teletype facilities were provided and used for the support of satellite activities, but it soon became necessary for the NASA authorities to carry out real time trajectory calculations at a central computing complex in the U.S.A., and the transmission of data at speeds higher than was possible with telegraph facilities became essential. Accordingly, a network of high-speed data circuits operating at speeds of 2400 bits per second and meeting C.C.I.T.T. M89 specifications were provided to the various tracking stations throughout the world over transmission media such as communication satellites, submarine cables, microwave radio systems, land lines and where other facilities were not available, H.F. radio circuits.

The design of the worldwide high-speed data network has been orientated around the use of communications processors. At the Goddard Space Flight Centre, near Washington, in the U.S.A., there are the main UNIVAC computers of the 490 type (now 3 Model 494) for controlling the network and which on-forward all teletype and high-speed data from the worldwide network to the 494 computers at the Mission Control Centre at Houston via 50.8 kilobit per second data streams whilst UNIVAC computers models 1230 and 1218 are provided at tracking stations to handle command tracking and telemetry data. In addition UNIVAC computers model 418 are in operation at the NASA switching centres to connect low-speed telegraph circuits to high speed data circuits. Further details of the C.C.I.T.T. specification M89 and other voice channel parameters for data circuits, as well as additional information on the UNIVAC computers, may be found in Reference 1.

*Mr. Liiv is Engineer Class 4 Country Branch, N.S.W. See. Vol. 16, No. 2, page 189.

For operation purposes, the tracking stations around the world and which are served by the worldwide NASCOM Network, can be grouped into—

(a) The Manned Space Flight Network (M.S.F.N.), which supported the Mercury and Gemini programmes and now supports the Apollo missions with voice, command, telemetry and tracking data services to the Mission Control Centre at Houston, Texas, and has 3 tracking stations in the U.S.A., 2 in Australia (Carnarvon, W.A., and Honeysuckle Creek near Canberra, A.C.T.) and 14 other tracking stations throughout the world.

(b) The Deep Space Network (D.S.N.) which supports Mariner, Surveyor missions, etc., with command tracking and data acquisition services to the Space Flight Operations Facility in Pasadena U.S.A., and has 5 tracking stations in the U.S.A., 2 in Australia (Tidbinbilla, near Canberra, A.C.T., and Island Lagoon, near Woomera S.A.) and 4 others.

(c) The Space Tracking and Data-Acquisition Network (S.T.A.D.A.N.), which supports the Nimbus programme, orbiting geophysical and astronomical observatories, etc., with command, tracking and data acquisition services to the STADAN control centre at Goddard (G.S.F.C.) and has 2 tracking stations in the U.S.A. and 4 outside the U.S.A., including 2 in Australia (Orroral Valley, near Canberra, A.C.T. and Carnarvon, W.A.).

Further details of the Australian tracking stations are given in the article on the development of the NASCOM Network (Ref. 1).

The network supporting the Apollo missions is the M.S.F.N. and one group of tracking stations including tracking ships and instrumented aircraft, are required to follow the spacecraft at launch, during earth orbits and on its return to earth. Tracking of the Apollo Spacecraft after it leaves the earth's orbit is carried out by three special stations having 85 ft. dish antennas and which are located at Goldstone, U.S.A., Honeysuckle Creek, Australia and Madrid, Spain. These stations stand approximately one-third of the earth's circumference apart to provide continuous coverage.

High-speed data to be transmitted over the NASCOM Network for all missions falls into 3 main categories—(a) Command, (b) Telemetry, and (c) Tracking. Command data is transmitted from the Mission Control Stations to the spacecraft via the tracking stations, whilst Telemetry and Tracking data flow in the opposite direction. Moreover, a loss of communications to and from a tracking station in the M.S.F.N. during a manned Apollo mission could have very serious consequences concerning the safety of the astronauts or the successful completion of the mission, so that during these missions the reliability requirements are extremely high and special precautions are observed on communication systems throughout the world carrying NASCOM circuits during critical phases of manned missions. These periods are classified as 'Critical' for launch, recovery and lunar landing phases and 'Special' coverage at other times during an Apollo mission.

NASA SWITCHING CENTRE, CANBERRA.

General.

As the NASCOM Network developed with the increasing use of transmission of high-speed data over long haul circuits employing combinations of different communication media, it became impracticable to obtain end-to-end circuits which would meet the requirements of C.C.I.T.T. Specification M89 and sectionalisation of the network became necessary. At five locations (Canberra, London, Madrid, Honolulu and Guam) in the world, regional switching centres were established by the NASA authorities to control all high-speed data services which originated or terminated within their geographical sector. All data services within these sectors are switched through the communication centres for data regeneration and permit the C.C.I.T.T. M89 Specifications to be applied to each section of long haul data circuits. All high-speed data from any tracking station served by the centre would be regenerated at Canberra and depending upon the path chosen could be further regenerated at Guam, and/or Honolulu. For example, on a circuit from the Carnarvon Tracking Station to the G.S.F.C. in the U.S.A., regeneration is provided at Canberra, Guam and Honolulu on the circuit via Seacom. Some of these centres employ dual UNIVAC 418 computers to connect the low-speed telegraph circuits from the tracking sites to high-speed circuits to the G.S.F.C.

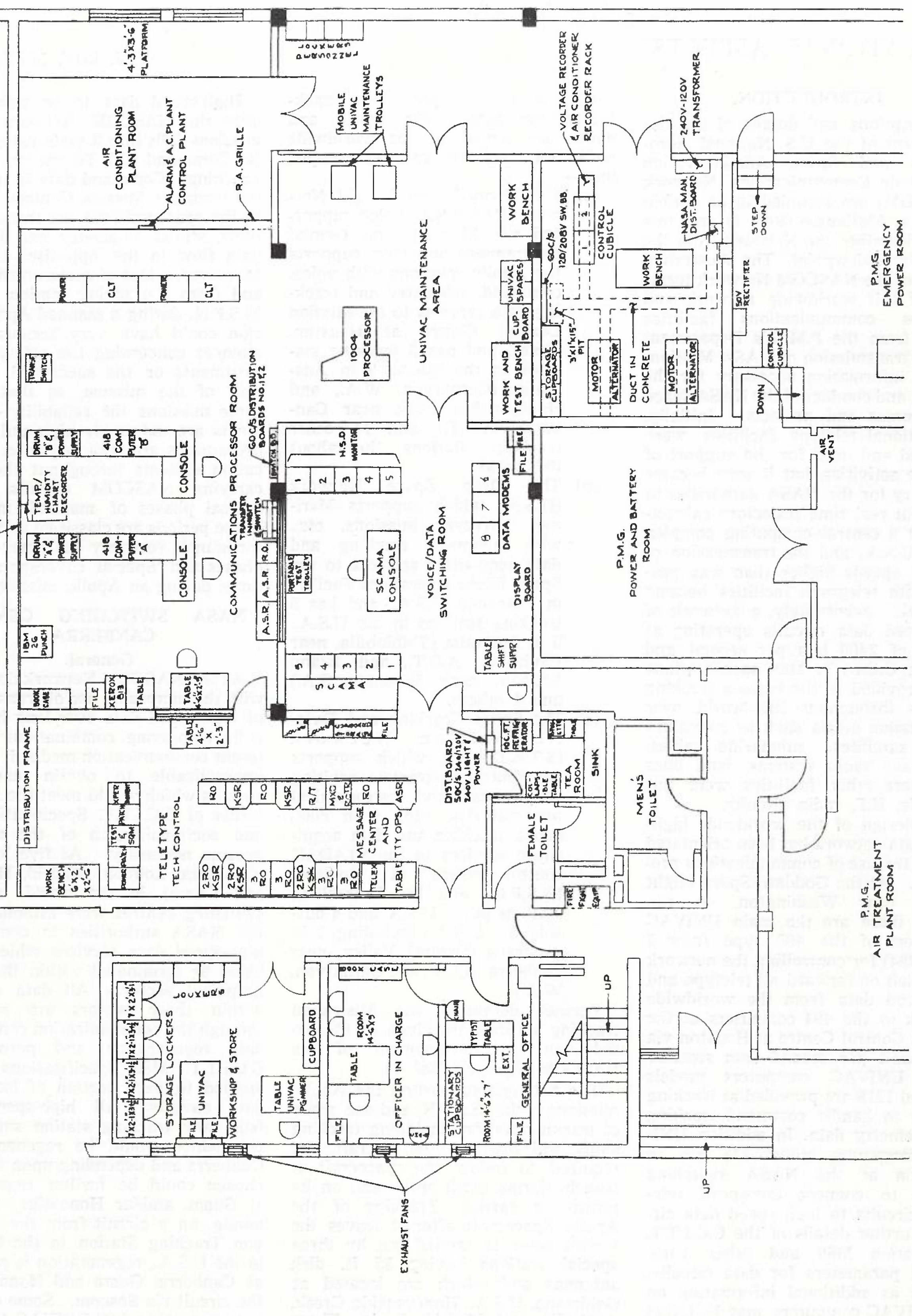

Fig. 1. — NASA Switching Centre — Floor Plan

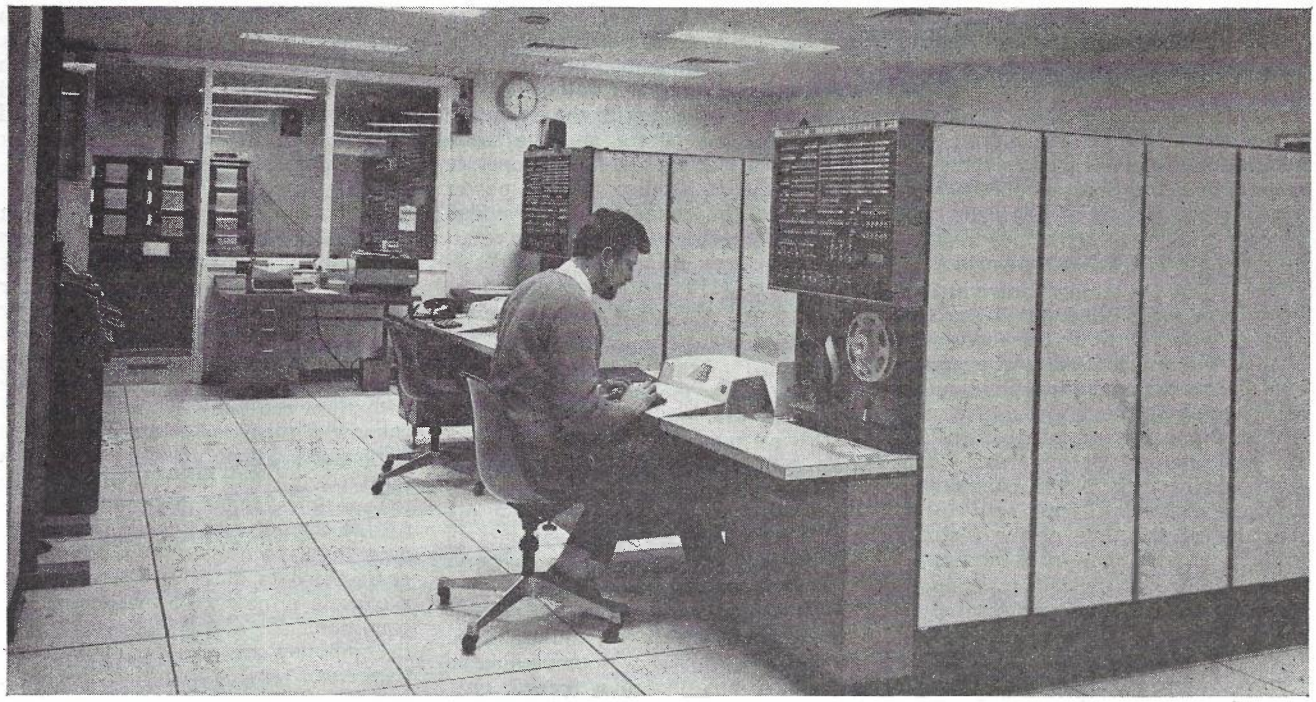

Fig. 2. — NASA Switching Centre — Canberra Processor (Computer) Room

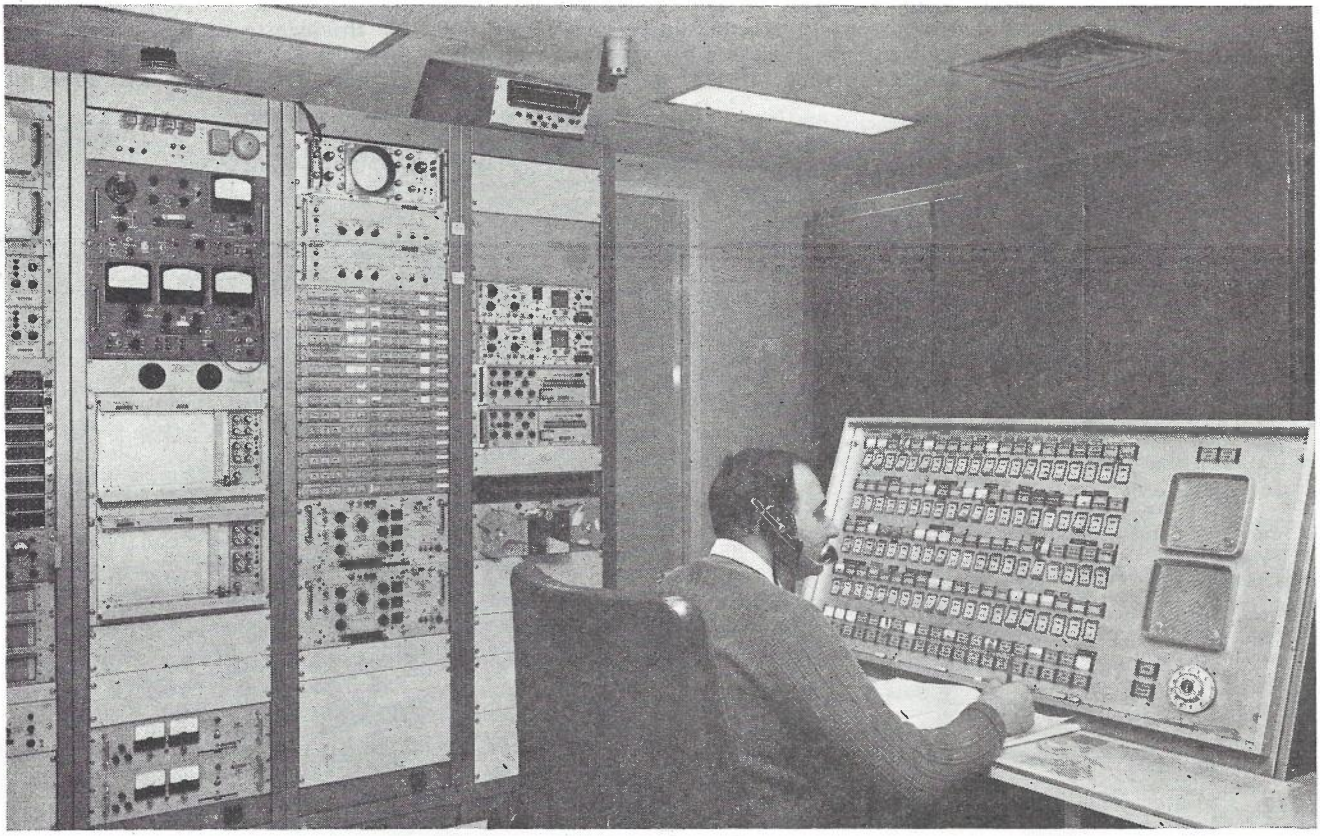

Fig. 3. — NASA Switching Centre — Canberra Voice Data Room

Additional advantages which are gained from segmentation and regeneration of long data circuits are increased flexibility obtainable in the network and the fact that circuit quality and error rates can be more conveniently monitored, as well as achieving more rapid location of faults and speedier restoration of service; two aspects vital to the reliability requirements of the NASCOM Network.

The NASA Switching Centre at Canberra was established on the ground floor of the Deakin Telephone Exchange building in 1965 and exercises control over communication facilities associated with the NASCOM Network in the Australian and part of the Pacific and Indian Ocean areas. This centre replaced the NASA communication centre which was set up in Adelaide at the time of the Mercury Projects as explained in Reference 1.

The Centre is divided functionally into 3 areas, the Processor (computer) room, the voice-data room and the teletype room. A floor plan of the centre is shown in Fig. 1 and views of the three rooms are illustrated in Figs. 2, 3 and 4.

Additional air-conditioning equipment (in duplicate) has been installed in the centre mainly to handle the temperature and humidity requirements of the UNIVAC 418 computers and a separate 150 KVA emergency diesel alternator set has recently been installed in the telephone exchange emergency plant room to provide standby power for the centre and to run the 'on-line' computer during missions. All equipment operates from the standard American voltage of 110 volts per phase and with the exception of the 418 computers and the associated peripherals, all items operate from a 50 Hz supply. 60 Hz power supply to the computers is provided from the special 50 Hz to 60 Hz rotating converters, delivering 208 volts 3-phase a.c. (110 volts per phase) at 37 KVA, installed in a separate room.

Processor (Computer) Room.

Installed in this room are the two UNIVAC 418 model computers employed in a redundant configuration to switch all telegraph type data to and from tracking sites, process and reformat this data and transmit it at 2400 bits per second to the Model 494 UNIVAC computers in the G S.F.C. in the U.S.A. and provide similar facilities in the reverse direction. In operation, one UNIVAC 418 computer is the on-line system, which is handling data, whilst the other 418 computer is in standby (operating in a receive only mode), ready to assume the on-line functions as required.

The UNIVAC 418 computer system consists of four communication line terminals (C.L.T.'s), to which are connected two fully duplex high-speed data circuits and 56 C.L.T.'s for connection to 28 fully duplex low-speed (75 baud) circuits, interconnected by the 418 processor having a store of 4096 decimal 18 bit words and a rotating drum system (FH 330), which has a capacity of 1,000,000 octal 18 bit words. In addition there is associated with the 418 processor, a UNIVAC Model 1004 high-speed page printer and card reader, used to carry out computer programme maintenance and modifications.

Data, after being processed by the UNIVAC 418 into computer-words, is transmitted over the 2400 bit per second high-speed data circuits for entry into the UNIVAC 494 computer system at the G.S.F.C. The data format includes 'sync' and housekeeping words, sum and parity checks and the data flow can only be maintained if acknowledgment as to its correctness is received. If no acknowledgment is received, the data block is repeated up to four times, and if this is not successful the computer switches to the alternate high-speed data circuit and repeats the data block and arranges for a console print out of the unstandard condition.

Computers are provided only at the Canberra and Madrid Switching Centres, as the other switching centres perform purely switching functions.

Telegraph Room.

From this area, all low-speed telegraph-type circuits forming part of the NASCOM Network in Australia are monitored and supervised. Telegraph facilities are used to provide back-up for the high-speed data services and for telemetry information in the form of summaries, histories, etc. For this

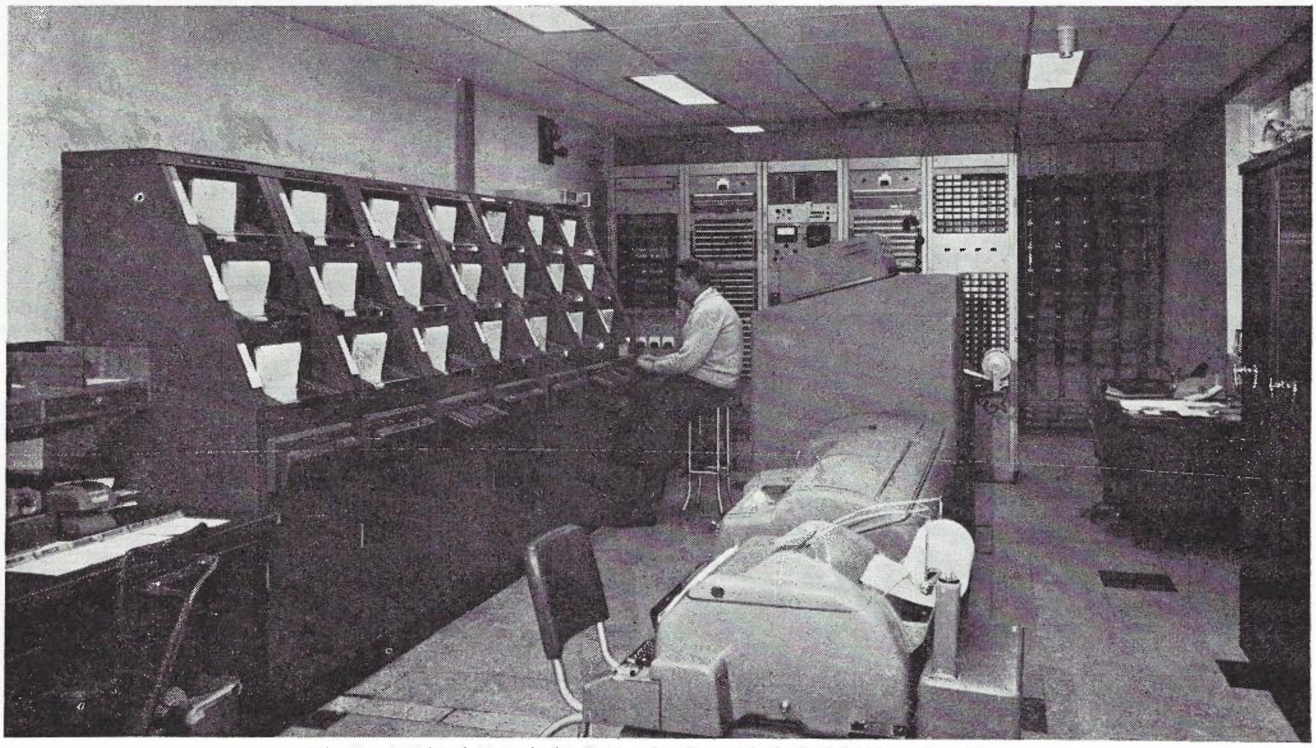

Fig. 4. — NASA Switching Centre — Canberra Telegraph Room

LIIV — NASCOM

purpose the following equipment is installed:—

23 Receive Only Monitoring Printers
5 K.S.R.'s (Keyboard Send/Receive).
3 A.S.R. (Tape Send/Receive)
3 Multiplex Tape Transmitters
6 R.O.T.R.'s (Receive Only Tape Reperforations)
Signal Quality Monitor
Open Line Alarms
Data Analysis Centre Test Set

All telegraph machines are of Western Electric 28 Teletype manufacture and operate at 75 bauds, and the test and monitoring equipment is manufactured by the Stelma Corporation.

The operation of the telegraph area is divided functionally into two classifications — (a) the facilities control, which covers the normal NASCOM operational requirements, and (b) the 'Off- System Refile' functions where incoming information is re-directed to other authorities and for handling administrative telegraph traffic.

The main monitoring equipment used to supervise the quality of telegraph transmissions is the Signal Quality Monitor, which continuously monitors for 'out-of-range' conditions and provides an alarm condition when the distortion exceeds a pre-set condition or an open circuit condition is encountered. The Open Line Alarm equipment provides an alarm condition when an open circuit condition is encountered within the centre. Where the monitoring equipment indicates a fault or Out of Specification condition the Data Analysis Centre (Stelma DAC-V), which provides facilities for the comprehensive analysis of synchronous and start-stop telegraph signals to determine the type and magnitude of signal distortion in a signal, is brought into operation to either analyse the received Telegraph Signal or provide an undistorted repeated transmission of a selected character or a test message with programmed identification to assist in determining and rectifying the trouble.

Voice Data Room.

This area provides facilities for the transmission of high-speed data over voice circuits and for the switching functions for voice and voice data ciruits in the NASCOM Network. The Western Electric Model 205B data modems are installed in this room as well as the associated test and patch bays, data transmission test sets and audio test equipment. The centre of activities in the area is the Voice Switcher, which is basically a switching matrix controlled from a console. The present voice switcher has a capacity of 80 lines and comprises five cabinets containing crossbar switches and amplifiers and a central console equipped with push buttons, lamps, etc. The voice switcher provides facilities for the rapid interconnection and conferencing of NASCOM circuits as required for a particular mission, simulation tests or other operations. It is designed for four-wire operation throughout, a high degree of reliability and is compatible with the 1000/20 Hz signalling systems used on voice circuitry.

Descriptions of the WE 205 B data modem sets may be found in Reference 1.

Because of the high cost of leasing voice bandwidth data circuits to C.C.I.T.T. Specifications, particularly across the Pacific, and of the desirability of taking advantage of the benefits of data transmission at speeds higher than 2400 bits per second, the NASA authorities carried out tests between Canberra and G.S.F.C. in the U.S.A. with prototype data modems capable of operating at data rates up to 9600 bits per second. As a result of these tests, Western Electric data modems capable, at present, of operating speeds up to 7.2 Kilobits per second are being obtained for the Canberra Switching Centre and are expected to be placed into service for extended trials during April, 1970. With modifications, the operating speed of these W.E.203A type data modems can be increased to 10.8 Kilobits per second, if desired. The W.E 203A data modems can be operated at different data rates: at 2400 b.p.s. using 2-level modulation, at 4800 b.p.s. using 4-level modulation, and at 7200 b.p.s. with 8-level modulation. The data modems are designed for 2, 4, or 8-level modulation with suppressed carrier and vestigial sideband (V.S.B.) line signal shaping together with automatic adaptive equalisation as well as for synchronous detection with upper and lower pilot tones being transmitted near the edges of the V.S.B. spectrum and so providing means for carrier recovery.

NETWORK CONFIGURATION FOR APOLLO MISSIONS.

Because of differing requirements for each Apollo mission, new computer programmes for the control of mission data are generated for the tracking station computers and produced on magnetic tape at the G.S.F.C. compiling centre. Also circuit requirements and Network configurations differ to match the variations in mission requirements (e.g. T.V. transmissions, etc.). For the Apollo 11 Mission the basic tracking sites had the capability to track and provide data communications for two spacecraft, the lunar module (LM) and the command service module (CSM) simultaneously within the bandwidth of the single antenna. A unified S-band (U.S.B.) antenna system utilised a single carrier frequency in each direction 2270-2300 MHz for the down link and 2090 to 2120 MHz for the up or command link. Subcarriers of 1.024 MHz modulated with PCM telemetry signals at data rates of either 1.6 Kilobits per second or 51.2 Kilobits per second and of 1.25 MHz modulated with a voice signal and 6 biomedical signals spaced from 3.6 KHz to 15.6 KHz (for the Portable Life Support System) were used to pack all downcoming information as well as providing for Television signals on the same S-band carrier.

Prior to each mission a comprehensive series of simulation activities controlled from the M.S.F.N. Centre at Houston are carried out to check all facilities associated with the communications capability of the NASCOM Network and the Tracking Stations. The simulation activities can be grouped as follows:—

(a) Network Simulation
(b) Station Simulation.
(c) In House Simulation for Tracking Station Equipment.
(d) Local Communication Centres Simulation.

The NASA Switching Centre at Canberra is not involved with item (c), but provides the required circuits back to Houston for simulation tests (a) and (b). The Network Simulation (item a) is the major activity required on the NASCOM Network and during these tests a complete simulation of the Mission is performed to include all important phases of the Mission, such as lunar landing, ascent, descent, translunar injection, etc. Two Network simulations are held within two weeks of the actual commencement of the mission. The communications simulation tests cover all checks of emergency procedures, functioning of important circuits and equipment, etc. Moreover, a review of action required in case of a major contingency such as the complete loss of the Canberra Switching Centre during a mission, is also carried out.

Details of the circuit configurations of the more important circuits used for data transmission and voice purposes in the Apollo 11 mission are illustrated in schematic form in Fig. 5. Apart from the circuits interconnecting the UNIVAC 418 computer at Canberra to the control computer at Houston, the circuits serving the various facilities in the Australian and Pacific Sectors were grouped into the following communication networks for the purpose of running the mission, as shown in Fig. 5.

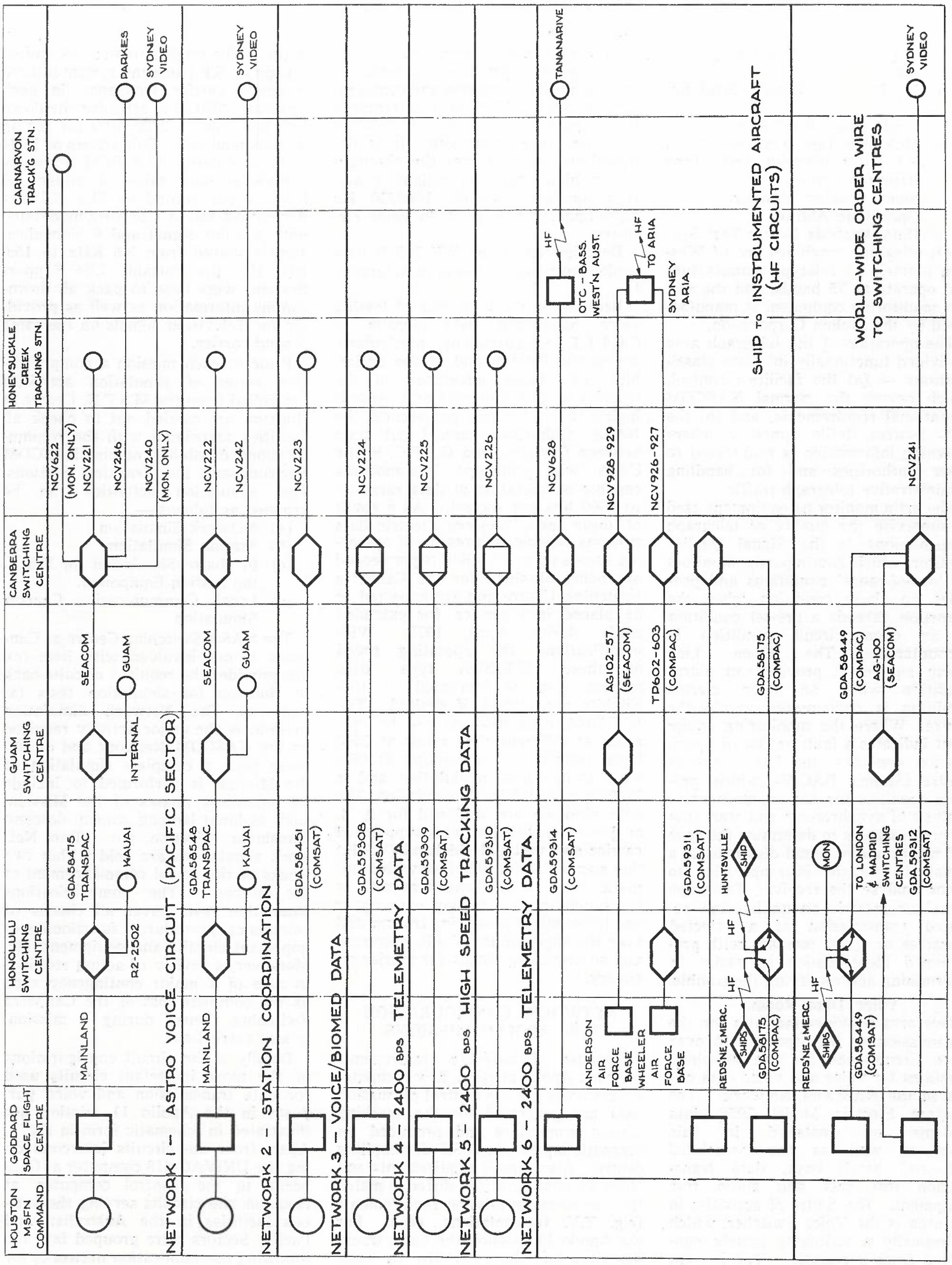

Fig. 5.— Apollo Circuit Details — Schematic

Net 1 Astro voice.
Net 2 Station Co-ordination Circuit
Net 3 Biomedical Data.
Net 4 Telemetry/Command Data.
Net 5 Tracking Data.
Net 6 Telemetry/Command Data.

In addition to the above there were the order wires, recovery circuits, the T.V. co-ordination circuit between the Australian Stations and the Sydney Video Centre, and the Public Affairs circuit, etc. Data received at a tracking station and which indicated an 'out of limit' condition in the spacecraft or in the biomedical information about an astronaut (these conditions are usually programmed separately for each mission), it would be immediately 'flagged' out by the tracking station computer system and sent to the Houston Mission control Centre on a priority basis for attention. The use of the C.S.I.R.O. radio telescope station at Parkes, N.S.W., for the reception of signals, including T.V. from the moon, has been included in Reference 1.

Television.

Australia played a vital role in the Apollo 11 Mission as at the scheduled time of the lunar landing, the only communication 'window' available from the moon was to Australia and special facilities were provided by the P.M.G.'s Department from the Parkes Telescope and Honeysuckle Creek to the Video Centre in Sydney. As the downcoming signal contained voice transmissions, biomedical and telemetry data, as well as T.V., this data when received at Parkes was transmitted to Sydney with the T.V., where the T.V. signals were removed by filters and the data was transmitted over another video link from Sydney to the Honeysuckle Tracking Station for demodulation and processing by that Station's computer system.

The special video bandwidth links provided from Honeysuckle Creek to Sydney (TV), Parkes to Sydney (TV and data) and Sydney to Honeysuckle Creek (data) were by means of radiocommunication facilities made up of outside broadcast links (in duplicate) between the Honeysuckle Creek site and the P.M.G. radio repeater at Williamsdale and between the Parkes Telescope and P.M.G. Radiotelephone station at Coonambro and the use of microwave radio bearers between Sydney and the Radiotelephone stations to provide the most reliable service possible.

The P.M.G. radio facilities were controlled from the Redfern Radio Telephone Terminal in association with the Television Operating Centre at City South for the coaxial cable sections used, and fault handling, patching and restoration procedures, use of test patterns, etc., were established in conjunction with the NASA authorities in each section of the circuits after taking into consideration the requirements for service on each route, the phase of the mission, time of day, etc. These procedures were promulgated and observed by all staffs involved in the provision and operation of the video facilities. Staff were assigned to various radio repeater stations to carry out manual patching of bearers or equipment on instructions from the Redfern Control Station. The radio bearer between Sydney and Moree was also given special attention as the telephony bearer forming part of the COMSAT satellite circuits used for data transmission was of prime importance notwithstanding the fact that TV from Australia to the U.S.A. and other parts of the world was also transmitted from Sydney over this route and the facilities available were limited.

Canberra Trunk Test Room.

The Canberra Trunk Test Room located in the Canberra Central Broadband Carrier Station is the nominated circuit control station for all NASCOM circuits provided by the P.M.G.'s Department in Australia. As such, it is responsible for the satisfactory performance of the circuits and for all routine and special attention required in connection with fault clearances, routine maintenance, etc. To assist the Canberra Trunk Test Room (TTR)

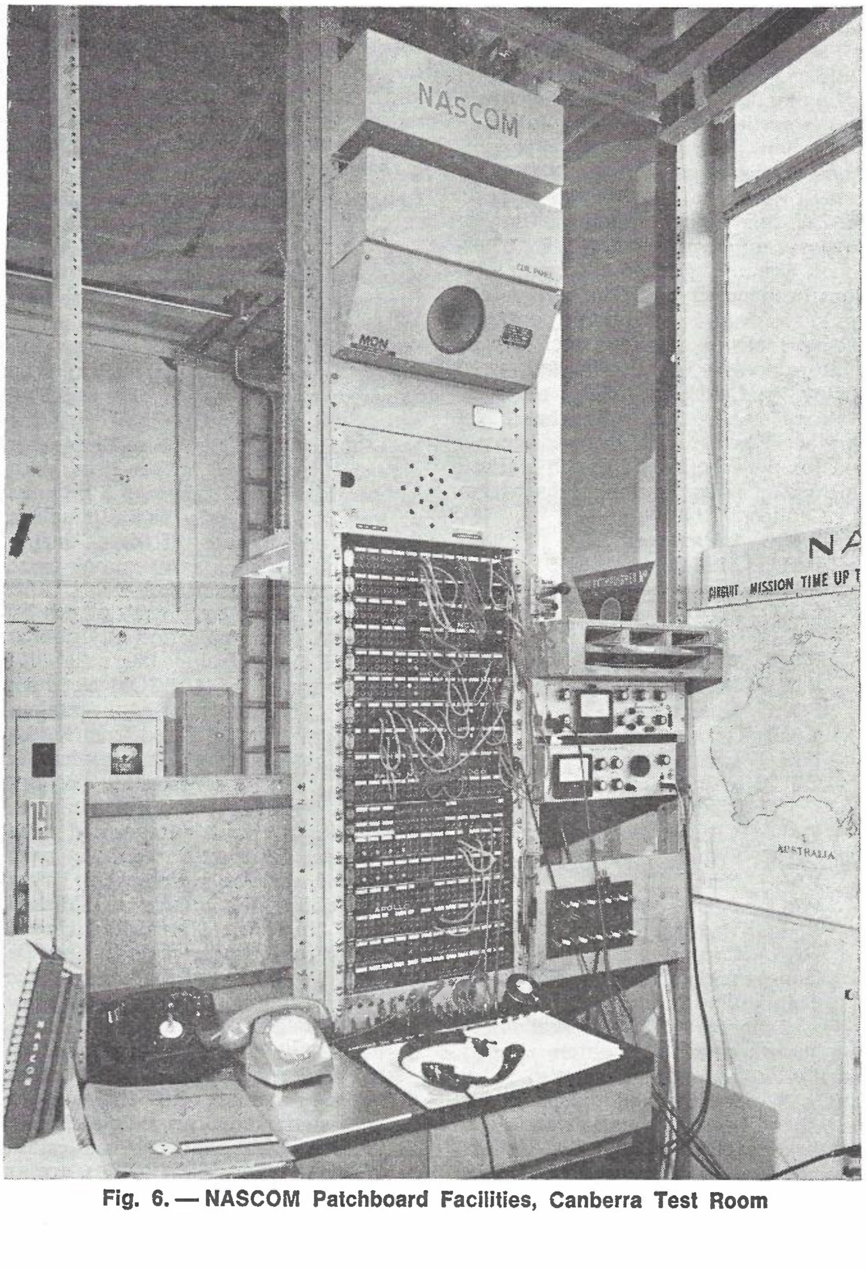

Fig. 6. — NASCOM Patchboard Facilities, Canberra Test Room

in the management of the network, the Adelaide TTR has been assigned as a circuit section control for all sections of circuits and groups West and North of Adelaide. The Canberra TTR has facilities for the patching of NASCOM circuits, has access to order wires to important stations, is equipped with automatic patch relay sets for VF Telegraph systems and has available sufficient test equipment to adequately supervise the quality of circuits provided by the P.M.G.'s Department for the NASCOM network. A view of the patching facilities on the trunk test boards at the Canberra TTR is shown in Fig. 6.

Associated with the Canberra TTR is the CTO Canberra, which controls the telegraph circuits in the NASCOM network and which has similar patching facilities for the restoration of telegraph circuits in the network.

The NASCOM patchboards at the Canberra TTR are continuously staffed during an Apollo mission to effectively supervise the network and a full-time Australian Fault Order Wire is provided at the request of the NASA authorities prior to the Simulation Tests and during actual missions for the purposes of facilitating fault clearances, repair work and keeping stations, concerned with the NASA circuits, informed of circuit outages, progress of the mission, etc. The fault order wire is called up and tested out by the Canberra TTR as required. Stations on the Australian Fault Net vary according to mission requirements and for the Apollo 11 Mission stations on the Australian Fault Net apart from the Canberra TTR were:—

P.M.G. Carnarvon.
P.M.G. Mullewa.
P.M.G. Perth.
C.T.O. Perth.
O.T.C. Bassendean.
P.M.G. Adelaide.
P.M.G. Melbourne.
P.M.G. Deakin
NASA Deakin.
P.M.G. City North (Sydney).
C.T.O. Sydney.
C.T.O. Canberra.
P.M.G. City South (Sydney).
O.T.C. Sydney.
P.M.G. Red Hill.
P.M.G. Parkes
P.M.G. Redfern.
NASA Carnarvon.
Honeysuckle Creek Tracking Stn.
Tidbinbilla Tracking Station.

The Canberra TTR has available a number of nominated patch circuits, usually on an alternate route, to all major NASA sites and the patch circuits have been attenuation and delay equalised to meet C.C.I.T.T. Specification M89 over patching sections so that prompt restoration of service can be provided during missions. To assist the Canberra TTR staff and other staffs working on systems carrying NASCOM circuits and to outline measures considered necessary to ensure reliable operation of the NASCOM circuits, particularly during missions, a set of operating instructions has been prepared by the P.M.G.'s Department in conjunction with the Department of Supply, detailing the precautions which should be taken and the patching procedures to be followed during nominated 'Special' and 'Critical' periods. The test equipment in use at the Canberra TTR for NASCOM circuits includes a test oscillator AWA, type G.250, a transmission measuring set AWA type A.215, and a W. and G. type LD-2 Sweep Group Delay Measuring Set is available as required. This measuring set consists of a LDS-2 send unit and a LDE-2 receive unit working in the range 0.2 to 600 kHz for the measurement of group delay and attenuation variations. The output of the measuring set is read on an inbuilt meter or can be fed into a recorder, etc.

Reliability and System Performance.

As a high degree of reliability is required of the NASCOM Network, alternate routing, inbuilt flexibility in the Network, etc., are provided as part of the complex system for establishing and maintaining communications contact with the Apollo spacecraft and the astronauts on the moon. The M.S.F.N. reliability requirements are for the NASCOM circuits to be available for almost 100 per cent. of the time, with a desirable restoral time of 5 minutes or less during a mission, although a loss of one minute of data during critical phases such as at launch or at re-entry could be serious.

A report is prepared each month by the NASA Communication Division at the G.S.F.C. analysing the reliability performance of the NASCOM Network circuits. This analysis is undertaken from information obtained from NASA Circuit Logs and Daily Communication Reports. In the monthly report, which is issued for world distribution, summaries of circuit outages and reliabilities are presented together with details of circuits which were below the reliability objectives established for the NASCOM Network during a month or for a longer period. Specific outages which contributed to the decrease of individual circuit reliability are described with respect to cause, duration and date of outage and the paths affected. The present reliability requirements for the various transmission media providing circuits in the NASCOM Network, as established by the NASA authorities, are as follows:—

(a) Communications Satellite, 99.8 per cent.
(b) Microwave Radio and Landlines, 99.5 per cent.
(c) Submarine cables, 98 per cent.
(d) High-frequency Radio, 95 per cent.

As referred to in the article by K. E. McKenzie (Ref. 1), a high order of reliability has been achieved in the Australian Sector of the NASCOM Network. Detailed analysis from the NASCOM reports indicates that a circuit/mile reliability of 99.825 per cent. with a Standard Deviation of 0.08 per cent. has been achieved on the average for circuits when scheduled for operation.

The NASA performance objective for the transmission of data at a speed of 2400 bits per second over the NASCOM Network is an overall bit error rate of one in 100,000 bits. This level of performance is generally being achieved on long circuits and it is not unusual to obtain a performance of 1 error in 10^8 bits on data circuits between the NASA Switching Centre at Canberra and the three tracking stations in the Canberra area. To achieve this circuit performance over various combinations of transmission media, suitable on-line quality monitoring devices, reliable yet practical circuit testing and evaluation techniques are used throughout the Network and many of the special monitoring and testing devices employed at the NASA Switching Centre at Canberra are described later. In addition, by the use of diverse operational routes (coaxial cable and radio) and by adhering to special precautions as outlined in the NASCOM operating instruction, the desired high degree of reliability has been achieved in the Australian Sector of the Network during manned Apollo missions.

Test and Monitoring Equipment.

The overall performance of the overall data transmission facilities is checked by a number of on-line monitoring devices provided at NASA Switching Centres and tracking stations, together with circuit test equipment for the detailed evaluation of each data transmission link forming part of the NASCOM Network. The most effective monitoring device used by the Canberra Switching Centre for monitoring the performance of actual data being transmitted is the Model 547 Error Detection Monitoring Decoder, which provides means for monitoring the high-speed data between Canberra and remote locations in Australia or overseas. Before transmission of the data, an error detecting pattern is affixed to the data by on site computers. This pattern together with the data is examined at its destination and each regeneration point by a decoder which determines the degree of accuracy of the pattern and either accepts or rejects the transmission. The decoder accepts data at any bit speed from 600 b.p.s. to 10,000 b.p.s., but it must be in a 240, 600 or 1200 bit block format. The data for tracking purposes is in 240 bit block format and the first group of bits, 6 in this case, in each block forms the 'Sync' word, and this is followed by the data, which, in turn, is followed by a Polynomial Error Code word of 33 bits to complete the 240 bit block. 600 bit blocks are used for telemetry data on the Mariner Mars Missions and are monitored in a similar manner. This monitoring equipment is used continuously and can be connected to a Print-Punch Recorder for recording details of errors.

Another on-line monitoring device used is the Data Quality Monitor (Stelma Model DQM-1). This is a programmable high-speed data quality monitor which is used for the measurement of total errors and error rates of known format patterns within a stream of digital data. Pre-programmed bit patterns or parity bits are searched out, checked and treated as a representative portion of the overall data. Deviations from the expected bit or word pattern are displayed as an indication of data quality. The D.Q.M. can also be used as a pseudo-random pattern generator for evaluating a data-transmission system. It has internal self-checking features which provide indications of the operational status of the monitor.

Test equipment at the NASA Centre for detailed evaluation of the data transmission circuits, provided by the department as part of the NASCOM Network, include the Frederick Electronics Model 600 Data Transmission Test Set for error rate tests, the Acton Transmisson and Delay Measuring Set Models 451A and 452A for line amplitude response and phase delay measurements as well as noise counters, noise and distortion test sets, etc. The Model 600 Data Set can generate a 2047 bit pseudo random pattern at any bit rate from 10 b.p.s. and this pattern is transmitted over the data circuit and compared with an identical pattern generated at the receiving end by another Model 600 Data Set. Errors in the bit pattern are displayed on a counter and are fed into print punch recorders providing a page copy and a five level punched paper tape for record purposes and for detailed computer analysis at the G.S.F.C. The allowable error rate for bit errors is one bit in 100,000. A second method of recording errors is to measure data 'through-put' in terms of a percentage of good to corrupted data blocks. This system uses a programmable block error counter (P.B.E.C.), capable of detecting a single error in a pseudo-random pattern having a fixed block length of up to 4096 bits. A standard block length of 600 bits is used by NASCOM with a required 'through-put' of 99.8 per cent. Using a print punch recorder in association with the P.B.E.C. and the Model 600 Data Set, it is possible to provide fairly comprehensive information on the make-up of the errors (burst or single) and the probable impact on the operational data.

The Acton Transmission and Delay Measuring Set is used to measure, in the range 200 Hz to 12 kHz, the circuit parameters of amplitude response and envelope delay characteristics, of the circuit under test. The test set consists of a transmitter and receiver as separate units and each contains tuning forks to keep the local and remote modulating oscillators from drifting. The test results are displayed on meters although the results are usually plotted on an X-Y recorder (Hewlett-Packard Model 7035AR).

Maintenance Testing.

A series of monthly tests is carried out on all permanent circuits throughout the NASCOM Network, and, for circuits in the Australian Sector, these tests are controlled by the NASA Switching Centre in Canberra. The more important and the temporary circuits called up for individual missions would also be tested prior to a mission as required. The purpose of the tests is to ensure that all circuits are working within the requirements of the C.C.I.T.T. Specifications for data transmission and to refer to the P.M.G.'s Department for attention those circuits where the test figures show a significant deterioration of performance. The circuit tests carried out include loss and variation of loss, circuit noise, harmonic distortion, envelope delay distortion, frequency response, frequency shift and impulse noise. Equipment will shortly be available at the Centre to measure, directly, phase stability or jitter.

A test programme of 24-hour data checks on voice-data circuits is also carried out so that each permanent circuit is tested once every two months to determine the standards of performance being obtained for the transmission of high-speed data.

ACKNOWLEDGMENTS.

It is desired to acknowledge the assistance given by the staff of the NASA Switching Centre, Canberra, in particular Mr. K. Westbrook, and the Department of Supply Public Relations Office for permission to use photographs of the Centre. Permission to use material from various NASA publications is also acknowledged with thanks.

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TRANSMISSION LINES AND MEASUREMENTS — PART 2: CABLE

*K. M. RAY, M.E.**

PAIRED CABLES.

Paired cable is the most extensively used form of transmission line in telecommunications and finds application for subscribers' distribution cables, metropolitan junction circuits, minor trunk V.F. and carrier bearers as well as bearers for major trunk routes. In New South Wales alone we expect to install approximately 444,000 pair miles of cable during 1969/70. In considering paired cables two separate groups or types of application may be formed. These are:

(i) Local type voice frequency cables (usually large number of pairs);

(ii) Carrier type cables.

Local Type Cable.

Local type cable is that cable which is used for the distribution of subscribers' services from exchanges to the subscribers' premises and to provide the junction type circuits between exchanges. Cable has been manufactured in Australia since 1923 and quad layer type construction was selected by the Department for its cable design. Earlier cables consisted of pairs of paper insulated wires twisted together with varying pitch, laid in layers and contained in a thick lead sheath. In those applications where phantoms were commonly used, a second type of cable was developed in which the twin pairs were twisted together in groups of two before being layered. This cable was called multiple twin. The disadvantage of this type of cable was its bulky size for the number of pairs provided i.e. it required more duct space per pair. The quad type construction was developed to overcome this size disadvantage and consists of a basic unit of four wires set in the corners of a square. These wires are twisted and the twisted quads are laid in layers around a central core. Adjacent quads have different twist lengths and adjacent layers spiral in opposite directions. Crosstalk within a quad is rather high and it is necessary to reduce this by balancing condensers when the cable is used for voice frequency operation. Crosstalk between quads is generally satisfactory due to the use of different twist lengths for adjacent quads and the screening effect for other quads.

The demand for larger capacity cables and lower costs led to the introduction of 4 lb. conductors made up of unit twin construction. After transmission limits were extended, greater use was made of this light gauge cable and the maximum size is now 2700 pairs. Up to recently the unit twin cable was restricted to subscribers' cables.

In the junction network quad type cable has been used in a balanced and loaded form. The loading reduces the attenuation of the pair, while the balancing reduces the crosstalk between the pairs of a quad. The standard applied to balancing was an unbalance between pairs in a quad to be less than 350 pf. This ensured that the resulting crosstalk between reasonably long circuits was better than 60 dB at 1.6 kHz. Balancing was achieved by measuring the unbalance between pairs in a quad over a 6000 ft. loading section and switching in reversals in the legs of two pairs at three intermediate joints (at the 1500, 3000 and 4500 ft. points) until a combination was obtained which produced an acceptable unbalance. For those cases where the 350 pf limit could not be bettered a condenser was installed to cancel out most of the residual unbalance. While this technique was effective, it proved to be rather costly and it involved considerable manhours to balance a cable to these limits. Recently there has been greater use made of voice frequency amplifiers, both two wire negative impedance and the 4-wire type, and this has the effect of requiring a higher standard of crosstalk in these local type cables due to level differences being introduced. Calculations made on average cable losses, gains and locations of amplifiers resulted in the old standard of 350 pf being reduced to 150 pf (for 10 lb. cable) corresponding to a new crosstalk standard of 67 dB.

A unit twin cable has been designed as a means of meeting the higher crosstalk required and at the same time does not need the balancing effort necessary in the quad type cable. In addition the cost of this twin type cable is less than that of the quad. These savings are significantly greater than the duct penalty costs which result from the 10 per cent. increase in diameter of twin cable compared with quad.

At the design stages it was considered that the unit twin cable should provide adequate crosstalk characteristic for junction and subscribers' circuits in a load passive condition. With random jointing, an additional crosstalk gain of 6 dB was expected, particularly with the heavier conductor gauges. Controlled field tests have been performed in N.S.W. on four different cables totalling 3600 pairs in all. In these tests adjacent pair crosstalk was measured for all pairs in each cable and comprehensive crosstalk for the first 30 pairs in each unit of 100 pairs. In the test cables some units were straight jointed, while the remaining were "random" jointed. For each cable, for each method of jointing, the mean and standard deviation was obtained for adjacent pair and comprehensive crosstalk.

The rotation jointed units produced a mean adjacent pair near end crosstalk of 81 dB and comprehensive crosstalk of 89 dB. The random jointed units gave values of 86 dB and 91.5 dB respectively. It can be seen that the random adjacent pair crosstalk showed a 5 dB improvement. The overall result, though, showed that with random jointing the number of adjacent pairs having crosstalk in the 60-65 dB range was 0.1 per cent. compared to 0.5 per cent. in rotation jointed units.

From this study it was concluded that with loaded random jointed unit twin junction cables 99.7 per cent. of the pairs will have crosstalk ratios better than 70 dB, which will satisfy the requirements of the junction network. One drawback of random jointing is that it increases the cost of identification as the pairs can no longer be located by position and electrical techniques must be used. Random jointing will be restricted to the junction and main subscriber cables. The worst case will be that of a major fault, necessitating the replacement of a length of cable. However, the introduction of gassing all major cables, both junction and subscribers', has reduced the incidence of cable faults. The plastic insulated distribution cables already of unit construction with fully colour-coded pairs, will continue to be jointed in colour sequence to facilitate identification.

In the factory, the manufacture of unit type large size cable is simpler than an equivalent size layer type cable. The production cost can be reduced further in unit twin cables by the introduction of bunched construction in the units rather than layer construction with whippings as is at present the case. With bunched units the pairs occupy an approximate position rather than a precise location, as is found in layer cables.

Thus the adoption of random joint-

*Mr. Ray is Engineer Class 3, Mechanisation of Planning Processes, N.S.W. See Vol. 20, No. 2, P. 182.

ing therefore improves the crosstalk characteristics of the cable and also permits a reduction in manufacturing costs.

Junction Carrier Systems.

The above has been the major development in local type cable of recent years. The question now being looked at in this area is the application of carrier systems in the junction network both frequency division multiplex (FDM) and pulse code modulation (PCM) types. FDM systems have been used for many years in the Sydney junction network mainly 6, 8, and 12 channel systems operating up to 108 kHz. The installation of these systems required much testing and balancing of the pairs used for bearers. The systems were used for the longer circuits, e.g., City to Avalon, Liverpool and Miranda, and the number of pairs suitable for use in a cable was restricted by crosstalk limitations over the relatively long repeater sections between exchanges.

Current FDM systems being installed, e.g., the Lenkhurt 81A-24 channel system, use all solid state components and have manhole repeaters every 6000 ft. The use of these systems greatly simplifies the allocation of pairs for this operation compared with the longer high level repeater sections of earlier systems.

The alternative to this type of system is the PCM system and N.S.W. is currently carrying out field trials of a new Phillips system involving seven 24 channel systems between Newtown and Miranda.

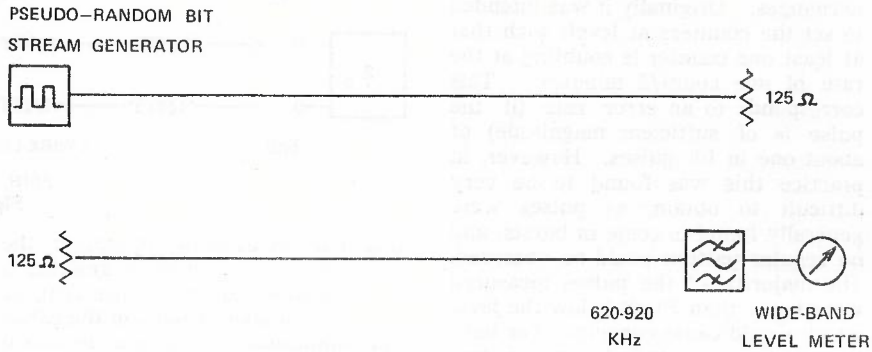

Fig. 14. — P.C.M. Method of Crosstalk Measurement

For this initial field trial a special series of measurements was designed to evaluate cable and system performance. It is hoped that future installations will be made with a minimum of transmission measurements on the cable. The 20 lb. cable pairs have been selected such that one pair from seven adjacent quads are used for one direction of transmission and one pair from seven adjacent quads, separated by a layer from the first group, are used for the return pairs. The measurements required are:

(a) *D.C. Loop resistance* and resistance unbalance;
(b) *Insulation resistance* between pairs and pairs to earth;
(c) *Insertion loss* at 768 kHz between 125 ohm terminations. These measurements are necessary for the fitting of the suitable line-build-out networks associated with the regenerative repeater. These networks are added to each section so that the input to the preamplifier is constant (all repeater sections 28 dB loss), resulting in simplified repeater design. For a 24-channel PCM system the fundamental repetition frequency is 1.536 MHz. The pulses are converted to a bipolar stream which effectively halves the fundamental frequency to 768 kHz.
(d) *Crosstalk Measurement by PCM Method.* For these measurements a pseudo-random bi-polar bit stream generator is used. This produces a bit stream whose power density is very similar to that of the actual PCM pulses. The crosstalk attenuation is measured with a wide band level-meter through a band-pass filter. The band-pass filter covers a bandwidth of 620 kHz to 920 kHz, in which most of the energy of the bit stream is located. Figs. 13 and 14 illustrate this.
(e) *Crosstalk* at 768 kHz (sine wave), all pairs, and
(f) *Crosstalk versus frequency* from 50 kHz to 1.6 MHz on selected pairs.
(g) *Impulse noise measurements.* PCM systems are very tolerant to circuit idle noise and noise due to crosstalk because only the presence or absence of a pulse is of significance. However, impulse noise due to exchange switches can give rise to spurious pulses, causing errors in the received stream. The sections entering or leaving an exchange are most critical in this regard.

Impulse noise is measured for the sections adjacent to an exchange by an impulse noise counter, which, on a particular threshold setting, will count the number of pulses which occur above the threshold level in a preset period of time. In the N.E.C. counter used for the New South Wales tests there are three counters which are set at different levels. Impulses whose amplitudes lie between the first and second threshold levels will be recorded by the first counter, between the second and third threshold levels will be recorded by the second counter, and those above the third threshold level will be recorded by the third counter.

For this test, measurements were made at the sections adjacent to Miranda, Blakehurst and Newtown

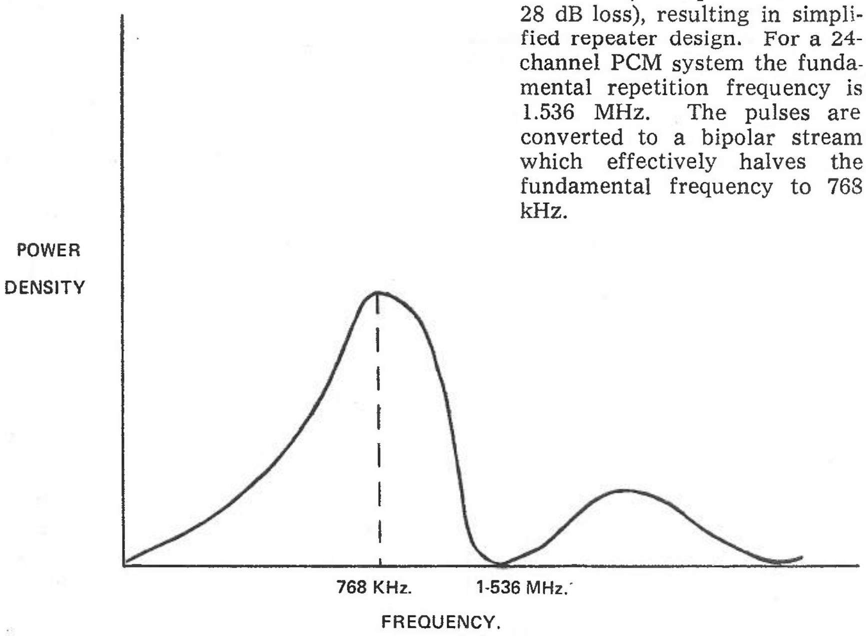

Fig. 13. — Spectrum of P.C.M. Line Signal

exchanges. Originally it was intended to set the counters at levels such that at least one counter is counting at the rate of one count/2 minutes. This corresponds to an error rate (if the pulse is of sufficient magnitude) of about one in 10^6 pulses. However, in practice this was found to be very difficult to obtain, as pulses were generally found to come in bursts, and no regular pattern could be observed. The majority of the pulses measured were lower than 20 dB below the level which would cause concern. For half-hour measuring periods one or two pulses were detected within 3 dB of the threshold range of the system.

The results of the crosstalk measurements indicate that satisfactory operation in this regard should result. In order to prevent interference between the go and return signals it is necessary that the minimum signal to noise ratio (signal attenuated by the section loss versus the noise induced via near-end crosstalk (NEXT) from the opposite direction) be about 12 dB, of which 6dB represents the minimum threshold level and 6 dB the necessary margin. For this trial the NEXT between "go" and "return" pairs was not less than 67 dB. Assuming this to be constant, and the repeater section loss is set at 28 dB the number of systems allowable may be calculated on the basis that the systems interference add on a voltage basis.

Thus we have:

$67 \text{ dB} > 28 + 12 + \log N$

This gives a value of 22 for the number of systems permissible.

Considering the far end crosstalk (FEXT) between pairs in the same direction, here the average value was about 52 dB. In this case there is no level difference to apply and thus the relation is:

$$52 > 12 + 20 \log N.$$
$$N < 100.$$

Thus it can be seen that the number of systems will be controlled by NEXT between go and return pairs; however, one layer of pairs should provide sufficient screening to allow sufficient systems to operate to more than double the circuit capacity of the cable.

Overseas operations have shown (Ref. 4) that:—

(i) On the majority of existing cables no preliminary measurements are strictly needed prior to the installation of PCM systems (the only parameter to be determined is the repeater spacing).

(ii) For single cable operation it can be safely assumed that between 10 and 15 per cent. of the existing pairs can be loaded with PCM systems.

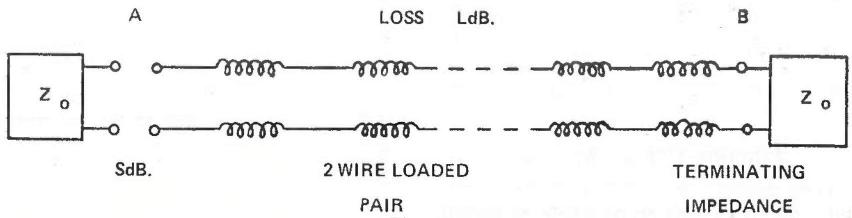

Fig. 15.

(iii) For twin cable operation the maximum number of systems is between 20 and 30 per cent. of the number of pairs in the cable.

(iv) Additional systems may be added if detailed measurements and analyses are made.

Minor Trunk Cables.

The term minor trunk cable refers to those cables providing circuits between terminal exchanges and their immediate parent switching centres. It also includes the direct links between terminal exchanges. Minor trunk cables provide those circuits which at various times have been called 'country junctions' and 'trunk junctions.'

These cables are invariably less than 100 pairs in size and are frequently of the order of 20-50 pairs. They are provided on the basis of loaded voice frequency operation, and because of the distances involved (5 to 25 miles) amplifiers either 2-wire or 4-wire are often required. In addition to the VF circuits some pairs are left unloaded for future carrier system operation. For these cables there are several features which require special attention. they are:

(i) Loading design (controlling structural return loss);

(ii) Balancing limits (controlling crosstalk);

(iii) Carrier system pair allocation.

Loading Design. The loading design is based on a mid-secton 88 mH—6000 ft. scheme. This is done firstly to achieve a substantial reduction in insertion loss of the cable pairs and secondly to produce an equalisation effect over the VF range 300-3400 Hz. In recent years additional constraints have been placed on the characteristics of these long loaded cables. It has been necessary to revise the tolerances allowable in the layout of the loading sections of the cables. These constraints are imposed on the network from several considerations, the most important being the greater use of negative impedance amplifiers and the requirements of echo and stability return losses.

The N.I.R.'s are used on the longer cables which may have a loss of up to approximately 12-13 dB. Frequently, however, the N.I.R's must be used in a terminal mode (with the N.I.R. at one end of the circuit), as these cables may not pass through any intermediate exchange. This requires a high degree of matching between the cable and N.I.R. impedances. Echo and stability return losses standards have been set for the network and their importance is being recognised with the increasing use of long distance connections.

The characteristics of these loaded cables, which are of significance in this context, are 'structural return loss.' This effect is shown in Fig. 15.

A signal from A will be attenuated by the line as it travels to B. At B there will be a reflection due to the mismatch between the terminating impedance and the characteristic impedance of the cable pair. There are other reflections which arise from the irregularities in the loaded cable pair due to the variations in the spacing and inductance of the loading coils, in the capitance of the cable conductors and (to a lesser extent) in conductor resistance. The sum of these effects may be expressed as a return loss, S dB, as measured at A with respect to the nominal impedance Zo of an ideally loaded line. Hence structural return loss may be defined as the degree of uniformity of impedance throughout the cable and a measure of the degree to which this impedance matches the nominal impedance of an ideally loaded line.

The effect of the irregularities of impedance which cause signals to be reflected back to their source is:

(i) To directly reduce the gain which may be inserted by N.I.R.'s for a given stability margin.

(ii) To worsen the echo return loss and stability return loss measured at the 4-wire points if this circuit is switched through to a carrier or VF amplified channel.

The standard required for structural return loss is 23 dB minimum over the VF frequency range. To achieve this value a high degree of uniformity is required in the layout of the loading sections. A computer programme (Ref. 5) is available which analyses any given loading design and calculates the structural return losses. It has been found that if a 2 per cent. maximum deviation is allowed, i.e., 6000 ± 120 ft. for all sections and 3000 ± 60 ft. for terminal half sections, the resulting S.R.L. will always be satisfactory. This compares to the former standard of 5 per cent. deviations, i.e. 6000 ft. ± 300 ft. and if the end half section is at a terminal exchange this half section may be any length less that 4000 ft. However, it has also been determined that under certain conditions larger tolerances than the 2 per cent. may be allowed. The final result will be determined by such factors as size and location of the deviations, the adjacent section lengths, phase and propagation relationships between deviations, location of building out condensers, overall length and insertion loss of the cable.

The complex nature of the relationships between the above factors and their effects on the structural return loss makes it difficult to formulate simply to what extent the 2 per cent. tolerance may be exceeded and still produce an acceptable design. In these cable installations exchanges may not be conveniently located, restrictions imposed by rivers, creeks, roads, break-off points, existing manhole locations, available drum lengths, existing cables, etc., all tend to make it desirable to exceed the 2 per cent. limit specified. Where this cannot be avoided it is best to locate the irregularities away from the end sections. The terminating half sections and the next two or three full sections have the greatest effect on the structural return loss. If possible, these should be set out first as near to the ideal lengths as possible. When a design does not meet the 2 per cent. loading tolerance the details are punched on cards and the design is checked by the computer. Thus any unsatisfactory designs can be corrected early or what is most common the most convenient (and usually cheapest) suitable design is installed.

Control of Crosstalk.—Minor trunk cables still use the quad type cable and to date unit twin has not been used in this area, but this is at present under review. Balancing is therefore still required and the standard is controlled by the use of amplifiers in these cables. In dealing with the metropolitan type cable a new balancing standard (150 pf) was found necessary due to the introduction of V.F. amplifiers. However, in the country, conditions are such that cables are usually longer and there is often no intermediate exchange where amplifiers may be placed. Generally then, larger passive losses exist and larger level differences are created when amplified circuits are used. This necessitates a higher standard for balancing and accordingly 100 pf for full sections has been used in N.S.W. This ensures that within quad crosstalk should be better than 72 dB. It is not practicable to raise this standard much higher because the between quad crosstalk becomes controlling. Measurements made on between-quad-crosstalk indicate, for these local type cables, a mean of about 80 dB with a standard deviation of 7 dB. The 100 pf within quad unbalance decreases this type of crosstalk to approximately the same standard as that between quad crosstalk.

If better values are required it is necessary to introduce systematic (or cross-quadding) jointing and even lower values of balancing. This has been done on several country cables (Maitland-Cessnock, Campbelltown-Camden); however, the increase in cost and complexity of jointing cannot be justified for the small improvement obtained. Additional problems arise in subsequent pair identification, particularly if carrier systems are required to be installed at a later date.

Application of Carrier System in Minor Trunk Cables. — In planning these minor trunk cables an allowance is made for future carrier operation generally on the basis of doubling the voice frequency capacity of the cable by the use of 12-channel (108 kHz bandwidth) systems. Thus for 20-30 pair cable, 2 x 12-channel systems are provided for, 30-50 pair cable 3 x 12-channel systems and so on. These pairs are selected (and left unloaded) such that the pairs have a maximum separation and have a different length of twist. The inductive coupling is reduced by increasing the physical separation and introducing relative lengths of twist while the capacative coupling is reduced by the shielding effect of the intermediate quads.

Figs. 16 and 17 indicate the pairs

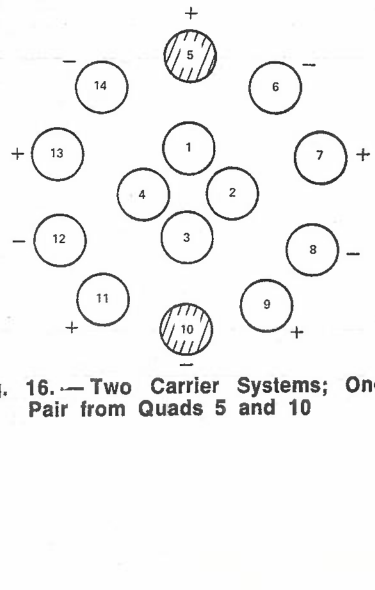

Fig. 16. — Two Carrier Systems; One Pair from Quads 5 and 10

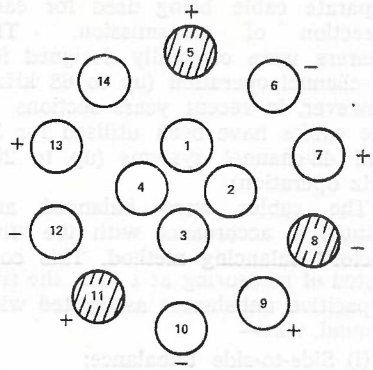

Fig. 17. — Three Carrier Systems; One Pair from Quads 3, 8 and 11

which would be selected for carrier operation for a 28-pair cable.

Results of this type of carrier pair selection have indicated that satisfactory crosstalk can be expected over repeater sections of approximately 8000 yds. for 20 lb. cable without any carrier balancing.

In addition to this application of 12-channel systems, measurements have been made on a number of minor trunk cables to investigate the possibility of using larger capacity systems. These measurements were made on 6000 ft. sections over a frequency band-width from 100 kHz up to 1.5 MHz. The results of these measurements indicate that it should be possible to operate several larger capacity systems in these smaller cables, e.g., in a 20-pair cable it should be possible to carry 2 x 60 (550 kHz) systems and possibly 3 over 6000 ft. repeater sections with a 65 dB FEXT. With 24-channel PCM systems where a lower value of crosstalk is permissible it should be possible to operate 4 or 5 systems. Thus it can be seen that future high frequency systems operating over shortened repeater spacing will enable the channel capacity of these small size cables to be increased significantly. Whether these systems can be applied economically over these short distances (say 5 to 15 miles) will depend on the extent of future cost reductions of the system components. There seems to be little doubt that these reductions will occur and a wider bandwidth than the 110 kHz presently used in the 12-channel cable systems will be utilised.

Paired Carrier Cables.

Multi-pair Carrier Cables.—The first major carrier cables laid in N.S.W. were the Sydney-Maitland and the Sydney-Orange cables (Refs. 6 and 7). Laying of the Sydney-Maitland cable was commenced early 1940 and the system was commissioned in 1943. These cable systems consist of two carrier type 24 pairs 40 lb. cables, a separate cable being used for each direction of transmission. The bearers were originally designed for 17-channel operation (up to 68 kHz); however, in recent years sections of the cables have been utilised for 34 and 48-channel systems (up to 204 kHz operation).

The cables were balanced and jointed in accordance with the "five factor" balancing method. This consisted of measuring at 1 kHz, the five capacitive unbalances associated with a quad, viz.:—

(i) Side-to-side unbalance;
(ii) Phantom to Side 1 unbalance;
(iii) Phantom to Side 2 unbalance;
(iv) Side 1 to Earth unbalance;
(v) Side 2 to Earth unbalance;

and preparing a jointing schedule to reduce these five unbalances to within specified limits for each quad. In addition, systematic joints were inserted at regular intervals to reduce between quad crosstalk. Finally balancing frames were installed at each repeater station to correct for any remaining poor crosstalk combinations over the repeater sections. The result was a cable system which produced acceptable crosstalk figures for all pairs but which involved a most complex set of jointing records and one which required careful checking each time a cable deviation was made. The carrier systems originally installed on these cables were valve type equipment employing high level repeaters. Present day carrier cables employ solid state systems having power fed manhole repeaters. As described previously, the 12-channel 108 kHz system is most common, having a repeater spacing of approximately 8000 yards.

The first new-type carrier cables were laid specifically to carry these 12-channel systems on all pairs (excepting gas alarm pair). In addition to the original 24-pair carrier type cable a new 14-pair type was produced. It consists of a core quad surrounded by 6 layer quads—each quad having a different twist length.

In 1966 when these newer carrier cables were beginning to be installed it was felt that a more efficient method of balancing the cable would be required to overcome the problems of the five factor method. As a result tests were made on several installations and a method was devised which would—

(i) reduce field work;
(ii) do without the need for balancing frames.
(iii) provide simple jointing requirements;
(iv) provide straightforward easily referenced records;
(v) enable carrier operation on all pairs.

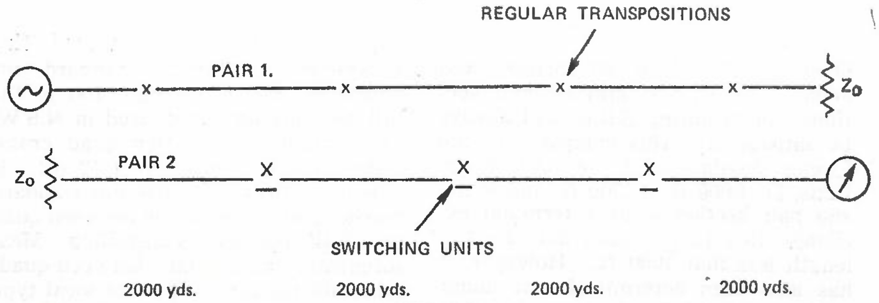

Fig. 18.

The old five factor method required the following sequences of events: field measurements to be made; the readings to be relayed to the divisional office; calculations made to determine joints and prediction of resulting unbalances; jointing order to be relayed back to field; joints made; final unbalances of the two lengths measured; these compared to predicted failures; and so on through the repeater section for each joint.

The new technique consisted firstly of jointing the repeater sections through leaving three intermediate joints open (at the 2000, 4000, 6000 yard points). At all other joints a transposition is inserted in one pair of each quad, while the other pair is straight jointed. The repeater section is then balanced by the use of high frequency switching units at each of the three intermediate locations and measuring the resulting far end crosstalk over the repeater section. The centre quad (pairs 1 and 2) is balanced first (see Fig. 18).

The eight combinations of the switching units are tried and that combination giving the best value of crosstalk is recorded. The pair is jointed accordingly. Check measurements, by interchanging the disturbing and disturbed pairs are made. Then pair 3 is balanced against pair 1 (this is between quad crosstalk) and pair 3 is jointed through. Pair 4 is balanced against pair 3 (within quad crosstalk) and so on through the cable. Any combination which cannot meet the 65 dB standard is checked with an admittance unbalance bridge. This measures, at 110 kHz, the admittance components, the G and C values in micromhos and picofarads, of the coupling between the two pairs concerned (see Fig. 19).

The combination of switches which produces values of G and C most easily balanced by the later jointing of condensers and resistors into the cable is selected. For example an unbalance of +10 micromho, +28 pf would be more easily balanced than say +10 micromho, —20 pf. The same signs may be balanced with one network, opposite signs may require two. When all the pairs are jointed the comprehensive FEXT is measured between all pairs. Any combinations failing to meet the 65 dB standard are balanced by jointing in condensers or, if necessary, condenser/resistor, series/parallel networks. Experience has shown that only three or four condensers per repeater section are necessary and the resistor/condenser network is seldom required.

The method therefore has achieved the desired results, particularly in keeping the cable as simple as possible—pair 1 remains pair 1 throughout, and all pairs are suitable for 12-channel operation. Tests have been made at higher frequencies and it has been found that at least 7 pairs could be used at 300 kHz.

Single Quad Carrier Cable. — This is a recent development in Australia and is simply a cable of one quad designed for high frequency operation. The concept is not new; the old DISQ cable consisted of one quad and was used as a connection between open wire routes and carrier stations for 12-channel systems. The new single quad cable has been designed to operate up to frequencies much higher than the 150 kHz of the disq cable and has been tested up to 1.5 MHz, for 120-channel system operation.

The purpose of this new cable is to provide a bearer system (either single or dual cables) for those routes requiring a medium capacity, in outback or low density areas where the separation between drop-off points is large. The system is therefore seen as being one alternative in the replacement of open wire routes. Solid state buried repeaters are used, being power fed from widely separated points.

The cable has been designed to meet the following requirements:—

(i) Suitable for ploughing. The cable must be light and robust;
(ii) Freedom from pest or insect attack;
(iii) Freedom from lightning damage within the average Australian environment;
(iv) Suitable transmission characteristics to carry 120-channel systems.

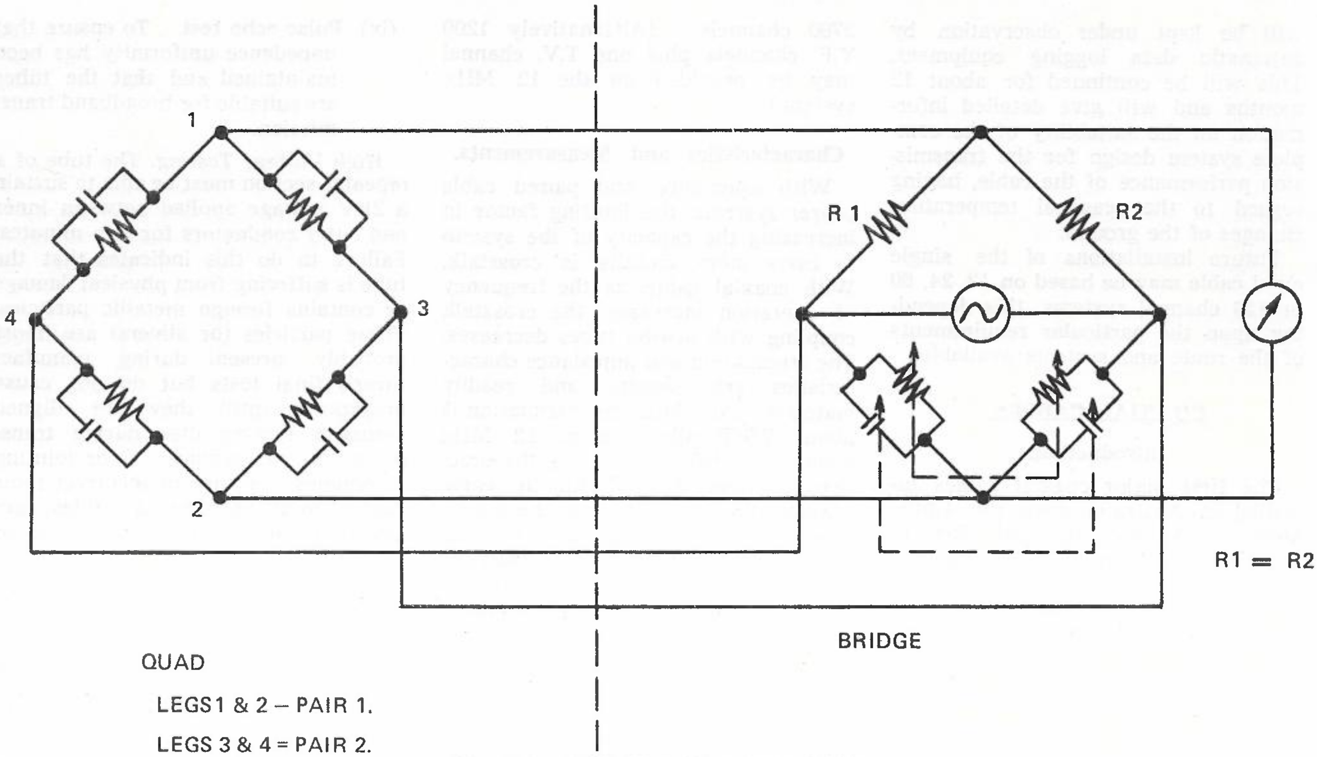

Fig. 19 — Admittance Unbalance Bridge

(v) Sufficient copper to allow power feeding over distances up to 60 miles.

Construction. — The four 40 lb. conductors of the cable are insulated with polythene and quadded around a solid polythene core. The quad is whipped with a coloured tape, wrapped with polythene, terepthalate tape and covered with a robust polythene sheath. A copper tape screen is applied longitudinally over the polythene sheath and the whole covered with a hard nylon jacket. Two types of cable are made, the difference being in the twist length of the quad. These are distinguished by a blue coloured whipping to denote the 'go' type and orange denotes 'return' type cable.

The first trial installation was between Horsham and Natimuk (Victoria) in 1966, which led to a design modification to reduce the unbalances within the quad. The modification was to change the centre string of the quad from a polythene tube to solid polythene. This resulted in the four conductors being held more rigidly in their relative positions, ensuring more accurate positioning of the conductors.

The first installation in N.S.W. was a two-cable system between Parkes and Peak Hill, a route distance of approximately 32 miles. This system was designed to take a 120-channel system on the blue cable and two 12-channel systems on the orange cable.

The cables were laid simultaneously by mole ploughing to a depth of 2 ft. 6 in. The design of the joints for this cable is based on the use of epoxy resin encapsulation technique. The first requirement was to maintain the accurate quad formation of the conductors and at the same time allow for the difference in dielectric constant of the epoxy resin and that of polythene. Special phenoxy spacers were designed to meet the dielectric requirements and to provide accurate spacing between the conductors. The electrical continuity of the copper shield was maintained across the joint by heavy copper wire, which was earthed by a brass bolt connection.

At each joint a transposition was inserted in one pair to reduce the 'spiral' crosstalk effect which becomes apparent at frequencies above 250 kHz (Ref. 8). This was the only crosstalk reduction effort made. No balancing as a result of measurements, or insertion of condensers or resistors was made.

An extensive series of measurements was performed firstly on selected individual drum lengths and finally on the completed 3000 yds. repeater sections, all measurements being made up to 1.5 MHz. The individual drum lengths were tested to compare the results to factory tests on drums to determine whether any significant change takes place during, or after, the installation. The measurements consisted of conductor resistance, resistance unbalance, insertion loss, FEXT, NEXT, insulation resistance. Ground temperature at the depth of the cable was recorded at the same time. The results of the measurements showed the very satisfactory performance of the cable.

A 120-channel system (Marconi manufacture) has now been installed but not placed in traffic. The system is a 4-wire type employing different frequency bands for the two directions of transmission, the A to B direction 312-804 kHz and B to A 924-1,416 kHz. Only selected channels have been installed and white noise generators applied at various inputs. The system

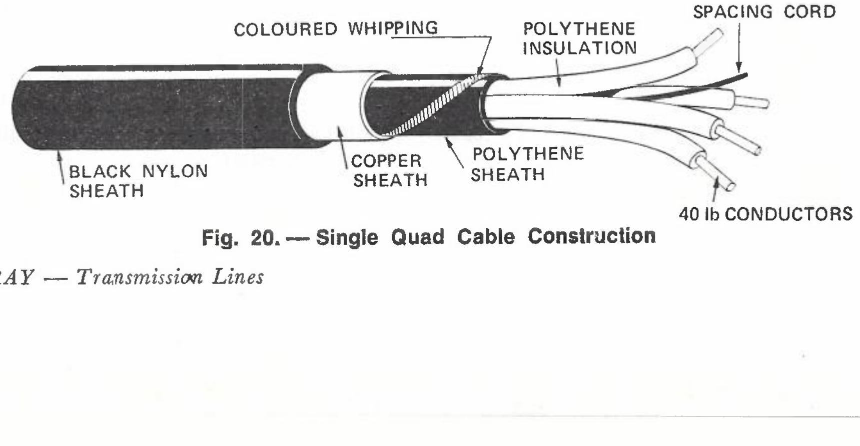

Fig. 20. — Single Quad Cable Construction

will be kept under observation by automatic data logging equipment. This will be continued for about 12 months and will give detailed information on the suitability of the complete system design for the transmission performance of the cable, having regard to the seasonal temperature changes of the ground.

Future installations of the single quad cable may be based on 12, 24, 60 or 120 channel systems, this depending upon the particular requirements of the route and systems available.

COAXIAL CABLES.

Introduction.

The first major coaxial cables installed in Australia were the 4-tube Melbourne-Morwell in 1961 (Ref. 9) and the 6 tube Sydney-Melbourne 1962 (Ref. 10). Since then a large number of cables has been installed and at present the total is approaching 10,000 tube miles. In N.S.W. the major cables which followed the Sydney-Melbourne are Newcastle to Tweed Heads (Newcastle to Taree still being tested), Wollongong to Nowra (to be extended to Bega), Wagga-Narrandera-Griffith and Sydney to Blacktown. Currently the first major two-tube cable is being laid from Orange to Wagga and will be extended to Echuca on the Victorian border. In addition to these major cables a large number of short cables (several miles in length each) have been installed between microwave radio terminals and the associated trunk line equipment stations. Finally a Sydney metropolitan coaxial network is being installed from City to Chatswood, Dee Why and Liverpool; Parramatta and Blacktown, as well as to all T.V. transmitter locations.

All cables installed in Australia have been of the 'standard' coaxial cable (0.375 in. internal tube diameter or the 9.5 mm metric equivalent). Small-diameter coaxial cables of 0.174 in. tube diameter have not been used in Australia. Due to the relatively small market, production costs required for manufacturers to produce both types of cable have retarded the introduction of small diameter cable.

The early coaxial cable systems were valve type 6 MHz, with a repeater spacing of 5.7 miles. The 6 MHz system was adopted because of the need to relay 625 line television signals. Since 1966/67 the cable systems employed 4 MHz or 12 MHz solid state equipment utilising manhole type power fed repeaters. The 4 MHz system provides 960 channels per pair of tubes, while with the 12 MHz system this number is increased to 2700 channels. (Alternatively 1200 V.F. channels plus one T.V. channel may be provided on the 12 MHz system.)

Characteristics and Measurements.

With open-wire and paired cable bearer systems, the limiting factor in increasing the capacity of the system to carry more circuits is crosstalk. With coaxial cable, as the frequency of operation increases, the crosstalk coupling with nearby tubes decreases. The attenuation and impedance characteristics are smooth and readily matched. At 4 MHz the attenuation is about 7.5dB/mile and at 12 MHz about 13.5 dB/mile. It was the practice to measure crosstalk in early coaxial cable installations at the lowest frequency of operation (60 kHz) and was specified to be greater than 90 dB. As the values measured always exceeded this 90 dB standard, there was little point in continuing with the test. Similarly, measurements made during acceptance testing for insertion loss of repeater sections again provided the specified values; these also were discontinued during acceptance testing of the cable.

The characteristic which is critical for satisfactory coaxial cable operation and must be checked and corrected where necessary during installation, is the regularity of impedance. Any change in the dimensions of the tube will alter the impedance, causing a mismatch and hence reflection of signals in the tube.

The transmission tests which are normally made on the new cables may be divided into two groups:

(i) D.C. tests which include conductor resistance, high voltage breakdown and insulation resistance;

(ii) Pulse echo tests which include measurement of the magnitude of impedance irregularities, end impedance and the electrical length of the tubes.

The reasons for these tests are as follows:—

(i) Conductor resistance. To detect open circuits and high resistance joints.

(ii) High voltage. To prove the suitability of the repeater section for high voltage power feeding. (This ensures that there are no dents, creases or foreign particles in the tube and that the centre conductor has not been displaced.

(iii) Insulation resistance. To determine that the insulation quality of the cable lengths has been maintained and that the jointing techniques are satisfactory.

(iv) Pulse echo test. To ensure that impedance uniformity has been maintained and that the tubes are suitable for broadband transmission.

High Voltage Testing. The tube of a repeater section must be able to sustain a 2KV voltage applied between inner and outer conductors for two minutes. Failure to do this indicates that the tube is suffering from physical damage or contains foreign metallic particles. These particles (or slivers) are, most probably, present during manufacturer's final tests but do not cause breakdown until they are aligned across a spacing disc, during transportation or laying. Poor jointing techniques, e.g., use of incorrect tools during joint opening of cables, are also a cause of the production of slivers.

A special bridge is available for the location of these high voltage faults. A d.c. voltage is supplied to a Wheatstone bridge from a high voltage source, incorporating a current limiting device. The voltage is gradually increased, until the faulty tube breaks down. The bridge has a sliver burning circuit, which supplies a high voltage with increased current output from a charged condenser, so that any sliver present may be burnt out. When this cannot be done, the bridge is balanced during the breakdown periods and the distance to the fault is calculated by the Varley (3 wire) method. Careful operation allows faults to be located to about 0.1 per cent. accuracy.

Pulse Echo Testing. The standards set for Pulse Echo Tests are to ensure satisfactory performance for 12 MHz operation. C.C.I.T.T. has set (Ref. 11) this as 'the impedance irregularity and matching limits such that a roll in the frequency - attenuation characteristic not exceeding 0.09 neper (1 dB) at the end of a 2500 km hypothetical reference circuit.' The resulting limits set by the A.P.O. are:

1. Impedance irregularity within drum lengths:—
   (a) All coaxial tubes .... 50 dB
   (b) 95 per cent. of coaxial tubes .... 54 dB
2. Pulse measurement of impedance irregularity over repeater section:
   (a) Single worst corrected 48 dB
   (b) Single worst uncorrected .... 54 dB
   (c) R.M.S. of 3 worst corrected .... 51 dB
3. Impedance mismatch between line and repeater:—
   (a) 4 MHz system
   $f < 300$ kHz 40 dB
   $f > 300$ kHz 48 dB

(b) 12 MHz system
$f > 300$ kHz 48 dB

(c) Far end crosstalk 60 kHz 91 dB

In these impedance tests a series of pulses (normally an 0.1 u sec d.c. pulse) is transmitted down the tube. These are partly reflected at all impedance changes of the tube and the reflected signals are received back at the transmitting point. The time taken for each reflected signal to arrive back at this point is measured together with its magnitude. An uncorrected measurement refers to simply the magnitude of the received reflected signals compared to the transmitted magnitude. Corrected measurements involve taking into account the loss suffered by the pulse in being transmitted to and from the point of reflection. A figure of 48 dB is equivalent to an 0.4 per cent. reflection factor or a mismatch of 0.6 ohms (at 75 ohms).

Impedance irregularity faults may occur due to excessive mismatches at joints (these are controlled at the initial stages by careful allocation of drum lengths), damage during transportation or laying, or to deterioration of previously acceptable irregularities. Damage during laying is the most common cause, particularly when the cable is being laid in difficult country. This may be when the cable is being ploughed into wet, muddy or rocky ground or when there is a changing gradient. Excessive tensions plus sudden movements of the cable plough can cause distortion of the tubes. In some cases in which large reflections have occurred it has been difficult to determine the reason for the fault.

The 4-tube non-layered cable without armouring has proved to be most susceptible to these faults. When layer pairs are around the tubes or wire-armoured cable is used the fault incidence drops by a factor of over 3. This has been found if the cable was installed by the original ditching and back-fill method or by modern rip and plough method.

The accuracy in fault location varies depending upon the nature of the fault. Under good conditions the pulse echo test set will locate faults within 5 to 10 ft. for a 500 yard drum length and within 50 ft. for a repeater section.

To date one of the biggest problems for the field test teams has been the pulse echo test sets themselves going faulty. The instruments are large and heavy, and while adequate for normal long line station use, quickly develop faults when transported over the rough ground alongside the cable track. New solid state units are now becoming available, which should overcome this problem.

Future Uses of Coaxial Cable.

In the United States a coaxial cable system, with a line system designated L4 with capacity of 3600 circuits per pair of tubes, has been developed for very heavy trunk routes. They have found in these areas that the radio frequency spectrum has become saturated. This system has repeaters spaced every two miles and utilises a bandwidth of 16 MHz. A 20 tube cable has been installed giving the route a capacity of over 30,000 circuits.

A fundamental study has been made by the P.M.G. Research Laboratories on the transmission parameters of Australian manufactured coaxial cable at frequencies up to and in excess of 60 MHz (Ref. 12). This study has found that this cable will be quite suitable for line systems utilising a 60 MHz bandwidth provided factory manufacture is controlled to reduce repetitive capacitance effects on impedance. One system design available overseas provides 10,800 voice channels per pair of tubes, repeater spacing one mile, having a mean gain of approximately 29 dB. Whether existing installed cables would be suitable would be determined by programme of measurements on the actual cables.

Another approach has been made in Japan in regard to future uses of coaxial cable. Previous work has been based on the design for maximum attainable gain and a satisfactory distortion coefficient in a given transmission band in order to obtain maximum repeater spacings. This new study is based on the design of a 1-neper repeater-section loss in order to maximise the transmission band. The results show that while 100 MHz is the limit of a conventional coaxial cable FDM system, the new system allows higher transmission frequencies. The limit for this new system is about 1 GHz on a coaxial cable having a 30 mm inner conductor and would provide between 150,000 to 200,000 channels/system.

CONCLUSION.

The basic problem which has confronted the Transmission Planning Engineer is how to economically provide for the ever-increasing demand of additional circuits. On the major trunk routes the answer has been to use broadband microwave radio or coaxial cable systems. However, in many areas where the number of circuits required is not so large, the problem requires considerable investigation to determine the correct solution. The alternatives of upgrading open-wire for additional carrier systems or installing voice frequency cables, combined voice and carrier cable, multi-pair or single quad carrier cable, or coaxial cable must be analysed.

Over the years the trend has been to increase the bandwidth or system capacity of existing bearers. Open-wire routes have been upgraded, retransposed, etc., to allow additional carrier systems to operate. Paired cable performance has been investigated to allow carrier operation up to 1.5 MHz. Coaxial cables have been studied in order to increase their capacity from 960 to 10,800 channels per pair of tubes.

As for the future, while no doubt there will be developments in waveguide transmission, lasers and satellite relays to make these an economical proposition, there will remain a need for transmission bearers as described here. Advances in solid state devices, reduced costs and increased reliability will enable carrier systems either FDM or PCM types to be economically applied over shorter distances. This will place greater demands on the Lines and Transmission Engineer to exploit the transmission bearer to the fullest.

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HISTORY OF SMALL COUNTRY AUTOMATIC EXCHANGES IN VICTORIA

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INTRODUCTION.

It is desirable that progress in certain fields of Australian Post Office activities be recorded for historical purposes and this article is written primarily for that purpose.

The author was employed on the installation of R.A.X. units from 1934, when three were in service, until 1958, when 320 were established. He was also closely associated with the development of the A.P.O. type B, C and D units, which was carried out in 1946. Details of the original three units were obtained by him from staff concerned with their maintenance.

As a Senior Technical Officer for Country Service, the author remains closely associated with R.A.X. problems that arise when these 20-year-old units are required to provide modern facilities such as S.T.D. or to perform satisfactorily over high resistance junctions using integrated or segregated dialling.

The following are the full designations relative to the letters appearing in the text.

- R.A.X. Rural Automatic Exchange: Title for small country automatic exchanges using step-type equipment. Accommodates 40 to 200 subscribers.
- A.R.K. Crossbar Country Exchanges: Accommodates 50 to 2000 subscribers.
- S.C.A.X. Small Country Automatic Exchanges: Could be either of the above types.
- S.T.D. Subscriber Trunk Dialling: Introduced in 1961 to allow subscribers to dial trunk calls.

Manufacturers:

- B G.E. British General Electric.
- S.T.C. Standard Telephones and Cables.
- A.T.M. Automatic Telephone Manufacturers.
- T.E.I. Telephone Electrical Industries.

HISTORICAL DEVELOPMENTS.

Part of the remarkable progress in the telecommunication field that occurred in the decade to 1970 is the impressive advancements in the conversion of small manual exchanges to automatic operation by the installation of S.C.A.X.'s. Fast disappearing are the magneto switchboards located in the family kitchen or in the small country store, with their restricted services. This march of progress is viewed with mixed feelings by the average subscriber. Gone is the personal contact, the receipt of news or the ready means of giving the grocery order. However, experience has shown that in a few weeks this nostalgia is usually replaced by appreciation in recognition of an advanced service. Some benefits are as follows:

- The choice of a colorphone with its improved transmission qualities;
- The reluctance to call the former manual operator at an inconvenient time is removed by the available continuous service;
- The convenience of S.T.D. and the ready availability of trunk lines eliminates the former long delays incurred in connection to another area;
- The passing of the multi-party line with poor transmission and high fault liability has given way to the exclusive service, which is assured of privacy.

With the passing of time, the increased use of the motor car has closed many small country stores and consequently the exchange has to find a new location. This is often difficult, as with the general increase in living standards, few people are prepared to offer regular attendance for telephone facilities. The reluctant acceptor sometimes provides an inferior service so that a change to automatic operation is welcomed. This condition is far removed from the headlines printed in the 'Unofficial Postmasters' newspaper of 1937, entitled 'The Menace of R A.X.'s threatens the employment of Unofficial P.M.'s.'

One particular example of the changed conditions was evident at Quantong. This fruitgrowing district was formerly served by a number of party lines connected to Horsham, each line having up to 10 telephones connected. One wall telephone of each party line was installed around a room in the fruit agent's premises and it was his custom to remove all the handsets at 1 p.m. each day, stand in the centre of the room and shout the fruit prices received at the Melbourne market that particular morning. Thus, growers would lift off and listen at that time. Reception was extremely poor, but most heard the prices and were satisfied or otherwise according to the state of the market. Later, with R.A.X. operation, it was necessary for the grower to dial the agent, but this action was soon superseded by progress in radio communication.

Early Installations.

Let us now return back 45 years and trace the history of the first attempts to convert small country exchanges to automatic working. A district called Barep, situated seven miles from Tongala in the irrigation area of northern Victoria, was the location of the first R.A.X. in 1925. No resident could be persuaded to accept the switchboard and it was decided to build a small automatic exchange by the Workshops. It was a 30-line installation using line finders and Strowger final selectors. Ringing current was provided by a pole changer and ringing occurred only when additional 0's were dialled after the number. Thus, to call subscriber 23, you would dial 23-0-0-0 until they answered, or to get Tongala, 0-0 repeated. Ring tripping of course did not exist. You waited for the ring to cease before lifting off, otherwise you received a ring in the ear. Batteries were charged over special wires from Tongala. The building was placed in an unfortunate location close to the drainage dam of an adjoining cheese factory. This created an invasion of flies, resulting in almost unbearable conditions. The cheese factory manager was paid a fee to change over the batteries daily and plug out any looped lines. As cabling was not enamelled, he kept three kerosene lamps burning continuously to prevent dampness. On one occasion a reliever turned the lamps too high and they smoked excessively. The result was a blackened room with strings of soot hanging from every surface. This took days of cleaning and painting to restore. Nevertheless, this unit gave fair service and was replaced by an A.P.O. R.A.X. in 1950. Most of its maintenance was carried out by the present Supervising Technician at Kyabram, Mr Phil Evans, who supplied this information.

The first imported R.A.X. was installed at Buninyong near Ballarat in 1928. This unit was manufactured by British General Electric of Coventry, U.K. It was equipped for 100 lines and was housed in two large cabinets enclosed by polished veneer wooden frames. Equipment consisted of B.P.O. No. 1 uniselectors as line finders and B G.E. pre-2000 type bimotional selectors. In 1950 it reached subscriber capacity and rather than obtain additional equipment, it was replaced and transferred to nearby Burrumbeet. There it served for another 12 years and was finally scrapped. This unit

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gave reasonably good service and was the forerunner of many other similar units. Its principle of operation followed conventional practice and could be readily maintained by country technicians who, at that time, had had little automatic equipment experience.

The third R.A.X. was installed at Kariah, seven miles north of Camperdown, in 1929. It was manufactured by Siemens Bros., of Woolwich, near London, and was known as the Siemens No. 26. It catered for 50 lines and used the common switching apparatus principle, which is similar to that now being used in crossbar exchanges; markers and registers being somewhat equivalent to the Siemens 'mechanical operators.' The complicated mechanical operator, which contained three uniselectors and 26 relays as one unit, was very difficult for the average country technician to understand as most were inexperienced in automatic telephony at that stage. Detached contacts were used in circuit diagrams of the equipment for the first time. Unfortunately, faults occurring in the common apparatus frequently isolated the whole exchange. As at Barep, the location of the Kariah R.A.X. was not well chosen. It was erected near the bank of a salt lake on a concrete slab with poor drainage. Dampness and a high content of mildew caused havoc with the equipment. Here again the kerosene lamp was necessary, but there is no record of any similar dire result as at Barep when the lamps were burned too high. Battery charging was carried out from a rectifier at Camperdown over special wires. Difficulty was experienced in maintaining the batteries in charged condition. It was later discovered that the switchboard night telephonist at Camperdown turned off the noisy rectifier, which was located in the switchroom, for most of the night. In 1951 it was replaced by a larger unit at a new site far removed from the lake. The original unit was installed and maintained for some years by Mr. Bob Stevenson, now retired. Bob later moved to Melbourne and gained fame as a staff recruiting officer in the difficult post-war era both in England and Australia. He also occupied prominent positions in the Postal Telecommunication Technicians' Association. To Bob, I extend my gratitude for supplying details of the Kariah R.A.X. Advances in basic equipment design and housing for R.A.X. over the past 40 years have been such that very much more reliable service is obtained from equivalent modern crossbar type exchanges.

In 1932 an unusual ten-line Ericsson unit was installed at Research, near Eltham, then regarded as being in the Outer Metropolitan area. Magneto telephones with dials were used. To call out, the generator was turned and this operated a relay which connected battery to the line. Subscribers numbers were from 1 to 9, and 0 was dialled for a trunk outlet. At conclusion of call, a ring-off was necessary to clear down. Failing this action, release was effected on a time delay basis. This unit was later transferred to Pound Creek, near Inverloch, where it served for many years and was then scrapped.

In 1933 a concerted effort was made by Central Office to install more R.A.X.'s. Tenders were accepted from four English companies to A.P.O. specifications and units were designated as follows: — B units; 50 line ultimate; C units, 50-line extensible to 200 lines by the addition of 50-line extensions called D units. Siemens supplied 16 C and D units of types No. 27 and later No. 28 based on the No. 26 installed at Kariah. S.T.C. supplied 10 B units, also based on the common apparatus principle. B.G.E. and A.T.M., Liverpool, supplied 12 C and D units, which were improved versions of the former Buninyong R.A.X. Early installations of this group were as follows:—

- 1934—2 Siemens No. 27 at Tyabb and Somerville;
- 1935—2 A.T.M. units at Thornton and Yallourn;
  2 B.G.E. units at Iona and Bamawm;
- 1936—2 S.T.C. units at Hall's Gap and Tarranlea;
- 1937—2 B.G.E. units at Macedon (Vic.) and Dareton, (N.S.W.)

The author's R.A.X. duties commenced with the Tyabb-Somerville installations and continued until 1958. Completion of the installation of this group of 38 R.A.X.'s was made in 1941, then in the third year of war. Their performance was superior to the initial three, namely Barep, Buninyong, and Kariah, mainly for these reasons:—

(a) Reliability of battery charging: Extension of commercial power enabled rectifiers to float the battery with generally trouble-free service. Locations without

Fig. 1. — Official Opening at Clydebank R.A.X. Near Sale Vic. About 1940.

power were either float charged over a special pair of wires from the nearest power supply or by use of wind-driven generators.

(b) Low insulation troubles in internal cables were eliminated by use of enamel covered conductors and improved buildings.

(c) Introduction of 3000 type relays.

(d) Improved subscriber understanding and manipulation.

Referring in more detail to note (d), in the early days it was most difficult to educate subscribers in remote areas. In most instances, subscribers had not seen an automatic telephone and found it hard to interpret the instructions and manipulate the dial. Following magneto practice, most dialled with the receiver on the hook and of course got no progress. Some elderly ladies were somewhat terrified by the repeated ring and refused to go near the telephone. Others were so gentle in their dialling movements that they failed to pull the dial to the stop and obtained wrong numbers. One bulky gentleman had the impression that to dial you inserted one finger in each number required and pressed simultaneously. This effort to insert three huge fingers together looked extremely awkward and somewhat comical. After much tuition we eventually taught him to dial correctly. One aged lady from Ireland conducted the magneto wall switchboard at Trentham East. When Trentham became on R.A.X. a dialling line was fitted to the Trentham East switchboard. She stubbornly refused to use the 'new fangled dial' and left this duty to her son. When he wasn't around, bad luck for any calls required to Trentham. With the spread of automatic telephony and the increased mobility of people due to the motor car, telephone users became more experienced and subscriber education became a simpler process. However, the circuitry of the common apparatus units of S.T.C. and Siemens was such that complete failure sometimes occurred, and most of the units have now been replaced. The B.G.E. and A.T.M. units were more reliable and most are still in service. They should be replaced by 1975 with A.R.K. units.

One unusual exchange known as a U.A.X. (Universal Automatic Exchange) manufactured by B G.E. was installed at Kallista in 1938. It contained many features considered to be advanced practice for that era, such as multi-metering. However, this facility gave a determined number of meter pulses at the end of each three-minute period, and was never used. It was later moved from Kallista to Monbulk and then to Kerrie. It was recently replaced by an A.R.K.

Accommodation and Travel.

An interesting aspect of installation in this era was accommodation costs and transport. Travelling allowance was paid at sixpence per hour or 12 shillings per day for the first three weeks. It was then reviewed and dropped to 35 or 42 shillings per week in most cases. Accommodation in boarding houses was 25 to 30 shillings and in hotels 35 to 50 shillings per week. In some towns, such as Yallourn or Mildura, hotel costs were above the amount received. In such cases receipts were obtained and extra allowances were granted. However, in some instances, accommodation was cheap and one particular case may be quoted. Carisbrook is situated five miles from Maryborough, where hotels were numerous. We inquired at the Carisbrook hotel and were quoted 25 shillings per week. On stating that we would return to Melbourne for week-ends, the publican said 'A bob a time will do.' This meant a shilling for a bed and each meal. Thus we paid 17 shillings or $1.70 per week, which is rather a contrast to the present motel room at $10 per day. Beds

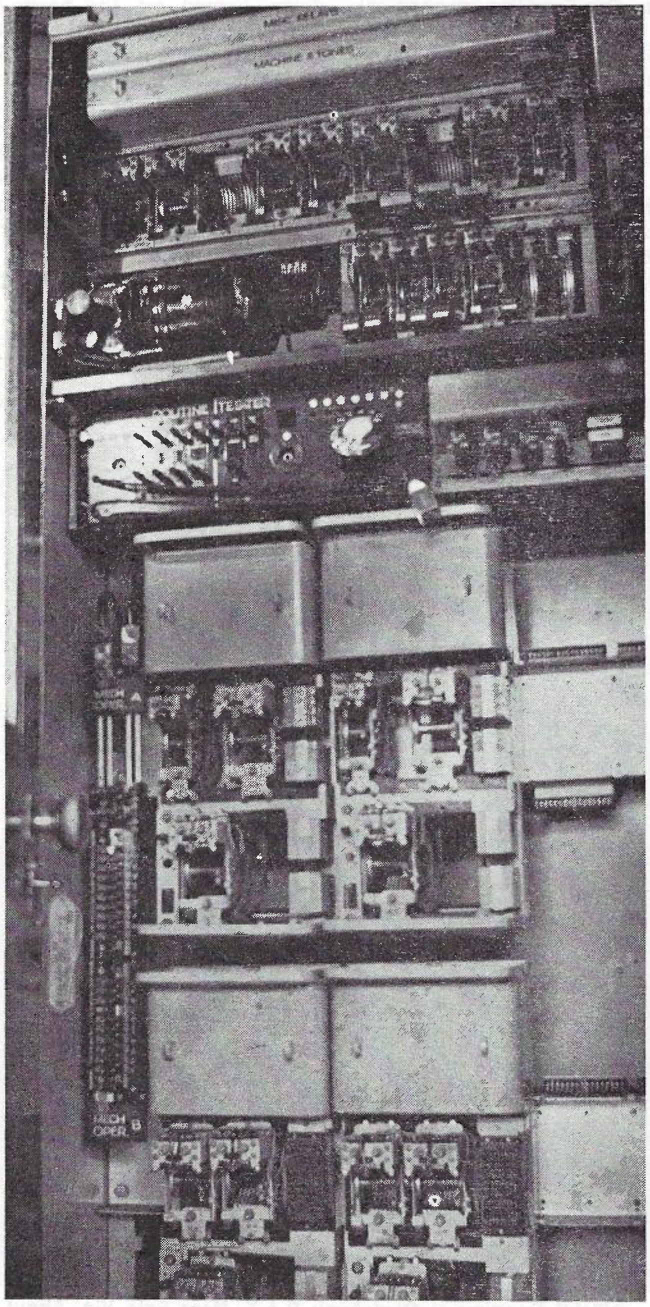

Fig. 2. — Common Apparatus Rack — Siemens R.A.X. Carisbrook R.A.X.

were comfortable, meals were eaten mainly in the kitchen with the family and were very good, but the toilet way down the yard was only fair. Bar closing time was then 6 p.m., but it was an interesting although dull spectacle to see the after hours patrons sitting at the bar without lights, their presence betrayed by a row of cigarette glows.

However, facilities were not so good in some remote hotels. At Darlington, for bathing purposes, you had to pump water from a well into a dish placed on the tank stand in the yard. That is, if you were lucky. Often when the pump failed to work, you had to lower the bucket to obtain water. As the next nearest hotel was 15 miles away at Mortlake and petrol was rationed, we had no option but to remain there.

The transport position during the war and for some years after was rather difficult. As petrol was rationed, travel by rail to and from country centres was necessary. Long trains, drawn by overworked A2 class locomotives burning inferior coal, resulted in slow speeds and invariably late arrivals. One typical example was a journey where we left Swan Hill at 8 a.m. on a mixed train which arrived at Bendigo, 115 miles distant, at 5 p.m. after shunting trucks at most intermediate stations. There we joined a passenger train and arrived in Melbourne at 10 p.m.

Trains scheduled to arrive in Melbourne between 9 and 10 p.m. were sometimes delayed until after midnight. Last suburban trains were held back or passengers were sent home by taxis. Excess travelling time, limited to five hours per day, was certainly hard-earned cash under those circumstances.

Post-War Years.

With the conclusion of the war in 1945, a large-scale programme of R.A.X. installation was envisaged. Fibro cement prefabricated buildings of a standard size 15 ft. x 9 ft. were obtained and located on site by the Works Department. Experience gained from the previous types was used as a basis for the production of standard A.P.O. units. Two types were designed, one, a B type unit, catered for 40 subscribers and five trunks, and the other, a C-type unit, catered for 45 subscribers and five trunks, and was extensible to 200 by the addition of D units. The C units, although somewhat similar to earlier B.G.E. units, were designed to eliminate as much common apparatus as possible and so avoid complete failures. 2000 type bi-motional switches were used initially and SE50 types later. Prototypes were manufactured and installed as field trials. Tenders were then called for bulk supply and units were manufactured by G.E.C. and A T.M. of England and later S.T.C. and T.E.I. of Sydney. 500 B type units were manufactured in 1950 by G.E.C. for £500 or $1000 each for Australia, the Victorian quota being 125 units. The number of C and D units in service in Victoria are 263 and 236 respectively. Installation was commenced in 1951 and was completed about 1961, when the revised policy called for A.R.K.'s. Although the R.A.X.'s were wired for multi-metering, this was for the fixed three-minute timing and was therefore unsuitable for the system adopted, i.e., charging only for time used. New multi-metering bases have now been supplied for R.A.X.'s and this, together with minor modifications, should extend the useful life of R.A.X. equipment into the 1980's. At June, 1970, there were 650 S.C.A.X.'s in service in Victoria; 390 R.A.X.'s and 260 A.R.K.'s. There are still 540 manual exchanges to be converted, probably by A.R.K. installations.

CONCLUSION.

In conclusion, mention might be made of two odd R.A.X. units which preceded A.R.K.'s. One manufactured by Telephone Manufacturing Company of England was described as a crossbar type. This 50-line unit used 3000 type relays with extra coils and extended armature pieces as crossbar switches. After 15 years good service at Yan Yean it was replaced by an A.R.K. It is now in the Post Office Museum.

The first Swedish Ericsson crossbar exchange was installed at Panton Hills in 1959. This unit had been to several countries as a demonstration model and could be described as a 'bitzer.' Its trunking arrangements to a parent magneto exchange at Hurstbridge proved difficult to arrange and were never entirely satisfactory. After nine years' service it was replaced by an A.R.K. Its equipment, not being compatible with the present day crossbar system, was scrapped.

TECHNICAL NEWS ITEM

COLOURED WALL TELEPHONE

A new style of wall telephone (see Figure) has been developed as a co-operative effort by the Australian Post Office and Amalgamated Wireless (Australasia) Ltd. The instrument is to be known as telephone 891 and will incorporate a similar circuit to the present coloured table telephone, 800 series, with the same transmission performance.

The new wall telephone will be manufactured by A.W.A. at Ashfield, N.S.W. and will be available early in 1971 with a choice of three colours, appliance white with a brown base, powder blue or black. Other colours yellow, green or grey will be available later.

A 'micro-switch' installed as a gravity switch will be operated when the handset is held vertically by a polycarbonate cradle on the front cover of the instrument. If a subscriber wishes to leave the instrument during a call, the handset can be placed horizontally on the cradle without disconnecting the call.

THE A.R.M. BUTTINSKI

*J. J. McDERMOTT, B.Sc**

INTRODUCTION.

When the Subscriber Trunk Dialling network was expanded late in 1967 with the introduction of the A.R.M. 201/4 telephone exchanges, maintenance problems associated with call tracing and testing line relay sets led to the development of a new portable handset. This handset, or buttinski, capable of line signalling on incoming and outgoing relay sets, enables the user to speak on a four-wire circuit. It is based on the No. 4 buttinski currently on issue to linemen and technicians.

TESTING EQUIPMENT IN A.R.M. TELEPHONE EXCHANGES.

In the A.R.M. Telephone Exchanges, two maintenance aids are supplied for testing line relay sets and common equipment. They are:

(a) Automatic Exchange Tester (A.E.T). (see Fig. 1).—The A.E.T. connects either to the line side of an incoming line relay set or to the exchange side of an outgoing relay set. It cannot connect to a register or any other common equipment, but the devices can be tested by establishing test calls with the A.E.T.

Line signalling relay sets that the A.E.T. can test are usually of the following types:

(i) 2-wire loop disconnect signalling. This is used on routes to terminal exchanges or to minor switching centres such that the transmission losses from the A.R.M. exchange to the terminal exchange do not exceed 6 dB.

(ii) 4-wire loop disconnect signalling. This is used to terminal exchanges where the two-wire losses exceed 6 dB, or to minor switching centres that are remote from the A.R.M. exchange.

(iii) T-type or pulse signalling relay sets for use over carrier systems. A short pulse in the forward direction picks up the distant end relay set. A 150 ms short pulse in the backward direction indicates that the called party has answered. A long pulse of approximately 600 ms in the forward direction indicates that the calling party has released the connection, while a long pulse in the backward direction indicates that the called party has replaced the receiver.

* Mr. McDermott is Engineer Class 2, Trunk Service, N.S.W.

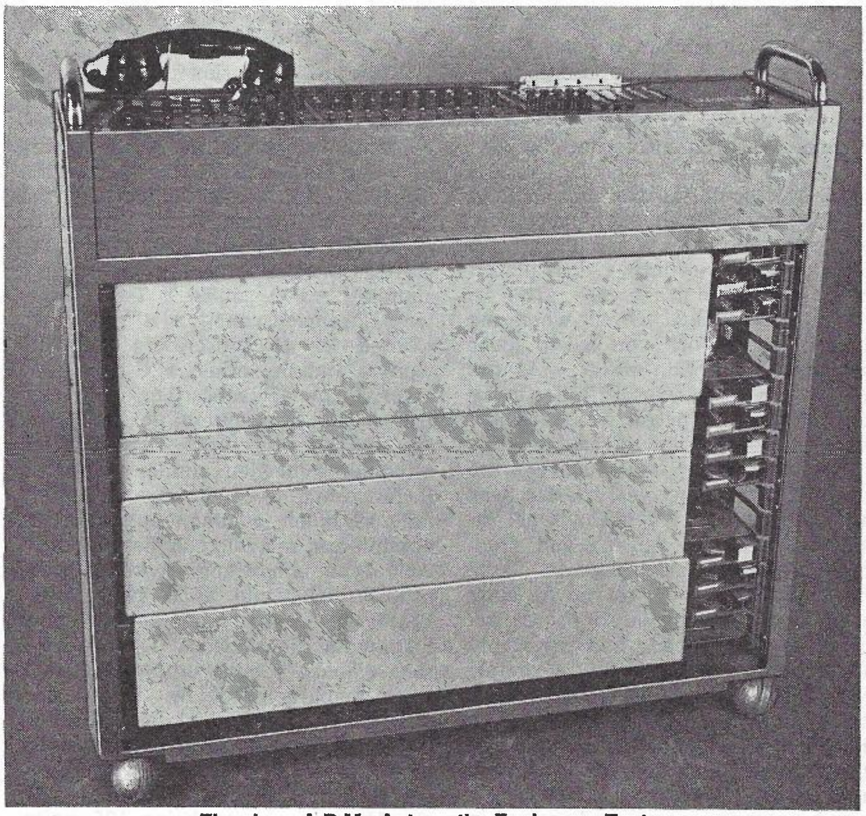

Fig. 1. — A.R.M. Automatic Exchange Tester

For each of the types of line signalling mentioned above there are two types of information signalling. Information signalling relates to the number dialled by the subscriber, whether it is a special type of service and details relating to the called subscriber.

The two types of information signalling are:

(i) Multi-frequency Code (M.F.C.) Signalling. This is used between A.R.M. exchanges and also from an A.R.F. exchange to the A.R.M. exchange.

(ii) Decadic Signalling. This is used between step-by-step exchanges and A.R.M. exchanges. Decadic signalling is also used between the operator-controlled network and the A.R.M. and also to and from small country exchanges.

(b) The A.R.M. Tariff Tester.— Tariff is established at the originating A.R.M. exchange in the incoming line relay set. Some A.R.M. exchanges do not provide this tariff setting facility, the tariff being set at the originating minor switching centre.

The tariff tester is used to check the tariff setting relay set FIR-Z, and can be programmed to check up to ten relay sets on each of the seven metering rates. A key on the tariff tester, when operated, terminates the call on a test relay set in the A.R.M. exchange. This relay set sends an answer signal back to the FIR-Z, and metering commences. The tariff tester checks the pulse from the FIR-Z with the pulse that is supplied to the rack. A faulty test brings up an alarm on the tariff tester indicating that attention is required on the particular FIR-Z.

DEVELOPMENT OF THE A.R.M. BUTTINSKI.

To overcome the shortages and disadvantages of the A.E.T. and tariff tester, an A.R.M. buttinski was developed by N.S.W. Trunk Service Section in conjunction with the A.R.M. Transmission Measurements Working Party, which was set up by Headquarters to develop transmission measuring techniques for the A.R.M. grid.

Mechanical.

The A.R.M. buttinski (Fig. 2) is a modified version of the red No. 4 buttinski, which is commonly used by technicians and linemen. On the back of the buttinski are fitted four double-throw toggle switches and one non-locking push button. The lamp,

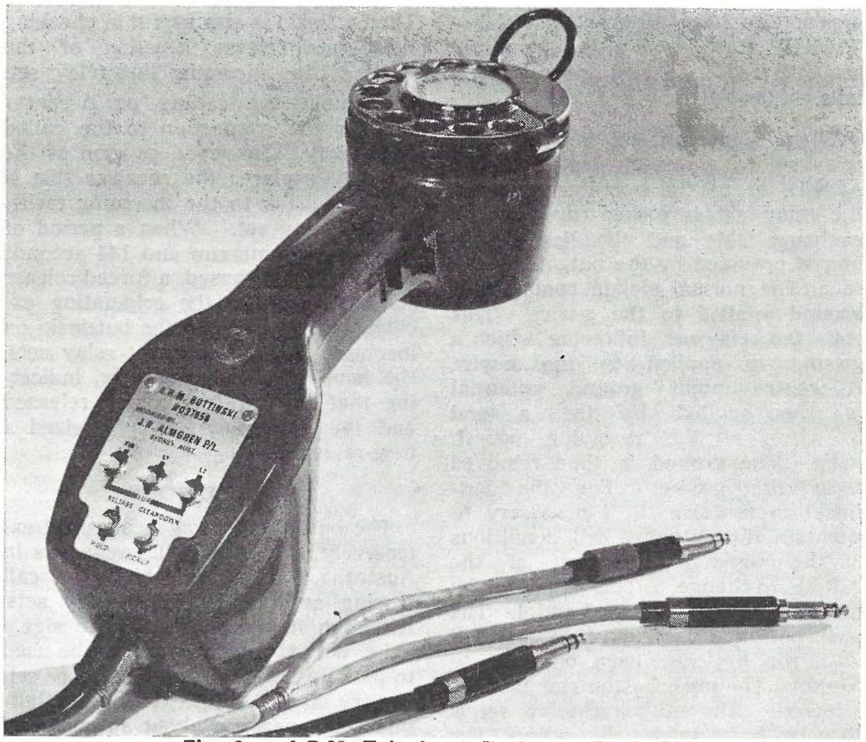

Fig. 2. — A.R.M. Telephone Exchange Buttinski

which is a standard feature, has been incorporated to observe line signals which are generated by the relay set.

A black cord is supplied with the buttinski and has been fitted with an L M. Ericsson plug. Its purpose is to supply normal exchange battery and ground to the buttinski for speech current in the four-wire path. It is also used for certain signalling conditions.

An additional cord, which splits into two, is also fitted with L.M. Ericsson plugs. One of these plugs is covered with a red band, which identifies the sending side of the four-wire speech path. The black plug identifies the receiving side of the speech path. On each of these plugs the tip and ring connections are used for speech and the sleeve is used for signalling.

An adhesive label attached to the back of the buttinski gives the main details relating to correct operation.

Electrical.

The A.R M. buttinski can be used to monitor and speak on incoming, outgoing and bothway line relay sets. It connects to the exchange side of

TABLE 1.—CALL TRACING WITH A.R.M. BUTTINSKI.

(a) To DIAL on the following line Relay Sets.

Relay Set	Grey Cord		Black Cord	Keys Operated on Buttinski.			
	Red Plug	Black Plug	Battery	Speak	Toggle Switches	Push Button	Remarks
FIR-L1M-H2/Y2	TJ1	—	No	Yes	FIR-L1	No	Lamp Lights on Pickup
FIR-L2M-H2/Y2	TJ2	TJ1	Yes	Yes	FIR-L2	No	Lamp Lights on Pickup
FIR-TM-H2/Y2	TJ2	TJ1	Yes	Yes	FIR	150 ms 'Pickup' 600 ms 'Cleardown'	Lamp Flashes on 'T-Type' Signals
FUR (Decadic or Manual) NOTE 1	TJ3	TJ4	Yes	Yes	(1) FUR-Release (3) 'Pickup' & 'Hold' (4) 'Hold'	(2) 'Pickup'	To release FUR, operate key to 'Release'

NOTE 1: Numbers give sequence of operation on picking up relay set.

(b) (i) To monitor on ALL Line Relay Sets
(ii) To speak on ALL Line Relay Sets } Assuming Relay Set picked up and switched.

Relay Set	Grey Cord		Black Cord	Keys Operated on Buttinski.			
	Red Plug	Black Plug	Battery	Speak	Toggle Switches	Push Button	Remarks
FIR-L1M-H1 H2 Y1 Y2	TJ4	TJ3	Yes	(i) No (ii) Yes	FUR Release	No	
FIR-L2M-H1 H2 Y1 Y2	TJ4	TJ3	Yes	(i) No (ii) Yes	FUR Release	No	
FUR-TM C	TJ3	TJ4	Yes	(i) No (ii) Yes	FUR Release	No	

each of these relay sets at Test Jacks 3 and 4. The key on the side of the handset allows the operator to choose between speaking and monitoring.

Limitations of A.E.T. and Tariff Tester.

The A.E.T., because of its complexity and cost, is usually supplied on the basis of two per A.R.M. exchange. Its function is to generate test calls to gauge the performance of the exchange and its line relay sets. It is also used to find faults within the exchange. These two functions tend to clash at times and it may become necessary to stop an A.E.T. test programme on an outgoing route to meet a distant end technician on a faulty line relay set.

The tariff tester is physically similar to the A.E.T. and difficult to manoeuvre around the exchange. Its main limitations are:

(a) It cannot test an FIR-Z for unit fee and no-fee setting.

(b) It cannot detect a fault in the rack wiring as it compares the pulses generated by an FIR-Z. from the relay set.

(c) It cannot detect noisy meter pulses generated by an FIR-Z.

The buttinski can also be used to pick up (seize) any A.R.M. line relay set and establish calls from line relay sets employing decadic information signalling.

The buttinski is plugged into the line side of the incoming line relay set, thus disconnecting the line or channel. It is necessary to ensure that all keys are thrown to 'FUR' - 'RELEASE' before signalling commences. Depending on the type of relay set, the appropriate keys 'FIR' - 'L1' - 'L2' - 'PICKUP' (for T-type pulse signalling) are operated. Table 1 gives full details.

When signalling on an outgoing relay set to a step-by-step exchange, ARK-D, or to the operator network, the relay set is picked up on the exchange side and the line signalling is provided by the outgoing relay set. The normal pickup condition is ground applied to the g-wire. This tests the relay set, following which a ground is applied to the c-wire A centre point ground potential is then applied to the a and b wires of the receiving speech path. The ground is then removed from the g-wire. For the buttinski to function, it is necessary to simulate the outgoing call conditions of the common equipment of the A.R.M. exchange. This is done by plugging into Test Jacks 3 and 4. The push button is used and held operated until the key has been operated to 'Hold.' The push button can then be released. The outgoing relay set is then ready to receive dial pulses. The relay set can be released by restoring the key to 'FUR Release.'

The A.R.M. buttinski can also be used as a portable tariff tester. After establishing a call with the buttinski, metering commences after answer. Each meter pulse flashes the lamp on the buttinski. Table 2 gives full details of metering under all types of metering conditions found in the A.R.M. exchange. The buttinski can also check no-fee and local fee settings. The buttinski is also useful in checking the forced release function of the tariff setting incoming line relay set.

Normally the calling or A party releases the connection to the called or B party. However, as soon as the B party replaces the receiver this is signalled back to the incoming tariff-setting relay set. When a period of 72 seconds minimum and 144 seconds maximum has elapsed, a forced release signal is sent to the originating exchange. When using the buttinski on incoming loop disconnect relay sets, the lamp glows permanently, indicating that the call has forced released and the line relay set has seized a new register.

CONCLUSIONS.

The buttinski is now being used extensively in most A.R.M. exchanges in Australia. It is used chiefly for call tracing and testing line relay sets. Although it is not possible to signal m.f.c. with this handset, it can be used to pick-up and hold any line relay set. In very large A.R.M. exchanges a buttinski can perform about 40 per cent. of the functions of the Automatic Exchange Tester and Tariff Tester, in the manual mode. However, the cost of the buttinski is only about 3 per cent. of the combined cost of the two testers.

ACKNOWLEDGMENTS.

The author records his appreciation of the assistance of the N.S.W. Trunk Service staff and J. N. Almgrem Pty. Ltd. in the development of this maintenance aid.

TABLE 2.—TARIFF TESTING WITH AN A.R.M. BUTTINSKI (NOTE 1)

Type of FIR	Type of Call	Condition of Lamp on Buttinski				
		Before Answer	On Answer	1st Meter Pulse on Answer	Next Pulse	Subsequent Pulses
FIR-ZL1M-H2 or FIR-ZL2M-H2	Wanted, did not Answer (W.D.A.)	On	—	—	—	—
	Local Fee	On	Off	On-Off	None	None
	No Fee	On	Off	None	None	None
	Multimeter Fee	On	Off	On-Off	Suppressed	On-Off
FIR-ZTM-H2	(W.D.A.)	Off				
	Local Fee	Off	On-Off	On-Off	None	None
	No Fee	Off	On-Off	None	None	None
(NOTE 2)	Multimeter Fee	Off	On-Off	On-Off	Suppressed	On-Off

NOTES 1: The lamp on the back of the buttinski indicates meter pulses.
2: On FIR-ZTM-H2 lamp will flash for a much shorter period than for other types of FIR's. Meter pulses can be heard in the receiver as well as seen on the lamp.

OUR CONTRIBUTORS

M. K. WARD

M. K. WARD, co-author of the article, 'Program Control of the IST Project,' joined the Postmaster-General's Department as Cadet Engineer in Queensland, in 1960. He completed the Bachelor of Engineering degree at the University of Queensland in 1963, gaining First Class Honours and winning a University Medal. After one year's full time post-graduate work he was awarded the degree of Master of Engineering Science. In 1965 he joined the Circuit Theory Division of the Research Laboratories, where he was involved in the development of digital computer techniques in the synthesis and analysis of electrical filters and networks. In 1967 he transferred as Engineer Class 2 to the Switching Sub-Section of the Research Laboratories, where he has worked on the digital control and interfacing of the IST project. Mr. Ward has recently been appointed Engineer Class 3, Telephone Exchange Equipment, Engineering Works Division, Headquarters.

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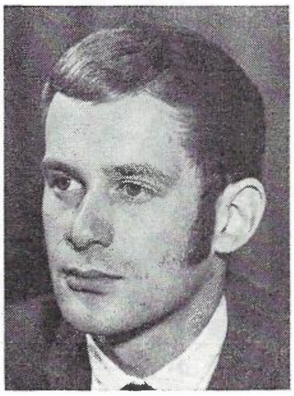

R. J. DEMPSEY

R. J. DEMPSEY, co-author of the article, 'The Perth to Port Hedland Channel Doubling System,' obtained the B.E. degree from the University of Melbourne in 1965. After graduation he was employed for a year by Brown and Watson Electronics. In 1966 he joined the Postmaster-General's Department Research Laboratories, where he worked for two years in the Electrical Standards Division. In 1968 he transferred to the Multichannel Systems Division, where he is presently employed.

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R. R. NELDER

R. R. NELDER, author of the article 'The Victorian History of Small Country Automatic Exchanges,' joined the Postmaster-General's Department as a Telegraph Messenger in 1923 in Melbourne. He completed the technicians' training course in 1927 and commenced R.A.X. installation in 1934. Then followed 24 years on Country Installation, the majority of this period being spent as Senior or Supervising Technician, associated with R.A.X.'s on an installation and developmental basis. From 1958 until the present time, he has been employed as the Senior Technical Officer, Regional Works and Services, Country Branch, Victoria. Mr. Nelder designed the standard 40-line B type R.A.X. used throughout the Commonwealth prior to the introduction of standard crossbar type exchanges.

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D. A. GRAY

D. A. GRAY, author of 'The Work of the Telephone Transmission Study Groups of the C.C.I.T.T., joined the Research Laboratories of the Postmaster - General's Department after graduation from Melbourne University in 1941. His initial appointment was as Engineer to work on instrumentation problems. Subsequently, after a brief period during which he directed studies of telephone instrument performance, he became Class 3 Engineer in the Multichannel Systems Division of the Laboratories, and was responsible for special carrier equipment designs for the Bass Strait submarine cable and for open wire routes. At present he is leader of the Principles Group in the Systems Section of the Laboratories with responsibilities for studies of telephone transmission standards, probability and circuit theory, and electrical measurement standards.

J. J. McDERMOTT, author of 'The A.R.M. Buttinski,' joined the Department in 1959 and worked in the costing and drafting sections.

J. J. McDERMOTT

D. L. SHAW

G. J. SEMPLE

F. J. W. SYMONS

In 1967 he graduated from the University of N.S.W. with a degree of Bachelor of Science (Technology) in Electrical Engineering. From 1967 he has held the position of Engineer Class 1 and then acting Engineer Class 2 in Trunk Service No. 2 Division, Sydney. In this division he has been the controlling engineer for Haymarket A.R.M. and Long Line Station.

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D. L. SHAW, co-author of the article, 'Perth - Port Hedland Channel Doubling System,' joined the Postmaster-General's Department as a Cadet Engineer in 1950 whilst he was undertaking a course of Electrical Engineering at the University of New South Wales. He obtained his B.E. degree in 1953 and completed his cadetship in 1954. From 1954 to 1965 he was employed in the New South Wales Long Line and Country Installation Section on the installation of carrier systems power equipment, trunk signalling equipment, manual and automatic exchanges and subscribers' equipment. In 1965 he was promoted to the position of Engineer Class 3 in charge of the Multi-channel Division of the Systems Sub-section of the Research Laboratories. This division studied transmission aspects of the APO network and developed items of specialised transmission equipment. The Division was given the Port Hedland system as a special development project in the middle of 1968. In July, 1969, Mr. Shaw transferred to the Data Division of the Subscribers' Equipment and Telegraph Section of the Engineering Works Division, where he is responsible for the provisioning of data modems and the establishment of practices associated with the provision of datel services for subscribers. Mr. Shaw is a Member of The Institution of Engineers, Australia.

G. J. SEMPLE, co-author of the article, 'The Perth to Port Hedland Doubling System,' graduated from the University of Melbourne with a Bachelor of Engineering degree with honours in 1966. In January, 1967, he joined the P.M G. Research Laboratories and in March of the same year he was granted fifteen months' leave without pay to do post graduate work in the field of error correcting codes at the Melbourne University. In 1968 he obtained a Master of Engineering science degree and returned to the Multichannel Division of the Research Laboratories, where he was involved in the 'Channel Doubling' project. Since 1969 Mr. Semple has worked in the Pulse Systems Division and his work has been mainly concerned with PCM and digital transmission systems.

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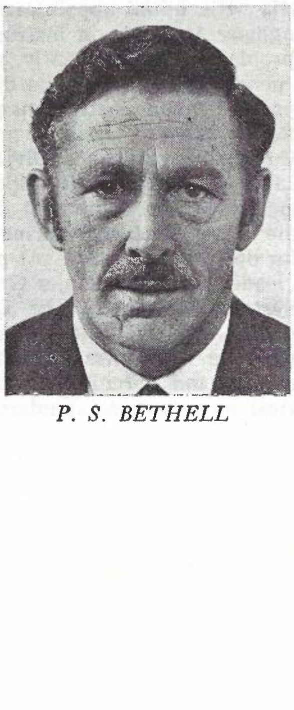
P. S. BETHELL, author of the article 'Computers and Communications—the Present and the Future,' joined the Post Office as a Clerk in 1940. He was appointed a Cadet Engineer during war service and completed his



P. S. BETHELL

training in 1949, having graduated as a Bachelor of Science at the University of Melbourne. After two years as a Group Engineer in Telegraph Maintenance, Victoria, he transferred to the Telegraph Section in Headquarters. During the next ten years as a Class 3 and later a Class 4 Engineer, he played a major part in the planning, design and implementation of the TRESS network for handling public telegrams and in the planning and specification of the automatic Telex network. After three years as Liaison Engineer in the London Office, Mr. Bethell joined the Fundamental Planning Section in Headquarters in 1966, where his work has included the study of new developments in telecommunications services and in particular assessing the needs of the Department's data communication services. At the time of preparing this article Mr. Bethell was acting Assistant Director-General, Fundamental Planning Section.

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F. J. W. SYMONS, co-author of the article, 'Program Control of the IST Project,' joined the Postmaster-General's Department as a cadet engineer in 1955. After graduating from the University of Adelaide with First Class Honours in Electrical Engineering in 1959, he worked for fifteen months as an Engineer Grade 1 with the Planning Section, South Australia. In January, 1961, he left for England, having been granted leave without pay to accept a GEC Overseas Fellowship for two years. The two years with GEC were spent in the Telecommunications Division, Coventry, and the Research Laboratories, Wembley, together with three weeks with the British Post Office Headquarters and Research Branch. The time with GEC and the

BPO was mainly concerned with transmission equipment and electronic exchange design and operation. Mr. Symons remained in England on an IEE scholarship to undertake the post-graduate course in Communications and Electronics at the Imperial College of Science and Technology, London, concentrating on statistical Communication Theory. For this course he was awarded the Diploma of Imperial College (D.I.C.), after submission of a thesis on Matched Filter Detection.

On return to Australia, Mr. Symons joined the Research Laboratories and worked as an Engineer Class 2 in the Multichannel Systems Division for 18 months, mostly on the delay tests over the COMPAC cable. Late in 1965 he was appointed acting Engineer Class 3 in the Probability Division and in early 1967 he was transferred to acting Engineer Class 3 in the Semi-conductor Circuitry Division, where active work on the IST project was just commencing. Since that time Mr. Symons has been concerned mainly with the responsibility for the design and development of the programs for the IST project, initially as Engineer Class 3 in the Semiconductor Circuitry Division and from early 1968 as Engineer Class 3 in the Switching Processors Division. From March to May, 1968, Mr. Symons visited administrations and manufacturers in Japan, England and Europe to discuss the application of stored programme control to telephony.

ANSWERS TO EXAMINATION QUESTIONS

Examinations No. 6071 to 6075, 18th July, 1970, and subsequent dates, for promotion or transfer as Technician (Telecommunications), Postmaster-General's Department.

TELECOMMUNICATION PRINCIPLES

QUESTION 1:

The battery in Fig. 1 has no internal resistance. The p.d. across R1 is 10 volts and R4 dissipates 4 watts.

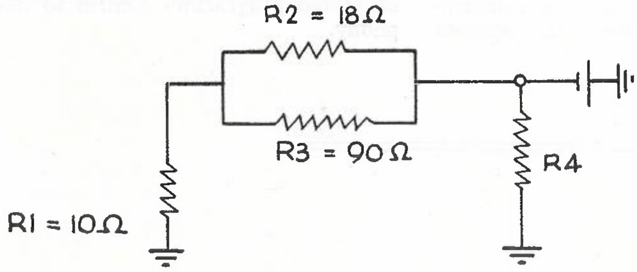

Fig. 1.

QUESTION 1 (a):

Calculate the e.m.f. of the battery.

ANSWER 1 (a):

$$\text{Joint Resistance} = \frac{R2 \times R3}{R2 + R3} = \frac{18 \times 90}{18 + 90} = 25 \text{ Ohms}$$

$$\text{Current in R1} = \frac{E}{R} = \frac{10}{10} = 1 \text{ Amp}$$

$$\text{P.d. of R2, R3} = I \times R = 1 \times 15 = 15 \text{ Volts}$$

$$\text{Total p.d.} = 15 + 10 = 25 \text{ Volts}$$

QUESTION 1 (b):

Calculate the resistance of R4.

ANSWER 1 (b):

The p.d. across R4 is the e.m.f. of the battery, 25 volts.

$$R = \frac{E^2}{P} = \frac{25 \times 25}{4} = 156.25 \text{ Ohms.}$$

QUESTION 1 (c):

Calculate the total power dissipated in the circuit.

ANSWER 1 (c):

$$\text{Power in R1} = E \times I = 10 \times 1 = 10 \text{ Watts}$$

$$\text{Power in R2, R3} = E \times I = 15 \times 1 = 15 \text{ Watts}$$

$$\text{Power in R4} = 4 \text{ Watts}$$

$$\text{Total Power} = 10 + 15 + 4 = 29 \text{ Watts}$$

QUESTION 2 (a):

Draw a labelled vector diagram showing the circuit voltages and currents for an A.C. circuit containing a resistance, an inductance and a capacitance all in parallel. The reactance of the capacitance is greater than that of the inductance.

ANSWER 2 (a):

See Fig. 2.

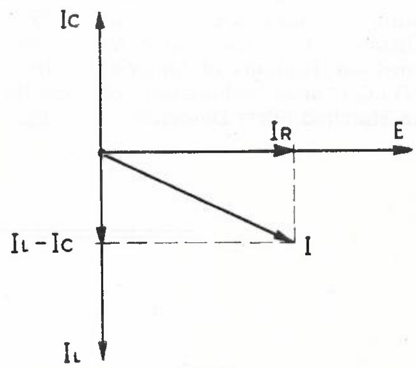

Fig. 2.

QUESTION 2 (b):

The circuit is now made resonant by altering the frequency. Explain the effect that this would have on each of the parts of your vector diagram above, and draw a new vector diagram showing the circuit conditions at resonance.

ANSWER 2 (b):

For the circuit to become resonant, Ic must be increased and Il decreased until they are equal. Ir is not affected by frequency and remains the same, and E is unchanged. As Ic and Il are equal, the only current is Ir, so the circuit current decreases to this value and is now in phase with the circuit voltage. This condition is shown in Fig. 3.

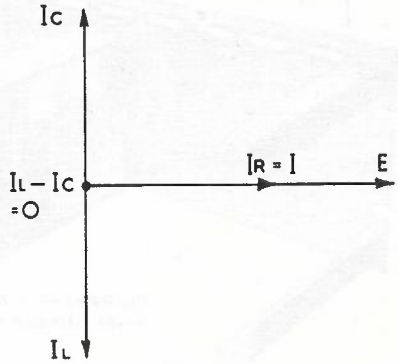

Fig. 3.

QUESTION 3 (a):

With the aid of diagrams, explain why bias is necessary for transistors used as Class A amplifiers. Include reference to the effects of operating the transistor without bias.

ANSWER 3 (a):

Bias is necessary to prevent distortion in the amplifier. With no bias, the signal is applied to the zero point of the Ic/Ib characteristic and as shown in Fig. 4a, only negative half cycles of the signal appear in the output. When bias is applied, the signal operates on the linear section of the characteristic (Fig. 4b) and the output signal is not distorted.

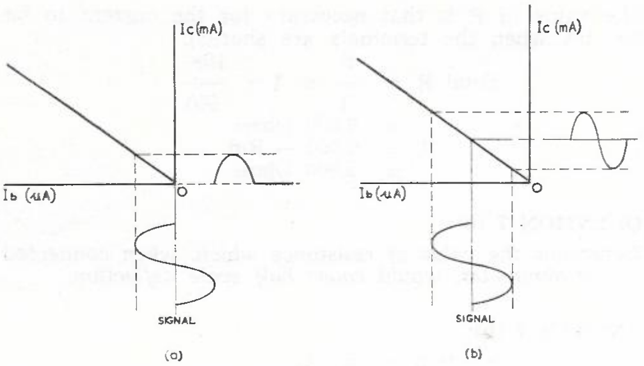

Fig. 4.

QUESTION 3 (b):

Draw the circuit elements necessary to provide 'combination bias' for a transistor and briefly explain how the bias is obtained.

ANSWER 3 (b):

The circuit is shown in Fig. 5. R1 and R2 form a voltage divider across the supply battery and the potential E2 developed across R2 makes the base negative with respect to earth. Its value depends upon the ratio of R1 and R2 and the supply voltage.

A potential EE is developed across RE by the emitter current through RE. This potential makes the emitter negative with respect to earth and is less than E2. As the bias voltage is the difference between base and emitter, its value is E2 — EE.

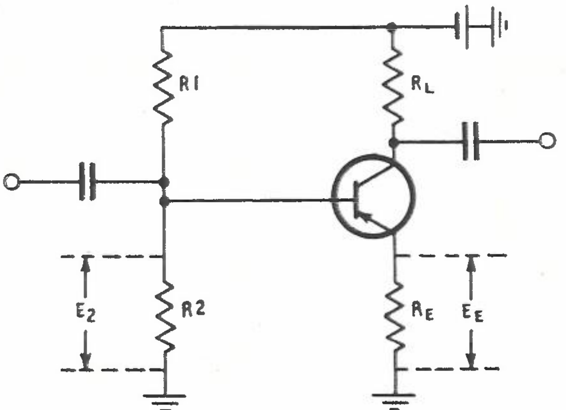

Fig. 5.

QUESTION 4 (a):

A double coil relay has its second coil short circuited by one of its own break contacts as shown in Fig. 6. Explain the effect that this contact and winding have on the operate and release times of the relay.

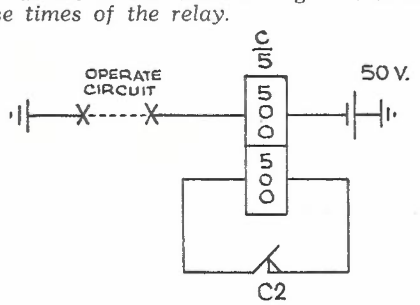

Fig. 6.

ANSWER 4 (a):

The relay will be slow to operate and normal release.

When the operate circuit is completed, current starts to rise in the operate winding, producing a rising flux which cuts the second winding. This flux induces an e.m.f. in the second winding and as there is a closed circuit via C2, a current flows in this winding which produces a flux opposing the original growth of flux (Lenz's law). The rate at which the primary flux grows is made slower, thus increasing the time that the relay takes to reach its operate value of flux, and making it slow to operate. When the relay operates, C2 opens.

When release conditions are applied, C2 is open, and although the decaying flux induces an e.m.f. in the second winding, the circuit is not complete and no current flows. The release time is therefore not affected.

QUESTION 4 (b):

Some relays, such as those used in transmission bridges, must be made to have high impedance.

(*i*) *State how the impedance of a relay may be greatly increased without altering the coil winding.*

(*ii*) *Explain the principle involved in* (*i*).

ANSWER 4 (b):

(i) By using nickel-iron sleeves over the core.

(ii) Nickel-iron has a high resistivity and so reduces eddy currents generated by the A.C. speech signals in the core material. (These eddy currents are mainly confined to the outer surface of the core.) Reducing eddy currents increases the inductance of the relay, which increases its inductive reactance and so its impedance.

QUESTION 5:

When a resistance and inductance are connected in series across a 48 volt 800 Hz supply, the current is 240 mA at a power factor of 0.6 lagging. Calculate the current and power factor when the same components are connected in parallel across the same supply.

ANSWER 5:

(i) Series Circuit (See Fig. 7a).

$$
\begin{aligned}
Z &= \frac{E}{I} = \frac{48}{240} \times 1000 \\
&= 200 \text{ Ohms} \\
R &= Z \times \text{P.F.} \\
&= 200 \times 0.6 \\
&= 120 \text{ Ohms} \\
XL &= \sqrt{Z^2 - R^2} \\
&= \sqrt{200^2 - 120^2} \\
&= 160 \text{ Ohms}
\end{aligned}
$$

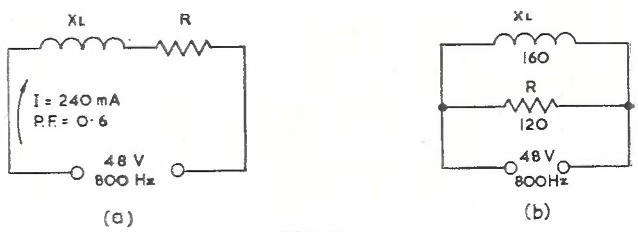

Fig. 7.

(ii) Parallel Circuit (see Fig. 7b).

$$
\begin{aligned}
IR &= \frac{E}{R} = \frac{48}{120} \times 1000 \\
&= 400 \text{ mA} \\
IL &= \frac{E}{XL} = \frac{48}{160} \times 1000 \\
&= 300 \text{ mA} \\
I &= \sqrt{IR^2 + IL^2} \\
&= \sqrt{400^2 + 300^2} \\
&= 500 \text{ mA} \\
\text{P.F.} &= \frac{IR}{IZ} = \frac{400}{500} \\
&= 0.8 \text{ Lagging}
\end{aligned}
$$

QUESTION 6 (a):

The three basic functions in an electronic logic system are the AND, OR and NOT functions. State what is meant by each of these by expressing the functions:
(i) As a word statement.
(ii) As a Boolean expression.

ANSWER 6 (a):

(i) AND: The output is logic 1 only when all inputs are logic 1.
OR: The output is logic 1 when any input is logic 1.
NOT: The output is logic 1 when the input is logic 0.
(ii) AND: $C = A.B$
OR: $C = A + B$
NOT: $C = \overline{A}$

QUESTION 6 (b):

Fig. 8 shows a combination of logic gates.
(i) Construct a Truth Table (Table of Possibilities) for all conditions of the inputs.
(ii) Write a Boolean expression which describes the logic diagram shown.

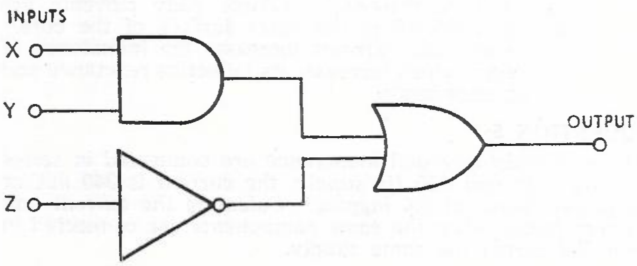

Fig. 8.

ANSWER 6 (b):

(i) See table below.

INPUTS			INTERMEDIATE		OUTPUT
X	Y	Z	X.Y	$\overline{Z}$	
0	0	0	0	1	1
0	0	1	0	0	0
0	1	0	0	1	1
0	1	1	0	0	0
1	0	0	0	1	1
1	0	1	0	0	0
1	1	0	1	1	1
1	1	1	1	0	1

(ii) Output $= (X.Y) + \overline{Z}$.

QUESTION 7 (a):

Draw the circuit of a basic series ohmmeter. Determine the value of any other components required to construct your circuit if a 3 volt battery and a meter with a resistance of 200 ohms and a full scale deflection of 500 uA are available.

ANSWER 7 (a):

See Fig. 9.

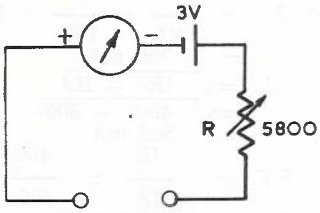

Fig. 9.

The value of R is that necessary for the current to be 500 uA when the terminals are shorted.

$$\text{Total R} = \frac{E}{I} = 3 \times \frac{10^6}{500}$$
$$= 6{,}000 \text{ Ohms}$$
$$R = 6{,}000 - Rm$$
$$= 5{,}800 \text{ Ohms}$$

QUESTION 7 (b):

Determine the value of resistance which, when connected to the ohmmeter, would cause half scale deflection.

ANSWER 7 (b):

Half scale deflection is 250uA.

$$\text{Total R} = \frac{E}{I} = 3 \times \frac{10^6}{250}$$
$$= 12{,}000 \text{ Ohms}$$
$$\therefore Rx = 12{,}000 - (5{,}800 + 200)$$
$$= 6{,}000 \text{ Ohms}$$

QUESTION 7 (c):

The scale below represents the original scale of the meter. Mark on it the positions for the following values of resistance:
(i) Zero Ohms.
(ii) 12,000 Ohms
(iii) 120 Ohms
(iv) The value determined in question 7 (b).

ANSWER 7 (c):

See Fig. 10.

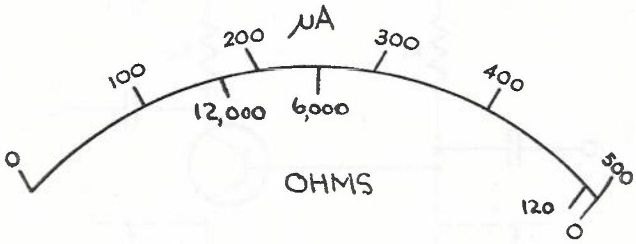

Fig. 10.

The values of current are calculated below.

(i) Zero Ohms:
$$I = \text{F.S.D.} = 500\text{uA}$$
(ii) 12,000 Ohms:
$$I = \frac{E}{R} = \frac{3}{6000 + 12000} \times 10^6$$
$$= 167 \text{ uA}$$
(iii) 120 Ohms:
$$I = \frac{E}{R} = \frac{3}{6120} \times 10^6$$
$$= 490 \text{ uA}$$
(iv) 6,000 Ohms:
250 uA

QUESTION 8:

Three capacitors are connected as shown in Fig. 11.

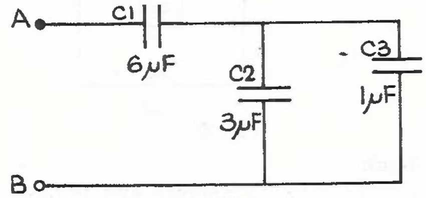

Fig. 11.

QUESTION 8 (a):

Determine the current through C2 if a supply of 5 volts at 1600 Hz is connected to terminals A and B.

ANSWER 8 (a):

Joint capacitance of C2 and C3 is 4uF.

$$\text{Total capacitance is } \frac{4 \times 6}{4 + 6} = 2.4\text{uF.}$$

$$\text{Xc Total} = \frac{1}{\omega C} = \frac{10^6}{1600 \times 6.25 \times 2.4}$$

$$= \frac{1000}{24} \text{ Ohms}$$

$$\text{I Total} = \frac{E}{Xc} = \frac{5}{1} \times \frac{24}{1000} \times 1000$$

$$= 120 \text{ mA}$$

As the reactance of C3 is 3 times that of C2, the current through C2 is $\frac{3}{4}$ of the total current.

$$I2 = \tfrac{3}{4} \times 120$$

$$= 90 \text{ mA}$$

QUESTION 8 (b):

Determine the p.d. across C3 if a D.C. supply of 50 volts is connected between A and B.

ANSWER 8 (b):

The circuit is C1 (6uF) in series with C2 and C3 in parallel (4uF). The ratio of the p.ds is inversely proportional to the capacitances.

$$\text{E across C3} = \frac{6}{6 + 4} \times 50$$

$$= 30 \text{ Volts}$$

QUESTION 8 (c):

A 100 volt D.C. supply in series with a resistor of 50,000 ohms is connected to terminals A and B. How long would it take (for practical purposes) for C1 to become fully charged?

ANSWER 8 (c):

All capacitors in the circuit would charge together and the time to become fully charged is 5 times the time constant of the combined circuit.

$$\text{Time} = 5CR$$

$$= 5 \times 2.4 \times 10^{-6} \times 5 \times 10^4$$

$$= 600 \text{ mSecs.}$$

QUESTION 9 (a):

Draw the basic circuit arrangements and typical attenuation/frequency characteristics of the following types of inductance/capacitance filters:

(*i*) *Low Pass.*
(*ii*) *Band Pass.*
(*iii*) *Band Elimination.*

ANSWER 9 (a):

(i) See Fig. 12.

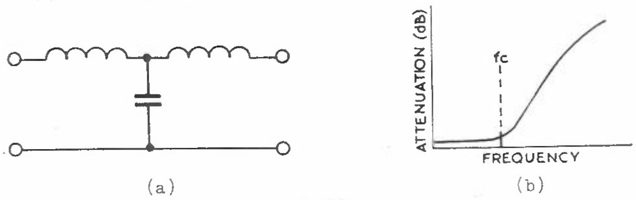

Fig. 12.

(ii) See Fig. 13.

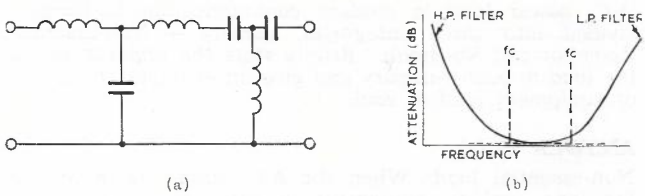

Fig. 13.

(iii) See Fig. 14.

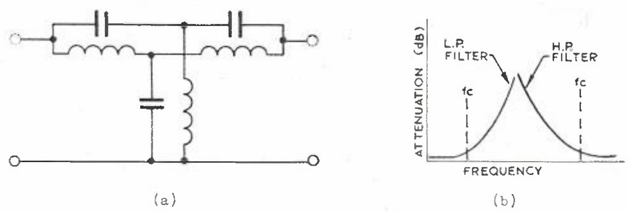

Fig. 14.

QUESTION 9 (b):

With the aid of sketches, explain why it is necessary to use attenuation equalisers with transmission lines.

ANSWER 9 (b):

They are necessary to prevent the frequency distortion, which is caused by most transmission lines having an attenuation which increases with frequency. As shown in Fig. 15, the equaliser has an attenuation characteristic which is opposite to that of the line, so the overall attenuation, although increased by the equaliser, is constant over the frequency range. This eliminates the frequency distortion.

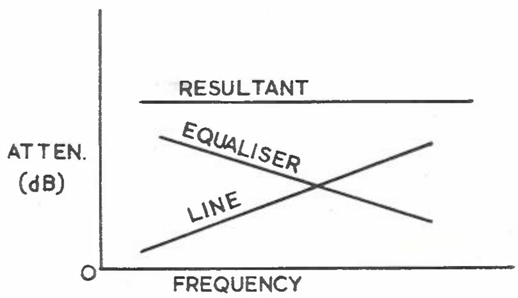

Fig. 15.

QUESTION 9 (c):

State one main advantage of crystal filters over L.C. filters in the frequency range of about 60 kHz to 150 kHz.

ANSWER 9 (c):

Any one of the following:

A low attenuation in the pass range and a high attenuation in the range of frequencies to be rejected.
A sharper cut-off.
A higher Q factor, which makes them very stable when used as narrow band pass filters.

QUESTION 10 (a):

A.C. power load in modern communication buildings is divided into three categories, namely — Non-essential, Essential and No-Break. Briefly state the requirements of the load in each category and give an example of the type of equipment load in each.

ANSWER 10 (a):

Non-essential load: When the A.C. supply is interrupted for long periods, equipment in this category does not cause dislocation of communication services. The normal station amenities, such as lighting and air-conditioning, are examples.

Essential load: Equipment included in this category can withstand an interruption to its A.C. supply for a limited period, without causing dislocation of communication services. Rectifiers used for battery charging, and A.C. inputs to no-break sets, are the main items in the essential load.

No-break load: Interruption of the A.C. supply to equipment in this category results in immediate and serious dislocation of communication services. Typical no-break loads consist of Broadband systems and Tress exchanges.

QUESTION 10 (b):

Draw a block diagram of a typical all-electric no-break set and explain its operation:
(i) Under normal conditions.
(ii) When a mains failure occurs.

ANSWER 10 (b):

Fig. 16 shows the main elements of a typical 3 machine no-break set. It consists of an alternator, A.C. motor, D.C. motor, control circuit and a battery. The alternator and motors are coupled together.

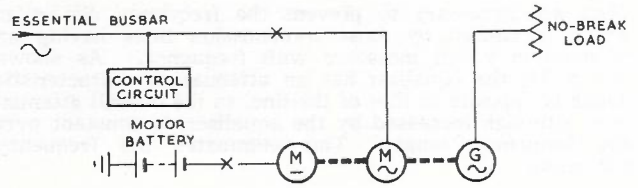

Fig. 16.

Under normal conditions the A.C. motor drives the alternator which supplies the no-break load. When the mains fail, the D.C. motor is connected to the battery and becomes the primary driving unit. The A.C. motor is disconnected. If the failure is prolonged, a normally stationary diesel set is started and this then drives the A.C. motor and the D.C. motor is disconnected. (Circuit and description of a 2 machine set was an alternative answer.)

QUESTION 11 (a):

The term 'Astable' applied to a multivibrator indicates a continuing output with or without external triggering. Briefly explain what is meant by the terms 'Bistable' and 'Monostable.'

ANSWER 11 (a):

Astable means that it has two stable states. It will change state when an external trigger pulse is applied, then remain in that state until a further trigger is received, when it again changes state.

Monostable has only one stable state. When a trigger pulse is applied it changes to the other state and then returns to the original a fixed time after the trigger is removed.

QUESTION 11 (b):

Briefly explain the operation of the phase-shift oscillator shown in Fig. 17. Include reference to the components which control the frequency of the oscillator.

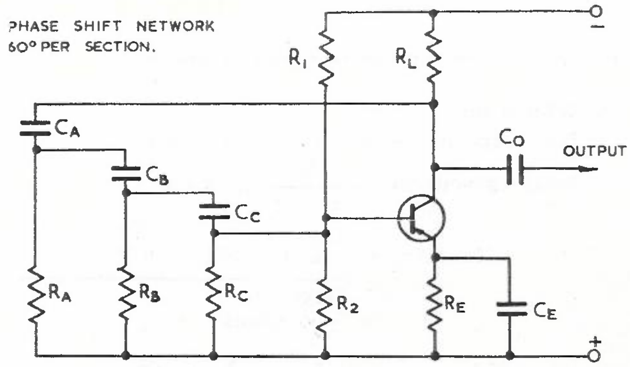

Fig. 17.

ANSWER 11 (b):

The circuit is basically an amplifier with positive feedback at one frequency. A phase shift of 180 deg. takes place between the base and collector as the transistor is operated in the common emitter mode. The feedback is taken through the three stages, CA and RA, CB and RB, CC and RC, each of which produces 60 deg. phase change at a particular frequency. These networks therefore determine the oscillator frequency, and this frequency is fed back to the base with a total phase change of 360 deg., giving positive feedback. The transistor has sufficient gain to make up for the circuit losses and provide the output. Combination bias is provided by R1, R2, RE.

QUESTION 12 (a):

With the aid of sketches, briefly explain the construction of a typical mains type power transformer and list two main power losses in this type of transformer.

ANSWER 12 (a):

The transformer has two basic parts, the winding and the core. The core usually consists of sheets of iron, insulated from each other, which are stacked to make the required size. The shape of the laminations depends upon the type, a typical arrangement being the 'E' and 'I' types shown assembled in Fig. 18a to make up a 'shell' type core.

The windings are normally insulated copper wire of suitable gauge. The number of turns for each is determined by the voltages required (Fig. 18b).

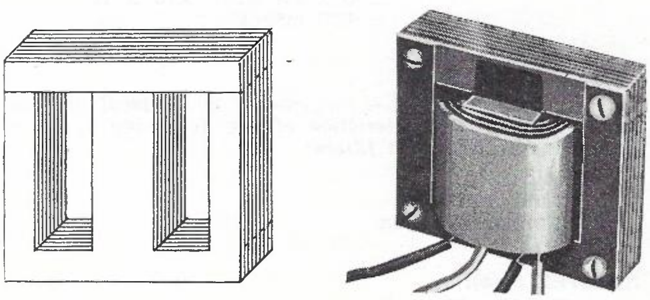

Fig. 18.

In power transformers, a shield of copper sheet is placed between the primary and secondary windings to prevent electrostatic coupling between them. An external shield is sometimes placed around the outside of the transformer to prevent interference to external circuits.

The main losses are: Winding loss, eddy current loss, hysterisis loss and magnetic leakage.

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2	June	1970	103-196
3	October	1970	197

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

ANSWERS TO EXAMINATION QUESTIONS.

The Australian Post Office
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in conjunction with meetings of CCITT Study Groups XII and XVI in Melbourne in February/March 1970.

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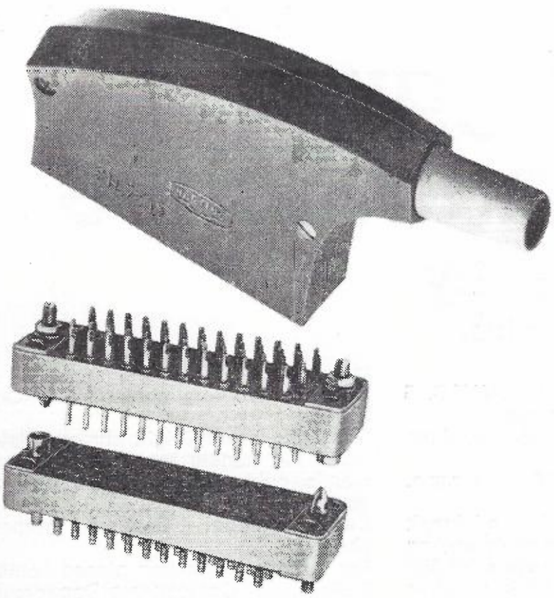

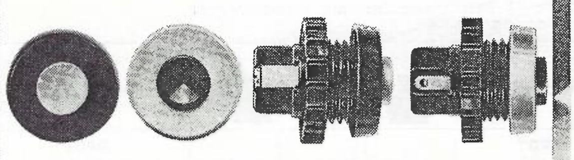

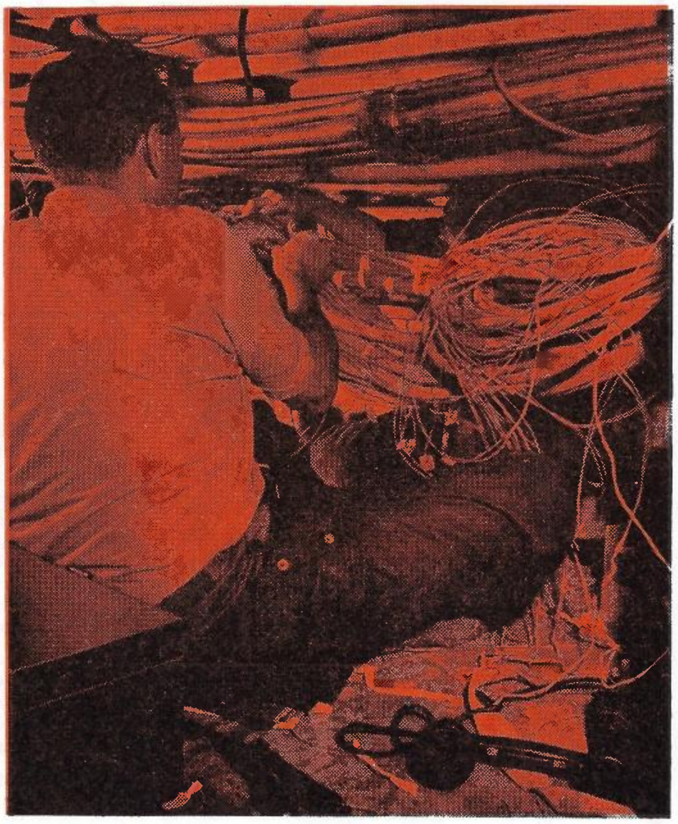

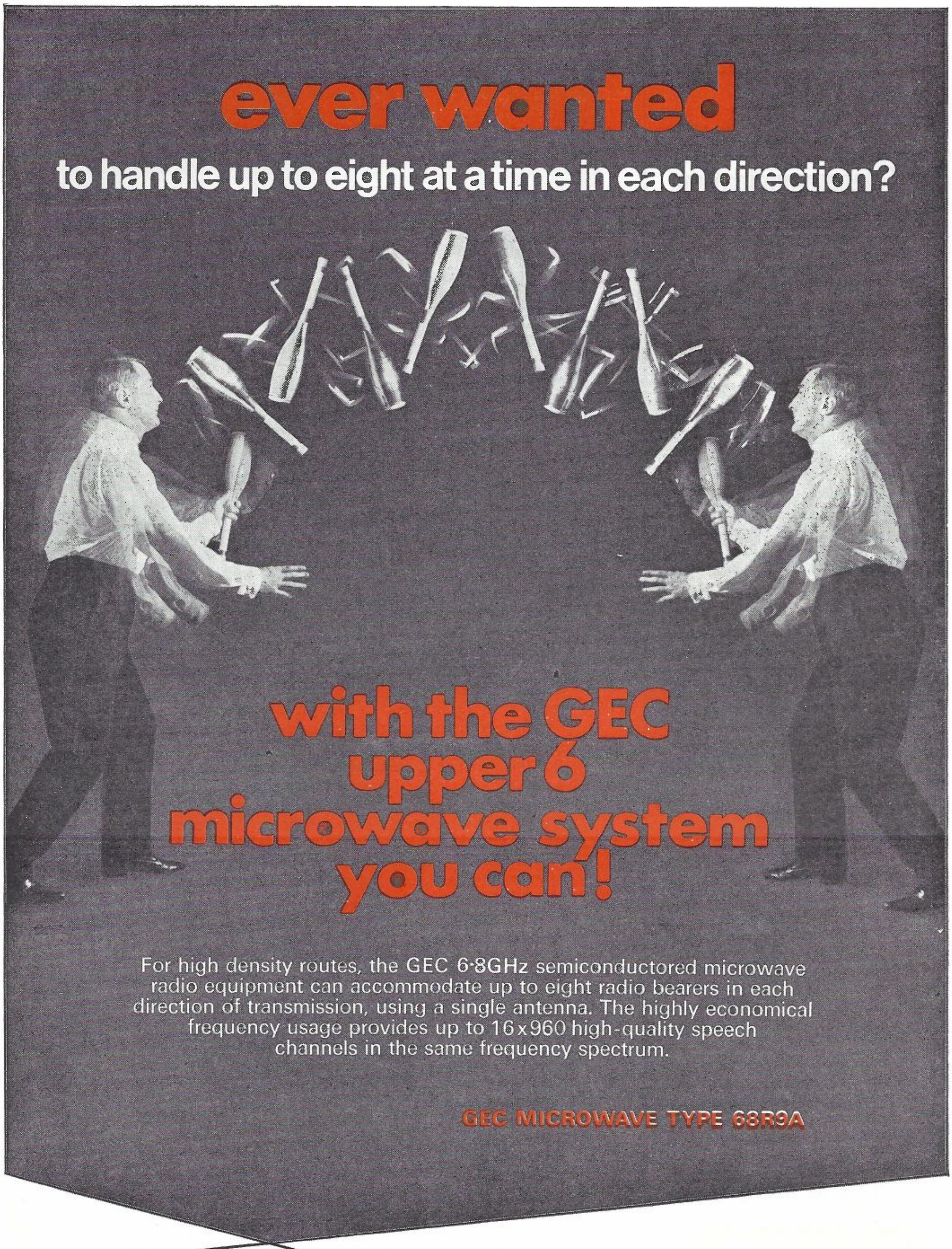
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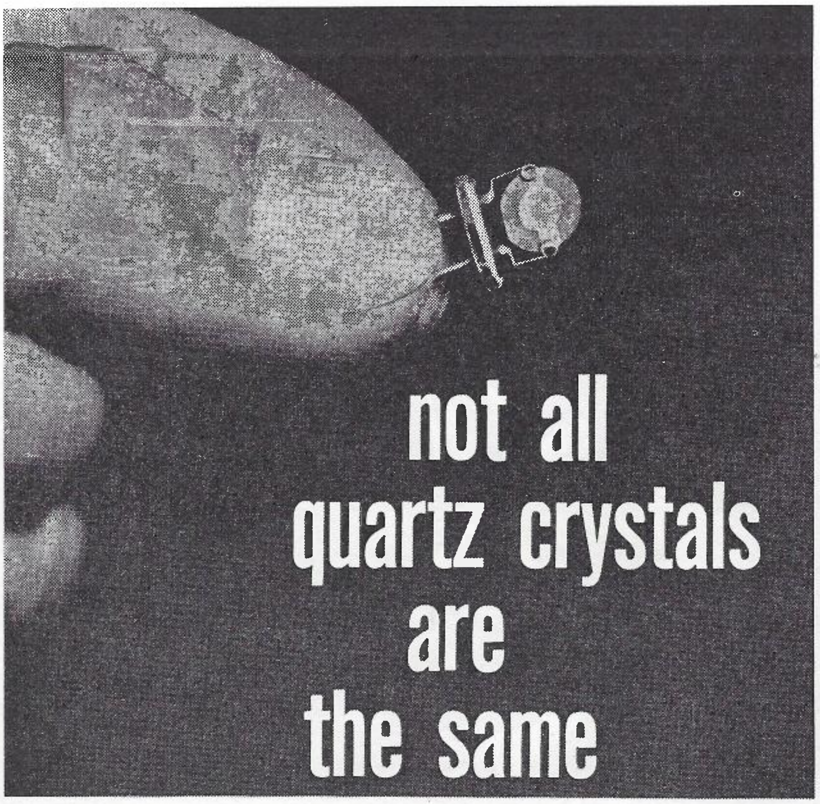

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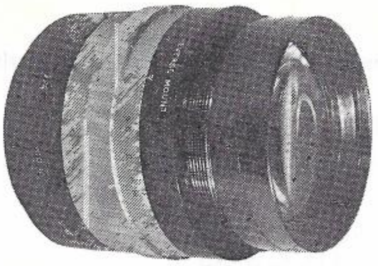

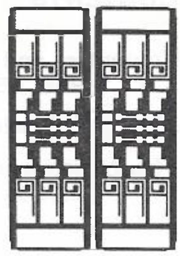

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5″ f/4	40 : 1 20 : 1 10 : 1 5 : 1	1¼″ square 240 lines/mm.	1⅔″ square 200 lines/mm.	2″ square 160 lines/mm.
10″ f/4	20 : 1 5 : 1	2½″ square 200 lines/mm.	3¼″ square 150 lines/mm.	4″ square 100 lines/mm.

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The TELECOMMUNICATION JOURNAL of Australia

ABSTRACTS: Vol. 20, No. 3

BETHELL, P. S.: 'Computers and Communications—the Present and the Future'; Telecom. Journal, of Aust. October 1970, page 199.

The paper discusses the present communications explosion and forecasts that data transmission will grow rapidly in the 1970's as a result of the marriage between computers and communications. Growth in time sharing will be a major factor in the data increase. Likely future trends in computer usage, transmission speeds and switching techniques are also discussed.

DEMPSEY, R. J., SEMPLE, G. J. and SHAW, D. L.,: 'The Perth - Port Hedland Channel Doubling System'; Telecom. Journal of Aust., October 1970, page 243.

The paper describes a 24-channel telephone carrier system of voice bandwidth 300-2200 Hz, which was produced in Australia to meet a short term deficiency of telephone channels resulting from the rapid development of Port Hedland, Western Australia The system places two telephone channels in the frequency band normally occupied by one channel. The particular equipment described is a modernised version of a system originally designed in the United Kingdom for application to the first Trans-atlantic Telephone Cable in 1957.

FLATAU, G.: 'Reliability Testing of Components'; Telecom. Journal of Aust., October 1970, page 249.

A brief discussion of the fundamentals of reliability theory is followed by a presentation of constant stress and step stress testing concepts in accelerated ageing techniques. The physics of failure of components is discussed and some practical aspects of reliability testing are presented. Interpretation of reliability test results is discussed and reliability data for some common components is included, together with some indication of the implications of recent component manufacturing developments. A section on reliability standards briefly surveys the position in U S.A., Europe and Australia.

GRAY, D. A.: 'The Work of the Telephone Transmission Study Groups of the C.C.I.T.T.; Telecom. Journal of Aust., October 1970, page 237.

Some major questions under study by Study Group XII (Telephone Transmission Quality and Local Networks) and Study Group XVI (Telephone Circuits) are reviewed in the light of discussions at the meetings of these two Study Groups in Melbourne in February March, 1970. Probably the questions of greatest contemporary interest are those relating to echo and propagation time, in which there is a resurgence of interest due to the use of communication satellites, and those arising from pulse code modulation transmission systems being used in increasing numbers.

KELLOCK, A.: 'The Feasibility of Domestic Satellite Communications for Australia'; Telecom Journal of Aust., October 1970, page 232.

This paper describes feasibility studies of domestic satellite communications to provide point to point trunk telephony, multiple access telephony, T.V. relay and distribution, and subscribers' telephone service.

LIIV, J.: 'The A.P.O. Role in NASCOM: Part 2, Operational Aspects'; Telecom Journal of Aust., October 1970, page 257.

This paper describes operational aspects of the NASCOM network in Australia. Included are descriptions of the NASA switching centre at Canberra, the network configurations for the Apollo missions and the role played by Australia in televising the lunar landing. Reference is made to the reliability requirements specified by NASA and achieved in the Australian sector, as well as to test and monitoring equipment and maintenance testing procedures.

McDERMOTT, J. J.: 'The A.R.M. Buttinski'; Telecom Journal of Aust., October 1970, page 278.

This article outlines the development and facilities of a special Buttinski or portable test handset. It is used in ARM 201/4 telephone exchanges to trace calls through the exchange and to test all decadic line relay sets. It can also be used to check tariff on tariff setting line relay sets.

McKINNON, R. K.: 'The Development of Data Transmission Services in Australia'; Telecom. Journal of Aust., Oct. 1970, page 203.

In this article the main factors influencing the effectiveness of machines transmitting over communication channels, both fixed and switched are isolated. Modem equipment used to translate machine signalling to a form adapted to the communication channel is described and the boundary conditions affecting the design of this class of equipment discussed. The introduction of data services in Australia using this class of equipment and the types of service and organisations making use of data transmission facilities are described. New developments in data switching, such as the message switching Common User Data Network are mentioned, with particular reference to the use of datel links between network centres and to subscribers' terminal equipment.

NELDER, R. R.: 'History of Small Country Automatic Exchanges in Victoria'; Telecom. Journal of Aust., October 1970, page 274.

This article has been written to provide an historical record for the Post Office of the events associated with the establishment of automatic telephony for rural areas in Victoria. The author, having been connected with RAX's on a development, installation or service basis, for 37 years, has collected and recorded the information before his retirement.

RAY, K. M.: 'Transmission Lines and Measurements; Part 2: Cables'; Telecom Journal of Aust., Oct. 1970, page 266.

Developments in paired and coaxial cable transmission lines and transmission measuring techniques are reviewed. Included are discussions from the transmission point of view of junction carrier, minor trunk and multipair and single quad carrier cables. The characteristics and associated measuring techniques for coaxial cables are also reviewed.

SYMONS, F. J. W., and WARD, M. K.: 'Program Control of the IST Project'; Telecom Journal of Aust., Oct. 1970, page 217.

A description is given of the operation of the program control system which has been developed to control the digital telephone exchange in the IST (Integrated Switching and Transmission) Project. This project is being conducted in the Melbourne metropolitan network and is a practical feasibility study of the telephone network of the future. The program control system described is the first complete program control system for a telephone exchange which has been developed in the A.P.O.

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